THE PATH TO SUSTAINABLE FISHERIES

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Introduction

Human use of the oceans takes many forms, but one of the most crucial is surely that of marine fisheries, a key source of food and livelihood for millions. Yet fisheries are also among the most complex of human activities, and difficult to manage. Sustainable use of the oceans clearly is essential for achieving both environmental and economic security. It is also clear that efforts to achieve sustainable use of the oceans must pay particular attention to fisheries. A series of questions need addressing in this direction. What exactly constitutes a "sustainable fishery"? How can fishery sustainability be assessed and predicted? What policy directions serve to promote sustainable fisheries? These three questions form the focus of this chapter.

What is a "Sustainable Fishery"?

Central to fishery thinking world-wide is the question: What harvest can be taken today without harming the resource available in future years? Indeed, analysis of this balancing act between present-day benefits and future rewards pre-dates by a considerable margin the current popularity of "sustainable development" discussions (Schaefer 1954; Beverton and Holt 1957; Gulland 1977; Ricker 1987; World Commission on Environment and Development 1987).

Attention has typically focused on determining "sustainable yields," annual harvests (Total Allowable Catches) that can be repeated indefinitely into the future. This determination has been largely the purview of biologists, but in fact there is a range of sustainable yields that will provide biological sustainability—the choice amongst these will depend on other fishery objectives (Charles 1992a,b).

For example, some emphasize the pursuit of "economically-efficient" fisheries, to maximize resource rents—the return to resource owners, analogous to the profits and wages that the owners of capital and labour receive for their inputs. Indeed, this "rationalization" perspective, taken to its extreme, provides no inherent assurance of ecological sustainability; as Clark (1973) showed, in a fishery managed for rent maximization, the natural capital may be "liquidated" (with the fish stocks driven to extinction), as the proceeds are invested elsewhere.

A second line of thinking focuses on social and community concerns, particularly the well-being of people in fisheries and coastal communities. Emphasis is placed on small-scale community-based management, using "appropriate" technology. Within this perspective, the acceptance of sustainable yields is due not to an inherent concern for fish conservation, but rather as a means to preserve the way of life in fishing communities. Equity considerations (*how* the yield of fish is distributed) are considered as important as actual levels of harvest.

While considerable conflict in fisheries arises due to differences over the desired objectives to be pursued, it is appropriate in examining sustainability to recognize the need for simultaneous achievement of several sustainability components. Charles (1994) proposed a set of four fundamental components of sustainability in the fishery context:

> **Ecological Sustainability** implies (a) maintaining the resource base (and related species) at levels that do not foreclose future options, and (b) maintaining or enhancing ecosystem capacity, quality and resilience.
>
> **Socio-economic Sustainability** focuses on the "macro" level, on maintaining or enhancing overall socio-economic welfare, aggregated across the system under consideration. Since the economic and

social criteria involved are inseparably linked in the process of policy formation, this socio-economic welfare is based on a blend of relevant economic and social indicators, such as levels of resource rent (or sustainable net benefits), of distributional equity, and of viability within local and global economies.

Community Sustainability emphasizes the "micro" level, focusing on the need to sustain communities as valuable human systems in their own right (being more than simply collections of individuals). This involves maintaining or enhancing the community's economic and socio-cultural well-being, its overall cohesiveness, and the long-term health of the relevant human systems.

Institutional Sustainability involves the maintenance of suitable financing, administrative and organizational capability over the long term, as a prerequisite for the above three components of sustainability. Institutional sustainability implies that there be no decay over time in the quality of institutional arrangements, a point related in particular to the manageability and enforceability of resource use regulations.

The first three of these sustainability components can be viewed as the fundamental "points" of a Sustainability Triangle. The fourth, institutional sustainability, interacts amongst these, potentially affected (positively or negatively) by any policy focused on ecological, socio-economic and/or community sustainability. If overall sustainability requires reasonable levels of all four components, a proposed fishing activity or fishery management measure will be unacceptable if it were to have an excessively negative impact on any one component. This provides a general guideline for policy development, which will be utilized in the following discussion, focused on developing a practical framework for assessing sustainability in fisheries.

How can Sustainability be Assessed and Predicted?

Evaluating the nature and extent of sustainability involves two related tasks: (1) assessing the current state of the system (for example, the sustainability of an existing coastline), and (2) predicting the future state of the system *a priori* (such as the effects of a proposed management approach or development project on sustainability). The first of these might be seen as a "status report" (e.g., assessing ecological and human carrying capacities) while the second concerns the "impact" of *proposed* human activities, building on analogous methods in environmental impact assessment.

A process of "sustainability assessment" for accomplishing such evaluations, both qualitatively and quantitatively, involves three steps:

1. A concrete set of criteria (a "checklist") that must be met in order to achieve each component of sustainability.

2. A corresponding set of quantifiable "sustainability indicators," reflecting the status of each of the criteria.

3. Where appropriate, aggregations of indicators into "indices of sustainability."

Sustainability Checklists

What elements of a fishery system must be considered to assess its sustainability? The components of sustainability described above can be refined to provide a multi-faceted sustainability "checklist," a tool to highlight "trouble spots" in fishery systems. Such a checklist must incorporate aspects of the ecosystem, the macro-level socio-economic structure, the micro-level well-being of local communities and the institutional integrity of the system. Table 1 depicts a possible checklist of criteria, a framework that is meant to be broad in scope; not all items in the checklist will be relevant for a particular fishery under consideration.

Table 1: A Sustainability Checklist

ECOLOGICAL SUSTAINABILITY
Are exploitation levels (catches) on directly impacted species such that ecosystem resilience is maintained (or at least not reduced excessively)?
Are indirect biological impacts reasonably understood to the extent required to ensure sustainability?
Are impacts on the ecosystem as a whole reasonably understood to the extent required to maintain overall resilience?
Are alternative systems of management/utilization available so that pressures from any increased demands placed on the system under consideration do not increase beyond institutional management capabilities?
SOCIO-ECONOMIC SUSTAINABILITY
Will the activity increase the aggregate long-term rate of employment?
Will the project enhance economic viability in the local and regional systems?
Are the current and projected levels of distributional equity in the system sufficient?
Will long-term food security and livelihood security be increased, as measured in both average and minimal terms?
COMMUNITY SUSTAINABILITY
Is the project likely to increase the long-term stability of affected communities?
Are traditional value systems of importance to the community maintained?
Are local socio-cultural factors (such as tradition, community decision-making structure, etc.) incorporated?
Are traditional resource and environmental management methods utilized to the extent possible?
Are there adverse impacts, at any level or in any component of the system, that unduly affect particular components of the community (e.g., gender-related impacts)?
INSTITUTIONAL SUSTAINABILITY
Will the long-term capabilities of corresponding institutions be increased?
Is financial viability likely in the long term, or does the intrinsic importance of the system justify ongoing support from society regardless?

Sustainability Indicators

The above checklist must be quantified if one is to assess the extent of sustainability problems, and to make comparisons between sustainability criteria. This requires a set of clear-cut *measures* of sustainability, referred to here as "sustainability indicators," based on criteria in the checklist. A preliminary attempt in this direction is suggested in Tables 2, 3 and 4, for the cases of ecological, socio-economic/community and institutional sustainability respectively. (It should be noted that the particular criteria selected, and the corresponding indicators chosen, are not definitive, but are meant to provide an idea of the proposed approach, as well as a base from which to extend and improve the set of indicators.)

Sustainability Indices

The above indicators are fundamentally noncommensurable, in that each measures a different aspect of the fishery system. In particular, a comparison between indicators representing different components of sustainability is not a technical matter, but rather one that should be left to policy makers as a "political" task. On the other hand, it might be argued that indicators within a given component of sustainability are at least somewhat comparable and that, using suitable weightings and averaging, one might aggregate across such a set of indicators to create "indices" of sustainability:

- ecological sustainability index;
- socio-economic/community sustainability index; and
- institutional sustainability index.

Table 2: Ecological Sustainability Indicators

Sustainability Criteria	Indicator
Catch Level	(MSY-Catch)/MSY
Fish Population Size	Biomass (relative to historical average)
Biomass Trend	Multi-year Average Annual Percentage Rate of Change
Fish Size	Average Fish Size (relative to historical average)
Environmental Quality	Quality (relative to historical average) + (% Rate of Change)
Diversity (Harvested Species)	(# Species)/(Hist.Avg.) + (Diversity)/(Hist.Avg.)
Diversity (Ecosystem)	(# Species)/(Hist.Avg.) + (Diversity)/(Hist.Avg.)
Rehabilitated and Protected Areas	Area Rehabilitated and Protected as % of Total Area
Ecosystem Understanding	Level of understanding [subjective]

Table 3: Socioeconomic / Community Sustainability Indicators

Sustainability Criteria	Indicator
Community Resiliency	Index of Diversity in Employment
Community Independence	Percentage of Economic Activity Based Locally
Human Carrying Capacity (Livelihood)	Current (or Potential) Sustainable Employment (relative to Population)
Human Carrying Capacity (Environment)	Natural Absorptive Capacity / Human Waste Production
Equity	Ratio of Historical to Current Gini Coefficients of Income and/or Food Distribution
Sustainable Fleet Capacity	Ratio of Capacity for Harvesting at MSY to Current Capacity
Food Supply	Food Supply Per Capita (Relative to minimum nutritional needs)
Long-term Food Security	Probability of Sufficient Food Being Available Over Next 10 Years

Table 4: Institutional Sustainability Indicators

Sustainability Criteria	Indicator
Management Effectiveness	Level of Success of Stated Management and Regulatory Policies
Use of Traditional Methods	Extent of Utilization
Incorporating Local Input	Extent of Incorporation
Capacity Building	Extent of capacity-building
Institutional Viability	Level of Financial and Organizational Viability

What Policy Directions Promote Sustainable Fisheries?

This section focuses on four key elements required for sustainable fisheries: (1) reasonable *attitudes*, at the institutional level, about the need for management and the limitations of that management, (2) feasible management, which works in practice, (3) the adoption of precautionary approaches in fishery science and management, and (4) methods for coping with the complexity of fishery systems, both in research and in coastal development.

Fishery Management: Recognizing the Need

A sense of the world's oceans as limitless frontiers, containing abundant resources for all, has dominated much of history. Indeed, fishing has tended to attract those with a desire for the adventure of the hunt, an entrepreneurial "free enterprise" view of the world, and a dislike of regulations that interfere with the "business of fishing." This at least has been the experience of Western culture in recent centuries.

This perspective has diminished with time. As experiences world-wide show the folly of unregulated laissez-faire exploitation, its incompatibility with long-term sustainability has become apparent. Yet even today, there persists in many fisheries merely a grudging acceptance of the need for regulations to limit harvesting activity, combined with a widespread distaste for such controls. The conservation benefits of regulation remain in constant conflict with the freedom sought by fishers to travel the world's oceans in search of fish and profit.

Sustainability in fishery systems undoubtedly requires appropriate attitudes amongst fishers, a "conservation ethic." Yet more is needed. Appropriate "conservation first" attitudes are required not just on the part of the individual harvesters but throughout the system; in the scientific process, in the design of management measures, in the structure and operation of the fishery, and within the decision-making bodies (Charles 1994).

Fishery Management: Recognizing the Limits

While the need to control fishery exploitation has become generally recognized over time, it is only recently that the limitations on what is possible through management have emerged clearly. Indeed, the complexities and uncertainties inherent in fishery systems make it folly to assume that any such system is really "controllable" through management.

Fishery management has been driven, in many cases, by a "fallacy of controllability," a belief that more can be controlled in the fishery than can be achieved in practice. One manifestation of this fallacy of controllability is the widespread use of "quota management"—setting and enforcing limits on the total catch taken from each stock. While, in theory, this ensures that a firm limit is placed on what can be removed from the ocean, in practice quota-setting has left much to be desired.

First, the setting of quotas requires knowledge of the fish biomass, something that (due to the unfortunate habit fish have of living underwater) is never known with certainty. Secondly, quota management creates inherent incentives to harvest more fish than is allowed in the established quotas. This could be done by exceeding the quota (whether this be a TAC or an individual quota), "high-grading" to maximize the *value* of what is reported as caught (typically by discarding lesser-valued fish overboard), and/or dumping prohibited fish (so as to be able to continue fishing for other stocks). Finally, not only are quota controls difficult to calculate and to enforce, the anti-conservationist behaviour they induce decreases the quality of data (and biases that data) in the stock assessment process, thereby tending to produce faulty assessments of stock status, and over-estimates of feasible catch levels. While quota management does have its strong points, these various problems suggest that it may require greater controllability than is realistically possible.

Feasible Management: Partnerships

In most fisheries world-wide, management has been implemented in a centralized manner, typically through regulatory frameworks imposed "top-down," with limited decision-making power on the part of fishers and coastal communities. Indeed, regulators have often taken sole responsibility for conservation, while fishers are typically viewed as selfish profit-maximizers, driven to take as much from the resource as possible [in keeping with Hardin's (1968) *Tragedy of the Commons*]. Unfortunately, this assumption about fisher behaviour often became self-fulfilling; left outside the decision-making system, they indeed had no other role than that of catching as much fish as possible. Pressure *increased* to "beat the system." No level of enforcement, however extensive, was able to prevent illegal fishing.

Fortunately, fishery management is evolving today, as regulatory bodies come to realize that efforts at total control have failed to achieve conservation (Berkes et al. 1989). Fishers, their organizations and their communities must have a clear stake in managing local resources, a degree of decision-making power, and the responsibility (with government) to ensure the fishery's sustainability. Furthermore, when the fish in the sea are publicly owned, as in most national fisheries, the public (as resource owners) should play a role in management. An emerging focus in this direction is community-based co-management, the joint development and enforcement of regulations by fishers, communities and government (e.g., Berkes 1989; Pinkerton 1989).

Feasible Management: Use Rights

It has become clear that well-defined "use rights" are crucial to sustainable fisheries. Indeed, the greatest threat to sustainability comes in cases where use is unrestricted, as has been the case with high seas fisheries outside national jurisdiction. Various approaches are in place to define use rights—notably limited entry schemes and various forms of "quasi-property rights," under which portions of the allowable harvest are allocated each year to individuals, fishing firms, communities or cooperatives. Rights might be market-based [e.g., "individual transferable quotas" (ITQs) which can be bought and sold (Clark et al. 1988)] or based on community institutions [e.g., TURFs—"Traditional Use Rights in Fishing" (Christy 1982)]. It should be emphasized, however, that restricted use rights do not guarantee sustainability. For example, ITQ systems may increase rent levels, but could actually diminish ecological sustainability, if incentives to maximize quota values lead to "dumping" (over-exploitation) of small or low-valued fish.

The Precautionary Principle: Rethinking the "Burden of Proof"

Fishery decisions must be made by balancing risks—the risk of stock and ecological collapse (due to excessive exploitation or environmental damage) versus the risk of lost economic benefits (if conservation measures are excessive). The fundamental question is: in considering these risks, does the burden of proof favour exploitation or conservation? In other words, is a precautionary approach to be followed?

The need to rethink the burden of proof arises both in the scientific realm and in fishery management. For example, given the complexities of ocean and fish dynamics, it is impossible to "prove" the common-sense idea that the future size of a fish population will depend on how many fish spawn in the present generation. This has had negative consequences, in the Atlantic Canadian groundfishery for example, where an absence of such proof meant that the scientific process paid relatively little attention to determining "healthy" levels for spawning stocks, and in fact omitted this consideration from "yield per recruit" calculations of allowable harvests.

On the management side, a controversial issue concerns the choice amongst "harvesting technologies," and in particular the impacts of trawlers on long-term conservation. By its nature, trawling affects the ocean bottom habitat, yet the vagaries of the ocean make it virtually impossible to "prove" any negative impacts on the food chain and on ocean productivity. In assessing where the burden of proof should lie, a "Precautionary Approach" (Garcia 1994) might suggest minimizing the use of trawlers, even without definitive proof, yet this is clearly controversial since trawlers currently catch a large share of the ocean harvest.

A third example concerning the burden of proof in fisheries lies in the debate over causes of fishery collapses. It is not uncommon, in fishery collapses, to blame any available non-human cause. For example, when Canada's Northern cod stock collapsed in the early 1990s, initial government press releases made no mention of human impacts on the resource, instead stating that "the devastating decline in the stock of northern cod" was due "primarily to ecological factors" (Department of Fisheries and Oceans 1992). While to this day, no one knows exactly what caused the collapse, there is growing evidence that over-fishing was in fact the dominant cause (Taggart et al. 1994; Hutchings and Myers 1994).

In heavily-exploited fisheries, a precautionary perspective would lead us to *assume* (unless shown otherwise) that human impacts are responsible for stock declines and that conservation actions should be taken to limit exploitation. Indeed, while the connection between fish population dynamics and the environment is certainly a complicated one, it seems that although ocean conditions might act as a "trigger" to initiate a stock collapse, the principal underlying cause of the collapse is more likely to be high levels of resource exploitation. The overall sequence of events may be as follows:

1. During periods in which ocean and environmental conditions are "acceptable" (from the perspective of the fish), fundamentally unsustainable harvest levels may *appear* to be sustainable.

2. Inevitably, and quite naturally, ocean conditions will deteriorate at some point (again from the viewpoint of the fish), so that heavily-harvested stocks are subject to additional stress—environmental conditions inhibiting growth and reproduction.

3. Faced with intense over-fishing, and a "trigger" in the form of an adverse environment, the fishery collapses.

This scenario seems to reflect experiences world-wide, from the British Columbia herring fishery collapse of the 1960s (Hourston 1978) to the Peruvian anchovy collapse, triggered by ocean cooling known as "El Nino" but due fundamentally to massive exploitation (Hilborn and Walters 1992).

The Precautionary Principle: Adaptive Management

In some fisheries, annually-determined allowable harvests (TAC) are viewed as fixed and unchangeable within the fishing season. In the groundfishery of Atlantic Canada, for example, allowance was made "on paper" for in-season changes in response to new information about the stocks, but such changes were very rare. The focus was on a stable fishery, to allow firms to keep to their "business plans." Any adjustment to the TAC was left to the following year. Even then, a so-called "50% rule" (Department of Fisheries and Oceans 1991) limited downward adjustments in quotas to just 50 percent of the scientifically-recommended cuts, to avoid disruption in the industry. (This gradualism did not apply in the opposite direction; if scientific analysis suggested an increase in the allowable harvest, the full increase could be made immediately.)

Such approaches need to be reassessed in an industry in which uncertainty is so pervasive, one in which no one can be certain how much of the key ingredient is available in any given year, nor the effect production will have on future availability of that input. A flexible, adaptive approach is needed. Fishing plans, and individual "business plans," must be designed to adapt to unexpected changes in the natural world. A "conservation first" perspective recognizes that short-term stability in catch levels, while undoubtedly desirable, comes at the cost of longer-term ecological risks.

Coping with Complexity: Multidisciplinary Research

The fishery is a highly complex bio-socio-economic system, with multiple species and a spectrum of fishers, as well as processors, distributors, marketers, consumers, and regulators. To deal with this complexity, there is a need for greater attention to multidisciplinary fishery research—from linkages between oceanographic and biological considerations, to research focusing on fishery management, fishing processes, fisher behaviour and the human dynamics of fishery systems. Promotion of such research has a substantial history (Andersen

1978; Charles 1991; Durand et al. 1991; Fricke 1985; Pollnac and Littlefield 1983; Pringle 1985). Recently, an advisory body to the Canadian Minister of Fisheries and Oceans—the Fisheries Resource Conservation Council—emphasized several of these themes in recommending a "new approach" to fishery research:

> It is important that a multidisciplinary team approach be implemented in addressing fishery research questions—both in the laboratory and in the field.
>
> It is important that a real move be made towards an ecosystem approach to fisheries management. The various bits and pieces of ecological knowledge must be reflected in a better understanding of the whole system. Thinking in terms of whole ecosystem must become an essential and integral part of day-to-day activities ...
>
> It is important that scientists study fishing scientifically as a system and strive to better understand the relationship between fish (resource) and fishing (fishing practices, gear technology, capacity analysis, etc.). This must reflect the recognition that fishery science involves more than the natural sciences and that scientific research is a part of the development, implementation and evaluation of fishery management measures and economic policy tools.
>
> It is important that a genuine thrust be made to give a more effective role in fishery science to those with practical experience and knowledge in the fishery, and the role must be rigorous and transparent. (FRCC 1994: 118)

Certainly, some progress is being made. For example, on the latter point, research partnerships are being developed in many fisheries around the world [such as the Fishermen and Scientists Research Society, a Canadian organization dedicated to conducting joint research and providing scientific training to fishers (King et al. 1994)]. However, there is much potential for more targeted research on these themes, a point highlighted in the United Nation's *Agenda 21* document.

Coping with Complexity: Integrated Development

Many coastal fisheries globally face a trio of fundamental problems: over-exploited resources, over-extended fleets, and a lack of non-fishing alternatives. Unfortunately, fishery policy has often ignored the latter problem, having been developed and implemented in isolation from other coastal and marine activity, such as aquaculture, shipping and tourism. For example, to deal with excess effort in fishing, emphasis is often placed on removing "surplus" fishers, without considering where these "redundant" people are to go. This tends to be unfeasible as a policy measure, since pressure on the fishery resource is often redirected through illegal channels. Generating employment alternatives is simply crucial to effective resource conservation (Smith 1981; Charles and Herrera 1993). To this end, fishery planning could be combined with community-based diversification, through so-called "Integrated Coastal Development" (e.g., Arrizaga et al. 1989). This could focus on creating employment alternatives that build economic strength within the community, taking advantage of local comparative advantages in ocean-related activity (such as development of alternative fisheries, fish farming, coastal tourism, and the like).

Discussion

This chapter has combined a conceptual discussion of sustainability in fisheries with suggestions of practical policy directions. Key aspects of these themes, and a number of corresponding research questions, are summarized here.

Sustainability Assessment

A tentative framework has been provided for assessing sustainability, based on ecological, socio-economic, community and institutional components of sustainability, and use of quantitative indicators to evaluate the process of sustainable development. This framework is speculative in nature, and a clear need exists for practical testing to demonstrate the validity of the proposed indicators and the feasibility of measuring each indicator under varying circumstances. A number of research questions are also notable, such as:

> What are suitable geographical boundaries for a fishery system within the process of sustainability assessment? Should these reflect ecological, economic, socio-cultural or political factors? Should emphasis be on the "natural" boundaries of coastal zones or on the *de facto* human boundaries?
>
> Given that in a coastal fishery system, the socio-economic environment influences the "carrying capacity" of human activity, just as the natural environment determines the carrying capacity of the resource, how can one best measure indicators of carrying capacity, both natural and human?
>
> How can one model the adjustment processes involved in shifting fishery systems between sustainability states (e.g., from one of non-sustainability, or one that is sustainable but unproductive, to a state in which overall sustainability has been improved)?

Policy Directions

A set of policy directions to promote sustainability has been described, focusing on (a) recognizing at the institutional level both the need for management and the limitations of that management, (b) developing feasible management approaches that are effective in practice, (c) adopting precautionary approaches in fishery science and management, and (d) developing methods for coping with the complexity of fishery systems, through multidisciplinary research and through coastal development. In developing management approaches in these directions, study is needed on:

> What are the implications for sustainability of centralized versus decentralized management? Of state versus market-based versus community-based management? Of controls placed on fishing activities (effort) versus those placed on catch ("TAC")? How does this depend on the nature of the fishery, whether small-scale community-centred or large-scale "industrial"?
>
> What factors make a management system acceptable to the various fishery participants, so that conservation needs and management measures will be accepted and self-enforced?

Given the importance of marine fisheries as a source of food and livelihood, as well as their socio-cultural significance, it is clear that a prerequisite for sustainable use of the oceans is the active pursuit of sustainability in fishery systems. However, the inherent complexity of these systems, combined with the history of ecological, social and economic crises commonplace in fisheries around the world, makes this a challenging task. This chapter has attempted to provide some policy measures to aim in the right direction, together with a framework for evaluating progress toward sustainability.

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