



Agency, social networks, and adaptation to environmental change

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ABSTRACT

Environmental change is escalating across the globe, threatening the livelihoods and wellbeing of millions of people. Substantial effort and resources have been committed at a global scale to support adaptation projects in affected communities to confront these changes. Yet not everyone has equal capabilities to adapt, guide adaptation decisions, and contribute to envisioning alternative futures. Drawing on theories of agency, social networks, and adaptation and employing a unique time-series dataset including 653 individuals across five Kenyan coastal communities, here we examine how agency over adaptation decisions is socially differentiated and the disparities that exist regarding who is able to bolster their level of agency over time. Our results show that involvement in local environmental decision-making processes, where adaptation to environmental change is negotiated, is strongly associated with feelings of effective power. Yet this power is largely concentrated among older individuals, community leaders, those with greater assets, and those with social ties to leaders – pointing to existing social hierarchies and resource differentials that drive adaptation decisions. The only significant predictor of changes in agency over time was network exposure: individuals with direct contact with those who were actively involved in environmental decision-making (individual agency) were likely to become more involved themselves; yet contact with passively involved partners (proxy agency) led to decreases in agency over time. Our results suggest a dynamic ripple effect in agency through social networks, suggesting that social networks can both catalyse and inhibit perceptions of effective power over adaptation decisions through participation in environmental decision-making. Our findings underscore the importance of social networks in enabling and constraining agency, highlight the role of leadership and power dynamics in environmental decision-making and locally led adaptation, and provide a foundation for future research on fostering inclusive and just adaptation.

1. Introduction

The magnitude of environmental change being experienced across the globe has spurred a flurry of research on adaptation. This work has demonstrated that diverse groups of people and communities from across the globe have rich histories of adaptation (Agrawal and Perrin, 2009; Lebel, 2013), and they plan to adapt, and in many cases already are adapting, to current environmental change through various strategies (Berman et al., 2020; Berrang-Ford et al., 2021). These strategies include, but are not limited to, diversifying resource use practices,

building new infrastructure, and shifting livelihoods to reduce risks and vulnerabilities to changing conditions (Barnes et al., 2020; Berman et al., 2020; Salgueiro-Otero et al., 2022).

As the need for adaptation becomes more pronounced, there are increasing calls for adaptation funding to be directed to support localized adaptation projects through community-led, bottom-up approaches (Manuamorn et al., 2020; Rubin et al., 2023). Yet large and growing body of research on environmental justice has demonstrated that not everyone has the capability to adapt or equal levels of agency over adaptation decisions (Brown and Westaway, 2011; Malloy and Ashcraft,

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2020; Schlosberg, 2007), and importantly, these issues often play out at the community level (Holland, 2017; Sovacool, 2018). Though there is a significant scholarly focus on how policies and programs at national and international levels can be designed to address issues of justice and equity (Coggins et al., 2021), to date little attention has been paid to the micro-level social dynamics *within* communities that affect levels of agency over adaptation decisions and the factors that drive changes in agency over time. The factors that enable people to increase their level of agency over adaptation decisions (Villasante et al., 2022), thereby increasing their personal ability to control and/or respond to environmental risks and contribute to envisioning alternative futures (Blythe et al., 2018), is particularly critical to understand to address issues of justice and equity in community-level adaptation (Schlosberg, 2019). However, dynamic (longitudinal) examinations focused on the dynamics of agency in the context of adaptation remain largely under-represented. Our understanding of who is able to increase their level of agency (and how), and who is left behind in communities navigating environmental change is therefore limited.

Here, we draw on theories regarding agency, adaptive capacity, and social networks to explore the factors that underpin who has agency over decisions regarding community-level responses to environmental change, and who is able to bolster their levels of agency over time. Our specific objective is to demonstrate how agency is socially differentiated, and the disparities that exist regarding who is able to bolster their level of agency over time when faced with significant environmental change. We achieve this objective by drawing on longitudinal, primary data from five fishing communities in coastal Kenya – a region that has already experienced significant environmental change that is having profound impacts on local livelihoods (Cinner et al., 2013; USAID, 2018). Before describing our study context in more detail, we first clarify our theoretical assumptions regarding the concept of agency, its role in adaptation and adaptive capacity, and the relevance of social networks in this context.

2. Theoretical foundations

Historically, research focused on whether and how people adapt to environmental change focused heavily on determining underlying levels of skills and resources to support adaptation, such as human, physical, and financial capital (Mortreux and Barnett, 2017; Siders, 2019). Yet having the access, influence, and capability to harness and combine these resources to support adaptation processes and envision alternative futures is just as critically important (Brown and Westaway, 2011; Choudhury and Haque, 2016) – and sometimes even more so (Barnes et al., 2020). The concept of agency thus now prominently features in adaptive capacity theories and frameworks focused on understanding and outlining the determinants of adaptation. For example, in a recently developed framework initially contributed by Cinner et al. (2018) and further refined in Cinner and Barnes (2019) which has since been applied in numerous studies (e.g., Bartelet et al., 2023; de la Torre-Castro et al., 2022; Nyboer et al., 2022; Pike et al., 2022), agency is positioned as critical for activating other components (i.e. ‘domains’) of adaptive capacity, such as learning, flexibility, and assets. The authors of the framework argue that despite other domains of adaptive capacity; for example, people’s underlying level of knowledge regarding risks produced by environmental change (‘learning’), their flexibility to change strategies (‘flexibility’), or their financial capital to support these changes (‘assets’); people will have little incentive to adapt unless they are confident their actions can produce desired outcomes (or avert undesired ones) (Cinner et al., 2018). This sentiment is similarly echoed in discussions around transformation (Blythe et al., 2018; Colloff et al., 2021), capabilities approaches to (just) climate adaptation (Malloy and Ashcraft, 2020; Schlosberg, 2012), and other recent extensions of the adaptive capacity concept (Galappaththi et al., 2019; Mortreux and Barnett, 2017).

Agency is generally understood to mean the capacity of individuals

to act independently and to make their own free choices (Brown and Westaway, 2011). People do not always have direct control over conditions that affect their lives. This is especially true for many coastal fishers, whose livelihoods and well-being are often directly dependent on a common-pool resource system whose health and productivity can be affected by not only the actions of other fishers (Barnes et al., 2019a), but also by external factors (e.g., climate shocks) and environmental management decisions (Badjeck et al., 2010; Galappaththi et al., 2019). Recognizing these sorts of complexities, social cognitive theory distinguishes among additional modes of agency beyond personal/individual agency, where people are able to independently influence their own functioning and environment. One of these additional modes is referred to as *proxy* agency, or socially mediated agency, whereby people exercise influence over others who have the knowledge, resources, and ability to act on their behalf to secure the outcomes they desire (Bandura, 2006).¹

Conceptualizations of agency are strongly linked to notions of power and social structure. Agency is the force behind social action, and thus exercising agency is argued to be inherently linked to the ability to exercise some forms of power (Choudhury and Haque, 2016; Dietz and Burns, 1992). Yet people do not operate in a vacuum as autonomous agents; rather, they are embedded in webs of social relationships, or social networks, that can provide opportunities for, or pose constraints on human action, thereby creating and reinforcing power relations that can shape agency (Bandura, 2006). For example, having certain positions in social network structures (e.g., highly central ones, or those that bridge or broker between others) can provide access to tangible and intangible resources, such as financial support and opportunities for learning, which can enable people to exercise individual agency (Borgatti et al., 1998; Cook et al., 1983; Stevenson and Greenberg, 2000). Being centrally located in social networks and/or having ties to others in positions of power (e.g., decision-makers) can also help to amplify an individual’s influence and capacity to advocate for change at broader levels, key aspects of proxy agency (Ling and Dale, 2014; Stevenson and Greenberg, 2000). Social organization, or the social network ties and structures linking individuals and communities, has thus been widely identified as a critical determinant of adaptive capacity (Adger, 2003; Barnes et al., 2017; Cinner and Barnes, 2019).

Though social organization can support adaptation in its own right [e.g., through building community-level social capital (Adger, 2003)], recent empirical work demonstrates that social networks can interact with agency in complex ways to determine whether and how people adapt to environmental change. For example, a recent study found that households who had been exposed to a number of others in their social network who had adapted to the impacts of climate change were significantly more likely to do the same, yet this effect was moderated by perceived levels of agency (Barnes et al., 2020). Recognizing that agency is fundamental to mobilizing other components of adaptive capacity (Brown and Westaway, 2011; Cinner et al., 2018), here we extend existing scholarship by exploring how social networks and other social determinants associated with adaptive capacity shape who has agency (and who doesn’t), and who is able to bolster their level of agency over time in response to environmental change.

3. Study context

This research was conducted in five small-scale fishing communities

¹ Social cognitive theory also recognizes collective agency, which refers to situations in which individuals are able to pool their knowledge, skills, and resources, and act collectively to shape their future [Bandura, A. (2006) Toward a psychology of human agency. Perspectives on psychological science 1, 164–180]. Our research focuses on individuals rather than groups, and thus collective agency – though critical for shaping community responses to change – is outside the scope of our inquiry.

on the coast of Kenya that have established collaborative, community-level management arrangements and where our research team has a long history of working (Fig. 1). We followed Barnes et al. (2019b) in defining communities geographically as consisting of common living (i. e., villages) and fishing areas. All five communities have a high reliance on local fisheries resources for food and income, yet these resources continue to dwindle due to rising human impacts and climate change, which now presents a significant and increasing threat to both the biodiversity and productive capacity of marine resources throughout the Western Indian Ocean (Hicks, 2011; McClanahan et al., 2020; McClanahan et al., 2011; van der Elst et al., 2005). Fishers in our study communities use a variety of gear types (e.g., spear, nets, line) targeting different assemblages of coral reef-associated fish species [such as rabbitfish, parrotfish, and emperors (Barnes et al., 2019b)]. Most fishers are men, though one community has a substantial number of women octopus fishers (site 5, Fig. 1).

Kenya is a largely collectivist and historically patriarchal society with a high level of ethnic diversity. The country is known as one of the most cosmopolitan countries in Africa and it has the largest and most diverse economy in East Africa. Despite this, poverty remains a critical issue, particularly in rural and coastal areas (Eichsteller et al., 2022), and the country suffers from historical legacies of corruption and domestic conflict (Murunga et al., 2021). Councils of community elders historically governed coastal fisheries in Kenya, though fisher

cooperatives began appearing in the 1970s and were eventually replaced with formalized collaborative, community-level management systems, i.e. Beach Management Units (BMUs), after national-level policy changes decentralized resource management in 2006 (Cinner et al., 2012b; Murunga et al., 2021).

BMUs are decentralized community-level entities legally mandated by the fisheries department in Kenya to co-manage fisheries and other coastal resources at the local level. The goals of these management institutions are typically ecological (e.g., improve resources, conservation) as well as social (e.g., improve livelihoods, change perceptions about the environment). The director of fisheries (a senior-level government employee responsible for regulation and management of fisheries) in consultation with BMUs is mandated to develop management plans that describe the measures to be undertaken within the area to ensure resource sustainability (Cinner et al., 2009b). Within their area of jurisdiction, BMUs develop their bylaws that guide all fishing activity, e. g., they can restrict space, time, gear, species, and life history stages of fish being caught, or establish a complete fishery closure. At the local level, an executive committee of elected representatives that formally leads the BMU regularly organizes and coordinates meetings to facilitate information and knowledge exchange among fishers and other stakeholders (~ 4x/yr). Occasionally, government and local NGOs also engage fishers in public forums ('fisher forums') to further support local fishery management and capacity building.



Fig. 1. Study context: small-scale fishing communities on the Kenyan coast. A) Map of Kenya showing the location of each community. B) Fisher returning to shore after fishing with a small mesh gill net. C) Fishers sort catches to sell to traders. D) Fisher holding catch. Photos appearing in B-D were taken by the authors of this manuscript and the individuals pictured granted their written permission for use of the photos.

In line with other types of collaborative, community-level management arrangements (e.g., co-management, adaptive co-management, locally led management, etc), BMUs are by nature a form of power-sharing intended to empower local resource users. BMU meetings and public fisher forums are considered to represent an important avenue for fisher engagement and empowerment, in part due to the opportunities they create for individuals to exert power over decisions regarding fishery resources and management (Barnes et al., 2019b; Cinner et al., 2012a). Fishers may also become more directly involved in environmental decision-making in their communities by serving on the BMU committee as a representative. Though BMU bylaws often attempt to bolster diversity on their respective committees (e.g., by stipulating representation be split equally amongst boat owners, fishers/crew, and traders; specifying term limits; and encouraging equal opportunities for youth and other representatives from vulnerable and/or marginalized communities), existing research shows that participation in collaborative management arrangements often remains socially differentiated (Gurney et al., 2016) and can be strongly mediated by social relationships and power asymmetries (Quimby and Levine, 2018). We contribute to and extend this body of research by drawing on novel longitudinal data to highlight the role of social networks in shaping agency, and provide new knowledge regarding who is (and who is not) able to increase their level of agency in community-level co-managed fisheries over time in response to environmental change.

4. Methods

4.1. Data collection

We conducted two rounds of fieldwork conducting detailed survey questionnaires with the same respondents in the same locations. Both rounds of fieldwork formed part of an ongoing, long-term collaboration between several of the co-authors of this manuscript investigating complementary topics associated with marine and coastal resource management, livelihoods, and sustainability in the context of global change. The first round of fieldwork was between January-May 2016 (t_1); and the second was from June-October of 2019 (t_2). Our field team consisted of the same individuals at each time point, including the lead author and two co-authors of this manuscript (positionality statement for all authors included in section 4.5).

Fieldwork consisted of surveys including both structured and semi-structured questions conducted face-to-face in Swahili (the most widely spoken official language in Kenya) at fisheries landing sites and/or in fishers' homes if they preferred with the same trained enumerators in each time period. The surveys included basic sociodemographic questions as well as questions about the livelihood activities the respondent and their household members engaged in, fishing activities including gear use, involvement in marine resource use and management activities, perceived changes in the fishery due to climate change or other social or environmental factors, and indicators of adaptive capacity (see Table 1). Because our study design included social network variables, we also collected detailed social network information (additional information regarding the social network data and its collection are provided in the below 'Indicators of agency' section, Table 1, and in the SI). Our survey questionnaires were first workshopped in detail amongst our team and then pre-tested in a coastal fishing community north of Mombasa, Kenya over a seven-day period at both time points (note that the community who agreed to allow us to conduct our pre-test was not included in our study).

Gathering 'complete' network data requires a comprehensive understanding of the social connections within each community. We therefore aimed to survey at least 75% of the total population of fishers in each site (rather than take a sampling approach) in our initial round of fieldwork at t_1 . We accomplished this by obtaining estimates of each community's total fisher population upon arrival in each site in consultation with BMU representatives and formal community leaders

Table 1

Adaptive capacity and other baseline indicator variables. Indicators represent a baseline of the respondent's status at t_1 which are used to predict baseline levels of involvement in decision-making at t_1 (baseline models), as well as changes in their level of involvement in decision-making between t_1 and t_2 (change models).

Category ^a	Indicators	Description
<i>Adaptive capacity</i>		
Assets	Material Style of Life (MSL)	Composite index of household possessions, energy sources, and materials used to construct homes
	Boat owner	Respondent owns the boat they use to fish
	Access to credit	Access to credit through formal or informal means; e.g., banks, institutions, friends or family
Flexibility	Age	Age
	Livelihood diversity	Number of different livelihood activities that bring food or money into the respondent's household
Organisation	Technological diversity	Number of different types of fishing gears used
	Trust in institutions	Median of Likert scale responses regarding trust in community leaders, local government, and police
	BMU member	Active member of the local Beach Management Unit
	Ties to leaders	Number of ties to community leaders ^b
Learning	Network exposure: passive	Number of ties to others ^b who are passively involved in decision-making (at t_1)
	Network exposure: active	Number of ties to others ^b who are actively involved in decision-making (at t_1)
	Attended fisher forum	Respondent has attended at least one fisher forum
	Info network prominence	Number of incoming fisheries-related information and advice ties
Socio-cognitive constructs	Info network brokerage	Extent to which respondent acts as a broker in the fisheries-related information and advice network (i.e., betweenness centrality)
	2 nd /3 rd generation fisher	Parents or grandparents were also fishers
	Perceived fishery decline	Perception that there are less fish on the reef than 5 years ago
<i>Other contextual variables</i>		
Socio/spatial demographics	Leader	Holds a leadership position
	Ethnic minority	Not a member of the dominant ethnic group within their community
	Minority gear user	Does not use the most dominant fishing gear type in their community
Baseline level of involvement ^c	Minority landing site user	Does not use the most popular landing site within their community
	Active involvement in decision-making	Respondent is actively involved in decision-making in t_1 (i.e., they hold a leadership position and/or they attend and speak up at meetings and directly engage in deliberations)
	Passive involvement in decision-making	Respondent is passively involved in decision-making in t_1 (i.e., they attend meetings, but do not always speak up or directly engage in public deliberations)

^a Categories are based on Cinner and Barnes (2019).

^b Based on a composite network including a range of different types of social and economic ties relevant for fishing and fishery management, including knowledge exchange, resource sharing, and trade networks (see SI Methods).

^c Only included in the change model (i.e., not included in the baseline models).

prior to data collection. Fishers were then approached at fisheries landing sites in consultation with local guides. From an initial sample of 706 respondents at t_1 representing 76–84 % of the total estimated population of fishers in each community, we were able to re-survey 664 participants at t_2 (62–74% of the initial estimated fisher population, see [Table S1](#)). 11 of these participants were excluded due to missing data, leaving 653 participants in the final study (see [Table S1](#) for a breakdown by community). Our data thus represents a novel panel dataset of repeated observations from 653 of the same individuals over time representing the majority of fishers in each study community.

Research protocols were approved by the Human Ethics Committee at James Cook University (Approval No. H7603 and H6461). Informed consent was obtained from all respondents.

4.2. Perceptions of environmental change

We first sought to establish a contextual understanding of how fishers across our study communities were perceiving and experiencing environmental change. At t_2 we asked respondents what significant changes they had noticed in their fisheries and reefs since our last field visit (t_1), and what they believe had caused the change(s). Fishers were able to describe any change that they had noticed that affected fisheries and associated reefs and ascribe these changes to any cause they perceived them to be linked to. Responses were recorded and coded thematically to construct a narrative describing fisher's experiences with environmental change, with an underlying expectation that some level of change may be necessary for fishers to (where/when possible) seek to increase their level of agency over decisions that affect the marine ecosystem which supports their livelihoods.

4.3. Measuring agency

As discussed in [Section 2](#) (Theoretical Foundations), the concept of agency has been theorized and empirically measured in various ways across a wide range of disciplines. Here, we followed theoretical work on agency ([Alsop et al., 2006](#); [Ibrahim and Alkire, 2007](#)) as well as previous work in related fisheries contexts ([Barnes et al., 2020](#)) to measure an 'effective power' aspect of agency, which was: *involvement in decision-making about marine resources and marine resource management*. Specifically, we measured whether fishers were actively or passively involved. *Active involvement* was associated with holding a decision-making, leadership position and/or speaking up and actively engaging in deliberations at community meetings where decisions about marine resources and marine resource management are being made. Being actively involved in this manner allows fishers an opportunity to directly influence critical issues and events that affect their livelihoods, and is therefore linked to the concept of individual (or 'personal') agency ([Bandura, 2006](#)), as discussed in [Section 2](#) (Theoretical Foundations). *Passive involvement*, on the other hand, is captured in attending community meetings where decisions about marine resources and marine resource management are being made, but not always speaking up publicly or directly engaging in public deliberations ([Table 1](#)). We argue that passive involvement is thus likely more indicative of socially mediated, proxy agency ([Bandura, 2006](#)) as discussed in [Section 2](#) (Theoretical Foundations), as it allows fishers an opportunity to gain the knowledge and relationships necessary to influence others to act on their behalf. It is important to note that although fisheries in this context are co-managed as described above in the 'Study context' section, we intentionally asked about involvement in decision-making about marine resources and marine resource management more broadly, rather than involvement in the collaborative management system itself. We did so to capture a broader conceptualization of effective power over any decisions or decision-making processes (either inside or outside the collaborative management system) which could have been relevant for defining adaptation options and guiding fisher responses to environmental changes affecting the fishery system.

To test the assumption that involvement in decision-making regarding marine resources and marine resource management was indeed associated with a sense of effective power, and thus a valid construct for capturing this aspect of agency, at t_2 we implemented the ladder of power method ([Alkire, 2008](#)).² Specifically, we asked respondents to consider a ladder of power including 10 steps, where at the bottom stood people who were completely powerless and without rights when it came to the fishery (i.e., access to fishery resources and making decisions about fishery management), and on the highest step stood those who had a lot of power and rights when it came to the fishery. Using a laminated picture of a ladder as a visual aide, respondents were asked to consider this ladder of power, and then to answer the question "on which step of this ladder are you?". We used the information collected through this approach to test the association between perceived power (i.e., which step on the ladder each respondent felt they were) and involvement in decision-making at t_2 using a one-way ANOVA and post-hoc Tukey tests. We used the same approach to test whether increasing or decreasing one's involvement in decision-making over time (i.e., between t_1 and t_2) was associated with perceptions of power at t_2 . Levine's tests and visual examination of residuals indicated no significant homogeneity of variance or non-normality.

4.4. Indicators of agency: Social networks, adaptive capacity, and socio-spatial demographics

To predict changes in agency over time, we first examined factors associated with baseline levels of agency (baseline models); i.e., the factors associated with whether people were actively, passively, or not at all involved in decision-making in t_1 . Next, we examined factors associated with an increase or decrease in agency between t_1 and t_2 , i.e., our longitudinal model (change model). We employed 16 indicators associated with five different domains of adaptive capacity ([Table 1](#)). As shown in [Table 1](#), this included five social network indicators, which following existing research ([Barnes et al., 2020](#); [Salgueiro-Otero et al., 2022](#)) we classified under the social organisation and learning domains of adaptive capacity. These were: (1) ties to leaders (direct ties to community leaders in a composite network including a range of social and economic relationships, see SI), (2 and 3) network exposure variables, which capture the number of (composite) network ties individuals had to others either passively or actively involved at t_1 , (4) info network prominence [a centrality measure, (normalised outdegree centrality), computed on a network capturing information and advice flows about fishing and fishery management], and (5) info network brokerage [a bridging/brokerage measure (normalized betweenness centrality), computed on a network capturing information and advice flows about fishing and fishery management]. As described in [Table 1](#), we also captured key socio-spatial demographic variables to capture other forms of social differentiation. Each of the indicators presented in [Table 1](#) has been discussed in detail in recent related research [e.g., ([Barnes et al., 2020](#); [Bartelet et al., 2023](#); [Salgueiro-Otero et al., 2022](#))]. We therefore present only a brief description of them in [Table 1](#), with additional details provided in the SI Methods. In our change model, we also included controls for baseline levels of agency. All baseline indicators were collected at t_1 , allowing us to leverage the longitudinal nature of the data to capture community members' involvement levels and predict changes over time.

4.5. Modelling approach

To examine the relationship between respondent's baseline level of involvement in decision-making (at t_1) and their adaptive capacity (including social network characteristics) and other socio-spatial

² The ladder of power question was not included in the initial survey administered in t_1 .

demographic variables (also at t_1), we used two binary general linear mixed models to (1) identify factors associated with whether fishers were involved in decision-making in any way at t_1 , and (2) of those who were involved, whether they were passively or actively involved. All continuous predictors were standardized to ease interpretation, and community was included as a random effect to control for any potential community-level effects. We used binomial distributions with logit link functions in addition to bootstrap confidence intervals to account for the inherent interdependence of social network measures. This analysis was conducted using R and the glmmTMB package (Brooks et al., 2017). We performed residual diagnostics using the DHARMA package (Hartig, 2022) and conducted an examination of Variance Inflation Factors, which indicated the models were valid with no significant multicollinearity.

In our longitudinal change model, we modelled factors associated with changes in involvement in decision-making between t_1 and t_2 using a multinomial logit model. Specifically, we leveraged the time dimension of our data by using adaptive capacity and social network indicators, socio-spatial demographics, and baseline levels of involvement in decision-making at t_1 as indicator variables to predict whether respondents had decreased (-1), increased (+1) or made no changes (0) in their level of involvement in decision-making between t_1 and t_2 . All continuous predictors were standardized to ease interpretation, and dummy variables for each community were included to control for any potential community-level effects. The model was fit using the mlogit function in Stata17 using the sandwich estimator for robust standard errors to account for the interdependent network measures included as indicators. An examination of Variance Inflation Factors showed no signs of multicollinearity. The R package ggplot2 was used to generate the results figures for baseline and change models (Wickham, 2016).

4.6. Positionality statement

The field team included the lead author, a White Native American-Australian academic, and two Kenyan co-authors based in Kenya. The remaining co-authors include two Kenyan academics (one based in Kenya and one in Australia), an Australian academic based in the UK, and a Czech-Australian academic in Australia. All Kenyan authors have lived experience relevant to the study context, while the other co-authors have extensive experience working in rural, resource-dependent communities in East Africa and/or the Indo-Pacific. We believe these experiences, along with our long-term collaboration, enriched our interpretation of the quantitative results. Acknowledging potential biases, we engaged in reflexive practices, using our team's diverse perspectives to challenge assumptions and deepen our understanding of the social, cultural, and environmental dynamics. While our positionalities informed the research, they may also shape our interpretations, which we invite readers to critically assess.

5. Results

The average age of our respondents was 36, with over 70% self-identifying as a second or third generation fisher and less than 10% owning their own fishing boat. Only 13.5% of fishers were actively involved in decision making at t_1 , with another 45% being passively involved. Between t_1 and t_2 , only 12% increased their level of involvement, whilst 35% decreased their level of involvement. For a full breakdown of all our response variables and adaptive capacity indicators, including socio-demographic variables, see Table S2.

5.1. Perceptions of environmental change

We found strong perceptions of environmental change across all five study communities. Specifically, 90% of respondents felt that there had been a significant decline in fisheries resources and/or other related environmental conditions. 93% of respondents cited factors they

perceived to be the cause of these changes (the remaining 7% stated they were unsure). Multiple causes of these environmental changes were sometimes mentioned, with economic development (29%), climate change (23%), and an increase in the number of fishers (23%) being the most frequently cited causal factors. Other factors mentioned included advances in fishing technology (15%) and illegal fishing (12%), with only a small minority ascribing changes to divine intervention (3%), ecological dynamics (1%), or policy changes (<1%).

5.2. Involvement in decision-making as an 'effective power' aspect of agency

Our results regarding the validity of our agency construct show that our indicators of agency (involvement in decision-making and increases in decision-making over time) were both significantly associated with perceived power across our sample. Specifically, as shown in Fig. 2, those who were not involved in decision-making at all at t_2 had significantly lower levels of perceived power than those who were involved, either passively ($p < 0.001$) or actively ($p < 0.001$). Moreover, fishers who increased their level of involvement over time had significantly higher levels of perceived power than those who decreased their level of involvement ($p < 0.001$) or made no change ($p < 0.001$; Fig. 2). These results provide evidence that involvement in decision-making can be considered a reliable proxy for the 'effective power' aspect of agency, at least in this case.

5.3. Predictors associated with baseline levels of agency

Our baseline models show that a range of factors were associated with agency, measured here as involvement in decision-making at t_1 (Fig. 3). Measures of assets (i.e., owning a boat or having access to credit), flexibility (age, livelihood diversity), and social organization (trust in institutions, being a member of the local BMU) were important predictors of being involved in decision-making in any capacity at t_1 (Fig. 3A). Having attended a fisher forum was also significantly related to being involved in decision-making. Socio-demographics were notably not significant, nor were socio-cognitive factors (such as being a 2nd or 3rd generation fisher).

Among those who were involved in decision-making, we found that ethnic minorities were significantly less likely to be actively involved (as opposed to passively involved), whereas the opposite was true for older individuals and community leaders (Fig. 3B). People who were actively involved rather than passively involved were also more likely to have social network ties to leaders. Other aspects of social organization and learning also significantly predicted active involvement, i.e., having attended a fisher forum, being a member of the local BMU, and holding a brokerage position in the information and advice network among fishers.

5.4. Predictors of changes in agency over time

Of all the factors we tested to predict changes in agency over time, the only variable we found to be significant aside from baseline levels of involvement was network exposure (Figs. 4, 5), i.e., being connected to others in a composite network (including a range of social and economic ties) who were passively or actively involved. Specifically, respondents who had direct network contacts who were actively involved at t_1 were significantly likely to become more involved themselves between t_1 and t_2 (Fig. 4A). Fig. 5 shows a graphical representation of this phenomena using data from community 3. In contrast, those who had network contacts that were passively involved at t_1 were more likely to decrease their level of involvement over time (Fig. 4B). As mentioned, baseline levels of involvement were also important for predicting changes in involvement over time. Specifically, those who were passively or actively involved were more likely to decrease their level of involvement and significantly less likely to increase their level of involvement;

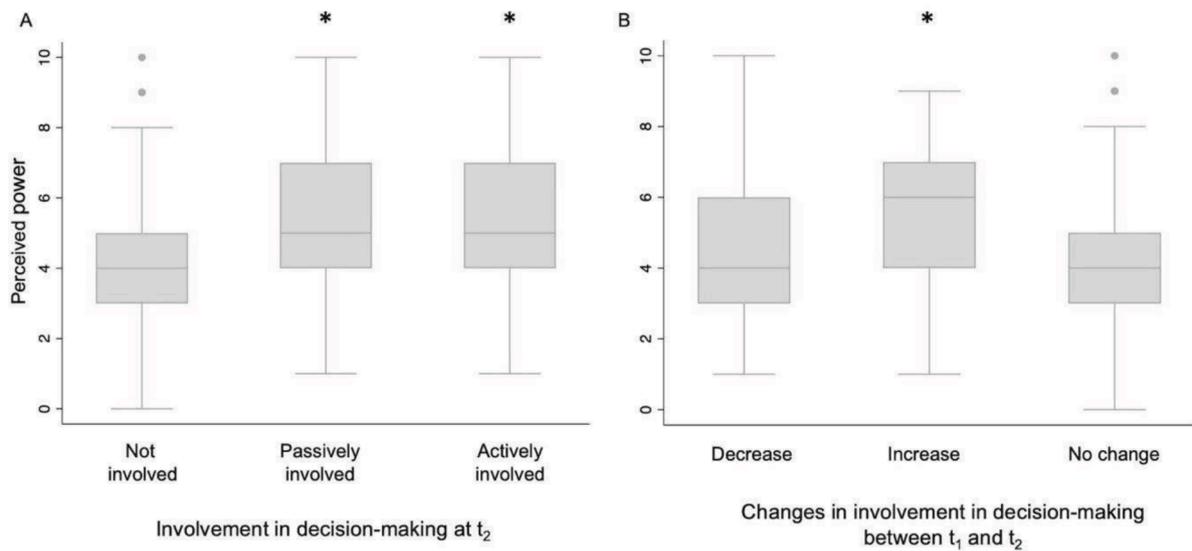


Fig. 2. Construct validity: involvement in decision-making as an ‘effective power’ aspect of agency. (A) The relationship between self-assessed perceived power (y-axis) and involvement in decision-making (x-axis) at t₂ (note that data on perceived power was not collected at t₁). Those who were not involved in decision-making at all at t₂ had significantly lower perceived power than those who were involved either passively (p < 0.001) or actively (p < 0.001), denoted by a *. (B) The relationship between perceived power at t₂ (y-axis) and changes in involvement in decision-making between t₁ and t₂ (x-axis). Fishers who increased their level of involvement had significantly higher levels of perceived power than those who decreased their level of involvement (p < 0.001) or made no change (p < 0.001), denoted by a *. There was no significant difference between those who were passively or actively involved at t₂ (A), or between those who decreased their level of participation vs made no change over time (B).

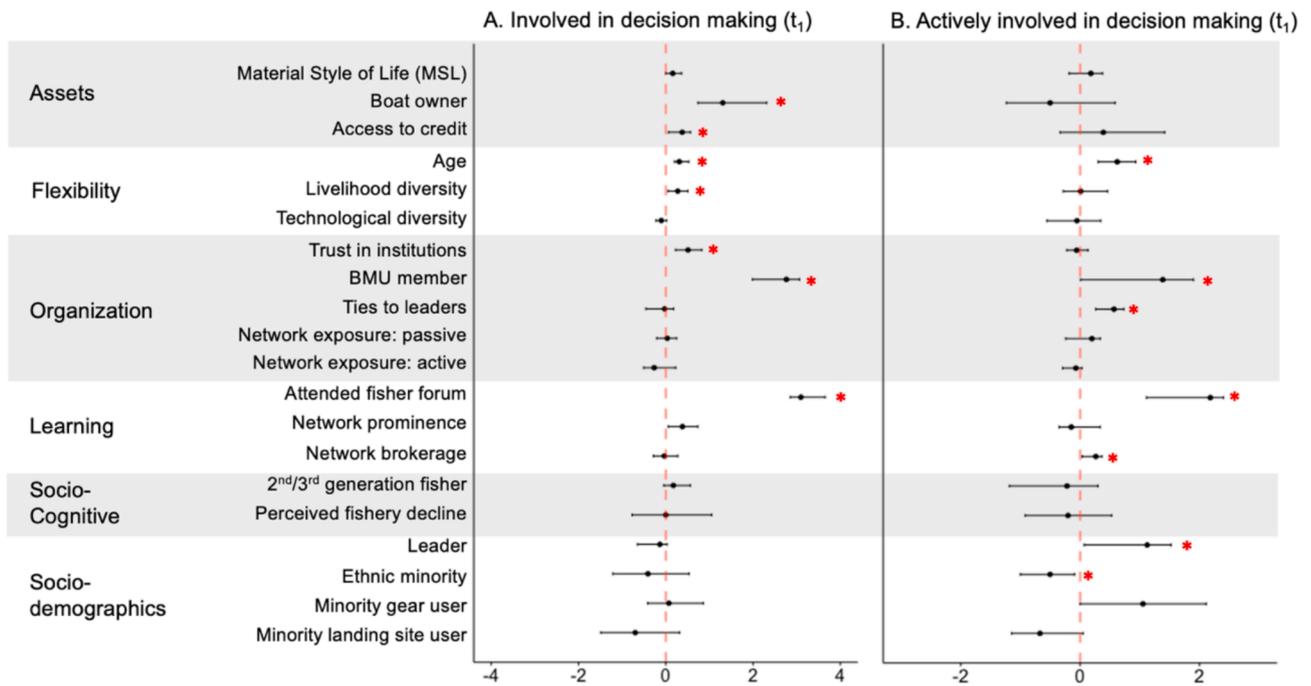


Fig. 3. Baseline models predicting agency, measured as involvement in decision-making regarding marine resource use and management. Results are derived from two binary general linear mixed models with community included as a random effect and bootstrapped confidence intervals to account for the inherent interdependence of social network measures. (A) Factors associated with any level of involvement in decision-making at t₁ (n = 653). (B) Factors associated with active (as opposed to passive) involvement (n = 380). Full model results are reported in Table S3.

reflecting an overall decline in involvement among those who were initially involved.

6. Discussion

Our research presents nuanced insights into the dynamics of agency in communities facing significant environmental change that is having

profound impacts on local livelihoods. We found that involvement in environmental decision-making processes, where adaptation responses to environmental change are negotiated, is strongly associated with feelings of effective power – a key aspect of the concept of agency (Fig. 2). Our research sheds light on the potential of social networks as catalysts for fostering and constraining this aspect of agency which provides a foundation for community-level, locally led adaptation, and

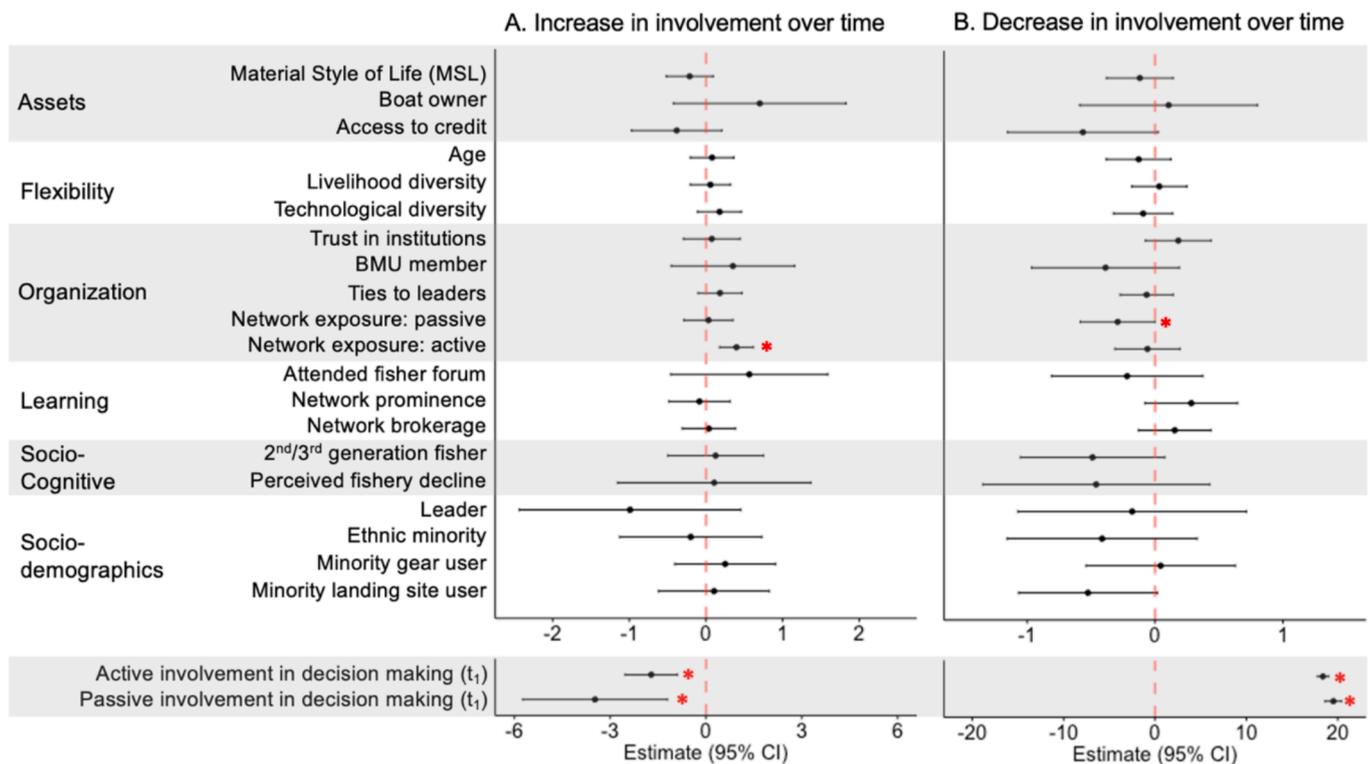


Fig. 4. Change model demonstrating the factors predicting an increase (A) or decrease (B) in agency (measured as involvement in decision-making) between t₁ and t₂ (n = 653). Results are derived from a multinomial logit model with the baseline set to “no change” and robust standard errors estimated to account for the interdependent network measures included as indicators. All predictors were measured at t₁ in order to leverage the time dimension inherent in the data with the exception of the controls for initial levels of involvement in decision-making. Full model results reported in Table S4.

provides insight into how agency interacts with power imbalances and social hierarchies that are prevalent in many communities around the world. Specifically, our research examined factors that seem to enable certain individuals to participate more actively in environmental decision-making processes where adaptation options are deliberated and decided on, underscoring the social differentiation of agency and contributing to conversations regarding the need for inclusive and just adaptation policies and interventions.

6.1. Social networks as catalysts and barriers of agency

The study’s most novel contribution is arguably the identification of network exposure as a significant predictor of changes in agency over time (Figs. 4, 5). Network structure and position have long been thought to be associated with agency, yet much less has been written about network exposure as a potential source of what could be referred to as ‘second-hand agency’. Here, we found that individuals with direct contact with those who are actively involved in environmental decision-making [reflective of the concept of individual agency (Bandura, 2006)] are likely to become more involved themselves over time (thus increasing their own individual agency). Conversely, contact with passively involved partners [associated with proxy agency, (Bandura, 2006)] is associated with a decrease in agency over time. It appears that one’s passive involvement, or proxy agency, is more detrimental to their network partners’ agency over time than no involvement at all, whereas the experience of effective individual agency appears to spill over in a more positive manner.

The transformative potential of networks has been noted by numerous authors. Networks at their best can lead to collective action and change (Stevenson and Greenberg, 2000). Our results suggest a dynamic ripple effect in agency through social networks and imply that social networks can both catalyze and inhibit perceptions of the effective power aspect of agency through participation in environmental

decision-making, the latter resonating with literature on the dark side of social capital (di Falco and Bulte, 2011; MacGillivray, 2018).

The decrease in agency among individuals connected to passively involved partners potentially signifies the importance of network quality over mere structure, also echoing the sentiments of Quimby & Levine (2018) that the nature of ties can either empower or hinder agency. Clearly, agency is not derived solely through positions in social network structures. Having the network architecture is not enough, the types of resources it provides access to (Lin, 2001) and what flows through the network matters, but often gets neglected in social network research of adaptation and other environmental issues predominantly focused on analysing network topologies (Matous and Bodin, 2024). In this case, individuals apparently harnessed agency from their actively involved network partners only, perhaps reflective of individuals learning how to harness effective power by witnessing their network partners do so.

The capacity of individuals to learn through their network contacts is known to be critical for fostering adaptive strategies (Ling and Dale, 2014). Learning itself is argued to be a strong predictor of adaptive capacity, and it can be activated and reinforced through agency (Cinner et al. 2018). Interactions with network partners, in addition to the participatory nature of BMUs and the collaborative fisher forums being organized by NGOs, can all be seen as platforms for social learning, where the exchange of knowledge and experiences can ideally empower individuals to engage more actively in the decision-making processes where community-level adaptation decisions are being made. Indeed, the results from our baseline models at t₁ (Fig. 3) indicate that aspects of social networks (such as occupying a brokerage position) and several indicators of social organization more broadly (such as being a member of a BMU and attending fisher forums) were strongly correlated with both active and passive involvement in environmental decision-making – reinforcing arguments regarding the intricate interplay between social networks, social capital, and agency in shaping adaptation outcomes (Adger, 2003; Barnes et al., 2020). Yet our results regarding how social

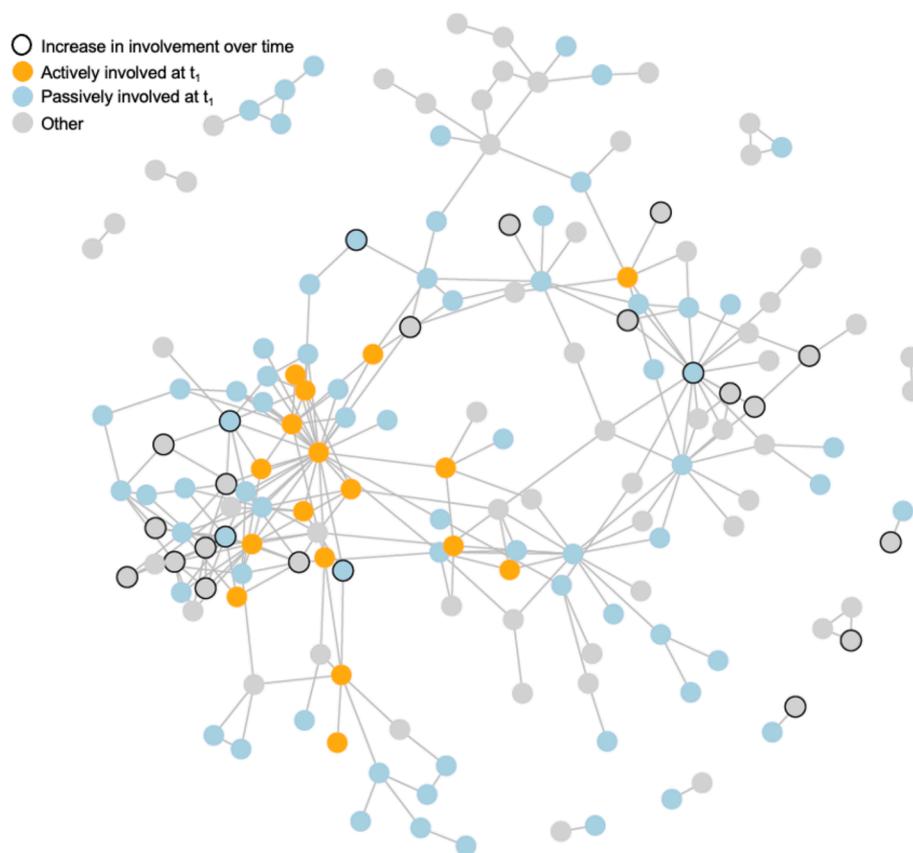


Fig. 5. A depiction of network exposure and increases in agency over time. An example of the composite network measured at t_1 in one of our study communities (community 3) with node colors corresponding to initial involvement in decision-making (orange = active, blue = passive) and identifying those who increased their level of involvement over time (black outline).

and economic factors influence who has greater agency, which we discuss in the following section, reminds us of common power imbalances and social hierarchies that are often prevalent in the social networks that comprise communities which may negatively impact the ability of participatory and collaborative community-level endeavours to function as effective, and equitable, social learning platforms (e.g., by determining who gets invited to the table) (Delgado-Ramírez et al., 2023; Wiber et al., 2009). This matters as these venues serve as focal points for adaptation decisions that are pertinent to the livelihoods of all community members.

6.2. Power dynamics, social hierarchies, and leadership

Power dynamics can be a significant determinant of who gets to participate in environmental decision-making venues where adaptation decisions are negotiated, and whose interests are represented (Cassidy, 2021; Stone and Nyaupane, 2014). For example, in the context of Kenyan coastal fisheries, Murunga et al. (2021) point to the intricate power plays within BMUs, where historical legacies of social hierarchies and ethnic discrimination continue to shape the collaborative decision-making context. This is mirrored in our findings, which show that older individuals, community leaders, and those with ties to leaders are more likely to be exerting individual agency over environmental decision-making (Fig. 3). We also found that having a greater level of assets was positively related to agency and that ethnic minorities were significantly less likely to be exerting individual agency (Fig. 3).

Our results regarding leadership and age may stem from role expectations, as elders and leaders in the Kenyan context are often recognized as authority figures and afforded traditional respect (Murunga et al., 2021), and could also be reflective of accumulated knowledge and social capital built up over time and through leadership

opportunities (Brass, 2001). Effective leaders can provide proxy agency to others by advocating and exerting influence on their behalf (Bandura, 2006). The role of such individuals in decision-making processes can be crucial in navigating the complexities of collaborative, community-level management, ideally leveraging their agency for community-wide benefits (Ferrol-Schulte et al., 2014). However, influential individuals can also act as self-interested agents of exploitation within local social hierarchies (Roberts et al., 2022), and can congeal their communities within the status quo when adaptation is needed (Barnes et al., 2020; Matous et al., 2024). The significant involvement of elders and leaders hints at potential barriers to participation for others, especially when coupled with the decreased likelihood of active involvement of less prominent ethnic groups. Elitism and problematic social hierarchies have previously been identified in other fishing communities along the Kenyan coast (Cinner et al., 2009a; Mbaru and Barnes, 2017; Murunga et al., 2021), and are commonly found in many rural communities of the Global South (Pratiwi et al., 2022). These power imbalances can inadvertently lead to the exclusion of marginalized voices, including those from younger community members and women (Matous and Bodin, 2024). Understanding local power relations and exploring options for more collective “socialized leadership” (Whyte et al., 2022) is therefore essential for developing inclusive adaptation strategies that broadly leverage the strengths of community members beyond a few individual leaders.

The nuanced relationship between assets and agency also underscores the intersection of economic power with social influence (Mason et al., 2022). Owning a boat or having access to credit can reflect an individual’s capacity to invest in the fisheries sector, thereby increasing their stake in, and potential influence over environmental decisions. This economic agency could translate into decision-making power, aligning with Stevenson and Greenberg’s (2000) suggestion

that social structures and positions can provide leverage in environmental governance systems. The significance of assets in predicting agency also supports Pfeffer and Salancik's (1978) resource dependence theory, which posits that control over critical resources can lead to power imbalances. Addressing these types of material and power imbalances is widely recognized as essential for ensuring equitable participation in collaborative, community-level structures (Berkes and Folke, 2000).

6.3. Decline of participation in decision-making over time

The overall decline in active involvement among those initially involved could reflect a range of issues such as disillusionment, fatigue, or evolving personal circumstances as well as a possible regression to the mean from initially high values. Interestingly, such regression to the mean was not observed on the other side of the spectrum, i.e. those who were not involved in the beginning were in general more likely to remain uninvolved. It is also noteworthy that socio-demographics and socio-cognitive factors like generational status did not predict changes in agency in the observed period. This suggests that historical and family ties are a relatively stable part of the community social fabric that likely present longer-term influences (Donkersloot et al., 2020), rather than drivers of the observed short-term changes.

Potential disillusion or fatigue regarding involvement in environmental decision-making could be due to unequal distribution of benefits, historical legacies of conflict, and exclusionary norms and practices that existing research has emphasized can shape access to opportunities and resources in the Kenyan context (Kawaka et al., 2017; Murunga et al., 2021). Some fishers may also simply lack the time to participate in prolonged engagement, particularly when they are spending long hours looking for fish due to declining resources. Other possible reasons include a lack of reciprocity (mobilization of resources) or the effect of outsiders (NGOs, government) promising more than they can deliver (Kawaka et al., 2017; Reed, 2008). Critically, a lack of involvement in environmental decision-making can breed further resentment over adaptation decisions that affect the entire community, leading to increasing conflict over time (Carrick et al., 2023; Murunga et al., 2021).

6.4. Implications for locally led, community-level adaptation

The findings from our research have important implications for understanding disparities in agency over adaptation decisions that we argue are not only relevant within the context of Kenyan coastal communities, but have broader implications for community-level adaptation worldwide. This is particularly the case as locally led approaches to adaptation; where communities define, prioritize, monitor, and evaluate adaptation decisions; have gained significant political momentum over the past several years (Rahman et al., 2023; Soanes, 2021). Though the shift from top-down to bottom-up approaches centred on enhancing the agency and power of local people and communities has largely been welcomed as a positive step toward advancing climate justice, several scholars have cautioned that power inequalities and injustice may persist in locally led adaptation when, for example inequalities are reproduced through micropolitics and existing social and cultural structures (Rahman et al., 2023; Tschakert et al., 2016). Similar cautions have been discussed in strongly related bodies of literature on community-based adaptation and collective/community-based/community-level co-management (Singleton, 2000; Vincent, 2023).

Our results contribute a cautionary tale to this evolving discourse by demonstrating that meaningful power imbalances associated with collective environmental decision-making at the community-level are not only present but can persist, thus highlighting a critical need for strategies that enable more equitable participation in the decision-making arenas where community-level adaptation decisions are negotiated. Our results suggest that enabling more equitable adaptation decision-making at the local level could involve creating platforms that amplify

the voices of ethnic minorities and those without traditional forms of power or assets. Our findings also showed that active versus passive involvement in arenas where community-level adaptation decisions are made plays a distinct role in determining perceptions of agency. Interventions could thus be designed to strengthen participation in these arenas (Naderpajouh et al., 2023; Whyte and Mottee, 2022), particularly targeting those with passive involvement to encourage and facilitate a more active role in decision-making. This aligns with Ling and Dale's (2014) emphasis on the importance of social capital and networks in enhancing individual and collective agency. Overall, our results suggest that interventions aimed at supporting locally led, community-level adaptation need to consider the structure and, importantly, the quality of social relationships within communities and any existing social hierarchies in order to prevent invertedly retrenching existing power dynamics.

6.5. Limitations and implications for future research

There are some limitations we encountered in this study. Due to resource and time constraints, we were only able to measure individual and proxy agency over time, missing other key components such as collective agency. Future research on agency over adaptation decisions at the community level should consider diverse community characteristics and seek to understand how micro-level social interactions associated with individual and proxy agency scale up to impact collective agency. Future research could also aim to identify more specifically the mechanisms through which social networks can be supported to enhance individual agency and collective adaptive capacity (Dapilah et al., 2020). Does the active involvement of network contacts provide access to information, resources, or a sense of empowerment that encourages greater participation? Empirical analyses isolating the impact of targeted interventions on social network structures and the corresponding changes in community adaptation practices that carefully explore the ethical and practical feasibilities of orchestrating connections would be particularly insightful. Additionally, examining the role of power dynamics and power asymmetries in more depth could reveal insights into how traditional leadership structures interact with modern community-based, collaborative environmental governance frameworks to foster (or potentially constrain) inclusive decision-making processes and just, locally led adaptation. Longitudinal studies could further explore the long-term impacts of agency on the sustainability of adaptation strategies themselves. Are there critical thresholds of involvement necessary to ensure sustainable adaptation outcomes? Understanding such dynamics will be crucial for working with communities to craft effective adaptation policies and interventions that foster resilience in the face of environmental change.

7. Conclusion

In this paper, we contribute to the discourse on agency and social networks in adaptation to environmental change. While this study generated a number of new questions, its findings improve our appreciation of how agency is distributed within communities and emphasize the need for further research and policy considerations to address potential imbalances. In particular, the results underscore the importance of local social networks in enabling and constraining community members' agency, highlight the role of leadership and power dynamics in environmental decision-making, and provide a foundation for future research on fostering inclusive and effective adaptation projects and strategies.

CRediT authorship contribution statement

Michele L Barnes: Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation,

Conceptualization. **Sarah Sutcliffe**: Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation. **Innocent Muly**: Writing – review & editing, Validation, Investigation. **Nyawira Muthiga**: Writing – review & editing, Validation, Resources, Funding acquisition. **Stephen Wanyonyi**: Writing – review & editing, Validation, Investigation. **Petr Matous**: Writing – review & editing, Writing – original draft, Visualization. **Michael Murunga**: Writing – review & editing, Writing – original draft, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethics statement

Research protocols were approved by the Human Ethics Committee at James Cook University (Approval No. H7603 and H6461). Informed consent was obtained from all respondents.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.gloenvcha.2025.102983>.

Data availability

Summary data is provided in the SI. Raw data is protected under our ethics agreement, but de-identified data can be shared under certain circumstances (e.g. to verify results) upon request.

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