Sustainability indicators for fisheries: their use in fisheries management. Part II

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This paper discusses a variety of different approaches to fisheries management, asking if it is possible to assess a fishery using ecological or economic criteria, and if so, what is assessed? A Fisheries Management Plan for the geographical management unit and its resources is needed, where ideally management measures should be dictated by "fisheries control rules" drawn up under precautionary principles suggested by the Code of Conduct for Responsible Fisheries. Licensing issues affect how fishing effort control in multispecies fisheries may operate, with the focus on management methods actively controlling fishing power and effort. Combining effort control with the closure of areas of ecological importance seems to provide a context that protects spawners and recruits as well as protected species. The Traffic light approach is suggested as a management aid in situations where a wide range of ecosystem and environmental issues are important, and need to be reviewed first, before a particular management framework, guided by multiple indicators, is set up for a properly managed multispecies fishery. This raises the issue of what constitutes 'best practice' in ecosystem management, and although stock assessment is needed to identify where single species fisheries are in relation to their reference points, a broader range of indicators are available than catch, effort and size composition which will contribute to ecosystem management where biodiversity issues are important. This paper is the second part of one published in *Ciencia Pesquera* 18(2) in November 2010: "Biological indicators and their use in stock assessment to achieve sustainable levels of fishing."
Key words: Environmental and fishery reference points, empirical management, control rules, fishery management plan, traffic light approach, ecosystem management, biodiversity.

Indicadores de sustentabilidad en pesquerías: su uso en el manejo de las pesquerías. Parte II

Se presenta una variedad de diferentes enfoques de la gestión pesquera, a la vez que cuestiona si es posible evaluar una pesquería con criterios ecológicos o económicos y, si es así, ¿qué se evalúa? Es necesario instrumentar un *plan de manejo pesquero* para la unidad de gestión geográfica y sus recursos, donde idealmente las medidas de gestión deben establecerse por "reglas de control de la pesca" elaboradas conforme los principios precautorios sugeridos por el Código de Conducta para la Pesca Responsable. La operación de las licencias afecta el esfuerzo pesquero en las pesquerías multiespecíficas, con énfasis en los métodos de manejo que controlan activamente el poder de pesca y el esfuerzo. La combinación del control del esfuerzo con el cierre de zonas de importancia ecológica parece proporcionar un marco que protege a los reproductores y reclutas, así como a especies protegidas. Se sugiere el enfoque semáforo como una ayuda para el manejo en situaciones donde asuntos de una amplia gama de ecosistemas y ambientes es importante, y deben revisarse primeramente, ante un marco de manejo en particular, con la guía de múltiples indicadores, para establecer un buen manejo de las pesquerías multiespecíficas. Esto plantea el cuestionamiento sobre cuáles son las "mejores prácticas" en el manejo de ecosistemas y, aunque la evaluación de la población es necesaria para identificar cómo se encuentra la pesquería de una sola especie en relación con sus puntos de referencia, existe una gama más amplia de indicadores, además de captura, esfuerzo y composición por tallas, que contribuirá al manejo de los ecosistemas donde la diversidad biológica es importante. Este artículo es la segunda parte del publicado en *Ciencia Pesquera* 18(2) en noviembre 2010: "Indicadores biológicos y su uso en la evaluación de poblaciones para lograr niveles sustentables en la pesca."
Palabras clave: Puntos de referencia ambientales y pesqueros, manejo empírico, reglas de control, plan de manejo pesquero, enfoque de semáforo, manejo del ecosistema, biodiversidad.

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Who does the assessing and how and what is assessed?

Often national fisheries in developed countries are assessed by the staff of government institutes with key personnel holding a doctorate or equivalent qualifications in applied population biology, statistics, or population dynamics. Sometimes overseas consultants may be hired to overview the results of such calculations, but since these calculations are typically carried out on an annual basis with supplementary activities and specialized staff dedicated to data collection, age reading, research vessel surveys, it is largely impractical to subcontract all these activities to the private international sector, although in some developed countries and some fisheries commissions this is occurring, especially where the fishing industry is contributing to the cost of research and data gathering. One aspect that can be commented on here is that since the institute concerned usually comes under the ministry responsible for fisheries management implementation, government scientists may be placed in a difficult position if their advice is that very low exploitation rates are required to rebuild the stock. Since in this case the fishing industry representatives usually have closer access to the ear of the minister than his technical advisers, decisions have been known to 'average up' the level of quota or effort, above, the range of options proposed by technical staff.

Usually what is assessed is the capacity of the resource to produce "sustainable yield", according to the biological parameters of the resource, or in relation to standardized levels of fishing effort or fishing mortality based on past responses of the resource to different levels of effort exerted in the past. Economic analyses may also be carried out, although this is not always the case, and not usually on an annual basis. Fisheries economists may often intervene at a higher level in the decisional process, taking more into account socioeconomic and market forces than fisheries assessments. "Bioeconomic analysis" resulting from the cooperation of assessment scientists and economists seems potentially an important joint role, but does not yet appear to be commonly practised, though in some countries but few fisheries Commissions to my knowledge, it is more commonly seen than previously, when the two professions and their disciplines were usually kept separate.

The annual cycle for fisheries management as practiced by many commissions or national departments responsible for fisheries within EEZs, broadly resembles the sequence in *figure 1*. At least once a year (and in some jurisdictions twice), data inputs allow research personnel to generate evaluations of resource status and fleet capacity, and to formulate management options and estimate their likely consequences on the stock. A consultation procedure then typically follows as advice is consolidated by discussion between scientists and managers or operational staff, and sometimes with industry representatives, before, typically, a political overview occurs. This may involve the need for some form of legislation, or more typically, regulations are formulated which delegate decision-making on fishing effort or level of allowable catch, to the fisheries managers concerned, giving them some operational discretion. Allowable shares in this case are typically divided up between fleets, communities, gear types or individual vessels licensed to fish, following criteria that ideally are published in the public domain.

In recent decades devolution of management decision-making to the fishing industry has occurred in some jurisdictions, and mechanisms such as Individual Transferable Quotas (ITQs) or Community Based Quotas may be applied, where the right to fish is strictly controlled but delegated in part to local government bodies. In the case of ITQs, fishing rights have acquired an economic value and can be traded. In practice, this mechanism has been hailed as providing an incentive at the individual harvester level to purge excess effort from the fishery. With community-based management, decisions at the community level are also supposed to constrain access to those fishermen who have won the right to harvest due to precedence or through some competitive process within the community. Both approaches are called "rights-based" (See Shotton, 2000), and are often believed to represent a promising step forward in ensuring that it is the rights holders not just the government, who are responsible for proper management.

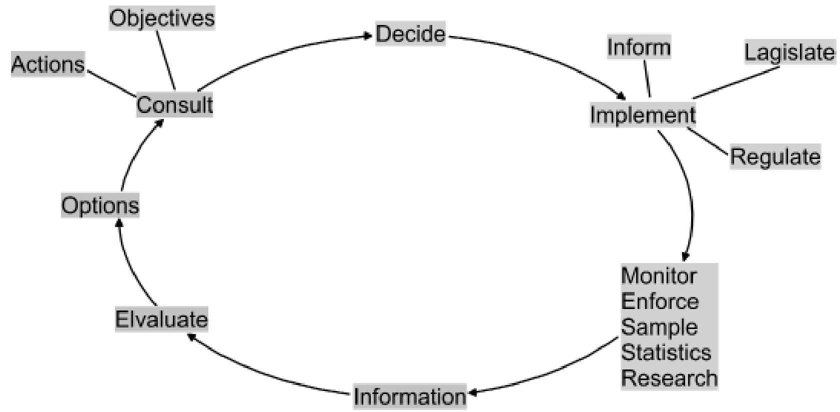

Fig. 1. Political framework to idealized "management cycle" repeated annually and as intended to link scientific data collection and analytical functions, consultation with the fishing industry, political decision making and its enforcement in a single mechanism (taken from Caddy, 1999).

From an ecological perspective, Robert Costanza (1991) and others have proposed that three aspects are vital to the sustainability of a healthy ecosystem; these could also provide important criteria for considering a fishery ecosystem's response to exploitation or to other environmental impacts:

1) Vigor: The ability to maintain a high and sustained productivity.
2) Organizational stability: The ability to maintain its internal structure and functions
3) Resilience: The ability to achieve *1)* and *2)* in the face of external stresses.

Extending these qualities to also include social and economic aspects of a fishery, some criteria of relevance to fisheries may be suggested in *table 1*.

Table 1

Classification of indicators for vigor, organization and resilience that may be used in deciding fisheries policy

Category	*Vigour*	*Organization*	*Resilience*
Ecological	- High primary production/ unit area. - High and diverse multispecies production.	- High biodiversity, and high diversity of exploitable species. - High diversity of economic products. - Fishery of central importance sociologically, with many participants. - Critical habitat are protected.	- System recovers quickly from stresses? - Is ecosystem sensitive to small errors in management? - Can sensitive or protected species be conserved by small changes in exploitation strategy? - Are critical areas/habitats such as spawning nursery areas protected? - Are prey species on which commercial species depends protected?
Biological	- High and stable production of key commercial species.	Prey and predator populations are not threatened by anthropogenic factors. - Critical habitats are not degraded by human actions.	Does the species harvested show increasing fluctuations in abundance or recruitment collapses as fishery intensifies?
Social	Stakeholders and managers are sensitive to limits of productivity. Access to the resource is limited and effort is controlled.	- Agreements between resource users are in place. - There is a high awareness of limits to productivity. - Conflicts with other users are limited. - Environmental externalities are limited.	Is the equity in the resource and the management system easily affected by human (e.g. political) actions? Does the management infrastructure provide for dispute resolution between users?
Economic	Is the return on investment positive?	Are the economic objectives of different user groups reconciled and means for reducing overcapitalization in place?	Are there mechanisms within the fishery law for reducing fishing effort without excessive economic losses?

Modes of overfishing

Fisheries management should take into account that the impact of fishing may take various forms, and that there are other forms of anthropogenic stress to take into account, and if possible correct (Table 2).

A similar table was suggested in relation to Black Sea fisheries, largely based on *table 2* which makes the point that not only fishing leads to impacts on resources (Table 3).

Table 2
A classification of types of overfishing (based in part on Regier *et al*., 1999)

Mode of overfishing	*Definition*	*Qualifications/comments*
Growth overfishing.	Fishing rate on existing year classes in the fishery beyond FMAX or F0.1 so that yield/recruit is suboptimal.	
Recruitment overfishing.	Fishing rate that reduces the probability of future recruitment.	Reference points should be aimed at conserving spawning stock and/or responding to reduced recruitment.
Economic overfishing.	Fishing rate that reduces the economic returns to unacceptable levels.	Measures are needed to control excessive investment in the fishery.
Overfishing by national industrial scale vessels within their EEZ for export.	Fishing beyond yield optima, however defined, by industrial scale vessels.	This category may include overfishing by distant water fleets, or on shared/straddling stocks and in intnt'l waters.
Local overfishing from adjacent communities by small scale or artisanal fishers.	Fishing beyond yield optima, however defined, by small scale fleets.	Where rights of access are not restricted, small scale fishers can lead to overexploitation.
Spatial or interceptive overfishing.	Overfishing in critical areas or zones of passage where the stock is especially vulnerable.	Includes fisheries where the stock is concentrated (e.g. spawning, nursery areas or estuaries and narrow straits on migration routes.
Ecological overfishing.	Overfishing that has negative impacts on other species in the ecosystem, and on their habitat.	Here several subcategories are given below:
Overfishing of predators or prey.	By reducing prey species, predator stock levels will be reduced by starvation. Concerns with predator declines due to their proposed role in health of prey populations.	There needs to be a decision on the relative sizes of these populations, bearing in mind their sensitivity to overfishing and trophic needs.
Habitat destruction/ modification.	Indirect effects of fishing or other human activities that reduce productivity of habitats critical to fishery resources.	Examples here are loss of 'vegetative' bottoms (e.g. mangroves, sea grasses, corals) necessary to early life history stages due to dragging gear on bottom, or coastal pollution/sediment deposition.
Overfishing of protected or charismatic species.	Effects of fishing on marine turtles, mammals, birds, sharks and long lived/ slow-growing species.	May be tackled by modifying gear or fishing method, or by avoiding seasons/areas of high risk of incidental capture.
Indirect overfishing or through by-catch.	A broader category including the last one, but also applying where multispecies fisheries operate.	In general, main incidental effects of overfishing on by-catch are those affecting juveniles, slow-growing and low-fecundity species whose optimal fishing rate is lower than for target species.

Table 3
Fishery and environmental stresses on a resource: the Black Sea example

Types of overfishing that lead to stress		*Similar stresses caused by environmental changes or other anthropogenic effects*
1	Growth overfishing.	Selective environmental changes that eliminate older fish (*e.g.* dams?)
2	Recruitment overfishing.	Environmental impacts that selectively kill larger, mature fish (as above), or adversely impact spawning or nursery areas (*e.g.* point pollution sources)
3	Economic overfishing.	Any goods or services provided adjacent to, or in an aquatic environment, that lead to excess investment and its side effects on the aquatic habitats through consequent environmental degradation.
3a	- Industrial overfishing.	Side effects of industrial-scale investments or developments adjacent to, or within the watershed or adjacent to the aquatic environment, that affect it, and therefore its fish populations.
3b	- Overfishing by distant water fleets.	Effects of industrial scale investments or activities by non-locals with domicile distant from the impact area (e.g. pumping ballast tanks for shipping; oil spills from shipping; acid rain from non-local industrial plants)
4	Overfishing by artisanal fishers.	Any impacts from small-scale local activities close to the coast such as tourism, yachting, scuba etc.
4a	- Local overfishing from adjacent communities.	Local pollution/habitat modification, which are most pronounced adjacent to coastal communities – such as anchor damage by moorings on coral reefs, effects of sewage disposal or locally intensive aquaculture effluents.
5	Ecological overfishing.	Generally, any anthropogenic factor other than fishing that disrupts food webs, such as nutrient outflows that lead to algal blooms, reducing light penetration to sea grasses which form nursery areas for important commercial species such as shrimps.
5a	- Sequential or interceptive overfishing.	Effects of human activities that block migration routes – (e.g. pollution of the Bosphorus could be affecting migrations of bonito into the Black Sea from the Mediterranean through this narrow strait).
5b	- Overfishing of prey.	Ecosystem impacts of other anthropogenic activities that affect organisms lower in the food chain, where *e.g.* blooms of exotic algae are not edible to larval fish.
5c	- Overfishing of predators.	e.g. impacts of human activities such as coastal developments or tourism on turtle/seal breeding sites. Or effects of diseases (e.g. canine distemper from human pets or from hospital waste on seal and porpoise populations)
5d	- Overfishing of keystone or 'sensitive' species.	Similar impacts on habitats/environment from other anthropogenic activities to 5a -5c.
5e	Overfishing of competitors of target species (thus unbalancing the food web).	Introduction of exotic species which out-compete native fauna.
6	Habitat destruction/modification by towing fishing gear on the sea floor.	Bio/geo/chemical modifications to adjacent aquatic habitats by land reclamation, watershed runoff, dredging, etcetera.
7	Spatial overfishing.	Impacts of other human activities such as coastal development, in specific zones which pose risk to resident or migratory species.

Recent changes in the approach to fisheries management

Over the last decade since the UNCED conference, widespread changes have occurred in the objectives expressed for fisheries management, which evidently have taken into account the various modes of overfishing listed in *table 3*. This change in perspective obviously affects how judgements on the success of fisheries management measures are made. *Table 4*, modified from Garcia & Grainger (1997), lists some different management objectives. Many fisheries still follow procedures listed in the first column, but fairly dramatic changes in procedures have occurred in developed country areas, and these are still not general elsewhere. Nor is the scientific and bureaucratic infrastructure and funding to support the approaches listed in the last column always available. It is clear however that there should be an interest in having access to precautionary indicators that measure the changeover from column 1 to column 2, and the procedures in the third column that make these objectives feasible.

The work carried out by a management authority is of course divided up between different specialities and categories of personnel. One convenient way of dividing the overall task between them is to use the PSIR classification (Table 5) described in the first part of this paper (Caddy, 2010). This also could be the basis for an overall monitoring of resource management functions.

The Response indicators in *table* 5 are assumed to be largely the responsibility of the Monitoring Control and Surveillance (MCS) arm, after appropriate consultation with stakeholders. MCS should ensure that the fishing industry is respecting the need to maintain effective effort levels in check. Specific committees should consider fleet replacement plans and proposals. Technological developments will presumably also need to be carefully monitored in order to keep an overall cap on the inevitable growth in fishing pressure that can result from neglect of these aspects.

The geographical management unit

The context of management is usually a statistical or stock area, called in the Mediterranean a Geographical Sub-regional Area (GSA). This is believed to hold a “unit stock” of a given species of commercial importance. This stock may be a

Table 4
Changing objectives in scientific management of fisheries

A change in objectives: From	*To*	*New tools and procedures*
Exploiting target stocks target stocks by aiming at a target reference point.	Avoiding stock collapses, sustaining ecosystems: protected species and biodiversity conserved.	Multi-species indicators and ecosystem reference points defined. Precautionary procedures and limit reference points adopted.
Maximizing annual catches.	Seeking economically efficient fisheries that provide for food needs and employment.	Collecting data to create indicators that monitor the fishery from recruitment on the grounds to consumers.
Open access situations apply.	Limited entry regimes, (marketable) user rights, community-based rights; devolvement of some management rights from government to industry.	More efficient and extensive data collection, storage and data access to agreed stakeholders through computerisation and the WWW.
Top-down management and risk-prone measures.	Risk-averse and precautionary approaches adopted.	Changing from deterministic to probability-based fisheries models.
Focusing on short term decisions.	Working through a fisheries plan that dictates appropriate actions for a wide range of possible eventualities.	Achieving agreement on a long-term Plan with industry. NGOs to monitor application of the plan and ensure public involvement.

Table 5
A purely hypothetical division of labour using a PSIR framework for monitoring a fishery and its environment

	Pressure	*State*	*Impact*	*Response*
Time frame	Annual & Longer term.	Annual	Annual	Real time collection and responses.
Personnel	Research, environmental & statistical officers.	Research and assessment workers.	Research and assessment workers.	Monitoring, control and surveillance (MCS).
Roles	Collect + collate data sets, survey results, & develop indicators with measures of variance.	Develop data sets into series of indicators using simple models where necessary.	Collaboration between all sectors to decide on indicators, LRPs, and the current distance of indicator from the agreed LRP.	Ensure a collective fishery law is equitably applied, and that responses to critical values of indicators are enforced.
Performance measures of:	Appropriate data coverage; prompt collation of information	Cross calibration of indicator responses to ensure changing stock and environment status are correctly monitored.	Develop consensus around LRP values that are precautionary. Assess probability that current values infringe pre-agreed LRP levels.	Good communication with industry to ensure that rationale for indicators, LRP s and appropriate responses are understood, and industry inputs are incorporated.

genetically separate entity, a “metapopulation” consisting of adjacent sub-populations that may mix, or simply be the adult fish occupying that area whose degree of mixing with adjacent populations is assumed to be low, but usually has not been quantified. Population genetics is now beginning to be applied to marine fish stocks, but few of them have been characterised in terms of their genotypes as yet: a *stock* may occupy separate grounds as adults, but larvae from adjacent adult stocks may mix and be dispersed in the plankton. This may all seem very theoretical, but population models are emerging that show that this aspect may result in different responses to management measures.

The resources of an area may be fished by one or several “Operational Units” (OU) – a term used in the Mediterranean to describe a group of homogenous vessels of approximately the same size using a similar fishing method. In the Mediterranean Commission (GFCM) the definition of an Operational Unit is:

“For the sake of managing fishing effort within a Management Unit, an Operational Unit is the group of fishing vessels practising the same type of fishing operation, targeting the same species or group of species and having a similar economic structure. The grouping of fishing vessels may be subject to change over time and depends on the management objectives to be reached”.

In general, if an OU is the *only* group of vessels fishing a particular resource wherever it is located, the summarised effort data exerted, and the catch realized by this OU, can be used in a standard production modelling approach. However, in the likely case that more than one OU, or a Local Operational Unit (LOU) based in a given port is fishing the same resource in another Geographical Sub-regional Area (GSA), then of course the issue of standardisation and combination of the data generated by each OU must be resolved before an effort-based resource assessment can be attempted. If the intent is to measure the economic performance of a group of vessels fishing resources from different stocks in all areas within access of the port (or on the high seas), the approach will have to be rather different, and perhaps the definition of targeted resource can be less precise. Nonetheless, Accadia & Franquesa (2006) recommend that *areas occupied by distinct populations of various species be clearly established before an inventory of OU ´s is formulated.* This seems sound advice, and the present paper, as for all approaches aimed at assessing and managing a resource in a sustainable fashion, assumes this has been done.

In addition to the issue of measuring/standardising the fishing effort exerted by an OU on a group of resources within a given GSA, we have to acknowledge that a unit resource may be fished by two or more OU's whose economic structures are *not* similar (*e.g.*, a trawler fleet and a fleet of inshore vessels using gill nets). If so, then their catch (and after fishing power inter-calibration the fishing effort and intensity they each exert), will have to be combined to arrive at a useful resource assessment.

Effort definition in multi-gear, multispecies fisheries

The problem of implementing resource management by effort control for multispecies fisheries is a methodological one, where there is relatively limited experience to point the way. The common approach of catch quota control has not proved an unmixed success, since early filling of one species quota in a mixed species fishery leads to discarding of fish for which no quota is currently open. One other consequence of mixed-species fisheries is that short-lived, high fecundity species can usually withstand a higher fishing pressure than slow-growing, low-fecundity species such as most sharks for example. As a result, as fishing effort increases, the species composition will inevitably change, which suggests that one might use relative species composition of fast and slow growing species to measure overall fishing pressure. At the same time, setting aside a significant proportion of closed areas or MPAs to protect fragile environments and species, could coexist with effort control, and can serve the additional purpose of protecting nursery areas and providing spawning refugia.

A simple approach to effort control

(The following 2 sections comes from Caddy (2004a) on effort control in the Mediterranean)

Considering the issues just mentioned, the paper of Shepherd (2003) noted that the quota system as applied in the North Atlantic "is no longer adequate", and certainly has not halted declines in key stocks. The difficulties with the TAC or quota approach he mentioned are:

- Assessments need to be updated annually
- Assessments must be accurate to better than (+ -) 10%, if TAC's are to be set correctly, which is at the limit or better than the usual level of precision achieved
- Under-reporting or misreporting is common, and undermines the whole quota system
- Discarding a species in a mixed fishery when its quota is filled is common practice, but is not recorded and hence biases assessments.

He advocated some form of effort control, which has the advantages that:

- The level of fishing mortality is restrained directly,
- The level of fishing only needs occasional adjustments as fishing power slowly increases.
- Landings will vary from year to year, but do not need to be predicted, and it is not necessary to know stock size to a high accuracy.
- Occasional assessments require biological sampling of catches and surveys to correct for slow changes in fishing power, but assessments need not be annually.
- The discard problem will largely disappear, and the small fish problem will be addressed by closing nursery areas.
- Equity between fleets/countries will be easier to maintain, involving shares of an overall total of standard fishing effort units, though swaps or loans of effort allocations will be allowed between participants on a short-term basis.
- "Days at sea" is perhaps the most logical effort measure, but set at the individual vessel level.
- Due to slow increases in efficiency, compensating reductions will need to be applied from time to time, and he envisages these as requiring some state intervention.

Shepherd emphasized that fine-tuning of the fishery by management is impossible under this framework (unless presumably actually days at sea is the regulatory measure used), since controlling capacity units is largely a coarse-tuning measure. As he noted, TAC control has not worked as a conservation measure for most species, and in a mixed fishery such as most trawl fisheries, management separately by key species will also be difficult to achieve, and as he said, is "largely a mirage" under TAC control; simply increasing the discarding problem, and eliminating slow growing or less fecund species. Decommissioning of old vessels and their replacement by smaller ones, will be the best opportunity to correct for fishing power "creep" mentioned elsewhere in this paper.

The key to Shepherd's proposal is the maintenance of an accurate track record of both catch and effort for individual boats and combining these for fleet segments or OUs; if necessary, after inter-calibration. The share of the total recorded catch taken by each boat for a given number of fishing days registered will provide the basis for the fishing effort calculation and eventual effort allocation – thus avoiding the need to do specific fishing power calibrations. The number of standard effort units, fv_i exerted by the ith vessel as a proportion of that for the fleet as a whole, is in roughly the same proportion as its catch is a proportion of the total catch.

To use this approach, it would be advisable however to calibrate the 'standard catch rate' from year to year, since this "standard effort unit" will also vary from year to year with technological developments. Monitoring daily catch rate per vessel as well as days fished should at least provide an estimate of the relative number of standard fishing effort units exerted by different boats.

In arriving at a practical method of effort control, at this point a decision will have to be made at the political level whether the effort allocations will be measured in nominal effort units or be divided up between individual boats in terms of calibrated effort units. A powerful boat exerting (say) 18% of the effort in nominal days fished, might in fact exert 40% of the calibrated fishing days, and hence the total fishing mortality, but a less powerful boat which exerted 25% of the number of nominal days fished, in fact only exerted 5% of the fishing mortality caused by the whole fleet. The usual way to adjust these anomalies is to divide the vessels into recognized fairly homogenous classes or OU s, and use effort allocation by OU to achieve the political objective for the fishery (*i.e.* to favour either a semi-industrialized, or an artisanal fleet). On the other hand, going directly to allocations based on standard effort units, while egalitarian, will penalize the more efficient skippers. Nonetheless, where several jurisdictions fish a common resource, the national or regional allocations will probably have to be made in terms of standar-dized effort units.

Management methods to control fishing power and effort

Setting long-term targets inevitably means entering the political process, and criteria will need to be established involving mainly technical measures (gear, access rights, closed seasons or restricted fishing areas), to supplement the effort cap. Shepherd (2003) noted that both fairness, shared equity and stability of allocations, are important principles for public acceptance of new regulations.

Technical measures to be applied in all years, but to manage fishing effort, two approaches are possible:

1) Short term management measures:

- Decide on the number of days of the week when fishing vessels can leave port to fish.
- Allocate each vessel a number of fishing days at the start of each season.
- If the spawning stock is depleted, close areas (temporarily?) where adult refugia occur, or permanently inside MPAs.

Of course if number of days fished/week are limited, individual fishers will probably demand the right to specify which of the x days per week they wish to operate –in this case they will be obliged to inform the harbour master when they propose to leave port–.

2) Longer-term measures:

Some options are to reduce fleet fishing power radically at the time of vessel replacement, to require 2-for-1 license swaps, or to implement a buy-back scheme. As suggested by Shepherd (2003), government intervention (and presumably a special type of subsidy, the government buy-back), may be required to bring fleet size, at least initially, into line with productivity.

A first practical issue to consider where a stock area is fished by several fleets, perhaps from different jurisdictions, is to construct a fishing vessel registry including all OUs currently active, including all licensed fishing vessels by all parties. The major vessel/gear characteristics and usual port of operation should be recorded in the registry, as well as any infringement of regulations by the vessel and its owner/operators. Eventually, it will be desirable to use common criteria for license transfer between fishing power category in the case of vessel replacement.

In fact, it may be more effective and socially acceptable, to make fishing power adjustments slowly by imposing criteria at the time of replacement of old vessels, requiring that they be replaced by those more homogenous with the existing fleet or equity, or by smaller vessels with a lower fishing power to compensate for technological improvements. Using a vessel scrapping policy to ensure "old" boats do not re-enter the fishery seems an essential measure, but is effectively counteracted if technological improvement or 'capital stuffing' is allowed to increase the fishing power of the remaining licensed vessels.

A control of fleet fishing power is highly desirable, and several options have been proposed in the literature for this purpose.

a) *1* for *2* swaps or "build down" procedures.
b) "Sleeping policemen" or obstacles against trawling in areas where effort must be excluded.
c) Rotating harvest schemes.
d) Economic or social controls.

Several options for controlling effort exist:

a) Direct (control vessel horse power, tonnage, days at sea).
b) Indirect control (close critical habitats; institute seasonal closures).
c) Allocate effort units between vessels and fleets.

The FAO Compliance Agreement potential could aid registration of legally fishing vessels –it imposes a requirement that flag states licensing their vessels operating on the high seas take responsibility for their actions– this mechanism is beginning to be used by tuna Commissions as a way of tracking the origin of vessels applying for membership, and for setting uniform standards. It might even eventually provide a data base to be used to coordinate different regional satellite tracking systems by providing a global list of vessels which have infringed local regulations.

A Fisheries Management Plan

Ideally a multi-year plan has been established as a basis for action by government or those running the fishery after consultation with the fishing industry, as a basis for further discussions. A fisheries control rule and an established series of events from data gathering through sampling and analysis to management actions, vessel licensing and replacement procedures, the responsibilities of a licensed fisherman, etc., may be components of such an established Fisheries Management Plan, together with other factors. The Plan establishes, ideally with consensus of the fishing industry, where the fishery is expecting to develop in the future, and the rules it has established for its operation.

Different management frameworks

The types of management systems applied in fisheries today are varied; hence a simple indicator that could apply to all is not readily available, so that monitoring will have to be by function. It is also evident that significant changes are underway in the way that fisheries are managed, that have already been mentioned. Management by TAC is probably still the main mechanism applied by Fisheries Commissions and in many 'Developed Country' fisheries, despite the advantages of direct control of fishing effort, as just discussed while referring to the paper by Shepherd (2003). Some alternative management procedures can be seen as focussed on effort reduction, even if quotas may still apply, notably in ITQ systems and Community-based management systems (See Shotton, 2001). The issue here is to what extent regulatory frameworks allow the devolving of mechanisms for reducing capacity, data gathering and analysing systems, to local entities as opposed to centralized national

Departments of Fisheries. On this point, the use of the internet for registering information makes the precise location of data storage facilities less critical than formerly, though the issue of confidentiality must be considered.

This report avoids entering into too much detail on the issue of quota control and how it may affect overcapacity of fleets, except to note that the existence of quota control is itself a direct indication of overcapacity, since it makes clear that it is unlikely that quota will remain uncaught at year end, and often quotas are "overshot", especially if discards and mortalities of species whose quota is filled are taken into account (not always the case). The recommended safe catch is likely to be taken well before the end of the season. The disadvantages of quota control both in terms of the cost of monitoring, losses through discards, the high demands on research advice for routine analyses, and the uncertain performance for conservation given that quota evasion is rampant and capacity is in excess, all suggest that some form of capacity control is a priority. The use of effort control is not necessarily without its problems, but these are focussed mainly on cross-calibrating the fishing power of the means of capture –requiring research effort to measure and regulate the fishing power of the harvesting vessels–. Using an approach which places infringements on the vessel's entry in the registry and tying these to some economically important restriction, seems one way to promote self-enforcement by the industry.

Management by a "fisheries control rule"

This approach does not differ radically from the management cycle (Fig. 1), except that in theory, decisions at the political level are supposed to be made *before* the "rule" is established, and not during its application. This is not a "hard and fast" distinction of course, and rules have been countermanded as a result of protests by the fishing industry if the rule was perceived to result in hardship. One approach to a fisheries control rule that has been proposed in Canada, but not yet implemented, is represented by *figure 2*.

The Traffic light approach as a management aid

The traffic light approach has been used during the World Trade Organization (WTO) fisheries

Stock condition: → Productivity regime ↓	Healthy	Moderate	Poor	Collapse
High	TAC MAY BE RAISED	TAC MAY BE RAISED	TAC TO REMAIN STABLE	BYCATCH ONLY
Intermediate	TAC MAY BE RAISED	TAC TO REMAIN STABLE	TAC SHOULD DECREASE	MORATORIUM
Low	TAC TO REMAIN STABLE	TAC SHOULD DECREASE	MORATORIUM	MORATORIUM

Fig. 2. Consideration matrix, a possible graphical aid to decisions based on assessments and the management authorities interface, as suggested by the Canadian FRCC. This places the stock in one of 12 "boxes" judging by stock condition and current productivity: each box containing a rule for management action with a certain flexibility in implementation (from Caddy, 2004b).

discussions to illustrate one negotiating option, but a more extensive literature is now developing on the use of this mechanism, not only for monitoring multiple indicators, but also for decision-making.

Fisheries development off the Yucatan peninsula

An example is given in *figure 3* (from Seijo *et al*., 2006) of a traffic light display of fisheries data in which annual landings and effort data are listed vertically. A contrasting situation to the NW Atlantic traffic light diagram shown in the first part of the paper (Caddy, 2010) prevails here, in which exploitation over time has proceeded in a more or less synchronised fashion for most shelf species (tunas in the last column being an oceanic fishery, are a notable exception). No dramatic collapse in landings has yet occurred, but additional information suggests that

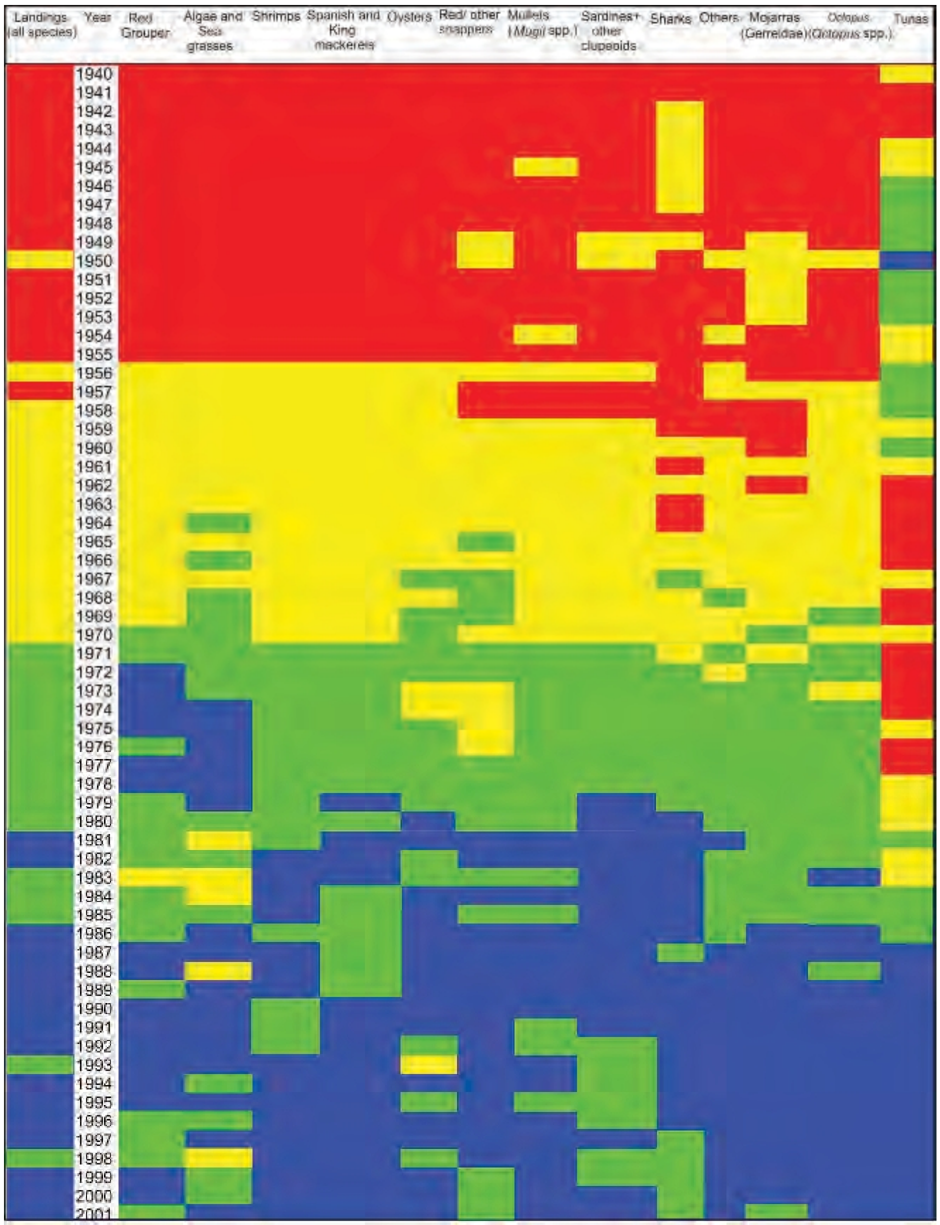

Fig. 3. Dividing Mexican landings from the Gulf of Mexico (1940-2001) for a wide range of resources into four quartiles (red is low and blue is high) makes it clear that (except for tunas) a degree of coordination of fishery policies applies. (Note: here the "red" category does not imply overfishing, but simply the low landings taken early on in the developing fisheries).

most fisheries are fully exploited, and some overexploited. The extraordinary feature of these fisheries which is *not* evident from a simple plot of landings, is the apparently coordinated progress in relative landings achieved for each fishery, suggesting that a common socio-economic factor or factors is in play.

A second chart (Fig. 4, also from Seijo *et al*., 2006) from the same fishery confirms what was evident from landing statistics, namely that independent data series of fishing effort and financial support for inshore, offshore and finfish fleets show the same trends as does financial support to fleet development, suggesting that reducing financial support might reduce also fishing effort, at least for the less efficient boats. Although this chart does not show the onset of overcapitalization, the colour scale has been reversed, since a high level of subsidy is not necessarily precautionary. It would also seem useful to ask what net benefits have accrued to the industry from the high levels of financial support they have received since 1995?

Other examples may be provided showing how a traffic light bar chart provides a useful way of integrating a wide range of data series. Two approaches should be born in mind however: The original approach (Caddy, 1999) saw the colour transition as coinciding with specific limit or target reference points for fishing effort, mortality or biomass. The charts for the fisheries illustrated here use an arbitrary slicing of data series in order that a large number of variables may be scanned contemporaneously. "Red" may therefore not be negative: if low landings occur early in the history of the fishery it was probably associated with underexploitation, but it would be precautionary to assume that if red occurs late in the series there may be reason for concern. Obviously, as information accumulates, it would be wise to adjust the cutoff points in the colour

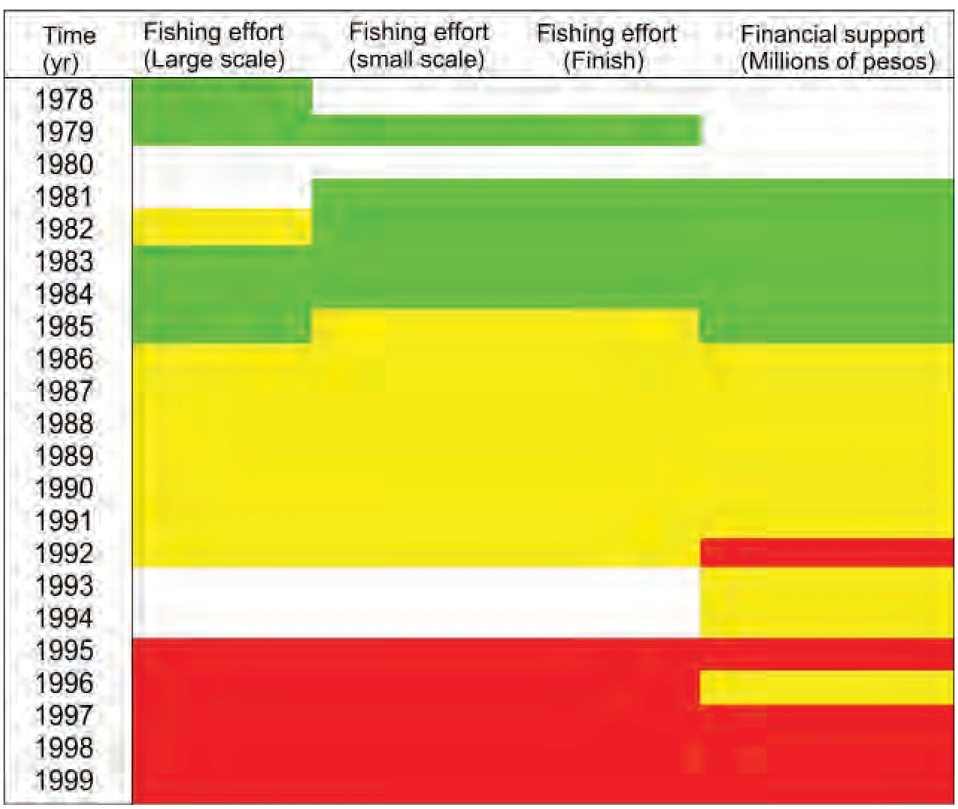

Fig. 4. Traffic light plots for three indicators of fishing effort and one of financial support, which have been divided into three equal colour ranges. These show closely coordinated boundaries in time. (Here the colours are reversed from that in *figure 3*, making the "red" colour more likely to represent fully exploited or over-exploited resources).

chart to represent real thresholds of biological, economic or social importance.

What are the indicators for a properly managed multispecies fishery?

Rephrasing Gilbert *et al*. (2000), good management may be inferred when an indicator reaches a target value, or is maintained above an established limit reference point (for biomass, catch rate, or net earnings from the fishery; or remains below an established LRP (for fishing mortality or capacity). Hitting the target value has proved elusive, but maintaining a desired position relative to an LRP, however formulated, can be expressed as a probability (for example: for a given number of days fished there may be a probability of 90% of not exceeding the fishing mortality rate corresponding to MSY). Prager *et al.* (2003) provided a framework for these kinds of statements which is largely independent of the type of indicator being considered.

Often it is convenient to refer an indicator to a specific situation which is supposed to be known (such as a year or of low production around 1985), and Prager *et al.* (2003) pointed out that when a management measure is expressed as a ratio between (*e.g.*) an indicator value in 1985, and the same indicator in the last year fished, the indicators are dimensionless. This is a desirable property, especially when comparisons are made between multiple indicators expressed in different units. Indicators expressed as ratios are used by the New Zealand Fisheries Department (Gilbert *et al*., 2000). These make use of both empirically-determined quantities, (e.g. the Maximum Constant Yield, MCY, which is the highest level of catch estimated to be sustainable from the fishery year after year), or can be derived from models (*e.g*. MSY; or the virgin stock biomass, B_0, which is usually derived from models since surveys prior to fishing are rare).

Ecosystem management

Ecosystem management requires that higher level processes be also monitored by means of indicators. Murawski (2000) pointed to the difficulties of arriving at a series of criteria for defining ecosystem overfishing based on events in three marine ecosystems: the Gulf of Thailand demersal fishery, the NE USA shelf fishery and the North Sea. As is evident, while one criterion may not apply to a particular fishery, another will, and as presented in *table 6*, it would be difficult to arrive at a quantitative comparison between these systems.

Attempting to gain a better perspective of changes in the fishery seems to require the ability to view overall changes in a large number of indicators (oceanographic, biological, economic and social) contemporaneously.

The International Council for the Exploration of the Sea (ICES) hosts one of the largest groupings of scientists globally, and performs advisory functions for a range of fisheries commissions and other organizations. Although it has produced many innovations over the years, its large membership and range of advisory functions means that innovations in its mode of action may occur "incrementally" Sparholt (2006). ICES now increasingly integrates fisheries and ecological advice, and reports by regional ecosystem rather than by species categories as formerly, and "where reference points cannot be established or present knowledge does not enable an assessment of the state relative to reference points, ICES may advise on basis of past pressure which was found to be sustainable". If there is insufficient information to demonstrate an impact, the Precautionary Approach (FAO, 1995) is used, and a considerable reduction of fishing pressure is advised. The primary effects of fishing on a number of ecosystem components is considered, rather than attempting to produce an "overall ecosystem model" which at present, ICES does not consider to be practical.

The first step is to list human activities in the sector and identify the ecosystems affected. In many cases nowadays, this step is implemented by storing relevant spatial data in a GIS system to search for spatial overlapping between resources, impacts and potential causes. Although this is not made explicit in the ICES context, integrating spatial and temporal information in a data storage system may lead to useful conclusions without modelling; not only on resources and their habitats/environments or migrations, but

Table 6
Comparing changes in biomass, diversity, and inter-annual variation in resilience and net benefits from three fisheries (extracted from Murawski, 2000).

Criterion	*Gulf of Thailand*	*NE USA shelf*	*North Sea*
The biomass of one or more important species falls below minimum acceptable limits.	Increased effort led to sharp declines in small prey species, large and intermediate predators and demersal species, but landings continued high.	Rapid efforts build up resulted in excessive harvests of all species; dropping to historic lows in 60's and 90's. Changes in species dominance and then sequential depletion of non-traditional species harvests occurred.	Round fish harvest rates have steadily increased since WWII. Increased harvests of small "industrial" species replace gadoids as key species.
Biological diversity declines.	Demersal fish declined to 1/10 of 1960's levels by 1990's.	Species dominance changed with serial depletion of non-traditional species.	Diversity of the system has fluctuated without trend.
Increased year-to-year variation in populations/catches.	No increase in inter-annual variations in trawl catches composition.	Declining stocks of high-value species led to "recruitment" fisheries with high inter-annual species fluctuations.	Not obvious that recruitment or catch variation has increased.
A significant decrease in resilience of ecosystem to perturbations.	Although diversity is lower, no significant decrease in resilience observed.		
Lower cumulative net economic and social benefits than with a less intense fishery.	A growing proportion of catches consists of cuttlefish/squid and shrimp, which (more than?) compensate in value for declining finfish landings (which tend to become discards, used as feedstock in shrimp farming – author).	(Despite initial sacrifices?) Rebuilding of stocks has added hundreds of millions of dollars in additional benefits to the fishing community.	Changes in dominance of pelagic fish and demersal fish may not be related to fishing. Several non-target species have increased in abundance.

also on fishing grounds and fleet distribution patterns. Essentially what is being recommended with this ecosystem approach to fisheries is a "mapping and monitoring" approach first, with modelling postponed until the integrated multi-dimensional approach has generated reasonable hypotheses. The insertion of a traffic light display function that can be readily understood by non-technical personnel seems the essential step in the revised process, with modelling under a number of hypotheses, the final step.

Biodiversity issues and fisheries

Recent policy initiatives seek to reduce biodiversity loss due to fishing and integrate environmental concerns into fisheries management, and Dulvy *et al.* (2006) noted that there are few marine indicators of biodiversity loss. A threat indicator such as used by IUCN for including species on the Red List of threatened species was calculated from declines in catch rates as a weighted average of species taken in trawl surveys, which has been steadily declining over the "greater of ten years or three generations". Thresholds defined were: >90% –'critically endangered'; > = 70% decline – 'endangered'; and > = 50% decline -"vulnerable". (The average for large groundfish in the North Sea since 1983 has been a 34% decline). As noted, this combined indicator may mask more serious declines in individual species, and although alone, it may not guide management action, this indicator is consistent with the goals of the World Summit on Sustainable Development, 2002, of seeking to actively reduce the rate of loss of diversity from natural ecosystems.

One of the deficiencies of approaches that depend on recent time series has also been noted by other authors, namely the "shifting baseline" for judging the relative impact of earlier stock declines which are subsequently forgotten (Baum & Myers, 2004). At the same time, it must be accepted that all exploited ecosystems show shifts in size composition (*e.g.* Pope *et al*., 1988) due to harvesting which generally affects first the larger, longer-lived species with the lowest natural death rates. As long as they are not eliminated from the population or seriously reduced, biodiversity changes can presumably be tolerated.

More condensed indicators for fishery management

In the context of how a body such as the WTO might monitor overcapacity, given that it is not in a position to monitor fisheries in detail, many of the indicators discussed in paper Part I (Caddy, 2010) would be infeasible, and a more restricted set of data might be suggested under the following headings which could be converted easily into a questionnaire. Annex I summarises the data needs for judging a management system under a number of information categories.

Pressure

- Is there a system of monitoring of the fishery/ resource status?
- Are surveys carried out of the number and type of vessel fishing, and is an up-to-date vessel registry maintained?
- Are observers placed on commercial vessels/ Is it a log book reporting system mandatory/ Is there a satellite or other electronic system for monitoring fleet operations and the location of fishing vessels?
- Are changes in fishing power that result from technological improvements of fishing vessels being monitored?
- Is there a control on the number of licenses issued in the fishery/vessel tonnage/ hold capacity/ total HP exerted? Are details of these provided in the fleet registry?
- Is fishing pressure within and outside of EEZs being monitored: give details of procedures and expenditures.
- Have limit reference points been defined for biomass and mortality, and is fishing effort regulated to avoid them being exceeded?
- Is fishing pressure regulated annually in relation to the abundance of new recruitment?
- Have environmental/ecological changes occurred over the last decade that has affected exploited populations?

State

- What percentage of the catch from the fishery is examined/sampled at the point of landing?
- Are biological surveys carried out annually involving abundance/biological characteristics of the stock?
- What is the population biomass for the target species with estimate of variance, and how has the ratio catch/biomass changed over the last five, ten years?
- Have there been significant changes in the environment that have affected population viability?
- Has the average level of annual recruitment to the population declined since the last decade?

Impact

Have there been significant changes in:

- Age or size structure
- Percent mature animals in the stock
- Species diversity
- Catches or mortalities of “protected” species
- The rate of discarding in the fishery

Response

- Does the licensing system limit effective effort/fishing mortality exerted?
- Has an effective cap been placed on capacity in the fishery?
- Is vessel replacement designed to avoid increases in fleet capacity?
- Have damaging gears or fishing methods been eliminated?

- Are permanent closed areas or MPAs in place, and what percentage of the management area is so protected?
- What percent of the catch landed value is spent on MCS (ADD) and research (ADD)?
- Is illegal fishing under control?

What constitutes "best practice", and can we identify fisheries that are "patently under-managed"?

As noted in paper Part I (Caddy, 2010), the established regulatory framework, fleet "capacity" and fishing effort exerted, are inputs to the fishery, while catches, catch trends, landed sizes, or species composition, adherence to regulations, etc., are outputs. The point needs to be made therefore that judging "best practice" simply by measuring inputs will not be sensitive to the net effect of human interventions on the population. A number of measures will have to be monitored which are equally distributed between "inputs" (which can be compared with norms and standards accepted by the international community), but in the long run, the state of the resource is the key variable that has to be controlled. This can be done if formal assessments are available in relation to a reference point, or if that is not the case, as suggested in paper Part I (Caddy, 2010), evidence of stock landings falling significantly below a general MSY level could be the fall-back position.

What indicators and data sources are available internationally that would be useful to a WTO dispute panel?

Considering the points just made about the need to keep a handle on both inputs and outputs, some evidence that acceptable procedures are being followed, could be provided by completion of the Annex questionnaires to this paper, or their modified versions.

On the question of judging from outputs, while it has been suggested that general procedures such as those used by FAO to arrive at a classification of fisheries into five categories might not satisfy an independent review process (and were not, as explained, intended for that purpose). Where a full assessment is not available, establishing the position of the fishery in relation to MSY, the FAO series of landed data could however be analysed, using a modification of the procedure suggested by FAO /CITES to establish what proportion of fisheries in the EEZ or fishing zone are recognizably depleted and in need of urgent management action. The by-catch and status of protected species caught incidentally in a fishery should also be a contributing factor to a decision process. If fisheries in the area are judged sustainable by a body such as the Marine Stewardship Council, this itself would be positive evidence in favour of sustainability and management competence.

On the input side, an account of the established regulatory framework and how it has worked in practice, with a measure of infringements detected, would be important evidence. Evidence of the use of precautionary measures where data are unavailable would be positive. Evidence that the licensing system is inclusive of all OUs working in the area, and that vessel replacement schemes are accounting for increases in fishing power due to technological improvements of the method of fishing would be positive evidence.

Perhaps the data series that is least uniformly available is on existing capacity. Lloyd's Registry provides a list (not necessarily complete of course) of large vessels, with some breakdown by function, but this does not give enough information on their relationship to a particular area or fishery. Contents of a local, regional or national registry of vessels currently working, with records updated annually for at least the last five years, should ideally list vessels by size/capacity, target species and date of construction. Listing the disposition of vessels replaced by new units, either scrapped or which left the fishery, would be a useful basis for judging compliance with effort control and overcapacity control.

Providing a list of subsidies by category and an accompanying analysis of their impact on fishing pressure would be positive, but will be addressed in another paper.

Just what level of "non-compliance" with the above generally non-quantitative criteria would lead to a hypothetical WTO sanction, is however a matter which would require more discussion and input than one consultant can provide.

Management in transboundary regimes

The problem of managing shared or transboundary fishery resources continues to be one of the most intractable issues faced by maritime nations today. Whether the sharing is between fleets from different nations, or between local fleets within a single EEZ, in one sense the solution remains the same –the need to establish a special management regime that reconciles the aspirations of all established stakeholders with the productive capacity of the resource– (Fig. 5). WTO will probably be faced with dealing with this type of problem, since it may involve several member countries seeking a common solution.

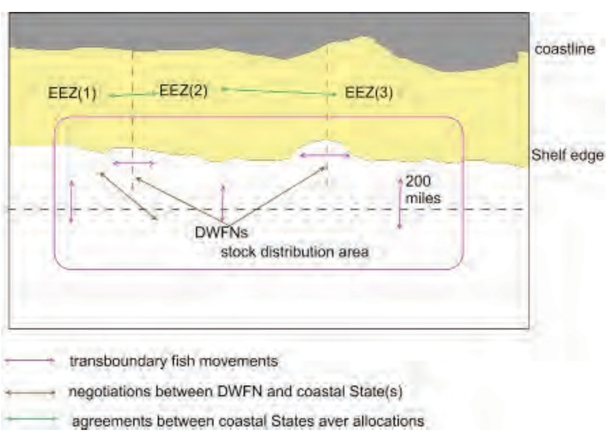

Fig. 5. Situations where resources are shared between different jurisdictions (from Caddy & Seijo, 2005).

Recently, the WWF produced a booklet describing procedures to follow to ensure a precautionary approach to Access Agreements (Martin *et al*., 2001). In many cases however, the problem is one that does not relate to distant water fleets, but stems from bilateral misunderstandings, the lack of common mechanisms for managing resources, and differing objectives for stocks shared by adjacent coastal countries. We are unable to ignore here however, the fundamental problem of sharing resources even within national waters. This could require special regimes to be set up for particular resources or sub-areas of a single EEZ in order to ensure the safe exploitation of a resource purely national in character which is fished (for example) by two vessel categories from different ports; perhaps targeting different age groups of the same species.

Several types of situation of resource sharing, both within EEZ s and between them, share similar features:

Stocks shared by contiguous states

With respect to stocks shared between adjacent coastal States, although the Law of the Sea dedicates an article to the issue of stocks shared between countries, and requires those involved to cooperate in management of such fisheries, evidence of cooperation is not easy to find. At best, such joint management regimes which apply both within and between EEZ's, where they exist, can usually be described as dictating the rules of "controlled competition" between two or more fleets fishing the same resource.

Of the more than 500 maritime boundaries between EEZ's (not including those with the high seas, rivers or small archipelagic states) mentioned earlier, from Caddy (1998), very few of the adjacent states appear to have taken formal steps to set in place a management regime allowing negotiation on the optimal level of removals. Often the level of removals by an "adversary" or "neighbouring" fleet is unknown, and so is the optimal level of harvest it can support. This situation inevitably leads to stock decline.

The conventional approach of course is to establish a joint commission with representatives from the governments concerned meet regularly. Examples here are the agreements between Argentina and Uruguay on resources of the River Plate and adjacent continental shelf, and that between Argentina and Britain (Falkland Is), and this option may take many forms, depending on the local situation.

A number of theoretical studies of shared resource situations follow the concept of "games theory" developed first to study "cold war" tactics between adversaries. These have led to quite convincing mathematical models showing the difficulties of optimizing use of a common resource by two or more joint owners. A range of difficulties may emerge, of which the lack of common information as well as common goals and perceptions play a major part in leading to a mismatch between expectations and results.

Using these same approaches, solutions may be suggested that can be adapted to a particular case however. One approach that leads to a more rapid convergence on optimal solutions in a gaming context is where a side payment (either in monetary terms, or in terms of some other concession, whether or not in the field of fisheries), is made by one "player" (*i.e.* State) to the other. Such a "payment" may be made, for example, by the party having the highest "commitment" to the resource, in order to have a guaranteed or predominant share of the joint catch. The "receiving party" may for example have a higher priority in another area of bilateral relations than fisheries. This illustrates that in practice, negotiation of fisheries agreements may include factors that fall outside of the immediate areas of fisheries such as access to ports or tax-free goods, etcetera.

Another approach is one where common ownership of a shared resource is turned over to a common fishing company in which the coastal countries (and possibly also DWFNs) concerned, may have shares or a common interest. This company may harvest the resource using vessels from all parties concerned, and pay dividends to the parties under an established format. Here the organization can be either mixed government-industry, or even in the private sector with government supervision on the board of the international company set up for this purpose.

Problems of shared access within national waters

Countries in fact may have considerable difficulties in negotiating with their neighbours due to political differences, or information exchange may be poor, or there may be problems in deciding on access. One of the major problems that a country will face in attempting to enter into negotiation with a contiguous state will be in reconciling fishing strategies of two or more of its national fleets. Evidently this has been the cause of failure of a number of shared stock negotiations, which have led to "back room" conflicts between industry representatives within national delegations, which overshadowed their discussions with "the opposite side". What this highlights is the fact that similar conflictual situations between groups of stakeholders exist at the national level, and will need to be resolved by national administrations through setting up special regimes that perform the same function as has just been described for international regimes.

Evidence to date suggests that solving the requirement for limiting access to a fishery resource is the primary precondition for successfully managing it, but there are serious difficulties in eliminating open access regimes by means of regulations applied at the national level: these range from the mobility of fleets, the lack of data and scientific advice, the lack of an appropriate legal framework, or the problems of effective joint MCS functions. It seems that where management has been tackled more or less successfully, it has been through the establishment of special management regimes within which access is limited and active stakeholder participation with government(s) has been established.

A number of examples of special management regimes may be considered

1) *Locally*: Access to a local resource within a geographically circumscribed area is restricted to two or more ports/fleets, whose vessels have special licenses to exploit the resource, and whose fishers have agreed to and negotiated a fishery regime that is precautionary. Implicit here are the concepts of co-management or community-based management.
2) *Nationally*: A migratory resource that is taken throughout national waters with relatively little repercussions or by catch from other resources may be managed by a special regime which is not local in its operation.
3) *Internationally*: The resources of a lake, estuary or coastal area divided by a boundary

may be taken by fishers of both nationalities operating from a specific number of ports or landing sites on both sides of the border. In this case the situation mentioned under 1) can be envisaged to apply with the proviso that the special management regime is administered by a committee where the two nations and the fishing communities involved are represented. A similar situation may apply for shared stocks of the boundary region, or for resources of offshore banks fished by two or more countries.

Fundamental here, is that the private sector participate in mechanisms for joint management of shared fishery resources. We may even propose establishing a multilateral management mechanism which operates mainly through cooperation of stakeholders in the private sectors of the nations involved with government playing mainly the role of guarantor for the parties concerned.

Whatever special management regime may be proposed, it presumes, as for other mechanisms already mentioned, the existence of a consultative and joint management mechanism between the government and/or private sectors concerned. Whether this mechanism is called a steering committee, a board of directors or a shareholders meeting, is a matter of choice; the main concern being that some mechanism is found that reduces the confrontation and competition between parties harvesting the same resource, and that rent is generated through savings in capitalization.

A hypothetical control mechanisms that could apply

1) TAC's may be divided by allocations to each party which result in individual catch quotas by fleet or boat. In this case the suspicion remains that the "other side" is not keeping count of real catches, hence some form of mutual or "impartial" inspection seems required.
2) Areas and/or seasons are negotiated within which fishing fleet operations are restricted to one or other fleet(s).
3) Harmonized regulations and conditions of harvesting, as well as measure to protect incidentally-caught species, will be formulated.
4) One possible solution would be if a common fishing Company or arrangement, issuing shares to (the private sectors?) of participating States. The Company could have exclusive rights to harvest the shared resource, conditional on established access rights agreed to (which might be in a common fishing zone lying across EEZ boundaries). The Company employs vessels from both sides to catch a safe TAC agreed to provide the best long term return to the company. Such considerations also decide the level of harvesting required to take the resource. The Company may also act as a joint marketing company, may apply for ecocertification for the product under the MSC for example, and could provide ancillary services to fishers such as insurance, bulk purchase of equipment, etcetera.

A draft proposal

One country (in the case of resources shared within an EEZ), or two or more countries (where the resource lies across maritime boundaries) may request assistance in setting up a special management regime for a local or international resource.

1) A team consisting of:
   - A lawyer with experience in fisheries legislation
   - An experienced resource person
   - A sociologist with experience in co-management and community-based management
   - And others as appropriate, will spend up to three weeks talking to stake holders (fishers and their representatives, fishing companies, local NGO's, etc.), government and university experts as appropriate, and will submit a report spelling out a limited number of options for further development.
2) The government will meet with other national parties and consider the report. The option

that seems most promising will be chosen with the practical provisos that come to mind.

3) The team will return and develop a more specific plan of action including the data gathering needs for management, management measures and infrastructure.
4) The government will implement the setting up of the necessary infrastructure (and in the case of stocks shared between neighbouring countries) will pass harmonized legislation permitting for the resource in question, a common approach to management.
5) The appropriate body of the WTO will rule on the appropriate response, or request such follow-up work as seems necessary.

Acknowledgements

This paper and "Biological indicators and their use in stock assessment to achieve sustainable levels of fishing" printed in *Ciencia Pesquera* 2010, 18(2): 87-124, were based on informal draft papers prepared with support from The United Nations Environmental Programme (UNEP) and the World Wide Fund for Nature (WWF). Their permission to reproduce these informal papers is gratefully acknowledged. These papers led to a more general one (Schorr & Caddy, 2007: 'Sustainability criteria for fisheries subsidies: options for the WTO and beyond'), which addressed a more specific question: how the WTO (World Trade Organization) might take a more active role in fishery management by means of a control of subsidies to the means of production.

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Recibido: 22 de febrero de 2010.
Aceptado: 24 de mayo de 2010.

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Annex 1: Some data requirements for a scientific management system

The requirements for proper management of resources call for a properly integrated system of data collection and storage. Some of the data modalities that may be included are given under the following headings:

a) Fleet data

- Trends in catch and effort.
- Trends in fishing power of fleets.
- Numbers of fishing licenses issued by species by country.
- Conditions of licensing.
- Transfer of ownership between vessels/ owners/new vessel construction/purchase.
- Changes in fishing power and technologies.
- Information on profitability of fishing enterprises.
- Funds available nationally for fleet re-dimensioning.

b) Setting up a fleet register: The objective here should be to maintain an updated registry of vessels fishing the management area under different flags or from different ports/different harvest modalities, as a basis for discussions on a common management regime. It would be useful to draw on experience within other regional organizations such as CARICOM, the Bay of Bengal Programme of FAO, as well as the COPEMED and ADRIAMED projects in the Mediterranean, all of which have useful experience in setting up fisheries data bases. Details of these projects are available via their respective web sites, and provide examples of regional approaches that can be useful.

c) Indicators from analysis of trends: An alternative approach was given in a recent background paper to an FAO, Technical Consultation (FAO, 2001) which examined the suitability of CITES extinction criteria for inclusion of endangered commercial aquatic species in CITES Appendix I (species threatened by extinction for which trade is forbidden) or into Appendix II (species that may become threatened with extinction unless trade in them is subject to strict regulation). Some ideas on this issue have already been mentioned, but three were proposed:

- Recent-rate-of-decline (the trend over the last ten years was suggested).
- Historical rate-of-decline (the long term trend over the time series) and most importantly in their view,
- "Historical-extent-of-decline" –this requires current abundance to be expressed as a fraction of some "historical baseline", which could be B_{MSY} (the biomass level shown to be capable of providing MSY as a sustainable yield), B_0 the virgin biomass, or as suggested in FAO (2001), the average of the four largest spawning biomasses in the historical time series.

d) Scientific infrastructure and programmes: There is a need for information on:

- Research programmes, facilities, research vessels, regular surveys.
- Scientific capabilities and programmes, especially in quantitative science, statistics and assessment.
- Available staff and their qualifications.
- Current and planned research programmes.

e) Relevant legislation and regulations: It is of particular importance to create a data base of national legislations and regulations as a possible basis for future harmonization. The FAO, Legal Branch has had considerable experience with this exercise in various world regions. It would be essential here to know what is the budget and manpower expended for Monitoring, Control and Surveillance (MCS) of fisheries regulations by key fishery in each riparian State, and the facilities (patrol vessels, equipment) available for this purpose.

f) Spatial indicators: The onset of poor environmental conditions often leads to a reduction in the species range, and vice versa. It follows that one of the most convincing form of indicator will be changes in the geographical range of a species –this may be established from annual surveys or log book data and will involve use of GIS methodologies–.

g) Environmental considerations and stock recovery: Often stock recovery time was found to depend on regime changes, and natural productivity may be tied to climatic factors. It seems evident, and can be confirmed from time series of fisheries landings, that recoveries of fish stocks after depletion are not easily achieved. They may occur independent of fisheries capacity due to an improvement of environmental conditions, or collapse of a fishery due to overcapacity may lead to vessels moving into other resources allowing some recovery to occur. In areas of upwelling or environmental instability (*e.g.* the SE Coast of S. America, the Arabian Sea, and off Namibia), production may fluctuate naturally in response to regime changes (Steele, 1996). Evidence from simulation studies has shown that if crafting a fisheries management system is difficult under close to "steady state" conditions, it is much more so where the need for conservation requires that capacity fluctuate in close response to changing productivity. All of these just-mentioned situations, combined with limited data and limited management capability and responsiveness, render the restraints needed to achieve recovery particularly difficult to achieve, both for developed countries, but more so for developing countries. They place the onus on not allowing a resource to reach an endangered state, even if this requires some other sector of the economy to provide employment and livelihoods to those affected by recovery plans.

h) Effort overshoot and recovery plans: No signal flare goes up when a fishery exceeds f_{MSY} or any other target reference point. This event may only be detected in retrospect after several years have elapsed, when recruitment, and catch rates remain low or irregular. At this point, a feature of overfished stocks emerges: a return to productive condition takes longer to achieve than the previous move in the opposite direction. This is one of the reasons why f_{MSY}, which was the "official" target for UNCLOS, has largely been superseded. We cannot measure its position accurately enough to avoid an overshoot, and as stated, an overshoot is difficult and painful to recover from.

Annex 2: Some ideas for checklists or questionnaires for monitoring the sustainability of fisheries to be used in conjunction with WTO deliberations

Many of the ideas for indicators that emerge from this study would be too detailed to implement, and although some indications have been pointed to in the text, such measures would be better addressed by a questionnaire. Such a questionnaire could follow the format of the Code of Conduct (e.g. my papers on transforming the Code into a questionnaire (Caddy, 1999), and the further questionnaires I since developed for the WWF meeting in Mexico on the Code, see Annex 1). Alternatively, such questionnaires could be made more specific to the needs of the fishery management body. Tables are provided below which illustrate various approaches to designing such a questionnaire which would need to be modified after expert discussion.

It seems likely that for many national fisheries, quantitative estimates of the state of resources or their management may not be assessed or available, or the data series used in assessment and management will be too detailed. Ideally, the response should be both based on inputs and outputs. An indication for each national fishery of the state of exploitation in relation to MSY conditions, and the existence of effective controls on fishing pressure, as well as any subsidies on the fishing fleets or processing plants dependent on it. This seems unlikely to be available in many cases, and some indicators of potential interest would probably have to be largely based on the scoring of positive responses to questionnaires of the types listed below.

While a descriptive account makes quantitative evaluation of the state of the fishery problematical, a first approach would probably have to rely on a listing of necessary background information. An example follows (Table A):

A semi-quantitative score could be obtained from the proportion of positive replies in a questionnaire such as the following, which aims to establish concordance with international norms and standards: e.g. the questionnaire approach proposed for the Code of Conduct for Responsible Fisheries (Table B).

Table A
A questionnaire incorporating general information on the fishery and its regulation

Activity Being Monitored		*Type of Indicator*
1	Fleet capacity measurement.	Tonnage of registered vessels.
	Capacity monitoring and measures for reduction as necessary, exist.	Provide time series of vessel capacity operating in the fishery.
2	Subsidies recently applied.	List subsidies in operation.
3	An efficient system of distant monitoring of vessel operations, or adequate funding for at-sea surveillance or observers.	Descriptive account.
4	What catch allocation procedures are followed?	Describe allocation procedures.
5	Compliance with regulations.	Number annual infringements/ fleet size.
6	Regulation of harmful fishing gear and the loss of synthetic netting (ghost fishing).	Provide an account of technical measures controlling gear used in the fishery.
7	Reduce pollution due to fishing and disposal of garbage at sea.	Describe measures used to reduce this problem on national vessels.
8	Ensure food safety.	Describe inspection procedures and regulations governing food safety.
9	Adequate monitoring capabilities provided to detect infractions at sea to fisheries regulations.	List patrol vessels/officer complement/annual expenditures.
	Adequate fisheries research facilities provided to carry out necessary research.	List research facilities/ personnel by qualification/ resesarch vessels/ computers+data storage/ annual research expenditures.
	Socio-economic analysis of fishery performance.	Qualified personnel and expenditures.
10	Promote public awareness of fisheries and the basis for management.	Evidence of published notification in media.
11	Proportion of the fishing grounds closed for conservation purposes.	% of EEZ and territorial waters closed inside MPAs and equivalent closures.
12	Measures taken to protect critical habitats and endangered species and evidence of their effectiveness.	(List examples).
13	Adequate funding provided for monitoring, research and resource assessment (MRA).	%MRA functions of fisheries budget.
14	Practical evidence that the precautionary approach is being applied.	(Provide written description of examples).
15	Regular consultations with fishing industry.	Provide reports of recent meetings.
16	Public access to summarised data on the fishery.	Provide references to recent reports.
17	Mechanisms available for conflict resolution.	Descriptive account with examples.
18	Habitat rehabilitation measures applied.	Descriptive account with examples.
19	Measures taken to protect endangered species.	Descriptive account with examples.
20	Evidence that recovery plans are applied where and when necessary.	Descriptive account with examples.
21	Environmental, habitat and resource recovery procedures in place and examples of their application.s	Descriptive account with examples.

To establish a final questionnaire, a meeting of experts from different fisheries would be required to agree on a feasible and adequate approach to a delicate problem – and the current papers may best be regarded as background documents to such a process–. The WWF –sponsored workshop held under the aegis of WWF Mexico in 2004– though not yet published, made an attempt to develop a monitoring approach of type B/ for the Gulf of California based on six articles of the Code of Conduct, plus extra articles on the Ecosystem Approach and on stock recovery planning. These questionnaires are available. The approach used in this particular WWF exercise, was to hold a workshop in which nine experts familiar with the fisheries of the sub-region independently provided responses to questions based on the FAO Code, plus supplementary questionnaires established subsequently. A cutoff for the percent of satisfactory answers was proposed (> = 50%); a low positive score overall suggested that management measures needed to be taken on the question concerned, but the question of at what level of scoring should a WTO response be mandated is not discussed here. A second measure was established in the Mexican meeting to establish the degree of agreement or otherwise between experts. A statistic representing a low agreement between the responses of the nine experts to a question, suggested that further specific research was needed.

Table B
Items from Article 7 – Code of Conduct (incomplete)

(A short comment should be provided verifying the response to each question, with one or two examples, or reference to the relevant documentation)	*Requirements (at least 50% of expert responses should be positive?)*	
Question	*Yes*	*No*
Are conservation and management measures based on the best advice available?		
Is a population analysis updated regularly and verified by a group of scientists with training to at least masters degree in quantitative population biology?		
Have all removals (directed or incidental) from the stock been considered (for example, in the case of shared or migratory stocks)?		
Is there transparency in government sponsored assessments/ decision-making on management measures?		
Is the stock assessed by an international fisheries commission?		
Is the basis for conservation and management measures given effective dissemination to the public?		
Are fisheries monitoring, control and surveillance activities carried out to ensure compliance with management measures?		
Are impacts of fishing on protected species or habitats considered in fisheries management measures?		
Do management measures on the industrial fisheries ensure protection of the interests of the small scale, artisanal and subsistence fishers?		
Have management measures been taken to ensure that depleted stocks are allowed to recover?		
Have adverse impacts of human activities on the resource been identified and minimized?		
Has catch (commercial and non-commercial) by lost and abandoned gear been minimized?		
Have selective, environmentally-safe and cost-effective fishing methods been developed and applied?		
Is there a multi-year management plan for the fishery?		
Are the objectives incorporated into a management plan made available to interested parties?		
Has relevant research been carried out on cost benefit analysis?		
Are timely and reliable statistics meeting accepted standards, available on catch, effort (and catch composition) so as to allow sound statistical analysis?		
Has sufficient information been gathered by relevant research on social, economic and institutional factors, and has it been analysed?		
Has the absence of data *not* been used as a reason for postponing conservation/ management measures?		
Have safe targets for fisheries been established?		
Have actions been taken to set safe targets and limits for exploitation?		
Have contingency plans been established in case of an adverse impact of environmental change or fishing on the stocks?		
Are mechanisms in place to evaluate the capacity of fishing fleets?		
Are procedures in place to review efficiency of current conservation and management measures?		
Have depleted species been protected and their recovery facilitated?		
Has agreement been reached on the means whereby necessary functions for fishery management will be financed?		
Can management cost-recovery measures be implemented for the fishery?		
Has an agreement on cost recovery measures been signed?		
Have pollution and waste been minimized?		

Table C
Resource monitoring and management activities

	(Accompany responses with a short description, and if a Y/N answer is not possible, attach an answer that seeks to estimate the percentage of conformity with the question, or mentions efforts currently underway to improve the situation).	*Yes*	*No*
1	Are personnel in place in the principal ports to collect fisheries data on a regular basis?		
2	Are data collected on fisheries landings by species and published?		
3	Are dedicated personnel available in port or on board commercial vessels to collect fisheries data?		
4	Is there biological sampling of the catch in port to establish size composition of the catch and species present?		
5	Are fishery biologists with qualifications (at least at the Masters level in quantitative science) employed to analyse fisheries data and monitor the state of resources?		
6	Are annual fishing or research vessel surveys carried out at sea?		
7	Is a register of active fishing vessels maintained and regularly updated?		
8	Are all industrial fishing vessels operating licensed to fish?		
9	Is there a limitation on the number of these fishing licenses?		
10	Is there a control on license transfer to ensure that fishing power does not increase on vessel replacement?		
11	Do fishery inspectors establish conformity of vessels, gear and catch with relevant regulations?		
12	Is there at-sea surveillance of fishing operations or is a satellite monitoring system in place?		
13	Do meetings take place between government and fishing industry representatives?		
14	What is the national expenditure annually specifically on Monitoring, Control and Surveillance functions as a proportion of the value of fisheries?		
15	What is the annual expenditure on fisheries research in support of management activities as a proportion of the value of fisheries landings?		