

# **Building Blocks of Sustainability in Marine Fisheries Management**

*Stakeholders, objectives, and strategies*

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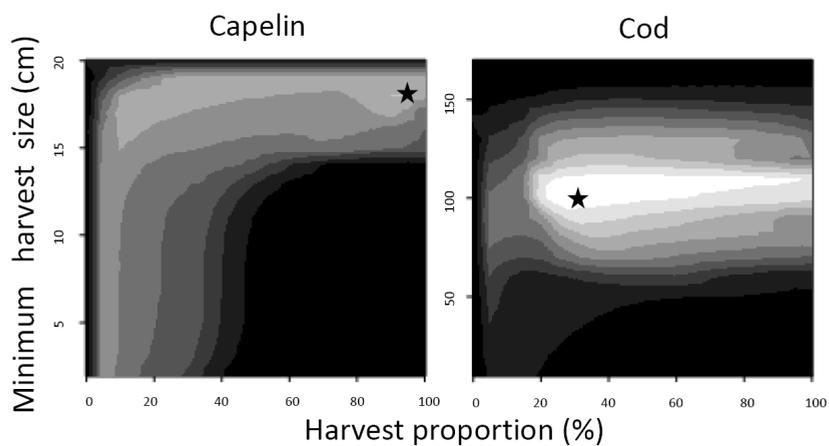


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## Errata

Page 94: The left panel (Capelin panel) contains an error. Figure 5 should be replaced with the following figure:



## Scientific environment

This study was prominently conducted in the Pelagic fish Research Group at the Institute of Marine Research in Bergen, Norway with strong affiliation to the Department of Biology at the University of Bergen. Parts of this work were conducted at the Evolution and Ecology Program at the Institute of Applied Systems Analysis (IIASA) in Laxenburg, Austria and the School of Marine Science and Technology (SMAST) of the University of Massachusetts, Dartmouth, USA.

The Norwegian Research Council funded the entire PhD work through a grant from the HAVKYST program as well as a 3 month stay in Austria at IIASA as part of the Young Scientists Summer Program and a 3 month stay in the United States at SMAST. An additional 3 month research grant for a research stay in Austria at IIASA was supported by the European Marie Curie Research Training Network *FishACE* (Fisheries-induced Adaptive Changes in Exploited Stocks), funded through the European Community's Sixth Framework Program (Contract MRTN-CT-2004-005578)



International Institute for  
Applied Systems Analysis



Forskningssrådet



Fisheries-induced Adaptive Changes  
in Exploited Stocks  
A European Research Training Network



**HAVFORSKNINGSINSTITUTTET**  
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## Summary

Fisheries management, freshwater or marine, is found in virtually every country in the world. Fisheries management is the activity of organizing and controlling the extent of human exploitation of a single fish resource or combination of fish resources. Management can be as informal as communal social norms or as official as federally controlled departments or formal multi-national agreements.

The overriding objective in modern fisheries management is sustainable exploitation. Although policy-makers and stakeholders can relatively agree with this objective, the means to the end are highly debatable and uncertain. Therefore, normative science is not able to correctly describe how sustainable exploitation should take form and a new post-normal science view is needed.

Intricate system components of biology and socio-economy as well as political issues are parts of modern management. Although these system components are broad and far-reaching, research in the realm of modern management tends to be specialized in single components (biological studies, economical studies or social studies) rather than through interdisciplinary work. Management success becomes more probable when the biological, economical, and sociological research is bridged through holistic system discussions and conclusions.

This dissertation tackles some specific topics within marine fisheries management through four papers: a review of management case studies, modelling stakeholder utilities for consensus-building, theoretical aspects of harvest control rules, and finally, mapping biological, economic and employment consequences of a menu of management options resulting from use of different marine demersal trawls.



# Acknowledgements

I have been so fortunate for the opportunity to start my career in fisheries science in Bergen, Norway. This doctoral thesis was conceived in 2003 on board G.O. Sars somewhere in the Norwegian Sea after a brief conversation with Dankert Skagen. “You did your master’s on harvest control rules?” he asked while griping his pipe slightly from his mouth. “That’s something we could think about taking a bit further.” I am very privileged to have had Dankert as my main advisor these three years. His experience and insight are rich and I have learned how his involvement in the ICES community is rightly well respected. I thank him for his guidance and look forward to future collaboration in Bergen.

Mikko Heino has been my mentor from the start of my master’s thesis in Bergen in 2002. Our professional relationship has evolved from our first meetings when I understood about 10% of the concepts he was explaining to me to today where we exchange different insights on fisheries management issues. Mikko has greatly broadened my scientific network first by encouraging me to present at the ICES Annual Science Conference in 2003 and later through the Young Scientists Summer Program in 2007 at the Institute for Applied Systems Analysis and involvement in FishACE. I am indebted to his patience as I learned mathematical modelling and to his attentive ear when I became fascinated by the societal issue in fisheries. I thank Mikko for introducing international collaboration to me and showing me how fun it really is.

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Steve Cadrin opened the door for me to conduct research in my home country. My summer in Massachusetts (2008) was a chance for me to apply my doctoral work in a new place with new stocks, new stakeholders, and new colleagues. I thank Steve and the great students in his lab for hosting me in Massachusetts and opening my eyes to everything collaborative research with fishermen can achieve.

The Pelagic research group at the Institute of Marine Research has been my scientific home the past three years. I thank all the Pelagikere for cozy times around the coffee table where we trade stories at sea and sometimes dirty jokes. I especially remember the way Sigmund and Anne-Liv took me under their wing during my first cruise with G.O. Sars (the same cruise where I met Dankert) and showed me the ropes above and below deck. They made me feel welcome and helped me feel like a part of the IMR team for the first time.

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I thank Mom and Dad, wonderful and supportive parents, for encouraging me to find out how I could be most useful in this world. To Grandma: Thank you so very much for always loving me and supporting me (on and off the court!), even when I'm so far away in Norway. To my Grandad Corky: Hillsdale was a great choice for me. I wouldn't be where I am today in my enthusiasm for systems and cross-disciplinary thinking without my conservative liberal arts degree. Thank you for your strong direction towards a solid education. To my grandmother Lee: Your strong will, long-term viewpoints, and intellectual curiosity have helped open up my self-confidence. Thanks for pushing me hard to achieve great things! I am truly blessed to have been raised by such a wonderful family. Thank you all for stretching my boundaries through education and emotional support so that a little girl from Indiana could dream about the sea and reach out to other parts of the world.

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During my doctoral studies, my dear husband has endured around 10 months of me being away from home. The last months, while I have been home, I have often worked late hours. To Simon: Thank you for all the love you give me. You have done so much at home, like cooking for me so that I could relax after hectic days. I thank you for being so supportive and loving. I look forward to returning the kindness, favors, and love as you finish your PhD. Eg elsker deg høyt.

A handwritten signature in black ink, appearing to read 'Cory E. Powell'. The signature is fluid and cursive, with the first name 'Cory' written in a larger, more prominent script than the last name 'Powell'.

BERGEN, March 30, 2009

## Definitions

**Stakeholder:** “A person or group likely to be affected by (or who think they will be affected by) a decision – whether it is their decision to make or not.”<sup>1,2</sup>

“Stakeholder groups that have a direct or indirect "stake" can be at the household, community, local, regional, national, or international level.”<sup>3</sup>

**Sustainability:** “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”<sup>4</sup>

**Normal science:** “A concept originated by Thomas Samuel Kuhn and elaborated in *The Structure of Scientific Revolutions*. The term refers to the relatively routine work of scientists experimenting within a paradigm, slowly accumulating detail in accord with established broad theory, not actually challenging or attempting to test the underlying assumptions of that theory. Kuhn identified this mode of science as being a form of "puzzle-solving." According to Kuhn, Normal science possesses a built-in mechanism that ensures the relaxation of the restrictions that bound research whenever the paradigm from which they derive ceases to function effectively. Silvio Funtowicz and Jerome Ravetz eventually developed the concept of post-normal science.”<sup>5</sup>

**Post-normal science:** “A concept developed by Silvio Funtowicz and Jerome Ravetz, attempting to characterize a methodology of inquiry that is appropriate for cases where "facts are uncertain, values in dispute, stakes high and decisions urgent". It is primarily seen in the context of the debate over global warming and other similar, long-term issues where we possess less information than we would like.”<sup>5</sup> Funtowicz and Ravetz believe that since values are embedded in science, post-normal science should integrate stakeholders in an extended peer-community.

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<sup>1</sup> Susskind, Lawrence, Sarah McKearnan and Jennifer Thomas-Larmer, eds. *The Consensus Building Handbook: A Comprehensive Guide to Reaching Agreement*. Thousand Oaks, CA: Sage Publications, 1999, 1147 pp.

<sup>2</sup> Note from the Candidate: In this dissertation, I do not define scientists and managers as being stakeholders.

<sup>3</sup> FAO (1997): *Fisheries management. FAO Technical Guidelines for Responsible Fisheries*, 4: 82 pp.

<sup>4</sup> WCED. 1987. *Our Common Future. The Report of the World Commission on Environment and Development*. Oxford: Oxford University Press.

<sup>5</sup> [www.wikipedia.com](http://www.wikipedia.com) (accessed March 27, 2009)



# List of papers

## Paper I

Dankel, DJ; Skagen, DW and Ulltang, Ø. 2008. "Fisheries management in practice: A review of 13 commercially important fish stocks. *Reviews in Fish Biology and Fisheries* 18: 201-233.

## Paper II

Dankel, DJ; Heino, M and Dieckmann, U. 2009. "Can integrated assessments reconcile stakeholder conflicts in marine fisheries management?" Manuscript.

## Paper III

Dankel, DJ and Skagen, DW. 2009. "Dankel, DJ; Heino, M and Skagen, DW. 2009. "Properties of Generic Marine Harvest Rules." Manuscript.

## Paper IV

Dankel, DJ; Jacobson, NS; Georgianna, D. and Cadrin, SX. 2009. "Can we increase haddock yield within the constraints of the Magnuson-Stevens Act?" Submitted.

The papers are henceforth referred to by their Roman numeral, indicated above.

*"I believe that rocket scientists have it easy, they deal with largely physical phenomena that have well-understood laws. They can experiment on small scales and learn their lessons rapidly. Management of fisheries deals with much more complex biological systems and more complex human systems. The USA was able to put a man on the moon within a decade of setting that goal. Achieving biological and economically sustainable fisheries has proven more elusive." (Hilborn 2007)*



# 1. Building blocks of sustainability in marine fisheries management: Objectives, stakeholders and strategies

DOROTHY J. DANKEL

Environmental sustainability and the sustainable use of natural resources are goals adopted by member countries of the United Nations (UN 2008) as well as repeated in many international agreements and declarations (Heino and Enberg 2008). An important component in these goals is the security and sustainability of marine resources, such as fish and other seafood. Natural resources harvested from the ocean are a significant source of animal protein for billions of people (Pauly et al. 2005; FAO 2009). In addition, marine resources are a large source of economic activity, through harvesting, production, and transport of seafood and the associated secondary activities of ship building, maintenance, and fishing supplies. Despite the recognized importance of marine resource sustainability, it is not the norm (Heino and Enberg 2008). Only 22% of the world's fisheries are considered sustainable (UN 2008). The challenge remains how to organize effective practices that are able to successfully promote fisheries sustainability.

In 1992, the United Nations agreed to a principle that shifts the burden of proof from science under uncertain conditions.

*"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." (UN 1992)*

The concept of the precautionary approach is used widely among developed nations. For example, the International Council of the Exploration of the Sea (ICES) uses a precautionary framework when commissioned by its Member States in Europe to review candidate management plans. In the United States, the Magnuson Stevens Fisheries Conservation and Management Act clearly states that the conservation of marine resources take precedence over exploitation (Anonymous 2006). But it is evident from the current state of fisheries that the precautionary approach in practice does not have an impressive record; it is simply a first step towards marine resource sustainability and not the whole answer.

Fisheries management cannot be evaluated if there are no clear objectives. Indeed, the formulation of management objectives in the absence of stakeholder dialogue is likely to create tension between managers and the user groups who are ultimately affected by management objectives and regulations. It is plausible that the biggest argument against stakeholder involvement in fisheries management is that conflicting objectives make such attempts futile.

Hardin (1968) coined the term "tragedy of the commons" to describe the dilemma facing, among other topics, sustainable renewable resources. Hardin foresaw the current overfishing problems and lack of sustainable stewardship we are faced with today by lack of ownership of exploited fish stocks causing little incentive for fishers to protect fish stocks for future generations. Despite the simplicity of the concept of the "tragedy of the commons", no effortless solution exists to eradicate it.

Even though fisheries management around the world varies widely, I believe there are three common building blocks that can form the foundation for sustainable fisheries management: (i) the recognition, identification, and organization of the resources primary stakeholders; (ii) setting the objectives for the resource in line with stakeholder desires and international

agreements; and (iii) creating a strategy to implement the objectives, in compliance with the precautionary approach.

## 1.1 The fishery system

The first step towards sustainable marine exploitation is the recognition of all integral parts of the fishery system. The three most essential components are the natural ecosystem, the human system and the management system (Charles 2001; ICES 2006). There are numerous internal dynamics within each of these three components. Temperature change, ocean current changes, algal blooms, and resulting stochastic fish reproduction and recruitment are some examples of events that can occur in the natural system. The human system includes fishers, conservationists, and other stakeholders and their associated dynamics including employment and economic variations, interactions, and conflicts. The management system includes the process of applying knowledge of the natural ecosystem and the human system towards actions that best fulfill policy objectives.

Fisheries science is inherently uncertain due its vast and viscous medium, the ocean, which contains abundant stochastic influences. Fisheries management is also uncertain. Human behavior in the form of fishing activity, and the resulting political issues it entails, can play a large role as stochastic events affecting the dynamics of the fishery system. Fisheries scientists strive to understand these dynamics and managers endeavor to manage them. However, scientists are often confronted with large amounts of uncertainty that, especially when not successfully communicated, can disillusion stakeholders (Rosenberg 2007) and breed distrust towards scientists and their methods.

## 1.2 Objectives in fisheries management

Successes and failures in fisheries are reasoned from the underlying objectives. A regime considered a biological success may also be judged an economic failure (Cunningham and Bostock 2005; Hilborn 2007; Dankel et al. 2008). Objectives are often elicited on different levels and can be broad or specific, explicit or implicit. International agreements often state broad objectives like “long term conservation and sustainable use of fisheries resources” (FAO 1995) but may not be legally binding. The United Nations Convention of the Law of the Sea sets standards for marine conservation and protection of resources and is legally binding (UN 1982). More specific objectives, like maintaining catch stability at a specified level (Skagen et al. 2003), can be set for a fishery according to stakeholder’s desires. Political objectives are often kept implicit. One example of an implicit objective is to have the “minimum sustainable whinge” (Hilborn 2007) or to curtail stakeholder discontent as much as possible.

There are many different objectives for resource use (Figure 2) (Caddy and Mahon 1995). The resource’s stakeholders can be broadly partitioned into groups according to their objectives. For example, fishers usually represent stakeholders who may forgo biological risks for high yields and profit, whereas conservationists are those who are vocal toward habitat preservation and biodiversity issues. Thus a resource’s management objectives should aim to strike a balance among different, possibly conflicting, objectives. However, a politician may not want to take a stance to lay down explicit biological, economic, and social objectives. Doing so runs a high risk of unnecessary stakeholder conflict and discontent aimed at the decision-maker. Even though objectives in management are im-

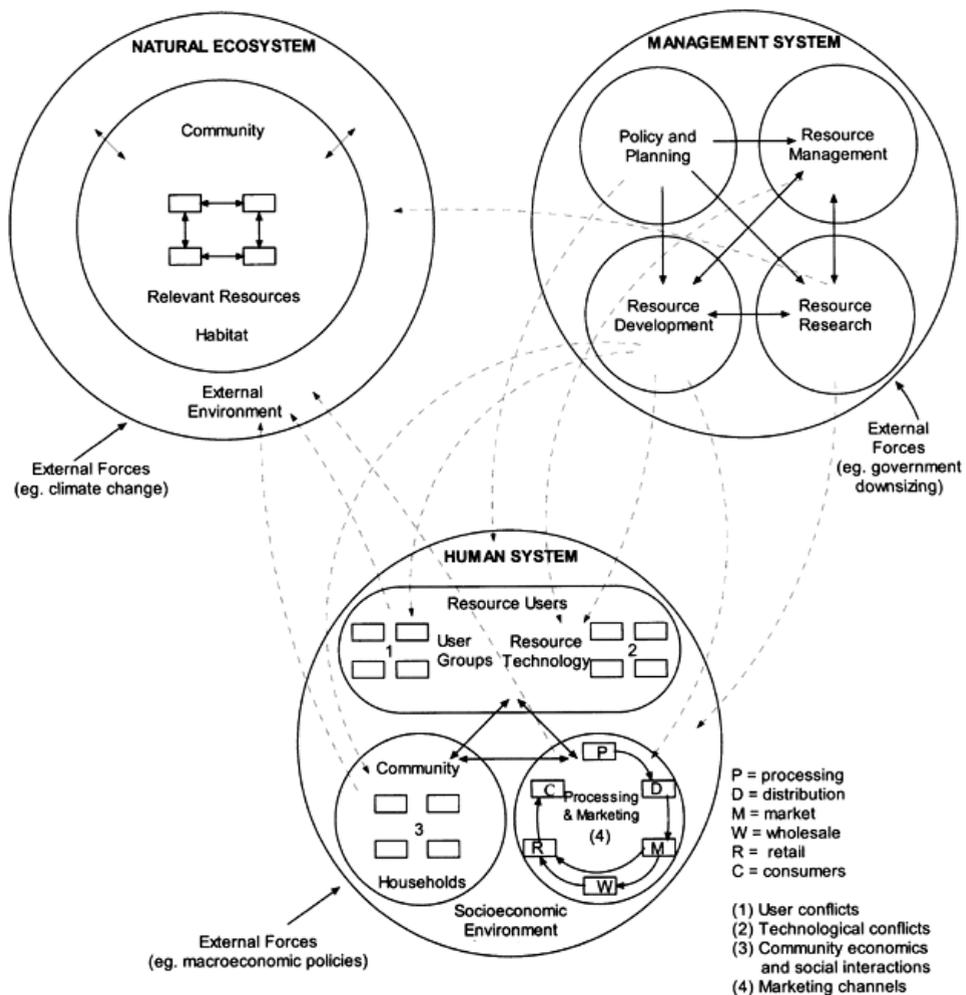


Figure 1. The fishery system including the three major sub-systems (natural ecosystem, management and human) and their associated major components within (from Charles 2001).

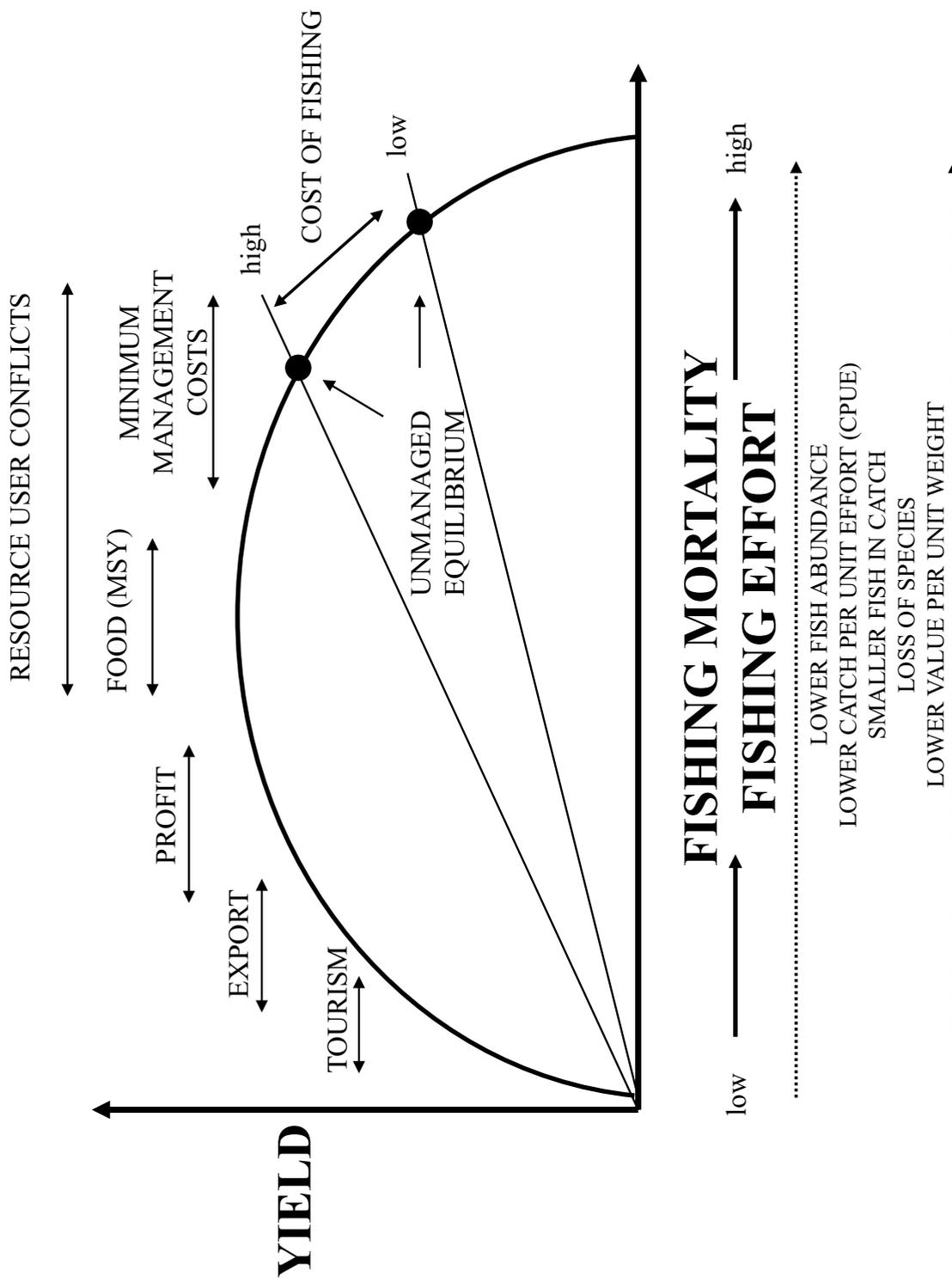


Figure 2. A schematic representation of fishing mortality rates corresponding to different societal objectives for marine resource use. The context here is of a multispecies surplus production model for reef fisheries (after Mahon 1992). Modified after Caddy and Mahon (1995).

perative, clear objectives are not always the norm (I).

It is important, but not easy, to strike a multi-dimensional balance in fisheries objectives that can reflect the biological and socio-economic components related to the resource and its stakeholders (Cunningham and Bostock 2005). The lack of clear and explicit objectives can act as a barrier blocking sustainable management. However, setting sustainable objectives in marine fisheries does not necessarily mean that one must endure the wrath of conflict. On the contrary, conflict arising from stakeholder diversity can be put to work for sustainable management (Follett 1955).

### *1.2.1 Scientists as facilitators*

The role of scientists in marine fisheries management has traditionally been to collect and disseminate data from scientific surveys and catch reports from the fishing industry to managers in the form of a recommended TAC (Reeves and Pastoors 2007). But when stocks face crises, the scientists' role in the "TAC machine" can become less relevant (Schwach et al. 2007); crises cannot be solved when TACs are routinely overshot (Cardinale and Svedäng 2008). Biologists become easily overworked by political pressure to come up with the "answer". In most instances, the questions asked by fisheries managers are beyond the boundaries of natural science and are better confronted across scientific disciplines (Schwach et al. 2007) in a post-normal scientific framework (Funtowicz and Ravetz 2008).

Post-normal science is the idea that since science-related management deals with deep inherent uncertainties and interdisciplinary realities, normal science is unable to offer solutions that best benefit society (see Definitions). Instead, complex systems are best managed by expli-

citly acknowledging uncertainties and extending traditional peer communities to accommodate interdisciplinary science in a dialogue with decision-makers and stakeholders (Funtowicz and Ravetz 2008). In a post-normal world, scientists who provide advice for management are better suited as society's scientific facilitators if the uncertainty and values at stake are acknowledged. Scientists have a responsibility to disseminate and synthesize results from data and lessons learned from model application to stakeholders. But facilitation does not stop at dissemination. On the contrary, communicating science is just the beginning of a dialogue with the resource's stakeholders in order to share and communicate ideas and observations in an effort to build credibility, transparency, and trust. Scientists' job is to advocate for the objective use of the best methods towards answers to stakeholder's questions (ICES 2008a) as well as help identify a common ground when stakeholder conflicts stand in the way of sustainable fisheries (II).

In order to practice interdisciplinary post-normal science, fisheries scientists should acquaint themselves with the societal issues surrounding the resource. The first step to do this is to recognize what I call the stakeholder landscape.

## 1.3 Recognizing the stakeholder landscape

The human sub-system in the fishery system (Figure 1) has traditionally been the system least connected to fisheries science and, ironically, it is the human system that fisheries management strives to sustainably control. In many cases, fisheries management is a top-down bureaucratic exercise with centralized control (Gray and Hatchard 2003; Prince 2003; Daw and Gray 2005). Top-down control has several convenient advantages (such as clear lines of control and the

ability to enforce tough decisions) but has a tendency of disconnecting the human system in fisheries management by not explicitly including the human dimension and its user groups.

The lack of stakeholder integration in management decisions was recognized in the European Union and led to a reform of the European Common Fisheries Policy in 2002. One of the results of this reform was the creation of seven Regional Advisory Councils (RACs) intended to be a forum for stakeholders to provide consensus advice to the European Union regarding fisheries management. The birth of the RACs was an attempt to include stakeholder voice in top-down management. At first, however, the EU was logistically unable to handle this new-found consensus voice to the detriment of some of the key RACs (Gray and Hatchard 2003).

But it is as important for scientists to recognize the human system as for governments. I define the stakeholder landscape as the case-specific societal context of a resource found within the human dimension of the fishery system. By getting to know the stakeholder landscape, a scientist is enlightened on the day to day socio-economic realities that stakeholders face as well as the political motivations that exist. Scientists have the advantage of being considered an objective part of society by default. By nurturing and protecting this societal perception, a scientist has a solid foundation on which to build stakeholder trust, a vital component towards initiating a post-normal dialogue to support sustainable resource management.

### *1.3.1 Steps to meet the human system in fisheries*

Dialogue has proved to be an important part of trust building between scientists and stakeholders for different reasons. First, through active dialogue,

communication of uncertainty is improved; scientists are able to inform stakeholders of the many uncertainties involved with annual stock assessment that use scientific survey and fisheries dependent data. Second, stakeholders can communicate their experiences at sea from which scientists may derive important information. Dialogue between stakeholders and scientists is crucial in the development of management rules (FAO 1995; Charles 2001; Caddy and Seijo 2005; Cunningham and Bostock 2005; ICES 2006; Anonymous 2007; ICES 2007; ICES 2008b; Brady and Waldo 2009).

Reflections on the reform of the EU Common Fisheries Policy give promise to closer stakeholder collaboration in the realm of management strategy development. The new scientific advisory council organization of the International Council for the Exploration of the Sea (ICES) is one way the European scientific community is striving to give advice in a post-normal world (ICES 2008a) and there are examples of how ICES is starting to put these ideas into practice (ICES 2007; ICES 2008a; ICES 2008b). In recent management strategy development cases, it is scientists, or scientific organizations like ICES, who use their status as an objective entity of the concerned resource to initiate a dialogue regarding management issues like objectives and appropriate strategies (Roel and De Oliveira 2007).

## **1.4 Integration of stakeholder objectives in fisheries management**

After the stakeholder landscape is recognized and objectives for each interest group are collaboratively discussed and identified, it is possible to proceed with the next building block of successful

fisheries management: integration of objectives. But stakeholder objectives often seem conflicting. According to American social anthropologist and management philosopher Mary Parker Follett (1868-1933) there exists three ways to resolve conflict: domination, compromise, and integration. Domination is by far the most common method due to its familiarity and ease. In a compromise, some stakeholders have to sacrifice some of their desires to achieve consensus. Integration of a common solution starts with each individual, or stakeholder, re-evaluating their desires. An integrated solution is conceived if this re-evaluation produces a reasonable homogeneity of objectives that consensus may arise.

*“Integration involves invention, and the clever thing is to recognize this and not let one’s thinking stay within the boundaries of two alternatives which are mutually exclusive.”... “Compromise does not create, it deals with what already exists; integration creates something new...” (Follett 1955, pp. 33 and 34)*

Since integration produces a new, collaborative view as a solution to a conflict, the conflict is settled and not likely to come about in the future. Compromise, on the other hand, is only a temporary give-and-take scenario that is likely to be faced again. Integration is therefore the preferred method to resolve conflict (Follett 1955). Follett (1955) summarized steps towards integration including uncovering the real conflict and taking all stakeholder groups’ objectives and breaking them up in their constituent parts (II).

### ***1.4.1 Stakeholder conflicts of objectives***

Hilborn (Hilborn 2007) qualitatively discussed conflicts of objectives in fisheries noting that some objectives may not be as conflicting as previously thought. Ecosystem preservation and fishers’ profit are an example; in most situations, both

objectives are fulfilled at a fishing level lower than that which gives maximum sustainable yield (MSY). In this case, fishers concerned about maximizing profit and stakeholders interested in conserving the resource are likely to come to a consensus that total fishing levels should be below MSY (II).

However, there will also be stakeholders concerned about other objectives, like yield and employment. In order to integrate other components of the fishery, **Paper II** introduces a framework that explicitly focuses on dividing and weighting different preferences for a stakeholder group, thus quantifying Follett’s second step of integration.

### ***1.4.2 Obstacles to an integrated solution***

Some practitioners in fisheries management are sure to dismiss Follett’s description of an integrated solution as wishful thinking. But do not let me make the impression that an integrated solution is easy. Before the integration steps are put into place, it is important to identify obstacles and devise strategies to avoid possible pitfalls. Follett (1955) outlines some typical obstacles that can block successful integration. The first one is a requirement of a “higher order of intelligence”; recognizing the need for integration requires a superior level of consciousness since domination and compromise are much easier and more common alternatives. Another obstacle, and in my opinion the most relevant, is the lack of training in integration and the need for courses in the art of cooperative thinking (Follett 1955). It is possible that many fisheries crises can be avoided if scientists and managers recognize the need for cooperative thinking techniques and put them to use. Domination in fisheries tends to favor the strongest stakeholders which are usually the ones with highest economic interests. Cooperative thinking

towards an integrated solution is also a natural component of democracy contrary to domination. In a democratic society, all stakeholders should be represented when management objectives are drafted.

Top-down management has its strengths: when decisions are made the path toward implementation and upholding regulations is straightforward, especially when conflicts are real and no agreement can be reached. However, one negative consequence that usually transpires top-down regimes is impersonal orders directed from the top ranks of management down to the stakeholders. There are psychological repercussions that can result from the focus of orders on individuals or groups of individuals but advantages can occur when orders are depersonalized. Follett (1955) comments on the observation that orders are more likely to be followed when they are given by the situation at hand and not from a dominating person or group. I think this remark is relevant to fisheries. Again, though, only when the integral order, or situation at hand, is understood by all stakeholder groups can orders be depersonalized. This highlights the need for small, regional focus groups to aid in education (of the consequences of different management regulations, for example) and cooperation.

There is also some theoretical and empirical evidence that stakeholders are more likely to look for common solutions to conflicts of objectives when they acknowledge that there is heterogeneity of objectives (Shelling 1960). Shelling (1960), writing mostly under the context of the Cold War, states that “uniqueness avoids ambiguousness.” These qualitative discussions on stakeholder conflicts in other fields are relevant to fisheries, but

There is therefore scientific motivation to quantify stakeholder heterogeneity (II). But in order to include the whole stakeholder landscape, biological and socio-economic consideration must be able to be quantified (II, IV). Dankel et al. (II) bridge a biological and a socio-economic

model for two contrasting fisheries in the Barents Sea. The result is an explicit view of the stakeholder consensus that emerges. Although a quantification of probable stakeholder consensus cannot solve all fisheries crises, it is important for scientists, as facilitators, to present stakeholders with useful information to aid their decisions and actions (Kaplan and Levin 2009).

The next step towards sustainability in fisheries is the development of a management strategy that is robust to uncertain conditions (such as environmental variability and fishing implementation) and incorporates the stakeholder landscape (aided by quantitative examinations of their preferences [III]).

## 1.5 Harvest Control Rules as a modern tool in fisheries management

As far as fisheries are concerned, the only thing humans can really control is the amount and type of exploitation that occurs. In modern society, management objectives should be democratically selected. Then, managers have a clear foundation on which tactics to achieve these objectives can be formulated. A harvest control rule (HCR) is a clear, quantitative framework that determines the amount of fishing pressure or allowable catch according to a given level of the resource. HCRs can be used on an annual or multi-annual basis. Pre-agreed by stakeholders, HCRs are implemented by managers after scientists have tested the rule according to the precautionary approach or other constraints usually including robustness to environmental or recruitment variation. Ideally, once an HCR has been agreed, it stays in effect until the rule is up for review.

There is no “one size fits all” harvest rule for marine resources and each HCR

is rightly created on a specific case by case basis. There exists, however, some general statutes for best practices regarding HCRs. Harvest rules should be detailed and specific, such that there is no “wobble room” for stakeholders to interpret the HCR in different ways (ICES 2008b). The harvest rule must be able to be defined quantitatively; if it is not able to be explicitly coded in a mathematical model, for example, it is most likely vulnerable to interpretation and perhaps future litigation. Finally, HCRs should be developed in a dialogue with stakeholders. Although the conception of an HCR can come from either scientists, managers or stakeholders, the end product is more likely to be accepted and correctly implemented by stakeholders if a transparent dialogue has taken place (ICES 2006; ICES 2007; ICES 2008b). Experiences show that dialogue and communication with stakeholders during the development of a harvest rule should not be underestimated. Numerous iterations among scientists, managers, and stakeholders are necessary and it can take up to several years to get the process going (ICES 2008a).

### 1.5.1 HCRs in post-normal science

Figure 3 places HCRs in the context of the fishery system. Harvest rules are a concluding step towards completing a management plan or strategy. The success of a harvest rule depends on the appropriateness of the overall policy (strategic management system) and ability of managers to implement it. Some examples of HCRs are illustrated in Figure 4.

It is the scientists’ job to test the HCR for performance measures dictated by managers and stakeholders and for compliance under the precautionary approach which includes little risk to stock collapse or other negative occurrences. Scientists’ mission as facilitators entails exploring and communicating trade-offs of different performance measures to stakeholders.

Consequently, scientists should have an understanding of the underlying characteristics of HCRs in the context of different types of fish resources (III).

Under a normal science paradigm, scientists are commissioned to give scientific advice for a variety of questions, including developing harvest control rules for stocks that conform to the precautionary approach. The HCR would determine the level of total allowable catches for a given year. As such, HCRs have been more or less understood in the case-specific stock for which it was developed. However, the difference between understanding how an HCR performs in a stochastic model and how it performs in real life is broad. HCR application in the wild is subject to a learning curve dictated by ecological and financially expensive trial and error experiences.

For post-normal science to work, scientists should use fundamental understandings of their discipline to guide them in their cross-disciplinary dialogues. In order to get a better theoretical grasp on the mechanics of HCRs, it is best to start on relatively simple grounds. The objective of **Paper III** is to understand important properties of a generic harvest rule.

## 1.6 Putting it in practice: An interdisciplinary aid to guide management regulations & strategies

Harvest control rules represent the innermost layer of the fishery system, but concrete regulations (such as gear type, minimum harvest size, and mesh size) are part of the more overlying tactical decision system (Figure 3). **Paper IV** focuses on a case study from the New England groundfishery in the United States and illustrates the role scientists can play in facilitating the understanding of different

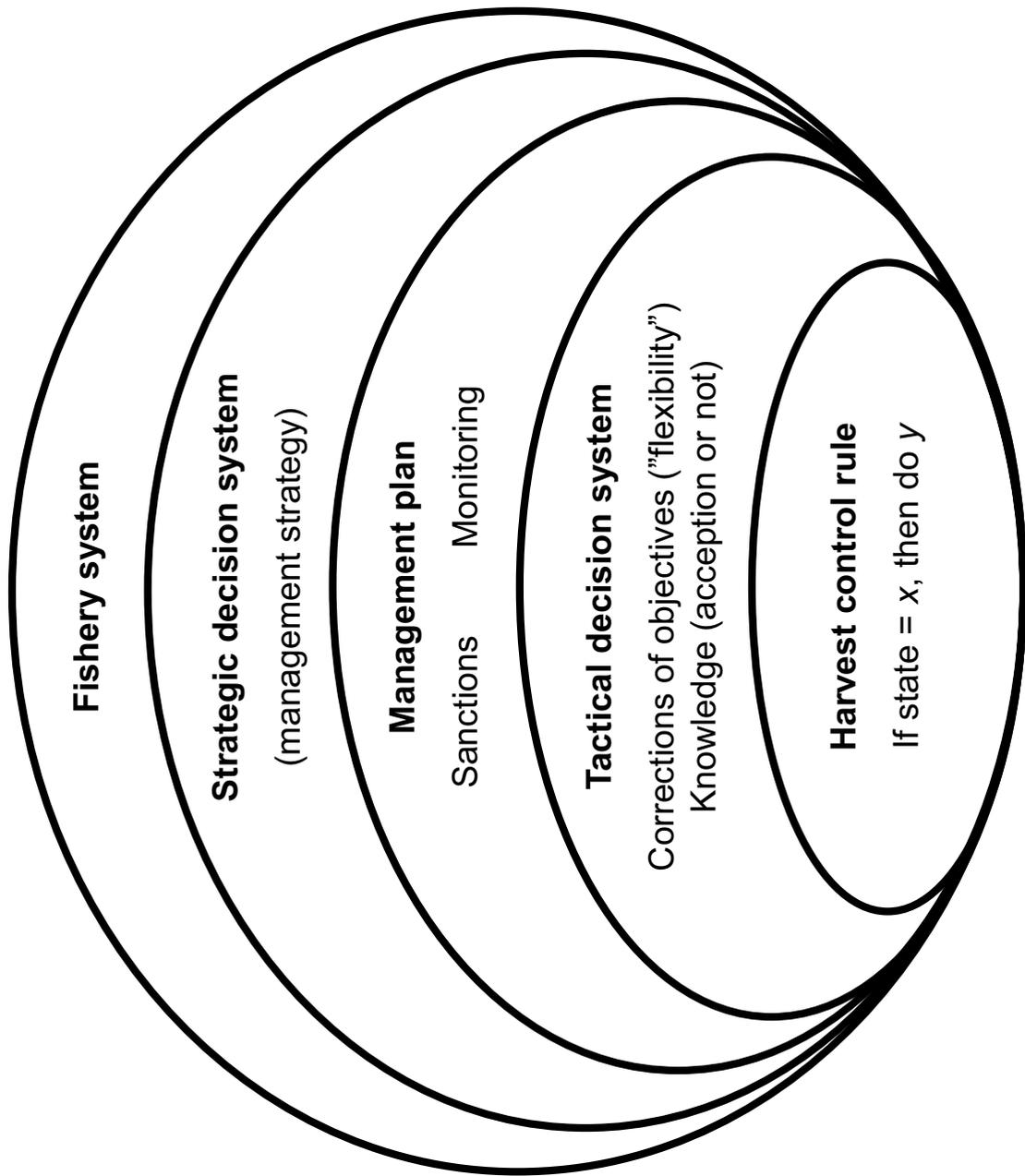


Figure 3. The management onion. (ICES 2005)

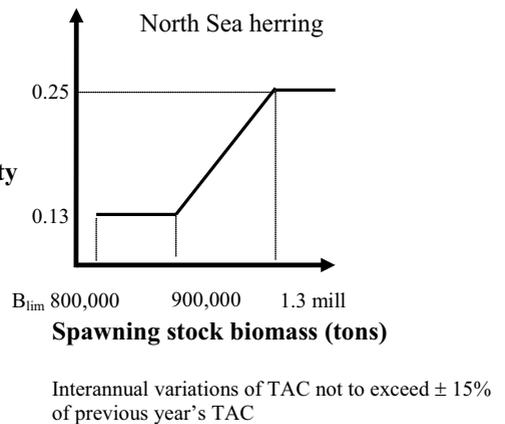
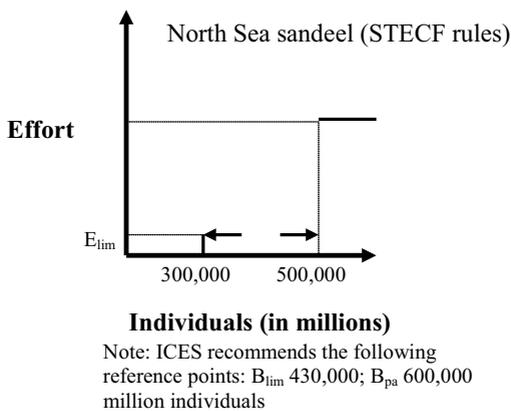
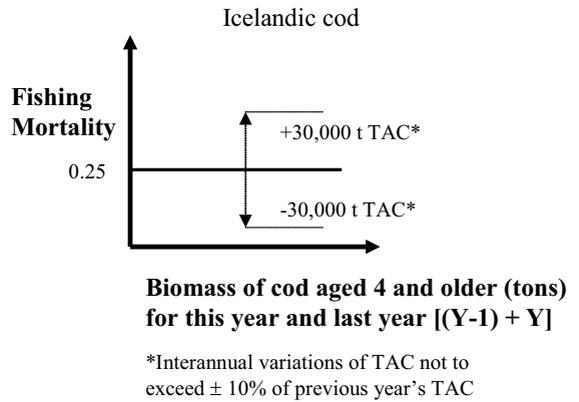
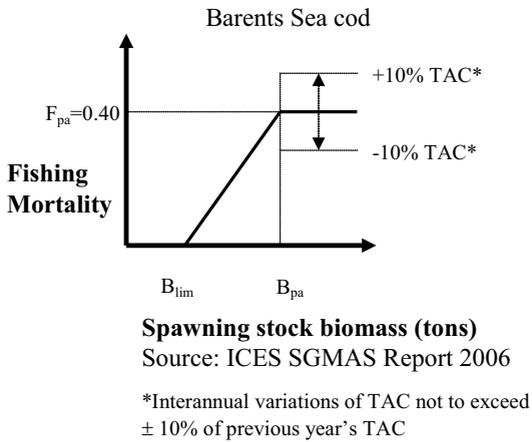


Figure 4. Examples of harvest control rules.  $F_{pa}$  and  $B_{pa}$  represent fishing mortality and biomass, respectively, that corresponds to the level specified in the precautionary approach.  $F_{lim}$ ,  $E_{lim}$  and  $B_{lim}$  represent fishing mortality limit, effort limit and biomass limit, respectively, which correspond to the level specified in the precautionary approach as parameters of the management strategy.

regulations in the tactical decision system.

In developed fisheries, there is often a large amount of data that are collected annually in regards to the target and non-target species in the fishery as well as socio-economic data, mainly in the form of fleet composition, associated employment, and costs. Traditionally, fisheries science has been rooted in the realm of natural science and most money towards scientific research has been allocated to biological studies. For larger, more industrial fisheries, economic analyses are significant to guide policy makers as well as indicate the approximate amount of future investment and development of the fishery. As coastal fisheries can be staples of the economy for some regions, socio-economic studies help scientists understand the human dimension of the fishery system and its significant aspects.

As an example of how fisheries science can move forward to facilitate post-normal science for resource management, **Paper IV** offers some practical insight. First, cross-disciplinary science in a fisheries context requires that the natural system, the human system and the management system be represented. We made use of appropriate multi-species biological data from scientific surveys conducted by the scientists at the United States National Oceanographic and Atmospheric Administration (NOAA) in a mixed-species model of the natural system. Next we utilized the available data on employment, fishing effort costs and revenues (landed fish prices) from NOAA economists to parameterize a socio-economic model. Cross-disciplinary science is not about biologists posing as economists; it requires that scientists explain and guide each other in the correct interpretation and use of data from an unfamiliar discipline. Likewise, our contact with NOAA economists here was essential in preparing the correct data from their databases and applying it acceptably in our models. Finally, we disseminate our results both in the short- and long-term for

four different main outputs: yield, employment, producer surplus (a proxy for profit), and multi-species spawning stock biomass (a proxy for ecosystem preservation). I feel our presentation of results correctly highlights stakeholder heterogeneity and would be a helpful aid for decision-makers to frame the dialogue on what gear regulation measures would be appropriate for the New England groundfishery.

### *1.6.1 Fishery system perspective from a policy maker*

Fisheries management in practice is engrained in the political system (Schwach et al. 2007). I wanted to test a politician's reaction to **Paper IV** and so scheduled a meeting with Massachusetts State Senator Bruce Tarr on September 29, 2008 at the Massachusetts State House in Boston. Senator Tarr welcomed the dialogue I initiated and praised the scope and relevance of **Paper IV**. Senator Tarr consequently offered some main points that sum up my synthesis of the building blocks of sustainability. The following paragraphs represent my summary of the political perspective and outlook on research in fisheries management he communicated to me.

First, the goal of a management strategy is to manage the fish stocks as a source of protein-rich food that we want to export and make a profit on. In order to do this, a sense of long-term ecological stewardship is needed. The fishery includes a stock and a human element and it is of utmost importance to better understand how the species interact with each other and with humans (including fishermen) so the fishery community can develop a type of regulatory partnership that is in sync with the environment.

Second, socio-economic models should include the shore side fishery infrastructure (**II, IV**) since many people in the fishing sector are employed here and

therefore is an important constituency for politicians. The Commonwealth of Massachusetts supported the creation of the University of Massachusetts School of Marine Science and Technology (collaborators in **Paper IV**) to merge science with the fishermen and to take the fishermen's knowledge seriously and collaboratively. Tax-payer money is used to fund biological and socio-economic impact studies, so it is a relief to see that scientists are actually synthesizing these data sets (II, IV).

Finally, regional policy makers need to encourage scientists to take on a more holistic, fisheries system and intrinsic interdisciplinary basis for research. But this should also be recognized at the federal level in the form of appropriate financial support if this is to become a reality.

## 1.7 Conclusions

In the previous sections, I outline three topics that I feel act as catalysts towards sustainability. These building blocks are general enough to be applied to all renewable natural resource management, although my focus here is marine fisheries. The first building block recognizes the human dimension of fisheries while the second is concerned with integrating the human dimension into management objectives. Finally, I discuss how management strategies, based on tactics quantified in a harvest control rule, can include the interdisciplinary nature of marine fisheries and facilitate post-normal scientific advice.

### *1.7.1 Future work and outlook*

In effect, this synthesis outlines many of the goals of the Ecosystem Approach to Fisheries (EAF) (Garcia and Cochrane 2005). Norway is an example of one of the many countries that have pledged to

move forward with EAF. There has rightly been an impressive boom of ecosystem models to scientifically support EAF. Even though new and complex ecosystem models are timely and attractive (Fulton et al. 2004; Walters and Martell 2004), they are of little use towards more sustainable fisheries if they are not communicated properly and solidly integrated in the fishery system. I recommend that managers do not overlook the human system and the role of science as informers when setting up protocols of EAF implementation if they wish to have any success with the gargantuan exercise EAF implies. Financial support should be allocated towards numerous meetings of focus groups and facilitators from all relevant disciplines; experience shows that many iterations are needed to fulfil the requirements of that dialogue among all relevant stakeholders and the extended scientific community (ICES 2008a; ICES 2008b).

In this synthesis, I outline different ways scientists can bridge the sub-systems of the fishery system for a wider base of knowledge needed for sustainable fisheries. Scientists in all disciplines have a responsibility to facilitate system comprehension toward managers and stakeholders. Current failures in marine fisheries may be attributed to managers, scientists, and stakeholders' lack of acknowledgement of the fishery system, resulting in conflicts from working against the system and not with it. Indeed, Follett (1955) warned that a "higher order of intelligence" is warranted in order to achieve integrated solutions to conflict. Perhaps we have not achieved this higher order which has also led to the deficiency of scientific collaboration across disciplines. A reason for this is that scientists tend to focus on specializations and can use whole careers dedicated towards single methods or concepts instead of applying their research in a broader context (Berkes and Folke 1998; Degnbol et al. 2006). Degnbol (2006) describes this neglect as "tunnel vision" in which scientists ultimately use sub-optimal methods

(“painting the floor with a hammer”) due to their lack of branching toward different scientific communities. Whether the blame for the absence of interdisciplinary science is lack of funding from federal sources or “inbreeding” of scientific communities, is bait for debate. As a biologist, I prefer to practice interdisciplinary science because of the professional and personal rewards of cross-disciplinary interaction and improved societal application of my work. Perhaps others will be attracted to the joy and challenge of systems thinking, find new relevance of their efforts, and follow suit.

Interdisciplinary questions deserve interdisciplinary answers. Wilson (1998) writes about the importance of uniting the sciences to produce a synthesis, or consilience, of human endeavors. The trend of exponential increase and unlimited availability of scientific data tends to breed tunnel vision among scientists (Degnbol et al. 2006) while linkages across scientific communities are ignored. Wisdom is not a by-product of the overwhelming amount of data that exist for natural resource management (Wilson 1998). Likewise, the solutions to post-normal science questions posed in natural resource management cannot be offered by one scientific discipline or science alone. The building blocks of sustainable marine

fisheries are certainly dependent on the ability to synthesize theoretical and empirical observations through interdisciplinary science communicated by extended communities of scientists.

The fishery system is the complex and diverse context in which scientists are supposed to give advice, managers are supposed to implement the best available science, and stakeholders are to abide by the resulting laws and regulations. Put simply, we are all in this together; sustainable fisheries hinge on the ability of all system components to work successfully collectively. On the subject of nuclear war Hardin quotes J. B. Wiesner and H. F. York:

*“If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation.” (Hardin 1968)*

It is evident that societal willingness, not technical solutions, is needed to combat the depriving crises plaguing marine fisheries today, and is the first step towards ecological sustainability (Prince 2003). I believe it is scientists’ duty to inform managers and stakeholders with understandable, interdisciplinary knowledge in the direction of a better systems comprehension and international stewardship for sustainable fisheries.

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