

Frontiers in Ecology and the Environment

A system-wide approach to supporting improvements in seafood production practices and outcomes

Fiorenza Micheli, Giulio De Leo, Geoff G Shester, Rebecca G Martone, Salvador E Lluch-Cota, Cheryl Butner, Larry B Crowder, Rod Fujita, Stefan Gelcich, Monica Jain, Sarah E Lester, Bonnie McCay, Robin Pelc, and Andrea Sáenz-Arroyo

Front Ecol Environ 2014; doi:10.1890/110257

This article is citable (as shown above) and is released from embargo once it is posted to the *Frontiers e-View* site (www.frontiersinecology.org).

Please note: This article was downloaded from *Frontiers e-View*, a service that publishes fully edited and formatted manuscripts before they appear in print in *Frontiers in Ecology and the Environment*. Readers are strongly advised to check the final print version in case any changes have been made.



A system-wide approach to supporting improvements in seafood production practices and outcomes

Fiorenza Micheli^{1*}, Giulio De Leo¹, Geoff G Shester², Rebecca G Martone^{3,4}, Salvador E Lluch-Cota⁵, Cheryl Butner¹, Larry B Crowder^{1,4}, Rod Fujita⁶, Stefan Gelcich⁷, Monica Jain⁸, Sarah E Lester⁹, Bonnie McCay¹⁰, Robin Pelc¹¹, and Andrea Sáenz-Arroyo¹²

Environmental certification and consumer awareness programs are designed to create market incentives for implementing fisheries and aquaculture practices that are more sustainable. Typically focused on particular species and activities, such programs have so far triggered few changes to improve seafood sustainability. Here, we present a conceptual, system-wide fisheries and aquaculture certification program designed to recognize and promote change toward more sustainable and resilient seafood production systems. In contrast to previous efforts, this program concentrates on both ecosystems and various human stakeholders, relies on an adaptive management approach (termed “continual improvement”) to enhance outcomes, and considers socioeconomic factors. The goal of this program is to support the restoration and maintenance of healthy ecosystem states and thriving human communities as well as the improvement of whole social–ecological systems.

Front Ecol Environ 2014; doi:10.1890/110257

In recent decades, there has been growing awareness of widespread and escalating overexploitation of natural resources, degradation of whole ecosystems, and loss of a multitude of associated ecosystem services (Vitousek *et al.* 1997; MA 2005; Halpern *et al.* 2008). Incentive-based solutions that take advantage of consumer demand, including environmental certifications and consumer awareness programs, differentiate products in the marketplace, rewarding producers for sustainable practices through increased prices and/or market access. These approaches hold great promise because they create incen-

tives for managing natural resources sustainably, thereby aligning economic and conservation objectives.

Examples of environmental certification programs include the Forest Stewardship Council’s certification of sustainable forestry products, as well as the Fairtrade certification system, which helps producers in developing countries achieve better trading conditions (WebPanel 1). For the marine environment, product certification is conducted by several organizations, primarily the Marine Stewardship Council (MSC) for wild capture fisheries and the Aquaculture Stewardship Council (ASC) for the aquaculture industry (Figure 1; Table 1; WebPanel 1). The MSC applies a suite of criteria to identify sustainable fisheries (Ward and Phillips 2008; Gutiérrez *et al.* 2012); as of 31 March 2013, the MSC has certified 198 fisheries worldwide, with an additional 100 fisheries currently being assessed (according to the MSC’s Annual Report 2012/13; www.msc.org). Likewise, the ASC certifies aquaculture operations based on global standards for responsible production practices, with more than 60 ASC-certified tilapia and *Pangasius* farms in nine countries (as of January 2014; www.asc-aqua.org). A number of large corporations (eg Walmart US, Whole Foods) have made commitments to source MSC- and ASC-certified products. Seafood recommendation lists produced by organizations such as the Monterey Bay Aquarium’s Seafood Watch program and WWF are another important, complementary approach used to distinguish sustainable seafood from less responsibly sourced products (Figure 1; Table 1).

Unfortunately, in marine environments, progress toward more sustainable practices triggered by certification programs and recommendation lists has been rare

In a nutshell:

- Unsustainable fishing and aquaculture practices are degrading marine ecosystems while simultaneously exacerbating human poverty and social conflict
- To improve both ecological and social outcomes, we argue that seafood production should be assessed and sustainability promoted for entire systems, including ecosystems and the people associated with them, and for all types of fisheries and aquaculture
- New seafood certification programs could support improvement in socially and ecologically responsible practices rather than setting a fixed bar of difficult-to-reach goals that primarily consider biological metrics
- Expected benefits include more sustainable and equitable use of human, economic, and natural resources, increased income stability for producers, and a more reliable seafood supply

¹Hopkins Marine Station, Stanford University, Pacific Grove, CA (*micheli@stanford.edu); ²Oceana, Monterey, CA; ³University of British Columbia, Institute for Resources, Environment and Sustainability, Vancouver, Canada; ⁴Center for Ocean Solutions, Stanford University, Monterey, CA (continued on last page)



Figure 1. Certification labels and recommendation lists signal ecologically sustainable seafood products to consumers.

and their effectiveness has been debated (Jacquet and Pauly 2007; Ward 2008; Jacquet *et al.* 2010; Froese and Proelss 2012; Martin *et al.* 2012), in part because existing certification programs do not comprehensively examine whole marine ecosystems and the human societies that depend on them. Fisheries or aquaculture operations can be certified despite degradation of marine ecosystems, loss of income among local people, and negative social impacts from the non-certified fisheries and aquaculture operations that overlap certified production systems. Furthermore, the high financial costs and data requirements associated with meeting certification and recommendation-listing standards often discourage or prevent small-scale seafood harvesters and producers from participating (Ward and Phillips 2008). For instance, while a substantial fraction of global fisheries catch and most fisheries jobs are generated in developing countries, developing-world fisheries account for only 8% of the total MSC-certified fisheries. Even in the developed world, smaller vessels are often unable to afford the high cost of certification assessment (Reed *et al.* 2013). For these seafood producers, alternative approaches are needed to incentivize sustainable practices.

We suggest that new recognition programs for sustainable fisheries and aquaculture should focus on restoring and maintaining healthy ecosystems and increasing the prosperity of human communities. Key features of such programs would include:

- (1) Using a system-wide unit of assessment rather than focusing on single activities, including the full seafood-production process and other activities in a specified area, and their costs and benefits to both ecosystems and marine users;
- (2) Overcoming common barriers to change by addressing not just ecological but also institutional, social, and economic objectives and constraints, and the suite of social–ecological outcomes associated with different management actions; and

- (3) Adopting a continual improvement model rather than a static bar of sustainability to spur broader participation by small-scale and developing country fisheries.

Such programs would consider all fisheries and aquaculture activities within a system or region as well as their possible interactions with – and cumulative impacts on – ecosystems or marine users; management actions that promote ecological, social, and economic resilience; and the capacity of human communities to implement these actions and to equitably share costs and benefits.

■ Promoting system-wide fisheries and aquaculture sustainability

Our premise is that management of social–ecological systems, including fisheries and aquaculture, should strive to achieve both ecological and socioeconomic sustainability goals (eg Young and McCay 1995; Costanza and Folke 1997). Ecosystem health and human health are closely connected and interdependent (Fleming *et al.* 2006). Therefore assessing and promoting sustainability requires a focus on both ecosystems and people, and active participation and commitment by the latter. Stringent regulations may result in healthier ecosystems, but regulations are difficult to enforce and are unlikely to lead to sustainable outcomes if they entail high social and economic costs and lack legitimacy (defined as governance in which decisions are based on objective expertise, with clear and stable rules; include public dialogue; and are derived from an open and transparent process of decision making; Cosens 2013). Heavy reliance on enforcement may be ineffective due to negligible participation by users, high poverty levels, and limited economic alternatives that encourage people to engage in illegal activities including resource overexploitation (eg Brashares *et al.* 2004). More inclusive management strategies that incorporate community participation and create incentives for compliance (eg by allowing users to benefit directly from conservation and management efforts) can be more effective. Global assessments provide evidence of the benefits of increased participation and appropriate incentives (Costello *et al.* 2008; Gutiérrez *et al.* 2011; Cinner *et al.* 2012; Grimm *et al.* 2012) and of changes in stakeholder perceptions of fisheries management (Gelcich *et al.* 2009). For example, a highly successful program in the Kwazulu-Natal region of South Africa partnered the traditional mussel harvesters of the Sokhulu community with provincial wildlife managers to be jointly responsible for not only research and monitoring activities but also development and enforcement of regulations. This program has greatly increased regulatory compliance and improved sustainability of the mussel harvest, while simultaneously building capacity and skills in the local community in an area where the previous system of top-down management had failed to sustain the resource (Harris *et al.* 2003).

Table 1. Comparison of the primary seafood certification and sustainability assessment programs

Program	Certification or recommendation list	Wild-caught or aquaculture	Stock status	Stock welfare	Seafood safety and quality	Ecosystem impacts	Energy considerations and pollution	Socioeconomic considerations	Management systems	Website
Aquaculture Certification Council	Certification	A	X	X	X	X	X	X	X	www.aquaculturecertification.org
Blue Ocean Institute	Recommendation list	W,A	X		X	X	X		X	www.blueocean.org/programs/sustainable-seafood-program/seafood-choices
Environmental Defense Fund	Recommendation list	W,A	X		X	X	X		X	www.edf.org/page.cfm?tagID=13201
FishWise	Recommendation list ⁱ	W,A	X		X	X	X		X	www.fishwise.org/science/assessment-methods
Food & Water Watch	Recommendation list	W,A	X		X	X	X	X	X	www.foodandwaterwatch.org/fish/seafood
Friend of the Sea	Certification	W,A	X			X	X	X	X	www.friendofthesea.org
Greenpeace	Recommendation list	W,A	X			X	X	X	X	www.greenpeace.org/international/en/campaigns/oceans/seafood/red-list-of-species
Marine Conservation Society	Recommendation list	W,A	X	X		X	X		X	www.fishonline.org
Marine Stewardship Council	Certification	W	X			X			X	www.msc.org/about-us/standards/standards
Monterey Bay Aquarium Seafood Watch Program	Recommendation list	W,A	X			X	X		X	www.seafoodwatch.org
New England Aquarium	Recommendation list	W,A	X			X	X		X	www.neaq.org/conservation_and_research/projects/fisheries_bycatch_aquaculture/sustainable_fisheries/corporate_partners/methods_and_criteria_for_evaluation.php
Sea Choice - Canada	Recommendation list	W,A	X		X	X	X		X	www.seachoice.org/seafood-recommendations/seachoice-methodology
Sustainable Fisheries Partnership (FishSource)	Assessment of fisheries status ⁱⁱ	W	X			X			X	www.fishsource.org/faqs
World Wildlife Fund (WWF)	Recommendation list	W,A	X	X		X	X	X	X	www.panda.org/what_we_do/how_we_work/conservation/marine/sustainable_fishing/sustainable_seafood/seafood_guides

Notes: For each program we report the type of seafood extraction or production activities (wild-caught fisheries [W], aquaculture [A], or both) and the criteria used in assessments. ⁱFishWise is a program for retailers wishing to market fish based on the sustainability of their farming or catch methods. ⁱⁱFishSource is a resource about the status of fish stocks and fisheries targeted toward major seafood buyers.

A system-wide sustainability program may be perceived by users and managers as too complex and expensive, impairing progress by letting “the perfect be the enemy of the good” and setting the bar for sustainability out of reach. However, the goal is to create mechanisms and standards that will lead to progress toward more resilient and sustainable systems. Although the emphasis is both on the current ecological and socioeconomic condition of systems and on the steady improvement toward sus-

tainability goals, many years may be required to achieve the anticipated positive outcomes. Reasons for this are twofold. First, it is unlikely that many systems have achieved sustainable management of all their seafood production activities. Thus, criteria based on fixed thresholds for performance indicators that are reasonable for single fisheries (selected for certification because they are well managed) would greatly limit the range of candidate systems when multiple activities are considered.

Second, applying fixed thresholds for performance indicators across all activities may bias selection against systems that currently have insufficient resources or information to implement sustainable management but have institutions and conditions that may enable improvements, such as well-defined access rights. Examples include fishing cooperatives that hold concessions for target species and TURFs – territorial use rights fisheries (Gelcich *et al.* 2010; McCay *et al.* 2013). Thus it is vital to recognize the potential for improvement to engage more fishery and aquaculture systems in the quest for sustainability.

An emphasis on improving the seafood production process does not imply that the social–ecological system's current status is irrelevant; without evidence of acceptable and possibly improving ecological and social conditions, development of better processes would clearly not achieve the ultimate goal of creating more sustainable seafood production for ecosystems and people. Consequently, a fishery in which resource management efforts have improved while the system continues to deteriorate – for instance due to overharvesting and/or habitat degradation – should not be awarded certification. It is therefore essential to provide objective criteria and measurable indicators of the status and performance of fisheries and aquaculture throughout the whole system.

■ Assessing system-wide performance of fisheries and aquaculture

Criteria and indicators

Criteria used by current programs (Table 1) incorporate guidelines developed by the UN Food and Agriculture Organization (FAO), both for capture fisheries (FAO 2005) and aquaculture (FAO 2008). All programs assess the status of the targeted stocks, ecosystem impacts (eg bycatch, habitat damage), and the existence of effective management regulating the target fishery or aquaculture (Table 1). Yet these programs do not consider the cumulative impacts of multiple activities occurring in an area; only a few assessments include socioeconomic indicators, while none evaluate institutions that might promote sustainability (Table 1).

To identify possible criteria and indicators for system-wide assessments, we compiled indicators from 13 sources, including major certification programs, regional seafood sustainability initiatives, and socioeconomic sustainability programs (eg OXFAM and Fairtrade; WebPanel 1). We propose a set of indicators assessing (1) ecosystem condition and the effects of fisheries and aquaculture on ecosystem structure and function; (2) social context and outcomes, including investment in social and human capital; and (3) governance capacity and management mechanisms for maintaining ecological and socioeconomic resilience (eg access rights and other institutional arrangements for stakeholder involvement and stewardship; Table 2). Representing a synthesis of

indicators already in use by existing programs, these indicators, for the first time, are combined into a single program that evaluates ecological, social, economic, and governance attributes, as well as overall system performance.

Ecological and social indicators assess the current performance of the system and highlight areas where improvement is most urgently needed (eg rebuilding overfished stocks, addressing bycatch issues, improving working conditions) to achieve specified objectives (eg eliminating overfishing, maintaining intact food webs, providing fair wages and safer working conditions). Likewise, governance indicators assess the capacity to devise and implement actions to address these issues. In particular, metrics of effective leadership (Gutiérrez *et al.* 2011) and the presence of viable institutions for local-level and system-wide management can be used to evaluate a system's potential for improvement. A key goal of a system-wide program should be to identify such features and expand their scope to include a wider range of target species and activities.

Pre-assessment

Even seafood production systems that are extremely data-poor or face tremendous conservation challenges can participate in such programs, provided that there is the capacity for improvement. As a first step, the scale and scope of the system should be defined and the “client” (the stakeholders engaged in seafood production) identified. The next step is to pre-assess the system, using expert knowledge, to identify major issues (eg the absence of institutions with sufficient authority to implement regulations and monitor change) and to evaluate the potential for improvement. If the pre-assessment indicates that there is local capacity for improvement, then conducting a system-wide assessment of the current conditions and performance would follow.

Performance indicators and goals

Assessments entail scoring the performance indicators' information available in the peer-reviewed and gray literature as well as through interviews with resource managers and relevant stakeholders. Some indicators refer to pre-conditions for improvement and thus set the minimum acceptable standards that system-wide assessments would guarantee to businesses, governments, and consumers (eg free labor; Table 2). Clearly, systems where forced or child labor exist will require major social and political changes before other issues can be addressed. In contrast, some of the socioeconomic and all of the ecological indicators signal current performance of the system and reveal aspects that require improvement to achieve desired outcomes (eg fair wages; occupational health and safety; functioning, resilient ecosystems; Table 2).

Analyses of the effectiveness of certification programs suggest that a three-tiered risk-based assessment approach (eg high, medium, or low risk) may be most effective for incentivizing change, and such an approach could also be designed to be more inclusive of systems that have serious

Table 2. Criteria and indicators for system-wide assessments

Governance	Socioeconomic	Ecological
1. Leadership - Existence of a decision-making and management body	11. Equity - No discriminatory practices	21. Water quality - Water-quality parameters are within acceptable bounds
2. Legislation - Existence of effective legal and/or customary framework	12. Free labor - No forced labor	22. Native biodiversity - Strategies in place to minimize impacts of fisheries/farms on natural diversity
3. Enforcement of regulation - Existence/effectiveness of a regulation and sanction system	13. Compliance with child labor laws - No child labor	23. Habitat integrity - Strategies in place to minimize impacts of fisheries/farms on habitat structure and function
4. Governance structure and function - Governance has a nested structure, partial autonomy of different levels of authority	14. Socioeconomic development - High investment in community infrastructure and human capital	24. Food-web integrity - Strategies in place to minimize impacts of fisheries/farms on food-web structure and dynamics
5. Incentives - Existence/effectiveness of incentives for following the rules and promoting sustainable use	15. Education - High investment in younger generation, eg presence of adequate schooling	25. Resilience - Resilience is maintained by conserving key species, functional groups, and functional redundancy
6. Management plan - Long-term management plans in place	16. Fair wages and benefits - Meet or exceed minimum wage and benefit requirements	26. Stock abundance - Target stocks are at a level that maintains high productivity and has a low probability of recruitment overfishing
7. Harvest control - Well-defined and effective harvest control rules are in place	17. Occupational health and safety - Written risk assessment, policies, and procedures for safe and healthy working conditions	27. Interaction with endangered species - Fishery does not pose a risk of serious or irreversible harm to endangered, threatened, or protected species and does not hinder their recovery
8. User involvement mechanisms - High level of stakeholder involvement, information dissemination to the community, mechanisms in place for conflict resolution	18. Fair conditions of employment - Employers are up to date on labor regulations and comply with legal regulations and collective bargaining agreements	28. Connectivity - Connectivity maintained by avoiding extreme habitat and population reduction and fragmentation
9. Defined boundaries and access rights - Long-term tenure, use rights, and boundaries are clearly defined, documented, and legally established	19. Traceability - Products traceable from harvest to sale	29. Bycatch - Fishery does not pose a risk of serious or irreversible harm to bycatch species and does not hinder the recovery of depleted bycatch species
10. Presence of MPAs - Representative samples of existing ecosystems are protected	20. Diversification - Diversification of fisheries and non-extractive activities (communities do not engage in and depend on a single activity)	30. Chemicals/drugs/pesticides - Acceptable drug and chemical management, microbial sanitation, minimized and safe use of agrochemicals

Notes: Criteria were identified based on review and synthesis of 13 sources, including major certification programs, regional seafood sustainability initiatives, socioeconomic sustainability programs and frameworks, and Australia's Ecological Risk Assessment for the Effects of Fishing (see WebPanel 1).

conservation concerns yet have the capacity for improvement (Bush *et al.* 2012; Tlustý 2012). Risk-based frameworks that rely on literature reviews and expert judgment to identify ecosystem vulnerability to stressors (Productivity–Susceptibility Analysis; Hobday *et al.* 2007, 2011), human impacts on marine habitats (Halpern *et al.* 2007), and other data-poor fishery assessment tools (Honey *et al.* 2010) have been developed and applied to evaluate fisheries.

While thresholds for the performance indicators (Table 2) could be set to indicate minimal, moderate, and high levels of performance, regular audits could also provide information on how performance is changing over time. This information would allow wholesalers, retailers, and consumers to choose products from the assessed system, depending on the current level of sustainability, the trajectory of improvement, or both. Some businesses, for instance, may prefer to limit risk by sourcing products only from systems that currently meet a moderate or high level of sustainability, whereas others may prefer to support systems that are improving rapidly.

■ Promoting progress toward sustainability goals: the cycle of continual improvement

We envision the proposed process – once initiated – as a series of successive, iterative steps, similar to those of the two most widespread certified environmental management schemes (EMS): the European Union's Eco-Management and Audit Scheme (EU EMAS) and ISO 14001 (WebPanel 2). Our proposed cycle of continual improvement (Figure 2) is modeled on the Deming cycle, which consists of a logical sequence of repetitive steps. Applied to seafood production, this means that organizations managing production would continually assess conditions and issues, develop management *plans*, implement *actions* established through those plans, *evaluate* outcomes, and update and possibly *redirect* plans founded upon learning during the initial phase (Figure 2).

Much like the EU EMAS and ISO 14001 schemes, the cycle is designed to target both the seafood production process and outcomes (eg the ecosystem state, social conditions, aspects of governance). Analyzing and improving

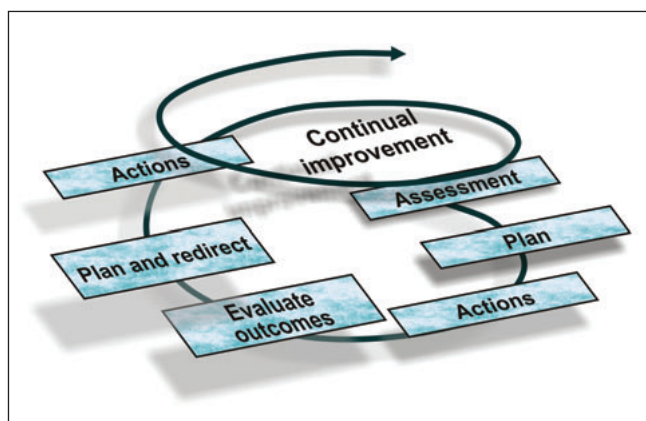


Figure 2. The cycle of continual improvement starts with an initial system-wide assessment that provides information for the development of management plans, followed in subsequent steps by the implementation of actions, the evaluation of outcomes, and the updating and, if necessary, redirecting of plans as additional information becomes available.

the seafood production process is critical to achieving sustainability outcomes, but focusing on process alone does not guarantee successful outcomes. While improvements in the process are attempted through the steps listed above, progress toward desirable outcomes – ultimately, achieving healthier ecosystems and human communities – is assessed, over a specified timeline, from changes in the ecological, socioeconomic, and governance performance indicators (Table 2).

■ Promoting system-wide sustainability in practice: a case study

Here, we illustrate why a system-wide approach is needed and how it might be implemented, using an example from the Pacific coast of Mexico. The California spiny lobster (*Panulirus interruptus*) fishery of the Vizcaino region of Baja California (Figure 3) was the first small-scale fishery to be certified by the MSC (Pérez-Ramírez *et al.* 2012). Fishers are organized in cooperatives that hold 20-year concessions granting exclusive exploitation rights for lobster, abalone (*Haliotis* spp), and other target marine invertebrates (McCay *et al.* 2013). Lobster management includes strictly enforced size limits, seasonal closures, and controlling fishing effort, as well as continued surveillance to minimize illegal fishing (Phillips *et al.* 2008).

Total lobster catches were stable from the 1970s through the 1990s, and have increased in the past decade. MSC and other independent assessments did not find serious ecological impacts of these fisheries on non-target species and habitats (SCS 2004; Shester and Micheli 2011). Thus, the Mexican lobster fishery is an ecological and economic success. However, finfish fishers in the same areas generally rely on gillnets that generate large amounts of bycatch and considerable impacts on habitat (Shester and Micheli 2011). Although pro-

viding a critical source of local income (Shester and Micheli 2011), these finfish fisheries lack a management plan and are at risk of resource overexploitation with consequent detrimental impacts on both the ecosystem and fishers' future livelihoods. In addition, a sustained decline in valuable abalone stocks, attributed to a combination of overfishing and climate-change impacts, poses a major threat to the economy of local communities. This example illustrates how current certification programs fail to identify issues affecting the broader ecosystem and its stakeholders, and neglect to create incentives for addressing these issues.

To achieve more sustainable seafood production, we recommend that long-term ecological targets should include demonstrated recovery of both abalone stocks and the broader ecosystem, socioeconomic targets should include improved employment opportunities within coastal communities, and governance targets should include expanding access privileges (ie cooperative exploitation rights to fish) to encompass the coastal ecosystem instead of a few species (Table 2). In our proposed program, outcomes would be periodically evaluated and actions may be redirected. Progress toward these targets would be assessed by local and regional organizations, as is currently being performed by the Vizcaino cooperatives in partnership with the Mexican non-governmental organization (NGO) Comunidad y Biodiversidad (<http://cobi.org.mx/en/programas/regions/baja-california-peninsula>).

Situations where certified or recommended fisheries overlap with fisheries that have high ecological impacts, inadequate management, or low performance because of external pressures (eg from pollution or climate change) are not unique to Vizcaino fisheries (eg the recently certified American lobster fishery of the US state of Maine [Steneck 1997; Steneck and Wilson 2010]; the Gulf of California sardine fishery [Sala *et al.* 2004; Sáenz-Arroyo *et al.* 2005]; and the northern shrimp fisheries of Atlantic Canada [Foley 2013]). In fact, the co-occurrence of multiple seafood production activities with variable impacts is likely the rule rather than the exception.

■ Challenges

System delineation and governance

In principle, system-wide assessments could be performed at local (eg a fishing community) to regional (eg a state) scales. As the geographic scope increases, however, so does the complexity of assessments and ensuing actions. Criteria for system delineation may include the geographic scope of the organization or producer responsible for managing seafood production. For instance, access privileges to particular marine regions or resources would be one reasonable criterion for delimiting the system, as in the case of the aforementioned Vizcaino example, the Management



Figure 3. (a) Lobster and (b) finfish fishing in the Vizcaino region of Baja California, Mexico.

and Exploitation Areas of Chile, and the coastal shellfish of Uruguay (Castilla and Defeo 2001; Castilla and Gelcich 2008; Gelcich *et al.* 2010). Where institutions are not sufficiently comprehensive and organized, lack jurisdiction over resources and ecosystems, or possess jurisdiction that is too localized or limited to specific resources, actions first must be directed toward building such capacity and tenure (eg Basurto 2005, 2008). Access privileges that extend to entire ecosystems are required to create stewardship incentives that extend to all the fisheries and aquaculture activities in a given area (Fujita *et al.* 2013). In some cases, it might be possible to form ad-hoc institutions (eg cooperatives or coalitions among governmental agencies, resource users, and other interested parties). Formalization and legal recognition of such institutions is important for durability of the program and effective stewardship.

Threats such as climate change and pollution may originate from beyond the boundaries of the focal system and if appraised as important, their potential effects and associated remediation must be taken into consideration. For example, local programs or organizations may take steps to address regional climatic impacts by reducing cumulative impacts from locally occurring stressors through the establishment of marine protected areas or by diversifying their activities (eg Micheli *et al.* 2012). It will be difficult, however, to apply system-wide assessments to pelagic fisheries because the ecosystem boundaries and associated human community may be too challenging to demarcate (Costa *et al.* 2012). Thus, system-wide assessments must at present be restricted to coastal fisheries and aquaculture with identifiable boundaries.

Costs

In existing seafood certification programs, the seafood producers absorb all or most of the costs. Nevertheless, innovative financing mechanisms and “hybrid” financing models that include contributions from foundations, governments, banks, and private investors are needed to ensure the long-

term sustainability and financial viability of improvement projects (Jain and Garderet 2011). Such financial strategies are necessary to encourage the broader participation of small-scale and developing-world seafood producers who could otherwise not afford the cost of participation. Another possible financing mechanism is to establish direct payments or performance payments to offset the costs incurred by local communities to conserve and restore their environment (Ferraro and Kiss 2002; Fujita *et al.* 2013). Contracts established with governments or NGOs compensate users of marine resources for the costs of their conservation efforts. Additionally, some organizations (eg Sustainable Fisheries Partnership, WWF) have successfully engaged seafood retailers in supporting improvement projects for individual fisheries in a fashion similar to retailers’ investment in the sustainability of their supply chain in terrestrial environments (eg Carrefour, the world’s second largest retailer in terms of revenue, after Walmart). Given the right market conditions, exclusive contracts could possibly be established between seafood retailers or other actors and seafood producers to absorb the costs of system-wide programs. For instance, Fish2.0 (www.fish20.org) is a recently launched business competition that aims to help promote companies that are operating profitably and creating positive social or environmental impacts. Their approach is to create connections between fishing and aquaculture businesses and investors interested in adding sustainable seafood businesses to their investment portfolios. Private foundations, NGOs, academic institutions, and government agencies would likely continue to be major contributors of financial and technical support, especially in the early stages of business development.

■ Anticipated benefits of system-wide sustainability programs

A major goal of our proposed program is to increase the resilience of ecosystems and human systems in the face of environmental, political, and economic shocks, thus reduc-

ing the risk associated with a variable and unstable seafood supply. Producers and businesses could benefit through increased stability of income, more reliable seafood resources (and in some cases higher-quality products and lower production costs), and a more sustainable use and allocation of human, economic, and natural resources.

Also, by influencing commercial transactions between seafood producers and retailers, system-wide programs could inform and guide the purchasing strategies of retailers committed to “greening” their businesses and provide incentives for businesses to purchase their seafood products from regions that (1) meet the minimum standards set through system-wide assessments and (2) have committed to specific actions aimed at improving their ecological and socioeconomic performance.

Furthermore, system-wide programs could result in benefits and incentives granted by regional governments through extended licensing periods, tax cuts, or other financial incentives (eg health care support, retirement programs). There is some evidence to suggest that certification attracts additional government investment (eg Pérez-Ramírez *et al.* 2012).

Finally, system-wide programs could direct investments of NGOs and philanthropic organizations toward regions or communities in need. Thus, benefits to producers could also come from increased visibility and support for improvement projects by NGOs and foundations.

■ Conclusions

Multiple tools for promoting a more sustainable future for marine ecosystems and the human societies that depend on them are urgently needed. Contemporary programs and approaches have met with some success, but the dire state of coastal marine ecosystems, world fisheries, and fishing-dependent communities demands novel approaches. Our proposed system-wide program would provide new mechanisms for promoting sustainable seafood production. By building on existing methodologies and standards, system-wide programs fill a current gap in the sustainable seafood movement by fostering recognition and support for a broader suite of small-scale and developing-world seafood production systems. These programs will provide a means for small-scale and developing-world fisheries and aquaculture to engage in improvement projects, access new markets, and create new cross-sectoral partnerships with commercial, governmental, environmental, and philanthropic organizations.

■ Acknowledgements

This work was supported by the Conservation and Science program of the David and Lucile Packard Foundation and the Biocomplexity in the Environment program of the US National Science Foundation. J Sherrill provided invaluable assistance with various aspects of this project, and L Botsford, C Chaffee,

A Cross, W Gilly, C Harvey, B Ack, J Humphreys, N Gutiérrez, M Sutton, H Johnson, and R Naylor provided useful comments and insights.

■ References

- Basurto X. 2005. How locally designed access and use controls can prevent the tragedy of the commons in a Mexican small-scale fishing community. *Soc Natur Resour* **18**: 643–59.
- Basurto X. 2008. Biological and ecological mechanisms supporting marine self-governance: the Seri callo de hacha fishery in Mexico. *Ecol Soc* **13**: 20.
- Brashares JS, Arcese P, Sam MK, *et al.* 2004. Bushmeat hunting, wildlife declines, and fish supply in West Africa. *Science* **306**: 1180–83.
- Bush SR, Toonen H, Oosterveer P, *et al.* 2012. The “devils” triangle of MSC certification: balancing credibility, accessibility and continuous improvement. *Mar Policy* **37**: 288–93.
- Castilla JC and Defeo O. 2001. Latin American benthic shellfisheries: emphasis on co-management and experimental practices. *Rev Fish Biol Fisher* **11**: 1–30.
- Castilla JC and Gelcich S. 2008. Management of the loco (*Concholepas concholepas*) as a driver for self-governance of small scale benthic fisheries in Chile. In: Townsend RSR and Uchida H (Eds). Case studies in fisheries self-governance. Rome, Italy: FAO.
- Cinner JE, McClanahan TR, MacNeil MA, *et al.* 2012. Co-management of coral reef social–ecological systems. *P Natl Acad Sci USA* **109**: 5219–22.
- Cosens BA. 2013. Legitimacy, adaptation, and resilience in ecosystem management. *Ecol Soc* **18**: 3.
- Costa DP, Breed GA, and Robinson PW. 2012. New insights into pelagic migrations: implications for ecology and conservation. *Annu Rev Ecol Evol S* **43**: 73–96.
- Costanza R and Folke C. 1997. Valuing ecosystem services with efficiency, fairness and sustainability as goals. In: Daily G (Ed). Nature’s services: societal dependence on natural ecosystems. Washington, DC: Island Press.
- Costello C, Gaines SD, and Lynham J. 2008. Can catch shares prevent fisheries collapse? *Science* **321**: 1678–81.
- FAO (UN Food and Agriculture Organization). 2005. Guidelines for the ecolabelling of fish and fishery products from marine capture fisheries. <http://www.fao.org/docrep/012/i1119t/i1119t00.htm>. Viewed 9 Mar 2014.
- FAO (UN Food and Agriculture Organization). 2008. Technical guidelines on aquaculture certification. ftp://ftp.fao.org/FI/DOCUMENT/aquaculture/TGAC/draft_tech_guid/certification_guidelines_e.pdf. Viewed 10 Feb 2014.
- Ferraro PJ and Kiss A. 2002. Direct payments to conserve biodiversity. *Science* **298**: 1718–19.
- Fleming LE, Broad K, Clement A, *et al.* 2006. Oceans and human health: emerging public health risks in the marine environment. *Mar Pollut Bull* **53**: 545–60.
- Foley P. 2013. National government responses to Marine Stewardship Council (MSC) certification: insights from Atlantic Canada. *New Polit Econ* **18**: 284–307.
- Froese R and Proelss A. 2012. Evaluation and legal assessment of certified seafood. *Mar Policy* **36**: 1284–89.
- Fujita R, Markham AC, Lynham J, *et al.* 2013. Ecomarkets for conservation and sustainable development in the coastal zone. *Biol Rev* **88**: 273–86.
- Gelcich S, Godoy N, and Castilla JC. 2009. Artisanal fishers’ perceptions regarding coastal co-management policies in Chile and their potentials to scale-up marine biodiversity conservation. *Ocean Coast Manage* **52**: 424–32.
- Gelcich S, Hughes TP, Olsson P, *et al.* 2010. Navigating transformations in governance of Chilean marine coastal resources. *P Natl Acad Sci USA* **107**: 16794–99.
- Grimm D, Barkhorn I, Festa D, *et al.* 2012. Assessing catch shares’

- effects: evidence from federal United States and associated British Columbian fisheries. *Mar Policy* **36**: 644–57.
- Gutiérrez NL, Hilborn R, and Defeo O. 2011. Leadership, social capital and incentives promote successful fisheries. *Nature* **470**: 386–89.
- Gutiérrez NL, Valencia SR, Branch TA, *et al.* 2012. Eco-label conveys reliable information on fish stock health to seafood consumers. *PLoS ONE* **7**: e43765.
- Halpern BS, Selkoe KA, Micheli F, *et al.* 2007. Evaluating and ranking the vulnerability of marine ecosystems to anthropogenic threats. *Conserv Biol* **21**: 1301–15.
- Halpern BS, Walbridge S, Selkoe KA, *et al.* 2008. A global map of human impact on marine ecosystems. *Science* **319**: 948–52.
- Harris J, Branch G, Sibiya C, *et al.* 2003. The Sokhulu subsistence mussel-harvesting project: co-management in action. In: Hauck M and Sowman M (Eds). *Waves of change*. Cape Town, South Africa: University of Cape Town Press.
- Hobday AJ, Smith A, Webb H, *et al.* 2007. Ecological risk assessment for the effects of fishing: methodology. Canberra, Australia: Australian Fisheries Management Authority. Report R04/1072.
- Hobday AJ, Smith ADM, Stobutzki IC, *et al.* 2011. Ecological risk assessment for the effects of fishing. *Fish Res* **108**: 372–84.
- Honey KT, Moxley JH, and Fujita RM. 2010. From rags to fishes: data-poor methods for fishery managers. *Managing Data-Poor Fisheries: Case Studies, Models & Solutions* **1**: 159–84. California Sea Grant College Program.
- Jacquet JL and Pauly D. 2007. The rise of seafood awareness campaigns in an era of collapsing fisheries. *Mar Policy* **31**: 308–13.
- Jacquet JL, Pauly D, Ainley D, *et al.* 2010. Seafood stewardship in crisis. *Nature* **467**: 28–29.
- Jain M and Garderet R. 2011. *Financing fisheries change: learning from case studies*. Carmel, CA: Manta Consulting.
- MA (Millennium Ecosystem Assessment). 2005. *Ecosystems and human well-being: health synthesis*. Geneva, Switzerland: World Health Organization.
- Martin S, Cambridge T, Grieve C, *et al.* 2012. Evaluation of environmental changes within fisheries involved in the Marine Stewardship Council certification scheme. *Rev Fish Sci* **20**: 61–69.
- McCay BJ, Micheli F, Ponce-Díaz G, *et al.* 2013. Cooperatives, concessions, and co-management on the Pacific Coast of Mexico. *Mar Policy* **44**: 49–59.
- Micheli F, Saenz A, Greenley A, *et al.* 2012. Evidence that marine reserves enhance resilience to climatic impacts. *PLoS ONE* **7**: e40832.
- Pérez-Ramírez M, Ponce-Díaz G, and Lluch-Cota S. 2012. The role of MSC certification in the empowerment of fishing cooperatives in Mexico: the case of red rock lobster co-managed fishery. *Ocean Coast Manage* **63**: 24–29.
- Phillips B, Bourillón L, and Ramade M. 2008. Case study 2: the Baja California, Mexico, lobster fishery. In: Ward T and Phillips B (Eds). *Seafood ecolabelling: principles and practice*. Oxford, UK: Blackwell Publishing.
- Reed M, Courtney P, Urquhart J, *et al.* 2013. Beyond fish as commodities: understanding the socio-cultural role of inshore fisheries in England. *Mar Policy* **37**: 62–68.
- SCS (Scientific Certification Systems). 2004. *An MSC assessment of the red rock lobster fishery Baja California, Mexico*. Emeryville, CA: SCS.
- Sáenz-Arroyo A, Roberts CM, Torre J, *et al.* 2005. Rapidly shifting environmental baselines among fishers of the Gulf of California. *P Roy Soc B-Biol Sci* **272**: 1957–62.
- Sala E, Aburto-Oropeza O, Paredes G, *et al.* 2004. Fishing down coastal food webs in the Gulf of California. *Fisheries* **29**: 19–25.
- Shester G and Micheli F. 2011. Conservation challenges for small-scale fisheries: bycatch and habitat impacts of traps and gill-nets. *Biol Conserv* **144**: 1673–81.
- Steneck RS. 1997. Fisheries-induced biological changes to the structure and function of the Gulf of Maine ecosystem. In: Wallace GT and Braasch EF (Eds). *Proceedings of the Gulf of Maine Ecosystem Dynamics Scientific Symposium Workshop*. Hanover, NH: Regional Association for Research on the Gulf of Maine. RARGOM Report 97-1.
- Steneck RS and Wilson JA. 2010. A fisheries play in an ecosystem theater: challenges of managing ecological and social drivers of marine fisheries at nested spatial scales. *B Mar Sci* **86**: 387–411.
- Thusty MF. 2012. Environmental improvement of seafood through certification and ecolabelling: theory and analysis. *Fish Fisher* **13**: 1–13.
- Vitousek PM, Mooney HA, Lubchenco J, *et al.* 1997. Human domination of Earth's ecosystems. *Science* **277**: 494–99.
- Ward T. 2008. Barriers to biodiversity conservation in marine fishery certification. *Fish Fisher* **9**: 169–77.
- Ward T and Phillips B (Eds). 2008. *Seafood ecolabelling: principles and practice*. Oxford, UK: Blackwell Publishing.
- Young MD and McCay BJ. 1995. Building equity, stewardship, and resilience into market-based property rights systems. In: Hanna S and Munasinghe M (Eds). *Property rights and the environment: social and ecological issues*. Washington, DC: The World Bank

⁵Centro de Investigaciones Biológicas del Noroeste, La Paz, México; ⁶Environmental Defense Fund, San Francisco, CA; ⁷Center for Applied Ecology and Sustainability, Departamento de Ecología, Pontificia Universidad Católica de Chile, Santiago, Chile; ⁸Manta Consulting Inc, Carmel, CA; ⁹Marine Science Institute and Bren School of Environmental Science & Management, University of California, Santa Barbara, Santa Barbara, CA; ¹⁰Rutgers University, Human Ecology Department, New Brunswick, NJ; ¹¹Monterey Bay Aquarium, Monterey, CA; ¹²Comunidad y Biodiversidad AC, Colonia Hipódromo Condesa, México DF, México

WebPanel 1. Additional information sources

We examined candidate criteria and indicators for system-wide assessments from the following sources:

- Anderson DL. 2010. Certification and labeling of capture fisheries products in California. Sacramento, CA: California Ocean Protection Council. www.opc.ca.gov/webmaster/ftp/project_pages/CSSI/Public%20Comment/OPC%20Seafood%20Certification%20report_DaveAnderson.pdf. Viewed 14 Mar 2014.
- ASC (Aquaculture Stewardship Council). 2011. Better management practices for *Pangasius* aquaculture. WWF. www.asc-aqua.org/upload/ASC%20Pangasius%20Better%20Management%20Practices_v1.01.pdf. Viewed 14 Mar 2014.
- COBI, Ecotrust, WWF. Delphos: decision-making tool for community-based marine conservation. Unpublished report.
- Fairtrade International. 2013. Fairtrade Trade Standards. Bonn, Germany: Fairtrade International. www.fairtrade.net/fileadmin/user_upload/content/2009/standards/documents/2013-12-13_TS_EN.pdf. Viewed 14 Mar 2014.
- Fisheries Association of Iceland. 2010. Responsible fisheries management specification: a tool for voluntary use in markets for products of marine capture fisheries. Reykjavik, Iceland: Fisheries Association of Iceland. www.responsiblefisheries.is/files/frettir/fai-rfs-draft-may31stfinal-for-public-comment.pdf. Viewed 14 Mar 2014.
- FSC (Forest Stewardship Council). 2012. Principles and criteria: international guidelines to forest management. <https://ic.fsc.org/principles-and-criteria.34.htm>. Viewed 14 Mar 2014.
- GAA (Global Aquaculture Alliance). 2009. Best aquaculture practices – aquaculture facility certification, shrimp farms. www.gaalliance.org/cmsAdmin/uploads/BAP-ShrimpF-909.pdf. Viewed 14 Mar 2014.
- GMRI (Gulf of Maine Research Institute). 2009. Branding standard for seafood from the Gulf of Maine region. Portland, ME: Gulf of Maine Research Institute. www.opc.ca.gov/webmaster/ftp/project_pages/CSSI/State%20Programs/Draft%20Gulf%20of%20Maine%20Branding%20Standard%20121709.pdf. Viewed 14 Mar 2014.
- Gutiérrez NL, Hilborn R, and Defeo O. 2011. Leadership, social capital and incentives promote successful fisheries. *Nature* **470**: 386–89.
- Hobday AJ, Smith A, Webb H, et al. 2007. Ecological risk assessment for the effects of fishing: methodology. Canberra, Australia: Australian Fisheries Management Authority. Report R04/1072.
- Iceland Responsible Fisheries. (no date). www.responsiblefisheries.is. Viewed 14 Mar 2014.
- Mayoux L and Williams P. 2001. Case study: Oxfam fair trade. Oxford, UK: Oxfam. www.sed.manchester.ac.uk/research/iarc/ediais/pdf/OXFAMFairTradeOct01.pdf. Viewed 14 Mar 2014.
- Monning B. 2009. Assembly Bill 1217. Ocean Protection Council: sustainable seafood. www.opc.ca.gov/2010/03/california-sustainable-seafood-initiative/. Viewed 14 Mar 2014.
- MSC (Marine Stewardship Council). 2010. Fisheries assessment methodology and guidance to certification bodies. London, UK: Marine Stewardship Council. http://opc.ca.gov/webmaster/ftp/project_pages/CSSI/MSC_Fisheries_Assessment_Methodology_v2%201.pdf. Viewed 14 Mar 2014.
- Pomeroy RS, Parks JE, and Watson LM. 2004. How is your MPA doing? A guidebook of natural and social indicators for evaluating marine protected area management effectiveness. Gland, Switzerland, and Cambridge, UK: IUCN. <https://portals.iucn.org/library/efiles/edocs/PAPS-012.pdf>. Viewed 14 Mar 2014.

WebPanel 2. ISO 14001 and EU EMAS

ISO 14001 (established in 1996 and revised in 2004) and the European Union's EMAS (EU EMAS; established by European Regulation 1836/93 and then revised in 2001 and 2009) are voluntary initiatives designed to improve the environmental performance of corporations through the implementation of a certified Environmental Management Scheme (EMS). ISO 14001 and EU EMAS provide further tools for an organization to use in addition to ecolabelling of specific goods and services to improve its environmental performance. With more than 200 000 organizations in 159 countries certified as ISO 14001 and almost 8000 sites registered as EU EMAS in the 27 EU Member States, these are the two most widespread EMS certification programs. Their aim is to recognize and reward those organizations that go beyond minimum legal compliance and continuously improve their environmental performance. The focus of these programs is the overall production process of the organization and not the environmental performance of one of the many possible goods and services they produce or provide. EU EMAS further requires that participating organizations regularly issue a publicly available environmental statement that reports on their environmental performance. It is this voluntary publication of environmental performance assessments, where accuracy and reliability are independently checked by an environmental verifier, that gives EU EMAS and its participant organizations enhanced credibility and recognition.

Certified EMSs do not specify standards or minimal legal requirements in terms of consumption of resources, waste production, or emission of pollutants, because quantitative targets beyond minimum legal compliance need to be defined and updated regularly by the organization (usually annually) based on a thorough and detailed assessment of the potential impacts of its activities and an objective means of ranking priorities.

ISO 14001 and EU EMAS are conceptually based on the Deming cycle, a continuous quality and learning improvement model consisting of a logical sequence of four repetitive steps:

- (1) Plan: recognize an opportunity, develop a strategic plan to implement changes, set priorities and measurable goals, analyze and predict the results.
- (2) Do: take small steps, possibly under controlled conditions, and implement and execute the plan (ie structure and assign responsibility, develop a code of conduct and precise instructions to support the EMS, implement monitoring programs and reporting schemes, maintain documentation, communicate with internal and external stakeholders, and prepare for emergency situations).
- (3) Check: assess achievements, identify positive outcomes, identify reasons why established goals were not reached, and learn from experience.
- (4) Act: take actions to standardize and improve the process based on what has been learned. If the change did not work, repeat the cycle using a different plan and implement corrective actions; if successful, incorporate what was learned from the test into wider changes. Use what was learned to plan new improvements, update goals or set new ones, and begin the cycle again.

Both ISO 14001 and EU EMAS classify organizations' activities, products, and services that can interact with the environment as direct environmental aspects (DEA) and indirect environmental aspects (IEA). DEA refers to activities over which an organization has an influence and direct control (eg the choice of fishing tools and mesh size, effort regulation, etc). IEA comprises actual or potential activities over which the organization can be expected to have some influence but no direct control (eg supply chains, fishing tools and other fishing materials, waste management, cleaning, fishing boat maintenance, seafood processing, or any other activity that is conducted by a third party). While organizations in their initial phase of implementation of an EMS might mainly target DEA, an organization with a mature EMS is expected (and somehow required under the two most popular EMS) to also account for the IEA, so that high impacting activities of the production process are not awarded to third-party companies. As a consequence, an organization should be held liable for all activities that it is directly responsible for or participates in, but it is also in the process of increasing responsibility and implementation of an EMS that becomes more sophisticated, precise, and articulated with time.

Another important aspect of EMSs such as ISO 14001 and EU EMAS is the emphasis placed on educating and training employees at all levels of the organization. As a consequence, all employees should take an active part in the implementation of the EMS, so as to acquire a good understanding of why it is important to improve the environmental performance of the organization and why the contribution of each member is crucial to achieving the goals established through the strategic plan. Training and education are key activities for ensuring that EMS implementation is not perceived as a top-down obligation, but as a unique opportunity for all members of an organization to commit to the achievement of environmental targets together.