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Three pillars of sustainability in fisheries

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Edited by Bonnie J. McCay, Stockton, NJ, and approved August 27, 2018 (received for review May 3, 2018)

Sustainability of global fisheries is a growing concern. The United Nations has identified three pillars of sustainability: economic development, social development, and environmental protection. The fisheries literature suggests that there are two key trade-offs among these pillars of sustainability. First, poor ecological health of a fishery reduces economic profits for fishers, and second, economic profitability of individual fishers undermines the social objectives of fishing communities. Although recent research has shown that management can reconcile ecological and economic objectives, there are lingering concerns about achieving positive social outcomes. We examined trade-offs among the three pillars of sustainability by analyzing the Fishery Performance Indicators, a unique dataset that scores 121 distinct fishery systems worldwide on 68 metrics categorized by social, economic, or ecological outcomes. For each of the 121 fishery systems, we averaged the outcome measures to create overall scores for economic, ecological, and social performance. We analyzed the scores and found that they were positively associated in the full sample. We divided the data into subsamples that correspond to fisheries management systems with three categories of access—open access, access rights, and harvest rights—and performed a similar analysis. Our results show that economic, social, and ecological objectives are at worst independent and are mutually reinforcing in both types of managed fisheries. The implication is that rights-based management systems should not be rejected on the basis of potentially negative social outcomes; instead, social considerations should be addressed in the design of these systems.

seafood | sustainability | social | economic | environmental

Fishing, as the world's last major hunting and gathering industry, supports livelihoods, food security, and human health (1–4). However, it is unclear whether, and if so, how fishing can achieve the aspirations of the United Nations that specify three pillars of sustainability: economic development, social development, and environmental protection (5). Several scholars have argued that the pursuit of economic objectives in fisheries, such as profit and trade, can lead to ecological decline and undermine social objectives, including employment, safe working conditions, and gender equality (2–4, 6). Such arguments have entered the policy dialog surrounding fishery management through two broad narratives. First, economic benefits require high harvest levels that undermine ecological sustainability. Second, only policies that limit access to a subset of fishers can reduce the effect of high harvest levels, but when implemented, they potentially compromise the achievement of wider social objectives.

Numerous studies in the fisheries literature support the first narrative by arguing that the pursuit of economic objectives is instrumental in overfishing and declines in marine ecosystems (7–13). There are three main lines of argument in support of this narrative. First, due to the commons problem, in which access is poorly (or not at all) regulated, individual fishers make privately beneficial decisions that lead to overexploitation of fish stocks that eventually reduce profit (7, 8). Sole ownership of the fishery resource, thought to be a solution to the commons problem (7, 14), does not necessarily prevent overfishing, and under some conditions, a sole owner would find it profitable to drive a fish stock to extinction (9). The implication is that fisheries require some form of management to set, implement, and enforce binding biological targets (15). Second, short-run profit motives in managed fisheries can create one-sided political pressure to set unsustainable harvest levels (10). New accountability measures and strengthened authority of scientific and statistical committees in the 2007 reauthorization of the US Magnuson Stevens Fishery Conservation and Management Act is one example of a response to this sort of pressure. Finally, especially in developing countries, the commoditization of fish and pursuit of economic development through industrialization and market expansion are the drivers of overexploitation and may be more important than the weak institutions associated with limited regulation of the commons problem (12, 13). Empirically,

Significance

The United Nations proclaims that sustainable development comprises environmental, economic, and social sustainability. Fisheries contribute to livelihoods, food security, and human health worldwide; however, as the planet's last major hunting and gathering industry, whether, and if so, how fishing can achieve all three pillars of sustainability is unclear. The relationships between environmental and economic sustainability, as well as between economic and social sustainability, continue to receive attention. We analyzed data from 121 fisheries worldwide to evaluate potential trade-offs. We found no evidence of trade-offs, and instead found that environmental, economic, and social objectives are complementary when fisheries are managed. Our results challenge the idea that the three pillars of sustainability are in conflict, suggesting that rights-based systems can be designed to support all three pillars.

Author contributions: F.A., T.M.G., J.L.A., C.M.A., and J.C. designed research; F.A., T.M.G., J.L.A., M.D.S., C.M.A., J.C., A.O., S.T., and S.V. performed research; F.A., T.M.G., J.L.A., S.R.B., M.D.S., and C.M.A. analyzed data; and F.A., T.M.G., J.L.A., S.R.B., M.D.S., C.M.A., J.C., K.A.G., A.L., K.L., A.O., S.T., and S.V. wrote the paper.

Conflict of interest statement: This work received funding from the Florida Agricultural Experiment Station. Several of the data points were obtained from funded projects, but the research did not involve analysis of the database itself.

This article is a PNAS Direct Submission.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1807677115/-/DCSupplemental.

Published online September 24, 2018.

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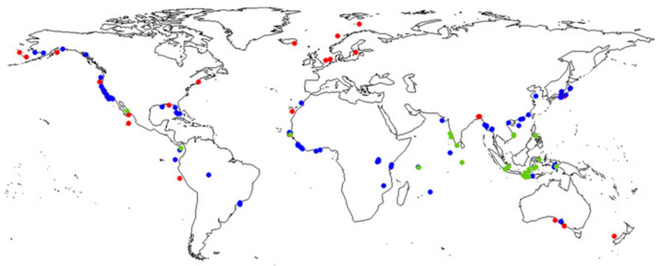

Fig. 1. Case study fisheries assessed with the FPIs (n = 121).

indicators of profitability (i.e., high price and low cost to exploit) are correlated with declines in fisheries (11). These findings could be consistent with any of the stories of conflict between profits and ecological outcomes in fisheries.

Maintaining or improving the biological health of fish stocks necessarily requires restricting fishers' behavior, which is expected to reduce profitability in the short run (15). The perceived conflict between economic and ecological objectives is then ambiguous; profits and fish stocks may be positively correlated in the long run but negatively correlated in the short run. Fishers may prioritize short-term economic gains over the long-term health of the fish stock if they are unable to capture the gains of responsible stewardship. When management allows fishers to capture these long-run gains, the cycle is broken, and the trade-off disappears. Indeed, there is increasing evidence that with effective management, ecological and economic objectives are not in conflict (16–18). Establishing harvest rights through catch shares, cooperatives, or territorial use rights for fisheries (TURFs) is one way to break the cycle (16, 18–22). A recent global modeling study even suggests that such management reforms create the potential for large long-run increases in both fish stocks and fishing profits (23).

The second narrative implies a conflict between economic and social objectives, although there are certainly examples in which this is not the case (2). Some argue that market integration, globalization of seafood markets, and the pursuit of neoliberal development objectives can threaten social and ecological outcomes in fisheries (24, 25). Particular attention has been given to the potential negative effects of limiting access to a small number of fishers—especially when managing with harvest rights designed to generate the maximum economic rent and reduce overcapacity in the fishery (26)—on the coherence and solidarity of fishing communities (27, 28). Indeed, much of the economics literature on fisheries focuses on rent maximization and not on distributional consequences, employment, or other social outcomes (23, 29–33). Critics argue that the focus on rent (or profit) maximization in developing countries could even have potentially disastrous consequences by limiting access to a source of livelihood during times of need (34), especially in very poor countries, where it may undermine macroeconomic growth (35).

Specific concerns about restricting access include reduced employment in the harvest sector, loss of identity, emigration from coastal communities, and promotion of economic inequality (34, 36–39). Exporting fish may also undermine local food security (3). Much of the literature echoes similar concerns about industrialization and commodification that are viewed as compromising the biological health of fisheries (12, 13). Despite growing attention to social issues (2–4, 40, 41), no published studies have systematically examined whether social objectives are in conflict with economic and ecological fisheries objectives. In the present study, we investigated these issues using a global dataset covering 121 fisheries from all continents and representing a wide variety of fishing technologies and management systems.

Results

Assessing the triple bottom line in fisheries systems at a global scale is challenging, because data are not available to compare these systems' social, economic, and ecological outcomes. In many parts of world, especially in developing countries, where dependence on fishery resources is often high, there are limited data on fish stocks and even greater limitations on economic and social data (2, 42). The data framework that we used to assess the triple bottom line, the set of Fishery Performance Indicators (FPIs), was designed to overcome these challenges and provide global coverage using a consistent set of metrics (Fig. 1 and *SI Appendix*, Tables S1, S2, and S4) (40). The FPIs include 68 outcome metrics grouped into 14 dimensions that can further be aggregated into the three indicators of environmental (Ecology), financial (Economics), and social (Community) performance (*SI Appendix*, Table S1). The FPIs also include 54 input metrics, partitioned into 11 dimensions (*SI Appendix*, Table S2). Although developed independently, the FPI Community outcome metrics incorporate key elements of a recent framework for social responsibility in the seafood sector (4) (*SI Appendix*, Table S3).

The first step in our analysis was to investigate the correlations among the three sustainability pillars using the entire dataset of scored case studies of fisheries from around the world (n = 121). All correlation coefficients were positive and statistically significant (Table 1), suggesting that the pillars of sustainability overall are complementary and not in conflict. This finding suggests that there are no trade-offs on average. As such, findings of trade-offs in the case study literature are likely due to specific institutional designs rather than to fundamental conflicts between economic profits and stock health, or between rights-based fisheries management and social objectives. Moreover, positive associations on average relationships suggest that the negative outcomes are avoidable. We used several methods to test the sensitivity of the results to influential data points and outliers, and found the results to be robust, as there were no differences in statistical inference and our conclusions remained unchanged.

Because the type of management can influence the performance of a fishery (16, 17, 20), and the type of management system often is the most contentious element in the discussions of economic and social impacts of a fishery (34, 36, 39), we continued analyzing the data by management system. The data

Table 1. Correlation results for the bottom line indicators of ecological, economic, and community performance by management system

	Coefficient (P value)		
Management system	Ecology	Economic	Community
All management systems			
Ecology	1.0	0.52 (<0.001)	0.23 (0.012)
Economic	—	1.0	0.50 (<0.001)
Community	—	—	1.0
Open access systems			
Ecology	1.0	0.20 (0.346)	0.09 (0.670)
Economic	—	1.0	0.23 (0.287)
Community	—	—	1.0
Access right systems			
Ecology	1.0	0.55 (<0.001)	0.25 (0.013)
Economic	—	1.0	0.53 (<0.001)
Community	—	—	1.0
Harvest right systems			
Ecology	1.0	0.67 (<0.001)	0.23 (0.260)
Economic	—	1.0	0.52 (0.007)
Community	—	—	1.0

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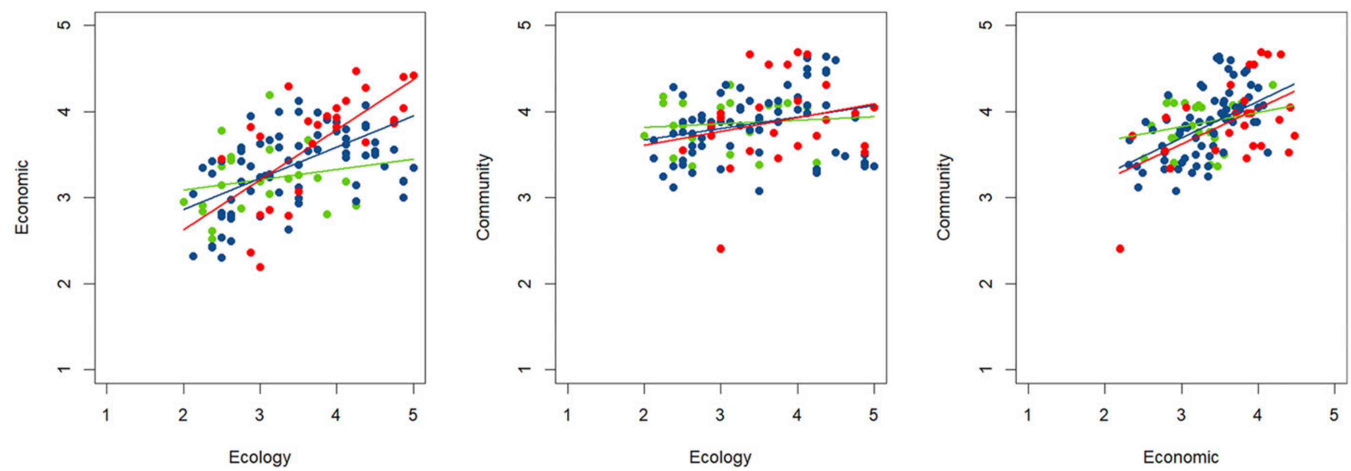

Fig. 2. Correlations of FPIs by management system: open access (n = 24) (green), access rights (n = 97, of which 71 are limited entry only) (blue), and harvest rights (catch shares; n = 26) (red). For open access fisheries, all correlation coefficients are statistically insignificant. For fisheries regulated with access rights, all correlation coefficients are statistically significant. For fisheries regulated with harvest rights, all correlation coefficients are statistically significant, with the exception of the relationship between ecology and community (Tables 1 and 2).

are divided into three categories of management systems: open access (i.e., fisheries with no or very limited management, in which access to the fishery is not regulated through a licensing or permitting process or restricted through technical measures, such as fishing days), regulated access rights (i.e., limited access to the fishery), and harvest rights (i.e., catch shares or territorial use rights). Ninety-seven of our 121 fishery cases (80%) have some form of regulatory restrictions or access rights. Of these, 26 fisheries with access rights also operate under a harvest rights system.

Ecological and economic outcomes are positively associated overall (Fig. 2 and Tables 1 and 2). When observations are grouped based on the strength of management, the associations are stronger with harvest rights, and there is no statistically significant relationship between ecological and economic indicators for open access fisheries (Fig. 2 and Tables 1 and 2). This indicates that economic and ecological objectives reinforce one another, but only with management that limits entry. The lack of association for open access fisheries is consistent with overfishing, the race to fish, and the tragedy of the commons (16, 20). In harvest rights-based fisheries, the tragedy of the commons is mitigated, and the economic benefits of healthy fish stocks can, at least to some extent, be reaped by the fishers. Underlying the economic incentives in rights-based fisheries are mechanisms for harvesters to capture the benefits of sustainability, with the assumption that fishers are induced to fish more sustainably because it is in their best economic interest, as well as in the community's best interest (43–45).

Ecological and community indicators are weakly positively associated in fisheries with access rights, but not in fisheries with open access or harvest rights (Fig. 2 and Tables 1 and 2). These relatively weak effects are not surprising given the many overfished stocks around the world spanning subsistence to industrial fisheries, and community outcomes are more likely to be dependent on national economic and social policies that extend beyond fisheries (1, 46). Nonetheless, the lack of negative correlation provides no significant evidence of a trade-off between ecological and social objectives.

Economic and community objectives are also positively associated, counter to the second policy narrative outlined above (Fig. 2 and Tables 1 and 2). As with ecology and economics, there are statistically significant positive relationships for fisheries with access rights and harvest rights, but not for open access or unmanaged fisheries. These correlations are consistent with specific findings showing that the introduction of harvest rights can enhance safety at sea (41) and does not necessarily reduce employment (47). While communities are able to extract greater economic benefits from fisheries that are regulated, and the benefits are greater when there are harvest rights, the benefits do not on average undermine noneconomic community objectives. Instead, profits can reinforce social objectives, including through expenditures in other sectors of the local economy. This alignment may reflect inclusive decision making in the management process that reinforces social goals and enhances local economic development (2, 43, 48).

To shed some light on the weaker effects of management on social sustainability, it is useful to look at the 14 output dimensions that are used to construct the three sustainability indicators by management system. These are shown in Fig. 3. The first dimension that relates to the ecological status of the system is very clear; stock health clearly improves with stronger rights. For the six economic dimensions, the results are more varied. With respect to harvest performance, harvest asset performance, and product form, there are clear improvements with stronger rights. For risk and trade access, there is little benefit of access rights, but improvement is observed under harvest rights, while the value of postharvest assets appears to be largely independent of management system. For the social indicators, the results appear to be even less dependent on the management system. The sole social dimension that uniformly improves with the strength of

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Table 2. Regression results

Outcome variable	Predictor variable	Coefficient	SE	t	P	R^2
Economic_U	Ecology_U	0.121	0.125	0.963	0.346	0.040
Economic_A	Ecology_A	0.359	0.057	6.311	<0.001	0.295
Economic_H	Ecology_H	0.537	0.137	3.923	<0.001	0.381
Community_U	Ecology_U	0.040	0.093	0.431	0.670	0.008
Community_A	Ecology_A	0.134	0.053	2.548	0.012	0.064
Community_H	Ecology_H	0.136	0.137	0.989	0.332	0.038
Community_U	Economic_U	0.166	0.152	1.091	0.287	0.051
Community_A	Economic_A	0.427	0.069	6.150	<0.001	0.285
Community_H	Economic_H	0.426	0.136	3.129	0.004	0.282

Subscript U represents fisheries with open access (n = 24), subscript A represents fisheries with access rights (n = 97), and subscript H represents fisheries with harvest rights (n = 26)

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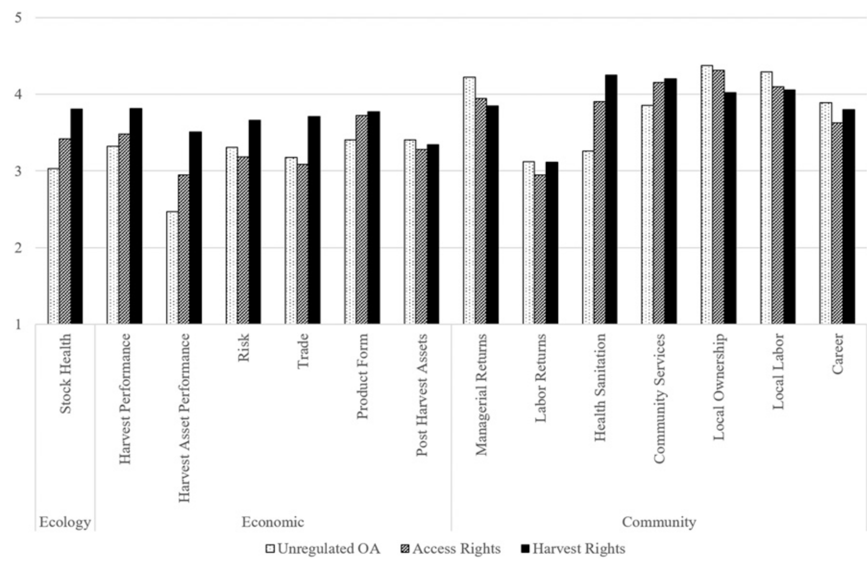

Fig. 3. Mean scores in FPI dimensions by management system.

rights is access to health and sanitation and community services, albeit to a small degree. Labor returns appear to be largely independent of management system, while managerial returns decline with stronger rights. Local ownership, use of local labor, and local career opportunities are best under open access management. While the aggregated results show no trade-offs among the three main sustainability dimensions, the disaggregated indicators show more nuanced differences among management systems, especially in those related to the social dynamics of fisheries sustainability.

Discussion

There are two key lessons from our analysis. First, the data show that advancing the triple bottom line in fisheries is possible, and that the three dimensions of sustainability reinforce one another, albeit to different degrees depending on the management system. Thus, the relationships among economic, ecological, and social sustainability should not necessarily be viewed as fundamental trade-offs, and policies based on an assumption that such trade-offs exist will be harmful for at least one sustainability pillar. Therefore, a well-designed management system that takes into account all three sustainability pillars appears to be a key to realizing the full benefits of a fishery. This result largely reinforces previously reported results (15, 16, 23).

Second, the data do not support opposition to rights-based management on the grounds that it undermines social objectives (34). Because there are no negative correlations among the pillars of sustainability, the data refute the claim that there is necessarily a trade-off between social and economic performance. Any particular policy design could have unintended consequences for a specific social objective, as case study-based research has clearly demonstrated (e.g., refs. 49–52). Our results do not suggest that there are no examples of negative consequences of rights-based management in specific fisheries, but show that on average, increased profitability associated with the extension of harvest rights does not undermine community outcomes. The identification of negative social outcomes as a result of some rights-based management system is more usefully viewed as a call to pay close attention to policy designs and not as rejection of this general approach to fisheries management.

The fact that management system has less influence on the association between the economic and social indicators (Fig. 3) reflects a greater role for contextual variation. A more detailed analysis of the separate indicators is an important topic for future research, which may provide more information about elements in the system design that improve not only environmental sustainability, but also economic and social sustainability. This may well reveal a more nuanced story when examining the more detailed aspects of the various management systems, including potential trade-offs at a finer scale than the three pillars of sustainability.

Methods

The FPIs are designed to assess "fishery management systems." A fisheries management system governs a fleet of similar fishing operations (usually vessels) harvesting a species or group of species under similar rules for access and harvest and selling into similar markets; it includes the environmental area under management, as well as the communities in which the core fishery production and postharvest activities occur. The fisheries management systems do not necessarily correspond to spatial limits of national borders; they may be local, national, or multinational. They also may be single or multispecies systems. The FPIs were developed through an iterative, consultative process of extensive piloting and revision. The approach was designed to be an independent, objective, comparable, and accurate representation of any fisheries management system (40).

Outcomes of fishery systems are assessed through 68 specific measures scored on a scale of 1–5, with bins defined to capture global variation. Rather than measuring few indicators with high precision, multiple measures are scored accurately but possibly imprecisely. There are 14 output dimensions, with several indicators in the assessment of each dimension intended to reduce the effect of potential mismeasurement and to triangulate more accurate values. The 14 dimensions are further designed to be aggregated to a framework that reliably captures key dimensions of ecological, economic, and community performance. The framework is described in detail in ref. 40 and is summarized in *SI Appendix*, Table S1. Ecological performance is captured in a single dimension reflecting the health of the stock, the degree of overfishing, and the general environmental status of the ecosystem. Economic performance measures whether the fishery is effectively generating market benefits and is determined by such factors as season length, ex-vessel and wholesale prices, and international trade. Community performance reflects the extent to which the fishery contributes to livelihoods and other benefits within the community.

In the design of the FPI approach, considerable attention was given to equity and fairness in fishery systems. Equity and fairness are multidimensional and generally cannot be measured directly except in highly data-intensive approaches to specific notions of equity (e.g., Gini coefficients). The FPI approach uses several measures as proxies to capture equity and fairness aspects. Data are collected for captains/vessel owners, crew, processing plant owners, and processing plant workers in each of the following areas: social standing, wages compared with nonfishery wages, wages

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compared with average regional earning, access to education, and access to health care. Data are also collected indicating the source of financial capital and borrowing rates, local participation in ownership and labor, and indicators of gender participation and management influence.

An essential feature of the FPI approach is the simultaneous collection of 54 similarly structured input metrics that reflect enabling conditions, such as macroeconomic conditions, property rights, spatial management, data availability and analysis (e.g., stock assessment), and infrastructure and are summarized in *SI Appendix*, Table S2. Input measures were designed with the intent of testing their causal effects with regard to ecological, economic, and community performance; it is not assumed that higher numbers necessarily represent "better". The measure of rights reflects the strength of access rights—those that grant the holder the right to participate in the fishery such as a permit—and harvest rights—those that give the holder the right to a specific quantity of the harvest, such as community or individual-based quotas or TURFs. The strength of the right is determined by the existence of the rights and the transferability, exclusivity, durability, security, and flexibility of the arrangements.

FPI assessments have been conducted for both data-poor and data-rich fisheries using consistent metrics and can describe artisanal and industrial fisheries, as well as fisheries in developing and developed countries around the world (40). Over the past 7 y, FPI assessments have been completed for 121 fisheries systems across the globe. Each assessment is led by a scorer, or team of scorers, who identifies the best available source of information for each metric, drawing on targeted data, proxy data, and local expert knowledge where data are not available. To minimize interscorer variation, there is an extensive FPI manual that clearly explains the justification of each metric and includes detailed examples for scoring (53). Finally, before entering an observation into the FPI database, all assessments are vetted by at least one experienced FPI analyst independent of the scoring team to ensure consistency.

While our nonrandom sample represents places where we have had the opportunity to score fisheries, it is the only available dataset with global coverage of the world's fisheries that has consistent and comparable data for the three dimensions of sustainability: social, economic, and ecological. Forty-two percent of the sample is from developed countries and 58% is from developing countries; Asia represents 31% of the sample; North America, 26%; Africa, 19%; South America, 6%; Europe, 6%; and Oceana, 3%. Artisanal fisheries systems are 36% of the systems assessed; industrial, 64%; 47% are multispecies and 53% are single species; 62% are near shore, 31% are offshore, 7% are inland; and 68% are finfish, 21% are crustacean, 7% are bivalve, and 4% are other.

ACKNOWLEDGMENTS. This work received funding from the Florida Agricultural Experiment Station. The views expressed are those of the authors, and not our respective employers or funding agencies. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of The World Bank, the FAO, or the governments they represent.

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