Scale and Aquatic Resource Management:

Some Thought Experiments

Douglas Clyde Wilson

Poul Degnbol

The Institute for Fisheries Management

presentation at People and the Sea II – Conflicts, Threats and Opportunities. Centre for Maritime Research (MARE) 4-- 6 September 2003 Amsterdam, the Netherlands.

Address comments to: Doug Wilson, IFM, North Sea Centre, Willemoesvej 2 P.O.Box 104, DK-9850 Hirtshals, Denmark phone:+45 98 94 28 55, fax: +45 98 94 42 68 e-mail : dw@ifm.dk

Abstract

This presentation is an attempt to bring together a number of our thoughts and publications on the subject of scale and aquatic resource management.We want to see how they fit together in order to both facilitate discussion and to help clarify research questions for our empirical work. The discussion draws on our research on African, Asian, European and North American fisheries and on integrated coastal zone management in the Europe. The presentation is organized around some basic scale concepts - scale, extent, level, resolution and hierarchy. A discussion of the definitions of these concepts begins the first part of the paper, which is an outline of general ideas about scale in physical, biological, and social processes. Then we turn to aquatic resource management. Our basic theme here can be roughly called 'social learning' as the emphasis is on the implications of scale for how management institutions can be structured to learn about and adapt to changes in the environment. We begin this second part with discussions of institutional level, extent and hierarchy. We then turn to the concept of resolution where we place the most emphasis. It is in the processes of making observations at various levels and communicating those observations across various levels where the question of scale becomes most entangled with ability of institutions to learn what is happening in the environment and to decide how to respond. We conclude with some tentative suggestions for research hypotheses and institutional mechanisms for facilitating learning across scale levels.

This presentation is an attempt to bring together a number of our thoughts and publications on the subject of scale to see how well they fit together in order to both facilitate discussion and to help clarify research questions for our empirical work. IFM’s core research agenda is participatory aquatic resource management - how can fishers and fishing communities participate in a meaningful and democratic was in the management of aquatic resources? In pursuit of this objective we continually run into the question of scale. This question usually takes one of two interrelated forms. First, how can resource users operating on one level of scale participate meaningfully in the management of a resource that operates on a much larger level of scale? Second, how do communities that depend on fisheries and other aquatic resources participate meaningfully in the decision making of necessarily bureaucratic institutions that manage those resources on regional, national and even international levels? We have not found any answers to these questions but we have found a few different ways of thinking about the problem that we feel are worth sharing.

1. General Characteristics of Scale

Before turning to the question of how environmental management institutions learn and respond, i.e, how they gather and use knowledge across scales. We begin with a discussion of the general characteristics of scale. After defining some of the key terms involved, we discuss scale in relation to four kinds of systems: simple physical scales; biological and ecological scales; economic scales, and; governance scales.

1.1 Critical Scale Concepts

The first problem in trying to understand scale is that many of the related terms are used in a number of different ways. In a recent review article on scale and environmental management, Gibson et. al (2000:218) offer a helpful set of definitions and conceptual clarifications that we mainly adopt for this paper. Their definitions are meant to address the use of scale in the social scientific analysis, but they also help us understand issues of scale in how institutions gain and use knowledge for fisheries management.

They define *scale* as the “spatial, temporal, quantitative or analytical dimensions used to measure and study any phenomenon.”

They define *extent* as “the size of the spatial, temporal, quantitative or analytical dimensions of a scale.”

They define *resolution* as “the precision used in measurement.” We expand this definition, because we are interested in the question of integrating different types of observations and so define *resolution* as the scheme for relating observations across time and space. This is not, in fact, a change in definition, it simply unpacks ‘measurement’ revealing that that term presupposes some theory of how observations should be made, recorded and communicated. These are precisely the areas of complexity we wish to examine.

They define *hierarchy* as a conceptually or causally linked systems of grouping objects or processes along an analytic scale.

They define *level* as “the units of analysis that are located at the same position on a scale. Many conceptual scales contain levels that are ordered hierarchically, but not all levels are linked to one another in a hierarchical system.”

These definitions can help us in several ways in our discussion. The term scale is often used as defined here as well as to mean what is defined above as level and as extent. Hierarchy is also easily confused with level, particularly for social institutions.

1.2 Scale in Nature

1.2.1 Physical Scale

Simple physical scale is straightforward, but it is the root of the reasons we have to be so concerned with scale. Physical scale runs across the three spatial dimensions and across time. The addition of a dimension to a variable means, literally, the application of an exponential function. From the perspective of impacts on our natural environment, non-linear processes that connote rapid, multiplicative outcomes to our decisions are built into the very structure of nature.

1.2.2 Biological and Ecological Scale

At the level of the individual organism the size of the organism and its range are the two main, and correlated, dimensions of scale.

Biological scale begins with allometry, the relative growth of a parts in relation to an entire organism. Allometric relations are charateristis of all organisms. Galileo noted in the 1630s that an organism could not grow in a linear fashion forever because bone strength is limited by the bone’s cross section while the mass of the organism is related to its volume. When the organism grows the bone cross-section grows along two dimensions while the volume grows across three dimensions. So, Galileo pointed out in general terms, the diameter of the support structure of any organism must increase faster then the length.Similar scale properties apply to the delivery of nutrients and the removal of waste. The basic structure of organisms requires that fractal-like branching patterns bring needed materials to all parts of the organism and the final unit of this branching pattern is always the same size. The optimization of energy required to achieve this material transport is a product of natural selection (West et al. 1997). The result of these basic structural principles is that many important variables of organisms, such as metabolic rate, life span and the size of major anatomical structures are proportional to body mass raised to quarter powers (West et al. 1997).

The scale of the organism has implications beyond the organism itself. The larger the organisms’ size the more energy it requires. Enquist (1990) found that for twelve orders of plant magnitude, that the individual plant’s rate of energy use is directly linked to the density of the plants in a given environment. The need of larger animals for more energy in most cases translated directly into the need for a greater foraging range.

In aquatic environments some scale dynamics are very different from terrestrial dynamics. Gravity is an important constraint on the potential size that terrestrial organisms, particularly predators that require speed and agility. The opposite is true in aquatic environments, hydrodynamics operate is such as way that larger organisms have advantages in speed and agility. Survival of aquatic organisms is directly related to rates of growth. The main restriction on size in aquatic organisms, because of the fact that as body size increases surface area increases more slowly than body mass, is the ability to extract sufficient oxygen from the environment. The lack of gravity also reduces avenues of escape for prey, e.g. there are no trees to climb. What the aquatic environment does provide for the relief of prey species is a third spatial dimension that is not available to non-avian terrestrial organisms. Thus, prey rely on the vast volume of water than predators must search to find them (Bakun 1996).

The upshot of this is that aquatic organisms frequently rely on a strategy of intermittent pulsations in both time and space. The example of a school of fish demonstrates the advantage of this pulsation. The school occupies a small, hard to find, point in a large volume of water, yet when it is found by predators the density of prey means that they are quickly satiated. (Bakun 1996). Aquatic energetics also means that many organisms rely on the water currents to move it to its food or its food to it. This intermittent pulsation phenomenon is also seen in many other forms. Organisms that are not seen for a long time and then appear in large blooms are common in aquatic system. The reproduction of shell fish that depend on successful sets is another example. In some tropical freshwater systems with seasonal shifts in water levels the bloom and bust patterns are so extreme and involve so many species that some argue that tradition approaches to protecting population levels through limiting fishing effort make no sense (Jul-Larsen et al. 2002).

Aquatic populations, both fish and other biota, can be usefully categorized in terms of spatial scale as local, connected, larval pool and source-sink (Nilsson 1999). Nilsson (1999) argues that management of aquatic populations is management of life cycles. Local populations migrate little and recruitment (new population members) comes from within the stock. Connected populations, which includes many invertebrates and some coral reef fish, have both short and long dispersal patterns, the population comes from several sources and the amount of local how much recruitment is local is variable. Larval pool populations, which includes some of the most valuable commercial species such as herring, cod and lobster, disperse over long distances from several source populations and depend on a shared larval area for recruitment. A source-sink population disperses over long distances (Nilsson 1999).

Scale has a profound effect on the observation, both scientific and casual, of ecological processes. Ecological hierarchy theory (O'Neill et al. 1986) argues that the scientific understanding ecological phenomenon requires understanding the constraints on that phenomenon from higher and lower levels of spatial and temporal scale. Ecologists cannot set up a single scale that will work for all investigations so they have to take extra care in generalizing their observations to the whole system (O'Neill et al. 1986). The centre of the theory is that ecological hierarchies are structured by frequency and differences in the rates of processes are the basis of ecological organisation (Allen et al. 1987, O'Neill et al. 1986). Phenomena are conceptualized and measured within hierarchies (organism, population, community, seascape) the boundaries of which are created by order-of-magnitude differences in the frequencies of state changes. Systems are defined by the range of rates through which nature is being observed (O'Neill et al. 1986) and the act of distinguishing an individual object of study from its background is also scale dependent (Allen and Hoekstra 1990).

The implication of this argument for people seeking to observe aquatic ecosystems characterised by intermittent pulsations in both time and space is fairly obvious. Because many important phenomena will occur in large pulsations separated by substantial amounts of time and space, the range of rates through which the aquatic ecosystem must be observed is very large if problems are to be identified and responded to.

1.3 Scale in Society

1.3.1 Economic Scale

On a micro level the economic basis of natural resource management is the bundle of property rights that control the benefit stream from the resources. These property rights are commonly categorised as private, common, state or open access, the later meaning that there are no functioning property rights. The type of property right regime likely to emerge is strongly influenced of the ratio of the value of the resource per unit of area and the costs of maintaining the property rights over that area (Bromley 1991), i.e. costs of excluding others, record keeping, etc. As this ratio climbs the likelihood of more individual property rights regimes increases, i.e. moving through the categories of property regimes from open, to state, to common, to private. In other words, open access and state property in terrestrial ecosystems tend to be found on large tracks of land with low value resources. Scale is directly related to this model through the fact that the numerator is in areal units and indirectly because of its potential impact on the costs of maintaining the rights. Property rights regimes in aquatic ecosystems, in contrast, are less driven by scale than in the terrestrial case. These regimes tend to be driven by the high costs involved in maintaining rights, particularly exclusion costs, which exist even at very low spatial levels in aquatic environments.

On a macro level economies of scale and comparative advantage lead to large scale trade. In respect to aquatic resources this means both a global market for seafood products and for fishing boats and gear. Young (2003) points to the importance of the interplay of economic and institutional dynamics at different levels of spatial scale. Trade and the commodification of natural resources through global markets, and the primacy of these issues for policy at the national and international level, has tremendous impact on processes on lower levels. Commodification has long been pointed to as a driving force in the breakdown of traditional small-scale resource management institutions (Ciriacy-Wantrup and Bishop 1975). When a resource becomes involved in a regional or global market its local value increases. Recognizing that most of these traditional institutions involved common property, and applying the model in the previous paragraph, we can easily see how global markets create the conditions for the breakdown of traditional, usually common property, management systems and the development of more individual ownership of resources.

International trade in the vast global surplus of fish harvesting capacity is a major challenge for trying to bring overcapacity under control. Awareness of this problem also has a long history, dating back at least as far as the role played by the movement of fishing capacity from the collapsed California sardine fishery in the early 1950s to the Chilean anchoveta fishery which collapsed, partially from overfishing, in the early 1970s (McEvoy 1086).

This interplay between economic processes operating on different level is instructive for our general understanding of scale because it shows how the concept of hierarchy operates very differently in social phenomenon than it does in natural phenomenon. A global market may have a profound effect on a village fishery. This effect might or might not be mediated by factors at the nation state, regional or municipal levels. The impact itself may, in fact, be traced from the global market to the fishing firm, then to the firm's employees and then to the fishing community. Indeed, the frequency-based structure of hierarchies that is the central concept of ecological hierarchy theory does not necessarily apply in social phenomenon, as state changes in processes happening on a global level quite often happen very quickly, while state changes in small communities may happen very slowly. What constitutes a social hierarchy, therefore, shifts depending on the problem at hand, and the concept of hierarchy may or may not be helpful for understanding . It is important to bear this in mind, because, as will be discussed below, scale as extent does have systematic, given implications for social institutions, where scale as hierarchy does not. The key implication of this is that social hierarchies are the products of design and this design can be done well or poorly.

1.3.2 Institutional Scale

Scale has some profound implications for the way that social institutions operate. To begin the discussion we need a definition of institution. Economists tend to define institutions as "rules-of-the-game" (Bromley 1991), whereas sociologists use definitions that reflect relatively permanent phenomena such as kinship, religion, or the state (Jepperson 1991). Some political scientists have taken a different tack, defining institutions as "political actors in their own right" (March and Olsen 1984:738). Many of the 'new institutionalists' from several disciplines use the following definition from Scott (1995, 33) "cognitive, normative, and regulative structures and activities that provide stability and meaning to social behaviour." This suggests that institutions are broader than rules, that they pattern interactions in stable ways, and that ontologically they a set of shared meaning. It does not require as a matter of definition, however, that the stability of institutions be demonstrated over the "longue durée of institutional time" (Giddens 1984, 35). Empirically, the key to the concept is patterned behaviour, when people can be observed operating according to a repeated pattern an institution is operating. This means we are dealing with a real institution, not one that exists only on paper.

Some of the basics of social institutions:

1. Institutions are created and maintained by an iterative process of people seeing what others are doing, interpreting that behaviour in terms of the institution and then basing their own behaviour

on that interpretation (Wilson and Jentoft 1998). This means that institutions, even long enduring ones, are always changing at the margins.

2. This process of creation and maintenance involves contests of power between social groups (Wilson 2003a). Groups with differing interests push for definitions and interpretations of institutions that reflect their interests. This happens both in struggles over the legal or regulatory definition of formal institutions and in the day-to-day expression in behaviour of both formal and informal institutions. Power in its essence is coordinated social action, discussions of power as a trait of individuals (Wartenberg 1990) all focus on how power comes to be steered by these individuals. The group which coordinates the action of the most people, by whatever means, directly or indirectly, from legal or monetary coercion to prestige and solidarity, wields the most power and has the greatest influence on how the institution will be defined and interpreted. Because a group must pattern behaviour over time to be effective in these power struggles, such a group is itself an institution (Wilson 2003a).

3. For an institution to pattern behaviour three things are required. The first is legitimacy, for an institution to be maintained over time, people must recognize the institution as constituting a normal demand on their attention and behaviour. The second thing is surveillance, people must be able to observe others conforming their behaviour to the institution. The third thing is enforcement, some sanctions must be involved if people refuse to conform to the institution. While these three things are to some degree substitutable, all three must be present if an institution is to pattern behaviour. How these functions will be carried out is central to the struggle over the institution's implementation.

4. Institutions are not only arenas of struggle and contention over definition and interpretation, however, institutions are also arenas of coordination or cooperation. Even institutions that are characterised by intense competition have certain aspects that must be coordinated among the competitors. Communication mechanisms are required so that people can understand how to proceed in conformance with the institution. Table 1 lists most of the communication mechanisms that are used in institutions, all institutions use a mixture of some of these mechanisms to coordinate action. The mechanisms are derived from Habermas' (1984, 1987) Theory of Communicative Action and are discussed in detail in Wilson (2003a).

The main difference between the mechanisms is the degree to which they are embedded in what Habermas (1984) calls the 'life world' which is a rich mixture of shared background meanings. The mechanisms toward the bottom of Table 1 are based on simple mutual understandings that require very little discussion. A can buy a candy from B without even sharing a language. If A has authority over B, A can get compliance from B with very little discussion. The mechanisms closer to the top of the table make much greater use of rich discussions and draw much more heavily on the shared lifeworld. The more embedded mechanisms use convincing to motivate behaviour and, as a result, lead to much less predictable outcomes than the less embedded mechanisms which rely more on coercion. This is a fairly broad use of the word coercion in that we apply it to choices in which people are faced with a take-it-or-leave it choice as well as situations in which direct sanctions are invoked to win compliance. The model in Table 1 is very similar to the state - market - civil society model, the first use of which is often credited to Polanyi (1957) and that is still widely used today (Jentoft and McCay 2003). The main difference is that it focuses on mechanisms, not particular institutions. All institutions need some rational communications and all institutions need some authority. The other difference is that it collapses the equivalents of the state and market into a single pole based purely on the similarity they share in relative independence from the life world.

It is this model of mechanisms for institutional coordination that leads to the claim that scale, as extent, has an identifiable and systematic influence on the operation of social institutions. The operative scale is number of people involved, not necessarily geographical. On lower levels, i.e. among fewer people, decision making can be handled in face-to-face or nearly face-to-face communications in which differences about facts can be sorted out and differences about values can be debated and compromises reached. This is the mechanism of 'rational communications.' Rational communications is never achieved, it does not need to be, the idea of rational communications acts for all participants as a model, Habermas calls it a ' partly counterfactual critical device' (Habermas and Nielsen 1990, pp 105), to evaluate the communicative situation. The idea of rational communications is rather like the idea of 'equilibrium,' it is a very useful concept but does not describe any actual empirical situation. If participants perceive that the situation deviates too far from the model then they know that a new mutual understanding about something is not being achieved. Hence, institutional rules that try to guard rational communication are actually very common. Where this process is truly effective, participants are free to introduce and discuss any information they feel is relevant, which is precisely what makes the decision making sensitive to all the relevant issues of fact and value. The presupposition of such a discussion is that it is oriented toward convincing participants that the decisions reached are the right ones (Habermas 1984). From an institutional viewpoint this orientation is what ensures that the information is thoroughly processed. This presupposition is not necessarily tied to the finalization of the decisions. It is a principle of the discussion process itself and it fulfill its function even where final decisions are not based on consensus.

Table 1. Four Continua Characterizing the Communications Mechanisms

					Examples of institutions that rely heavily on this mechanism
Rational Communications	More embedded in the lifeworld of shared communicative resources	Relies more on convincing	Less predictable outcomes	Operates more effectively on smaller scales	Science Social movements
Prestige Influence					Local Communities Social Networks
Authority Money	Less embedded in the lifeworld of shared communicative resources	Relies more on constraining	More predictable outcomes	Operates more effectively on higher scales	States Markets

On higher levels, however, these communication processes which allow for maximum sensitivity to factual truth and social values begin to break down. For one thing, the amount of information needing to be processed requires streamlining. The increasing number of participants and concerns means that some sort of culling process is required to simplify the information so that decision making is possible within a useful time period. Just as important, the orientation of the discussion toward convincing participants that something is true or right begins inevitably to break down. As the level on which institutions operate grows larger, their operations must begin to adopt a presupposition in communications that the opinions and values of individual participants do not matter. The presupposition that the goal of communications is to convince makes institutional operations too unpredictable, and increases the difficulty of maintaining uniformity and consistency in the way the institution functions. The behavioural outcomes that maintain the institution begin to require support by more and more coercive mechanisms that presuppose that communications are about confronting participants with specific choices and consequences. A top-down bureaucratic institution, for example, confronts individuals with the choice of complying with a requirement or risking sanction. A market confronts individuals with a series of dichotomous ‘take it or leave it’ choices that can be negotiated, but only within tightly predefined parameters. These kinds of institutions rely on surveillance, enforcement and incentive mechanisms to make their decisions meaningful. The larger the scale involved the greater the role that coercive mechanisms must play. This is not a design flaw, it is the reality of what must be in place if behaviour is to be coordinated across broad scale extents. The information processing problem it presents, however, is severe: the loss of richness and nuance in the information that the institution can identify and respond to. Institutional sensitivity to truth and value relies upon the presuppositions that communications are open to any claim and oriented to convincing participants that something is true or right. Where the presupposition of the institution's communications is a coercive, 'take it or leave it' choice such sensitivity is diminished and information is distorted or even lost entirely

2. **Scale and Institutional Learning in Coastal Zone and Aquatic Resource Management**

The remainder of this paper applies the discussion above to institutional problems involved with developing an adequate information base for the management of aquatic resources and the coastal zone. We follow the four key concepts outlined in Section 1.1, beginning with discussions of the questions of institutional level, extent and hierarchy. We then turn to the concept of resolution. It is in the processes of making observations at various levels and communicating those observations across various levels where the question of scale becomes most entangled with ability of institutions to learn what is happening in the environment and to decide how to respond.

2.1 Level and Extent: Matching Management Institutions to Environmental Processes

The physical extent of a biological or physical process is the starting point for how institutions managing human behaviour in relation to those processes should be structured, e.g., they should be global to deal with climate change, regional to deal with fisheries, on a community level to deal with a small watershed, etc. The extent of the physical dimension of the process gives an upper bound to the extent of the social institutions meant to manage that process, perhaps most centrally the administrative level responsible for overall management decisions. The principle of subsidiarity, that decisions should be made at the lowest competent level, applies with "competent level" being mainly determined by the physical extent of the process. Differences in perception, which are both driven by and to some extend define the level and extent of the natural processes, deeply complicate the problem of identifying this competent level.

2.2 Hierarchy: The Integration of Management Institutions Across Levels

2.2.1 The Integration Problem

Coastal zone and aquatic resource management has for more than a decade had as its ambition to integrate management across issues and sectors, based on the observation that the sectoral interdependencies in coastal zone and other areas dependent on aquatic resources are so prominent that it is an illusion to believe that it is possible to address one management concern in isolation. It is becoming difficult to find a text about costal zone management, for example, which does not put the I for 'integrated' in front of the CZM. This is based on the fact that the need for cross sectoral linkages is so evident as to be a truism and cannot be neglected in management.

It has however been difficult to develop mechanisms for integration which genuinely addresses the very different issues at stake in the sectors, and the central challenge has been how to deal with scale. "Integrated" management is not just a question of establishing communication and mechanisms for conflict resolution in the local context, integration, in most cases, requires communication across scales. One example is the integration of the management of fisheries resources with the development of local economies. Many basic decisions with extensive

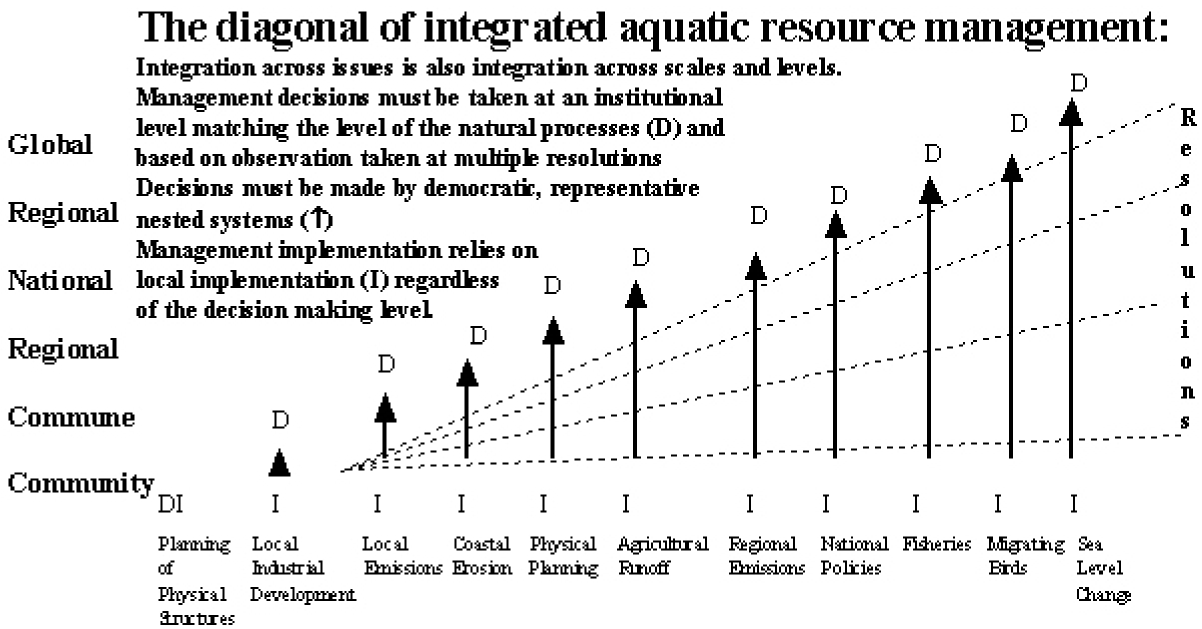

Figure 1: The diagonal of integrated aquatic resource management:

consequences for the future economy of local fishing industries are taken at international regional level without interaction with local communities or coastal zone management institutions. The development of other sectors are however dependent on infrastructure and a work force which may compete with fisheries activities.

Integration in coastal zone management will in most cases have to be 'diagonal', that is that different levels of management institutions must be involved according to the issues to be integrated (Figure One). The diagonal begins with the premise that integration across issues is also integration across scales and levels. Management decisions must be taken at an institutional level matching the level of the natural process but management implementation relies on local implementation regardless of the decision making level. Because the intermittent pulsation structure common in aquatic ecosystems, these management decisions will often have to be based on information generated at several levels with different spatial and temporal resolutions. Integration also requires that these observations be of multiple systems: species populations; ecological communities / seascapes; fleets; markets; and aquatic resource dependent communities.

2.2.2 Stakeholder participation in management[1]

The fact that implementation is always local and the reliance on observations at various resolutions makes some form of user group participation, some form of 'co-management' (Wilson et al. 2003) a requirement for effective aquatic resource management. Linking institutions across scales takes more than just delivering decisions up and down. Those taking decisions have responsibility vis-a-vis those they represent. Hence, accountability, and the transparency that makes accountability possible, is the core mechanism for the legitimacy, surveillance and enforcement necessary for fisheries management institutions to actually pattern behaviour in ways that reflect the realities of the natural system. Lower levels must be held accountable for implementation of behaviours required by natural processes at higher levels, while those making decisions about how to respond to higher level needs must be held accountable for not imposing more costs on lower levels than are necessary. Accountability depends on communications and the scale of management institutions has important implications for the ways communications can take place - how facts and interpretations of facts are exchanged, how conflicts are presented, and how agreements or compromises are reached.

We cannot, however, approach the question of co-management naively. User groups do not cooperate with government agencies as an expression of good citizenship and government agencies do not bear all the transaction costs that participation requires unless they see it as strictly necessary for the success of their policies. Real motivations are required and these motivations are generated where conflict and scale come together (Wilson 2003a).

The problem the state faces is holding the local accountable for behaving in ways that take into account natural process operating on higher levels. In creating co-management institutions, the state desires to make use of the richer communication mechanisms embedded in local cultures to facilitate this. This access to richer communicative mechanisms aids in access to information (Pinkerton, 1989) and in greater local acceptance of policies (Jentoft, 1989). These richer communications are critical for local ecological knowledge (LEK) (Neis and Felt, 2000; Wilson, 1999) and better information about how management mechanisms work at local levels, and less expensive surveillance and enforcement. The state's motivation for participating in co-management begins with its need for the communities' help in dealing with aspects of fisheries management that require richer, more sensitive and subtle tools than authority. Discourses at the local level are often quite different than those that predominate within government agencies, without these tools the state cannot understand how to design, enforce or evaluate management institutions.

[1] The material from this section is taken in large part from Wilson 2003a

The motivations of groups at the local level to cooperate mirror the state's. They want to tap into the state's disembedded bureaucratic authority and financial resources. Two motivations for cooperation with co-management are common. The first is simply a desire for the money and other resources that co-management programmes make available. The second is that the community is already facing a situation in which a) aquatic resources have declined and conflicts have arisen or b) new fishers or old fishers using more intensive fishing techniques threaten to create a decline in the resource and conflicts have arisen or c) new fishers or old fishers using gear taking up more space creates a competition for space and conflicts have arisen as a result. The key motivation at the local level is for help in resolving a conflictual situation. In most cases these conflicts are the product of forces and trends operating at a much higher than local level. The attraction of state involvement is in enabling legitimacy and in conflict management. The state can help establish legitimacy within the community for a local group to be involved in management by establishing them as a legitimate expression of bureaucratic authority. For many local people, legitimacy begins with state involvement, otherwise they see the group that is trying to manage the resource conflicts as overstepping their bounds (Wilson 2003a). The second attraction is based on the fact that most resource conflicts operate at higher levels than just the local. Local groups may not be able to have any affect on destructive fishing or habitat-related behaviour simply because it is generated elsewhere. Even if the behaviour does happen locally, it is likely part of a wider pattern and a commons dilemma is created. If one local group seeks to address the problem without broader cooperation; the behaviour will continue in other communities and only the benefits will likely be lost to the community that took the initiative.

The "state of the art" in organizing cooperative management institutions is through representation and and nested systems. The idea is to construct an institutional hierarchy that can mitigate cross-level impacts, facilitate cross-level information exchange and provide structures for the management of conflicts. The government must use its authority to contain and channel conflicts in creative ways. This means making it possible for more open and culturally embedded communications to play an effective role in institutional decision making processes. The creative channelling of conflict requires that the state use its authority for this purpose rather than attempting to micro manage the ecosystem from on high. By nested systems (Ostrom 1990) we mean that management institutions exist within a hierarchical structure in which decisions are taken at the lowest possible "competent" scale. The idea of nested systems is based on the principle of subsidiarity, meaning that negotiations and decision making should take place covering the smallest extent possible that reflects the bio-physical realities. Representation, then, is the mechanism through which decisions which must be made at higher levels are 'passed up.' It is within a nested system of representation that the legitimate solutions to scale issues in coastal zone and aquatic resource management is most often achieved. The solutions *per se* have to be reached through negotiations and possibly arbitration. The government's role for facilitating the management of purely local level problems, is to make sure that the conflicts do not tear the system apart. At both the local level, and in managing problems stemming from natural processes operating at higher levels, the government must be the final insurer of accountability through legal enforcement of decisions.

2.2.3 Accountability: The Normative Basis for Integrating Decision Making Across Levels

Figure Three translates the motivations described in Section 2.2.2 into the kinds of accountability that are required for the co-management institutions to function. This both describes the normative basis for the design of the institution and points to a beginning point for the next discussion, which is the kinds of knowledge and information that must be communicated across levels.

The top arrow describes what the lower level needs to see from the higher level. The first thing is the recognition of stakeholder decisions in a balanced way. This begins with Ostrom's (1990) design principle number seven: the minimal recognition of the right to organize. This makes begins the process of creating legitimacy for local participation in management. It is more than

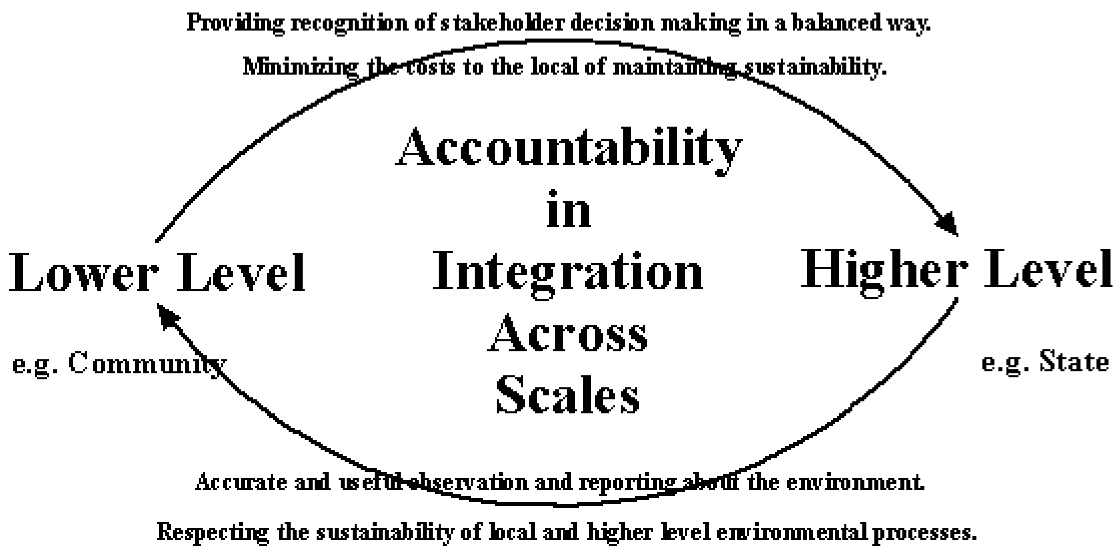

Figure 2. Accountability in the Integration of Decision Making across Scale Levels

that, though. Local management involves multiple stakeholders with various kinds and amounts of power and interests. Partly because of its ability to confer legitimacy, and partly because of its own enforcement authority, some level of government is often the only group that can perform the 'balancing act' (Wilson et al. 1999) that makes it possible for these groups to work together. Most critically, this means empowering those groups, e.g. small-scale fishers and traders, who have little influence on decision making, but whose cooperation is needed to make resource management both effective and democratic. This is a matter of accountability because unless the policies and activities that do this balancing are carried out effectively and consistently in a way that all stakeholders can observe and understand they cannot be effective.

The second thing the lower level must hold the higher level accountable for is that the costs that are imposed on them to ensure the sustainability of higher level environmental processes are not more than are necessary to achieve that goal. This is very often a major focus of inter-level conflict is resource management. The central issue is the 'science,' i.e. the understanding of what is happening in the environmental processes and what is needed to respond to it. These descriptions must be accurate and they must also be transparent to the cost bearers.

The bottom of Figure 3 is the things that the higher level must hold the lower level accountable for. The first is the basis of the science mentioned in the previous paragraph. The observations on which that science is based are always made on lower levels and the upper level that concentrates and analyses this information has a need for it to be accurate and usefully packaged. Second, the lower level is accountable for behaviours that ensure environmental sustainability at all scale levels.

2.3 Resolution: The Integration of Management Information Across Levels

Management decisions are based on specific perceptions of the character of the problem to be addressed and the prerogatives for its solution. Such perceptions are very scale dependent. Several studies have demonstrated that fishers' perceptions about the fish resources reflect observation made at smaller geographical and with greater resolution than the perceptions of civil servants in the management agencies or of the scientists which provide research based advice to management institutions. These differences in perceptions are further amplified by the discourses which fishers, civil servants or scientists participate in and which also relate to scale. One particular case point is when global agendas form part of a discourse related to management decisions that affect fishing communities.

2.3.1 Scale and Research Based Knowledge: Developments within Fisheries Management[2]

The development of fisheries research around the North Atlantic in the early 20th century established the discourse which still forms the basis for mainstream international fisheries research. One of the major actors in the development of fisheries biology in the first half of the 20th century, Michael Graham, summarised some tendencies in fisheries research from 1900 onwards when he presented his Buckland lectures in 1939 (Graham 1948). He noted that

> 'The underlying idea of the period of international research was that not enough was known about the life-histories of the food-fishes, about the causes of abundance and scarcity, the growth-rate, interchange of stocks, seasonal migrations, the proportion taken by fishermen, and other things that must be relevant to the problem of rational fishing. These things, naturally, had to be studied for each species separately, and consequently the work was first arranged according to species of fish. Then students of the several species became advocates of those particular measures that seemed best adapted for particular species that they studied, and the overfishing problem became, as it were, divided. The more diversity that was revealed, the less satisfactory did any simple action see; and this period lasted until 1935, when it became clear, as we shall see later, that it is possible to estimate the best possible course for all species of bottom-living fish taken together.'

He went on noting that

> 'the chief characteristic of the international period was that research discovered and adapted the sort of scale that was necessary for the solution of the overfishing problem. To give one example. In the early days men tried to find out the growth-rate of each species, whereas the international research showed

---

[2] The material in this section is taken from Degnbol 2003

> that the aim was to find out the average growth-rate for any particular area and intensity of fishing, there being a wide variation according to season and grounds. This is a much more troublesome thing to discover. Statistics of various kinds had to bulk large in all the work.'

What Graham describes here are the changes in the perspective of fisheries biology which were associated with its transformation into a tool which could form the operational basis for practical measures within a management system based on international cooperation between governments and formalised research. The development of ICES was at the core of this intellectual and institutional development (Mill 1989, Rozwadowski 2002) which according to Graham's account (Graham 1948)

> 'has produced a new psychological phenomenon - the combined opinion of scientists and of chosen administrators, who mutually educate each other year by year at the meetings. This new kind of opinion, international and exceptionally well informed, is obviously a most powerful weapon for advancing a cause such as improvement of the fishery in the high seas.'

The discovery of 'the sort of scale that was necessary for the solution of the overfishing problem' went hand in hand with the emergence of an international community of managers and scientists, mainly working for governments, who shared norms and understandings regarding the fisheries. It may appear as a happy coincidence that 'the sort of scale' which was identified by fisheries biology happened to coincide with the scale needed by governments cooperating internationally to handle the political decision-making processes of fisheries management. This coincidence may however also reflect a sensitivity in the international community of fisheries science to the requirement that the science should be useful for management.

Graham describes the development of management institutions and the transformation in research perspective as basically two sides of the same process – internationalisation and formalisation of the research base in management on one side and change of perspective from dealing with a range of spatial resolutions and a diversity of processes to an approach dealing with averages of a few key parameters over large scales on the other.

This transformation is central to an understanding of the development of a research discourse, which is often considered remote from or even contradictory to fisher's perspective. Remoteness and contradiction are of course evident from the frequent accounts of disagreements in the fisheries press. The point to be made here is however, that gaps between the perspectives are closely associated with the development of management institutions which required a specific type of scientific knowledge, namely knowledge based on large scale averages with low resolution in space and time and which could only be constructed on basis of sampling schemes and models which tried to overcome local variation rather than understanding it. Fisher's knowledge has the opposite focus – knowledge on the local variation of fish abundance in time and space is essential if one is to be a successful fisherman.

The identification of the 'fish stock' as the central unit of analysis and management was fundamental to further development of an operational research base for the internationalised fisheries management that was emerging in the 1930s. Fisheries management was increasingly seen as an international issue to be resolved through international cooperation both in terms of the production of the knowledge base for management and management itself. One may hypothesize that the change from understanding processes bottom-up at the resolution of the basic processes to creating a conceptual and research framework based on averaging and generalising over large scales was driven by this being a necessity if research was to produce the knowledge base for the emerging international, top-down management regime.

The change in perspective on scale and in the basic unit of analysis was accompanied by the development of a theory of 'rational exploitation' and, ultimately, on 'optimum fishing'. In the initial phases of fisheries research the focus had been on explaining variation. However, the concept of rationality appeared early on the agenda. The concept of rational fishing was expanded to include not just the need to base fisheries on formalised knowledge but also a requirement for *optimisation*, specifically maximisation of long-term yield. In the 1950s that the international breakthrough of a formalised base to operationalize optimality came fully about, initially by Beverton (1953) and culminating in the Principia Mathematica of fisheries biology, On the Dynamics of Exploited Fish Populations (Beverton and Holt 1957). This represented the pinnacle in the abstract operationalization of fisheries management: fisheries can be optimised by adjusting two basic parameters, the overall fishing mortality and the lowest age at which fish are caught. This approach was firmly based in the perspective that had developed during the first half of the century of internationalisation of fisheries science and management. This perspective was built on the notion that the basic unit of fisheries and fisheries management was the stock which represents fish populations on large (100+ nautical miles) scales and that the dynamics of the stock and the impact of fisheries can be understood and managed by averaging life history parameters and stock abundances over the total stock area. It was also based on the implicit assumptions that the main source of variation is recruitment to the stock, that management can be implemented on a stock-by-stock basis and that the effects of specific management measures can be predicted whereby fisheries can be optimised in terms of maximizing long term yield. Each of these assumptions is contradicted by the perceptions of fishers, as will be discussed below.

In the period ca 1955 to ca 1990 the main research discourse can be described as rational fisheries with an optimisation objective based on deterministic predictability. It can be characterised by an understanding that

The basic unit of fisheries and fisheries management is the 'stock'

The stock represents fish populations on large (100+ nautical miles) scales,

The dynamics of the stock and the impact of fisheries can be understood and managed by averaging life history parameters and stock abundances over the total stock area,

These parameters can be estimated on basis of data sampling schemes and estimation models

The main non-explained source of variation is recruitment to the stock,

But as far as management is concerned recruitment variation can be overcome by measuring the abundance of recruiting year classes before they enter the fishery

Management can be implemented on a stock-by-stock basis

The effects of specific management measures can be predicted

Whereby fisheries can be optimised in terms of maximizing long term yield

The scope of international fisheries management changed in the early 1990's when two new considerations entered the scene: the precautionary approach and the need to include considerations on the effects of the marine ecosystem at large into fisheries management. These additions were formalized in the Code of Conduct for Responsible Fisheries (FAO 1995) and the United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks (UN 1995). These considerations are at their core a critique of the main fisheries research discourse on predictability - the precautionary approach is fundamentally about accepting the fact that uncertainty is an integral part of management. In spite of this, the precautionary approach as it emerged in the management debates in the 1990's was treated as a supplementary consideration, and regulatory fisheries research responded by internalizing uncertainty into the existing research discourse. Models were developed in which uncertainties were quantified and predictions were associated with probabilities of various outcomes. This approach may be described as *stochastic predictability* because the basic concept of predictability was maintained but the predictions of the effects of management measures were expanded to include an estimate of the associated uncertainty. Another adaptation to the new management discourse was maybe more fundamental although less noticed. The management discourse has implicitly changed its objectives from targeting production, with optimization being the core concept, to emphasizing conservation and risk management, with precautionarity being the core concept. The most important outcome to be predicted within the new stochastic predictability is, therefore, not catch but spawning stock biomass.

From around 1990 the main research discourse can therefore be described as rational fisheries with an objective of risk avoidance in relation to stock conservation, based on stochastic predictability. Most of the basic assumptions and approaches of the optimization and deterministic predictability discourse have been maintained including notably that the basic unit of management still is the stock and that the relevant scale of relevant knowledge and management is still large (100+ nautical miles). The new components are that

These parameters can be estimated on basis of data sampling schemes and estimation models and *the estimates can be associated with uncertainty*

The main non-explained source of variation is recruitment to the stock, *but there is increased probability of low recruitment at low spawning stock sizes*

The effects of specific management measures can be predicted *with an associated uncertainty to the prediction*

Whereby *fisheries management measures can be devised which will be associated with a high probability of avoiding adverse situations*

Adversity is defined as low spawning stock biomass

There is thus an important change in the research discourse which reflects the changes in the management discourse. However, the basic approach has been maintained – to predict outcomes of management measures over large scales with the 'fish stock' as the basic unit.

2.3.2 Ecological Knowledge on the Local Level[3]

The need for observations and information from various scale levels and resolutions means that local participation in developing the management knowledge base is critical. Much of this information can be gathered in the traditional way through reproducing set research protocols. This can also be problematic, as will be discussed in the next section. This section focus on the knowledge that is generated at the local level by resource users.

2.3.2.1 The characteristics of local ecological knowledge.

Lay people's knowledge of nature is generated in part through their day-to-day activities. In fisheries, fishers can be expected to have extensive knowledge of the geographical range of fish populations and precise information on where and when fish congregate (Maurstad 2000, Neis et al. 1996). Different local groups have access to different types of knowledge. Power's (2000) research on women's knowledge of an Atlantic fishery found that extensive information about the fishery is available to women through both processing plant work and through tasks related to family fishing businesses. Some women have a better grasp of changes in gear and catch than fishers do because they are the ones who do the bookkeeping. When user groups do not trust the data on which management decisions are based they do not cooperate and may even develop confrontational postures (Pinkerton 1989). Pinkerton (1989) suggests that the best management arises when neither the government nor the users have a monopoly on data. One team of researchers that has played a central role in enabling the use of LEK in fisheries management found that data from fishers contributes to management by: 1) providing additional indices for use in stock assessments and scientific debates; 2) providing data on responses by fishers to management measures and on the status of poorly understood species 3) suggesting novel hypotheses and 4) enhancing long-term legitimacy of the management regime (Neis et al. 1995). Pederson and Hall-Arber (1999) found that fishers in New England have and can communicate useful knowledge of the sea floor, habitat structure, and fish distribution.

Many complications exist with the use of local ecological knowledge in natural resource management. It is difficult to evaluate LEK without a fairly broad knowledge of the local context (Felt 1994). User groups tend to view the resource in much smaller temporal and spatial scales than it is conceived of by managers, so the information they generate is more useful on small rather than large scales (Smith 1995, Pálsson 1995). In fisheries, users often see fisheries as systems in which small perturbations may have substantial future consequences (Smith 1990) and are likely to emphasize the importance of environment over population dynamics (Berkes 1993,

[3] The material in the section is taken from Wilson 2003b

Pinkerton 1989). Both of these viewpoints can be incongruous with management, where ecological complexity must be simplified to a point where decisions can be made.

A critical factor for the usefulness of LEK is the degree to which it is tacit. Tacit knowledge is knowledge that people have but that is not (easily) expressed. Some management scholars, notably Gísli Pálsson (1995, 2000), have argued persuasively that much of the knowledge fishers have of the resource is tacit knowledge. Pálsson's (1995, 2000) investigations have focused on skippers' knowledge of the fish resource. Skippers find it hard to explain why they know things, he argues, because their knowledge comes from emersion in the everyday world. The metaphor of knowledge as a sort of mental script or "container" is not accurate. Fishers' knowledge is part of their overall fishing skill and the knowledge that underlies a skill is intuitive and not easily articulated or even necessarily understood well by the possessor. New fishers learn these skills by imitating the actions of others, his research suggests that many of these practices are learned without ever involving discourse or even consciousness (Pálsson 2000). In Roepstorff's (1998) study of Greenland fishers, he found that the idea that knowledge is something learned by doing, and hence involving tacit as much as discursive knowledge, is an integral part of their identity.

Given these complexities, the transcription of LEK into forms that are useful for higher level management institutions is challenging. Many ways to identify and record LEK have been developed (Grenier 1998). This gathering of LEK is a process of translation and transcription (Latour 1987, Holm 2003). Tacit knowledge is not unique to LEK but is deeply embedded in research based knowledge as well, making the question of transcription generally applicable. To make knowledge useful for management requires taking this often tacit knowledge out of the local context in which it is embedded and creating more explicit, discursive knowledge (Wilson 2003b). Knowledge must be articulated to be useful in managing natural systems, and those who are able to articulate this knowledge arguably have more power than others in management debates (Wilson 2003a). Holm (2003) , following Latour (1987), argues that making LEK discursive is more than a process of translation and transcription. It is a process of "purification" in which many kinds of beliefs, speculations, hopes and exaggerations are stripped from the LEK, transforming it in to a discourse that can 'hold its own' in scientific debates. Agrawal (1995) argues that this process can change the LEK so much that it becomes unrecognizable to the resource users. The intention of empowering fishers and other resource users by mobilizing their local ecological knowledge can disempower them, as their knowledge is transformed, alienated or even distorted as it loses coherence out of context (Maurstad 2002).

These considerations suggest that the underlying practical issue in making use of LEK, just as it is in lay participation in science-based policy in general, is one of process. Tapping into local ecological expertise in a way that empowers user groups is not simply an issue of democratic ethics. The involvement of LEK in management in a way that does not alienate those having the knowledge is necessary to increase the legitimacy of the measures. Furthermore, because simply participating in a policy process does not seem to increase support for that policy (Hunt and Haider 2001), a critical question is whether the incorporation of LEK does increase general satisfaction with that policy. Furthermore, by what process can local ecological knowledge be made useful in management in a way that does not alienate those that possess it? One important option is collaborative research between fishers and scientists, which has become very common in North America over the last two decades (Wilson 1999). When these interactions are well structured, they can have the important effect of making tacit LEK available to both fishers and scientists. Too often, however, these collaborations have made use of fishers as providers of research platforms, research assistants or sources of data without the fishers having any input into the formulation of research questions or decisions about the use to which the data will be put. One unfortunate result of this has been fishers feeling that they are providing data that is then 'used against them' to justify management decisions with which they did not agree (Pederson and Hall-Arber 1999). Nonetheless, demands and opportunities for greater fisher involvement in research have risen in recent years.

2.3.3 Information and Communication in Learning Across Scales

2.3.3.1 A Brief Review of Literature Relevant to Learning Across Scales

Many theorists have addressed the question of institutional learning. Some focus on macro-level institutions. Both Giddens (1991) and Beck (1992) argue that Western society has become organized around the idea of risk and that society has become more reflexive in dealing with its environment. Science is the key institution for allowing this reflexivity to happen. Others focus more on micro-level learning processes. One school has developed around the work of Maturana and Varela (1987). It draws on analogies from nature to understand institutions as self-organizing cognitive systems learning from and responding to the complexities in their environment. People in a number of disciplines are working on social learning in various micro-level institutional environments (e.g. Leeuwis and Pyburn 2002). Douglas (1986) is perhaps the theorist of institutional learning that focussed the most on both macro and micro level institutions. Drawing on Durkheim, she argued that institutions create and maintain the categories of thought, making them appear natural, and that their permanence depended on their being grounded in a coherent analogy with nature. "Institutions do the classifying." she argues "Any problem you try to think about is transformed into the institutions organizational problems (92)."

The longest tradition in social science dealing with the movement of knowledge across scales is likely research on the diffusion of innovations. Rogers (1962) first introduced the classic S-curve model that posited that there are leaders, laggards, and a large group in the middle. A few leaders will adopt an innovation rapidly, then the majority will follow, and a few laggards will bring up the rear. This model has long been criticised and refined, by Rogers himself among others. Major attention has been given to the role of individual level variables such as education, wealth and tenure (Clearfield and Osgood 1986) each of which correlates positively with innovation. Other research has focussed on communication networks, arguing not only that the spread of innovation is accelerated when people speak with one another, but that the shape of the network is as important as its extent (Johnson 1986).

This tradition deals with how knowledge spreads, so at first glance it seems to be the opposite of our interest in how knowledge is concentrated for decision making. Diffusion theory focuses on how on set of information moves across a wide extent on the same scale level producing the same result or very similar results. Another word for this is replication. Replication is, however, important for cross-scale-level institutional learning processes because management institutions also have to be concerned with the diffusion of knowledge as part of the concentration process, e.g., standardized techniques for gathering and codifying information have to be replicated. Replication is also important in developing the institutional capacity that makes a nested hierarchy possible. The main take home lesson from this literature is that replication is an uneven process and that this unevenness is related to both individual and institutional variables.

Boison (1995) proposes a slightly more abstract diffusion model. A problem is identified and then first "stylized" into a language that suggests a solution. Then the solution is generalized through a process of abstraction so that it can apply to a broader group of problems. This abstracted knowledge is then diffused into the larger community where is eventually assimilated into the stock of knowledge in the wider community. The main difference between this and the classic diffusion model is the emphasis on the changing form of the knowledge, i.e., the transformation of the knowledge to the more abstract form for broader assimilation.

Actor Network Theory (ANT) (Latour 1987) makes a direct and serious challenge to the diffusion of innovation paradigm. Latour (1987) focuses on the process of the social construction of knowledge about nature. For him a truth about nature is a claim put forth by a network of humans, ideas, and natural objects that is able to resist the "trials of strength" that laboratories set against it. When no dissenter can modify the shape of the new claim about nature then it is real. Nature 'out there' comes into this process of creation too late to be considered the cause of the discovery. The technical literature is even more social than non-technical literature because of the way scientists defend their objects is by enlisting resources, mainly through citations to other people and objects, to give the object the strength to overcome opposition and be accepted. Latour (1987) contrasts ANT with the standard diffusion model. The diffusion model assumes established facts being replicated along a communication network. ANT looks at this process as one of "translation" where a chain of people borrow and use claims in association with other objects, people and events. Where the diffusion model sees society forming the path of the object that moves along powered by the fact that it is a useful truth, ANT sees a series of weaker and stronger links between ideas, people and technical processes. Gaining knowledge is understood as a process of accumulation rather than the negation of ignorance by learning. What allows this process of accumulation to continue is the continuous activity, which takes place at what he calls "centres of calculation," of rendering knowledge objects mobile, combinable and keeping them stable.

ANT offers important qualification to the diffusion model in illuminating aspects of how knowledge is transformed and transmitted according to its social usefulness. It points to the importance of the social construction of nature (Wilson 2003b) that is basic to understanding the relationship between management institutions and knowledge. It has been used effectively in clarifying fisheries disputes (Steins 1999). Particularly important, as argued by Holm (2003), are process of translation as information moves up and down scale levels and from fishers to scientists and back again.

Strongly taken, however, ANT would lead us to despair of the possibility of developing an adaptive learning process for management institution because under ANT the translation of information is a process that happens before facts about nature are able to exert an influence. Fortunately, ANT's major weakness is precisely that aspect of the theory that would lead to the most despair. ANT is based on an atomistic concept of society, albeit one in which the atoms are linked in networks, and a competitive model of human behaviour. It assumes - consciously or not - that the production of scientific knowledge is driven by competition, mainly for prestige but also for resources. Like much French scholarship, (e.g. Bourdieu and social capital) it seeks to transfer the effectiveness of economics as a discipline into other social arenas, forgetting that the reason that the *homo-econimicus* theory of behaviour works as well as it does in economics is not because humans are intrinsically more competitive than they are cooperative, but because the institutional context of a market requires competitive behaviour.

Competition is certainly an important part of science, but the application of scientific norms (Merton 1968) that set up a framework for rational communications (Table 1) is even more important because it allows the institution of science to be sensitive to factual truth. Latour (1987) is wrong when he says that nature enters the process too late to be a cause of its outcome. His theoretical eyeglasses focus on atomized individuals and objects linked into networks and miss the scientific communities (Barnes et al. 1996) in which shared understandings of nature and of the process of uncovering nature safeguard the communication processes that make possible a sensitivity to factual truth about nature. Granted, it is not immediately obvious that rational communications are more important in science than competition for prestige. However, the question has been put to an empirical test by Baldi (1998) who found that substantive relevance of content was a better predictor of inclusion of a citation in a paper than the prestige of the author as ANT would predict.

The upshot of this is that ANT has important insights to offer about the difficulty both spreading and gathering knowledge. This is particularly true when that knowledge is passing between groups in institutional contexts where rational communications are unprotected, or across large extents where more coercive communication mechanisms begin to replace mechanisms based on persuasion. It has, however, failed to demonstrate that such protected institutional environments do not exist or are not important, nor that the diffusion of a fact is a function of its social usefulness alone, divorced from its empirical validity.

2.3.3.2 A Model of Cross-scale-level Learning Processes

We suggest that a helpful model institutional learning across scales recognizes that learning requires that knowledge flow in two directions. Processes of translation and transmission is involved that cross scale levels both up and down. A process of *diffusion* is necessary from institutions operating at higher levels to establish and maintain the system of information gathering. This diffusion is a replication process because establishing the resolution of observation of the natural system operating on higher scales means repeating the same thing across the entire resolution field. Such diffusion proceeds across large extents and so takes the form of communications based more on coercion (Section 1.3.2) than persuasion, i.e. sets of detailed requirements for identification of objects of study, observations, and packaging of the resulting knowledge. Then a process of *concentration* of information is necessary to gather and condense the information to make possible the observation of natural processes that operate on higher levels. Concentration involve *packaging* information into a form that will be useable on the higher scale level. As just mentioned, this packaging is given form by the knowledge communicated in the diffusion process. The information that is the product of these packaging processes is not merely raw data and particular indicators, it includes findings and the products of scientific deliberations as well.

The packaging process involves four processes of transformation of knowledge:

> a) *Simplification* means the filtering of the knowledge to leave only that knowledge that will be useful on the scale level receiving the knowledge. This might be thought of as increasing the ratio of signal to noise in the information;
>
> b) *Abstraction* means formatting the knowledge for applicability to wider situations than the one that produced the knowledge;
>
> c) *Codification* means categorizing the knowledge within a symbol system that will be used to generate further knowledge through comparisons;
>
> d) *Standardization* means simplifying, abstracting and codifying knowledge according to a common system.

Taken together these are the processes of resolution. They are the tools of the institutional instrument that tries to focus on natural processes happening at different scale levels. Figure Two lays out the relationships between these processes.

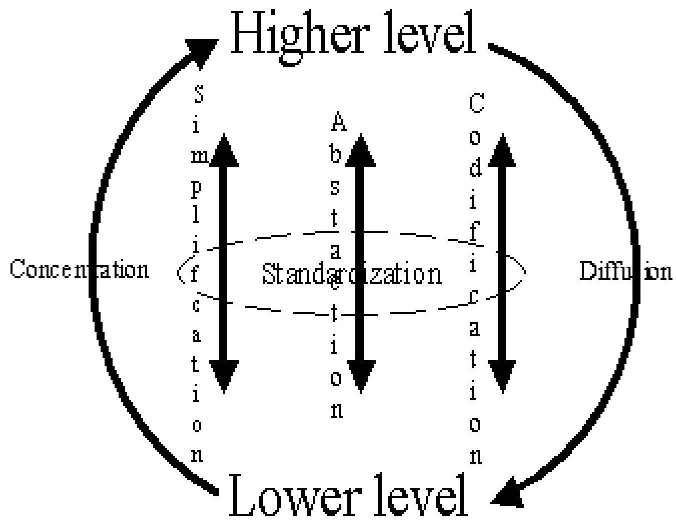

Figure 3 The Processes of Resolution: transformations of information as it moves between scales

2.3.3.2 Distortions of Communications

The heart of the problem of institutional learning across scales is the distortion of communication (Habermas 1987). Management decision making institutions are continually faced with these distortions. Experience with people who have commented on our earlier use of the concept of communicative distortions (Wilson and Degnbol 2002) suggest that it would be helpful to begin defining distortions in communication by saying what they are not. By communicative distortions we are not pointing to factual inaccuracies or poor interpretations of information. Nor are we pointing to the information packaging processes as such, though it is in these packaging processes that that the communicative distortions do their damage.

The distortions we are talking about are severe deviations from the basic requirement of rational communication: *that people can effectively raise a claim.* From an institutional viewpoint, as discussed above, it is the ability of participants in communications to raise claims about nature that provides the institutions with its sensitivity to factual truth. In the diffusion process claims making is often blocked by heavy reliance on coercion based communications mechanisms, as described in Section 1.3.2. This means, for example, that instructions about how to package information are juridified (i.e., made into legal technicalities) and administered by an enforcement institution that is not geared to take into account questions and observation raised about how well these packaging instructions handle the information they are meant to communicate. The packaging can become routinized to the point of being ritualized resulting in everyone being forced to take a cynical distance from the "knowledge" being created.

In the concentration processes as well, people can be blocked from raising questions about the knowledge being transformed. This is even true of scientists. In Wilson and Degnbol (2002) we outlined a case of communicative distortion. A group of scientists shared a belief about the condition of a fish stock. The key assumption of the model they chose to define the "best available science" for this fish stock, however, was the precise opposite of what they believed to be true. The issue here from the perspective of institutional analysis is not how well the model they selected reflected the real situation in the ocean, their original belief could also have been wrong. The issue is that a group of scientists were forced by a set of institutional imperatives to say the opposite of what they believed, they were effectively blocked from raising their claim about what they actually though was going on. What blocked them was a combination of legal requirements for particular model parameters and the characteristics of the institutional peer review process they were operating under.

Nor is this an isolated incident, it happens commonly in 'mandated science', i.e. science that is carried out in response to institutional mandates, particularly legal ones. Decision making institutions that draw on science look for firm structuring and classification of problems, clear distinctions about what is and is not at issue, precise decision rules and efficiencies in presentation and procedure (Smith and Wynne 1989). These institutional demands cut through the scientific process and create pressure to silence claims that suggest that nature does not fit neatly into the institutional categories. Furthermore, the products of mandated science, rather than being surrounded by caveats, are often idealized (Salter 1988). Decision-making institutions seek results that are intelligible to non-scientific audiences. They want science that facilitates clear choices, purports to represent a body of evidence, and appears to be rational. The science be portrayed as value-free, as using a method that produces credible results and as an inherently public enterprise with open debate, anonymous peer review, and academic publication.

Even as great as the difficulty that research-based knowledge has in meeting the both the demands and ideals of mandated science, so much greater are the difficulties faced by other forms of knowledge such as local environmental knowledge (LEK). LEK is generated and formed in discourses at the local level that are alien to those discourses that are used by people working in institutions at higher levels of scale (Holms 2003), who are generally used to the discourses of research based knowledge. The differences in these discourses create one more hurdle in the packaging and movement of knowledge across scales.

It is these patterns in the use of knowledge by institutions that pushes the question of distorted communications to the centre of the debate on how institutions can learn across scales. It is in processes of packaging knowledge to travel across scales that communicative distortions do the most damage. It is very easy to use the processes of simplification, abstraction and codification as means for excluding claims that make fitting knowledge into institutional forms more difficult. These packaging processes are necessary, it is impossible for higher level institutions to use the knowledge generated at lower scales without them. But they are also where the greatest danger from communicative distortions is found.

2.3.3.3 Hypotheses about the Nature of Communicative Distortions

We suggest for further investigation that the following hypotheses about communicative distortions can be investigated. These are an initial list and other hypotheses about communicative distortions can well be formulated.

From the perspective of the higher level decision makers, the knowledge they are gathering to make decisions about natural process is distorted in ways that :

1 Tend to make the problems they are making decisions about appear more tractable than they are. This is because during the simplification and standardization processes information about local nuances will be excluded and this will hide problems.

2. Tend to make their management seem more effective than it actually is. This is because the same information that is formulated through institutional imperatives is used to evaluate the effectiveness of the institution. The institution demand the knowledge be packaged in the form of indicators that are used to: 1) describe the natural system; 2) define the goals of management; 3) guide the implementation of management; and, 4) define success or failure by. Knowledge that is not packaged into these indicators, and which will inform the institutions where the indicators are creating circularity between the definition and achievement of goals, will tend to be excluded.

3. Tend to hide linkages between scale levels. The packaging of knowledge from the lower level is given form by questions that are driven by the institutional imperative, including the level and resolution at which the questions are posed. Claims about processes at higher and lower scales may be very relevant but when knowledge is packaged these claims may be excluded because the packaging already presupposes the level at which the natural phenomenon is operating.

4. Are subject to a positive feedback loop. The responses by higher level institutions to the results of communicative distortions are to create even more stringent packaging requirements, that then increase the distortions.

2.3.3.4 Bringing a New Kind of Professionalism to Communications Across Scales[4]

The discussion thus far should have made clear that the underlying issues in dealing with scale in environmental management are not ones of technique. Let us assume that we have built a state-of-the-art nested system with democratic representation, what more can we do to manage make this politicised information processing system as effective and responsive as possible?

The information processing problem is fundamental to both decision making and accountability. Representation and nested systems contribute in important ways to resolving these issues. We would like, however, to propose a third kind of institution that focusses even more directly on facilitating effective information processing across scales. Could we not develop a new kind of management expertise that is specifically focussed on the problem of facilitating the processing

[4] The material in the section is taken from Degnbol et al. 2003

of information across scales? By 'developing an expertise' we mean moving toward both credentialing and certifying this expertise and using various sorts of funding and to create a demand for it.

As discussed above, representation works by creating communicative space for large scale institutions that reproduce the factors that make small scale institutions sensitive to truth and value. Representation must be structured, however, by large scale institutions that suffer from the same insensitivity as other large scale institutions. A credentialed professional field, however, is an institution that functions to a large degree through the prestige of its incumbents. Prestige, as we use it here, is a mid-scale institutional mechanisms that we can contrast with the bureaucratic authority and market mechanisms operating most effectively on higher scales and with the fully open discussions among equals that operate most effectively on lower scales. Prestige operates as a communicative mechanism for the institution by investing specific individuals with the ability to guide communicative outcomes in desirable directions (Table 1). Prestige is a way that institutions process information that can operate on greater than local levels while still retaining a good deal of the openness and orientation toward convincing that make possible the sensitivity of small scale communications. Guiding outcomes increases their predictability over fully open discussions, but it does so in a less distorting way than mechanisms which rely on 'take it or leave it' coercion. Prestige operating through the institution of a professional field processes information in ways that share both strengths and the weaknesses of the large and small scale institutions discussed in the last section. This makes the creation of such a professional field for environmental management a useful supplement to the representation and nested systems approaches.

The role of these practioners would be to move among the nested management institutions and between the nested institutions and the higher scale institutions in which they are nested. They would provide a downward and lateral link that would negotiate the implementation of the priorities and decisions set at the higher level. They would also provide social and natural science based informational support to the representative system that produces these priorities and decisions. One could think of them as "circuiters" working with a number of nested institutions. Perhaps the closest existing model for what we are pointing to are the third party certifiers that work with natural resource harvesters to ensure that they meet the environmental standards set by ecolabelling programs.

The required expertise is two-fold. First, practitioners of this field would need expertise in the facilitation of local decision making and conflict management. This would involve sociological, economic, and managerial skills. Second they would need expertise in the identification of management indicators of a number of types, this would involve biological, economic, ecological, statistical and measurement theory skills.

Conflict management is perhaps the key skill our practioners would need to put to use. Conflict management usually works best on a small scale because of the complexity of finding acceptable compromises between conflicting small scale interests and between small scale and larger scale interests. Outside facilitation is often helpful, indeed often necessary, in negotiating and renegotiating compromises. This would be a key role played by our practitioners. This expertise would involve skills in conflict assessment, i.e., discourse analysis and social impact assessment. Ongoing conflict management would involve facilitating planning to identify management goals and plans to reach those goals. This later function would involve considering both local needs and the implications of higher scale decisions and priorities. This function also means that the practitioners would have to be tied to some institution that has a coercive capacity. Prestige alone will not suffice to empower powerless groups or check powerful ones. This link would need to be indirect, however, which is why the third party certification model suggests itself.

These efforts, however, would have to be backed up with ongoing accountability and that means these negotiations have tie their local management plans and goals to indicators of progress and effectiveness. To this end, our practitioners would need to be well grounded in general measurement theory, particularly in understanding the varying roles that quantity and quality play in defining and measuring goals. Substantive expertise would be required in the natural science aspects of the management questions. This would include questions particular to the management issues, such as pollution measurement or fish stock assessments, as well as an understanding of the principles of ecological interactions. Such expertise need not rise to the level of being able to identify and carry out edge research, but certainly to the level of being able to understand and evaluate research. Our practitioners would also have to understand how to work with different types of knowledge, including both and experience based (local) and research based knowledge.

These reflections, however, are only a first draft and a rough outline of the expertise our practitioners would need to call on.

Finally, a reasonable question to put to our proposal is why we need an entirely new profession. Why not do this with multi-disciplinary teams, then we would have deeper knowledge behind all these skills? The answer is that be creating a new profession we create the things that go with it: job descriptions, professional societies, certification standards, and incentives for professional advancement. Multi-disciplinary teams are almost always one shot affairs and usually ones with little incentive for making multi-disciplinary work the focus of a career. (This cannot simply be addressed by encouraging professions to ‘value’ multi-disciplinary work as this would create an impossible performance assessment problem for those professions.) By creating a profession focussed on addressing cross-scale issues in environmental management we are putting into place an institution that will both facilitate management and continually focus on how to improve that facilitation.

References Cited

Agrawal, Arun 1995 "Dismantling the Divide Between Indigenous and Scientific Knowledge" *Development and Change* 26: 413-439

Allen, T.F.H. and Hoekstra, T.W. 1990 The confusion between scale-defined levels and conventional levels of organization in ecology" *Journal of Vegetation Science* 1:5-12

Allen, T.F.H., R.V. O'Niell, and T.W. Hoekstra 1987 Interlevel Relations in Ecological Research and Management: Some Working Principles from Hierarchy Theory" *Journal of Applied Systems Analysis* 14:63-78

Bakun, Andew 1996 Patterns in the Ocean: Ocean Processes and Marine Population Dynamics NOAA California Sea Grant College Program

Baldi, Stéphane 1998 "Normative versus Social Constructivist Processes in the Allocation of Citations: A Network-Analytic Model" American Sociological Review 63(6):829-846

Barnes, B., D. Bloor, and J. Henry 1996 Scientific Knowledge: A Sociological Analysis Chicago: University of Chicago Press

Beck, U. 1992 Risk Society: toward a new modernity New Delhi: Sage

Berkes, F. 1993 "Traditional Ecological Knowledge in Perspective" Pp 1 - 9 in Inglis, J. T. (Ed) Traditional Ecological Knowledge: Concepts and Cases Ottawa: International Program on Traditional Ecological Knowledge, International Development Research Center

Beverton, R. 1953. Some observations on the principles of fishery regulation. *Journal du Conseil*, XIX (1).

Beverton, R.J.H. and S.J.Holt (1957) On the dynamics of exploited fish populations. Her Majesty's Stationary Office, London

Boisot, M. 1995 Information Space - A Framework for Learning in Organizations, Insitutions and Culture London: Routledge

Bromley, D. 1991 Environment and Economy: Property Rights and Public Policy Oxford: Basil Blackwell

Ciriacy-Wantrup S.V. and R.C. Bishop 1975 " 'Common Property' as a Concept in Natural Resources Policy" *Natural Resources Journal* 15:713-727

Clearfield, Frank and Barbara T. Osgood 1986 Sociological Aspects of the Adoption of Conservation Practices. Washington DC: Soil Conservation Service

Degnbol, Poul 2003 "Science and the user perspective: The gap co-management must address" pp 31-50 in Wilson, D.C., J.R. Nielsen and P. Degnbol (Eds) The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects Dordrecht, The Netherlands: Kluwer Academic Publishers

Degnbol, P., D. C. Wilson, H. A. Grolin and S. Sverdrup-Jensen 2003 “Spatial Scale in Coastal Zone Management: Current Approaches, Challenges and Possibilities” Paper presented at: Rights and Duties in the Coastal Zone, 12-14 June 2003, Stockholm, Sweden. Working paper no 1-2003. Institute for Fisheries Management & Coastal Community Development.

Douglas, Mary 1986 How Institutions Think Syracuse: Syracuse University Press

Enquist, B.J. 1998 “Allometric scaling of plane energetics and population density” *Nature* 395:163-5

FAO. 1995. Code of Conduct for Responsible Fisheries. FAO Fisheries Technical Paper 350.

Felt, Lawrence,1994 "Two Tales of a Fish" in Dyer C. L. and J. R. McGoodwin (Eds) Folk Management of the World's Fisheries Boulder: University of Colorado Press

Gibson, Clark C., Elinor Ostrom, T.K Ahn 2000 “The concept of scale and the human dimensions of global change: a survey” *Ecological Economics* 32:217-239

Giddens, A. 1984 The Constitution of Society Berkeley: The University of California Press

Giddens, A. 1991 Modernity and Self-identity: self and society in the late modern age Cambridge: Polity Press

Graham, M. 1948. Rational Fishing of the Cod of the North Sea. Being the Buckland Lectures for 1939. London: Edvard Arnold.

Grenier, Louise 1998 Working with Indigenous Knowledge. A guide for researchers. Ottawa: International Development Research Council (IDRC)

Habermas, J. 1984 |The Theory of Communicative Action Volume I Reason and the Rationalization of Society Boston: Beacon Press

Habermas, J. 1987 The Theory of Communicative Action: Volume II Lifeworld and System: A Critique of Functionalist Reasoning Boston: Beacon Press

Habermas, J. and T.H. Nielsen 1990 “Jurgen Habermas: Morality, Society, and Ethics: an Interview with Torben Hviid Nielsen" Acta Sociolgia 33:93-114

Holm, Petter, 2003 “Crossing the border: On the relationship between science and fishermen's knowledge in a resource management context” MAST 2(1) 5-33.

Hunt, L. and W. Haider 2001 "Fair and Effective Decision Making in Forest Management Planning" *Society and Natural Resources* 14:873-887

Irwin, A. 1995 Citizen Science: A study of people, expertise and sustainable development London: Routledge

Jentoft, S. 1989 "Fisheries Co-management" *Marine Policy* 13:137-154

Jentoft, Svein and Bonnie J. McCay 2003 “The place of civil society in fisheries management: A research agenda for fisheries co-management” pp 293-308 in Wilson, D.C., J.R. Nielsen and P.

Degnbol (Eds) The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects Dordrecht, The Netherlands: Kluwer Academic Publishers

Jepperson, R.L. 1993 "Institutions, Institutional Effects and Institutionalism" pp 143-163 in Powell W.W. and P.J. DiMaggio The New Institutionalism in Organizational Analysis Chicago: University of Chicago Press

Johnson, J.C. 1986 "Social Networks and Innovation Adoption: A Look at Burt's Use of Structural Equivalence" *Social Networks* 8:343-364

Jul-Larsen, E., J. Kolding, R. Overå, J. Raakjær Nielsen and P.A.M.van Zwieten 2002 Management, co-management or no management? Major dilemmas in southern African freshwater fisheries. Part 1: Synthesis Report, FAO Fisheries Technical Paper 426/1. Part 2: Case Studies, FAO Fisheries Technical Paper 426/2. Rome:FAO [73pp]

Latour, B. 1987 Science in Action Cambridge: Harvard University Press

Leeuwis, C. and R. Pyburn (Eds) Wheelbarrows full of frogs: Social learning in rural resource management Assen, The Netherlands: Koninklijke Van Gorcum

March, J.C. and J.P. Olsen. 1984. "The New Institutionalism: Organizational Factors in Political Life" *American Political Science Review* 78:734-49

Maturana, H. R. and F.J. Varela 1987 The Tree of Knowledge: the Biological roots of human understanding Boston: Shambala Publications

Maurstad, Anita 2000 "Trapped in Biology: An Interdisciplinary Attempt to Integrate Fish Harvesters' Knowledge into Norwegian Fisheries Management" pp 135-152 in Neis, Barbara and Lawrence Felt (Eds) Finding our Sea Legs: Linking Fishery People and their Knowledge with Science and Management St. John's, Newfoundland: ISER Books

McEvoy, Arthur 1986 The Fisherman's Problem Cambridge: Cambridge University Press

Merton, R.K. 1968 Social Theory and Social Structure New York: The Free Press

Mill, E. 1989. Biological oceanography in early history 1870-1960 Cornell University Press, New York

Neis, B. J. Hutchings, R. Haedrich, and L. Felt 1995 "Scientific Debates, Lumpy Lumpfish and Slubby Nets: Fishers' Vernacular Knowledge and Adaptive Management" paper presented at the annual meeting of the American Fisheries Society, Tampa Florida

Neis, B., L. Felt, D. C. Schneider, R. Haedrich, J. Hutchings, and J. Fischer. 1996. ANorthern Cod Stock Assessments: What Can be Learned from Interviewing Resource Users@ DFO Atlantic Fisheries Research Document 96/45

Neis, Barbara and Lawrence Felt (Eds) 2000 Finding our Sea Legs: Linking Fishery People and their Knowledge with Science and Management St. John's, Newfoundland: ISER Books

Nilsson, P. 1999 “Management of biological resources on different spatial scales” paper presented at the conference on Holistic Management and the Role of Fisheries and Mariculture in the Coast Community. Tjarno, Sweden 11-12 Nov.

O’Neill, R.V., D.L. De Angelis, J.B. Wade and T.F.H. Allen 1986 A Hierarchical Concept of Ecosystems Princeton: Princeton University Press

O'Neill, R.V. 1989 "Perspective in Hierarchy and Scale" Pp. 140-156 in Roughgarden, J. May, R.M and Levin, S.A. (eds) Perspecitives in Ecological Theory Princeton: Princeton University Press

Pálsson, G. 1995 "Learning by Fishing: Practical Science and Scientific Practice" Pp 85-97 in Hanna, S. and M. Munasinghe (Eds) Property Rights in a Social and Ecological Context: Case Studies and Design Applications Stockholm: The Beijer Institute

Palsson, Gisli 2000 "Finding One's Sea Legs" 26-40 in Neis, Barbara and Lawrence Felt (Eds) Finding our Sea Legs: Linking Fishery People and their Knowledge with Science and Management St. John's, Newfoundland: ISER Books

Pederson, J. and M. Hall-Arber 1999 "Fish Habitat: A Focus on New England Fishermen's Perspectives" *American Fisheries Society Symposium* 22: 188-211

Pinkerton, E. 1989 "Introduction: Attaining Better Fisheries Management through Co-Management - Prospects, Problems and Propositions" Pp. 3-36 in E. Pinkerton (Ed) Cooperative Management of Local Fisheries. Vancouver: University of British Columbia Press

Polanyi, K. 1957 “The Economy as Instituted Process” pp 243-270 in K. Polanyi et al. (Eds) Trade and Markets in the Early Empires New York: The Free Press

Power, Nicole Gerarda 2000 "Women Processing Workers and Resource Users" pp 189-203 in Neis, Barbara and Lawrence Felt (Eds) Finding our Sea Legs St John's Newfoundland: ISER Books

Rogers, E. 1962 The Diffusion of Innovation Boston: The Free Press

Rozwadowski, H. 2002. Without prejudice to the future: Marine science, North Atlantic fisheries, and one hundred years of International Council for the Exploration of the Sea (ICES). ICES. In press.

Salter, L. 1988 Mandated Science: Science and Scientists in the Making of Standards Dordrecht, Holland: Kluwer Academic Publisher

Scott, R. 1995 Institutions and Organizations Thousand Oaks CA: Sage Publications

Smith, M. E. 1990 "Chaos in Fisheries Management" *Marine Anthropological Studies* 3(2): 1-13

Smith, M. E. 1995 "Chaos, Consensus and Common Sense" *The Ecologist* (25): 80-85

Smith, R. and B. Wynne 1989 "Introduction" pp 1 - 22 in Smith, R. and B. Wynne (Eds) Expert Evidence: Interpreting Science in the Law London: Routledge

Steins, N.A. (1999) All Hands on Deck: an Interactive Perspective on Complex Common-pool Resource Management based on Case Studies in the coastal Waters of the Isle of Wight, (UK), Connemara, Ireland, and the Dutch Wadden Sea Wageningen: Wageningen University.

UN. 1995. United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks. gopher://gopher.un.org/00/LOS/CONF164/164_37.TXT

Wartenberg, T.E.1990 The Forms of Power: From Domination to Transformation Philadelphia: Temple University Press

West G.B., Brown J.H., Enquist B.J. 1997 "A general model for the origin of allometric scaling lasws in biology" *Science* 276:122-6

Wilson, D. C. 1999 "Fisheries Science Collaborations: The Critical Role of the Community" Institute for Fisheries Mangagment Research Publication No. 45

Wilson, D.C. and S. Jentoft 1999 "Structure, Agency and Embeddedness: Sociological Approaches to Fisheries Management Institutions" pp 63-72 in Symes, D. (Ed) Alternative Management Systems for Fisheries Oxford: Blackwell Science

Wilson, D.C., M. Medard, C.K. Harris, and D.S. Wiley 1999 "The Implications for Participatory Fisheries Management of Intensified Commercialization on Lake Victoria" *Rural Sociology* 64(4):554-572

Wilson, D. C. and P. Degnbol 2002 "The Effects of Legal Mandates on Fisheries Science Deliberations: The Case of Atlantic Bluefish in the United States" *Fisheries Research* 58:1-14

Wilson, D.C., J.R. Nielsen and P. Degnbol (Eds) 2003 The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects Dordrecht, The Netherlands: Kluwer Academic Publishers

Wilson, D. C. 2003a "Conflict and Scale: a Defence of Community Approaches in Fisheries Management" pp 193-209 in Wilson, D.C., J.R. Nielsen and P. Degnbol (Eds) The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects Dordrecht, The Netherlands: Kluwer Academic Publishers

Wilson D.C. 2003b "Fisheries Co-management and the Knowledge Base for Management Decisions" pp 265-280 in Wilson, D.C., J.R. Nielsen and P. Degnbol (Eds) The Fisheries Co-management Experience: Accomplishments, Challenges and Prospects Dordrecht, The Netherlands: Kluwer Academic Publishers

Young, Oran R. 2003 " Institutional Interplay: The Environmental Consequences of Cross-Scale Interactions" pp 263-291 in National Research Council Committee on the Human Dimensions of Global Change Ostrom, E., T. Dietz, N. Dolsak, P.C.Stern, S. Stovich and E.U. Weber (Eds) The Drama of the Commons Washington DC: National Academy Press