Conservation needs exposed by variability in common-pool governance principles

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Abstract: *Common-pool governance principles are becoming increasingly important tools for natural resource management with communities and comanagement arrangements. Effectiveness of these principles depends on variability in agreements, trust, and adherence to institutional norms. We evaluated heterogeneity in governance principles by asking 449 people in 30 fishing communities in 4 East African countries to rate their effectiveness. The influences of individuals, their membership and role in stakeholder community groups, leadership, community, and country were tested. The membership and role of people were not the main influence on their perceptions of the effectiveness of governance principles. Therefore, drawing conclusions about the effectiveness of specific principles would be difficult to make independent of the individuals asked. More critical were individuals' nationalities and their associations with the shared perceptions of a response-group's effectiveness of each principle. Perceptions of effectiveness differed strongly by country, and respondents from poor nations (Madagascar and Mozambique) were more cohesiveness but had fewer and weaker between-community conflict-resolution mechanisms. Overall, group identity, group autonomy, decision-making process, and conflict resolution principles were perceived to be most effective and likely to be enforced by repeated low-cost intragroup activities. Graduated sanctions, cost–benefit sharing, and monitoring resource users, fisheries, and ecology were the least scaled principles and less affordable via local control. We suggest these 2 groups of principles form independently and, as economies develop and natural resources become limiting, sustainability increasingly depends on the later principles. Therefore, management effectiveness in resource-limited situations depends on distributing power, skills, and costs beyond fishing communities to insure conservation needs are met.*

Keywords: common property, coral reefs, decentralization, democracy, fisheries management, Indian Ocean, Ostrom principles, polycentric governance

Necesidades de la Conservación Expuestas por la Variabilidad de los Principios de Gobernanza de Recursos Comunes

Resumen: *Los principios de gobernanza de recursos comunes se utilizan cada vez más como una herramienta importante para el manejo de recursos naturales en las comunidades y los arreglos de co-manejo. La efectividad de estos principios depende de la variabilidad de los arreglos, la confianza y el apego a las normas institucionales. Para evaluar la heterogeneidad en los principios de gobernanza le pedimos a 449 personas en 30 comunidades pesqueras de cuatro países del este de África que calificaran la efectividad de los principios. Se evaluaron la influencia de los individuos, su afiliación y su papel dentro de los grupos de liderazgo, dentro de la comunidad de accionistas, dentro de la comunidad y dentro de los países. La afiliación y el papel de las personas no fueron la influencia principal sobre sus percepciones de la efectividad de los principios de gobernanza. Por lo tanto, llegar a conclusiones sobre la efectividad de los principios específicos sería complicado, independientemente de los individuos a los que se les pide la calificación.*

Fueron más relevantes la nacionalidad de los individuos y su asociación con las percepciones compartidas sobre la efectividad de un grupo de respuestas de cada principio. Las percepciones de efectividad difirieron fuertemente entre países, y las respuestas de las naciones pobres (Madagascar y Mozambique) fueron más cohesivas, pero tuvieron menos mecanismos de resolución de conflictos entre comunidades, además de ser más débiles. En general, se percibieron como más efectivos y con mayor probabilidad de ser impuestos por las actividades de bajo costo dentro de un grupo. Las sanciones graduadas, la partición de los costos de los beneficios y el monitoreo de los usuarios de los recursos, las pesquerías y la ecología fueron los principios que menos aparecieron en la escala de las calificaciones y también fueron las menos costeables para el control local. Sugerimos que estos dos grupos de principios se formen independientemente y, conforme se desarrollan las economías y los recursos naturales se vuelvan limitados, que la sustentabilidad dependa cada vez más de estos principios. Así, el manejo de la efectividad en situaciones de recursos limitados depende de la distribución del poder, las habilidades y los costos más allá de las comunidades pesqueras para asegurar que se cumpla con todas las necesidades de conservación.

Palabras Clave: arrecifes de coral, descentralización, democracia, gobernanza policéntrica, manejo de pesquerías, Océano Índico, principios de Ostrom, propiedad común

摘要: 公共资源管理原则正在逐渐成为社区和共同管理计划中的自然资源管理的重要工具。公共资源管理原则的有效性取决于共同认知、信任和对制度规范的遵守情况的差异。我们通过收集四个东非国家 30 个渔业社区中 449 人对这些管理原则有效性的评价, 对管理原则的异质性进行了评估。本研究分析了个体差异、个体在利益相关者社区团体中的成员关系和身份、领导地位、所在社区和国家对结果的影响。结果表明, 个体的成员关系和身份不是影响他们对管理原则有效性的看法的主要因素。因此, 得出的对于具体原则有效性的结论因人而异, 主要的影响因素是个体的国籍及其与响应群体对各项原则有效性看法的关系。不同国家的受访者对管理原则有效性的看法差异很大, 贫穷国家 (马达加斯加和莫桑比克) 的受访者更遵守这些原则, 但他们解决社区间冲突的机制也较少较弱。总体而言, 群体认同、群体自主性、决策过程和冲突解决原则被认为最有效, 且很有可能通过重复的低成本群体内部措施得以实施。分等级制裁、成本效益共享和对资源使用者、渔业及生态进行监测等原则受到的评价最低, 且通过地方控制难以负担得起。我们认为可以独立建立这两大类原则, 并且随着经济日益发展、自然资源日益稀缺, 可持续发展将越来越依赖于第二类原则。因此, 在资源有限的情况下, 管理有效性将取决于渔业社区以外的权力、技能和成本的分配, 来确保保护需求得到满足。【**翻译: 胡怡思; 审校: 聂永刚**】

关键词: 公共财产, 珊瑚礁, 去集权化, 民主, 渔业管理, 印度洋, 奥斯特罗姆原则, 多中心治理

Introduction

Studies of common property and collective action theory frequently evaluate common-pool resource management institutions (CPRs) and user groups as a social unit (Poteete & Ostrom 2008; Cinner et al. 2012). Evaluations find that the CPR governance principles (Table 1) can be effective but varies with specific principles, measures of success, and contexts (Cox et al. 2010; Oldekop et al. 2010; Araral 2014). The key assumption of common property institutional theory is that effective institutions and associated norms will reduce uncertainty and thereby increase trust and reciprocity (Ostrom 2000). Certainty and trust are likely to be reflected in the variation of perceptions of key institutional principles, compliance, effectiveness, and cost–benefit trade-offs (Krebs & Janicki 2004; McClanahan & Abunge 2016). Societies and CPR groups are organized by norms, roles, and responsibilities, which are influenced by perceived and actual costs, benefits, and prospects for success (Ajzen 1991; Agrawal 2003; Klöckner 2013). Consequently, variability in these factors should have consequences for the success of collective actions that influence natural resource management. Therefore, evaluating perceptions of effectiveness and its variability at various social scales is expected to provide insights into the causes of institutional strengths and weaknesses (Cumming et al. 2006).

Although the CPR user group is frequently defined as a set of individuals with the same rights and responsibilities, this hypothetical membership and fairness is commonly breached in practice (Poteete & Ribot 2011). There are differences among stakeholders, and they must exist for individuals to specialize enough to solve the various collective social problems addressed by the governance principles (Table 1). Specialized actions include the functions of developing boundaries and group cohesion, creating and implementing rules, extracting resources, distributing benefits, resolving conflicts, processing, monitoring and protecting resources, and interacting with other resource-affiliated groups. Thus, specialization and social stratification is likely even among small groups of people whose livelihoods are associated with common property such as forests and fisheries. Membership is important for knowing goals, playing roles, and getting benefits; but, broad societal awareness of institutions should reduce outsider breaches and weakest-neighbor matching (Cudney-Bueno & Basurto 2009; Agrawal et al. 2013). Nevertheless, much of the theoretical and empirical studies of CPR start their analysis

Table 1. Common-pool governance design principles proposed for successful management and their context within East Africa.

Governance Principles[a]	Conditions expected to lead to increased management effectiveness[a]	East African fisheries context[b]
Group identity	1A. User boundaries: clearly defined boundaries between legitimate users and nonusers. 1B. Resource boundaries: clear boundaries that define a resource system and separate it from larger biophysical environment.	Resource users expected to be members of fishery organization associated with stretches of coastline. Groups have various names and acronyms (described in Supporting Information). Licensing of fishers and their vessels legitimizes users but with less compliance and spatial restriction. Fisheries acts frequently provide provisions for local-area and conservations-area designations. These include locally managed and closure areas that often have weak capacity for enforcement.
Costs and benefits	2A. Congruence with local conditions: appropriation and provision rules congruent with local social and environmental conditions. 2B. Appropriation and provision: benefits obtained by users from common-pool resources, as determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules.	Rules can be made at the local level by committees and formalized through approval of bylaws by national authorities. Most fisheries product pricing is determined by market forces of supply and demand with various types of markets ranging from subsistence to international exports.
Decision making	3. Collective choice arrangements: most individuals affected by operational rules can participate in modifying the rules.	Collective action varies from weak to strong national influences and levels depend on level of trust among members and leaders. Decisions range from consensus, to majority or two-thirds voting, to leadership authority.
Monitoring	4A. Monitoring resource users: monitors accountable to the users monitor the appropriation and provision levels of the users. 4B. Monitoring resource: monitors accountable to users monitor the condition of the resources. 4C. Monitoring ecology. (We added this activity to our survey to distinguish collecting information on marine products from nonproduct aspects of the marine environments.)	Monitoring users is part of enforcement by fisher organizations but are often limited to local members. Collaboration with fisheries department and other relevant government institutions such as park services, police, and military exists, but roles are often unclear and inconsistently implemented. Complaints about inability to enforce, selective enforcement, and poor collaboration with authorities are common. Monitoring of fish catch is variable and mostly not reported to resource users, with notable exceptions. Ecological nonproduct monitoring is sometimes carried out by researchers—mostly nongovernmental actors.
Sanctions	5. Graduated sanctions: appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on seriousness and context of the offence) by other appropriators, officials accountable to the appropriators, or both.	Such sanctions are present and often based on customary law but seldom fully formalized as by-laws or consistently enforced by community or other forms of governance. Various social affinities influence consistent applications.
Conflict resolution	6. Conflict-resolution mechanisms: appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.	Conflicts among members are resolved by warnings, fines, and capture and destruction of gear. Sometimes conflicts are forwarded to government authorities. The resolution process is usually selective and slow because local leaders do their work on a volunteer basis. Enforcement of nonmember, neighbor, and migrant users is often difficult due to conflict with local customary versus national laws.
Autonomy	7. Minimal recognition of rights to organize: rights of appropriators to devise their own institutions are not challenged by external government authorities.	Comanagement arrangement allows resource users to form subcommittees according to their objectives. Common subcommittees include monitoring, conflict resolution, finance, and data collection. Groups are also allowed to devise by-laws within the fisheries gazette regulations.

Continued

Table 1. Continued.

Governance Principles[a]	Conditions expected to lead to increased management effectiveness[a]	East African fisheries context[b]
Governance	8. Nested enterprises: appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities organized in multiple layers of nested enterprises.	Fisheries regulations support comanagement involving government and resource user groups. Government participates in policy formulation and collaborates with enforcement in nested ways that are often not agreed on or fully formalized at present. Devolution has decreased national government relative to county or district and fishery organization powers.

[a]*Principles and proposed solutions to common-pool management problems known as Ostrom principles are as modified by Cox et al. (2010) in their table 4.*
[b]*East African descriptions are generalities and differ by country; see Supporting Information for more information on national context.*

by establishing the presence or absence of specific institutions at the CPR social unit. An alternative is to evaluate perceptions of effectiveness at the membership, role, or individual or intergroup level and within the context of governments, economies, and markets (Wolfe & Putler 2002).

Meta-analysis of case studies has become a key way to measure effectiveness and, while providing generalizations, averaging and weighting responses at and above the level of the user group is another analytic-scale decision that can influence estimates of social heterogeneity (Cox et al. 2010; Araral 2014). Many studies of fisheries management, for example, are missing key descriptors, use qualitative metrics to evaluate complex drivers such as leadership and social capital, find interaction effects, and use metrics resulting from competitive trade-offs rather than indicators of whole-system success (Oldekop et al. 2010; Gutierrez et al. 2011; Wamukota et al. 2012). Further, most evaluated cases were from field studies of small-scale organizations and may be less applicable in larger-scale contexts where populations, market economies, and individual property rights and national rule-of-law influences dominate (Poteete & Ostrom 2004). Thus, the heterogeneity of people, their perceptions, decisions, and the effectiveness of their governance systems would be expected to change across gradients of human organization and development (Agrawal 2001). These considerations provoke a need to evaluate how governance effectiveness changes across these scales (Araral 2014). Further, what does this variability mean for addressing the roles and needs of social-ecological contexts when promoting CPR management (CPRM)?

We evaluated the governance effectiveness responses of people associated with community or comanagement fisheries institutions in the western Indian Ocean. People with different roles were asked to scale their perceptions of governance effectiveness or Ostrom principles (described in Table 1). Our null hypothesis was that user group responses to statements of effectiveness are homogeneous, and we evaluated this hypothesis at the

individual, leadership, membership, community, and government levels. Our purpose was to determine how perceptions differed between principles, social scales, roles, and national governments and to identify principles that provoked the most heterogeneity and could therefore weaken trust and successful CPRM. Given that social capital and cohesion should contribute to effective collective action and sustainable conservation, it behooves conservationists to evaluate the variability inherent in specific social contexts and plan management accordingly.

Methods

Sites and Experimental Design

Our objective was to evaluate small-scale fisheries governance in the emerging process of devolution of natural resource management from national to local or comanagement systems in Africa (Cinner et al. 2012). We focused on new or planned protected areas and potential control sites, specifically the transboundary communities of Kenya, Tanzania, and the Zanzibar-Pemba governance system of Tanzania, as well as sites without transboundary communities in Mozambique and northwest Madagascar (Fig. 1). These marine areas have been identified as having coral reefs with high diversity and potential for climate refugia (Ateweberhan & McClanahan 2016). Consequently, these reef areas are priorities for protections intended to resolve local and international fisheries conflicts (Levin et al. 2018; McClanahan & Abunge 2018). The most sampling took place in southern Kenya, Northern Tanzania, and Pemba (Zanzibar) Island at the boundaries of these 3 nations. That Pemba has its own government separate from Tanzania provided an opportunity to evaluate related management among governments with different histories. Some sites were chosen because they were away from parks and in the future might act as control sites for evaluating governance effectiveness. However, because the protected areas were planned or new, we did not evaluate
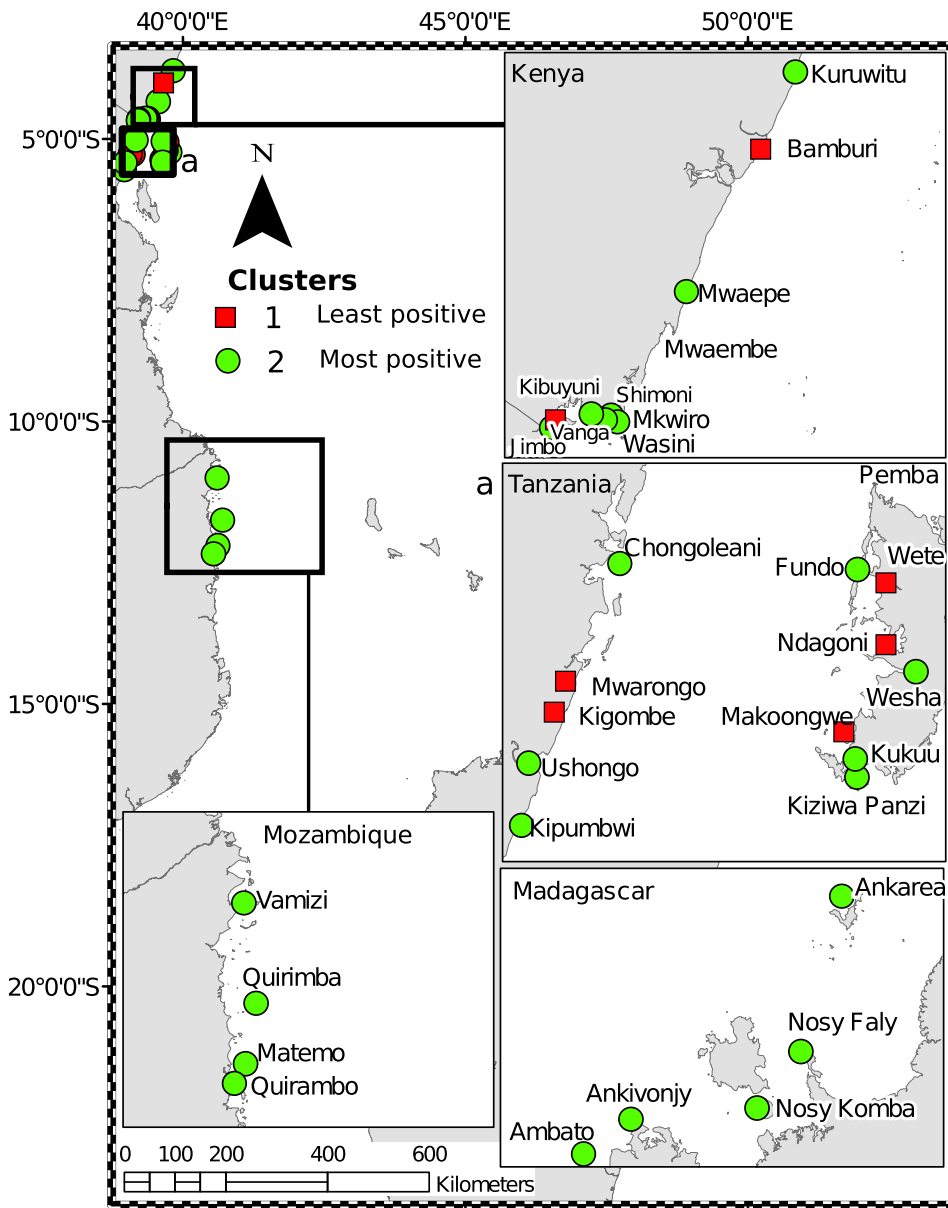
Figure 1. Locations of study sites where interviews of fishing community respondents were conducted in the 4 studied countries and grouping of mean effectiveness of the governance-effectiveness principles at the site level.

possible effects of parks and control sites. Field sampling was undertaken from October 2016 to August 2017.

Common pool resource governance systems had different local names or acronyms but were generally characterized by independent leadership consisting of an executive committee and assembly of village or fish landing site members (Supporting Information). They differed in their membership in that beach management units (BMU) and locally managed marine area (LMMA) members were mostly marine resource users and stakeholders, whereas Tanzania's village level committees (VLC) and Pemba's Shehia, and Mozambique's community fisheries councils (CCP) involved more general membership from the village communities. Some of the sites were chosen because they were engaged with either

existing or planned national parks (Kenya: Bamburi, Mwaepe, Wasini, Mkwiro, Kibuyuni, Shimoni; Tanzania: Mwarongo, Kigombe, Chongoleani; Pemba: Wesha) and community closures (Kiruwitu, Kibuyuni, Mkwiro, Wasini, Vamizi). Four sampled Pemba island communities worked with Mwambao Coastal Community network, which engaged in monitoring and training communities on management issues, such as octopus closures. Madagascan sites were organized under LMMAs, located in the northeast, and surrounded 2 newly created protected areas. Mozambique sites included 2 communities; Quirimba, Quirambo, and Matemo were communities within the Quirimbas National Park; and Vamizi was associated with a private community closure. All Mozambique sites were organized under CCPs that included members who were not strictly marine resource users.

Interviews

Interviews were designed to include a balance of leaders, members, and nonmembers. Prior to interviews, 2 meetings were held, one with leaders of either landing sites and a second with the larger village community where leaders introduced the researchers and their goals and requests for interviews. Once permission was granted, we interviewed approximately half the executive leaders and a few subcommittee members. Leaders were asked to make a list of all members, their gender, age, and occupation. From this list we randomly selected ∼5 members from the groups to proportionally represent gender, age, and the occupations in the list. Identifying informed nonmembers required introductions from the leaders to identify people who lived within the community, were aware of the group, but had chosen not to pay the joining fee or become members.

To undertake the interviews, we trained local enumerators from each country to insure language and cultural congruity. A total of 449 persons were interviewed and approximately weighted proportionally between leaders ($n = 170$), members ($n = 153$), and nonmembers ($n = 125$) (Supporting Information). The sample size depended on the size of the subcommittee or people assigned leading roles for different activities of the group. Sample sizes ranged from 11 to 19 interviews per sites and 51 (Mozambique) and 146 (Kenya) people per country. Subcommittee leaders were more common in Kenyan BMU than in Village Liaison Committee and Shehia fisher committee of Tanzania, LMMAs of Madagascar, and CCPs of Mozambique. Interviews at each site were completed within 7 working days.

The standardized questionnaire assessed the respondents' perception on the presence and strength of the institutional governance principles. We asked respondents to rate their agreement on the statement's strength of the group's effectiveness in enacting governance principles with the response options of agree completely, agree somewhat, neutral, disagree somewhat, disagree completely and do not know. Each principle represented the potential strengths of group identity; proportional costs and benefits; consensus decision-making process; monitoring of 3 resources (resource users, fisheries, and ecology); graduated sanctions; fast and fair conflict resolution among group members and among neighboring groups or communities; and local autonomy (Table 1). This resulted in 7 principle subjects but 10 specific questions. Monitoring effectiveness was broken into 3 components that were found to have variable responses that needed specific questions based on pilot surveys. We asked about interactions with other forms of government (i.e., local, county, and government) and recorded responses as either present or absent (Supporting Information). The final questions differed somewhat from the original CPR governance language due to the piloting of questionnaires prior to the field work. It was necessary to use both less abstract and more direct and precise questions (e.g., What types of monitoring do you undertake or conflicts do you encounter?) to be understood and receive confident responses. Our research and interview protocols received clearance in accordance with guidelines of the Wildlife Conservation Society's Institutional Review Board.

Statistical Analyses

We analyzed responses at individual interviewee, roles, and site level scales. We checked data for errors and completeness and some missing values were imputed by the random proportional imputation method, which is suitable for nominal or ordinal data. Thereafter, we evaluated the similarity between responses by a profile test (SIMPROF: Ward clustering method) and identified significant clusters of response associations at the 90% confidence level for the 3 social scales. We calculated similarities in interviewee responses by Gower distances, which is a method appropriate for noncontinuous categorical data. The Glower metric computes the distance between pairs of variables and then combines distances to a single value per record pair yielding a number between 0 (identical) and 1 (maximally dissimilar). To better visualize statistically significant clusters at the 3 social scales, we used nonmetric dimensional scaling (NMDS), which is most appropriate for ordinal data and Gower distances (Supporting Information). Differences between responses for the 3 social scales and clusters for each principle were tested by nonparametric Wilcoxon–Kruskal Wallis rank test (Supporting Information). Finally, and because the responses pooled at the site level were normally distributed, we tested for differences and the interaction between roles and national government by a 2-way analysis of variance (ANOVA) (Supporting Information). A *t* test was used to test for differences among principles within clusters (Table 2). Statistical analyses were performed in JMP version 13.0, and figures were produced with Sigma plot.

Results

Overall, mean similarities within communities were moderate to high at 74.0% (SD 8.0) among the 15 clusters, but the number of significant cluster groups declined along the social gradient of individuals, roles, and sites. There were 15 significant clusters at the individual, 4 at the roles, and 2 at the site level (Supporting Information). Despite the large number of significant clusters, differences were not significant when responses were analyzed at the mean individual, role, and site levels for all 10 questions. Consequently, differences and cluster formations were largely attributable to individual responses. Most

Table 2. Results of *t* test evaluation of specific differences in common-pool principles for the individual response level for each statistically significant cluster group.[a]

Clusters[b]	R2[c]	Mean effectiveness (SD)	Decision-making	Local autonomy	Conflict resolution members	Graduated sanctions	Group identity	Conflict resolution neighbors	Monitoring resource users	Monitoring fisheries	Monitoring ecology	Cost-benefit sharing
Individuals												
Cluster 10	0.04	1.94 (0.03)	1.38‡	−0.58†	2.37*	1.87†	−3.55†	2.37*	−2.56†	1.38‡	−1.08†	−1.58†
Cluster 9	0.39	178 (0.08)	2.04*	2.04†	−2.66†	1.25‡	−0.31†	−8.14†	2.82*	2.04*	2.84*	−1.88†
Cluster 14	0.87	1.57 (0.05)	3.87*	6.95*	5.19*	6.51*	5.19	6.51*	6.07*	6.07†	4.75*	−51.08†
Cluster 11	0.26	1.53 (0.08)	2.96*	1.97†	2.47*	−0.99†	−2.96†	0.99†	−1.48†	−3.45†	−1.97†	2.47*
Cluster 8	0.83	1.52 (0.10)	3.48*	3.48*	2.03*	2.03*	−21.18†	2.76*	2.76*	0.58‡	2.03*	2.03*
Cluster 7	0.73	1.32 (0.12)	0.06‡	−11.10†	1.82‡	2.41*	−1.12‡	1.82‡	1.82‡	1.82‡	0.06‡	2.41*
Cluster 15	0.58	1.27 (0.08)	2.25*	1.63‡	2.88‡	0.38‡	1.31‡	3.19*	−11.21†	2.88‡	2.25*	−5.57†
Cluster 13	0.84	1.20 (0.12)	3.65‡	2.89*	−0.15†	0.61‡	2.13*	−4.72†	3.65*	2.89‡	3.65‡	−14.61†
Cluster 6	0.51	1.19 (0.04)	4.95*	3.22†	−17.00†	5.10*	2.64*	−12.09†	4.23*	3.65‡	4.52*	0.77‡
Cluster 1	0.51	1.02 (0.04)	7.02*	6.22*	4.46*	3.92*	2.71*	0.69†	−3.22†	5.54*	−20.89†	−6.46†
Cluster 5	0.41	0.99 (0.05)	5.02*	3.02*	5.29*	−15.54†	−1.92†	1.95*	3.55*	3.02*	−0.99†	−3.39†
Cluster 2	0.61	0.83 (0.04)	6.87*	7.62*	6.72*	7.47*	5.22*	5.07*	−7.50†	−18.12†	−11.69†	−1.66†
Cluster 12	0.44	0.70 (0.07)	4.63*	−3.20†	2.62*	3.74*	−0.96†	0.38‡	0.16‡	0.83‡	1.72‡	−9.91†
Cluster 3	0.18	−0.16 (0.05)	3.99*	3.55†	1.54‡	0.98‡	1.32‡	1.54‡	−2.70†	−5.26†	−3.48†	−1.47†
Cluster 4	0.49	−0.50 (0.10)	0.42‡	−0.70†	−2.39†	−2.95†	3.23*	−3.51†	5.75*	2.11*	1.26‡	−3.23†
Role or membership												
Cluster A	0.05	1.31 (0.02)	7.15*	4.04*	−1.36†	0.83‡	0.60‡	−2.80†	1.53‡	2.78*	−3.50†	−9.26†
Cluster B	0.23	1.22 (0.03)	4.30*	3.61*	3.50†	3.84†	1.20‡	3.98*	−4.42†	−7.06†	−5.80†	−3.16†
Cluster C	0.12	0.62 (0.06)	3.60‡	3.31*	2.24*	−0.09†	1.08‡	1.08‡	−0.57†	−2.41†	−3.38†	−4.84†
Cluster D	0.18	0.61 (0.07)	4.26‡	2.40*	2.98*	−1.21‡	2.05‡	1.12‡	−2.61†	−1.44‡	−5.40‡	−2.14†
Sites												
Most effective	0.06	1.32 (0.03)	8.28‡	4.30*	−0.35†	1.57‡	0.54‡	−1.83†	0.99‡	1.39‡	−5.01‡	−9.89†
Less effective	0.13	0.71 (0.07)	5.26*	5.06*	3.81*	0.32‡	2.62*	2.36*	−3.69†	−4.61†	−6.26†	−4.87†

[a]*Key:* *, positively significant; †, negatively significant; ‡, neutral or not significant. *Details of these results and roles and site level results presented in Supporting Information.*
[b]*Cluster groups and principles arranged from most to least positive.*
[c]*Summary of the fit of the entire comparison model.*

fishing communities had individual responses distributed between different cluster-response groups. For example, on average each site had individuals falling within 7.0 (SD 2.0) distinct cluster groups.

Reponses to governance principles were generally positive with a mean effectiveness of 1.04 (SD 0.12) (Table 2). Eighty-four of the 449 individual respondents were in Cluster 10, the most positive cluster having a mean effectiveness of 1.94 (SD 0.03) and responses to the 10 questions were weakly differentiated. However, 261 respondents were also listed in the 7 weakest effectiveness scaling clusters (6, 1, 5, 2, 12, 3, 4) with means ranging from −0.5 to 1.2. Each of these clusters had a variety of principles that differentiated them. For example, cluster 6 scaled a low effectiveness for conflict resolution, cluster 1 a low effectiveness for ecological monitoring, cluster 2 all forms of monitoring, cluster 12 low cost–benefit sharing, and clusters 3 and 4 identified a number of principles with low effectiveness. The moderate clusters were composed of 104 individuals who were contained in 7 clusters (9, 14, 11, 8, 7, 15, 13) with mean effectiveness ranging from 1.20 to 1.78. Effectiveness was seldomly scaled negatively, but low scaling was found for clusters 13 and 14 for cost–benefit sharing, cluster 15 for resource user monitoring, cluster 8 for group identity, and cluster 7 for local autonomy.

Averaging responses of individuals by roles and sites produced 4 and 2 significant clusters, respectively (Supporting Information). Evaluation based on roles showed that Kenya and Tanzania had roles distributed among all 4 clusters, but all Madagascar and Mozambique roles were clustered together in the most positive group. At the site level, the majority of sites (71%) were in the most positive cluster (A), but the mean response was moderate at 1.34 (SD 0.03). All Madagascar and Mozambican sites clustered in the most positive cluster irrespective of role, whereas Kenya, Tanzania, and Pemba groups were distributed in the 3 less-positive clusters. The national government pattern was stronger than the roles pattern because leaders were not always more positive about effectiveness than members or nonmembers. A 2-factor ANOVA pooling responses at the site level showed differences between countries for most principles except for decision making (Supporting Information). For example, conflict resolution among members was the most variable principle between countries. Madagascar scaled it very low and Mozambique scaled it high, whereas Mozambique and Madagascar scaled between-neighbor conflict resolution low. Graduated sanctions effectiveness was scaled low in Mozambique and mainland Tanzania. Fisheries and resource user monitoring was scaled low in both mainland Tanzania and Pemba Island. In contrast to nation, the respondent's roles had no effect on their scaling with the exception of group identity; leaders scaled identity higher than members and nonmembers, respectively. Interactions between roles and countries were mostly not significant with the exceptions of local autonomy and conflict resolutions with neighbors.

The overall order of effectiveness scaling from most to least effective was decision making, local autonomy, conflict resolution-members, graduated sanctions, group identity, conflict resolution-neighbors, monitoring resource users, monitoring fisheries, monitoring ecology, and proportional cost and benefits (Supporting Information). For all societies combined, decision making, local autonomy, and conflict resolution of members were scaled highest and cost–benefit sharing, various forms of monitoring, and conflict resolution with neighbors were scaled lowest. Overall patterns of effectiveness scaling and variation in responses indicate inverse relationships between the mean and between-site variance for the 10 responses at each social scale (Fig. 2). Variance declined from the individual, to role, to site level in Kenya and Pemba Island, Tanzania ($R^2 = 0.55, 0.41, 0.19$ and $R^2 = 0.78, 0.63, 0.42$, respectively). Therefore, the variance in responses to each question was best explained at the individual level. For the Tanzanian mainland and Mozambique, explained variation was highest at the role and lowest at site level. In Madagascar, explained variation was lowest at the individual level. Response variance also declined for each specific question from the individual to the site level (SD 1.8, 1.6, 1.2, respectively), but the change in variance was particularly pronounced for the cost–benefit sharing principle. There were also large between-country differences in the presence of interactions with other governance bodies; Kenya had the most interactions, followed by Tanzania, Mozambique, and Madagascar (Supporting Information).

Responses pooled at the site level produced 2 significant clusters (Fig. 3). All Madagascar and Mozambique sites were in the most positive cluster followed by Kenya (78%), Tanzania (60%), and Pemba (57%). The cluster that scaled principles as least effective was distinguished by weaker scaling of cost–benefit sharing and graduated sanctions and monitoring of resource users, fisheries, and ecology. There was also notable between-site variation within countries in respondent's views of specific principles (Supporting Information).

Discussion

Results support the proposition that heterogeneity in the perceptions of effectiveness of common-pool governance principles is sufficient to have repercussions for classification and evaluation of CPR principles and management outcomes. This heterogeneity is less driven by differences between leader and members or the social scale from the individual to the site. Rather, it is the individual's context within their country that most influences the views of effectiveness. Heterogeneity of people, their perceptions, decisions, and the effectiveness of
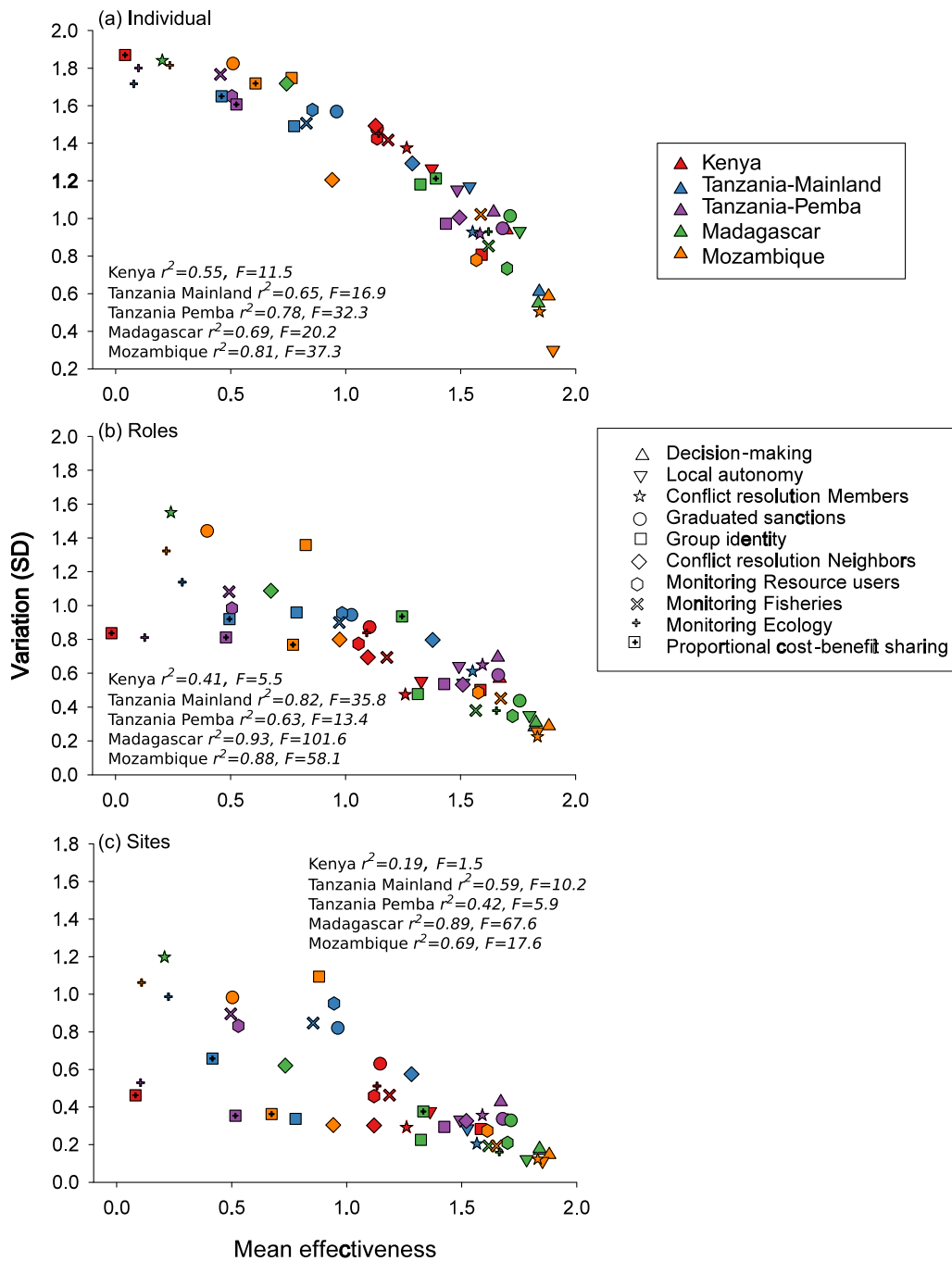
Figure 2. Relationship between mean and variation in perception of effectiveness of the governance principles at the (a) individual, (b) role or membership, and (c) site level.

their governance systems was different between nations and likely to reflect some underlying aspects of human organization and economic development. We also identified governance principles with sufficient variability to reduce trust, provoke conflict, and weaken CPRM effectiveness, similar to conflicts exposed for fisheries restrictions (McClanahan & Abunge 2016, 2018). Finally, the frequencies of interactions with noncommunity government bodies were very different among nations and increased as the nation's wealth increased (Supporting Information). Our findings therefore support the need to acknowledge this variability in governance principles, scales, restrictions, and collaborators when proposing and evaluating CPRM options (Cumming et al. 2006).

Social Scales

Pooling responses indicated good agreement in scaling effectiveness between roles and sites that belies heterogeneity at the individual and subsequent cluster-group
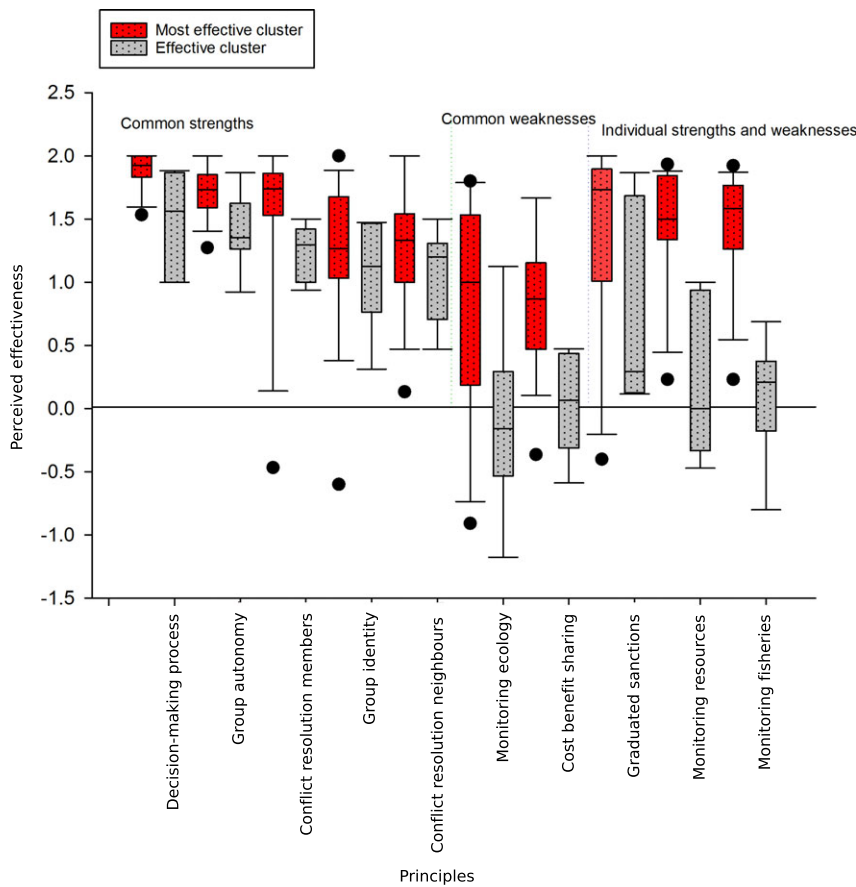
Figure 3. Perceived effectiveness of governance principles for the 2 significant clusters of responses at the site level (circles identify most effective clusters).

level. Group agreement in the CPR principles differed strongly by country and suggests, at the role level, that poorer countries (Madagascar and Mozambique) had more cohesion in agreement concerning effectiveness than wealthier nations (Kenya, Tanzanian mainland, and Zanzibar Pemba). Intra-group cohesion was, however, associated with lower scaling of effectiveness in resolving conflicts with neighbors. Moreover, the distribution of individual responses among cluster groups indicated a spread of individuals between clusters even within countries with more homogenous groups. These findings suggest that evaluating CPR principles at a site is likely to miss, misclassify, or poorly estimate the principles' effectiveness and possible dissent depending on how this information is gathered and compared.

Given the observed variability, the practice of recording the presence or absence of CPR principles is likely to over simplify the more complex scaling and variability of group perception and competence within and between principles (Fig. 2). For example, our pilot studies indicated the principle of monitoring required 3 categories to get informed and accurate answers. Moreover, there were notable differences between the categories. Effectiveness declined, as expected, from resource users to fishery resources to nonresource ecology. Evaluations of these principles based on the presence/absence of

principles by other investigators has resulted in variable, interactive, additive, and low CPR success (Cox et al. 2010; Oldekop et al. 2010; Gutierrez et al. 2011).

Comparing Governance Principles

Respondent's scaling of principles showed that variance declined as the mean scaling increased and along the social scale from individuals to roles to sites. Overall, the highest and least variable scaled governance principles were group identity, group autonomy, decision-making processes, and local conflict resolution. Consequently, within-community self-regulating mechanisms had the strongest perceived effectiveness. Regular encounters and meetings at fish landing sites may help to achieve these practices at the lowest cost. Overcoming common's dilemmas is frequently achieved by regular verbal communications between resource users (Balliet 2010). When groups are isolated, resources abundant, and rule-breaking infrequent, these boundary, decision, and distribution problems may be easily addressed (Ostrom et al. 2002). Given the high effectiveness scaling and low variability, these principles should be the most trusted and effective in East African fisheries. However, low explained variation and effect sizes for these principles when evaluating resource outcomes by meta-analyses

indicates challenges for provoking successful CPRM and sustainability (Cox et al. 2010; Oldekop et al. 2010).

The most variable and lowest scaled principles were graduated sanctions, cost–benefit sharing, and monitoring resource users, fisheries, and ecology—CPR governance principles likely requiring higher expenditures of time, skills, and resources to be effective. Consequently, it could be problematic for communities to detect changes in users and resources and communicate with and enforce compliance with distant neighbors or migrant fishers. These activities are likely to be costly because they either take more time in terms of detecting rule breakers, communicating between disparate groups, or expertise and commitment to collecting, storing, and analyzing information (Ostrom et al. 2002). In many of the highly resource-limited situations in East African coastal communities, interventions and support for these actions may be required to increase effectiveness. Meta-analyses indicate monitoring and fair cost–benefit sharing have among the highest effect sizes for improving resources (Cox et al. 2010). In East Africa, positive responses among resources, yields, and income metrics have been shown to improve through adaptive monitoring and community feedback (McClanahan 2010; McClanahan et al. 2015; Oliver et al. 2015).

We found that the fair distribution of costs and benefits was a key obstacle to CPRM effectiveness. A fair balance will be challenged by public ownership and because costs are complex and nonmonetary, such as opportunity and transactions costs (Williamson 1979). Additionally, open fish markets and prices are largely outside of local CPRM control. Connections to larger markets is expected to lead to demand and prices beyond the local production, resource autonomy, and distribution controls or that considers local cultural and food needs (Cinner et al. 2016; McClanahan & Abunge 2017). Cost–benefit effectiveness variance from the individual to the site declined more than others. Yet, an individual's perceptions of fairness, trust formation, and participation are critical. Therefore, resolving transactions problems and agreements will be challenged by individual perception when individuals meet in groups. Fair cost–benefit distribution is associated with high CPRM success rates (Cox et al. 2010), so it behooves developing mechanisms to resolve the disparity.

Communities in wealthier nations report more contact with outside forms of government (i.e., county and national government bodies) than poorer nations. Given that taxes, spending, and presence of governments should reflect interaction frequencies, this was expected. Therefore, CPR communities in poorer and sparsely populated countries are unlikely to develop viable nested governance institutions. In these nations, all governance responsibilities are likely to fall on communities or in some cases be supported by private, international government, and nongovernment organizations—a form of polycentri-

cism. For example, most marine managed areas in Madagascar and Mozambique are funded by either large or private international donors, trusts, and nongovernment conservation and poverty alleviation organizations—forms of polycentric governance (Oliver et al. 2015; Gill et al. 2017). Nested governance exists in the wealthier countries but decision and power-sharing problems are commonly reported (Cinner et al. 2012). Moreover, intercommunity differences in preferences for management options and subsequent conflicts are also common (McClanahan & Abunge 2016, 2018). Finally, although nested governance was more common in wealthier countries, so was market integration. Among others, the problems of rent seeking and markets and centralized governments that concentrate information and expertise can produce power asymmetries that typically challenge CPRM (Araral 2014).

Caveats

Responses we recorded were subjective evaluations of 10 activities important for managing common-pool resource. Questions could potentially be answered based on values and vested interests influenced by roles, group identity, and culture. A simple values-based view of environmental behavior is, however, not a strong predictor of actual behavior because it does not fully account for behavioral costs (Kaiser et al. 2010; Klöckner 2013). In East Africa, some respondents have been asked and accepted responsibilities previously held by national governments (Cinner et al. 2012). Therefore, they should be personally aware of the added local costs and benefits. Consequently, we suggest that responses integrated perceived costs into their stated perspectives of effectiveness because the questions were specific. Responses should therefore be more tangible and objective about costs. Further, that costs are widely acknowledged and possibly objective is further supported by the weak effect that respondent's roles played in scaling effectiveness.

Twenty percent of respondents scaled most activities highly, which suggest some actors are not fully acknowledging differential effectiveness occurring in resource-limited situations. Undifferentiated positive scaling may be cultural in that respondents may wish to project a positive view of their group, or their culture may promote an acquiescence reflected in the scaling of questions. Certainly, responses to what might be construed as value-type questions can reflect these core cultural elements (Smith 2004). A positive acquiescence style has been associated with countries with high income inequality, poverty, collectivistic social organization, and low stability in governance and civil rights (Fischer et al. 2009). These attributes are common in our study region but perhaps strongest in Madagascar and Mozambique. Nevertheless, not all individual responses suggest

acquiescence and uniformity because respondents clustered distinctly in all countries. So, although roles in Madagascar and Mozambique fell into the positive cluster, individuals composing these roles differed and scaled some principles negatively - bringing down the overall scaling. A thorough evaluation of acquiescence shows that country-level biases are generally small but can change responses in a systematic way (Fischer et al. 2009).

Recommendations

The social, principle actions, and geographic complexity of CPRM governance appears to be appreciated and scaled accordingly by most stakeholders. Although the complexity is potentially daunting, there are some expected patterns that reflect common contexts and cost–benefits. Our findings offer the opportunity to make governance principles more contextually relevant– thus avoiding a panacea approach to governance and development (Ostrom et al. 2007). The most effective principles tend to be those concerned with local human self-organization and having low costs. Evaluations and responses for these types of local control factors have used a mix of presence or absence, descriptive, and qualitative information (Cox et al. 2010; Gutierrez et al. 2011; Wamukota et al. 2012). These principles of local human organization and autonomy are associated with success in some contexts (Gutierrez et al. 2011). Nevertheless, they may have lower chances of success in open market and top-down governments, such as Kenya and Tanzania, where local-national conflicts in management preferences are common (Araral 2014; McClanahan & Abunge 2016).

Collective actions, such as monitoring and adaptive management that were scaled weakly for local effectiveness, are expected to be among the costlier but possibly the most effective principles in catalyzing sustainable management (McClanahan 2010). In many cases, however, outside assistance has been required to achieve these successes (McClanahan et al. 2015). Consequently, it may be that what is perceived as effective here is not what actually improves natural resources. Outside forces, such as market integration, subsidies, and access to monitoring and enforcement capacity should greatly influence sustainability outcomes where resource for monitoring and enforcement are limited (Cinner et al. 2016). Furthermore, evaluating resource sustainability can be difficult when information is lacking or qualitative, as is the case in many CPRM projects and scientific evaluations (Wamukota et al. 2012).

We found variation in responses that suggest at least 2 types of success or classes of CPR effectiveness: local human self-governance and adaptive learning and broad-scale compliance with management choices. These collective actions have been recognized in theory but

less contextualized for specific CPRM recommendations (Ostrom et al. 2002). We found they differed across a sequence of human development and therefore are likely to have consequences for CPRM policies and success. Araral's (2014) critical review of CPRM governance concludes that many of the principles are most useful for small and locally governed communities but more problematic for larger-scale commons. We suggest there are at least 2 systems that have different contexts for their specific applications and effectiveness. Consequently, where human populations are mobile and large and economies are driven by market and national forces, the success of adaptive-compliance management with high intercommunity conflict is likely to be critical to CPRM effectiveness (McClanahan & Abunge 2018).

Depending on development state and spending priorities in each country, CPRM will often require outside assistance with monitoring, surveillance, fair enforcement, and market transactions. Many countries have fisheries collection and enforcement systems, but they are often focused on high-value and traded catches of national interest, and findings are seldom relevant or used to inform and influence local commons and decisions (Pauly & Zeller 2016). Data are frequently used for broad policies by central and international governments located beyond the interests and influences of CPR communities. National-level enforcement is frequently weak and contentious for a variety of reasons including costs, incentives for corruption, and difficult social and scale trade-offs (Cumming et al. 2006; Daw et al. 2015; Sundström 2015). Further, we see that some landing sites in the poorest countries have very little nested government interactions. Yet, nested and polycentric governance are key to establishing monitoring and enforcement systems that provide information to communities about their extraction relative to sustainable production rates. In this region, efforts to do this without outside support are uncommon, frequently fail, and are likely to require power, information, expertise, and cost sharing. More sharing and procedural justice within and between communities may also help reduce the sense of unfairness that pervades East African fisheries (McClanahan & Abunge 2016, 2018).

Supporting Information

Descriptions of the study sites national context (Appendix 1), sample sizes and totals by landing sites and countries (Appendix 2), nonmetric dimensional scaling for 3 societal levels (Appendix 3), frequency of individuals, roles, and sites in significant cluster groups relative to rating or governance principles (Appendix 4). comparison of perceived common-pool management effectiveness by individuals, roles, and sites (Appendix 5), scaling

and tests of differences among common-pool principles by cluster groups (Appendix 6), 2-factor ANOVA testing differences and interactions of governance principles between countries and roles (Appendix 7), and most and least effective principles for each studied landing site (Appendix 8) are available online. The authors are responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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