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Views of management effectiveness in tropical reef fisheries

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Abstract

The effectiveness and outcomes of management are expected to improve when people are informed, engaged and influential in governance and management procedures. The social-ecological and demographic contexts should, however, influence an individual's perceptions and willingness to engage and access appreciable benefits from management. To evaluate how engagement, procedures and perceived outcomes varied with geographic and social-ecological context, we asked 1582 heads-of-households in 38 fishing villages in four tropical countries to evaluate the benefits of their local fisheries management. Responses to 10 collective action, social performance and management procedure questions fell along three response axes, namely (a) the potential benefits of management, (b) resource status and the reliability of yields and (c) the respondents' ability to influence management decisions. Respondents were most positive about the organization of the existing management systems but more sceptical about their ability to influence decision-making and subsequent yields and resource status. More frequent negative opinions increased with urbanization (distance to cities and population density), which could arise from challenges of group cohesion, local control and subsequent management efficacy. Consequently, we argue that some common rural, decentralized, or collective fisheries management systems are inappropriate for engaging participation in urban contexts. Across all locations, there is a need to increase participation with management decisions and actions, and to transparently evaluate and respond to resource and yield outcomes. Crafting recommendations appropriate for urban contexts will be increasingly relevant as urbanization and commercialized fisheries expand in tropical countries.

KEYWORDS

centralization, common property, coral reefs, democracy, human development, markets, Ostrom's institutional design principles, small-scale fisheries

1 | INTRODUCTION

The state and distribution of common-pool resources (CPR) is expected to influence participants' perceptions and associated support for governance institutions and norms (Ostrom, 2000). Support for CPR management should, therefore, depend on the ability of governance processes to effectively balance human resource needs with resource productivity (Baggio et al., 2016; Cox et al., 2010). This balance will depend on the social-ecological context, which will change along human population and development gradients (Araral, 2014). Contexts, such as rural

versus urban, should therefore produce their own appropriate norms and governance institutions (Rodden, 2019). This begs the question of how resource management, as experienced by participants, can effectively address fisheries management objectives along gradients of increasing population, commercialization and urbanization (Cinner et al., 2016; Daw et al., 2012; McClanahan et al., 2009; McClanahan & Abunge 2020).

Whether management process is inclusive and incorporate collective decisions over resource use should affect compliance among fishers, resource users, community residents and local managers (i.e. stakeholders) (Agrawal, 2003; Ajzen, 1991). Moreover, the variability in stakeholder perceptions should have consequences for group cohesiveness, collective action, and therefore, the ability to effectively implement natural resource management (Poteete & Ostrom, 2004). Engagement and strengthening linkages within an adaptive cycle should improve decision-making and management outcomes (Redpath et al., 2013). However, these linkages are expected to function more effectively when the stakeholders agree on the management goals and causative relationships. Therefore, improved understanding of the variability in stakeholders' views of local benefits and ability to control decision-making should improve insights into barriers that might potentially undermine CPR management effectiveness (McClanahan & Abunge, 2018, 2019).

Engagement of local resource users in CPR governance potentially contributes to addressing socio-ecological CPR problems (Pahl-Wostl et al., 2007; Redpath et al., 2013). The reasons for this are both ethical and instrumental. The ethical standpoint is that people should be involved in the management of the natural resources on which they rely. The instrumental standpoint is that the likelihood that rules will succeed should increase as rules reflect stakeholder preferences and local conditions, and when management is perceived as legitimate (Gurney et al., 2016; Ostrom et al., 1993; Persha et al., 2011). Thus, a successful adaptive resource management cycle would be expected to integrate both ethical and instrumental aspects of participatory engagement (Walker et al., 2002).

We expect stakeholders' views of governance and the efficacy of management to vary with social and geographic contexts. Perceived effectives should, in turn, result in differential willingness to participate and improve adaptive management. Because trade-offs between local versus other economic options should influence decisions, individual participation should depend on their position and options within the larger economy (Dacks et al., 2020; Daw et al., 2012). Thus, the number and diversity of opinions and associated decisions concerning managing resources are expected to change across gradients of human development and market integration (Agarwal, 2001; Cinner et al., 2007, 2016; McClanahan & Abunge, 2016). For example, trends in human geography include gradients in rural–urban residence that include gradients in informal-to-formal education, subsistence-to-commercialized economies and low-to-high technology environments. In short, gradients in human life styles result from people's residence along rural–urban gradients reflect the classic sociological division between community and society. Psychologists examining perceptions along these gradients find, for example, differences in the independence of individual behaviours, engagement in commerce, monetary wealth and abstract thinking (Greenfield, 2009). Consequently, better acknowledging this geographic and demographic variability among social-ecological contexts should better illuminate emergent stakeholder opinions concerning management effectiveness and the potential to improve CPR governance (McClanahan & Cinner, 2011). Therefore, we tested for the expected demographic patterns in opinions using a sample of fishing villages across a gradient of tropical fisheries from Kenya to Fiji.

Here, we evaluated how individuals reliant on coastal fisheries in four tropical countries perceived their local management. We elicited respondents' opinions relating to: (a) collective choice rules (i.e. decision-making arrangements and processes regarding management rules, such as where people can fish); (b) the social performance of CPR management (e.g. effects on individual catches, catch reliability); and (c) status and changes in resource abundance (Table 1). The purpose of this study was to determine if the responses of individuals living in tropical fishing households could be classified into distinct typologies of opinions. If so, what were the geographic and socioeconomic factors that differentiated these opinions. Specifically, how variable were opinions along distances to cities and population gradients and how might this variability challenge or assist efforts to manage CPR resources? A key motivation of this study was to quantify variability among specific collective

TABLE 1 Questions used as indicators of fishing households' opinions concerning resource governance, management, and outcomes

Governance category	Specific indicators	Questions
Collective choice	Support for management	In general, do you support/agree with the management here? Very supportive (+2) to very unsupportive (−2)
Collective choice	Political influence	How much do you agree or disagree with this statement: People like me have influence on the management of marine resources? Strongly agree (+2) to strongly disagree (−2)
Collective choice	Fair decision-making	In general, do you think the way that decisions are made about marine resource use and management are fair? Very fair (+2) to very unfair (−2)
Social performance	Management effect on community	Considering these positive and negative impacts, what is the overall level of impact of fisheries management on this community? Very good (+2) to very bad (−2)
Social performance	Management effect on individual	Considering these positive and negative impacts, what is the overall level of impact of fisheries management on you? Very good (+2) to very bad (−2)
Social performance	Fairness in management effect	In general, do you think the distribution of the positive and negative impacts from the management here is fair? Very fair (+2) to very unfair (−2)
Social performance	Management effect on catch	In general, do you think management has affected the number of fish? If yes, how has the number of fish been affected? Much more (+2) to much less (−2)
Social performance	Management effect on ease of catch	In general, do you think management has made it easier or harder to catch fish (in terms of time, effort, or travel distance)? Much easier (+2) to much harder (−2)
Social performance	Management effect on catch reliability	In general, do you think management has affected the reliability of what you can catch? If yes, how has it changed the reliability? Much more reliable (+2) to much less reliable (−2)
Changes in resource abundance	Perception of resource change	Over the past 5 years has the numbers of fish in the sea around here changed? Large increase (+2) to large decrease (−2)

Note: Responses to these 10 indicator questions are the basis for subsequent evaluations. All responses were coded into 5-point Likert scale −2 to +2. Source: Gurney et al. (2019).

choice or social performance metrics in order to identify opinions that might challenge compliance with fisheries management proposals. A diversity of opinions should provide both positive and negative feedback to decisions that can influence trust, optimization, transformation and successful social-ecological change. Consequently, we wanted to better understand the status and variability of this local fisheries' institutions and governance processes for potentially developing prescriptive policies.

2 | METHODS

2.1 | Study sites

We studied 38 coastal communities dependent on coral reef fisheries in 4 countries, coastal Kenya (n = 6 communities), Madagascar (n = 23), Indonesia (n = 3) and Fiji (n = 8) (Figure 1; Table 2). Communities were selected based on their proximity to and dependence on coral reef fisheries, and whether they were associated with, or were planning, a local-, co- or government-managed area-based management. The purpose here was to evaluate subjective perceptions of the local management irrespective of the specific types of management. For example, in Fiji, communities have established locally managed marine areas with fisheries management rules, including traditional closures (*tabus*) within customary fishing grounds that are recognized under law (Jupiter et al., 2014). Madagascar and Kenya had similar community or co-management arrangements but these were recently developed and seldom fully evaluated for their success (Rocliffe et al., 2014; McClanahan et al., 2016; Maire et al., 2020). So, while many management systems were not fully implemented or evaluated, the interviews conducted here were to establish a baseline for long-term monitoring of responses that would evaluate outcomes that are more resolved in terms of the specific management and social context (Gurney et al., 2019). The sites were arranged along gradients of human population and distance to larger cities, ports, or major markets. Most fishing villages had fish traders who bought fish at local landing sites and transported them to various markets with higher values (Wamukota & McClanahan, 2017; Dacks et al., 2018; Maire et al., 2020). When sampling, we chose the sub-village most closely associated with the respective marine conservation or management project. The studied villages were often connected to nearby villages but we report and analyse the specific fishing village statistics (Table 2).

2.2 | Field sampling

We conducted interviews with 1582 respondents in the 38 communities. We targeted heads of households, which were selected using a systematic random sampling protocol whereby a sampling fraction of every ith household (e.g. 2nd, 3rd, 4th) was determined by dividing the total community population by the total sample size possible given survey resource constraints (Gurney et al., 2019). Heads-of-households included an equal ratio of fishing and non-fishing respondents, and we aimed for a gender balance by interviewing both male and female heads of households. For example,

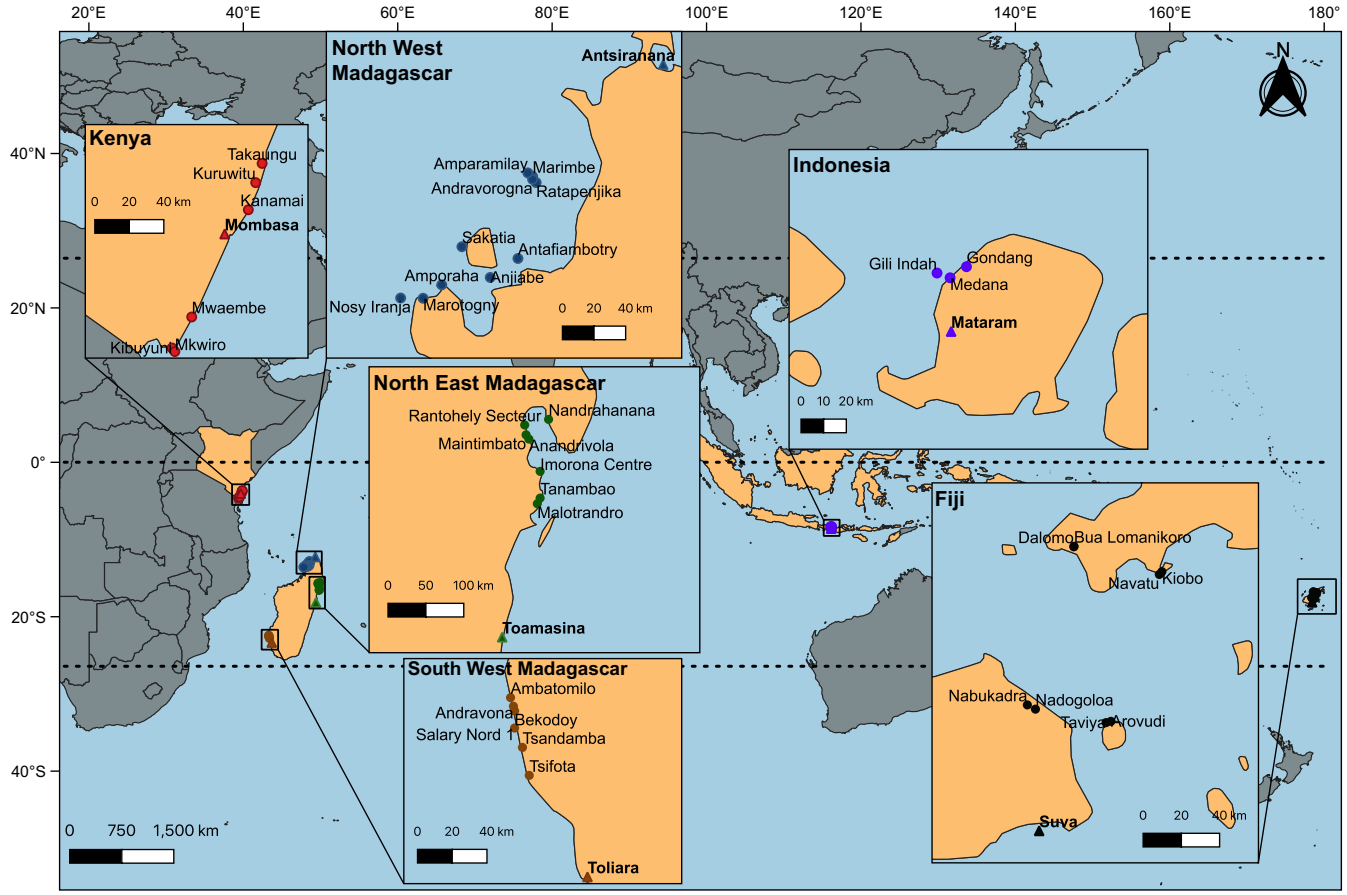

FIGURE 1 Map of study sites and their nearest large cities. Cities in the map are presented as triangles while study sites are represented as circles. Colours in the map represent study areas and villages in the countries and regions as follows; red – Kenya, blue – Northwest Madagascar, green – Northeast Madagascar, brown – Southwest Madagascar, purple – Indonesia and grey – Fiji. Triangles indicate nearby national and provincial capitals

women-headed households included 586 out of 1582 surveys with 29% in Indonesia, 42% in Fiji, 46% in Kenya and 65% in Madagascar. The number of interviews per community depended largely on the population of the village and the availability of time and other resources. For communities of less than 50 households, all households were interviewed when the head of household was present. Information about the number of households was sourced from government offices and was based on the recent national census at the geographical level of the location. The number of surveys per community ranged from 5 to 253 individuals who were stated heads-of-households. Surveys were conducted by trained interviewers, in local languages and dialects. The surveys were approved by the WCS Institutional Review Board and all surveyors underwent training in human subjects' research to protect subject privacy and data confidentiality.

2.3 | Indicators of resource governance, management and outcomes

We used ten questions to help evaluate the perceived state of resource governance and management. Questions were grouped into three categories (Table 1): collective choice (three indicators), social performance (six indicators) and changes in resource abundance (one indicator). These indicators comprised part of a broader social-ecological Marine and Coastal Monitoring Framework (Gurney & Darling, 2017). The framework was developed through a transdisciplinary process with the aim of supporting an international non-profit, in identifying the social and ecological outcomes of their coral reef management programmes (Gurney et al., 2019). The ten questions selected for this study used Likert-type five-point scale responses.

2.4 | Socioeconomic characteristics

We examined how opinions concerning resource governance and management were related to 16 socio-economic characteristics that might operate at multiple levels of social organization (individual, household, community and country) (Table 3). Data were derived from the interviews and online data sources. Individual-level characteristics included age, level of education, years in fishing, years of residency (when one moved or the age they were born at the village), number of occupations, the number of community and fisheries organizations

TABLE 2 Summary statistics of sampled fishing villages

Locations		Population and sampling				Primary livelihood of respondent		Gender of respondent		Missing sampling information	
Country	Village	Estimated population of village	Population within 100 km	Distance to nearest cities (km)	Number of household surveys	Fishing	Not fishing	Female	Male	Primary livelihood not specified	Gender not specified
Fiji	Arovudi	111	444,799	725.6	16	14	2	10	6	0	0
Fiji	Bua Lomanikoro	312	127,059	684.9	20	15	5	14	6	0	0
Fiji	Dalomo	122	127,390	685.1	6	5	1	4	2	0	0
Fiji	Kiobo	89	135,902	656.7	10	7	3	4	6	0	0
Fiji	Nabukadra	125	579,841	752.3	14	10	4	5	9	0	0
Fiji	Nadogoloa	115	538,920	750.5	16	12	4	9	7	0	0
Fiji	Navatu	141	137,600	658.7	16	8	8	8	8	0	0
Fiji	Taviya	121	452,139	727.8	21	19	2	12	9	0	0
Indonesia	Gili Indah (inside MPA)	5,961	5,615,695	26.4	253	185	68	56	197	0	0
Indonesia	Gondang (outside MPA)	8,895	4,472,348	29.2	5	0	5	0	5	0	0
Indonesia	Medana (outside MPA)	4,996	4,936,942	23.6	17	2	15	0	17	0	0
Kenya	Kanamai	1,800	2,997,887	19.6	70	18	51	19	51	1	0
Kenya	Kibuyuni	500	3,439,090	56.4	69	22	47	22	46	0	1
Kenya	Kuruwitu	30,000	2,986,981	34.6	74	41	33	24	50	0	0
Kenya	Mkwiro	1,637	3,397,664	55.5	48	15	31	20	28	2	0
Kenya	Mwaembe	1,000	3,288,230	51.5	62	32	29	21	40	1	1
Kenya	Takaungu	1,500	2,924,201	46.1	44	24	20	12	31	0	1
Madagascar	Ambatomilo	704	318,035	110.6	51	13	36	26	25	2	0
Madagascar	Amparamilay	80	533,983	107.9	15	5	10	7	8	0	0
Madagascar	Amporaha	200	431,612	194.7	33	19	14	11	22	0	0
Madagascar	Andravona	1,129	342,370	105.4	68	12	55	24	44	1	0
Madagascar	Anjiabe	1,500	569,031	171.3	50	33	17	20	30	0	0
Madagascar	Antafiambotry	1,000	608,809	151.5	50	17	31	21	28	2	1
Madagascar	Bekodoy	508	366,857	102.7	37	5	32	14	23	0	0
Madagascar	Imorona Centre	2,000	611,513	222.9	53	47	6	22	31	0	0
Madagascar	Maintimbato	843	803,697	267.3	84	64	18	32	52	2	0

(Continues)

TABLE 2 (Continued)

Locations		Population and sampling				Primary livelihood of respondent		Gender of respondent		Missing sampling information	
Country	Village	Estimated population of village	Population within 100 km	Distance to nearest cities (km)	Number of household surveys	Fishing	Not fishing	Female	Male	Primary livelihood not specified	Gender not specified
Madagascar	Malotrandro	396	692,736	180.7	55	45	5	19	35	5	1
Madagascar	Marimbe	100	566,288	107.1	25	15	10	12	12	0	1
Madagascar	Marotogny	425	386,835	208.8	41	20	21	15	25	0	1
Madagascar	Nandrahanana	4,100	729,236	291.8	54	43	7	21	29	4	4
Madagascar	Nosy Iranja	500	342,855	218.8	39	28	10	19	20	1	0
Madagascar	Rantohely Secteur	2,000	882,701	280.0	73	68	3	28	43	2	2
Madagascar	Ratapenjke	150	586,138	108.1	35	16	19	16	19	0	0
Madagascar	Sakatia	1,200	457,230	169.1	49	37	12	21	28	0	0
Madagascar	Salary Nord 1	1,140	443,734	93.7	52	13	37	11	41	2	0
Madagascar	Tanambao	805	624,394	188.8	84	70	13	24	60	1	0
Madagascar	Tsandamba	1,721	551,572	81.8	70	6	62	27	43	2	0
Madagascar	Tsifota	2,019	580,461	65.9	50	4	46	24	26	0	0
Average		2,104	1,264,020	248	48	27	21	17	31	1	0
Ratio						0.56		0.36			

TABLE 3 Description of variables of both national and global content used to evaluate fishing community households' perceptions of management and resources

Social indicators	Description of social indicators	Data source for both perceptions and social indicators	BRT relative influence (%)		
			PC 1[a]	PC 2[b]	PC 3[c]
Distance to nearest city, km	Based on nearest town	Yeager et al. (2017)	22.0	34.4	18.6
Population in 100-km radius of village	Estimated number per surrounding	Yeager et al. (2017)	18.8	13.4	17.3
Age of respondents	Years of age	Surveys	14.3	10.8	18.4
Years in village	Whether respondent was from the village or born somewhere else and how long they have lived in the village	Surveys	13.1	12.4	15
Social network	Whether respondent was involved in community organization	Surveys	12.4	6.5	8.0
Household size	Count of household members	Surveys	4.5	8.5	7
Fishing gear diversity	Count of different gears in use by respondent	Surveys	3.6	5.8	7.4
Number of livelihoods – Respondent	Number of different occupations currently held by respondent	Surveys	2.3	2	2.7
Country	Allows for comparison of countries within the study	Surveys	4.1	1.4	0.9
Number of livelihoods – Household	Number of different occupations in the household	Surveys	2.0	2.0	1.4
Gross national income	GNI per capita ($)	World Bank	1.2	NS	1.4
Mobile subscription (%)	Mobile users (per 100 people)	World Bank	NS	1.8	NS
Households with internet	Access to internet	World Bank	NS	NS	NS
Control of corruption	Reflects perceptions of the extent to which public power is exercised for private gain (%)	World Bank	NS	NS	NS
Governance effectiveness	Reflects perception of the quality of public and civil services (%)	World Bank	NS	NS	NS
Voice and accountability	Reflects perceptions of the extent to which citizens are able to participate in selecting their government as well as freedom of expression and association.	World Bank	NS	NS	NS

Note: Data sources include surveys and World Bank 2015–2016 scaling (https://www.worldbank.org). Rows are organized from most to least influential in the Boosted Regression Tree analysis (Figure 7). PCA axes represent *a*. management benefits *b*. perception of the resource *c*. influence of stakeholder engagement on management

an individual was involved in as a proxy of structural social capital. Community organizations included social or financial groups, and fisheries organizations that refer to groups concerned with fishers' welfare or fisheries management, such as Beach Management Units (BMUs), Locally Managed Marine Area (LMMA) councils in Madagascar, Resource Management Committees (RMCs) in Fiji, and community-led surveillance groups in Indonesia (POKMASWAS). Household-level indicators included household size (number of individuals living in the house), number of occupations held by the entire household, and number of fishing gears employed by the household.

National-level characteristics were derived from online data sources from the World Bank using their 2015–2016 data set, which aligns with the period when we collected village-level data. National-level indicators included gross national income, percentage of households with internet access, percentage of households with a mobile phone subscription, control of corruption by governments, voice and accountability of citizens and governance effectiveness (Table 3). The last three variables describe how the citizens of studied countries perceived the services provided by their national government. The human population within the larger 100-km radius of each village was accessed through the online Marine Socio-Environmental Covariates (MSEC) platform which contains global data layers of environmental and anthropogenic impact variables (Yeager et al., 2017) (Figure 1). The straight-line distance to the nearest provincial cities or ports was used here as a metric of potential commercial influence (Maire et al., 2016). Cities are based on the ESRI World Cities database and distances were calculated using the "distGeo" function in the geosphere package (Hijmans et al., 2016).

2.5 | Data analyses

The evaluation of patterns in the data presented here includes 3 statistical evaluations, namely cluster analysis, principal

component analysis (PCA) and Boosted Regression Tree (BRT) analysis. The cluster analysis was used to determine the number of group opinion associations that existed in the responses and the mean and variances in responses for each significant cluster. The PCA was used to simplify the 10 responses to a limited number of continuous axes, which could then be used to evaluate responses for associations with the independent environmental factors using BRT. Each used the household responses based on 5-level Likert scale to indicate perceptions, from agree completely to disagree completely. Responses were coded into −2 to +2 values. Our full data set initially had 1829 observations but missing data reduced the sample size to 1582 heads-of-households based on a >70% filling threshold for the 10 questions. Responses having missing values were imputed using MICE - Multivariate Imputation via Chained Equations [link] (www.analyticsvidhya.com/blog/2016/03/tutorial-powerful-packages-imputing-missing-values) with the multivariate imputation R package mice 3.8.0 (Buuren & Groothuis-Oudshoorn, 2011). In total, we generated 5 imputed data sets, each using 50 iterations and a predictive mean matching imputation method. Thereafter, data were standardized by adding 3 to each observation to remove negative values for purposes of conducting the analyses.

The cluster analysis was based on a Gower dissimilarity matrix of the response distances generated and linked by a hierarchical average-linkage clustering analysis (SIMPROF; Gower, 1971). Based on 1,000 permutations, significant clusters were determined at alpha 0.01 using the R package clustsig version 1.1 (Whitaker & Christman, 2014). Clusters with small sample sizes (<5 heads-of-households) were pooled with their closest cluster group based on results of Dunn's all-pair comparison test. This resulted in a final number of 37 statistically significant opinion clusters, which were ordered from most to least positive using the mean responses to survey questions. Mean response to each question for each cluster is presented along this opinion gradient to visualize how perceptions change for each opinion group along the overall negative-to-positive gradient.

PCA was used to reduce the main sources of variation in the ten questions to a limited number of axes with associated responses (Table 1). PCA factor analyses were done using the PCA() function using the FactoMineR package (version 1.40, Lê et al., 2008) conducted in R (version 3.3, R Core Team, 2017, https://www.R-project.org/). Outputs were visualized using the factoextra package (version 1.0.5, Kassambara & Mundt, 2017, https://CRAN.R-project.org/package=factoextra). Both individual and mean cluster responses were visualized simultaneously using the "fviz_pca_biplot()" function in the factoextra package (version 1.0.5, Kassambara & Mundt, 2017, https://CRAN.R-project.org/package=factoextra).

The final PCA metrics were partial contributions of the individual responses to the three strongest multivariate dimensions used to test for associations with the 16 socio-economic characteristics (Table 3). Partial contributions were evaluated by General Linear Model (GLM), forward stepwise regression analysis and Boosted Regression Tree (BRT). Models were explored to evaluate the effects of linearity and residuals on the patterns and strength of associations. We found that residual effects were strong and non-linearities common and that the BRT analyses better accounted for these properties. Also, unlike Random Forest methods, which average results as a final step, the BRT algorithm uses a stage-wise method that can reduce bias (Elith et al., 2008). Therefore, we restrict our presentation in the main paper to the BRT association results but additional results are included in a supplement. BRT analysis and partial dependence plots were outputs from R version 3.6.0 and the package "gbm" version 2.1.5. Tuning parameters were determined by adjusting for possible combinations of the parameters bag-fraction (0.5, 0.75, 0.8), learning rate (0.01, 0.025, 0.05, 0.001, 0.0025, 0.005) and tree complexity (1–10) while maintaining a minimum of 1,000 fitted trees. The set of parameters selected had the lowest cross-validation deviance. The "gbm.step" function was used in building models with the following settings: tree.complexity = 10, learning.rate = 0.005, bag.fraction = 0.75, n.trees = 50. Partial dependence plots were produced using the "gbm.plot" function and the smooth option set as TRUE, which are presented as red dashed lines in the plots.

3 | RESULTS

3.1 | Opinions of resource governance and management

Madagascar had the highest number of surveyed heads-of-households (61.5%), followed by Kenya (22.8%), Indonesia (8.3%) and Fiji (7.4%) among the 1582 interviewed people (Figure 1). SIMPROF cluster analysis produced 37 significant "opinion clusters" based on the ten questions (Figure 2). We numbered the clusters 1–37 based on the mean response or level of agreement with the statements about management effectiveness (Table 1). Cluster groups were significantly different but 72% of the respondents or the first 23 clusters, had overall positive opinions while 14 (clusters 24–37) had overall negative opinions about local management (Figure 2a). Communities had considerable variability with numerous cluster groups observed within a single community (Appendix S1). For example, Fiji had the most positive and least diverse opinions about management with respondents distributed in 4–11 different opinion clusters per fishing village. In contrast, the most response-diverse country, Kenya, had respondents distributed in 16–24 clusters per village. Kenya and Madagascar had more diverse opinions than Indonesia and Fiji (Figure 2b). Kenya and Madagascar had the highest percentage of respondents in the negative clusters. Indonesia had very few respondents in the most positive respondents (1–13), a high number in the moderate (14–25), and few in the most negative respondents (26–37) (Appendix S1).

Responses to the three collective choice questions roughly follow the overall negative to positive opinion trends but with some

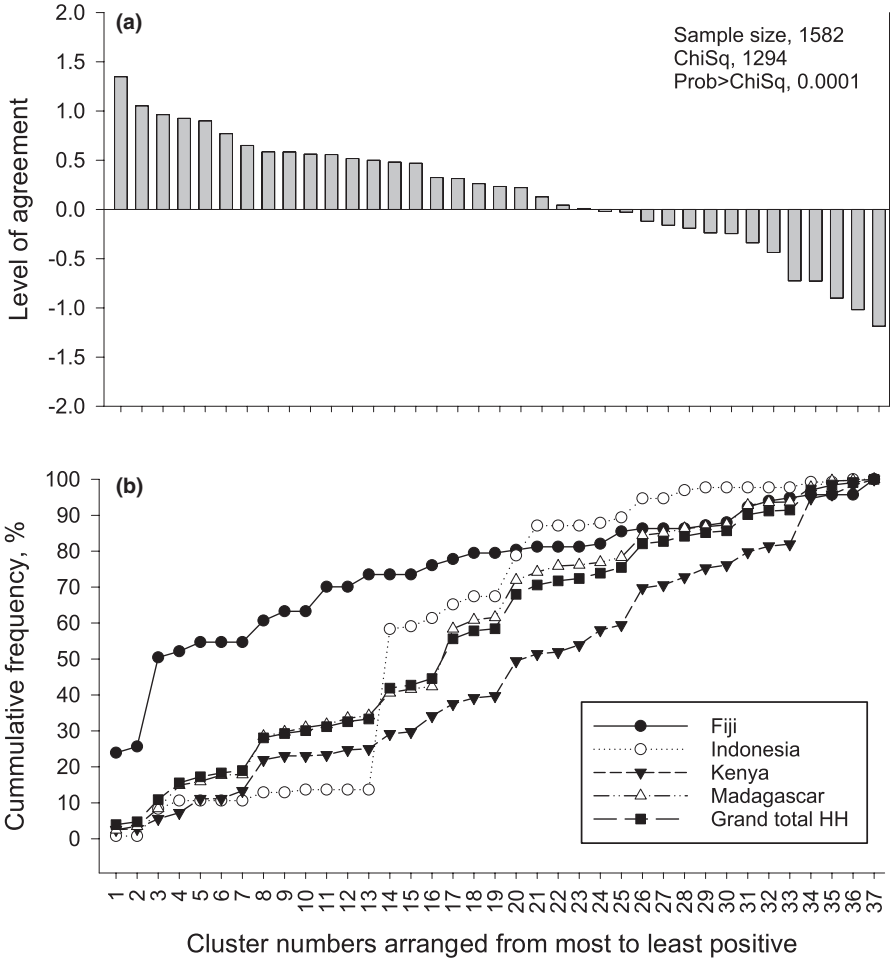

FIGURE 2 Cumulative frequencies of mean responses to all questions for (a) 37 unique opinion clusters and (b) the 4 studied countries. Clusters are arranged from the overall most to least positive agreement with the statements in Table 1

notable differences between neighbouring clusters (Figure 3). Respondents' support for local management was the most consistently positive response along this overall positive to negative opinion cluster axis (Figure 3a). Even for this question, however, clusters 19, 24, 25, 28, and most clusters from 31 to 37 were not supportive of existing management. Respondents' perceived ability to influence political decisions was the most variable and distinctive response. Here, there was no clear association with the overall positive to negative cluster gradient as many respondents believed they had little influence on decision-making (Figure 3b). The last ten clusters, for example, strongly disagreed with the statement that they had political influence. Fairness in decision-making was more aligned with the mean response patterns, but even some overall negative clusters, including 26, 27 and 35, were positive about fairness when their neighbouring clusters opinions were not (Figure 3c).

Respondents' opinions concerning the management effects on social performance outcomes generally followed the overall opinion gradient. However, there were noticeably more neutral to negative opinions for the effects of management benefits on individuals than on communities. For example, the negative opinions on individual benefits began at cluster 22 compared to 28 for benefits to communities (Figure 3d–e). Fairness in the distribution of management outcomes had more negative scaling, which started at cluster 6 and was mostly negative after cluster 15 (Figure 3f). Respondents' perceived effects of management on the catch, ease and reliability differed mostly in that only catch reliability was weakly associated with the overall opinion gradient (Figure 3g–i). After cluster 8, most respondents expressed opinions that management did not increase the reliability of catches (Figure 3i), whereas for the management effect and ease of catch, negative opinions became apparent after cluster 23. Respondents' perceived increases in resource abundance due to local management responses were uncommon with only about 7 of the 37 clusters stating that catches were improved (Figure 3j). By cluster 4, respondents believed there were declines in catches associated with management.

3.2 | Dominant responses

Responses evaluated by the multivariate analysis differentiated the positions of the 37 opinion clusters among the 10 questions (Figures 4, 5). The dominant axis explained 37%, the second 12% and the third 10% of the total variance. The perceived effects of management on people were the strongest axis. Specifically, respondents in clusters 1–16 perceived benefits, whereas those in clusters 17–37 did not agree that there were benefits from management. Management fairness and effects on individuals and community questions were the strongest contributors to this axis, followed by

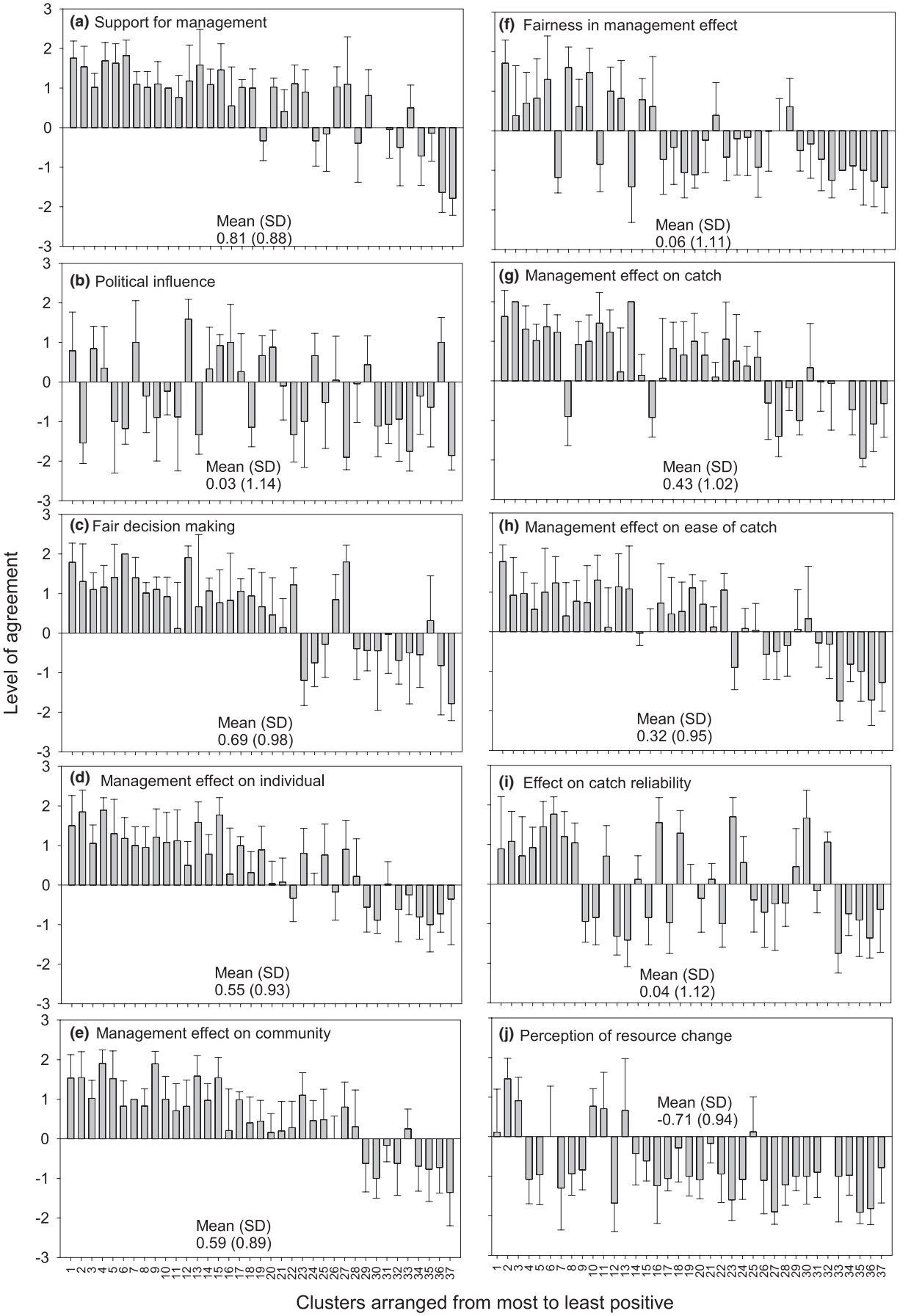

FIGURE 3 Level of agreement responses (mean ± *SEM*) to the 10 questions of management effectiveness for each of the 37 unique hierarchical average-linkage clusters. Organized as (a–c) collective choice, (d–i) are social performance, and (j) is a change in resource abundance metric (see Table 1). Clusters arranged from most (left) to least positive (right)

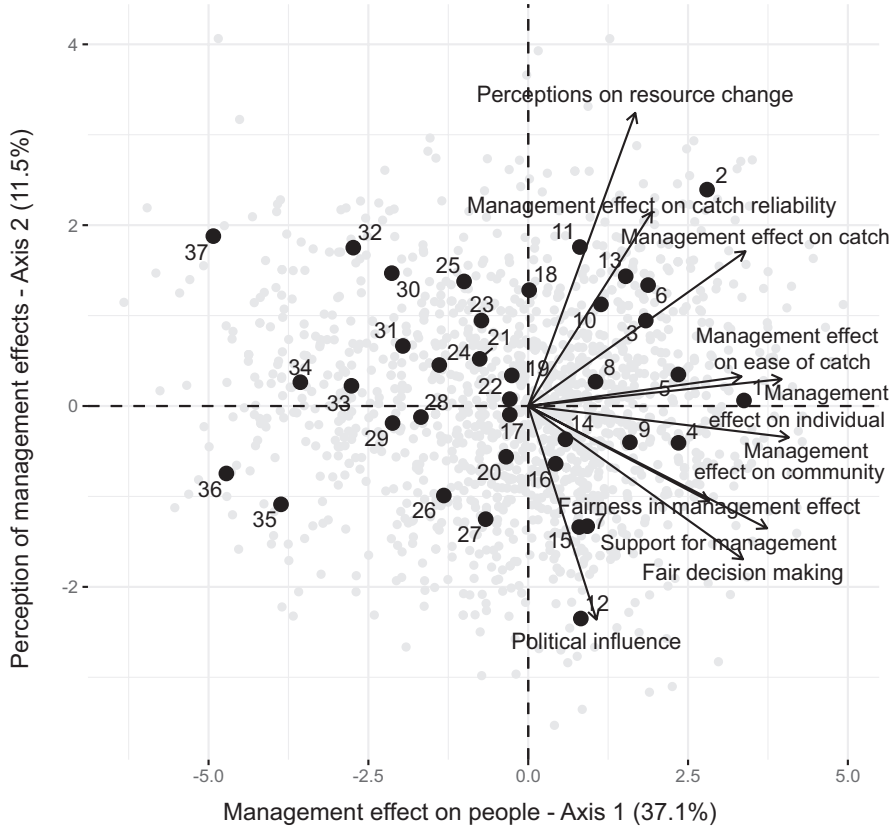

FIGURE 4 Multivariate analysis of the management effectiveness questions (Table 1) displayed as the first two Principal Component Axis, associated vectors, and positions of the 37 unique opinion clusters. The PCA is based on individual responses (light grey dots) but mean cluster responses (black dots) are overlain to ease interpretation

the ease and reliability of the catch (Figure 5a). The second axis or the perceived effect of management on the resource was influenced by slightly negative opinions concerning management on community benefits, fairness, political influence and support for management (Figure 5b). More positive opinions concerning the positive effects of management, the ease of catch and its reliability were less important in affecting this axis. The weakest axis was largely influenced by the respondents' opinions concerning their ability to influence the political process (Figure 5c).

3.3 | Demographic and socio-economic associations with response categories

Many relationships were found among the local and national demographic and socio-economic variables by the BRT analyses (Figure 6). For the strongest axis or the management effect on people, 11 of the 16 variables were selected. The distance to cities and human population numbers were the strongest variables and had a relative influence (RI) of >40% (Figure 7a). Respondents' perceived benefits of local management increased with the distance to cities until levelling at ~200–300 km. Similarly, respondents' perceived less benefits with increasing size of the human population at these cities, levelling at ~1 million people per 100-km radius. Age and years inhabiting the village were small to moderate influences (RI = 14% and 13%) but the relationships were more complex and sinusoidal, suggesting human-age cohort influences. Social network influences also suggest a small to moderate (RI = 12%) positive responses that increased up to 4 formal social networks before levelling. The other selected variables had <5% relative influence but included household size, nation, fishing gear, number of respondents and household livelihoods, and gross national income.

The second axis, or the respondents' perception of management effect on resources, also selected 11 of the 16 variables (Figure 7b). Similar to the first axis, it was associated most strongly with the distance to nearest cities (RI = 34%) and the human population size (RI = 13%). Again, there was a saturation response with positive views of management increasing away from cities. The relationship with population size was, however, less clear in terms of a simple predictable model or relationship. The respondents' age and years living in the village were, again, not linear and possibly also influenced by specific age cohorts. Most of the other selected variables were weak (RI<8.5%) but indicated respondents' perceptions of small declines in the respondents' perceived benefits of management with their household size, social networks, fishing gear diversity, numbers of household livelihoods and mobile subscriptions.

BRT results of the weakest axis or the respondents' perception of their ability to influence the local decision-making selected 11 of the 16 variables (Figure 7c). Distance to cities (RI = 18%) and number of people (RI = 17%) were weak but followed similar patterns with the market variables as the two stronger axes. Age was also a moderately important variable (RI = 18%) but largely reflected a cohort effect, with older adults perceiving more political influence but declining for people >70 years old. The other variable contributed <8% of the relative influence of the full model. These selected variables included a positive influence on political decision-making with increasing household fishing gear diversity, household size and number of livelihoods.

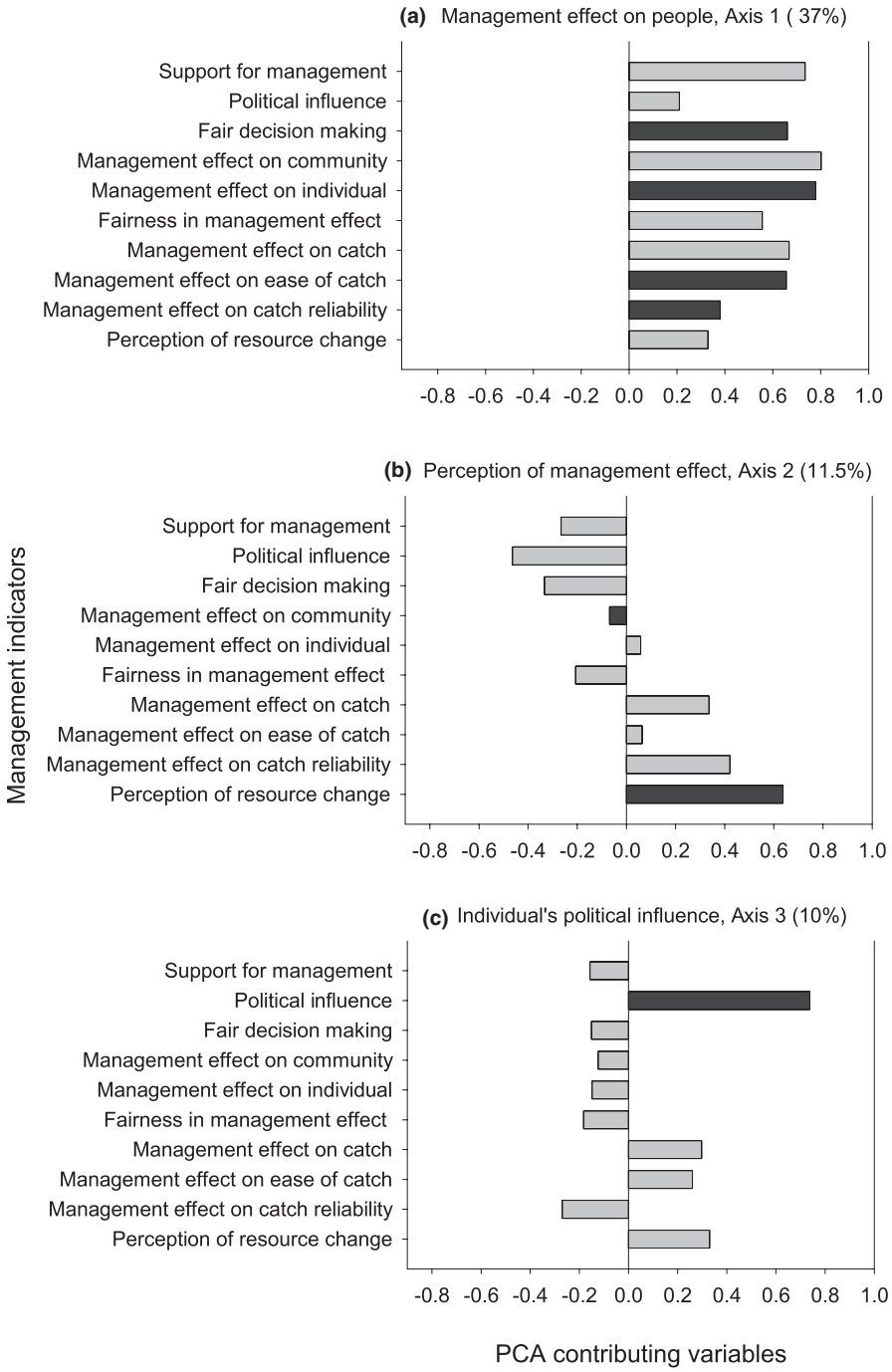

FIGURE 5 Contributions of the responses to the 10 questions to the scaling of the three dominant PCA axes. These are (a) the benefits of management, (b) the perceived state of the resource, and (c) the potential influence of respondents' engagement in management decisions. Dark bars represent strongest (high fit and low variance) while the light grey bars represent weaker variables

Respondents reported less political influence when engaged in more than two social networks.

4 | DISCUSSION

This multi-country study indicates the important role that human geography plays in influencing fishing village households' opinions of local fisheries management. It suggests the importance of the households' location in terms of the surrounding population density and distance to major commercial centres and less effect of the respondent's nation. Specifically, the perceived benefits of fisheries management declined with increasing urbanization. Individual-scale factors of age and residence influenced responses in ways that can modify these larger-scale influences but often in age- or cohort-dependent ways. Most of the other local household factors such as job and gear diversity, and social connectivity had significant but smaller influences, subordinate to larger-scale demographic and market forces. This study supports a number of regional studies of small-scale local fisheries that report population density-commercialization gradient influences on opinions, economic choices, jobs and food security (Cinner et al., 2010, 2018; Darling, 2014; McClanahan et al. 2006; Sulu et al., 2015).

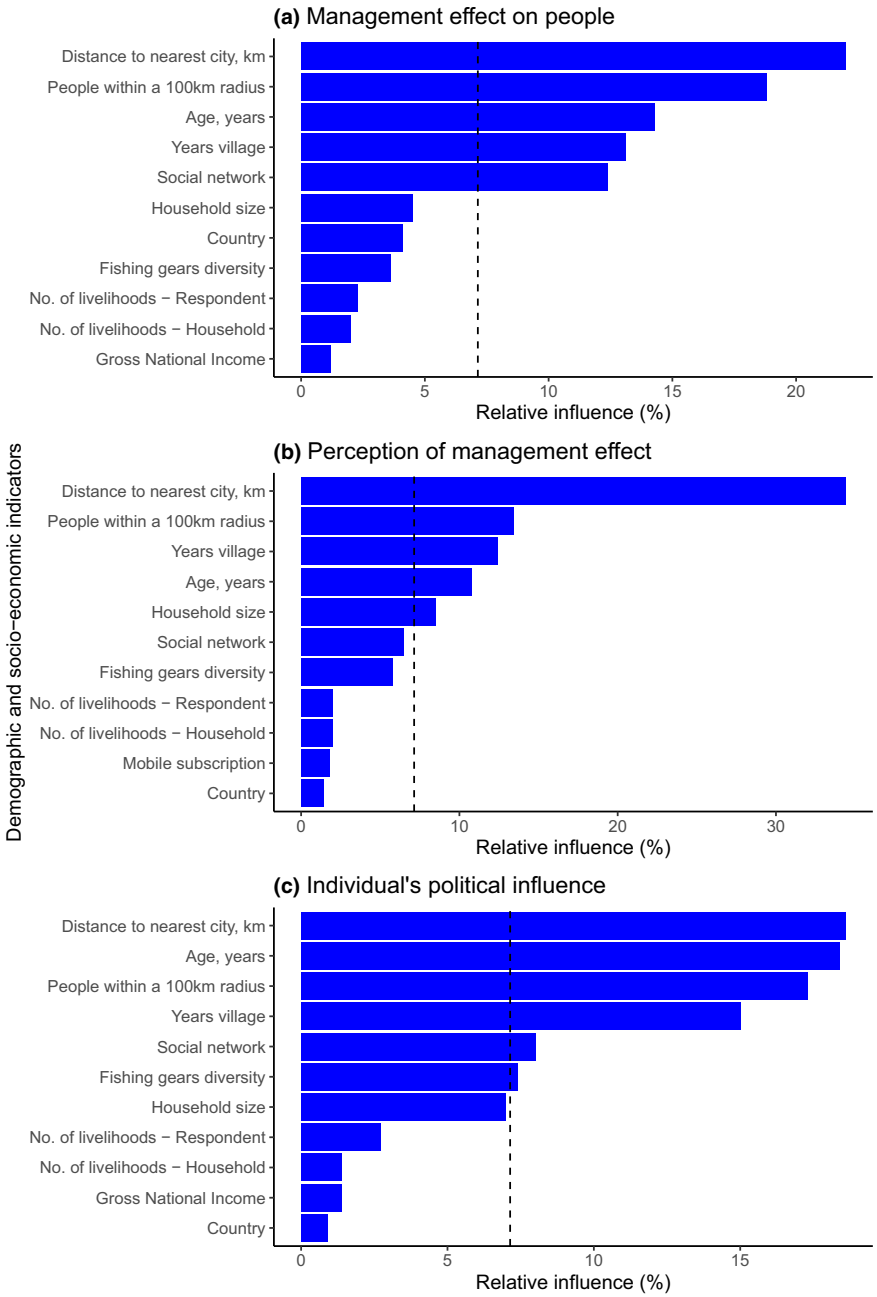

FIGURE 6 Per cent contributions of the independent geographic and demographic variables resulting from the Boosted Regression Tree (BRT) analyses. Result presented for three dominant multivariate axes that resulted from responses to the 10 questions associations

4.1 | Distance to cities (commercialization)

Increasing population, market connectivity and associated job specialization appeared to erode perceptions of the effectiveness of local engagement in management and subsequent outcomes. The reliability of collective action around CPR depends on the physical characteristics of the resource, the users and the governance structure (Araral, 2014; Baggio et al., 2016; Ostrom, 2009). Cities increase economic integration and connectivity, which has positive effects on human social adaptive capacity but does not always translate into improved natural resource governance (Crona et al., 2017; Cinner et al., 2018; D'agata et al., 2020; Maire et al. 2020). A study of community forest management, for example, found monitoring of resources improved close to cities (Epstein et al., 2021), which may be necessary to protect resources in socially diverse environments. Nevertheless, distance to cities, as a proxy for commercialization and possibly infrastructure, is expected to challenge the management of community-reliant collective action and some of the CPR institutions (Araral, 2009; Baggio et al., 2016; Dacks et al., 2020).

Large numbers of people and closeness to commercial centres can potentially undermine localized social cohesion, which is a core attribute required for governance of common property (Ostrom, 1990). Therefore, a central problem is the difficulty of catalysing collective actions to exclude and reduce resource competition as population sizes and market forces increase (Ostrom, 2003). Cities and human population numbers increase rivalry and challenge

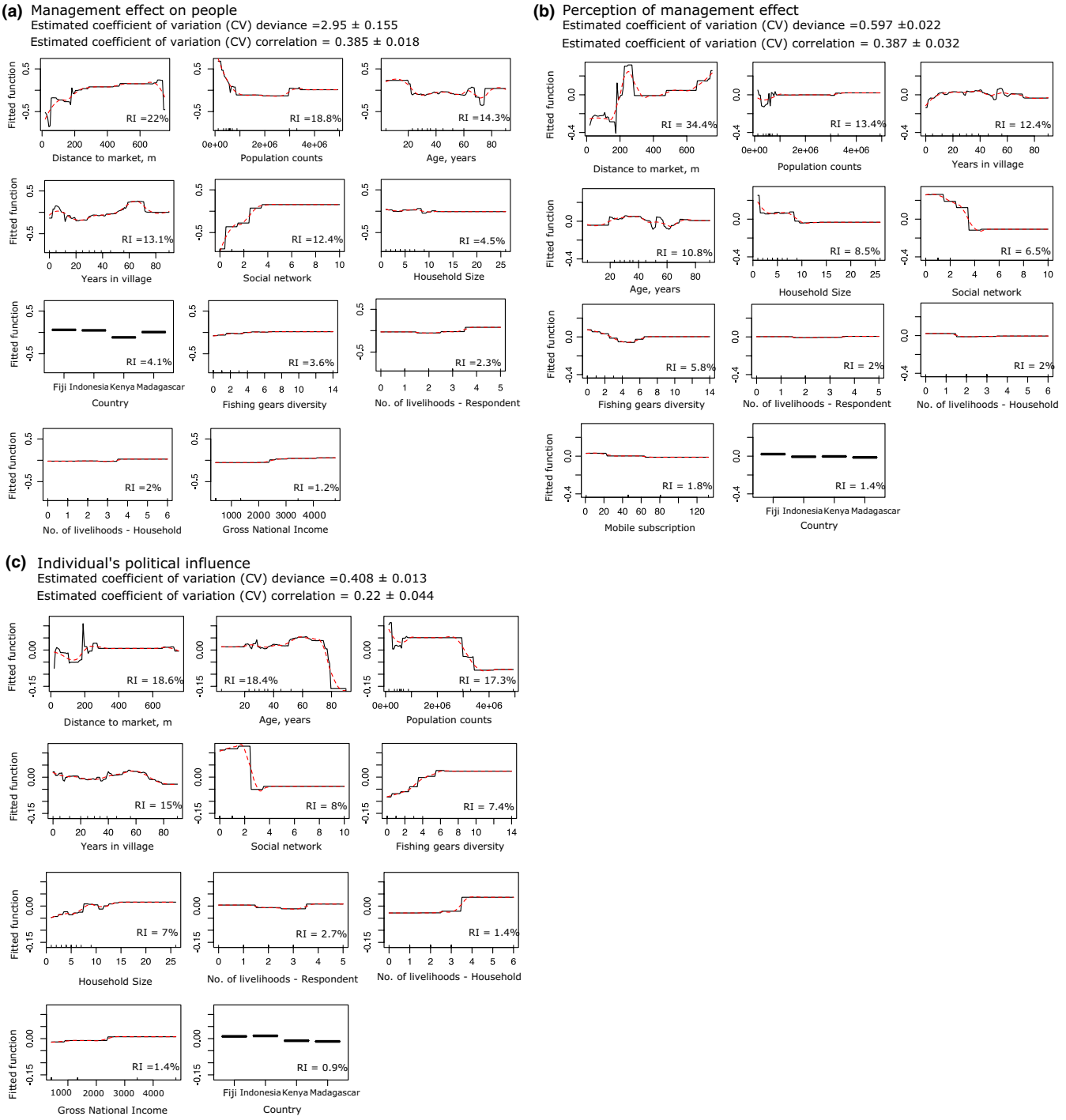

FIGURE 7 Boosted Regression Tree (BRT) results of main independent geographic and demographic variables associations with the three multivariate PCA response axes of (a) management effect on people, (b) perception of management effect on the resource, and (c) respondents' perceived ability to influence of fisheries management decision-making

efforts at exclusion, though perhaps to lesser degree, in countries with customary tenure systems (e.g. Fiji and across wider Melanesia archipelago). In principle, there are more options to exit a fishery created by more diverse labour markets near cities and also potentially more resource users to monitor. This can lead to increased free-riding, such that costs exceed benefits and graduated sanctions become increasingly costly to implement (Araral, 2014; Baggio et al., 2016). In some cases, however, local differences in profitability, subsidies and specialization can change incentives and reduce exiting behaviours near markets (Daw et al., 2012).

Linkages between people vary with commercialization and change peoples' ability to be adaptive or transformative (Bodin, 2017; Cinner, 2011; Greenfield, 2009). As human populations and commercialization increase, there is increasing knowledge and livelihood

specializations. Adjacent occupations, like fishing and agriculture, become less pervasive, which can reduce communal knowledge and agreement (Cinner & Bodin, 2010; Cinner et al., 2010). Neighbours diverge in their work activities, interests and preferences, which can lead to unfavourable costs and benefits, declining engagement in collective action and associated problem solving and compliance (McClanahan & Abunge, 2018; McClanahan & Abunge, 2020; Redpath et al., 2013). Thus, as work specialization increases, human organization becomes less modular, cohesive and able to broker small changes, which can lead to a lower capacity to reach agreements and optimize locally (Bodin, 2017; Dacks et al., 2020). For example, a study of rural Kenyan fishers showed that regular communication among competitors helped to reduce the chances of overfishing (Barnes et al., 2019). In contrast, more diverse jobs, resources and human linkages should help to catalyse larger societal transformations during periods of rapid change (Barnes et al., 2017; Daw et al., 2012; McClanahan et al., 2016).

Monitoring of behavioural compliance is critical for managing resources like nearshore benthic fisheries (Baggio et al., 2016). As human numbers and commercialization increase, local fisheries monitoring is increasingly costly. Therefore, monitoring behaviours often becomes a specialized activity of formal government bodies, sometimes where the state legally owns or has rights to the resources. Specialized management has some benefits but also separates users from managers, their values, perceived costs and benefits, and self- versus state-regulation (Hicks et al., 2013; McClanahan & Abunge, 2016; McClanahan & Abunge, 2020; McClanahan et al., 2016). Values and objectives held by external actors, such as biodiversity conservation and the protection of certain habitats and species become increasingly important when national managers are included (Daw et al., 2016; Hicks et al., 2015). This comes at the costs of having disparate stakeholders and disagreements on fundamental values and goals when communication, participation and reconciliation pathways are lacking (McClanahan & Abunge, 2018; Redpath et al., 2013).

4.2 | Variability in responses

At the larger geographic scale, variability in responses between countries was observed. While only four countries were evaluated, and not in equal proportions, there is some indication of differences in the geographic-cultural context. More sampling will be required to determine the strength of national cultural influences and inferences. In general, however, the studied Pacific and Asian communities of Indonesia and Fiji had the least variability in responses among individuals in fishing households. Madagascar was intermediate and Kenya had the highest diversity of perceptions. More research will be required to know how this diversity is influenced by cultural and personal histories, the interactions between questionnaires methods and responses, the degree to which traditional management systems are in place, the potential socio-economic drivers, and generational change. Findings do, however, question efforts to successfully transfer some soft infrastructure, such as management and behavioural institutions, between countries as well as hard infrastructure, such as urbanization gradients (Anderies et al., 2004).

High variability in responses existed in all villages; even in fairly isolated villages, such as those in Madagascar and Fiji. Consequently, cohesion and homogeneity should not be assumed when evaluating local opinions or rules concerning CPR, even in rural or isolated locations (McClanahan & Abunge, 2018). Gender and diversity in ethnicity, jobs and other factors that influence and diversify stakeholders and opinions can be challenging to evaluate, with studies finding both positive and negative effects on CPR management outcomes (Poteete & Ostrom, 2004). Like human linkages, some types of diversity may promote and others hinder optimization, transformation and innovation (Bodin, 2017). There are examples where a diversity of opinions promotes successful outcomes (Poteete & Ostrom, 2004). Generating ideas, mutualism and coercion can play roles when stakeholders are diverse, depending on the nature of the partnerships. For example, resource users may require managers to cover the costs of enforcement while managers may require broader stakeholder participation to achieve votes, compliance and other external social goals. These types of diverse dependencies can potentially resolve problems along commercialization gradients. They do, however, suggest that co-management will work better more than a community-based approach in urban-influenced organization. Because many of our sites were in the early stages of developing a new management system, it would be premature to evaluate differences and outcomes in management organization along this urbanization gradient.

Governance institutions vary in their influence depending on soft and hard infrastructure (Baggio et al., 2016). For example, the institutional governance principles of monitoring, enforcing graduated sanctions and balancing the cost-benefits of activities can become problematic as human populations, market influences and economic centralizations increase (Dacks et al., 2020; McClanahan & Abunge, 2018, 2019). With increasing commercialization, these institutions are likely to become specialized and lead to unique roles of paid managers. However, group identity, autonomy, decision-making and conflict resolution are less costly for rural or modular communities and should require less specialization of responsibilities. Success should rely on how groups and specific institutions are crafted along gradients from community to society, such that they are perceived as legitimate, effective and profitable (Baggio et al., 2016; Stern et al., 2002).

An interesting case study that highlights these attributes is a study of Zanzibar fishers who participated in experimental CPR games (Gehrig et al., 2019). Games played among fishers with and without histories of engagement in broader commercial and institutional scopes (i.e. more or less commercially integrated villages) regulated their extraction behaviour differently when playing with their own versus members of an out-group. The urban fishers regulated their extraction more when playing with rural fishers, whereas the rural fishers did the opposite. Thus, different historical commerce and institutional experiences differentiated social scales of trust and associated mutualistic decisions. Trust and learning to cooperate

vary with commercial geography and therefore can influence outcomes of CPR governance.

4.3 | Governance and management needs

Our findings highlight a number of potential weaknesses among our CPR institution linkages in terms of the adaptive management cycle (Redpath et al., 2013). In particular, the three weakest linkages in the cycle that require consideration are: (a) management actions to catch outcomes, (b) management actions to catch reliability and (c) an individuals' political influence on management decisions. These linkages generally become more problematic with the nearness and population size of cities. Most surveyed villages had decentralized fisheries management practices that may be most appropriate for rural and modular communities. Consequently, some of the current management methods being promoted may be less effective for fisheries increasingly linked to city commerce, provoking a reconsideration of appropriate management institutions. The findings indicate potential weaknesses of the decentralization model for commons governance. Yet, this model is increasingly being adopted by current global and national policies (Araral, 2014; Cinner et al., 2012). Regardless, there was a general perception here, irrespective of geographic context that the current local management is failing to improve reef fish catches.

Studies of developed-country fisheries find the importance of fisheries science and knowing the status of stocks and the governance commitments to apply recommended restrictions that maintain stock at or above sustainable levels (Hilborn et al., 2020; Melnychuk et al., 2021). These fisheries are large-scale, potentially highly profitable, and supported by specialized science and governance institutions. Here, we examined fisheries that are close to shore, part of diversified and subsistence livelihoods, low cost and profits, and frequently managed through traditional behavioural norms and leadership. Consequently, the sometimes well-functioning developed-world model may have high costs and therefore limited transferability to our study locations. In fact, a study of small-scale rural fisheries in Chile found that centralized organization was associated with weak fisheries performance, whereas local agreements with restrictions and the engagement of leaders resulted in better outcomes (Crona et al., 2017). Most of the countries studied here have tried and largely failed to replicate the developed-world management model. At best, case studies from well-studied fisheries provide some guidelines for best practices that are broadly described in the FAO Code of Conduct and Small-Scale Fisheries Guidelines (http://www.fao.org/voluntary-guidelines-small-scale-fisheries/guidelines/en/). Recommendations are useful but can be costly to implement, often leading to low compliance in developing countries (Pitcher et al., 2009).

Where the adaptive management cycle has been put into place, there are cases of success even without knowledge of stocks or sustainable yield thresholds (McClanahan, 2010; Weeks & Jupiter, 2013). Conversely, there are also cases where politically motivated decisions to subsidize patron-client relationships have led to failures that were detected only from detailed catch monitoring (McClanahan & Kosgei, 2019). Once sustainable thresholds and variability are known, there is increasing information and context to improve decisions (McClanahan, 2018; McClanahan & Azali, 2020). Thus, monitoring, variability, thresholds and feedback information provided to stakeholders are among the recent social-institution experiments that should benefit future collaborative decision-making. Despite many efforts, this process of discovery is often not sustained by the finances, skills and social organization of rural communities (Cinner et al., 2019; Cohen et al., 2015; Wells et al., 2007). Additionally, the scale of rural organization and agreement between communities is frequently smaller than the scale required to conserve species and ecosystems (McClanahan & Abunge, 2020a, 2020b; O'Leary et al., 2016).

Systems of nested governance, involving horizontal and vertical connections between institutions (Cox et al., 2010; Ostrom, 1990), are frequently needed to sustain community governance processes, such as participation (Gurney et al., 2016), which are important for both the ecosystem state and the adaptive management cycle. Thus, the feedback between catch and decisions will remain a challenge until this coupling is better addressed. This will require further case studies, experimental designs and trial-and-error processes. In particular, low-cost choices, management decisions and catch outcomes information and sharing forums are required. While top-down management may have historically created problems in these fisheries, there are good reasons to believe that, if coupled constructively with communal and nested governance systems, the performance of the adaptive cycle could be improved (Cohen et al., 2015; McClanahan, 2007). Thus, elements of science-based fisheries management may prove useful by providing key information, as more rural and subsistence fisheries become focused on optimizing commercial gains. Because the people interviewed here were positive about the prospects of management, there is still considerable hope for building successful adaptive fisheries programmes.

LMMAs are an example of social systems that have often been widely adopted in the Pacific for a number of purposes (Jupiter et al., 2014). They have also been promoted in the Indian Ocean region (Rocliffe et al., 2014) but their implementation and success in East Africa has often proven difficult and slow, or has resulted in low compliance (Katikiro et al., 2015; McClanahan et al., 2016). Part of the problem is the conceptualization, commitment and maximizing cost-benefits needed to adopt the practices (Kawaka et al., 2017). Moreover, the scale and importance of individuals' opinions of benefits to themselves, their communities and their nations as well as subsequent benefits of engagement are often problematic over the long periods relevant to fish population dynamics (McClanahan, 2021; McClanahan & Abunge, 2016). Here, we see that benefits to the individual are less acknowledged than to those to the community as overall perceived benefits of management decline. This will lead to problems in estimating the profitability of individual cost-benefits that can undermine engagement and compliance when there are few net benefits. This problem is expected to be heightened with market

integration and where human networks function more societally than communally. For example, in Melanesia, the benefits of long-term tenure of resources can override individual cost-benefits and be part of their social commitment to maintaining LMMAs (Jupiter, S. personal observation).

4.4 | Recommendations for change

Looking forward, our sites in 4 countries reflect changing conditions in many tropical countries, where there is increasing urbanization and commercialization of the use and trade of natural resources. These livelihood gradients also influence human psychology and subsequently the management systems that are conceivable and admissible (Greenfield, 2009). And, yet, many current policies and CPR management efforts in tropical countries assume rural people with communal social organization and associated values. This assumption is not aligned well with the current reality of rapid social-ecological change (Rosling et al., 2018). Therefore, as human and market forces increase, these fisheries management assumptions and models will have to adopt to preferences of stakeholders who are integrated into markets and exposed to broader societal values and ecosystem services (Daw et al., 2016).

Given ongoing social-ecological changes, there is a need to reconsider how communal to societal change will affect the goals of sustainability. Failure to acknowledge this change could provoke a social-ecological tragedy if models developed for rural communities are seen as the main solution to CPR, but fail to adopt the most needed soft and hard infrastructures required for each context (Araral, 2014; Baggio et al., 2016). Consequently, the challenge for policy and management in many of tropical nations will be to adapt these needed institutions to effectively integrate communities within broader urbanized societal organization. The current decentralization literature often relies on rural and communal case studies and contexts and therefore has limited ability to predict future needs where communal has been replaced by societal organization. Subsequent recommendations may increasingly become dated and poorly crafted to catalyse the unfolding social transition (Araral, 2014). Thus, it behoves investigators and managers to evaluate how effective social organization and perceived costs and benefits change along commercial gradients when considering the future value and transferability of CPR governance and management approaches. The high perceived failure rates in effectiveness found here begs the need for a transition towards contextual nuance.

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DATA AVAILABILITY STATEMENT

Data will be made available pending a formal request to the lead author.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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