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Evaluating taboo trade-offs in ecosystems services and human well-being

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Managing ecosystems for multiple ecosystem services and balancing the well-being of diverse stakeholders involves different kinds of trade-offs. Often trade-offs involve noneconomic and difficult-to-evaluate values, such as cultural identity, employment, the well-being of poor people, or particular species or ecosystem structures. Although trade-offs need to be considered for successful environmental management, they are often overlooked in favor of win-wins. Management and policy decisions demand approaches that can explicitly acknowledge and evaluate diverse trade-offs. We identified a diversity of apparent trade-offs in a small-scale tropical fishery when ecological simulations were integrated with participatory assessments of social–ecological system structure and stakeholders' well-being. Despite an apparent win-win between conservation and profitability at the aggregate scale, food production, employment, and well-being of marginalized stakeholders were differentially influenced by management decisions leading to trade-offs. Some of these trade-offs were suggested to be "taboo" trade-offs between morally incommensurable values, such as between profits and the well-being of marginalized women. These were not previously recognized as management issues. Stakeholders explored and deliberated over trade-offs supported by an interactive "toy model" representing key system trade-offs, alongside qualitative narrative scenarios of the future. The concept of taboo trade-offs suggests that psychological bias and social sensitivity may exclude key issues from decision making, which can result in policies that are difficult to implement. Our participatory modeling and scenarios approach has the potential to increase awareness of such trade-offs, promote discussion of what is acceptable, and potentially identify and reduce obstacles to management compliance.

coral reef fisheries | ecosystem-based management | participatory modeling | scenarios | gender

Despite the recent explosion of research evaluating the contributions of ecosystems to human well-being and poverty alleviation, our understanding of how ecosystem services contribute to the well-being of different people remains weak (1–4). A key challenge is to understand and deal with trade-offs, in which gains for one ecosystem service or group of people results in losses for others. Although trade-offs are ubiquitous, they are often poorly acknowledged in conservation and development policies and projects, which typically focus on more socially palatable win-wins (5). This selective focus on win-wins can cause important and value-dependent trade-offs to be overlooked, often with unintended perverse outcomes (6, 7).

Trade-offs can emerge from complex social and ecological processes that are difficult to perceive. For example, ecological dynamics on coral reefs result in a trade-off between carbonate and fisheries production, which operate on different spatial and temporal scales (8). Meanwhile, complex social relationships determine how the well-being of different groups of people is supported by these ecosystem services (9, 10), and result in trade-offs between them (11). A trade-off from one perspective may appear as a synergy from another (12), so that assessments conceal or reveal trade-offs based on what ecosystem service outcomes are valued and from whose perspective. Some ecological processes may be poorly understood and thus undervalued, whereas trade-offs affecting marginalized people can be overlooked if they are excluded from assessment processes. These factors all contribute to certain trade-offs being overlooked, and demand approaches to help make trade-offs explicit and salient to stakeholders and decision makers.

Trade-offs are not all equal. They vary in spatial and temporal scale (13), as well as in terms of what services, whose interests, or which types of values are traded off. Trade-offs between aggregate system-level processes, such as between carbon sequestration and water quality in a landscape (14), have dominated ecosystem service research to date, but trade-offs between the well-being of different groups of people, or between individual groups and system-level objectives are also critical, but are seldom evaluated by aggregate ecosystem service assessments (2).

Furthermore, little attention has been paid to the different kinds of values underlying ecosystem service trade-offs (15). The psychologist Tetlock (16) has shown that the nature of values underpinning trade-offs affects how they are perceived and

Significance

Environmental management inevitably involves trade-offs among different objectives, values, and stakeholders. Most evaluations of such trade-offs involve monetary valuation or calculation of aggregate production of ecosystem services, which can mask individual winners and losers. We combine a participatory, modeling, and scenarios approach to identify social–ecological trade-offs in a tropical fishery and the implications on well-being of different stakeholders. Such trade-offs are often ignored because losers are marginalized or not represented by quantification, and because the nature of underlying values may result in socially "taboo" trade-offs that pit incommensurable values against one another. A participatory modeling and scenarios approach can increase awareness of such trade-offs, promote discussion of what is socially acceptable, and potentially identify and reduce obstacles to compliance.

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addressed. All communities have “sacred” values (16) or “protected” values (17) (e.g., human life, nature, honor, justice) that they profess to not be willing to trade off for more secular values such as money. The sacredness of values can vary between communities and depends on context and discursive framing (18). Trade-offs that pit sacred values against secular values are taboo (see Fig. 3*A*), and it is morally problematic and psychologically uncomfortable to even consider them (16). “Taboo” trade-offs are inevitable in a resource-limited world, and when forced to consider them, such as when balancing the financial costs of protecting a child, people feel tainted, and onlookers respond with moral outrage. Consequently, people tend to avoid thinking about secular–sacred taboo trade-offs, either by pretending that they are not being made or by welcoming less taboo framings (16) (see Fig. 3*A*). “Routine” trade-offs between secular values do not involve incommensurable value conflicts and can be acceptably evaluated with rational benefit–cost logic. “Tragic” trade-offs involve difficult value trade-offs between sacred values but are not morally repugnant in the same way as taboo trade-offs, and it is considered virtuous to consider them carefully (19). Knowledge of sacred values helps understand how ecosystem services trade-offs may trigger intractable conflicts if stakeholders hold different value frames than decision makers, or if taboos are violated by weighing sacred values against secular, economic rationality.

In summary, a diverse range of ecosystem services-related trade-offs can exist, and different approaches are needed to address them. Technical and economic approaches to evaluate trade-offs deal adequately with routine trade-offs, but fail to acknowledge the social complexity, the multiple dimensions of well-being, and the political challenges that often characterize decisions around ecosystem services and resource management. Analytical frameworks and evaluative tools are needed to explicitly identify trade-offs, evaluate them with regard to the well-being of different stakeholders, and support deliberation and decision making in the face of hard choices (5). In the present work, we used well-being research, participatory workshops, the creation of a social–ecological “toy model,” and scenario development as tools to identify and consider a diversity of ecosystem service trade-offs hidden within an apparent win-win situation in a tropical fishery.

Case Description and Approach

The small-scale fishery at Nyali, Mombasa, Kenya is a social–ecological system that connects various primary stakeholders through their use of and impacts on the coral reef and seagrass ecosystem. Most of the primary stakeholders are poor, and they are differentiated by such characteristics as gender, vulnerability, and the way in which they benefit from the ecosystem. We mapped the benefits from this fishery to five primary stakeholders: captains of illegal but widely used large beach seine nets; laborers used in teams to pull beach seine nets; independent fishers using other gears, such as small gill nets and spears; male traders, who specialize in large fish for high-value markets; and female traders, who buy smaller and cheaper fish, typical of beach seine catches, and fry them to sell to local communities.

We used three methods to initially map out the social–ecological system and linkages to well-being of the five primary stakeholder groups. First, focus group discussions with each stakeholder group explored the subjective experience of well-being by these resource users and their relationship to the fishery (20). Second, long-term (~15 y) biological and fisheries data were used to parameterize a fisheries ecosystem model. Third, participatory conceptual modeling with local experts identified social and ecological linkages, feedbacks, and drivers of the system. These three data types were integrated into a simplified “toy model” of social–ecological dynamics and benefits (Fig. 1), as well as discursive scenarios of possible futures (Fig. 2). The toy model provided an interactive tool designed to support stakeholders’ exploration and learning about the complex dynamics in the social–ecological system (21). Toy models have been used in physics and complexity science to focus on key dynamics and support exploration of complex systems. The term “toy” is particularly useful in stakeholder engagement processes to emphasize that the model is designed to facilitate exploration and learning, rather than to accurately predict system behavior.

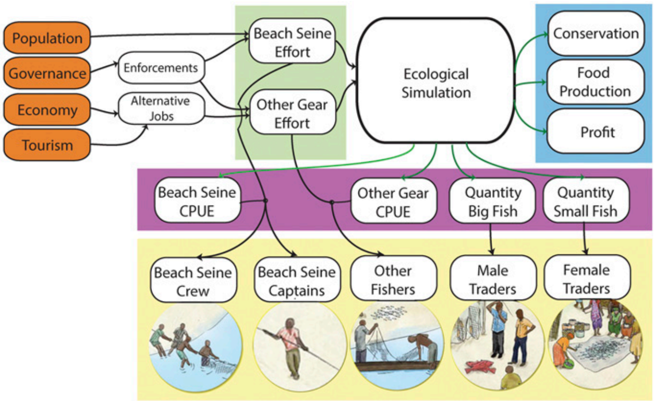

Fig. 1. The social–ecological fishery system as conceptualized by the toy model. A broad range of external drivers (orange) determine the nature and type of fishing activity (green background), which in turn determine aggregate outcomes (blue background), fishery outcomes (purple background), and the flows of benefits to the different resource users (yellow background). Black lines indicate fuzzy logic rules and green lines indicate ecosystem model outputs.

Our toy model represents how management and social drivers may affect fishing effort and the resultant effects on ecological dynamics, catches, and earning opportunities for each resource user, as well as aggregate indicators of conservation (fish biomass), food production (total catch), and profits (total net profits of fishing). The scenarios depict four possible futures under different combinations of drivers incorporating aspects of the toy model plus additional drivers and dimensions (e.g., tourism, development of offshore fisheries; *SI Appendix*). Stakeholders were engaged in playing with an animated version of the toy model and discussing the scenarios. These participatory tools were designed to stimulate awareness of ecosystem service and well-being trade-offs and to consider choices, agency, and possible future trajectories for the system. Learning by workshop participants was assessed by observation and follow-up qualitative interviews.

Emergent Trade-Offs. Our ecological fishery model suggested a generally positive relationship between the system-level goals of conservation and profitability (Fig. 3*B*) and a potential win-win improvement in conservation and profitability, achievable by reducing effort of the less-profitable beach seine (*SI Appendix*, Table S1). However, considering food production and specific benefits to different resource users revealed multiple potential trade-offs of different types (Fig. 3 *C*–*F*). Model outputs suggested that the potential conservation–profit win-win comes at the expense of food production, which would decline as a result of less fishing effort. In particular, the system was depicted as in a state in which any increase in food production or profit from the current state, represented by X, would require a decline in the other (Fig. 3*C*). Further increases in food production could be achieved through increases in catches of productive but low-value species by increasing the labor-intensive beach seine effort; however, this was predicted to negatively impact both conservation and profitability (*SI Appendix*, Table S1). In contrast, increases in profitability and conservation status through rebuilding appeared to require a reduction in beach seining and lower total catches from the system.

Disaggregating different stakeholders revealed a range of potential trade-offs and win-wins in different groups’ well-being. Some trade-offs were generated by straightforward distributional impacts of management; for example, effort reductions imposed on other fishers’ benefits was expected to benefit the beach seine crew owing to reduced competition (Fig. 3*D*). Other trade-offs emerged from social–ecological complexity; for example, ecological responses to changing fishing effort affected the

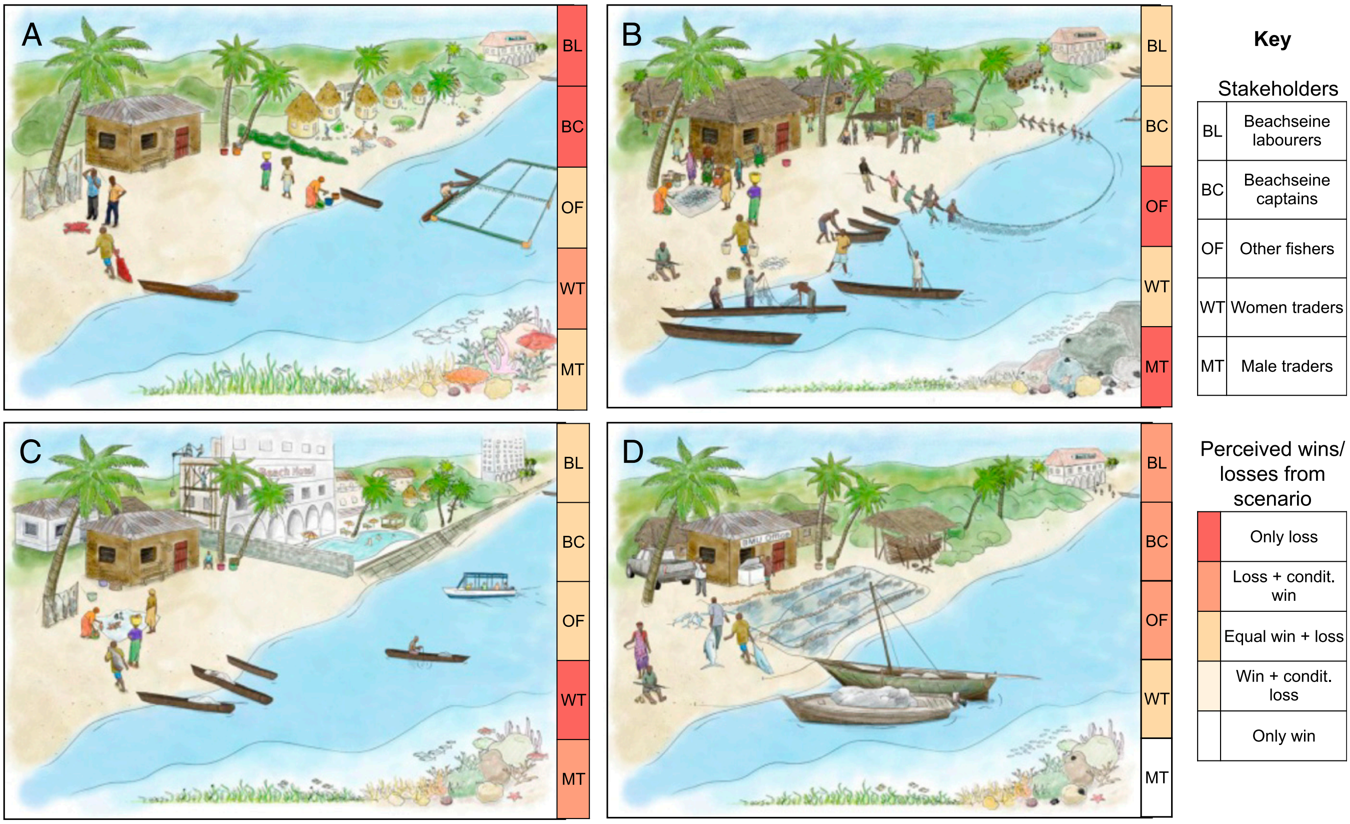

Fig. 2. Artistic representations of qualitative future scenarios of the system. (Complete descriptions are provided in *SI Appendix*.) (*A*) Low growth, eco-tourism, low exploitation, no beach seines. (*B*) High population, low enforcement. (*C*) Economic growth, mass tourism, abundant alternative earning opportunities. (*D*) Professionalization and offshore development of the fishery. Five primary stakeholder groups' perceptions of wins or losses under each scenario are indicated by shaded bars and described in *SI Appendix*, Table S3.

composition of catches, with implications for how well-being benefits are distributed among resource users. For instance, a reduction of fishing effort was predicted to increase the proportion of catches of larger and higher-value fish, benefitting non–beach seine fishers and male traders, who focus on these species for their livelihoods. Thus, there is a broad synergy between these two groups, as depicted by the toy model (*SI Appendix*, Fig. S1*C*). In contrast, however, female traders, who typically rely on trading small, low-value fish, would be disadvantaged by a shift toward catches of fewer, larger, and more profitable fish.

Trade-offs and synergies also existed between system-level goals and the well-being of individual stakeholders. For example, female traders were predicted to benefit from systems optimized for food production (*SI Appendix*, Fig. S1*D*), whereas a trade-off was generally predicted between female traders and either profit or conservation (Fig. 3 *E* and *F*).

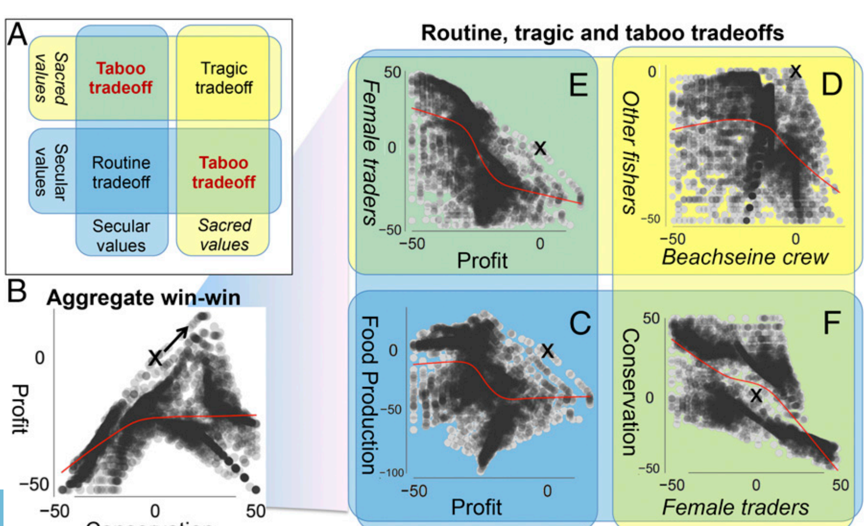

Fig. 3. (*A*) Classification of trade-offs according to the values involved in which trade-offs pitting sacred against secular values are taboo (16). (*B*–*F*) Plots showing selected relationships between different management objectives (*B* and *C*), the well-being of different stakeholder groups (*D*), and between objectives and well-being (*E* and *F*) from the toy model. (All plots are shown in *SI Appendix*, Fig. S1.) Possible configurations of the toy model are indicated by cloud of gray dots, and red lines indicate the smoothed relationships between objectives or well-being. Axis scales are fuzzy indications of relative change from the current situation, where "very high" equals 100 and "very low" equals −100. An "X" marks the current state of the system. (*B*) A positive relationship between conservation and profit suggests a general win-win and the potential to increase both from the current situation, indicated by an arrow. (*C*–*F*) Trade-offs categorized as routine (blue background), tragic (yellow), or taboo (green), reflecting the arrangement of *A* and the assumption that stakeholder livelihoods represent sacred values.

Table 1. Quotes illustrating how the process contributed to participants' understanding of emergent ecosystem service trade-offs

Aspect of learning	Indicative quote
Developing a system view	"[The workshop] broadened my...perception of the ecosystem and links to well-being of primary stakeholders, and so now I do not approach projects from a narrow perspective. Previously I might have shied away from a gender meeting, but now I am willing to attend, because I realize that there are interconnections to the work that I do in conservation."
Learning about trade-offs	"What really drove the idea of trade-offs home was the optimizing exercise [with the toy model], because it enabled me to see the interconnectivity between factors and I could visualize how when one increased, the other decreased."
Imagining future policy options	"I thought that by providing them with boats and vessels, they will just go offshore, get lots of fish, sell it, have money, and put food on the table. But I never saw it from the perspective of scenario D, which suggests that the program may not necessarily turn out all positive for the fishermen as we expect. This scenario opened my eyes to different possibilities of such a program."
Applying trade-offs to environmental management	"We sometimes have issues with poor stakeholders because they normally oppose whatever you propose. During the workshop, I actually came to understand why they normally oppose, and when I get a negative answer from them, I now understand why."

Exploring Trade-Offs with Stakeholders. Participatory workshops allowed key stakeholders to engage with the complexity around trade-offs and how these trade-offs might play out in a dynamic way. We observed and documented stakeholders expanding their systemic understanding of the nature of trade-offs. The participatory conceptual modeling elicited a wide range of interacting processes and drivers (*SI Appendix*, Fig. S2) that fed into the toy model and scenario design, and also helped participants conceive of a wider range of processes and interactions affecting the system (Table 1). An exercise of playing with the toy model and attempting to optimize multiple system-level objectives and resource user well-being highlighted the emergence of trade-offs from system linkages (Table 1).

The narrative scenarios included a wider range of processes and drivers than the toy model, and encouraged stakeholders to think more holistically about real future trajectories and their role within them. Primary stakeholders identified multiple kinds of wins and losses across the scenarios (Fig. 2 and *SI Appendix*, Table S2), whereas secondary stakeholders deliberated on policy responses to the trade-offs embedded in each scenario (*SI Appendix*, Table S3). Whereas the toy model simplified and clarified key trade-offs in the dimensions of fishing pressure and catches, the scenarios provided a more complex and holistic perspective and more nuanced impression of trade-offs resulting from the multiple wins and losses experienced across stakeholder groups in different scenarios (Fig. 2). Trade-offs were apparent both between stakeholders (e.g., between fishers and male traders in Fig. 2*D*) and within stakeholder groups, as indicated by their perception of both wins and losses from some scenarios (*SI Appendix*, Table S2).

Workshop entry and exit questionnaires suggested that participants expanded their understanding of trade-offs beyond direct conflicts between actors, to emergent trade-offs between system-level objectives, as well as system–actor trade-offs (Table 2). Participants also became more aware of trade-offs with food production and indicated that their increased awareness of trade-offs would facilitate their working within the system (Table 1).

Discussion

Our analysis suggests that diverse trade-offs are produced by both biophysical and social factors and their interactions. These include trade-offs between aggregate system-level objectives and also between the well-being of different primary stakeholders, as well as trade-offs between system-level objectives and particular stakeholders' well-being. This highlights the fact that secondary stakeholders concerned with system-level objectives may have different framings of the trade-offs and synergies than primary stakeholders owing to the different scales perceived by each group. Environmental managers need to understand these well-being trade-offs for both instrumental and ethical reasons. Instrumentally, management decisions may be impossible to implement if they are blocked or sabotaged by stakeholders whose well-being would be traded off; for example, attempts to implement the Diani/Chale Kenyan National Marine Reserve were foiled by violent resistance of fishers who were marginal to decision making (22). Ethically, trade-offs may involve the well-being of particularly poor or vulnerable stakeholders, like female traders in our case. Consequently, making well-being trade-offs explicit can identify both potential resistance as well as stakeholders who are at risk of serious harm.

Despite the increasing recognition that trade-offs need to be considered in resource management (23), this case illustrates four mechanisms that can cause them to be overlooked, and suggests how to increase their visibility. First, consideration of trade-offs can be easily ignored in favor of socially acceptable win-wins, such as the aggregate system-level win-win between profitability and conservation (Fig. 3*B*), achievable in this case by reducing fishing effort. This win-win was highlighted by previous scientific research (24) and reflected in workshop participants' narratives of synergies between conservation and economic benefits. The trade-off in total yield, particularly in lower volumes of small, cheap fish favored by poorer women traders, was easily overlooked. We propose that assertions of unconditional win-wins in ecosystem management should be scrutinized for losses of marginalized, undervalued, and less obvious stakeholders.

Second, trade-offs can be overlooked when they result from complex system connections. Although some well-being trade-offs are straightforward, such as from direct competition between tourism and fishing, others result from complex combinations of ecological dynamics and socially differentiated access mechanisms (11). These depend on more than the total volume or value of an ecosystem service, such as the landed value of fish. In this case, ecosystem responses to fishing pressure determined the sizes and types of fish landed, which in turn affected gender-based access to fish. To reveal these trade-offs, analysis needs to reflect complexities in the biophysical system producing the trade-offs, as has been the focus of recent advances in ecosystem service research (14); however, assessments also need to map out the processes that determine who benefits from ecosystem services, as well as how this enhances their well-being. Our combination of well-being research with scenarios and participatory modeling helped map out the distributional and well-being implications of ecosystem change.

Third, well-being trade-offs may be overlooked if losers, through poverty or political marginalization, have no voice in decision making. This is particularly problematic given that the poor may be more vulnerable to changes in ecosystem services (25). In this case, women traders are dependent on the system but have relatively little visibility or voice in governance (26), which is focused instead on fishers and tourism. We included marginalized female traders based on a stakeholder analysis of the system and used focus groups to include the groups' perspectives

Table 2. Trade-offs identified by participants before and after participating in the workshop

Before the workshop	After the workshop
Fishermen vs. government (n = 4)	Governance/economy vs. beach seines and women traders (n = 6)
Conservationists vs. fishers (n = 3)	Food vs. ecology (n = 5)
Fishers vs. fish traders (n = 3)	Fishers vs. tourism (n = 2)
Hoteliers vs. fishers (n = 2)	Population vs. ecology (n = 2)
Fishers vs. tourists (n = 2)	Tourism vs. ecology (n = 2)
Locals vs. private developers (n = 2)	Tourism vs. food (n = 2)

and appreciate otherwise unnoticed well-being implications of fisheries management.

Fourth, people have a psychological bias against perceiving taboo trade-offs, which pit deeply held sacred values against secular concerns, particularly when obfuscated by even minimal amounts of complexity (16). Sacredness varies by cultural group as well as by the framing of a particular problem (18); thus, conflicts can arise if primary stakeholders hold different sacred values than managers and government, or if sacred values are not reflected in the framing of decision making.

To illustrate the value of Tetlock's framework (16), we explored which trade-offs could be taboo based on the assumption that well-being of the poor represents sacred values and aggregate system-level objectives represent secular values. Such a classification reflects a poverty alleviation framing and the perspectives of primary stakeholders. Framed in this way, aggregate system-level trade-offs would be routine trade-offs (Fig. 3*C*), trade-offs between poor stakeholders would be tragic trade-offs (Fig. 3*D*), and trade-offs between the stakeholders and aggregate objectives would be taboo trade-offs (Fig. 3 *E* and *F*). Although we do not empirically demonstrate that these trade-offs are taboo, it is notable that there was little awareness of system versus well-being trade-offs among secondary stakeholders before the workshop (Table 2), consistent with the prediction that taboo trade-offs are easily overlooked.

Explicit consideration of the diversity of values and possible taboos help explain the deeply felt conflicts that can result from ecosystem service trade-offs, and ultimately support improved decision making processes. Examples of potentially sacred values include culturally and socially embedded fishing identities that frequently conflict with system-level goals to reduce fishing effort (27). Although people will resist engaging with taboo trade-offs, the sacredness of values appears to be somewhat dependent on context and framing (18), suggesting that taboo trade-offs can be reframed as routine or tragic trade-offs. Values can be secularized to frame trade-offs as routine, as with the quantitative, monetary valuation and benefit-cost analyses that dominate ecosystem services assessment (28, 29); however, this approach hides the incommensurable value conflicts, common in environmental decision making, that need to be deliberated and negotiated (28, 30). Ignoring the sacredness of such values and treating them as secular, for example, by offering financial compensation, can in fact exacerbate conflict (31).

An alternative approach is to reframe taboo trade-offs as tragic trade-offs, by linking secular goals or constraints to sacred values. For example, in this case, conservation could be framed in terms of the rights of future generations. Such reframing does not resolve trade-offs, but may facilitate deliberation over them and prevent them from being ignored, which can lead to unresolved conflicts. In contrast to the moral repugnance of taboo trade-offs, it is socially virtuous to carefully consider tragic trade-offs (19), supporting deliberation in which stakeholders engage with and try to find solutions to these trade-offs.

Our use of participatory modeling encouraged participants to engage with a wide range of trade-offs from different perspectives and beyond visceral reactions triggered by challenges to sacred values. The models exemplified the complexity of potential outcomes and spelled out the inevitability of hard choices (18). Meanwhile, the scenarios provided a neutral framework within which to discuss otherwise taboo and uncomfortable possibilities and to engage with taboo topics (19). Engagement with these trade-offs is exemplified by the specific solutions to scenario trade-offs created by workshop participants (*SI Appendix*, Table S3).

The combination of participatory modeling and scenarios can enhance transparency (through participatory modeling), accountability (through explicitly mapping winners and losers), and relevance (through a focus on people's well-being). Each of these is thought to support value pluralism (32) and deliberative environmental governance that has a greater chance of achieving socially equitable and sustainable decision making. We also recommend the inclusion of all relevant stakeholders, transparency, and trust-building discussions (33). Accounting for the sometimes-sacred nature of values and the trade-off consequences of decision making for different stakeholders are keys to achieving acceptable decisions about ecosystem services and their social distribution.

Methods

We used a combination of methodologies and interactions with both primary stakeholders (those with a high dependence on the fishery system) and secondary stakeholders (those with a high level of influence on the local system). Complete descriptions of the project and participatory activities are available at www.espa.ac.uk/projects/ne-i00324x-1.

Well-Being Focus Groups. Three rounds of focus groups were held with five primary stakeholder groups selected for their dependence on the fishery and their likelihood to be involved in ecosystem service-mediated trade-offs. The focus groups grounded the research in the subjective, lived experience of primary stakeholders (20) and explored the following questions: What is important for well-being? How do people perceive their level of well-being? How is well-being affected by changes in the fishery and other factors? How would the four scenarios impact on the well-being of different people? Focus group sessions were recorded, transcribed, and translated for thematic analysis.

Participatory Workshops. Secondary stakeholders with a strong influence on the system, including staff from local government and nongovernmental organizations dealing with fisheries and development as well as representatives of fisher and tourism interests, attended two 2-day workshops (the first with 12 participants and the second with 14 participants). The first workshop elicited processes of change, drivers that determine the status of the fishery and the well-being of primary stakeholders. An adapted version of the actors, resources, dynamics, and interactions methodology (34) was used to develop a collective conceptual model of the social–ecological system. The second workshop introduced participants to the well-being research, ecological modeling, toy model, and scenarios. An open workshop at the landing site presented the scenarios and a simplified version of the toy model to more than 100 primary stakeholders.

Ecological Model. Biological and fisheries data, including species composition, abundance, life history characteristics, diet composition, catches, and fishing effort, were collected from ecological monitoring, landing site surveys (35, 36), and online databases (37, 38). These data were used to develop a trophodynamic model in Ecopath with Ecosim (EwE) version 6.2 (39), which provided expected ecological and fisheries responses of the Mombasa coral reef and seagrass ecosystem under a range fishing effort scenarios. The model represented trophic interactions between 56 functional groups and the effects of five types of fishing gear: beach seine, fish trap, spear, hook and line, and net. Gear was grouped into beach seine and non-beach seine, and simulations were run in which effort by the gear groups corresponded to 0, 0.5, 1, 1.5, and 2 times the current (average of the 2000s) effort levels. Simulations were run for 30 y, and data on total catch, net present value of catches less fishing costs (discount rate, 11%), and total fish biomass were collected to provide indicators of food production, profitability, and conservation, as well as catch per unit effort by gear type and by functional group. Functional groups were classified as high value or low value based on fisheries monitoring data. We acknowledge uncertainties in the model outputs, particularly for simulations far from the current state; however, in

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this study, ecological model results were used not for prediction, but rather as input to the toy model and scenarios and to stimulate discussion.

Social–Ecological Toy Model. The rule-based toy model combined the key linkages of the participatory conceptual model from the workshop with the EwE simulations and well-being linkages to individual stakeholders. The network structure of the conceptual model was analyzed to identify key driver and response variables. Drivers were summarized in the toy model into population, governance, economy, and tourism, which resulted in changes in enforcement, alternative occupations, and fishing effort by beach seine and all other types of gear (Fig. 1). EwE simulations were incorporated into rules determining how effort changes affected conservation, food production, profitability, catch per unit effort by gear group, and catches of high- and low-value species. Well-being research informed rules determining how fishery outputs affect each stakeholder group. Based on the centrality of money as a means and an end in itself for well-being among these stakeholders (20), these rules focused on the effects of fishery outputs on earning capacity.

The toy model was implemented in Microsoft Excel, using fuzzy-logic rules to link system components. The toy model was a necessarily highly simplified representation of the system, and was designed as a "thinking tool" to illustrate the qualitative nature of trade-offs rather than quantitative precision and to prioritize holism over precision. Thus, we aimed to capture key social–ecological interactions or benefit flows even if they were not supported by extensive data. The trade-offs identified depend on assumptions embedded within the model structure emphasizing the importance of explicitly explaining these to participants and inviting them to critique and alter the model. Several iterations of the model were created, including adjusting rules in response to secondary stakeholder suggestions during the workshop (*SI Appendix*, Table S4). A simplified structure driven only by effort with the different gear types was developed for the open workshop at the landing site and to generate Fig. 3 (*SI Appendix*, Fig. S3).

Creation of the Scenarios. The four scenarios of plausible futures for the next 15 y in the Mombasa region incorporated the most emphasized drivers and dynamics from the conceptual model, as well as available secondary data and modeled responses from the EwE model. The scenarios were described in text, in a systems diagram, and pictorially (Fig. 2 and *SI Appendix*). Primary stakeholders were introduced to the scenarios in focus groups and asked to reflect on the positive and negative implications of different development trajectories on well-being. Secondary stakeholders explored emergent trade-offs from the scenarios in a workshop and discussed possible mitigating interventions and who had the responsibility and agency to address them.

Monitoring of Learning. Impacts of the workshops on participants were monitored by entry and exit questionnaires and a follow-up interview by an independent consultant. Participants were asked about the tools used, their learning, and the impact of the process on their ways of thinking about and working with coastal issues.

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