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DECIDING ON PRECAUTIONARY MANAGEMENT MEASURES FOR A STOCK AND APPROPRIATE LIMIT REFERENCE POINTS (LRPS) AS A BASIS FOR A MULTI-LRP HARVEST LAW

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Abstract

A checklist is provided incorporating some 30 qualitative or semi-quantitative criteria to be completed by resource experts as a preliminary basis for deciding on priorities for precautionary management of marine resources or fisheries. The four tables furnish a means of comparing unit resources in terms of the relative vulnerabilities to non-precautionary harvesting and in determining which aspects of the fishery require particular attention from research and management, including, if necessary, the formulation of appropriate Limit Reference Points. Such precautionary reference points may be relatively simply formulated but would need to be incorporated within a management system that is simple and pre-negotiated. A methodology for using a suite of simple limit reference points as a 'traffic light' indicating the state of the fishery in response to precautionary criteria is proposed.

Introduction

The need to distinguish between Limit and Target Reference Points in fisheries management (Caddy and Mahon, 1995) is now well established as one operational component of a precautionary management system as specified by the FAO Code of Conduct and the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks. The precautionary approach to the use of reference points as noted in FAO (1995) suggests that they should form part of a harvest control law for the fishery in question.

Most harvest control laws formulated to date are specified as an allowable trajectory of points between reference points specified in terms of biomass and fishing mortality, where it is assumed that the position of the fishery is known with a degree of precision and the management response and conformity by the industry required by the harvest law is also achieved with comparable precision.

For many fisheries, however, a history of quantitative estimates of past states of the fishery may not be available or regime shifts or changes in the fishery itself may mean that historical data is less than reliable as a guide for action or may be restricted to landings. It may be necessary then to seek a guide to action beginning with a broad review of all qualitative and semi-quantitative information on the fishery before deciding on priorities for setting limits to management action in the form of reference points or a control law incorporating them. Such a situation seems conducive to the use of a questionnaire such as is routinely used in environmental assessments of the degree to which environmental standards are being respected. Such a questionnaire (Caddy, 1996) has been proposed, strictly based on the management-related Articles of the Code of Conduct. A similar approach seems feasible and is proposed here, prior to introducing technical management measures. This could also be particularly useful in facilitating discussions between fishery scientists and fisheries managers and the industry.

The paper also addresses the problem of specifying reference points and harvest control laws in information-poor situations typical of developing-country fisheries. It is stressed that the success of simple 'rules of thumb' in setting limit reference points can only be envisaged if they are incorporated into a harvest law which specifies prompt and pre-negotiated responses to the signals from a suite of such LRPs. Such a hypothetical feedback mechanism is postulated in the form of an ' LRP traffic light'.

Proposed Methodology

It is suggested that for each unit resource a scoring be completed for each relevant category or row in Tables 1 to 4, based on information on past landings. Score red, green or orange once for the resource in Table 1, and score one point for each row in columns green, orange and red in Tables 2-4, whichever colour is judged to be most relevant to the resource for the category in question. Higher importance is placed on the red (and possibly orange) scoring, which should then be incorporated in a summary table which will form a useful basis for a 'precautionary statement' useful to managers in deciding on the relative importance of management measures, reference points or the necessary research or data-gathering activities to support such a system.

It would also be useful to group summary tables for those resources harvested together or which constitute predators and preys so as to provide, at least qualitatively, an information basis for a multi-species approach to setting reference points.

A Simple Multi-LRP Harvest Law

Simple LRPs as 'rules of thumb' for precautionary management

Caddy and Mahon (1995) note that, in circumstances where uninterrupted series of data on age composition and biomass are not available, and where it is not possible to fit a stock-recruit relationship, there may still be some information available from past harvesting which allows an approximation to MSY conditions to be arrived at, and estimates of growth, natural mortality and virgin stock size may have been made. Under these conditions, while it may be difficult to formulate a formal harvest law involving trajectories of fishing mortality and biomass, it may still be possible to formulate several limit reference points which, from experience with similar resources elsewhere, have a reasonable likelihood of being precautionary.

Following Gulland (1971), such reference points can be formulated in terms of biomass and virgin stock size as:

LRP (precautionary TAC) < xMB_0, where x is significantly lower than the 0.5 used by Gulland. For example, from empirical observations, Patterson (1992) noted that low values of x in Gulland's formulation MSY = xMB_0 are more precautionary for small pelagics (and presumably other stocks with high natural mortality rates). Caddy and Csirke (1983) proposed a reference point, the point of Maximum Biological Production (MBP), that is aimed at conditions when stock production to fishing and natural deaths is maximized, and Die and Caddy (1997) suggested that this is precautionary and relatively easy to calculate (Fig. 1). Based on a knowledge of von Bertalanffy's growth parameters and with some ideas on selectivity, Die and Caddy also suggested several simple reference points (Z^*, F^* and l_c^*) that can be formulated as inequalities (Fig. 2). These follow from the assumption that a precautionary reference point is one allowing the cohort a reasonable probability of spawning at least once before capture, and hence can be used to test other F-based reference points for their conformity with this principle.

The use of suites of LRPs

Recognizing that such simple reference points are not easily intercalibrated, nonetheless there may be advantages in not relying on measuring a single LRP with high precision. It is believed that a suite of simple 'rules of thumb' based on past experience elsewhere can provide multiple calibratable reference points and that it is unlikely that unsustainable fishing conditions can occur without one or more of them registering this situation. Like any other harvest law, such an approach only forms part of the total management system, and the rapidity and effectiveness of the management response to a LRP changing from green to red will determine whether a harvest law attains the required precautionary objective. Given that this latter component of the management system cannot be specified by the workshop, the justification for choosing very sophisticated reference points that need regular adjustment seems less convincing.

A suite of reference points as proposed here could form one component of a feedback system as long as management is prepared to provide the other component by taking prompt action when most or all of the LRPs register that the fishery is no longer precautionary.

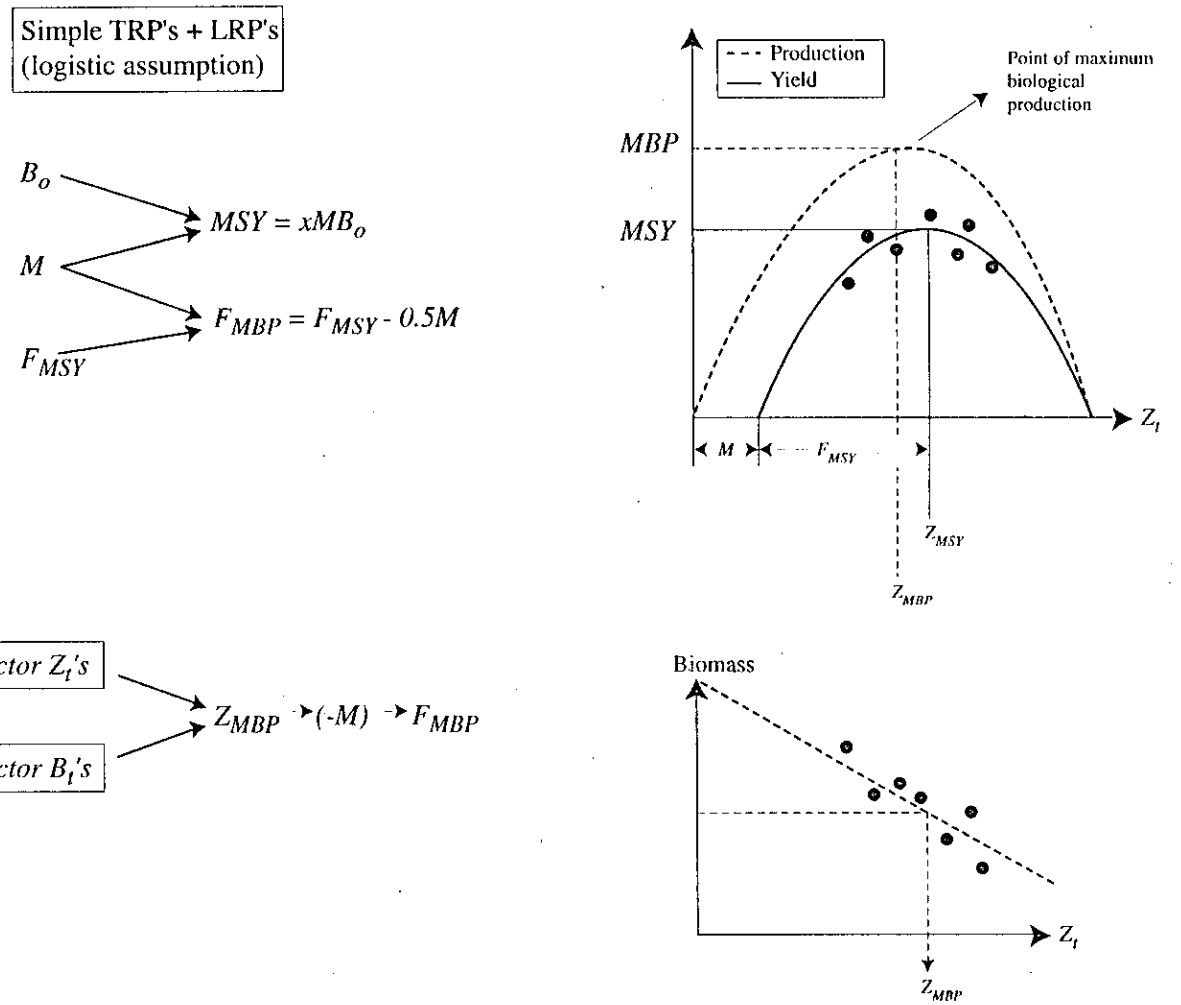

Fig. 1. Several reference points based on production and biomass (from Die and Caddy, 1997).

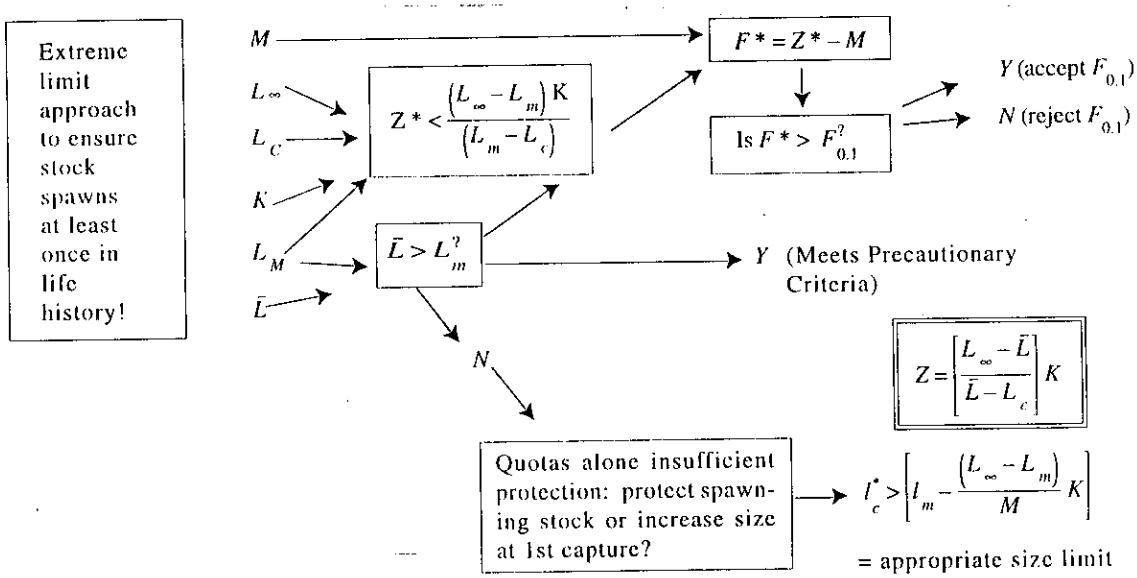

Fig. 2. Several simple size-based reference points formulated assuming that a precautionary approach should be to allow to spawn at least once in the life history (from Die and Caddy, 1997).

Following initial experience with such a suite of LRPs, management may make agreed adjustments which can either consist of modifying the LRP so as to reduce or increase the degree of precaution and/or change correspondingly the severity of management response when LRPs are exceeded.

It is suggested (Fig. 3) that a 'traffic-light' approach to the use of such limit reference points could be feasible and more easily understandable at all levels of the fishery management system, the management response being calibrated to be progressively more severe as the reference points pass from green to red conditions. Such a simple feed-back situation seems testable by simulation and could be still feasible in relatively data-poor conditions. An analogy can be made to systems of fuzzy logic which are progressively finding applications in control systems.

LRPs	STOCK "TRAFFIC LIGHT"	PRECAUTIONARY "TRAFFIC LIGHT"	
		# red lights?	Management Response?
$Z \geq Z^*$?	(Y)	5	Fishery Closure! (until at least 3?4? green lights?)
$B \geq 0.2\ B_o$?	(N)	4	Quota / Effort } Not to exceed 0.2* { MSY / f_{MSY}
$F \leq x.M$?	(Y)	3	Quota / Effort } Not to exceed 0.4* { MSY / f_{MSY}
$\tilde{R}_{t-n,t} \geq \bar{R}$?	(Y)	2	Quota / Effort } Not to exceed 0.6* { MSY / f_{MSY}
$F \leq$ [$2/3\ F_{msy}$? / $F_{0.1}$?]	(N)	1	Quota / Effort } Not to exceed 0.75* { MSY / f_{MSY}

= red = green

Fig. 3. A harvest law based on multiple LRPs integrated into a feedback loop incorporating staged management responses. A precautionary "traffic light" is envisaged, with variable (pre-negotiated?) management responses triggered progressively as the number of red lights increases signalling that LRPs have been exceeded.

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A Precautionary 'Traffic-Light' Approach for Deciding on the Importance of Management Measures and Limit Reference Points and as a Basis for a Multi-LRP Harvest Law

Table 1

Characteristics of historical landing trends
(After Caddy and Gulland, 1983, and Spencer and Collie, 1997)

Complete for each stock with single colour characterization

Environment	Past landing trend	Research priorities	Management actions
Stable ?	**No trend (GREEN)**	Check historical series. Investigate possible feedback mechanisms leading to 'stability'	Avoid exceeding recent/historical levels of exploitation/set cautious LRPs.
	Long-term trends?	*Possible concerns:* Climate change? Environmental forcing? Eutrophication? Simplified/changed food web? Behavioural change? Check biodiversity/ species interactions?	Thresholds should be based, inter alia, on biomass or R-based LRPs.
	Declining trend? (RED)	Check R! Check life history vulnerability/check variance in data sources/intensify surveys + environmental monitoring.	High level of precaution! Assume downward trend is continuing: adopt extreme precaution! Pre-negotiate responses/sharp effort cutback/negotiate stock rebuilding plan!
	Upward trend? (GREEN)	Has R increased? Change in effective effort/ availability? Predator temporarily scarce? New entrants? Misreporting?	Stock maintenance strategy/or constant harvest for stock rebuilding? Impact of increases on predators/prey?
	Regular fluctuations? (ORANGE)	Monitor R; Time-series analysis. Environmental linkages or predator prey fluctuations?	Forecasting possible? (Constant) escapement strategy with threshold? Biomass-or R-based LRPs?
	Aperiodic fluctuations? (RED)	Monitor environment/predators + prey. Time series analysis/VPA/Dynamic production models?	Constant exploitation strategy with threshold? Biomass-or R-based LRP's.
Unstable?	**Degraded?**	Habitat destruction? Stock depleted? Environment unfavourable or low spawning stock? Prey depleted?	Formal recovery plan with time schedule/clear objectives. Protect spawning/nursery areas/migration routes

Table 2

Characteristics of the environment and ecosystem

CRITERION	COMMENTS	GREEN	ORANGE	RED	MANAGEMENT IMPLICATIONS OF RED STATUS?	LIMIT REFERENCE POINT FOR RED?
Environment						
1. Latitudinal range	If a stock is close to latitudinal limits of species, stock size fluctuates more with environmental change.	The local fishery operates in the centre of the species range of distribution/few 'bad' recruitment years.	The annual recruitment declines when environmental conditions are extreme.	Recruitment is irregular, only being good in extreme (e.g. warm/cold) years.	Effort control leading to variable yields. Recruitment survey and periodic closures following 'bad' R years?	If R index falls significantly below mean value for n consecutive years, prepare to reduce catches/effort drastically.
2. Life-history vulnerability	Stocks with restricted range at one or more life history stage are vulnerable.	Stock occupies a large uniform environment throughout its life history.	Stock occupies a more restricted and variable environment during some critical life history stage.	Stock occupies a small, vulnerable, very variable environment during critical life history stage(s).	Pay attention to linkages with other societal sectors affecting nursery areas (pollution?): take (legal?) remedial action.	Recruitment and environmental monitoring of nursery areas or critical habitats. (Recruitment-based LRP as above).
3. Presence of unfishable areas in stock range	Refugia may be created by unfishable conditions.	Large part of stock area unfishable/no access.	Significant percentage of stock areas inaccessible.	All stock areas fishable.	Could consider closure of areas/ marine parks.	N/A
Predators and Prey						
4. Relative number/ value of predators	The status of predator populations and their food needs is a key issue.	The predators on the stock are depleted/ few/subject to heavy fishing/higher in commercial value than the target species.	The predators are moderately abundant/several/ subject to sustainable fishing/ similar in commercial value to prey.	The predators are very abundant/ many/of low commercial interest/ low rates of exploitation.	Promote balanced exploitation of food web components. Fit predator-prey model as basis for prediction?	Monitor predator/prey relative abundance as means of forecasting, e.g., increased M on juveniles. Use to develop predator-based LRP?

Table 2
(continued)

Criterion	Comments	Green	Orange	Red	Management implications of Red Status?	Limit Reference Point for Red?
5. Relative number/ value of prey	Predators dependent on a few, dominant food items depend on adequate biomass of these.	The prey species are diverse and not subject to significant fishing pressure/are not subject to serious abundance fluctuations.	The prey consists of only a few species, most of which are commercially fished/ are subject to moderate abundance fluctuations.	The prey consists of one or two species, which are heavily fished/are subject to serious abundance fluctuations.	Ditto. Allocate a biomass share of prey to predators.	An index of relative predator/prey abundance could warn of stock downturns or, vice versa, favourable conditions for harvesting.
6. Vulnerability to fishing gear	If gear is efficient for all ages, escapement depends solely on effort.	Only some age groups vulnerable to fishing in only part of range with current gear, i.e. refugium exists.	Fishable age groups available throughout range with current gear.	All age groups fishable throughout all range with current gear; high discarding or incidental mortality.	Monitor and regulate via discarding penalties/develop selective gear/take measures (seasonal/ area closures?) to ensure adequate escapement to spawning.	Use discard data (from observers or surveys) as basis for closure of areas of juvenile concentration. (Black- box systems useful to reduce costs of MCS.)

Table 3

Characteristics of the stock

CRITERION	COMMENTS	GREEN (TRP?)	ORANGE (LRP?)	RED (LTP)	MANAGEMENT IMPLICATIONS OF RED STATUS?	LIMIT REFERENCE POINT FOR RED?
1. Recruitment regularity		Annual recruitment is regular, and variation occurs within a limited range.	Annual recruitment occurs but is very variable.	Annual recruitment occurs intermittently.	(See Table 1.1)	(See Table 1.1)
2. Stock definition?	Absence of data on stock admixture seriously compromises stock assessment results.	Stock status clear with relatively minor admixture with adjacent stocks.	Stock status debatable/could be some admixture with adjacent stocks which are nominally managed separately.	Stock status unknown/likely to be mixed stocks/species managed together.	Genetic/tagging investigations a priority to define/separate stock/species components and extent of intermixing.	Precautionary reference points should be based on conservation of the most vulnerable of the suspected stock/species.
3. Surveys?	Current thinking gives more credibility to direct biomass estimates than from commercial statistics.	Properly designed surveys of stock area at least annually.	Occasional surveys of part or whole of stock area/fishery prospections.	No surveys or direct biomass estimates.	Priority to be given to a direct estimate of stock.	Once there is a survey in place, S-R and other sophisticated LRPs can be developed.
4. Biomass (of spawners?)	Levels of cut-off to be set based on species biology.	>30%? B(0)[1]	20-30%? B(0)	< 20%? B(0)	Need for immediate stock recovery plans/implement pre-negotiated drastic effort reduction.	20% B(0)?

[1]Virgin stock biomass

Table 3
(continued)

CRITERION	COMMENTS	GREEN (TRP?)	ORANGE (LRP?)	RED (LTP)	MANAGEMENT IMPLICATIONS OF RED STATUS?	LIMIT REFERENCE POINT FOR RED?
Vulnerable to recruitment/overfishing?						
5. Fecundity (MLF = Mean Lifetime Fecundity)	(Range from high-fecundity species to vivipary or brooding of young).	High (MLF = 200 000 - 1+ million?).	Fecundity medium (MLF = 10 000 - 200 000).	Fecundity low (< 10 000, or even (ov-/vivipary)	Monitor population fecundity/egg + larval surveys?	Especially for lower fecundity species, use life history table to determine F-based LRP's?
6. Age/size at maturity l_m [2] (Relative to size at = 0% gear retention l_c).	Species that are exploited before maturity are more vulnerable.	Small ($l_c \ll l_m$)	Roughly equal ($l_c = l_m$)	Large ($l_c < l_m$)	Be especially careful to keep exploitation low enough to avoid spawning stock depletion! Perhaps close areas of concentration of spawners/adults?	Use Z^2 as LRP. Use F-based LRP (within an escapement strategy?).
7. Marked spawning aggregations occur	Vulnerability of spawners and spawner areas well known.	Spawning diffuse, year round/closure during spawning season/lower value for ripe fish.	Spawning aggregations diffused, or not easily fishable or seasonal fishery/high value for spawners.	Spawning grounds well known, easily fishable/open year round and restricted in extent/'Ripe' fish command high prices.	Close/restrict access to spawning areas seasonally? Reinforce MCS[3] measures at this time. Monitor escapement.	Set escapement-based control measures such that 20?30? etc., escapement reference points are established.
8. Nursery areas	A localized nursery area close to coast is vulnerable to various impacts.	No nursery area: Juveniles everywhere in range.	Juveniles restricted in extent and season.	Associated with vulnerable/restricted habitat/in estuaries, lagoons, mangroves, etc.	(Seasonal) Closure of nursery areas, especially towed gear in contact with bottom. Annual survey of nurseries	Mesh/gear limitations? Develop recruitment index?

[2]Monitoring, control and surveillance
[3]See Die and Caddy, 1997

Table 3
(continued)

CRITERION	COMMENTS	GREEN (TRP?)	ORANGE (LRP?)	RED (LTP)	MANAGEMENT IMPLICATIONS OF RED STATUS?	LIMIT REFERENCE POINT FOR RED?
9. Species changes sex with age, or large dichotomy in growth by sex	Some fish, e.g. groupers, change sex with age; others grow at different rates, e.g. hakes.	No sex change/ growth difference with sex.	Minor changes but requires separate assessment by sex?	Wide difference between sexes in growth/range etc., or protandric/ protogynous hermaphrodites.	Avoid heavy fishing that unbalances sex ratio by fishing out individuals of larger sex.	Monitor sex ratio, and use as basis for a LRP?
Total mortality rate (Z) Useful if M uncertain, or death due to causes other than fishing can be important						
10. Z < Z(MBP)?[4]	Maximum Biological Production, e.g. Logistic Model, is Reference Point when total production (to fishery and predators) is maximized.	Z < Z(MBP)	Z = Z(MBP)	Z>= Z(MSY)	Monitor size/age composition to estimate Z.	Define Z-based LRP
Fishing mortality rate (F) (Z > Z?)[5] Assumes knowledge of M for VPA, or from catch curve analysis						
11. F(MSY) = M?[2]	Use of empirical LRP (based on similar stocks?)	(Demersals or low M species?)	(Small pelagics or high M species?)		Base cut-off points on experience with similar species?	Define and apply M-based LRPs.
F(MSY) > M?	ditto		(Demersals or low M species?)	(Small pelagics or high M species?)[6]	ditto	ditto
F(MSY)>>M?	ditto			(All)	ditto	ditto

[4]See Caddy and Csirke, 1983
[5]See Garcia, Sparre and Csirke, 1989
[6]See Patterson, 1992

Table 4

Characteristics of the fishery

CRITERION	COMMENTS	GREEN (TRP?)	ORANGE (LRP?)	RED (LTP)	MANAGEMENT IMPLICATIONS OF RED STATUS?	LIMIT REFERENCE POINT FOR RED?
1. Allocation of rights?	Fisheries where no rights allocation = open access are doomed to overcapacity/ decline!	Rights allocated completely/good industry/gvt cooperation/ITQs or community-based.	Some sectors are not included in rights allocation/ controversy over rights between participants.	No allocation of rights.	Move as soon as possible to specific allocations/user rights.	Use MCS-based index of infringements as measure of uncertainty of situation?
2. Management structure?	Is there a clear line of authority and action in management? If not, crucial decisions will not be made in timely fashion.	Management operates through clear structure of decision-making based on objective data accepted by participants.	Management decisions may be overridden by political considerations: decision tree is ambiguous.	No single body with clear management authority over whole stock area exists	Develop as soon as possible a clear decision making structure for management	N/A
3. Is there a management plan/decision rule/harvest law?	Agreement on long-term objectives is essential to proper management.	A harvest law exists, dictating when LRPs are triggered, and long-term objectives are met.	A number of (conflicting) objectives between stakeholders not yet resolved.	All decisions are made ad hoc and subject to detailed negotiation on annual basis	Move to structured plan based on proper simulation of likely futures, and contingency plans in case of failure	Adopt management plan/harvest law based on estimates of probability/risk.
4. Fishing strategy?	Problems of conflict between stake-holders weaken possibility of proper management.	Typically only one stock fished per trip/no transhipment at sea/data verified by observers and/or satellite-transponder system.	Some boats may fish two and more stocks in a single trip/transhipment at sea occurs/data from log books/port interview.	Fleets fish two and more adjacent stocks in a single trip/transhipment at sea frequent/no observer systems or log books.	Seek to negotiate allocations/fishing zones by fleet and consultative process. Do comparative fishing power analysis.	Use one or more fleet statistics as index of stock changes.

Table 4
(continued)

Criterion	Comments	Green (TRP?)	Orange (LRP?)	Red (LTP)	Management implications of Red Status?	Limit Reference Point for Red?
5. Is there a formal assessment?	In absence of regular (not necessarily annual) assessments, management is 'seat of the pants'.	A formal assessment has been prepared annually for a series of years and showed stock to be less than fully exploited.	The last assessment of the stock was some years ago, and showed stock to be fully exploited, but catch rates are holding up.	No formal assessment has been made, but there is symptomatic evidence of declining catch rates.	Priority to preparation of formal assessment/set precautionary reference points based on available data.	Probably assessment will allow precautionary reference points based on S-R/ biomass/total mortality.
6. Damage from fishing/discards	High discarding, if not properly recorded, leads to misleading information on stock status.	Low-level incidental damage/discarding in this or associated fisheries/high survival discards.	Moderate level incidental damage/ discarding/most survive.	High incidental damage by fishing/ high discards/few survive.	Close vulnerable areas to dragging gear/measures aimed at reducing discarding.	Monitor discards and use as ecological impact/ or monitor juveniles discarded.
7. Target species caught incidentally in fisheries aimed at other species	The by-catch of a depleted stock in another fishery can lead to commercial extinction if not controlled.	The 'other fishery' is small/localized in extent with respect to range of target species/is seasonal/is strictly regulated.	'Other fishery' coincides in extent with target species fishery/is of same size and importance/is almost year round/is loosely regulated.	'Other fishery' is larger than that for target species/is of greater importance/ is year round/is unregulated.	Ensure regulation of 'other species' has provisions to control by-catch/discards/ upgrading. Monitor and close areas temporarily with high level of discards.	The proportion of catch of target species in catch can be used as LRP for management of 'other species?

Table 4
(continued)

Criterion	Comments	Green (TRP)	Orange (LRP?)	Red (LTP)	Management implications of Red Status?	Limit Reference Point for Red?
8. Unit value of species	High value species are subject to infringements, even when depleted, which are difficult to detect.	The target species is of low value/price is independent of local abundance/the targeted fishery ceases at low catch rates/is not an important by- catch of other fisheries in region.	The target species is moderately valuable/ price goes up with decreased local abundance/and the targeted fishery ceases when catch rates drop to low levels.	The target species is highly valuable/price rises rapidly as local abundance declines/ occasional fishing will persist even on highly depleted stocks.	Access rights to be tightly enforced with monitoring through to consumer. MCS measures will need reinforcing, even on other fisheries taking species incidentally. Recovery plans for the stock must be agreed to.	Minimum biomass- or spawning stock-based measures will need developing, and possibly stock-recovery strategies.
9. Catch trends	Sharp increases in catch or sharp declines may presage problems.	Catch has been stable for a number of years.	Catch has been declining slowly.	Catch has declined sharply in last few years.	Monitor catch trends and correlate with size distribution changes.	Define a LRP based on, e.g., lower quartile of long-term catches?
10. Fleet trends	Evidence of new fleets/new gear/larger gear is index of future problems.	Fleet stable in size with same gear over last decade.	Fleet slowly growing/more powerful boats/ becoming more efficient/new gear being adopted.	Sharp changes in fleet size/power/strategy/ gear applied.	Monitor fishing power and licenses in fishery.	Use total HP as index of changes in fleet or better, use survey index.