Integrating indigenous livelihood and lifestyle objectives in managing a natural resource

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Evaluating the success of natural resource management approaches requires methods to measure performance against biological, economic, social, and governance objectives. In fisheries, most research has focused on industrial sectors, with the contributions to global resource use by small-scale and indigenous hunters and fishers undervalued. Globally, the small-scale fisheries sector alone employs some 38 million people who share common challenges in balancing livelihood and lifestyle choices. We used as a case study a fishery with both traditional indigenous and commercial sectors to develop a framework to bridge the gap between quantitative bio-economic models and more qualitative social analyses. For many indigenous communities, communalism rather than capitalism underlies fishers' perspectives and aspirations, and we find there are complicated and often unanticipated trade-offs between economic and social objectives. Our results highlight that market-based management options might score highly in a capitalistic society, but have negative repercussions on community coherence and equity in societies with a strong communal ethic. There are complex trade-offs between economic indicators, such as profit, and social indicators, such as lifestyle preferences. Our approach makes explicit the "triple bottom line" sustainability objectives involving trade-offs between economic, social, and biological performance, and is thus directly applicable to most natural resource management decision-making situations.

Panulirus ornatus | Torres Strait | management strategy | stewardship | indigenous fishing

Managing natural resources, whether aquatic or terrestrial, involves striking a balance between conservation needs and economic development, but less attention has focused on accounting for societal and cultural backgrounds (1–3), and even less where resource use is a key part of tradition and custom of indigenous communities. For these societies, cultural and lifestyle considerations may be as important as economic status and need to be accounted for in the decision-making process. Most natural resource management policies have focused on biological sustainability objectives (4). Increasingly, fishery harvest policies are turning to the maximum economic yield as the target harvest rate (5), additionally because it is achieved at a more conservative catch level than the biologically determined maximum sustainable yield level. However, social contracts between society and businesses increasingly require a scientific approach that is capable of optimizing resource extraction and livelihoods, yet demonstrates best practice in managing impacts on biodiversity and maintaining traditional lifestyle aspirations. Social objectives—the missing third pillar in the triple bottom line supporting effective management—are rarely explicitly included in the definition of fishery targets because of the mismatch between quantitative metrics and more qualitative social information (see ref. 6 as an example of one of the rare cases).

In our study, we developed an approach to capture both market-based economic and social objectives in a fishery characterized by a substantial traditional and cultural component as well as a commercially oriented sector. The Torres Strait tropical rock lobster (*Panulirus ornatus*) fishery provides an ideal case study because it is the region's economically most important fishery, includes multiple stakeholders, and social objectives are stated explicitly as part of a treaty between Australia and Papua New Guinea (which is a treaty between Australia and the Independent State of Papua New Guinea concerning sovereignty and maritime boundaries in the area between the two countries, including the area known as Torres Strait, and related matters): "... acknowledg[ing] and protect[ing] the traditional way of life and livelihood of the traditional inhabitants including their traditional fishing and free movement" (7). A total allowable catch of lobster is allocated between the two countries under the Treaty. Unlike many fisheries based on shared stocks, the resource is currently assessed to be above the maximum sustainable yield level (8). The fishery is complex in terms of international boundaries (the overall share of the fishery between Australia and Papua New Guinea is 67:33), multiple jurisdictions within Australia (the Torres Strait fishery and Queensland East Coast fishery, although the same stock, are managed, respectively, by federal and state agencies), and management objectives regulating a mix of indigenous and commercial fishers (Fig. 1 and Fig. S1). The Australian component of the fishery is exploited by both indigenous Islanders, for whom it has cultural significance, and commercial fishers, most of whom are non-Islanders. Within the Islander fleet there is also considerable heterogeneity, with a small number of fishers operating on a purely commercial basis but taking a high proportion of the catch, a large number operating for subsistence or traditional reasons taking a small proportion of the catch, and the balance taken by a group operating on essentially an income-supplementing basis.

The Torres Strait lobster fishery has historically been managed based on limiting nonindigenous access, closed seasons, and gear and effort restrictions (input controls). Policy initiatives are now being set in place to transition the fishery to one controlling the amount of catch in the fishery (output control). The exact nature of the harvestable output right is still to be determined for the traditional inhabitants, as well as the institutional arrangements for allocations of right to harvest a part of the resource. This study aimed to holistically explore the consequences of alternative quota management systems and allocation options, as well as the sensitivity of outcomes to external drivers (Table S1).

These three key dimensions are common to many other fisheries. We therefore sought to address first the planned transition

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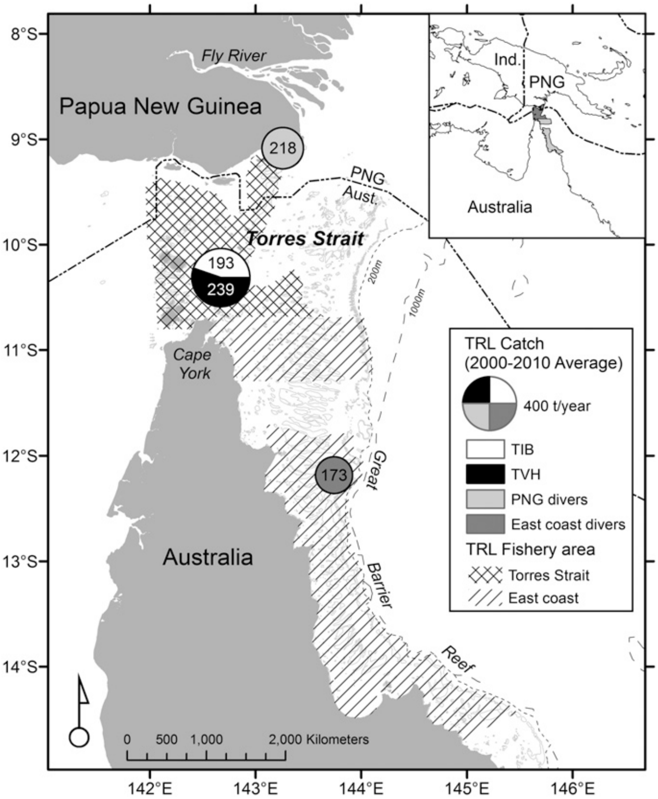

Fig. 1. Map showing different tropical rock lobster (TRL) fishery jurisdictions and sectors, together with the average catch (t) over the period 2000–2010 for the Torres Straits indigenous (TIB) and nonindigenous (transferable vessel holder) sectors, Papua New Guinea (PNG) and the East Coast sector.

of the fishery from the current input-based system to one involving output controls in the form of an overall quota across all sectors. Allocation of a share of this quota among different sectors and individuals constitutes the second dimension. The Islander share of total catch has increased substantially since 2005 through a targeted buy-back of around half the commercial fleet, resulting in an equivalent "nominal" quota allocation of 53:47 between Islander and commercial fishers in 2011, which is in line with a further key objective to promote indigenous fisher participation to meet their aspirations of achieving a greater control of the region's fisheries resources (9). A third dimension pertains to the role of external drivers: a program that funds part-time community work by Islanders emerged as a key driver.

Results and Discussion

The approach we adopted is based on the management strategy evaluation (MSE) framework, which involves simulation testing of the implications—for both the resource and its stakeholders—of alternative combinations of monitoring data, analytical procedures, and decision rules, which are increasingly used for evaluating the trade-offs between multiple objectives (10–12). We developed a framework (Fig. 2 and Table S2) that substantially expands on previous MSE approaches and introduces new linkages to holistically compare social, economic, and biological trade-offs anticipated under a range of proposed alternative management strategies and scenarios, as well as the sensitivity to related external factors (Fig. 3) (see *SI Methods* for a full description). We focused predominantly on evaluating trade-offs between alternative strategies comprising various derivatives of the introduction of an output control system in the form of individual transferable quota (ITQ) per Islander fishing license, a community-based system or an Olympic-type competitive system for the whole sector or part-thereof (Fig. S2 and Table S1). In an Olympic system a global total quota is set at the beginning of the season for this sector and the fishing season is open until the sector catch equals the quota. Hybrid versions imply future operational management systems that include some form of ITQ system for a subset of the Islander licenses (the commercial operators) and an Olympic-type system for the rest of the Islander sector to account for heterogeneity within the indigenous sector. Such hybrid systems have been implemented elsewhere in commercial fisheries, for example in the Norwegian cod fishery (13). Indigenous fisheries are usually managed separately using a different management approach from that applied to the nonindigenous fisheries (for example, the Maori in New Zealand and Mi'kmaq in Canada). However, within the indigenous sectors, a single management system is generally used rather than a hybrid approach, such as that considered here.

Our results highlight significant conflicts and trade-offs in traditional communities, such as the Torres Strait Islander fishers, where value was found to also depend on principles of equity, community coherence, resemblance to sea country and Island custom (Fig. 3). ["Sea country" is an Australian Indigenous term that relates to the authority held and responsibilities of particular groups of traditional owners to particular areas of sea, and is based on the cultural relationships with these areas (12)]. The right of everyone to enter the fishery commercially, recreationally, or for cultural reasons (a key social objective) was perceived to be best achieved by a competitive quota system. This system was also perceived to be least different from the current approach and thus most easily implemented. Community quotas were perceived to confer positive sociopolitical outcomes, but these preferences are correlated to coherent island communities and strong community leadership (14, 15). A hybrid system was perceived to have a reasonable economic outcome, but had significant negative cultural implications and reduced overall employment levels (Fig. 4). The policy of creating a hybrid management plan of ITQs for a subsector of a fishery combined with an Olympic-type management strategy for another part may have unintended consequences (*SI Methods*). There is no silver bullet or clear win-win solution, highlighting the utility of using MSE to make explicit the various trade-offs between objectives.

Meeting the social objective of increasing Islander participation and ownership in the fishery, for example by increasing this sector's share to 70%, has a large associated economic cost of approximately a 35% decrease in overall profits irrespective of the management system (Fig. 4). A clear trade-off is evident with total employment (another key social objective), which conversely increases with an increasing Islander share in the fishery, with the magnitude of the predicted changes highly dependent on decisions as to whether or not to retain the part-time community work scheme (Fig. 4). The presence (or potential absence) of the latter program is fundamental in terms of influencing the incentive to fish or not fish in this fishery and the maintenance of this program is independent of the fishery management authorities. Conventional management approaches ignore such externalities, but their impacts can dominate small-scale fisheries (3).

The heterogeneity of the Islander sector potentially increases the complexity of managing this fishery via output controls. A large proportion of Islander fishers currently fish part-time. Future increases in Islander fishing effort would positively affect economic and social outcomes of this group. However, the drivers to go full-time fishing for this group are unlikely to be impacted by the management system but rather by external factors, such as greater social capital and additional infrastructure in Island communities. Moreover, income- as well as nonincome-related factors may drive resistance to change (16, 17). Our findings were also underpinned by studies (15, 18, 19) that consider social capital a prerequisite for collective action and for social learning by quantifying the impact of the provision of logistics and infrastructure, enabling the

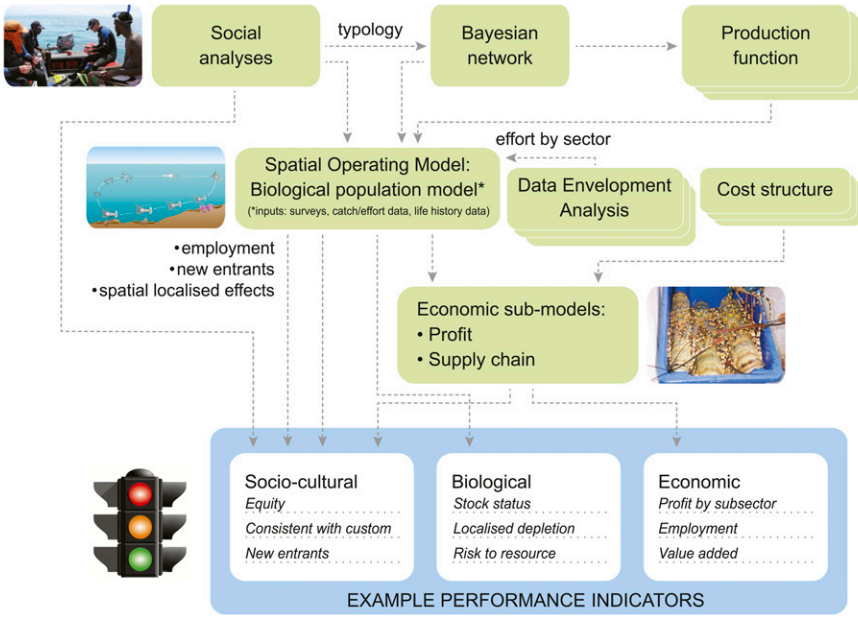

Fig. 2. Overview of the holistic MSE framework. The spatial operating model is conditioned using all available data (biological, social, and economic) and describes the lobster and fishery dynamics in each of 16 linked areas. Social and economic model components are used to parameterize alternative management strategies and future projections (for example, changes in the effort per sector). The impact of alternative management strategies is evaluated using triple-bottom line sustainability objectives, namely impacts on social and cultural outcomes, economic profitability, and resource status (via a traffic-light display where for a particular performance indicator red implies "worse off," amber means "same state," and green means "better off").

development of social capital (such as having key fishers and leaders in the island community) and building capacity (such as improving business knowledge).

There is an existing and still developing literature in which the social consequences of fisheries policies and management systems are evaluated (e.g., ref. 20). Social objectives are rarely explicitly included in natural resource management because of their largely qualitative nature, but it is increasingly recognized worldwide that businesses require a social license to operate. Society needs more holistic science approaches to support complex decision making not only in fisheries but also in conservation and multiple use contexts globally (Fig. 5). The holistic MSE framework we developed enables management authorities to understand not only the biophysical reality of a resource (21–24) but to also understand behavioral drivers and sociocultural outcomes in the human domain, and to thus meet triple-bottom line objectives for resource allocation and management, in the context of the overlying institutional setting (Fig. 5).

Although successful, our approach is highly data-intensive and requires sophisticated modeling capability such that high-end applications (such as our development of a single analytical framework) are unlikely to be broadly accessible, particularly for small-scale fisheries globally. At the same time, considerable effort is already devoted to biological and economic analyses for many natural resources, and our approach reinforces the principle of a more balanced approach capable of rigorously incorporating social considerations in the decision-making process. This approach provides a solid science foundation (the base of the pyramid in Fig. 5) for natural resource decision making, which is important globally; for example, small-scale fisheries alone directly support the livelihoods of some 78 million people in developing countries (25) (Fig. 5).

Acknowledging the considerable challenges in assessing triple-bottom line objectives, it is instructive to reflect on whether there are key social indicators that need to be considered as a first step in moving toward a triple-bottom line approach. Our study underscores the case-specific nature of appropriate social indicators, in part also because of the different drivers and desires of the indigenous and commercial sectors, and hence the challenges in standardizing the choice of social indicators in an analogous manner to that used for biological and economic indicators. The most commonly adopted approach to date has been to use employment as a proxy for social performance. Nonetheless, two key social indicators emerged unprompted in our study, namely equity and a sense of self-determination, and we propose that these are key universally, rather than solely applicable to indigenous communities. Both of these indicators correlate strongly with the level of buy-in to a management approach, the lack of which is one of the fundamental causes of failure of management systems globally (e.g., ref. 26). Equity is a complex social objective that could be interpreted in isolation as maximizing participation in a fishery, but when used as part of a MSE approach that makes explicit the trade-offs between different objectives, it will likely encompass the notion of the relative viability and profitability of different allocation models, as well as broader considerations, such as the basis for preferentially awarding access rights to some individuals (see also ref. 27). The importance of a sense of self-determination or ownership in facilitating compliance and buy-in is widely recognized, as evident from the increasing move toward co-management and similar approaches that aim to involve a broad suite of stakeholders in the decision-making process (28, 29). Interestingly, both these indicators are not easily quantifiable, nor are they necessarily linked dynamically to other modeled system components, but this does not diminish their importance or the central role they should play in natural resource decision making.

Social conscience accounting increasingly demands that businesses demonstrate best environmental practice principles, and communities worldwide face challenges in balancing poverty alleviation and resource utilization. To make science relevant in an increasingly complex landscape, it is vital that scientists engage with stakeholders in a two-way feedback process (*SI Methods*). Stakeholder stewardship and good governance facilitate sustainability of a resource and an incorporation of the economic and sociocultural objectives of the people that depend on them within the overall political economy of natural resource management.

Fig. 3. Traffic-light summary of economic, sociocultural, and biological performance indicators for alternative management strategies. Results are shown separately for each fisheries sector: full time, active part time, and casual indigenous (TIB, or traditional inhabitant boat); commercial nonindigenous (TVH, or transferable vessel holder), and Papua New Guinea sectors. The output-control management strategies are compared with the base-case current input control strategy. The first three alternatives are Olympic (A1), Community (A2), and hybrid Olympic with ITQs for commercial fishers (A3) for the TIB sector under the current TIB allocation of 53%; followed by the same strategies with an increased allocation of 70% for TIB (A7–A9). The last column compares strategy A1 with the employment program Community Development Employment Projects (CDEP) and a no-CDEP scenario S1. See also Tables S3 and S4.

Management of natural resources is a critical issue worldwide and this article outlines the need for a more holistic science approach, integrating biology, economics, and social science to support sustainable management that has the buy-in of communities and stakeholders because it accounts for economic needs and sociocultural rights and values. The formal analytical framework we developed permits laying out of alternatives for a resource management situation involving very heterogeneous resource users, including indigenous groups. These trade-offs are used by decision makers to ensure decisions made are both transparent and based on a balanced view of biological, economic, and social performance (Fig. 5). More broadly, our approach provides an example of a method for extending the use of MSE in natural resource management, by integrating all available social, cultural, biological, and economic information and data in an objective and transparent manner.

Methods

We developed a MSE (10) framework (Figs. 1 and 2, and Table S2) that substantially expands on previous MSE approaches, both in terms of the structure of each component and the range of components that are linked: a spatial biological model encompassing multijurisdictional stocks, a bio-economic model and supply chain, a semiquantitative Bayesian Network (BN), and qualitative social information. Full details of the methods are provided in *SI Methods.* At its core is a spatial and age-structured bio-economic model of connected lobster subpopulations in each of 16 model spatial areas (Fig. S1). The biological model is based on the Torres Strait lobster statistical catch-at-

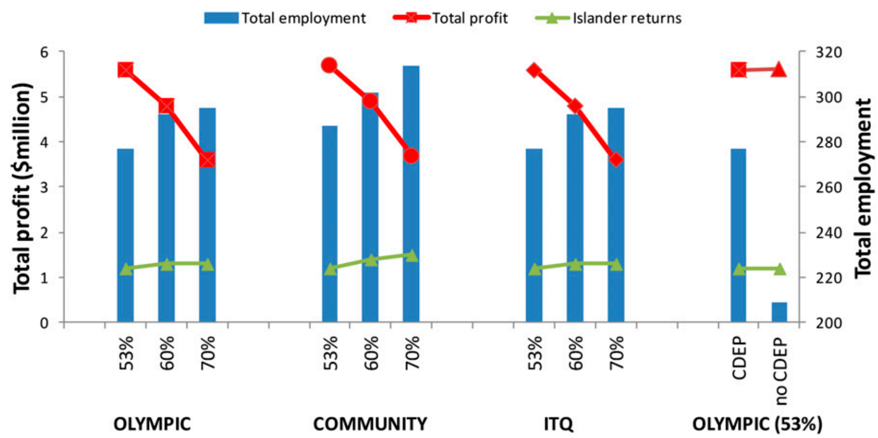

Fig. 4. Illustration of predicted trade-offs between economic (total profit and Islander owner-operator returns) indicators and a social (total employment) indicator as the indigenous share of the fishery increases from the current base of 53 to 60% or 70%, and when comparing the three alternative management systems (Olympic, Community, ITQ). The rightmost plots show the high sensitivity (under an Olympic system) of the social indicator to an external driver (CDEP).

age stock assessment model (8), but has been extended to be spatial (16 areas), includes the East Coast stock, has a monthly time step, models ages up until 3 y in the Torres Strait [when they migrate out the area (30)], but includes a 7-y plus group for East Coast lobsters. Recruitment is shared between spatial areas, with the base case assuming no shared recruitment with the Torres Strait stock consistent with the stock assessment approaches. Into this framework we added economic models describing production functions (to estimate economic performance), the supply chain (to estimate value added), and prediction of commercial fishing fleet changes.

Our method expands considerably on existing bio-economic model frameworks because in addition to defining and computing profit per sector/subfleet that include the basic elements of revenue streams and cost structures, we coupled in our framework a production function and frontier analysis (31), a data envelopment analysis (32) [to estimate which non-indigenous (transferable vessel holder) vessels might exit the fishery with lower quota levels], and included estimates of owner-operator returns to labor for the Islander traditional boat-holder license operators and evaluated the flow-on effects by including aspects of the supply chain (32). The integration of the supply chain with a bio-economic model to predict an additional performance indicator (value added) to the fleet profit is an important and unique step in development of methodology in this area of research, and also consideration of economic benefits beyond the direct benefits to the fishery (Fig. 3). [Value-added, as well as price-received by fishers, is affected by a range of factors beyond the control of fisheries managers (for example, exchange rates and transport costs). As with all models, these uncontrollable factors are assumed constant to assess the impact of management alternatives. Ongoing monitoring of these factors is important to ensure appropriate values are included in subsequent model use.]

One of the biggest challenges in attempting to simulate the outcomes of different management systems was the need to quantify how participation by each fisher subgroup would change. The Islander fleet was partitioned into three subfleets based on a typology of activity: a full time (commercial) subfleet, an active part-time (income supplementing) subfleet, and a casual (traditional or subsistence) subfleet. To estimate participation rate changes in the different components of the indigenous sector, which depends on social as well as economic drivers, a BN analysis was used to examine the effects of alternative licensing arrangements (as well as technical and economic factors)

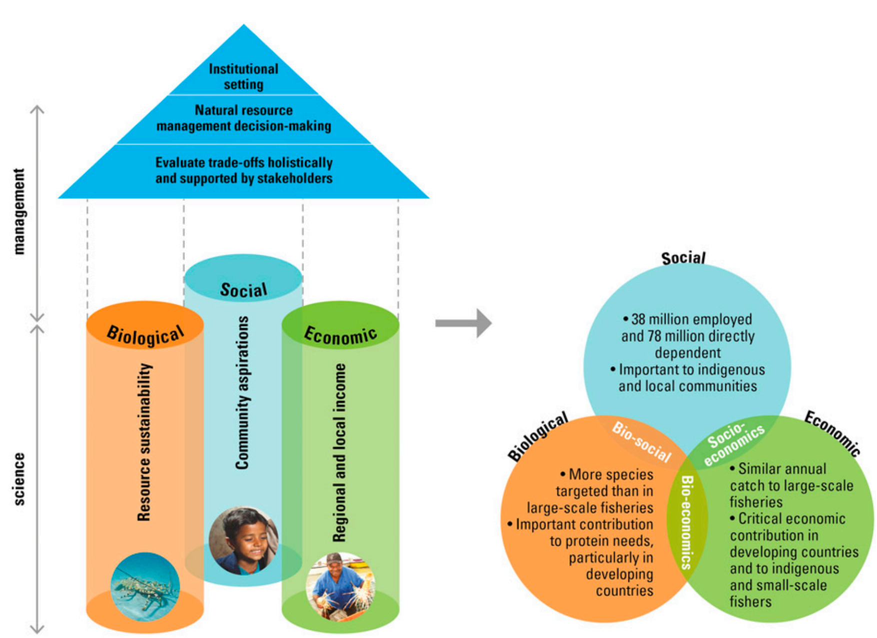

Fig. 5. Schematic of a general framework of a solid foundation for natural resource decision making. Social, biological, and economic variables are the three pillars needed to robustly support management decisions, in turn constrained by the institutional setting. *Right* highlights further why this is important using a specific example, namely small-scale fisheries (25).

and facilitate prediction of the changes in participation under alternative scenarios (14).

Through estimation of fisher participation in each of the three indigenous subfleets using the BN, a social model was also added to the framework, thus allowing for a dynamic feedback between social indices and the system dynamics. However, because the tropical rock lobster is a relatively short-lived recruit-driven species and the catch is capped each year, in this particular fishery there was no imperative to estimate long-term future participation beyond the timeframe of the biological cycle. However, long-term feedback could be modeled should this approach be implemented for a fishery with a longer-lived species.

Integrating the social dimension in our analysis was only possible because of the extensive stakeholder consultation. Using structured approaches we were able to convert, to the extent possible, social information into quantitative metrics that could serve as inputs to a quantitative bio-economic model using a BN approach. Moreover, we recognized the value of qualitative social information and incorporated this in our modeling framework by using a common currency (i.e., qualitative indicators that show whether the effect being tested is positive, negative, or neutral) to present our results and highlight biological, economic, and sociocultural trade-offs associated with different scenarios.

With respect to the social indicators, using the BN approach the increase or decrease in two dynamic continuous social indices, linked to the biological and economic model, could be measured (Fig. 3 and Table S4). We were also able to measure the positive or negative impact on two second-order discrete indices based on BN-calculated size and redistribution of fisher numbers between the three fisher subfleets. Furthermore, five nondynamic discrete indices were based directly on the indigenous fisher consultation process where the positive or negative social implications of the type of management system and relative indigenous allocation emerged.

We therefore used a traffic-light approach (33) to make explicit our findings (Fig. 3). The traffic-light scores in Fig. 3 are assigned based on comparison with the base-case input control strategy, but comparisons are also made between the relative performance of the alternative output-control strategies. Actual quantitative estimates (presented as the median and 90% confidence interval) or justification for qualitative scores are given in *SI Methods*. Our study is unique in fully integrating sociocultural, biological, and economic factors in an MSE applied to a marine fishery.

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