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RAPFISH: a rapid appraisal technique to evaluate the sustainability status of fisheries

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Abstract

RAPFISH is a new multi-disciplinary rapid appraisal technique for evaluating the comparative sustainability of fisheries. For the purpose of this analysis, fisheries may be defined flexibly as entities with a broad scope, such as all the fisheries in a lake, or with narrower scope, such as those in a single jurisdiction, target species, gear type or vessel. A set of fisheries may be compared, or the time trajectories of individual fisheries may be plotted. Attributes are chosen to reflect sustainability within each discipline, and although intended to remain fixed for all analyses, may be refined or substituted as improved information becomes available. Ordinations of sets of attributes are performed using multi-dimensional scaling (MDS) followed by scaling and rotation. Ordinations are anchored by fixed reference points that simulate the best and worst possible fisheries using extremes of the attribute scores, while other anchors secure the ordination in a second axis normal to the first. Randomly scored reference points act as anchors and define significant differences. Separate RAPFISH ordinations may be performed in ecological, economic, ethical, social and technological disciplines: a further evaluation field expresses compliance with the FAO Code of Conduct for Responsible Fisheries. Monte Carlo simulation can be used to estimate errors, while the leverage of each attribute on scores can be estimated with a stepwise procedure. Status results may be expressed on a scale from 0 to 100%, and scores from several fields may be combined in kite diagrams to facilitate comparison of fisheries or fisheries constructed to represent alternative policies. Some validations of the methodology are presented, using simulated fishery data. Results from published work using RAPFISH are reviewed briefly, along with prospects for further improvements to the technique. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Rapid appraisal; Multi-disciplinary; Attribute scoring; Ordination; Multi-dimensional scaling; Sustainability; Ethics; Code of conduct

1. Introduction

In fisheries stock assessment, much effort goes into determining stock status relative to biological reference points, such as levels of fishing mortality, spawning biomass or age structure (Smith, 1993), or to obtain diagnostics that may give early warning of serious depletion or collapse (Pitcher, 1995). Increasingly, stock assessment relies upon the estimation of many stock parameters and requires extensive current and historical data measured from the fishery and from independent biomass surveys. There is, however, a mismatch between the complexity of these stock assessment models and the high degree of uncertainty inherent in fisheries research (Walters, 1998). At the same time, extensive data requirements preclude the

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application of these models to many of the world's fisheries. Moreover, conventional stock assessment relates to the ecological, or occasionally, the economic sphere, and yet fisheries are in reality a multi-disciplinary human endeavour that has social, technological and ethical implications (McGoodwin, 1990). Evaluation of the sustainability of a fishery in all of these disciplines is required for objective decision making.

This paper describes a novel technique, RAPFISH, that employs simple, easily-scored attributes to provide a rapid, cost-effective, and multi-disciplinary appraisal of the status of a fishery, in terms of comparative levels of sustainability (Pitcher et al., 1998a). In RAPFISH, sustainability is described quantitatively by a set of defined criteria represented in a numerical analysis by a set of scored attributes. The technique is still under development and the most recent version is described here. Multi-variate ordinations of scored attributes evaluate fishery status separately within ecological, technological, economic, social and ethical evaluation fields: further areas such as compliance with the FAO Code of Conduct for Responsible Fisheries have also been developed. In this paper, we show how the method may be used to relate the status of fisheries to a fixed reference scale of 0–100%, to diagnose emerging problems and to compare the 'health' of fisheries using computed status scores. Simple kite diagrams may be used to compare the results of alternative fisheries policies.

2. Methods

2.1. The RAPFISH technique

While fisheries management is increasingly seen to be as much about managing human behaviour as about manipulating fish ecology (e.g., Jentoft, 1998), apart from economics, most analyses of the human aspects of fisheries have been non-quantitative with little predictive or diagnostic power. Nevertheless, this human dimension is so intertwined with the gear, vessels, markets, biological and economic sustainability, management, allocation and the rebuilding of depleted and collapsed stocks, that the study of fisheries can be regarded as truly multi-disciplinary. RAPFISH is a rapid appraisal technique designed to allow an objective, transparent, multi-disciplinary evaluation, but it is not intended to replace conventional stock assessment for setting quotas.

2.2. Definition of fisheries to be evaluated

The RAPFISH method is flexible about the definition of fisheries included in the analysis. For example, the ordination can be of a set of fisheries, or the trajectory in time of a single fishery, or both. Snapshots of a fishery in time may be taken at regular intervals such as every year or every five years, or at points when major shifts are known to have occurred. Points which plot very close together, or even fall at identical locations on the ordination, will not disrupt the analysis.

Additionally, the actual scope of the entities that are considered to be fisheries does not affect the results, provided that roughly the same scope is chosen for items to be compared. For example, at one extreme, all of the fisheries in a country or lake may be combined and compared *en masse* with those in other lakes or countries (e.g., for African lakes, Preikshot et al., 1998). At the other extreme, at a fine scale, the method can compare fisheries for two different species using the same gear type on the same vessel, such as the fishery for sardines and anchovies with 'volante' pair trawls in the northern Adriatic, or for the same species in the same location using two different gear types, such as the 'volante' and 'lampara' fisheries for anchovies, also in the Adriatic (for both see Pitcher et al., 1998b). Fisheries from individual fishing communities may also be compared, for example small-scale community-level fisheries in developing nations (Preikshot and Pauly, 1998). Moreover, once results are obtained, a hierarchical analysis can be performed by collapsing scores from groups of fisheries from a statistical region, ecosystem, gear type, or vessel type.

2.3. Attributes and data required for disciplines covered

Work using the RAPFISH technique to date has ordinated fisheries in five areas critical to the long-term viability of fisheries:

- Ecological (including fish population parameters and environment)

- Economic (including both micro and macro economic factors)
- Ethical (including industrial and community factors)
- Social (including social and anthropological factors)
- Technological (including gear and fishing characteristics)

Within each ordination, a set of 9–12 attributes considered critical to sustainability is defined. The number of attributes is designed to maximize discriminating power in the ordination technique: in order to ensure that outliers do not unduly influence the ordination, it is recommended to employ three times as many fisheries as attributes (Stalans, 1995).

Criteria for choosing attributes are that they are easily and objectively scored, and that extreme values are easily ascribed to 'good' and 'bad' in relation to sustainability, and that scores are available for all the fisheries and time periods in the analysis. Candidate attributes have been reduced in number by applying these criteria. Table 1 lists the current attributes and scoring schemes for the five disciplines outlined above, each of which expressing a different modality

Table 1
List and definitions of attributes used in the main RAPFISH analysis, divided into the five disciplinary areas, and showing the 'good' and 'bad' scores[a]

	Scoring	Good	Bad	Notes
Ecological analysis				
Exploitation status	0; 1; 2; 3	0	3	FAO-like scale: under- (0); fully- (1); heavily- (2); or over-exploited (3) [can consult FAO website for status]
Recruitment variability	0; 1; 2	0	2	COV: low <40% (0); medium 40–100% (1); or high >100% (2)
Trophic level	Number	High	Low	Average trophic level of species in catch
Change in trophic level	0; 1; 2	0	2	Is trophic level of fisheries sector decreasing: no (0); somewhat, slowly (1); rapidly (2)
Migratory range	0; 1; 2	0	2	No. of jurisdictions encountered during migration (includes international waters): 1–2 (0); 3–4 (1); >4 (2)
Range collapse	0; 1; 2	0	2	Is there evidence of geographic range reduction: no (0); a little (1); a lot, rapid (2)
Size of fish caught	0; 1; 2	0	2	Has average fish size landed changed in past five years: no (0); yes, a gradual change (1); yes, a rapid large change (2)
Catch before maturity	0; 1; 2	0	2	Percentage caught before maturity: none (0); some (>30%) (1); lots (>60%) (2)
Discarded by-catch	0; 1; 2	0	2	Percentage of target catch: low 0–10% (0); medium 10–40% (1); high >40% (2)
Species caught	0; 1; 2	0	2	Includes species caught as by-catch: low 1–10 (0); medium 10–100 (1); high >100 (2)
Primary production	0; 1; 2; 3	3	0	gC/m^2/year: low 0–50 (0); medium 50–90 (1); high 90–160 (2); very high >160 (3)
Economic analysis				
Price	0; 1; 2; 3; 4; 5	5	0	$/tonne of landed product for time of data point; >$250 (0); 250–900 (1); 900–1500 (2); 1500–3000 (3); 3000–5000 (4); >5000 (5)
Fisheries in GDP	0; 1; 2	2	0	Importance of fisheries sector in national economy: low (0); medium (1); high (2)
GDP/person	$/capita	High	Low	In region (country, province, etc) of fishery
Limited entry	0; 1; 2	2	0	Includes informal limitations: almost none (0); some (1); lots (2)
Marketable right	0; 1; 2	2	0	Marketable right/quota/share? None (0); some (1); full ITQ (2)
Other income	0; 1; 2; 3	0	3	In this fishery, fishing is mainly: casual (0); part-time (1); seasonal (2); full-time (3)
Sector employment	0; 1; 2	0	2	Employment in formal sector of this fishery: <10% (0); 10–20% (1); >20% (2)
Ownership	0; 1; 2	0	2	Profit from fishery mainly to: locals (0); mixed (1); foreigners (2)
Market	0; 1; 2	0	2	Market is principally: local/national (0); national/regional (1); international (2)
Subsidy	0; 1; 2	0	2	Are subsidies (including hidden) provided to support the fishery? no (o); somewhat (1); large subsidies (2)

Table 1 (*Continued*)

	Scoring	Good	Bad	Notes
Sociological analysis				
Socialisation of fishing	0; 1; 2	2	0	Fishermen work as: individuals (0); families (1); community groups (2)
Fishing community growth	0; 1; 2	0	2	Growth of local community over past 10 years: <10% (0); 10–20% (1); >20% (2)
Fishing sector	0; 1; 2	0	2	Households in fishing in the community: <1/3 (0); 1/3 to 2/3 (1); >2/3 (2)
Environmental knowledge	0; 1; 2	2	0	Level of knowledge about environmental issues and the fishery: none (0); some (1); lots (2)
Education level	0; 1; 2	2	0	Education level compared to population average: below (0); at (1); above (2)
Conflict status	0; 1; 2	0	2	Level of conflict with other sectors: none (0); some (1); lots (2)
Fisher influence	0; 1; 2	2	0	Strength of direct fisher influence on actual fishery regulations: almost none (0); some (1); lots (2)
Fishing income	0; 1; 2	2	0	Fishing income as % of total family income: <50%; 50–80%; >80%
Kin participation	0; 1	1	0	Do kin sell and/or process fish? no (0); yes (1)
Technological analysis				
Trip length	Days	Low	High	Average days at sea per fishing trip
Landing sites	0; 1; 2	0	2	Are landing sites: dispersed (0); somewhat centralised (1); heavily centralised (2)
Pre-sale processing	0; 1; 2	2	0	Processing before sale, ex. gutting, filleting: none (0); some (1); lots (2)
Use of ice	0; 1; 2; 3	3	0	None (0); some (1); sophisticated (ex. flash freezing, champagne ice) (2); live tanks (3)
Gear	0; 1	0	1	Gear is: passive (0); active (1)
Selective gear	0; 1; 2	2	0	Device(s) in gear to increase selectivity? Few (0); some (1); lots (2)
Power gear	0; 1	0	1	Is gear power-assisted? no (0); yes (1)
FADS	0; 0.5; 1	0	1	Are FADS: not used (0); bait is used (0.5); used (1)
SONAR	0; 0.5; 1	0	1	Is SONAR used? no (0); sounders are used (0.5); yes (1)
Vessel size	0; 1; 2	0	2	Average length of vessels: <8 m (0); 8–17 m (1); >17 m (2)
Catching power	0; 1; 2	0	2	Have fishermen altered gear and vessel to increase catching power over past 5 years? no (0); somewhat (1); a lot, rapid increase (2)
Gear side effects	0; 1; 2	0	2	Does gear have undesirable side effects (e.g., cyanide, dynamite, trawl); no (0); some (1); a lot (2)
Ethical analysis				
Adjacency and reliance	0; 1; 2; 3	3	0	Geographical proximity and historical connection: not adjacent/no reliance (0); not adjacent/some reliance (1); adjacent/some reliance (2); adjacent/strong reliance (3)
Alternatives	0; 1; 2	2	0	Alternatives to the fishery within community: none (0); some (1); lots (2)
Equity in entry to fishery	0; 1; 2	2	0	Is entry based on traditional/historical access/harvests? not considered (0); considered (1); traditional indigenous fishery (2)
Just management	0; 1; 2; 3; 4	4	0	Inclusion of fishermen in management: none (0); consultations (1); co-mgmt/govt. leading (2); co-mgmt/comm. leading (3); genuine co-mgmt with all parties equal (4)
Influences — ethical formation	0; 1; 2; 3; 4	4	0	Structures which could influence values: strong negative (0); some negative (1); neutral (2); some positive (3); strong positive (4)
Mitigation — habitat destruction	0; 1; 2; 3; 4	4	0	Attempts to mitigate damage to fish habitat: much damage (0); some damage (1); no ongoing damage or mitigation (2); some mitigation (3); much mitigation (4)
Mitigation — ecosystem depletion	0; 1; 2; 3; 4	4	0	Attempts to mitigate fisheries-induced ecosystem change: much damage (0); some damage (1); no damage or mitigation (2); some mitigation (3); much mitigation (4)
Illegal fishing	0; 1; 2	0	2	Illegal catching/poaching/transshipments: none (0); some (1); lots (2)
Discards and wastes	0; 1; 2	0	2	Discard and waste of fish: none (0); some (1); lots (2)

Table 1 (*Continued*)

	Scoring	Good	Bad	Notes
Code of Conduct analysis				
Intentions				
1. Management objectives	–	0%	100%	Results of ordination of 9 attributes
2. Framework (data and procedures)	–	0%	100%	Results of ordination of 7 attributes
3. Precautionary Approach	–	0%	100%	Results of ordination of 9 attributes
Results				
1. Stocks, fleets and gear	–	0%	100%	Results of ordination of 7 attributes
2. Social and economic	–	0%	100%	Results of ordination of 6 attributes
3. Monitoring, control and surveillance (MCS)	–	0%	100%	Results of ordination of 5 attributes

[a] Details of the six Code of Conduct fields are given in Pitcher (1999). Further guidance on standardized scoring of attributes may be found at www.fisheries.com — projects.

of sustainability. Future analyses will be comparable if the attributes are fixed. Most of the indicators of sustainability discussed in the literature (reviewed by FAO, 1999) are represented in this list, with the exception of detailed numerical single species stock assessment indicators, which are omitted since they are available only for small minority of world fisheries. They could be given their own new evaluation field using RAPFISH.

Scores for each fishery are determined from both peer-reviewed and 'grey' literature or from correspondence with experts on each fishery. Some values for economic and social areas can be obtained from the CIA world factbook (CIA, 1995). Scores from experts on individual fisheries should be moderated with wider comparisons in mind, and all scores must be carefully reviewed after a pilot analysis. All sources should be fully documented and published (see, for example, tables in Pitcher et al., 1998a,b). Most attributes are scored on a 3- or 4-point ranked scale that makes it relatively easy both to obtain a value in the absence of precise surveys and interviews, and for a group of experts to agree on a score. An interesting suggestion (M.P. Power, personal communication) is that fishermen, managers and others may be asked to self-score attributes, as the differences then may become revealing of different attitudes to the management process.

Recently, an additional field expressing compliance with the FAO Code of Conduct has been devised (Pitcher, 1999). This is a field of six scores, each of which derives in a hierarchical fashion from a RAPFISH analysis of a sub-field of attributes. The fields and attributes map onto the sections and clauses of the Code of Conduct. The Code analysis can provide a single score for a fishery that can be considered alongside the five sustainability fields described above.

2.4. Ordination method

After pilot work using Principle Components Analysis produced arched, biased plots, we have employed non-parametric multi-dimensional scaling (MDS) (Kruskal and Wish, 1978; Schiffman et al., 1981; Young and Hamer, 1987; Stalans, 1995), an ordination technique that can produce unbiased distance 'maps' of relative location (Clarke, 1993). These maps may be rotated and shifted linearly with no disruption since the relation of the cases to each other does not change (Clarke and Warwick, 1997).

A squared Euclidean distance matrix with attribute scores normalised using Z-values is employed in an MDS for ratio data because pilot work showed this produced the least disruption to monotonicity. We have used the SPSS statistical package (SPSS, 1996), which implements the robust ALSCAL algorithm for

MDS (Young and Harris, 1990) to produce two-dimensional ordinations. Goodness-of-fit is evaluated using stress values (values below 0.25 are considered acceptable by Clarke and Warwick, 1997).

2.5. Fixed reference points

To provide the ordination with fixed reference points, status is assessed relative to the best and worst possible fisheries that may be constructed from the set of attributes for each discipline. Two hypothetical fisheries, 'good' and 'bad', are thus simulated by choosing extreme scores for each attribute. Note that 'good' and 'bad' are evaluated in terms of sustainability of the fishery within the discipline. If these scores cannot easily be assigned to an attribute, then the attribute itself may not be useful for the RAPFISH analysis. The 'good' and 'bad' values are shown for the list of attributes in Table 1. The 'good' and 'bad' fisheries are plotted on the final ordination, and their positions are used to rotate and scale the plot, and to calculate percentage changes in status.

Additional fixed reference points, expressing two half-way scores that have the maximum mutual difference, are included in the ordination to ensure that new evaluations do not flip vertically to their mirror image, a tendency with MDS ordinations (see Pitcher, 1999).

2.6. Random reference points

To provide a measure against which to compare variation in the data, 20 random sets of attribute scores ('random' fisheries) are simulated for each discipline. Values are chosen at random from the score ranges for each attribute and entered as 'fisheries' in the ordination. These points are used as additional anchors to minimize shifts when overlaying points from different analyses (P. Kavanagh, personal communication). More than 20 random points might be chosen to improve statistical rigour, but there are limits because most MDS ordination algorithms allow only about 100 data points to be included. Since they act as anchors for the MDS distances, it is important for comparability among different analyses that the same set of randomly chosen points is used.

After pilot work, in which the random fisheries ordination positions were shown to be normally distributed about the centre of the plot (Pitcher et al., 1998b), random fisheries have been displayed as the mean and its 95% confidence limits. These are usually represented as crossed lines on the final ordination plot, and approximate the distances below which differences are unlikely to be significant.

2.7. Rotation and conventions for the display of results

In pilot work, in all cases the 'good' and 'bad' points fell very close to a straight line through the plot origin, and so, given the monotonicity investigated below, we felt justified in interpreting this line as representing the degree of comparative sustainability. It is often convenient to express status on a scale between 0 and 100%, which on the horizontal axis of a graph might run from left to right (or vertically from bottom to top). Accordingly, after ordination, we adopt a convention to rotate the whole MDS plot (to a least squares criterion) so that 'good' appears at the far right of a horizontal axis (azimuth 90°, relative to straight up as zero), and 'bad' at far left (azimuth 270°). The MDS ordination technique allows this rotation because it does not bias the relative map position of the points. At the same time ordination scores (which are in standard deviations) are rescaled to run from 0% (at the 'bad' locus) to 100% (at the 'good' locus). Similarly, rotated MDS scores falling on the new y-axis are scaled to run from -50 (at bottom) to 50 (at the top). Additional logic applied to the y-scores ensures that ordinations of similar data do not 'flip' vertically (see Pitcher, 1999).

Changes in the status of a fishery with time, or comparisons of status among fisheries, can then be represented as the score on the horizontal axis from 'good' to 'bad'. At the same time, changes normal to this axis (the vertical 'y' axis on the rotated and scaled plot) represent changes in fishery status that are not related to sustainability. This axis may be thought of as differences among fisheries achieved by obtaining the same sustainability rating from different combinations of attribute scores. For example, if the sustainability value were obtained by simply totalling the scores for the attributes, one could get the same total in a number of different ways. In practice, totals cannot be used since attributes run from high='good' to low='bad' and vice versa. Moreover, unlike ordination, totals do not allow a formal deconvolution of differences among fisheries that are related to sustainability and those that are not. Scores on the sustainability axis, between 0 and 100%, are generally carried forward to a further stages in the RAPFISH analysis.

Sustainability scores may be plotted against time, allowing us to follow changes in status. Attributes may be re-scored to construct 'forecast fisheries' in the analysis in order to compare alternative fishery management policies. The rank order of fisheries status can be used when there is considerable uncertainty in the attribute scoring. For example, we can look at whether a fishery falls in the top or bottom 10% of fisheries in a region, or would fall in this segment under alternative management policies. Examples are provided in Pitcher and Power (2000).

2.8. *Estimating loadings or leverage of attributes on RAPFISH scores*

To examine which attributes most influence an ordination, the sustainability axis may be taken as the dependent variable in a multiple regression with the normalised attributes as the independent variables. Regression coefficients that are significant show relationships of the original attributes to the sustainability axis. Because of the non-parametric nature of the MDS technique, these relationships hold only for an individual ordination and do not transfer to other analyses. An example is provided in Pitcher et al. (1998b).

Another method is to use multiple regression (e.g., in the canonical correlation package of *Statistica,* Statsoft, 1996). Such an analysis allows the interpretation of the meaning of derived axes from the attributes most highly correlated with them (Stalans, 1995). High positive correlations imply that when a particular attribute score was high for any fishery, it was likely to score high on an ordination axis. High negative correlations implied that low attribute scores were associated with high values on an ordination axis. It is important to remember, though, that the correlations should not be interpreted singly, for they determine the MDS axes jointly (James and McCulloch, 1990).

An alternative way of determining how much each attribute influences the scores of a fishery is to examine the leverage of attributes. A series of ordinations successively drops each attribute in turn out of the analysis. Then, for each of the attributes, calculate the sum of squares of the differences of the scores compared to those obtained with the full set of attributes. This stepwise analysis provides a standard error expressing the leverage of each attribute, which can be plotted as a bar chart. In an example of a leverage analysis in Pitcher (1999), nine attributes had leverage standard errors that ranged smoothly from 2 to 7%. A similar calculation can be carried out for the individual fisheries, to see which are most sensitive to the loss of attributes from the ordination. Moreover, plots can be made to show how this variation from the individual attributes affects the locus of a fishery on the RAPFISH ordination.

In all cases so far examined, leverage analysis has produced no surprises, in that no single attribute unduly affects the scores. In general, the position along the sustainability axis is affected by the loss of individual attributes far less than the vertical position on the *y*-axis, so that sustainability scores and the rank order of fisheries along this axis appear to be reasonably robust.

2.9. *Clustering the ordination*

Cluster analysis of the ordinated points can be used to group the fisheries in a mathematically objective fashion. A useful technique here is to promote 'clumpiness' using the complete Euclidean distance rule (e.g., using the CA package of the *Statistica* package, Statsoft, 1996), which creates groups by identifying each members farthest neighbours. The first readily identifiable groups may be chosen, as convenient or useful, since there are no clearly accepted rules for defining what constitutes a mathematical 'group' in such investigations (Cooper and Weekes, 1983). Tools such as amalgamation schedules (in the CA package of the *Statistica* package, Statsoft, 1996) may be used to judge the amount of variation explained by creating more groups. If such a plot shows little new variation being explained by adding extra groups, then the linkage distance is essentially the same (Statsoft, 1995).

2.10. *Comparison among scores in different evaluation fields using kite diagrams*

A convenient way to represent scores on the different axes of sustainability is a polygonal kite diagram. For each of the axes, a score of zero (0%) lies at the centre and a score of 100% lies on the rim of the polygon. For two- or three-way comparisons, the kite provides a simple visual representation, but more complex simultaneous comparisons produce muddled picture. Fig. 1 illustrates how scores from four fields go to make up the points of a kite. Comparison made with the kite may be of individual fisheries, or gear types, or large- and small-scale sectors, or fisheries for a certain species, or date. Kite comparisons may be made more rigorous by statistical tests applied to scores for each axis, or of the total kite area.

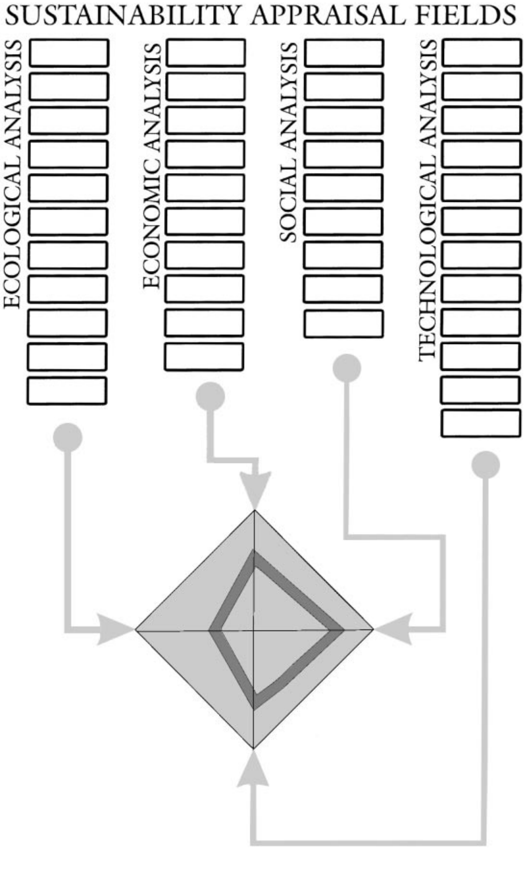

Fig. 1. Diagrams illustrating how RAPFISH evaluation fields for different modalities of sustainability can be considered together as scores on the axes of a kite diagram. Boxes represent the attributes used to ordinate fisheries within each evaluation field (as in Table 1). Connections, arrows and kite apices represent a score between 0 and 10% from each field. The outer rim of the kite is equivalent to 100% scores (=‘good’) in each field, while the centre of the kite represents scores of 0% (=‘bad’). Four evaluation fields are illustrated here, as in the examples from small pelagic fisheries shown in this paper. More recent work has employed five or six evaluation fields.

3. Results

3.1. Validation of the RAPFISH technique

To check that the method would ordinate fisheries monotonically, we simulated some fisheries whose status moved in single steps from ‘bad’ to ‘good’, scored on 10 ordinal attributes from 0 to 4. Fig. 2A shows the results from a RAPFISH ordination of two such simulated fisheries. The trajectories are encouragingly monotonic. Fig. 2B shows an ordination of another simulated fishery exhibiting periodic three-fold steps in status. The gaps occupy three steps relative to the single-step reference fishery, although distances at the edges occupy more space than at the centre, probably on account of the Z transformation of the data. The ‘random’ fisheries (cross) show that the approximate confidence limits on differences are similar to the ‘one-step simulations’.

Fig. 3 illustrates a RAPFISH ordination of three more simulated fisheries, together with the usual ‘good’, ‘bad’ and ‘random’ fisheries. Fishery C was simulated with large changes in the scores of individual attributes, but very little overall change in status — scores effectively were mirror images across the attributes. The resulting RAPFISH ordination reflects these large changes normal to the sustainability axis. They are accompanied by almost no change along the sustainability axis.

Simulated fisheries A and B each follow U-shaped curves on the plot. Fishery B decreases in status, remains at about the same level with some neutral changes in attribute sores, and then improves along a different trajectory towards the starting point. Fishery A was simulated as the reverse of this trajectory. In each case, the RAPFISH ordination in Fig. 3 follows the intended path quite well.

Fig. 4 shows the sustainability scores for the three fisheries plotted against time. The changes in the two fisheries mirror each other, as designed in the simulation, and they achieve the same sustainability status half way across the plot.

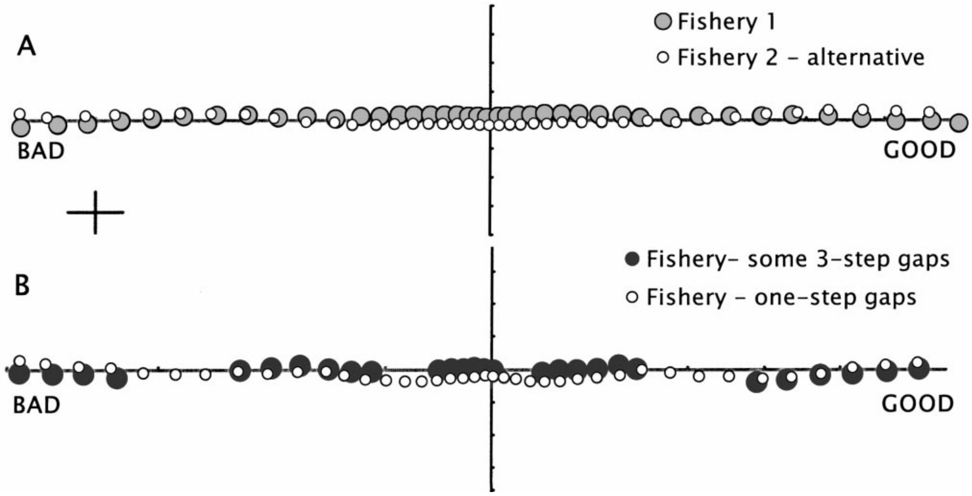

Fig. 2. Rotated and scaled MDS ordinations of the trajectory of simulated fisheries, illustrating that RAPFISH ordinations are reasonably monotonic. (A) Two fisheries exhibiting sequential steps in status from 'bad' to 'good', scored on 10 ordinal attributes from 0 to 4. (B) Large solid points follow a simulated fishery that occasionally jumps three steps in status. Small open points from a fishery with simulated single steps, as in (A). Cross shows size of standard errors of 20 fisheries with random allocation of attribute scores. (Note that the means, the centre of cross, actually lie very close to the centre of the plot at x=50, y=0, but are drawn displaced here to show standard errors.)

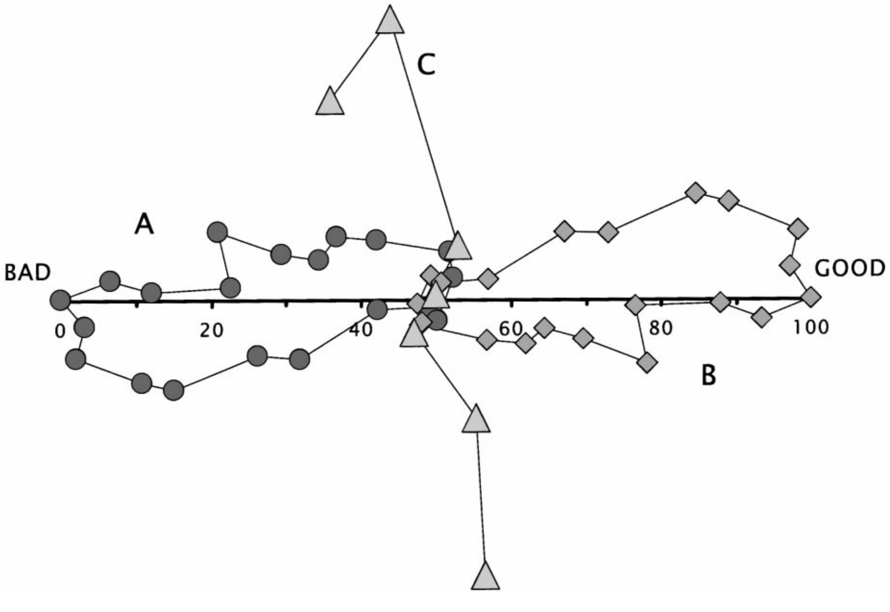

Fig. 3. RAPFISH ordination of three simulated fisheries where the horizontal axis represents sustainability scores between 0 and 100%, the 'bad' and 'good' fishery locations, and the vertical axis represents differences among fisheries not related to sustainability. Simulated fishery A (solid circles) increases in status, remains at about the same level with some neutral changes in attribute scores, and then deteriorates along a different trajectory towards the starting point at 0% (='bad'). Fishery B (solid lozenges) was simulated as the reverse of this trajectory. Fishery C (triangles) was simulated with large changes in the scores of individual attributes, but very little overall change in sustainability status — scores effectively were mirror images across the attributes. (Note 'hook' at top end of trajectory C represents a shift from a lower sustainability status.)

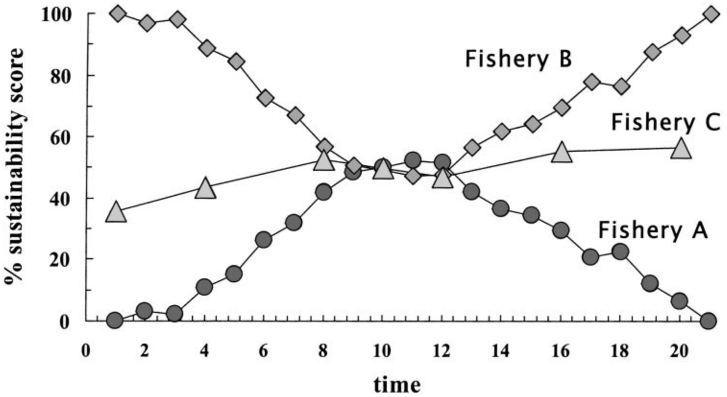

Fig. 4. Status scores from the simulated fisheries in Fig. 2 plotted against time. Here the vertical axis runs from 0% (='bad') to 100% (='good').

3.2. Example of RAPFISH results

By way of example, Fig. 5 shows an ecological RAPFISH ordination for some small pelagic fisheries (re-analysed from Pitcher et al., 1998b). Some general features are apparent from the plot. Pacific herring fisheries (lozenges) plot as more sustainable than Atlantic herring fisheries (triangles), and anchovy

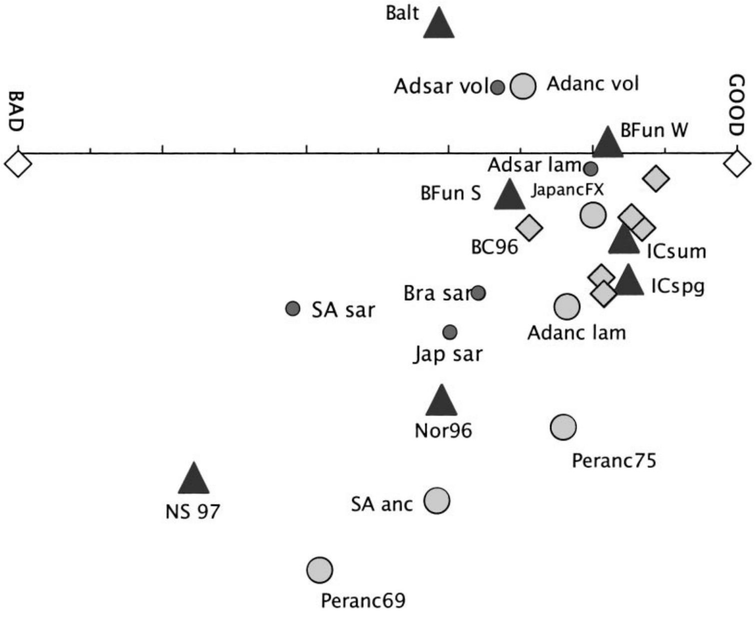

Fig. 5. An example of ecological RAPFISH ordination results for some small pelagic fisheries. A subset of the full results is shown. For further discussion see text. Fishery symbols — lozenges: Pacific herring fisheries, triangles: Atlantic herring fisheries, small circles: sardine fisheries, large circles: Anchovy fisheries. Abbreviations — Peranc69: Peruvian anchovy fishery, 1969; Peranc75: Peruvian anchovy fishery, 1975; Adsar vol: Adriatic sardine volante (pair trawl) fishery 1985; Adanc vol: Adriatic anchovy volante (pair trawl) fishery 1985; Adsar lam: Adriatic sardine lampara (light+purse seine) fishery 1985; Adanc lam: Adriatic anchovy lampara (light+purse seine) fishery 1985; Bra sar: Brazilian sardine fishery; SA sar: South African sardine (pilchard) fishery; SA anc: South African sardine (pilchard) fishery; Icsum: Icelandic summer spawning herring fishery; Icspg: Icelandic spring spawning herring fishery; Nor96: Norwegian spring spawning herring fishery 1996; Balt: Baltic herring fishery; JapancFX: Japanese fixed gear anchovy trap fishery; BFun S: Bay of Fundy seine herring fishery; BFun W: Bay of Fundy fixed weir herring fishery. Revised analysis from Pitcher et al. (1998a,b), where complete sources of data are tabulated.

fisheries (large circles) more than sardine fisheries (small circles). As an example of comparison of gear types, both sardine and anchovy 'lampara' (nocturnal purse seine with light) fisheries in the Adriatic have ecological sustainability scores higher than the equivalent 'volante' (pair trawl) fisheries. The Peruvian anchovy in 1969, just prior to the notorious collapse of 1971, plots with lower status than in 1975 after some recovery. This material taken from Pitcher et al. (1998b), where full details of the data sources, the history of these fisheries and more detailed interpretations are given.

Distances in the vertical dimension of the ordination plot are interpreted as differences between fisheries that are not related to the sustainability axis. For example, the Baltic and Norwegian herring fisheries have similar sustainability scores (about 55%) but lie far apart vertically. The reason lies in contrasting scores in attributes such as exploitation status, recruitment variability and discards and catch before maturity.

Fig. 6 illustrates a leverage analysis carried out for attributes defining the ecological evaluation field of the same small pelagics RAPFISH analysis. The results show that the 'number of species caught' attribute (see Table 1) has an influence (S.E. about 9%) about twice as great as others on the ordination position of fisheries on the sustainability axis. The next largest attribute is 'recruitment variability' with a S.E. of about 4%, followed by the rest of the ecological sustainability attributes whose standard errors decrease smoothly down to under 2%. This can be interpreted as indicating that the number of species caught with the targeted small pelagics has the greatest influence on sustainability, while no single attribute among the rest of the attribute stands out in influence. Leverage of attributes on the RAPFISH *y*-axis, differences among fisheries not related to sustainability is shown in the open bars on the left side of the plot. 'Species caught' again has the highest influence, and in general the two sets of influences are weakly correlated. The interpretation of these *y*-axis influences is less important for fishery management than those on the sustainability axis; they merely show the amount each attribute influences position on an axis of difference unrelated to sustainability.

Fig. 7 illustrates results obtained for three time series from herring fisheries from the same analysis as Figs. 5 and 6; Norwegian Spring spawning herring, North Sea herring (both Atlantic herring) and British

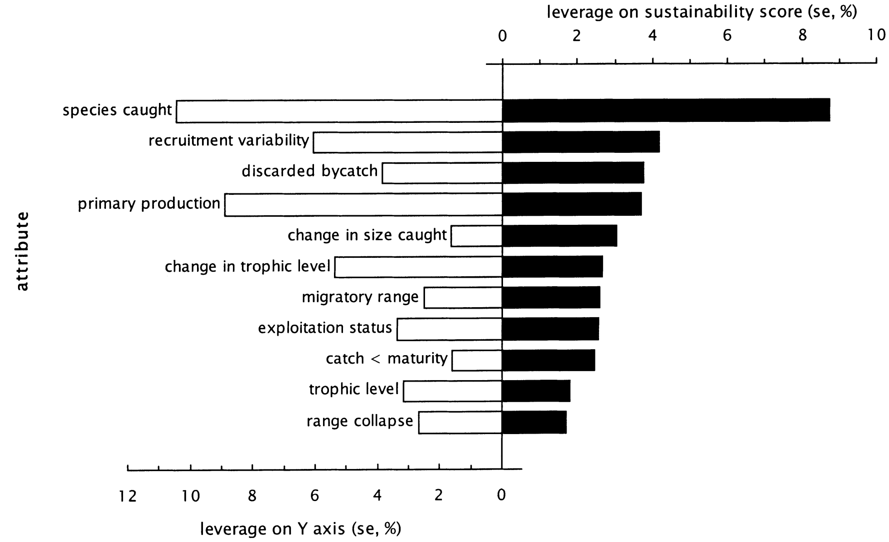

Fig. 6. Attribute leverage analysis of the ecological RAPFISH ordination for fisheries on small pelagics, shown, in part, in Fig. 5. Labels on bars are the attributes from the ecological evaluation field (Table 1). Leverage was calculated as standard error of differences between scores obtained with and without including the attribute. Solid bars to left show leverage as a standard error in percent on the sustainability axis from 'bad' to 'good'. Graph has been sorted to show highest to lowest leverage of the 11 attributes on this axis. Open bars to the right show leverage as a standard error as percent on the vertical '*y*' axis of the ordination. For further discussion see text.

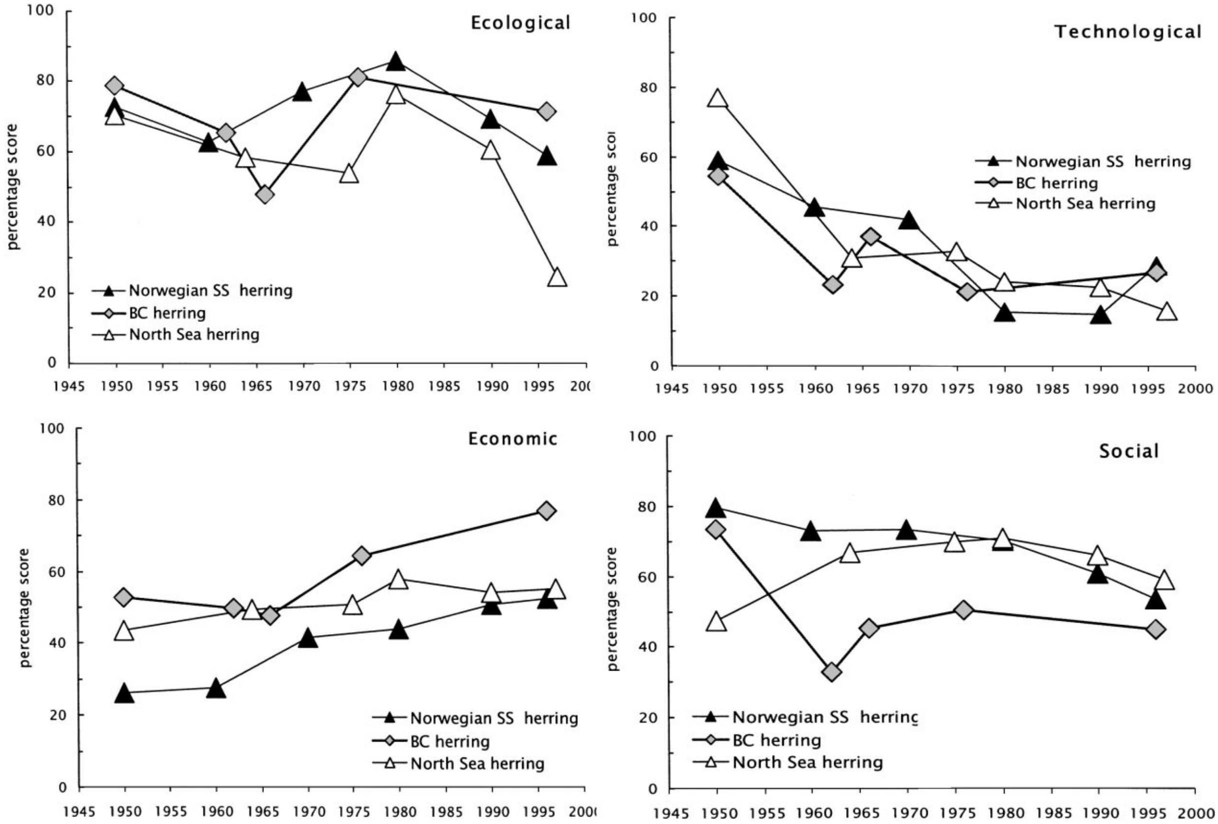

Fig. 7. RAPFISH sustainability scores (vertical axis) for three time series from herring fisheries; the Norwegian Spring spawning herring (filled triangles: Atlantic herring), North Sea herring (open triangles: Atlantic herring) and British Columbia (lozenges: Pacific herring). Four RAPFISH analyses are shown, for ecological, social, economic and technological evaluation fields. Revised analysis from Pitcher et al. (1998a,b), where complete sources of data are tabulated and detailed histories of these fisheries given.

Columbia (Pacific) herring. RAPFISH analyses are shown for ecological, social, economic and combined ordinations. In the ecological ordination, the BC herring has a U-shaped trajectory, a reduction in status being associated with a narrowly avoided collapse of the fishmeal fishery in the 1960s, followed by improvement after closure and re-opening as a carefully regulated roe fishery. This is like fishery B in Fig. 4, while the two Atlantic herring fisheries exhibit inverted U-shaped trajectories like fishery C. Both Atlantic fisheries end up in a worse position than their starting points in the 1950s, as collapse and closure is followed again by overfishing and depletion. In the Social ordination, we see the highest sustainability status in the Norwegian fishery in the 1950s, when small vessels were crewed by close kin from small integrated coastal communities. BC herring fisheries in 1950 get a similar score. With the exception of an early rise for the North Sea fisheries, in general the social status scores decrease to end up in the 1990s at half their peak values. In the technological ordination, the Norwegian and North Sea fisheries decline in sustainability scores across the plot as driftnets give way to purse seines and ever larger mid-water trawls, the Norwegian fishery improving its status towards the end on account of the use of by-catch reduction devices. The BC fishery declines rapidly during the fish meal phase and then improves as a closely controlled fishery for roe herring. The fourth ordination, in economics, exhibits a dramatically different pattern from the other three evaluation fields, in that, despite minor blips caused by collapses, all three herring fisheries more than double their economic status by the 1990s.

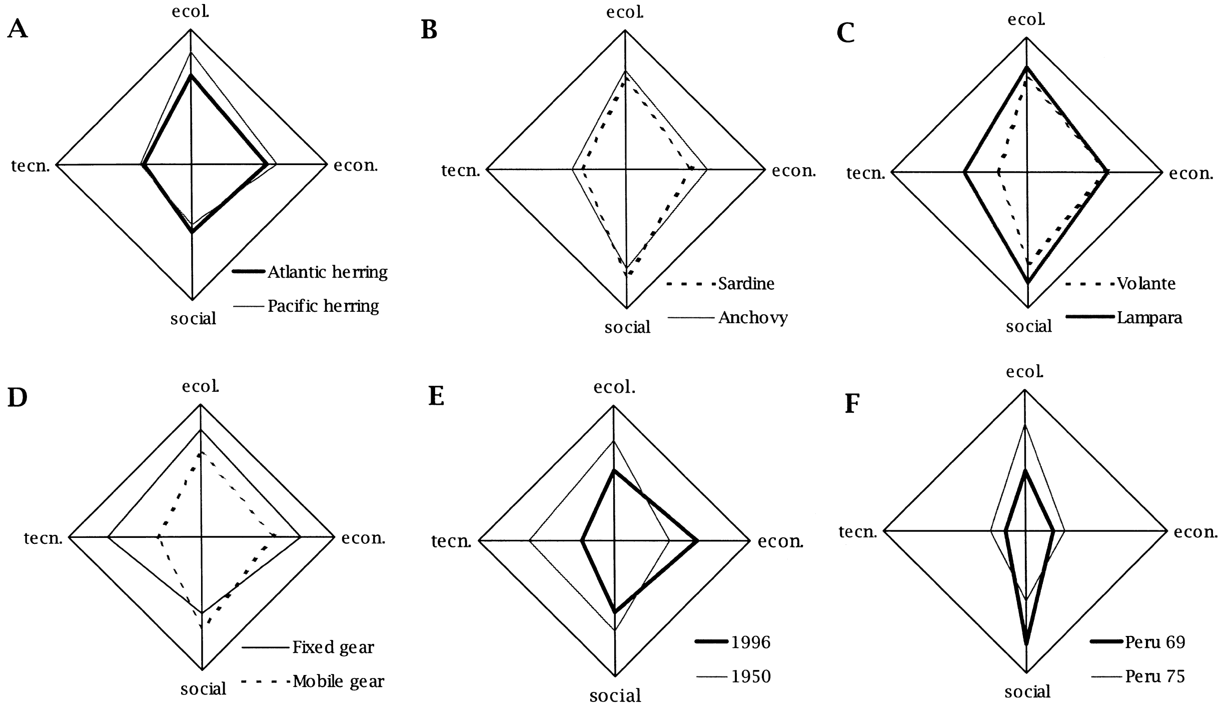

Fig. 8. Examples of the use of kite diagrams from some fisheries for small pelagics, illustrating how RAPFISH may be used in a hierarchical fashion to make comparisons among different aspects of the fisheries. Four RAPFISH status scores are employed in a four sided kite, for ecological, social, economic and technological evaluation fields. Note that the outer rim of the kite represents 100% scores. (A) Comparing average status scores of Atlantic (n=7) and Pacific herring (n=8) fisheries. (B) Comparing average status scores of sardine (n=6) and anchovy (n=7) fisheries. (C) Comparing average status scores of Adriatic volante (pair trawl, n=2) and lampara (light+purs seine, n=2) fisheries. (D) Comparing average status scores of fixed gear (n=4) and mobile gear (n=12) fisheries for small pelagics. (E) Comparing average status scores of fisheries for herring in 1950 (n=3) and in 1996 (n=3). (F) Comparing average status scores of the Peruvian anchovy fishery in 1969, just prior to the major 1971 collapse, and in 1975, after some recovery. Revised analysis is from Pitcher et al. (1998a,b), where complete sources of data are tabulated. Note that only four evaluation fields were available from this work.

Comparisons of status across all four evaluation fields from this analysis of small pelagic fisheries are presented as kite diagrams in Fig. 8. In each case, fisheries forming a category in the comparison have been averaged from pooled RAPFISH scores: statistical comparisons may be made using the distribution of the scores. Comparing Atlantic with Pacific herring (Fig. 8A), the kites clearly reveal differences to lie in the ecological and economic spheres: social and technological scores are similar. Analysis of variance shows that the difference between Atlantic and Pacific herring scores is significant at the 5% level, confirming the visual impression from Fig. 5. Fig. 8B indicates lower scores for pooled sardine than anchovy fisheries on three of the four axes. Fig. 8C shows that the Adriatic 'volante' versus 'lampara' comparison is most marked on the technological sustainability axis. The kite diagram in Fig. 8D illustrates remarkably high scores for fixed fishing gears on three of the four axes. On the social axis where pooled mobile gears score higher, in fact some fixed gears, such as traditional fixed weirs for herring in New Brunswick, also score highly. Fig. 8E dramatically illustrates one of the major challenges facing fisheries management: pooled 1950 scores in ecological, social and technological sustainability lie well above pooled scores for the 1990s, while the long right arm of the kite shows the high economic status of fisheries in the 1990s. Kites for the Peruvian anchovy fishery in 1969 and 1975 are shown in Fig. 8F. Here the method has been somewhat disappointing in that the anchovy fishery prior to collapse has a low, but not exceptionally low, status score.

4. Discussion

To date, RAPFISH analyses have been published for 26 world fisheries from commercial, subsistence, artisanal, and industrial sectors (Pitcher et al., 1998a); 24 small-scale artisanal fisheries from the tropics (Preikshot and Pauly, 1998); 32 African lake fisheries (Preikshot et al., 1998); 29 fisheries for sardine, Atlantic herring, Pacific herring and anchovy, including time series for three major herring fisheries (Pitcher et al., 1998b); comparison of the status of distant water UUSR fleets in Mauritania and Senegal (Pitcher and Preikshot, 1998); ethical analysis of 24 Canadian Atlantic and 18 Pacific fisheries (Pitcher and Power, 2000); and analysis of compliance of the same Canadian fisheries with the FAO Code of Conduct for Responsible Fisheries (Pitcher, 1999; Pitcher and Power, 2000).

The quantification provided by RAPFISH is intended to be useful. Wilson (1998) presents a vision of a powerful new synergy between the natural and social sciences, largely expressed though quantification, using examples such as evolutionary psychology (Wright, 1994), a field that has recently been applied to fisheries management (Hart and Pitcher, 1998). The RAPFISH technique aspires to be a part of such consilience between the natural and social sciences.

4.1. Interpretation of RAPFISH results

The examples illustrated in Figs. 5–7 show that the RAPFISH ordinations mirror in general what we know of the ecology, economics and sociology associated with known histories of collapse, rebuilding and changes to gear characteristics and relative status. Here, the RAPFISH technique appears to be providing helpful signals about shifts in sustainability status, which might be loosely defined as fisheries 'health'. Moreover, the kite diagrams aid visual comparisons, and can be given underlying statistical rigour.

This paper shows that RAPFISH can track changes in sustainability status, with the caveat that sustainability is as defined by the original choice of attributes. Differences normal to the 'good' to 'bad' axis represent changes in fishery status that are not reflected in sustainability. Note that an excess of points to one side or the other of the ordination zero does not represent analytical bias, but a greater or lesser number of fisheries above or below the median status score that lies in the middle of our fixed scale.

The RAPFISH method has promise in that it is robust in several senses. First, it can learn not only from refinement of historical analyses, but also from more formal stock assessment, about what are the 'good' and 'bad' attribute values that may be scored. Second, users can make their own choice of which discipline to concentrate on; the biological, ethical, social or economic analyses can be used alone or in combination with the technological area if required. RAPFISH also provides a quantitative way of considering interdisciplinary evaluations, a process considered essential in the management of many fisheries (Lane and Stephenson, 1997). Third, the new method is robust in the sense that responses to criticisms of attributes from within each of the disciplines represented by an evaluation field, serves to improve the power of the ordinations within each field, rather than invalidate the method. Finally, the RAPFISH technique forces us to make explicit the qualities we use to distinguish between fisheries, so that they may be used as attributes in the analysis. Downing (1991) shows how comparisons between apparently dissimilar objects can be performed using measured amounts of variables they share.

5. Conclusions

In conclusion, the RAPFISH technique outlined in this paper has demonstrated utility in comparing the status of fisheries, and in evaluating the potential impact of alternative policies on that status. It encompasses and systematizes a much broader range of evaluation fields than conventional stock assessment, reflecting the realistic policy choices and trade-offs that have to be made, especially among economic, social, ethical and ecological imperatives. The consequences of adopting polices that improve scores in one of these fields are made explicit. Unlike statistical or logical decision analysis, all processes leading to the RAPFISH sustainability scores for a fishery are transparent and depend on clearly defined assumptions about what is good and bad. The explicit definitions of 'good' and 'bad' may be modified where they turn out to be inappropriate for a particular case. Furthermore, anomalies in the scores can be probed and rectified and scores improved by incorporating more recent or more accurate information. Using kite diagrams, the scores can be amalgamated among groups of fisheries that share a common factor to facilitate comparison among gear types, sectors, geographical range, ecosystems or years.

In addition to providing a rapid assessment of status, the RAPFISH method could be useful in a 'triage' of fisheries (Pauly, 1998), to determine where limited management or research resources might be focused to greatest effect. It may also be used to track changes in a single fishery in an attempt to foresee problems before some combination of biological, economic or social effects leads to disaster. An important question is whether this technique can be used to diagnose key problems (such as environmental change, overcapitalisation or recruitment overfishing) early enough to give warning of impending trouble. The Peruvian anchovy example suggests that RAPFISH might be improved in this respect. Attributes that more clearly define the period immediately preceding a documented collapse (e.g., Pitcher, 1995, 1997) would increase the power of this method.

Additional RAPFISH analyses are in preparation that employ new evaluation fields, such as energy consumption and the impact of fishing on ecosystem structure, an important aspect of fisheries that has long been ignored (Pitcher and Pauly, 1998; Pitcher, 2000). Evaluation fields that capture special features of a fishing gear that evolves with time, such as the cod traps used in Newfoundland since the 1750s, might be valuable for special analyses. Finally, a more formal analysis of uncertainty, reflecting differences in opinion in the scoring of the attributes, and using Monte Carlo simulations from ranges of the input attribute scores, is in preparation.

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References

Central Intelligence Agency, 1995. World Factbook 1995–1996. Brassey, Washington, 512 pp.

Clarke, K.R., 1993. Multivariate analyses of changes in community structure. Aust. J. Ecol. 19, 117–143.

Clarke, K.R., Warwick, R.M., 1997. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth Marine Laboratory, UK, 144 pp.

Cooper, R.A., Weekes, A.J., 1983. Section 10: Multivariate analysis. In: Cooper, R.A., Weekes, A.J. (Eds.), Data, Models and Statistical Analysis. Philip Allan, Oxford, pp. 240–259.

Downing, J.A., 1991. Comparing apples with oranges: methods of inter-ecosystem comparison. In: Cole, J., Lovett, G., Findlay, S. (Eds.), Comparative Analysis of Ecosystems. Springer, New York, pp. 24–45.

FAO, 1999. The development and use of indicators for sustainable development of marine capture fisheries. FAO Technical Guidelines for Responsible Fisheries No. 8, Rome, 79 pp.

Hart, P.J.B., Pitcher, T.J., 1998. Conflict, cooperation and consent: the utility of an evolutionary perspective on individual human behaviour in fisheries management. In: Pitcher, T.J., Hart, P.J.B., Pauly, D. (Eds.), Reinventing Fisheries Management. Kluwer Academic Publishers, Dordrecht, pp. 215–225.

James, F.C., McCulloch, C.E., 1990. Multivariate analysis in ecology and systematics: panacea or Pandora's box? Ann. Rev. Ecol. Syst. 21, 129–166.

Jentoft, S., 1998. Social science in fisheries management: a risk assessment. In: Pitcher, T.J., Hart, P.J.B., Pauly, D. (Eds.), Reinventing Fisheries Management. Kluwer Academic Publishers, Dordrecht, pp. 177–184.

Kruskal, J.B., Wish, M., 1978. Multidimensional Scaling. Sage, Beverley Hills, CA.

Lane, D.E., Stephenson, R.L., 1997. Fisheries Management Science: integrating the roles of science, economics, sociology and politics into effective fisheries management. In: Hancock, D.A., Smith, D.C., Grant, A., Beumer, J.P. (Eds.), Developing and Sustaining World Fisheries Resources: The State of

Science and Management. CSIRO, Collingwood, Australia, pp. 177–182.

McGoodwin, J., 1990. Crisis in the World's Fisheries: People, Problems and Policies. Stanford University Press, Stanford, USA, 235 pp.

Pauly, D., 1998. When is fisheries management needed? In: Adams, T., Dalzell, P., Roberts, P. (Eds.), SPC/FFA Workshop on the Management of South Pacific Inshore Fisheries, Nouméa, New Caledonia, Vol. 3, pp. 97–103.

Pitcher, T.J., 1995. The impact of pelagic fish behaviour on fisheries. Sci. Marina 59, 295–306.

Pitcher, T.J., 1997. Fish shoaling behaviour as a key factor in the resilience of fisheries: shoaling behaviour alone can generate range collapse in fisheries. In: Hancock, D.A., Smith, D.C., Grant, A., Beumer, J.P. (Eds.), Developing and Sustaining World Fisheries Resources: The State of Science and Management. CSIRO, Collingwood, Australia, pp. 143–148.

Pitcher, T.J., 1999. Rapfish: a rapid appraisal technique for fisheries, and its application to the code of conduct for responsible fisheries. FAO Fisheries Circular No. 947, 47 pp.

Pitcher, T.J., 2000. Rebuilding as a New Goal for Fisheries Management: Reconstructing the Past to Salvage The Future. Ecological Applications (in press).

Pitcher, T.J., Pauly, D., 1998. Rebuilding ecosystems, not sustainability, as the proper goal of fishery management. In: Pitcher, T.J., Hart, P.J.B., Pauly, D. (Eds.), Reinventing Fisheries Management. Kluwer Academic Publishers, Dordrecht, pp. 311–329.

Pitcher, T.J., Power, M.P., 2000. Fish figures: quantifying the ethical status of Canadian fisheries, East and West. In: Coward, H., Ommer, R., Pitcher, T.J. (Eds.), Just Fish: The Ethics of Canadian Fisheries. Institute of Social and Economic Research Press, St John's, Nfld, pp. 225–253.

Pitcher, T.J., Preikshot, D., 1998. Rapid appraisal of the status of West African distant water fleet fisheries relative to home fleets using the Rapfish technique. In: Bonfil, R., Munro, G., Sumaila, U.R., Valtysson, H., Wright, M., Pitcher, T., Preikshot, D., Haggan, N., Pauly, D. (Eds.), Distant Water Fleets: An Ecological, Economic and Social Assessment. Fisheries Centre Research Reports, Vol. 6, No. 6, pp. 90–93.

Pitcher, T.J., Bundy, A., Preikshot, D., Hutton, T., Pauly, D., 1998a. Measuring the unmeasurable: a multivariate interdisciplinary method for rapid appraisal of health of fisheries. In: Pitcher, T.J., Hart, P.J.B., Pauly, D. (Eds.), Reinventing Fisheries Management. Kluwer Academic Publishers, Dordrecht, pp. 31–54.

Pitcher, T.J., Mackinson, S., Vasconcellos, M., Nøttestad, L., Preikshot, D., 1998b. Rapid appraisal of the status of fisheries for small pelagics using multivariate, multidisciplinary ordination. In: Quinn II, T.J., Funk, F., Heifetz, J., Ianelli, J.N., Powers, J.E., Schweigert, J.F., Sullivan, P.J., Zhang, C.I. (Eds.), Fishery Stock Assessment Models. Alaska Sea Grant, Fairbanks, USA, pp. 759–782.

Preikshot, D.B., Pauly, D., 1998. A multivariate interdisciplinary assessment of small-scale tropical fisheries. In: Quinn II, T.J., Funk, F., Heifetz, J., Ianelli, J.N., Powers, J.E., Schweigert, J.F., Sullivan, P.J., Zhang, C.I. (Eds.), Fishery Stock Assessment Models. Alaska Sea Grant, Fairbanks, USA, pp. 803–814.

Preikshot, D.B., Nsiku, E., Pitcher, T.J., Pauly, D., 1998. An interdisciplinary evaluation of the status and health of African lake fisheries using a rapid appraisal technique, J. Fish Biol. 53 (Suppl. A), 382–393.

Schiffman, S.S., Reynolds, M.L., Young, F.W., 1981. Introduction to Multidimensional Scaling: Theory, Methods and Applications. Academic Press, London.

Smith, S.J., 1993. Risk evaluation and biological reference points for fisheries management: a review. In: Kruse, G., Eggers, D.M., Marasco, R.J., Pautzke, C., Quinn, T.J. (Eds.), Management Strategies for Exploited Fish Populations. Alaska Sea Grant, Anchorage, USA, pp. 339–353.

SPSS, 1996. SPSS for Windows, Release 7.5.

Stalans, L.J., 1995. Multidimensional scaling. In: Grimm, L.G., Yarnold, P.R. (Eds.), Reading and Understanding Multivariate Statistics. American Psychological Association, Washington, USA, 373 pp.

Statsoft, 1995. Cluster analysis. Statistica, Vol. III: Statistics II. Statsoft Inc., Tulsa, USA, pp. 3165–3196 in Statsoft.

Statsoft, 1996. Statistica for Windows, Release 5.1 D. Statsoft Inc., Tulsa, USA.

Walters, C.J., 1998. Designing fisheries management systems that do not depend on accurate stock assessment. In: Pitcher, T.J., Hart, P.J.B., Pauly, D. (Eds.), Reinventing Fisheries Management. Kluwer Academic Publishers, Dordrecht, pp. 279–288.

Wilson, E.O., 1998. Consilience. Knopf, New York, USA, 332 pp.

Wright, R., 1994. The Moral Animal. Why We Are The Way We Are: The New Science of Evolutionary Psychology. Vintage Books, New York, USA, 466 pp.

Young, F.W., Hamer, R.M., 1987. Multidimensional Scaling: History, Theory and Applications. Erlbaum, New York.

Young, F.W., Harris, D.F., 1990. Multidimensional Scaling: Procedure ALSCAL. In: Norusis, J.J. (Ed.), SPSS Base System. User's Guide. SPSS Inc., Chicago, USA, pp. 396–461.