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Improvements to Rapfish: a rapid evaluation technique for fisheries integrating ecological and human dimensions[a]

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This paper reports recent developments in Rapfish, a normative, scalable and flexible rapid appraisal technique that integrates both ecological and human dimensions to evaluate the status of fisheries in reference to a norm or goal. Appraisal status targets may be sustainability, compliance with a standard (such as the UN code of conduct for responsible fisheries) or the degree of progress in meeting some other goal or target. The method combines semi-quantitative (*e.g.* ecological) and qualitative (*e.g.* social) data *via* multiple evaluation fields, each of which is assessed through scores assigned to six to 12 attributes or indicators: the scoring method allows user flexibility to adopt a wide range of utility relationships. For assessing sustainability, six evaluation fields have been developed: ecological, technological, economic, social, ethical and institutional. Each field can be assessed directly with a set of scored attributes, or several of the fields can be dealt with in greater detail using nested subfields that themselves comprise multidimensional Rapfish assessments (*e.g.* the hierarchical institutional field encompasses both governance and management, including a detailed analysis of legality). The user has the choice of including all or only some of the available sustainability fields. For the attributes themselves, there will rarely be quantitative data, but scoring allows these items to be estimated. Indeed, within a normative framework, one important advantage with Rapfish is transparency of the rigour, quality and replicability of the scores. The Rapfish technique employs a constrained multidimensional ordination that is scaled to situate data points within evaluation space. Within each evaluation field, results may be presented as a two-dimensional plot or in a one-dimensional rank order. Uncertainty is expressed through the probability distribution of Monte-Carlo simulations that use the C.L. on each original observation. Overall results of the multidisciplinary analysis may be shown using kite diagrams that compare different locations, time periods (including future projections) and management scenarios, which make policy trade-offs explicit. These enhancements are now available in the R programming language and on an open website, where users can run Rapfish analyses by downloading the software or uploading their data to a user interface.

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Key words: governance; indicators; multidisciplinary assessment; rapid appraisal; sustainability; trade-offs.

INTRODUCTION

Rapfish, a simple-to-use, multidisciplinary rapid appraisal technique to determine the sustainability status of fisheries, has been available in the fishery management toolbox for *c*. 12 years (Pitcher *et al.*, 1998; Pitcher & Preikshot, 2001). Rapfish evaluates fisheries sustainability along multiple performance modalities and has been especially useful not only in small-scale fisheries (Preikshot *et al.*, 1998; Preikshot & Pauly, 1999; Baeta *et al.*, 2005; Tesfamichael & Pitcher, 2006; Isaac *et al.*, 2009; Lessa *et al.*, 2009; Allahyari, 2010*a*, *b*) but also in some industrial fisheries (Murillas *et al.*, 2008). It has been used to track changes in fishery status with time and under alternative management scenarios (Pitcher *et al.*, 1999; Pauly & Chuenpagdee, 2003; Lessa *et al.*, 2009). The Rapfish evaluation scheme has been translated into several languages (*e.g.* Bahasa Indonesian: Hartono *et al.*, 2005, Portuguese: Isaac *et al.*, 2009 and Farsi: Allahyari, 2010*a*). The technique entails the simultaneous evaluation of status in a number of evaluation fields expressing a range of ecological and human dimensions (ecological, technological, economic, social and ethical in the original Rapfish, along with institutional in the updated version). Within each field, six to 12 attributes (indicators) are scored on a simple semi-quantitative scale. Scoring (generally on a scale of zero to 10) is normative, expressing how close the current (or some designated historical or future) state of the fishery lies to the best or worst possible status. Utility can be linear or non-linear, depending on how scoring is performed in relation to guidelines for each attribute. The principal advantages of Rapfish are that additional evaluation fields can be easily set up, the fisheries can be analysed with all or only some of the fields and attributes within each field can be easily adapted to a particular situation if the standard analysis needs to be augmented or altered. In the standard version, the status evaluated is sustainability, but alternative analyses can be conducted to evaluate compliance with or approach to some other norm or standard, such as the UN code of conduct for responsible fisheries (Pitcher *et al.*, 2009*a*, *b*) or ecosystem-based fisheries management (Pitcher *et al.*, 2009*c*).

This paper summarizes improvements to Rapfish since Pitcher & Preikshot's (2001) paper, including: (1) enhancements and revisions to the attributes in each Rapfish sustainability evaluation field, (2) explanations of and guidelines for scoring, (3) addition of a new institutional evaluation field assessing governance and management, (4) introduction of a nested evaluative approach, (5) recent application of Rapfish to forms of status other than sustainability and (6) improvements to the Rapfish algorithm, including an R-coded, web-based analysis.

IMPROVEMENTS TO THE SUSTAINABILITY RAPFISH

A conceptual representation of an updated Rapfish analysis, using the six evaluation fields for sustainability: ecological, technological, economic, social, ethical and institutional is displayed in Fig. 1. Each of these revised evaluation fields is discussed in detail below.

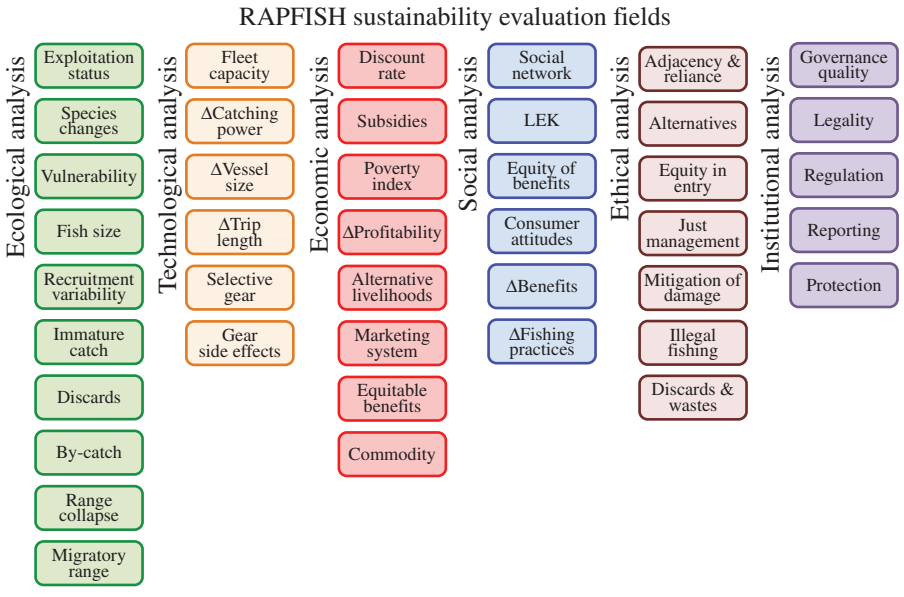

FIG. 1. Conceptual representation of a RAPFISH analysis in the six sustainability evaluation fields, with small boxes representing the attributes to be scored from Tables I to VI. LEK, local environmental knowledge.

REVISED EVALUATION FIELDS

The ecological, technological, economic, social and ethical evaluation fields were revised during and after an international, multidisciplinary workshop project in 2011 and 2012. Most of the modifications to the attributes involved small changes to descriptions and scoring guidelines aimed at better capturing sustainability or facilitating scoring. About eight former attributes that had not performed well in expressing sustainability, or had proved hard to score, were dropped from these fields, and four new ones were introduced. The scoring scale for all attributes has been standardized to run from zero (worst) to 10 (best), with a score of 4/10 representing a bare pass and 7/10 the threshold for a good score. Users of the algorithm are encouraged to assign upper and lower ranges for each score in order to express uncertainty for each attribute. To help users, more explicit scoring guidelines are now provided with each attribute description. Finally, it is important to note that many evaluation fields remain under continuous development in the light of experience and users are welcome to contribute to this process of improvement; the most recent versions for each evaluation field are available at www.rapfish.org.

Ecological field

This field scores 10 ecological and ecosystem attributes (Table I) that foster or inhibit biological sustainability of the resource (most of them represent small modifications from the previous version of Rapfish): (1) exploitation status of fishery in relation to sustainable levels; ecosystem factors, including (2) species changes and (3) intrinsic vulnerability index of fish species in fishery; fish life-history factors, including (4) size of fish in catch, (5) recruitment variability of exploited fish population and (6) catch before maturity; selective fishing factors, including (7)

TABLE I. Rapfish ecological evaluation field: attributes (version 3.0). This is a revised Rapfish evaluation field that scores ecological and ecosystem factors (attributes) that will foster or inhibit biological sustainability of the resource. Scoring scale is from zero (worst) to 10 (best), with 4/10 representing a bare pass and 7/10 a good score. Scoring guidelines are given with attribute description. Users can give an upper and lower range for each score to express uncertainty. (Please note that Rapfish undergoes continual improvement, and the most recent version of this scoring table will be found at www.rapfish.org)

Attribute	Description	Scoring guidelines
(1) Exploitation status of fishery in relation to sustainable levels	Assesses exploitation status scored on an FAO-like scale; assess using local experts, stock assessment, Kobe plot or consult FAO website for status (except collapsed)	Under-exploited (Rapfish score 10-9); exploited, less than MSY (8-6); fully exploited at approximate MSY (5-4); over-exploited beyond MSY (3-2); heavily exploited well beyond MSY to collapsed (2-0)
Ecosystem factors		
(2) Species changes	Assesses changes in species composition of catch in past 10 years, or compared to the first 5 years after the fishery began if information is available. A characteristic of overfishing in multispecies fisheries is a catch previously dominated by apex predators replaced by short-lived pelagic species. Score the number of species almost eliminated, greatly reduced or of changed identity in the catch (retained and discarded)	Low 0–4 (Rapfish score 10-9); medium 5–9 (8-6); high 10–14 (5-3); very high >14 (<3)
(3) Intrinsic vulnerability index of fish species in the fishery	A susceptibility measure for the species in the fishery (index values available by species from www.FishBase.org). Multispecies fishery might need an approximate average score. These Rapfish score categories are based on the frequency distribution of the vulnerability index for 30 000 species (range: <10 to 80+).	Vulnerability index value 0–9 (Rapfish score 10); 10–14 (9); 15–19 (8); 20–24 (7); 25–29 (6); 30–39 (5); 40–49 (4); 50–59 (3); 60–69 (2); 70–79 (1); >80 (0)
Fish life-history factors		
(4) Size of fishes in catch	Assesses if the average fish size is reduced in the past 10 years, or compared to the first 5 years of the fishery if information is available. Includes changes in population size structure and species composition	No or very little change (or fishes larger) (Rapfish score 10-9); yes, a gradual change (6-8); yes, a rapid large change (5-3), major rapid reduction (3-0)

TABLE I. Continued

Attribute	Description	Scoring guidelines
(5) Recruitment variability of the exploited fish population	Percentage variation in new fishes arriving at the fishery (= recruits), year to year. Sustainability is prejudiced by high variability and fishing increases this variability, but a major cause is often climate change. These two may interact having negative consequences for the resource	Low <20% (Rapfish score 10-9); medium 20–60% (8-7); high 60–100% (6-4); very high >200% (3-0)
(6) Catch before maturity	Percentage of the fish caught that are smaller or younger than the size or age of maturity	None (Rapfish score 10-9); some >30% (8-6); lots >60% (5-3); a very large amount >80% (2-0)
Selective fishing factors		
(7) Discards	Percentage of the catch biomass discarded (includes juveniles of the target species plus other species)	Low 0–9% (Rapfish score 10-9); medium low 10–19% (6–8); medium 20–39% (4–5), high >40% (2–3); very high >100% (<2)
(8) By-catch	Percentage of target catch biomass that is landed by-catch (includes juveniles of the target species plus other species)	Low 0–9% (Rapfish score 10-9); medium low 10–19% (8-6); medium 20–39% (5-4); high >40% (3-2); very high >100% (<2)
Spatial (geographical) stability factors		
(9) Range collapse	Assesses if there is evidence of geographic range reduction of the fish population in the past 10 years, and/or loss of sub-populations	None or very little (Rapfish score 10-9); some, slow (8-6); a lot, fast (5-3); very great, rapid (<3)
(10) Migratory range of target fishes	Assesses the number of jurisdictions encountered during life history of the target fishes (international waters may be counted as two jurisdictions because of the greater hazard faced in such waters)	1 only (Rapfish score 10); 2–3 (9-7); 4–5 (5-4); 6–7 (3-2); >7 (1-0)

MSY, maximum sustainable yield.

discards and (8) by-catch; spatial (geographical) stability factors, including (9) range collapse and (10) migratory range of target fishes. The trophic level indicators were dropped in light of recent demonstrations of problems in using such indicators to reflect the sustainability of fisheries (Branch *et al.*, 2012; Pitcher & Cheung, 2013).

Technological field

This field scores six technological attributes (Table II) covering fishing gear and activities that foster or inhibit biological sustainability of the resource: (1) fleet

capacity in relation to resource, (2) change in catching power, (3) change in vessel size, (4) change in trip length, (5) selective gear and (6) fishing gear side effects.

Economic field

This Rapfish evaluation field scores eight economic attributes (Table III) that will foster or inhibit biological sustainability of the resource: (1) discount rate in relation to fish productivity, (2) subsidies, (3) poverty index, (4) rate of change of profitability, (5) opportunity for alternative livelihoods, (6) marketing system, (7) equity of economic benefits and (8) commoditization. After much discussion among the multidisciplinary team members, the original gross domestic product attribute was dropped, as it was deemed not reflective of the economic sustainability of the fishery, and replaced by new attributes, *e.g.* profitability, commoditization and equity. Increasing commoditization of fishery resources is viewed negatively with sustainability (Lam & Pitcher, 2012*a*).

Social field

This Rapfish evaluation field scores six social attributes (Table IV) that will foster or inhibit biological sustainability of the resource: (1) strength of social network, (2) extent of local ecological knowledge, including a new cultural indicator that measures the number of continuous generations harvesting the fishery resource (Lam & Borch, 2011), (3) equity of fishing benefits, (4) consumer attitudes to sustainability, (5) change in fishing benefits and (6) change in fishing practices. A nested version of this social evaluation field is under development.

Ethical status

This evaluation field (Table V) was devised as a consequence of an international collaboration of ethicists who wrote a book on fisheries ethics (Coward *et al.*, 2000). Subsequent modifications of the attributes (Power-Antweiler & Pitcher, 2008) led to the version here: (1) adjacency and reliance; (2) alternatives; (3) equity in entry to fishery; (4) just governance; (5) mitigation, *e.g.* habitat destruction and ecosystem structure; (6) illegal, unregulated and unreported fishing; (7) discards and wastes. This field is being adapted within a more general framework of the ethical dimensions of fisheries that highlights ecosystem and social justice (Lam & Pitcher, 2012*b*), including paying for the privilege to fish and compensating for the ecological harm of fishing (Lam, 2012).

NEW INSTITUTIONAL EVALUATION FIELD

Human agency and well-being are incorporated partly in existing revised fields (especially economic, social and ethical status) and in a new human dimension evaluation field, capturing the institutional status of a fishery (Ostrom, 1990, 2009). The institutional Rapfish field encompasses both governance (quality and legality) and management (regulation, reporting and protection) of fisheries. It focuses on organizational practices, established and enforced by formal rules of behaviour, and their efficacy, as governed by both legal and cultural systems of accepted codes of conduct or norms.

TABLE II. Rapfish technological evaluation field: attributes (version 3.0). This revised Rapfish evaluation field scores technological (fishing gear and activities) factors (attributes) that will foster or inhibit biological sustainability of the resource. Scoring scale is from zero (worst) to 10 (best), with 4/10 representing a bare pass and 7/10 a good score. Scoring guidelines are given for each attribute description. Give a range for each score to express uncertainty. (Please note that Rapfish undergoes continual improvement, and the most recent version of this scoring table will be found at www.rapfish.org)

Attribute	Description	Scoring guidelines
(1) Fleet capacity in relation to resource	Assesses significant overcapacity in the catching power of this fleet/fishery	Appropriate capacity, under good control (Rapfish score 10-9); slight overcapacity, under control (8-7); overcapacity, but under good control (6-4); significant over capacity, under poor control (3-2); huge overcapacity (1-0)
(2) Change in catching power	Assesses whether fishers altered gear and vessel to increase catching power over past 5–10 years. Note that fishing power creep averages 2–3% per year in most fisheries. Investment in catching technology, *e.g.* electronic aids or replacing natural fibres with nylon, often has a major impact. Conversely, low tech or traditional materials often impose a limit on catching power	Very little change, or a decrease in catching power (Rapfish score 10-9); a small amount, <1% per year (8-7); somewhat, near the average of 2% (6-4); a lot, >2% per annum (3-2); a great amount, rapid increase (1-0)
(3) Change in vessel size	Assesses change in size (lengths, GRT) of vessels over past 5–10 years. Change measured as approximate percentage change in vessel capacity	Change <5% (increase or decrease) (Rapfish score 10-9); change 5–20% (8-7); change 21–50% (6-5); change 51–100% (4-3); change >100% (2-0)
(4) Change in trip length	Assesses recent changes in trip length in this fishery. Change measured as approximate percentage change in trip duration	Change <5% (increase or decrease) (Rapfish score 10-9); change 5–20% (8-7); change 21–50% (6-5); change 51–100% (4-3); change >100% (2-0)
(5) Selective gear	Assesses if the fishery deploys devices and handling of gear to increase selectivity and reduce by-catch and environmental damage	A great amount (Rapfish score 10-9); a lot (8-6); some (5-3); very little (2-0)

TABLE II. Continued

Attribute	Description	Scoring guidelines
(6) Fishing gear side effects	Assesses whether fishing gear has undesirable side effects on the habitats and other species. Either inherent or through the way the gear is used (*e.g.* cyanide, dynamite, bottom trawl, FAD and light attraction). Impacts of some trawls, drift nets and gillnets will depend on deployment and operation, so scores should be based on practice in this fishery	Very few (Rapfish score 10-9); some (8-6); a lot (5-3); fishery dominated by destructive fishing practices (<3)

FAD, fish attraction device used in a fishery (often floating branches or a light); GRT, gross registered tonnage of a vessel.

Institutional status

This is a new Rapfish evaluation field devised to better incorporate the human dimensions of fisheries. Five main attributes (Table VI) score institutional arrangements that foster or inhibit biological sustainability: these comprise two governance attributes and three management attributes. This field has two optional variants: a rapid version in which proxy indices are used for scoring or a nested version where each of the five attributes is treated as a subfield, each with a full set of sub-attributes subjected to a separate full Rapfish analysis. In the rapid version, indicators for a country or fisheries jurisdiction are used as fishery proxies, and modified according to expert knowledge of the fishery to assign Rapfish utility scores from zero to 10.

In the nested version of this evaluation field (Table VII), the governance section has two subfields: (1) quality and (2) legality. Quality subsumes four scored sub-attributes: (1) collaborative governance framework, (2) accountability, (3) transparency and (4) trend in conflict status among resource users to management changes. Legality has 12 sub-attributes, and may be performed as a stand-alone test of the legal status of a fishery. Further refinements of the governance section will include an explicit consideration of Ostrom's (2009) design principles. The management section has three subfields: (3) regulation, which has six sub-attributes; (4) reporting, which has five sub-attributes and (5) protection, which has five sub-attributes.

EXTENSIONS TO THE SCOPE OF THE RAPFISH ANALYSIS

The Rapfish approach can easily be adapted to almost any normative criteria, such as compliance with a standard, a set of goals or a fixed objective. For example, the use of the Rapfish technique to evaluate compliance with the Food and Agriculture Organization of the United Nations (FAO UN) code of conduct for responsible fisheries (www.fao.org/fishery/code/en) was featured in the original Rapfish paper

TABLE III. Rapfish economics evaluation field: attributes (version 3.0). This revised Rapfish evaluation field scores economic factors (attributes) that will foster or inhibit biological sustainability. Scoring scale is zero (worst) to 10 (best), with 4/10 representing a bare pass and 7/10 a good score. Scoring guidelines are listed for each attribute description. Attempt to score generic processes, not specifics. Give a range for each score to express uncertainty. (Please note that Rapfish undergoes continual improvement, and the most recent version of this scoring table will be found at www.rapfish.org)

Attribute	Description	Scoring guidelines
(1) Discount rate in relation to fish productivity	Assesses sustainability based on the ratio of discount rate to fish population reproductive rate (economic analysis shows that fishes should be wiped out when the discount rate is more than twice the reproductive rate of fish population)	Discount rate <20% of fish reproductive rate (Rapfish score 10-9), discount rate 20–40% of fish reproductive rate (8-6), discount rate 41–60% of fish reproductive rate (5-4), discount rate 61–80% of fish reproductive rate (3-2), discount rate >81% of fish reproductive rate (1-0)
(2) Subsidies	Higher subsidies are bad for sustainability. Assesses subsidy level as percentage of gross turnover of fishery. Including hidden subsidies (such as guaranteed off-season income for fishers, vessel building or fuel subsidies). National figures are available from Sumaila *et al.* (2010): these values may be used as a default if there is no specific information on the fishery	Subsidy <10% of turnover (Rapfish score 10-9), subsidy <20% of turnover (8-6), subsidy <30% of turnover (5-4), subsidy 30–100% of turnover (3-2), subsidy >100% of turnover (1-0)
(3) Poverty index	For this fishery, defined as difference between average fishing income and the national poverty level (divided by national level to normalize). Non-linear, but impact on sustainability is large when poverty is high. Values above poverty level are neutral to sustainability (non-linear utility)	Poverty index above or well above national average (Rapfish score 10-9), poverty index close to national average (8-6), poverty index up to 10% below national average (5-4), poverty index up to 30% below national average (3-2), poverty index more than 30% below national average (1-0)
(4) Rate of change of profitability	Assesses changes in profitability in either direction; large changes are bad for sustainability. Any trend up or down signals concerns for sustainability (non-linear utility)	Change <5% (increase or decrease) (Rapfish score 10-9), change 5–20% (8-7), change 21–50% (6-5), change 51–100% (4-3), change >100% (2-0)

TABLE III. Continued

Attribute	Description	Scoring guidelines
(5) Opportunity for alternative livelihoods	Assesses other sources of livelihood, other income	Many other sources of livelihood (Rapfish score 10-9), a lot (8-6), some (5-3), very few (2-0)
(6) Marketing system	Assesses the impact of the marketing system. Open system better for sustainability, *e.g*. open auction system. Closed system, monopoly buyer not good for sustainability	Fully open market auction system (Rapfish score 10-9), partially open market auction system (8-6); semi-closed market system (5-3), monopoly or government buyer, fixed price system (2-0)
(7) Equity of economic benefits	Assesses monetary and other material benefits. Benefits accrue to owners of fishing vessels, gears and licences, skippers and crew providing labour and skills, shore-side processing and marketing and villagers receiving common property fishes. Includes spatial location of benefits in that equitable local benefits are more likely to foster sustainability	Equitable distribution of economic benefits (Rapfish score 10-9), partially equitable distribution of economic benefits (8-6), inequitable distribution of economic benefits (5-3), grossly inequitable distribution of economic benefits (2-0)
(8) Commoditization	Treating fishery products as a global commodity is inimical to sustainability. On the other hand, labelling products with ecolabels, provenance or niche creates market pressures that could foster sustainability	Fishery products are marketed with a specific, local provenance and niche (Rapfish score 10-9), fishery products are to a large extent marketed with a local provenance and niche (8-6), fishery products are to a minor extent marketed with a local provenance and niche (5-3), fishery products are marketed as generic and global products with no local provenance or niche (2-0)

(Pitcher & Preikshot, 2001), based on analyses developed earlier (Pitcher, 1999); compliance results have been published for 53 countries (Pitcher *et al.*, 2009*a*, *b*). Versions of Rapfish (using the unmodified algorithm) have been used to evaluate fishery management performance (Mora *et al.*, 2009), the management performance of recreational fisheries (Pitcher, 2003) and the status of marine protected areas (Alder *et al.*, 2002). In this new version of Rapfish, the legality analysis, nested in

TABLE IV. Rapfish social evaluation field: attributes (version 3.0). This revised Rapfish evaluation field scores social factors (attributes) that foster or inhibit biological sustainability of the resource. Scoring scale is from zero (worst) to 10 (best), with 4/10 representing a bare pass and 7/10 a good score. Scoring guidelines are for each attribute description. When scoring, consider demonstrated resilience to change. Resilience is defined as capacity for recovery from a perturbation. Users may give a range for each score to express uncertainty. (Please note that Rapfish undergoes continual improvement, and the most recent version of this scoring table will be found at www.rapfish.org)

Attribute	Description	Scoring guidelines
(1) Strength of social network	Social distance factor. Assesses the strength of social peer-group support for fisher's actions and decisions (revision combines two former social attributes termed socialization of fishing and kin in fishery that essentially express the same influence). This metric could be considered to represent social resilience or social distance, and implies shared risks and shared experiences. Includes presence of leaders or peers (who may be kin) in the community who act to improve cohesiveness within the community and have outside interactions with the institutions responsible for management. Scoring may use the presence or absence of organized co-management like mechanisms, or local multistakeholder boards or local groups of fishers or processors	Score as a linear function: score 0 (lowest sustainability) to 10 (highest sustainability), with 4/10 representing a bare pass and 7/10 a good score
(2) Extent of LEK	Knowledge of resource factor Assesses contribution to sustainable fishing practices, ownership, management decisions and governance (this former social attribute is now broadened in this Rapfish revision to cover the same effect from other factors). Expresses the positive effects of LEK and intergenerational learning on sustainability. Traditional ecological knowledge (indigenous, but also knowledge from, for example, a council of elders) is included as a subcategory of LEK. Considers the age profile of the community, where large proportion of older fishers should aid sustainability. Two aspects of LEK influence can be considered:	Score as a linear function: score 0 (lowest sustainability) to 10 (highest sustainability), with 4/10 representing a bare pass and 7/10 a good score Alternative scoring using the G-index: $G = 0$, score 0; $G = 0{\cdot}5$, 1; $G = 1$, 2; $G = 2$, 4 (*i.e.* pass); $G = 3$, 6; $G = 3{\cdot}5$, 7 (*i.e.* good); $G = 4$, 8; $G \geq 5$, 10

TABLE IV. Continued

Attribute	Description	Scoring guidelines
	(1) the number of generations ($G = 1$ corresponds to 30 years) that local individuals, families or communities have conducted this fishery: more generations = better sustainability and (2) median age of fishers in the fishery: older fishers bring wisdom and perspective, so older median = better sustainability. The influence of LEK may be found in three aspects of the fishery: (1) fishing practices and ownership of licences or total allowable catch, (2) management decisions and (3) governance. Scoring may employ as a proxy for a new cultural indicator, the G-index, which is the number of generations the resource has been fished by individuals, families or communities living adjacent to resource (adjacent means within a day of the home port); high values should help sustainability	Score as a linear function: score 0 (lowest sustainability) to 10 (highest sustainability), with 4/10 representing a bare pass and 7/10 a good score Alternative scoring using the G-index: $G = 0$, score 0; $G = 0{\cdot}5$, 1; $G = 1$, 2; $G = 2$, 4 (*i.e.* pass); $G = 3$, 6; $G = 3{\cdot}5$, 7 (*i.e.* good); $G = 4$, 8; $G \geq 5$, 10
(3) Equity of fishing benefits	Socio-economic factor Scored as fishers:owners ratio. This attribute covers spatial and demographic equity in benefit distribution. Benefits include cultural and social benefits, not just monetary. Benefit distribution: estimate the ratio of fishers to recipients, beneficiaries, owners, patrons, buyers or processors: a lower ratio (*e.g.* a small number of fisher to many recipients of benefits or owners) = better sustainability. Local owners are more likely to foster sustainability; corporate remote owners the converse. A lower fishers:owners ratio acts for sustainability. Also include the type of debt to other sectors, which ranges from reciprocal or market regulated at the sustainable end of the spectrum to unregulated (loan sharking) at the unsustainable end (subsumes a former attribute of sector diversity). Weight the debt type and extent equally with benefit (*i.e.* more sustainable debts = greater owners) in assigning a score to fisher:owner ratio	Score as a categorical function: fisher to owner ratio; ratio >10 = poor (Rapfish score 0); ratio 10, (1); ratio 9, (2–3); ratio 8, (3–4) (*i.e.* 'pass' score); ratio 7, (5); ratio 6, (6); ratio 5, (7) (*i.e.* 'good' score); ratio 4, (8); ratio 3, (9); ratio ≤ 2, (10)

TABLE IV. Continued

Attribute	Description	Scoring guidelines
(4) Consumer attitudes to sustainability	Market factor Assesses how the social attitudes of consumers have an impact through demand on what the fishing community delivers to the market and can hence foster sustainability, *e.g.* niche markets, ecolabels, provenance information, sustainable sources of fish for restaurants, fishery improvement plans, traceability to source and overfishing status. Assess this through the extent of consumer (of the fishery products) participation rate and support for such initiatives	Score (and its uncertainty limits) as a categorical function: no market sustainability influence, (Rapfish score 0); some influence in place (score 1–3); medium level to assess (score 4–6), *i.e.* pass and above; ecolabels present, transparent provenance of fish products (score 7–10), *i.e.* good scores
(5) Change in fishing benefits	Change of state factor Change of state often signals concerns for sustainability. As for (3), it includes cultural and social benefits, not just monetary. More instability in fishing benefits signals concerns for sustainability. Assess using same underlying metrics as in (3), *i.e.* number of fishers, type and extent of benefits and debt	Change can increase or decrease: assess the rate of change, >40% per year, score 0; change 40–20% per year, score 1–2; change 20–15% per year, score 3; change 15–10% per year, score 4 (*i.e.* pass); change 10–5% per year, score 5 or 6; change <5 % per year, score 7–10 (*i.e.* good scores)
(6) Change in fishing practices	Change of state factor Change of state in a fishery often signals concerns for sustainability. May be changes in trip length, distance or time. Any trend in trip length up or down signals concerns for sustainability as it may be a response to new fishing gear, shifts in exploitation rates or serial depletion. Rarely, for well-managed recovering stocks, it might be a good signal, so it should be scored with care, taking account of stock condition or serial depletion. Trip length: duration and distance of median trips in the fishery either higher or lower than an established benchmark for median trip duration and length; this would be user-defined benchmark, could be set by community and fisher consensus for example to maximize social utility for the community in question. Or it could	Change can increase or decrease: assess the rate of change, >100% per year, score 0; change 100-50% per year, score 1–2; change 50-30% per year, score 3; change 30-20% per year, score 4 (*i.e.* pass); change 20-10% per year, score 5 or 6; change <10 % per year; score 7–10 (*i.e.* good scores). Score in the good range if the data come from one of those rare recovering fisheries

TABLE IV. Continued

Attribute	Description	Scoring guidelines
	simply be the duration and distance accurately known from some earlier time considered desirable or derived from a time series of data and knowledge; standardized by benchmark duration. Or it can be changes in the cultural diversity of fishery. Participants' demography: proportion of participants of each type of extraction from the stock (say commercial:aboriginal: recreational:subsistence); extent of shift away from a benchmark or target set by community and fisher consensus. This would be a user-defined benchmark, could be set by community and fisher consensus, for example, to maximize social utility for the community in question (or could simply be the duration and distance accurately known from some earlier time); standardized by benchmark diversity. Changes in any of these indicators, or expert opinion, can be used to assess the rate as scored here	

LEK, local environmental knowledge of fishers and their communities (includes here traditional environmental knowledge of indigenous peoples).

the institutional evaluation field (Table VII), could easily be employed on its own to evaluate the legality of a fishery, an increasingly important aspect of world fisheries.

Results of a Rapfish sustainability analysis using the six evaluation fields can be assembled into a kite profile, as depicted schematically in Fig. 2. Performance kites simultaneously express the multidisciplinary analysis inherent in the Rapfish evaluation fields and thus can make policy trade-offs explicit, as the user has the choice of including all or only some of the available sustainability fields. Moreover, variation in Rapfish scoring by different stakeholders or groups can make areas of agreement and disagreement transparent, rather like the widely used rapid rural appraisal technique used in sustainable development work (Chambers, 1994).

IMPROVEMENTS TO THE RAPFISH ALGORITHM

Numerical analysis in Rapfish employs a modified form of constrained multidimensional scaling (MDS) ordination, which some have found hard to implement. To address this problem, improvements to the Rapfish algorithm are described, including the use of R code, revised anchor points, Monte-Carlo routines to evaluate uncertainty in the results and a website (www.rapfish.org) to which data can be submitted for analysis.

TABLE V. Rapfish ethical evaluation field: attributes (version 3.0). This suite of ethical attributes assesses fisheries based on a range of ethical concerns, and integrates sustainability on many levels, including ecological and social. The ethical evaluation field in Rapfish was developed by a team of ethicists, social and natural scientists and has since been revised. Scoring scale is from zero (worst) to 10 (best), with 4/10 representing a bare pass and 7/10 a good score. Scoring guidelines are given with attribute description. Users can give an upper and lower range for each score to express uncertainty. (Please note that Rapfish undergoes continual improvement, and the most recent version of this scoring table will be found at www.rapfish.org)

Attribute	Description	Scoring guidelines
(1) Adjacency and reliance	Assesses geographical proximity and historical connection with resource	Not adjacent and no reliance (Rapfish score 0–2); not adjacent and some reliance (3–5); adjacent and some reliance (6–8); adjacent and strong reliance (9–10)
(2) Alternatives	Assesses alternatives to the fishery as sources of support within the community	None (Rapfish score 0–2); some (3–5); lots (6–8); very many (9–10)
(3) Equity in entry to fishery	Assesses whether entry to the fishery is based on traditional and historical access and harvests	Not considered (Rapfish score 0–3); considered (4–7); traditional indigenous fishery (8–10)
(4) Just governance	Assesses the inclusion of fishers in management and governance	None (Rapfish score 0); consultations (1–2); co-management and government leading (3–5); co-management/community leading (6–8); full co-management with all parties equal (9–10)
(5) Mitigation: habitat destruction and ecosystem structure	Assesses attempts to mitigate damage to fish habitat and/or attempts to mitigate fisheries-induced ecosystem change to predators, prey or competing organisms of fishery target	Much damage and no mitigation (Rapfish score 0); some damage (1–3); no ongoing damage or mitigation (4–6); some mitigation (7–8); much mitigation (9–10)
(6) Illegal fishing (IUU)	Assesses illegal and unreported fish catches (*e.g.* poaching and trans-shipments).	None (Rapfish score 10-8); some (7-6); a lot (5-3); a great deal (3-0)
(7) Discards and wastes	Assesses discards and waste and by-catch of birds, mammals, reptiles and structural benthic invertebrates	None (Rapfish score 10-8); some (7-6); a lot (5-3); a great deal (2-0)

IUU, illegal, unreported and unregulated fishing.

TABLE VI. Rapfish institutional evaluation field: attributes (rapid version 3.0). This new Rapfish evaluation field scores institutional arrangements (attributes) that will foster or inhibit biological sustainability. Five main attributes (comprised of one governance and four management attributes), includes a legality analysis that could be performed separately (the optional version has a nested analysis; see Table VII). Scoring zero (worst) to 10 (best), with 4/10 representing a bare pass and 7/10 a good score. Attempt to score generic processes, not specifics. When scoring, consider resilience to change when scoring (resilience is defined as capacity for recovery from a perturbation). Give a range for each score to express uncertainty. In this version, one key index is used as proxy for the attribute. Usually, the index refers to the jurisdiction or state; expert opinion may be used to modify the score for the particular fishery (or set of fisheries) being evaluated. Where several jurisdictions are involved in a fishery, an agreed average or weighted average might be used. (Please note that Rapfish undergoes continual improvement, and the most recent version of this scoring table will be found at www.rapfish.org)

Attribute	Description	Scoring guidelines
Governance: deals with the processes and principles by which decisions are made and concerns such aspects as the values underlying decision-making, the principles of transparency and accountability and the options available for engagement and participation of stakeholders in decision-making		
(1) Governance quality	Governance quality assesses the overall quality or capacity of jurisdiction (*e.g.* nation state) to provide enabling conditions for legal, regulated, reported and protected fisheries, as indicated by the WB governance indicators. Note that the score for the country, based on the WB index, can be modified for an individual fishery using expert opinion	Governance WB governance indicators are available (http://info.worldbank.org/governance/wgi/index.asp/) and assess six attributes of good governance (voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, control of corruption and rule of law). Here, an average of the six to be taken is suggested. WB provides errors, and these should be used to set the upper and lower bounds of scoring. WB gives the scores with mean zero and S.D. =1 (N.B., do not use the WB ranking scores directly) and hence for Rapfish scoring the following scale from zero to 10 is suggested: <-2 = score 0; -2 to $-1{\cdot}5$ = score 1; $-1{\cdot}5$ to -1 = score 2; -1 to $-0{\cdot}5$ = score 3; $-0{\cdot}5$ to 0 = score 4 (*i.e.* a pass score); 0 to $0{\cdot}5$ = score 5; $0{\cdot}5$ to 1 = score 6; 1 to $1{\cdot}5$ = score 7 (*i.e.* a good score); $1{\cdot}5$ to 2 = score 8; 2 to $2{\cdot}5$ = score 9; $>2{\cdot}5$ = score 10

TABLE VI. Continued

Attribute	Description	Scoring guidelines
(2) Legality	Demonstrated compliance to international obligations and national laws concerning the fishery, including the supply chain to the retailers. This can be approximated by the FAO (UN) code of conduct for responsible fisheries Compliance score, where it is available. Where code compliance is not available, the WB Rule of Law Indicator may be used, with the transformation to Rapfish scores as given in (1) above	The FAO (UN) code of conduct compliance scores are available for 63 countries at www.box.com/shared/ksukquipjf, and include errors that can be used to set the upper and lower bounds of scoring. The scale is already zero to 10, with 4/10 as a pass and 7/10 a good score, as used here. Note that the score for the country, based on the country compliance score, can be modified for an individual fishery using expert opinion
Management: state of responsible and effective management for this fishery in ensuring sustainable stock levels and healthy populations		
(3) Regulation	Management uses best available scientific evidence and managers follow scientific advice. Regulation includes EBFM, multispecies attempts, precautionary and ecosystem approach to management, monitoring and assessment and adapting to change. A good proxy is the average of the various components of the fishery management quality index from Mora *et al.* (2009). Where this is not available, the WB regulatory quality indicator may be used, with the transformation to Rapfish scores as given in (1) above	The fishery management quality index is available per country (and for some regions) at www.fmap.ca/ramweb/media/management_effectiveness/home.php?sub=34. Note that the score for the country can be modified for an individual fishery using expert opinion. Scoring conversion: multiply the Mora score (ranges between zero and 1) by 10
(4) Reporting	Assesses accurate, transparent reporting of fishing activities and fish extracted to national authority or RFMOs	The corruption perceptions index (CPI) from Transparency International can be used as a proxy, available at http://www.transparency.org/policy_research/surveys_indices/cpi/ The CPI is already on a scale of zero to ten and may be used directly in this Rapfish analysis. Note that the score for the country can be modified for an individual fishery using expert opinion

TABLE VI. Continued

Attribute	Description	Scoring guidelines
(5) Protection	Community-based or legislated protection for the productive value of the ecosystem for sacred, ceremonial or utilitarian purposes, habitat conservation and restoration, resource management, public trust and common heritage	Assign protection parameter index from extent and effectiveness of closed areas (extent of IUCN I and II designations) and fishery closures; readily available in qualitative form in most places. Alternatively, the score for the MPA question (3·8) in the code of conduct analysis can be used as a proxy. Note that the score for the country can be modified for an individual fishery using expert opinion

EBFM, ecosystem-based fishery management; MPA, marine protected area; RFMO, regional fishery management organizations; WB, World Bank.

R-coding for MDS

Early versions of Rapfish used MDS from the SPSS package (www-01.ibm.com/software/analytics/spss/products/statistics) or a code written in Visual Basic for Excel (Kavanagh & Pitcher, 2004). For cross-platform use, a robust MDS programmed for the free R programming framework and library (R Development Core Team; www.r-project.org) is now employed.

Anchor points

Anchor points are hypothetical fixed fisheries that logically establish parameter boundaries and median positions, entered as part of the data to be ordinated in the MDS. They were introduced for two reasons: first, to establish a normative direction to the MDS ordination, and second to stabilize mirror image flipping during Monte-Carlo runs (Kavanagh & Pitcher, 2004). Anchor points for the best and worst possible scores, and a set of fixed intermediate scores, have been improved and they are now automatically fed into the MDS algorithm without the need for intervention from users.

Uncertainty: Monte-Carlo analysis

Uncertainty in each of the attribute scores can be expressed in the MDS analysis for each evaluation field through Monte-Carlo runs. Random choices from flat or triangular prior distributions (between the upper and lower bounds on each score) are used to select each Monte-Carlo run. The overall median and quartiles (or 95 percentiles) of these results are used to report uncertainty in the ordination position of each fishery.

WEB-BASED RAPFISH ANALYSIS

The R code for the Rapfish algorithm has recently been made available on a publically accessible website (www.rapfish.org) to which users can submit comma-separated value data files (.csv format). Numerical results for one or more evaluation fields are returned with preliminary graph plots.

TABLE VII. Rapfish institutional evaluation field (nested version 3.0). This new Rapfish evaluation field scores institutional arrangements (attributes) that will foster or inhibit biological sustainability. Five main attributes are each treated as a subfield with a full scoring of sub-attributes and Rapfish analysis. The field includes a legality analysis that could be performed separately. Score from zero (worst) to 10 (best), with 4/10 representing a bare pass and 7/10 a good score. Attempt to score generic processes, not specifics. Consider resilience to change when scoring (resilience is defined as capacity for recovery from a perturbation). A range is given for each score to express uncertainty. (Please note that Rapfish undergoes continual improvement, and the most recent version of this scoring table will be found at www.rapfish.org)

Attribute	Description	Sub-attributes to score
Governance		
(1) Governance quality	Assesses the overall quality or capacity of jurisdiction (*e.g.* nation states) to provide enabling conditions for legal, regulated, reported and protected fisheries Four attributes to score	Collaborative governance framework: management responsibilities shared by government with fishing enterprises and corporations and civil society, including scientists, NGOs, consumers and community leaders Accountability (linear) Transparency (linear) Trend in conflict status among resource users to management changes (non-linear utility)
(2) Legality	Demonstrated compliance to international obligations and national laws concerning the fishery, including the supply chain to the retailers. Twelve attributes to score	*National legal compliance issues* Fishery is in compliance with national laws and fishery control measures Fishery is in compliance with conservation and management measures including catch limitations for this fishery The fishery management takes account of customary use and indigenous rights The fishery has proper documentation, registration, fees and taxes as established by law or local custom *Supply chain issues* The product can be traced to the fishery, and to the vessel and fisher The supply chain actively avoids purchasing illegally caught product The supply chain avoids purchase from blacklisted vessels The supply chain actively avoids co-mingling with products of unknown provenance *Code of conduct IUU issues* Amount of illegal fishing in this jurisdiction and fishery (Code Rapfish, Q6.4)

TABLE VII. Continued

Attribute	Description	Sub-attributes to score
		Control of illegal fishing in this jurisdiction and fishery (Code Rapfish Q6.5)
		Flags of convenience in this jurisdiction and fishery (Code Rapfish Q6.6)
		MCS quality score for this jurisdiction and fishery (scores may be available from Pramod Ganapathiraju; prammod.raju@gmail.com)
Management		
(3) Regulation	State of responsible and effective management for this fishery in ensuring sustainable stock levels and healthy populations. Uses best available scientific evidence and managers follow scientific advice. Regulation includes EBFM, multispecies management, ecosystem approach to management, monitoring and assessment and adapting to change Six attributes to score	Secure access privileges to allocations, fishing grounds or fishing periods; consider allocations to individuals, communities or cooperatives, transferability, durability.
		Participatory multistakeholder decision-making (*e.g.* co-management)
		Implementation of EBFM. Country score may be available from Pitcher *et al.* (2009*c*).
		Fishers' compliance with reporting regulations (incentives to misreport and illegal fishing).
		Precautionary approach (lack of scientific evidence that an action is harmful will not support that action to be taken) based on best available scientific evidence; default value can be country score available for precaution under the code of conduct compliance analysis
		Effectiveness of monitoring, control and surveillance (scores may be available from an analysis by P. Ganapathiraju; prammod.raju@gmail.com)
(4) Reporting	Assesses accurate, transparent reporting of fishing activities and fish extracted to national authority or RFMOs Five attributes to score	Publically or easily available data and analysis
		Reliable, mandated documentation of catch landings
		Scientific analysis of extractions (*e.g.* catch reconstructions)

TABLE VII. Continued

Attribute	Description	Sub-attributes to score
		Independent observer programmes or other appropriate safeguards to verify at-sea practices
		Verified reporting of discards and by-catch, and ongoing analysis of misreporting
(5) Protection	Community-based or legislated protection for the productive value of the ecosystem for sacred, ceremonial or utilitarian purposes, habitat conservation and restoration, resource management, public trust and common heritage Five attributes to score	Protected areas are applied for fishery purposes and outcomes (*e.g.* MPAs, spatial management and no-take zones)
		Protected species are recognized and avoided by fishery practices (*e.g.* in Canada, Species At Risk Act, Endangered Species Act or similar)
		Protected (closed) fisheries are recognized and implemented (*e.g.* international ban on whaling)
		Protective legislation or administrative arrangements ensure that protected and vulnerable habitats are protected from environmental harm (*e.g.* back-off rules in VMEs or bans against destructive or non-selective gear types and practices, such as use of trawls, drift nets, dynamite, cyanide or light traps and attractants)
		Protective legislation or administrative arrangements secures important and special relationships with fishery resources (*e.g.* indigenous peoples' access for food, social, and ceremonial purposes)

EBFM, ecosystem-based fishery management; IUU, illegal, unreported and unregulated fishing; MPA, marine protected area; MCS, monitoring, control and surveillance of a fishery; RFMO, regional fishery management organizations; VME, vulnerable marine ecosystem; WB, World Bank.

DISCUSSION

The former version of Rapfish has been compared favourably with a number of other rapid appraisal techniques for fisheries (Leadbitter & Ward, 2007; Andalecio, 2011). This revised version aims to become more generally useful, applicable to a wider range of fisheries by integrating the ecological and human dimensions more robustly and rigourously. It is easier to perform and has extended analytical scope, but could clearly be enhanced as further test cases are compiled. Feedback on performance and use is welcomed at www.rapfish.org.

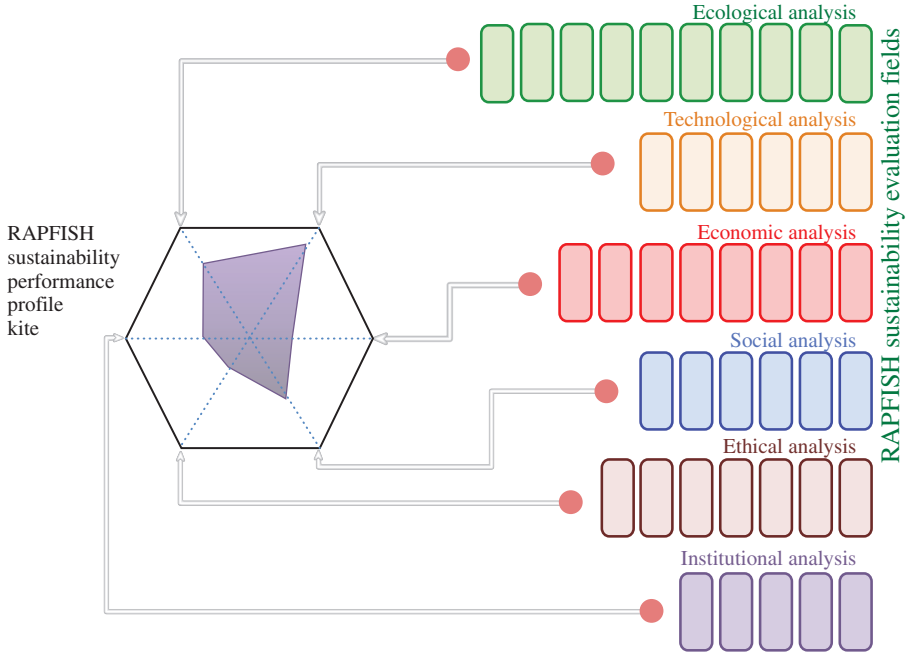

FIG. 2. Conceptual representation of results of RAPFISH analysis in the six fields assembled into a sustainability kite profile. Small boxes represent the scored attributes from Tables I to VI. Arrows denote the process of obtaining results from a Rapfish analysis of each field and plotting the result on an axis of a performance kite. Outer rim of the kite is the maximum possible score in each evaluation field. Example kite represents one fishery being evaluated, with one result per field forming its vertices.

For the attributes themselves, there will rarely be quantitative data, but qualitative scoring allows these items to be estimated. Indeed, one important consideration with Rapfish is the rigour, quality and replicability of the scores. To improve the scoring, a Delphi-like technique (Davis & Wagner, 2003) can be used to enhance the validity of scoring. For example, during the code of conduct compliance evaluation, a formal scoring protocol was employed to try to obtain the most accurate scores possible for each of the 44 questions in the six evaluation fields (Pitcher *et al.*, 2009*a*). Each country was first scored by one of the five primary scorers, based on published material. Particular attention at this stage was given to defining the minimum and maximum possible scores for each question. Documentary material and reference lists supporting the score range were then assembled. In the next step, two or more members of the scoring team reviewed and adjusted this material, using their own knowledge and sources. The country evaluation then went back to the primary scorer for a second round at finding the missing information. This version was then checked again by the team, and then uploaded to an open website to be available for external scrutiny and comment. (*e.g.* requests for comments by in-country experts were made subsequent to an FAO committee on fisheries meeting in 2005). At the next stage of validation, experts familiar with or from the country were asked to comment on the scores (validators were named or requested anonymity).

A further advantage of the updated Rapfish structure is that the scoring method allows users to adopt a wide range of utility relationships. The utility does not have to be linear, as scoring on the zero to 10 scale can be easily adapted to cover, for example, a U-shaped or a strongly skewed relationship with the attribute addressed. For each attribute, the upper and lower score limits express the range between the lowest possible score in this instance and the highest, and these limits are used in the overall analysis of uncertainty by the Monte-Carlo routine. Missing attribute scores can be accommodated by omitting the attribute entirely from the analysis or by inserting an average score.

The new structure and implementation of Rapfish also provides a user with the capability of conducting sensitivity analyses at a range of levels, which may assist in setting strategic priorities for new research areas and improved data capture systems to clarify specific management and sustainability issues. This could make an important contribution, *inter alia*, to assessing and reporting on the success of global initiatives in ecosystem-based management of fisheries and programmes for the design and delivery of fishery improvement plans, as these are now widely adopted across a number of global fishery certification programmes.

In conclusion, recent developments in Rapfish now better integrate the ecological and human dimensions to evaluate the status of fisheries. Appraisal status targets may be sustainability, compliance with a standard or the degree to which targets are met. For assessing sustainability, six evaluation fields have been developed and refined: ecological, technological, economic, social, ethical and institutional. Each field can be assessed directly with a set of scored attributes or nested with sub-attributes to comprise multidimensional Rapfish assessments for both data-poor and data-rich fisheries. An important advantage of Rapfish is the transparency in the evaluation, with overall results displayed in kite diagrams to compare different locations, time periods (including projections) and management scenarios of particular fisheries. Performance kites display the multidisciplinary analysis inherent in the Rapfish evaluation fields and thus make policy trade-offs explicit.

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