CHAPTER 18
GETTING THE SCALE(S) RIGHT IN OCEAN FISHERIES MANAGEMENT: AN ARGUMENT FOR DECENTRALISED, PARTICIPATORY GOVERNANCE

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Abstract

The focus of this chapter is on the problem of scale in fisheries governance. This is the problem of what is the appropriate scale of the marine ecosystem for fisheries management purposes. Current fisheries management regimes largely bypass this problem by focusing their attention on scale-less, single species populations. But such an approach rests on an inadequate mental model that ignores the complexity of the marine ecosystem. By contrast, the ecosystem-based approach offers an alternative mental model that deals with this complexity, not by bypassing it, but by scaling down to local ecosystem levels, which are best managed by decentralised, co-management governance arrangements that make full use of resource users' knowledge and also ensure accountability.

18.1 Introduction

Management of ocean fisheries is usually carried out at a broad geographical scale, often at the level of the nation state or some broader scale international political entity. There are numerous reasons one might cite for this choice of scale – for example, the absence of finer scale political boundaries; the costliness of ocean observing; the difficulty of conceiving and managing an ecology that is poorly known and understood; the need to match the scale of science with the scale of political authority; and the scientific belief that fish stocks are generally mobile and range over large areas (Degnbol 2001). Whatever the reason, most developed nations are caught up in institutional arrangements that require that they act as if a broad-scale, single-species approach is appropriate for the management of fisheries.

As our understanding of ocean ecosystems expands, there is growing reason to be sceptical about the scale of these institutional arrangements and their derivative scientific perspective. The current turmoil in fisheries science is telling evidence of the breadth of this scepticism. There are basically two reasons to be sceptical: an empirical reason and a theoretical reason. The empirical reason is the very poor results – the major failures – that generally obtain in ocean fisheries management (Pitcher and Pauly 1998). The theoretical reason is the serious difference between the holistic concept of the ocean held by ecologists, and the discrete, single species fish population model used as the conceptual basis for most management (Hutchings 2000*).* These empirical and theoretical reasons challenge some of the basic assumptions implicit in the design of our management institutions, and in the policy instruments such as quotas and individual transferable quotas (ITQs) which are generally favoured among managers and economists.

T. S. Gray (ed.), Participation in Fisheries Governance, 307–318.

Our conception of the biological structure and processes of the ocean is critical to our interpretation of the way human activity impacts the ocean, and to our sense of what we need to learn and do to manage those impacts for sustainability. The conventional scientific view is one that attempts to find a workable solution given political realities; the costly measurement and observation problems encountered when working in the ocean; and our fundamental computational and conceptual limitations. As a result, almost by default, conventional fisheries management science has simplified the complexity of the ocean into a series of scale-less (or single scale), independent, single-species models driven by assumptions of density-dependent, equilibrating processes. Every scientist ('every' may be too strong a generalisation) realises that this is a gross simplification of the ocean. The operative question, however, is whether it is an adequate simplification – that is, one that captures the essence of fish population dynamics and provides us with guidance about human behaviour that is appropriate for sustainability.

This question of operability is not easily resolved. For example, the manifest failures of fisheries management cannot necessarily be explained as the result of the inadequacies of this science. It is a commonly held view among scientists and others, especially those who have been the architects of conventional management, that the science is basically correct and that the failures we observe are simply the result of a lack of political will: that is, politicians and managers are unwilling to do what scientists deem necessary (Rosenberg *et al* 1993; Ludwig *et al* 1993). This proposition is not easily subject to scientific proof, nor is any proof generally thought to be necessary.

An alternative explanation for the failures of fisheries management is rooted, not in the idea that there is insufficient political will, but rather in the idea that both our science and governance processes are designed around a conceptual simplification that seriously mischaracterises ocean ecosystems. This proposition is also not easily proved but it is certainly worth exploring, not least because it forms a critical part of the argument for co-management. In this chapter, I explore this proposition, first, by presenting an alternative mental model of the important processes in ocean ecosystems, focusing especially on its relevance for the governance problem; second, by providing an interpretation of how current fishing regimes affect the ocean based on that model; and, third, by suggesting how we might reorganise our governance institutions and re-direct our science – really our overall approach to learning – so that we are better able to adapt to a spatially and temporally complex biological system.

18.2 An alternative mental model of the system

Conventional theories of fisheries management rely upon a mathematically elegant conception of ocean processes. The ocean system is viewed as a collection of independent, scale-less populations driven by density-dependent processes that create strong equilibrium tendencies. Because of those tendencies, the impacts of human interventions in the system are assumed to have predictable outcomes. This predictability implies control and the ability to manage each population for sustainability. In this chapter, I challenge these assumptions, and outline an alternative mental model of the structure and dynamics of an ocean system. This alternative model emphasises questions of scale and complexity, and is slanted towards those aspects of the system that appear to be particularly important to the design of governing institutions. Creating a mental model is an important exercise because it defines what we think the world is like, the collective learning problem we believe we face and, from that, the nature of the restraints we have to place on our own activities if we are interested in sustaining the resource. Probably just as important, it allows us to understand one another's perspective and makes a constructive dialogue more likely.

It is generally accepted that evolution has been the principal shaper of the structure and dynamics of living systems, including the ocean. A casual, or intense, reading of the literature on marine ecology strongly reinforces that view. It is, however, a view that is, by and large, absent from most of the science that is used for fisheries management. The reason for this, it seems, is that fisheries scientists tend to operate in the belief that the processes of concern to them – that is, the annual, or short-term, fluctuations in the abundance of fish populations – take place at a temporal scale that is essentially irrelevant to evolutionary processes. Occasionally, there is mention of fishing exerting a selection pressure that leads to earlier maturity among fished populations, but generally there seems to be a sense that the evolved structure of the system remains more or less constant. But the evidence certainly seems to contradict that basic assumption. For this reason, an important question that is not often asked is how fishing affects that structure – not just the genetic structure of individual populations, but also the cultural or learned behavioural attributes of fish populations and the interactions of those populations with one another, with the abiotic world and with humans. A large part of the scepticism about conventional fisheries management derives from a concern that the way we manage (or do not manage) fishing has led to a significant erosion, or deconstruction, of evolved population and ecosystem structure (Pitcher and Pauly 1998; Myers and Worm 2003; Jackson *et al* 2001).

Consider a physical environment with a diverse geology and topography, widely varying currents and tides, different salinities, temperatures and chemical circumstances – all subject to continuous perturbations by storms, climate and anthropogenic disturbances. In short, consider a physical environment that is diverse in space and time. For any living organism, finding the right place in that diversity is critical to survival. A cobbly, rather than a sandy bottom, for example, is important to a young lobster simply because cobble, compared to most other environments, provides better protection from predators, and adequate food and other resources that enhance survival (Walters 2000). The abundance of lobsters in areas that have a lot of cobble is the result of a long evolutionary process in which those lobsters that have led the early part of their life in cobble have had a higher rate of survival than lobsters that settle in areas that are dominated by, say, sandy bottom. Lobsters have evolved in close association with a large number of other organisms, some of which tend to eat lobsters, some of which lobsters like to eat and some with which lobsters compete for food and shelter. Given the particular physical and behavioural traits of young lobsters, cobble happens to be a place that lends itself well to the survival of lobsters. Something similar is true of every other organism in the ocean at any time in its life. There are places and times where the physical and biological circumstances are favourable to its growth and survival, and places and times where just the opposite is true. As a result, the co-evolved physical and behavioural traits of each organism combine with the varied abiotic characteristics of the system to create a spatially diverse and dynamic environment (Levin 1999).

Storms, seasonal changes, climate change and geological processes all alter the physical environment of the system at a variety of temporal and spatial scales. For each species, the impact of these physical perturbations is compounded by the adaptive responses to those same physical changes by the many species with which it interacts. A local storm might flush nutrients and fresh water from the land into the coastal zone, which might lead to an earlier phytoplankton bloom, which might lead to a whole cascade of biological responses, all of which take time to work their way through the system. For some species, these changes might provide an immediate new opportunity for increased growth and survival. For others, these changes might prove detrimental to growth and survival. If one species tends to be strongly favoured by a particular change, it may become very abundant in the near term, but that change simply leads to an opportunity for its predators in the longer term, and vice versa.

The interactions of species through these co-evolved, adaptive mechanisms constrain the proliferation (and the demise) of each population and, thereby, give order to a system that might otherwise lack any structure or persistence (Kaufman 1995). But that order is not the kind of order that is easy to summarise in a single mathematical equation or system of equations, nor is it reasonable to describe it as one with strong equilibrium tendencies, at least at the temporal and spatial scale of interest to fisheries management. There tend to be lags of various lengths that limit the constraining effect of other populations, and many species tend to be functionally very similar (Steneck 2001), with the result that very small changes in the circumstances surrounding, say, recruitment processes, will lead often to large changes in the fortunes of one rather than another species. The difficulty of prediction is made even greater because fish tend to move around and follow usually complex life histories. Populations that range over a broad area may have relatively discrete components that have adapted (genetically or behaviourally) to particular spawning grounds but then spend other parts of their life histories mixed up with the remainder of the larger meta-population. Some species at certain stages of their life may range very widely; others may be relatively sedentary; some may be both, and exhibit a variety of intermediate behaviours (Robichaud and Rose 2004; Kritzer and Sale 2002). Some may have eggs and larvae that drift widely; others may choose spawning areas and adopt behavioural responses that keep or entrain their eggs and larvae within very local areas. Local ecological regions may act as relatively coherent, almost closed systems for any short period of time but for longer periods they tend to become more and more open.

Generally, interactions with both the physical and biological environment tend to be characterised by thresholds, exponential growth and a variety of other non-linear events (Holland 1998; Levin 1999; Ulanowicz 1997; Pahl-Wostl 1995). The result of all this complexity is a patchy, diverse, dynamic and difficult-to-predict environment, especially if one focuses on particular species. But even at the level of functionally similar species and at the level of the ecosystem, stability is often hard to find. Marine systems seem to be prone to system flips, or alternative system states, that compound the problems of predictability (Gunderson *et al* 2002).

From an economist's perspective, the aspects of this kind of system that are especially important are: 1) the difficulty of ever knowing what populations are actually being fished, given the apparent localisations, mixing and overlapping of different stocks; 2) the absence of species-specific predictability and the resulting inability to engineer particular biological outcomes; 3) the very high information costs associated with monitoring the spatial and temporal complexity of biological diversity (Wilson 2002); and 4) the long time lags and other complex temporal dynamics, such as abrupt systems 'flips' or alternative states, that make it very difficult to learn about the dynamics of the system and, especially, the effects of fishing.

18.3 Changing our view of what is needed for sustainability

Conventionally, we have tried to cope with the complexity of the ocean by adopting an analytical perspective that asks the question 'how will the abundance of these populations change if all other things in the system remain stable?' This is a reasonable question if what is meant by stability is an environment that is not perfectly stable but one which exhibits statistical regularities that make the assumption of stability a good bet. It is also a reasonable question if the spatial structure of the system, and of the stocks therein, are simple and discrete, so we can match effort to particular stocks.

If, however, natural systems do not exhibit relatively stable dynamics and spatial simplicity, or if fishing disrupts or further destabilises a relatively unstable natural system – in other words, if the system conforms to the mental model outlined above – then the logic of this approach to simplification is questionable. The implication is that we have to search for a different way to simplify the complexity of the ocean: that is, a different way to fish that maintains the co-evolved relationships that are the ecological structure of the system. Generally, this means finding ways to establish rules about place, time and technologically specific ways to fish, ways that are sensitive to the particular spatial and behavioural adaptations of fish (Pitcher and Pauly 1998; Hutchings 2000). Importantly, it also means a psychological shift away from the idea that we can control individual populations (in the sense of producing particular statistically reliable outcomes) and towards the idea that, at a minimum, we have to find ways to manage and maintain ecological structure and processes.

This is a very different objective from the myopic concern with optimal fishing mortality that is the conceptual foundation of so much of conventional management activity. From a social and economic perspective, this changed objective is important, because it leads to a very different idea of the kinds of information and knowledge that we need to manage the system. In a single species approach, the information requirements relate principally to the changing abundance of each species. Collecting and analysing this data is not an easy task by any means, but it is a task that can be accomplished so that major trends, at least, are apparent over a period of a few years. However, if our scientific conception shifts so that it emphasises system-wide implications of species' adaptations, the information problem increases drastically. The broad-scale factors of conventional concern – the numerical abundance of each population – remain part of the equation, but the finer scale temporal and spatial attributes of each population, and the structure of the system as a whole, must also be considered. For example, for each stock it is important to know where it spawns and when. Its nursery grounds and habitat become important considerations, as does its range and the important interactions it has over its life cycle with other elements of the system. Behavioural, or cultural, patterns such as pre-spawning courtship activity, along with the spatial temporal patterns of these and many other aspects of the stock, also need to be understood. At the system level, there has to be an understanding of the link between oceanographic features and the organisation of biological activity – for instance, the particular local and wider adaptations of each species and the pattern of trophic linkages. And there has to be some coherent sense of how the spatial/temporal adaptations of the various species to one another and to the physical/oceanographic environment, add up to a constrained, orderly system. All of this amounts to a very large and, potentially very costly, information problem. It may be that over time we can sort these requirements down to a critical few that are important to sustainability. Most marine ecologists already have a good theoretical idea of what those requirements are likely to be, but we still have to learn what those requirements are for particular times and places. In other words, even if eventually we can parse our management requirements into a small set, until we get to that point we will have to incur large learning costs.

18.4 How to reorganise fisheries governance

When viewed 'in the raw', that is, without the filter of any prior theory, ocean systems appear immeasurably complex. If we are to adapt our behaviour to this complexity it is clear that we have to find ways to simplify that apparent complexity. This is what fisheries scientists have been trying to do for the last half-century or longer. However, the problem has always been addressed as if it was a classical problem in physics – searching for a way to condense the essence of the system into a few well-chosen equations, or lately, simulations. There has been little or no formal analytical recognition of the scientific limitations we have had to impose upon ourselves because of the way we have organised our scientific and fisheries management enterprises. In particular, broad scale management makes it very costly to monitor at an intensity that is meaningful for an ecosystem-based approach to management. Consequently, for all practical purposes we have closed off that scientific option. By re-designing the management enterprise we can act to reduce the costs of monitoring ocean systems, relax many of the limitations on our science (and more broadly our collective learning problem) and, consequently, delve a little more deeply and practically into the complexity of ocean systems.

The appropriate, efficient way to re-organise fisheries management depends almost entirely on the organisation of the ocean ecosystem (Simon 1996). What I mean by ecosystem organisation is the spatial pattern of coherent interactions, that is, of systems and sub-systems. That organisation is not simple but it does show regularities in time and space. Much of the system's physical (non-living) oceanographic attributes – its topography, currents, chemical make-up and pattern of seasonal change – are the most regular elements of the system. They are configured in ways that are strongly place-based and multi-scalar; recognisable, regular patterns occur at, say, the scale of the North Atlantic as well as at the scale of a small embayment. In fact, one can divide the North Atlantic, or any other large system, into a nested hierarchy of spatially defined, somewhat independent components, ranging in size from very small estuaries, to the North Atlantic as a whole, with each component displaying regularities that strongly reflect its unique oceanographic circumstances.

Without these regularities, learning and adaptation are not possible. The behaviours of fish, fishermen and the whole system reflect these place-specific, abiotic regularities. But populations of living organisms (and usually fishermen) are not confined, generally, to particular places. Depending upon their particular adaptation, they may move from one part of the ocean to another very quickly or very slowly – tunas vs. tunicates. For any temporal scale that one might choose, one's perception of the connectedness – of the systematic coherence – of places changes, as does one's perception of the relevant range of individual stocks of fish (O'Neill *et al* 1986). Over a very short period, say a matter of days, everything is more or less stationary, and any particular small place might be viewed as relatively independent from others. There is, at this short temporal scale, a local connectedness among organisms, but that connectedness dissipates quickly with distance. Over a period of a season or a year, the mobility of organisms increases and the extent of connectedness enlarges. Over a decade, there is still broader connectedness. For individual species this might result, depending upon their characteristics, in broad-scale but patchy populations, discrete localised populations or meta-populations whose internal dynamics occur at both fine and broad scales. Consequently, the perceived spatial organisation of the system depends upon the temporal scale of interest to the observer – that is, the observer's focal scale (O'Neill *et al* 1986). For periods of short duration, small and generally quickly changing sub-systems are the appropriate scale; for longer periods, larger and slowly changing sub-systems are relevant.

But, if one thinks of the observer as the collective action that we call 'management', no single scale is appropriate; all scales have to be addressed in ecosystem-based management. The critical role of organisation – specifically some sort of decentralised, multi-scale decision-making process – is that it gives us the collective ability to simultaneously address both fine and broad-scale aspects of the system. By matching (or approximating) the temporal and spatial scales of our organisation with those of the ocean, we can more easily partition the overall problem of learning about the system into sets of smaller, more tractable, place-based problems. Good boundaries, that is, ones that capture the internal coherence of sub-systems, create tighter feedback and make it easier to learn about each sub-system (Levin 1999). This organisational approach is not a conceptual simplification of the system such as a scientist might strive for, but it is a simplification that makes it easier to understand the system and solve the problem of human adaptation, and that, after all, is exactly what science is trying to do.

However, the current centralised, hierarchical mode of fisheries governance does not facilitate such an ecosystem-based management approach, and there are many reasons why we might expect re-organisation to make our management problem easier. A clear advantage of multi-scale organisation is the information/communication costs economies it offers (Arrow 1974; Williamson 1985). Centralised organisations operating in complex environments have to pass an enormous amount of information up, down and across the organisation. At a minimum, information is gathered locally, passed up the chain, coordinated, analysed, decided upon and then passed down the chain. The costs of transmitting and coordinating that information; the possibilities of distortion and misunderstandings; and problems arising from untimely responses – collectively transactions costs – can all be very large. However, if these costs are not incurred, the foregone information can seriously impair the effectiveness of the organisation. Nevertheless, for budget and other, usually political, reasons, centralised organisations frequently economise by adopting policies that try to dispense with the need for much of the information about the complexity of the system. These attempts are generally guided by a theory – scientific or managerial – that describes the essential, simplified information that captures the essence of the system and stays within the confines of what is deemed to be economical by the managerial system. Because theory defines the flow of scientific information (such as what needs to be monitored and what can be ignored; what needs to be analysed and what can be ignored), if it is inadequate or overly constrained by the need to economise, it will blind the organisation to the 'true' nature of its environment, and seriously impair the resultant policies it develops and its assessment of the outcomes of those policies. This is essentially the argument stated earlier about why we depend so heavily on single species management and, consequently, why our current institutions and policies are poorly adapted for ecosystem-based management.

The alternative to 'economising-by-ignoring' is to decentralise the organisation. But it should be realised that decentralisation is feasible and efficient only when the environment can be partitioned into relatively coherent, or self-contained sub-systems (Simon 1996). Thus, in fisheries there is a critical link between the organisation of the natural system and the organisation of management. Given relatively coherent sub-systems, local decision makers can be given authority over certain events, and the impact of decisions made under that authority are likely to be principally local. Consequently, provided their incentives are aligned with the goals of the organisation as a whole, and that their authority is limited to events with a local impact, local decision makers can be trusted to make decisions consistent with those goals. As a result, the overall organisation can avoid many of the transactions costs of centralised administration. The extent of efficiencies that can be achieved in this way depends critically upon two things: the extent of local coherence in the biological sub-system (that is, the degree to which the results of local decision making are actually retained within the locality), and the incentives of local decision makers (that is, the degree to which their self-interest is aligned with the broader goals of the organisation).

The transactions cost savings of decentralisation, while important, are not its most important attribute. Most important is the way decentralisation allows us to 'fit' our collective activities to the environment (Ostrom 1991). It is the equivalent of giving an organism new sensory capabilities. Put differently, it enhances our ability to learn about the environment in which we are operating. Learning is the essence of adaptive management (Walters 1986; Vodden *et al*, this volume). In a complex environment that means the ability to observe, learn and react at multiple scales. Events at a local scale are often incomprehensible without some understanding of broader scale phenomena. For instance, when we observe local system erosion, often we are not able to perceive the way such local events accumulate to broader phenomena. Conversely, events at a broad scale are often incomprehensible without knowledge of what is happening at a finer scale (O'Neill *et al* 1986). Major shifts in system structure, for example, are events we tend to notice and understand only after the fact because we tend not to see the fine scale erosion of the system. The problem at both fine and broader scales is that observers – individuals and scientists and organisations – are generally confined to a single scale, and communication across scales is sparse, biased and uncoordinated. As a result, the extent to which we can collectively assemble observations, learn about, and respond to significant events in the system is highly impaired. Put differently, in the absence of coordinated multi-scale organisation, the quality of information available for management is very poor, and management results can be expected to reflect that poor quality ('garbage in, garbage out', as they used to say).

Decentralisation, in these kinds of complex environments, also has the great advantage of lowering the cost and risk of experimentation and, consequently, of creating a greater likelihood that experiments and learning will be undertaken. By contrast, experimentation at a broad-scale in a heterogeneous environment is difficult, because it is hard to find broad-scale – that is, uniform – policies that are appropriate to the different circumstances of different areas. Because uniform policies almost always disadvantage some parties more than others, experiments that proceed under the assumption of uniformity tend to breed strong pockets of political opposition. The result usually is inflexibility, little or no experimentation and a retarded ability to learn by doing. It is much easier to adapt new policies – experiments – to relatively homogeneous local conditions than to a broad heterogeneous area (Wilson 2002). This means that political problems of experimentation are less, and the probability of learning about the system and finding new, effective policies is much higher.

It should go without saying that these adaptive advantages of decentralisation are not likely to be realised if local decision makers do not have the incentive to act in a way that is consistent with the broad social goal of conservation. This is a point that economists and other social scientists have been making for years, with some effect. Most of the material in this volume is devoted to the argument that the institutional arrangements generally known as participative governance are most likely to lead to incentive alignment – what economic theory defines as a necessary condition for an efficient solution to management problems. Consideration of complexity in ecosystems adds only one point to this literature, but it is an important point, that rights to fish have to be designed to match the circumstances in which they are embedded. The conventional arguments that lead fisheries economists to argue so fervently for ITQs, for example, are based on single-species, scale-less theories of population dynamics, and the idea that it is possible to generate statistically reliable biological outcomes through restraints on a single variable – fishing mortality. In this kind of simple biological situation, the establishment of rights to fishing mortality (such as ITQs) leads to both efficiency and incentive alignment, principally because in these assumed circumstances such rights allow a meaningful control over future biological states (NRC 1999).

In a spatially complex biological environment, however, where fish stocks mix and overlap; where predictable outcomes from human interventions are difficult to predict; and where ecological interactions are important, the fundamental premise of this approach is questionable. First, it may not (except in special circumstances) be possible to match fishing effort with particular stocks, and, as a result, quotas applied in a way that does not discriminate among multiple stocks may simply encourage a kind of pulse fishing. For each 'local' stock, conditions of open access obtain, and the regulatory environment induces a race to locate and fish down localised stocks (Wilson *et al* 2000; Frank and Brinkman 2001). The results can be expected to be similar, except perhaps in the scale of their incidence, to the devastation of the distant water fleets of the nineteen sixties. Second, even if it were possible to match effort to particular stocks, the complexity of the ocean is not likely to yield a statistically reliable control over biological outcomes, and, consequently, can provide little rational basis for long term, self-interested restraint that is consistent with sustainability. Species-specific mortality control, and access rights based on that control, do not address the common pool, ecological externalities that need to be internalised for sustainability. In short, they do not generate the conditions required for socially efficient property rights. Consequently, in a complex fishery governed by a regime of species-specific fishing rights, individual incentives to maintain ecosystem structure are basically non-existent, and do nothing to resolve the fundamental incentives of open access. Even if fishermen understand the importance for stock sustainability of fish habitat, behaviour and other ecological factors, any steps that they might take to conserve those aspects of the environment generate costs that they incur but that their less scrupulous competitors do not. They cannot capture the benefits of their own restraint and, consequently, are not likely to behave in a way that is consistent with sustainability of the resource. As a result, one would expect these kinds of rights regimes to contribute to the long-term erosion of ecological structure and processes.

Finding rights that will avoid the erosion of ecological function is likely to be the most difficult and important part of ecosystem-based management. More than anything else, the complexity of these systems requires rights systems that facilitate collective learning – both individual and scientific. The argument here suggests particular criteria that should be met by individual rights arrangements: Fishing rights should:

1. Extend to all the species in the regime (to the extent possible) in order to internalise the externalities that would arise with more narrowly defined rights, and for the purpose of generating systemic rather than simply species-specific knowledge.
2. Be place-based, multi-scalar and associated with a distinct oceanographic regime in order to increase the capture of feedback about the impact of human and natural activity, and contribute, thereby, to learning and accountability.
3. Be embedded in a decentralised governance regime in order to mobilise and coordinate through collective forums operating at multiple scales, the knowledge of individual users (and scientists), thereby improving the quality of information available to decision-makers, and promoting learning and accountability.

Ecosystem-based co-management, conducted in a regime of individual owner operators, old-fashioned yeomen if one prefers, is likely to be the only organisational form able to successfully meet these criteria. The reason for this is perhaps best explained by a comparison of individual incentives under corporate and under owner-operator regimes. In a relatively simple system in which the principal controller of sustainability is fishing mortality, the decision-making discretion of individual fishermen is limited. In these circumstances, corporate owners of fishing rights can effectively monitor the results of employees' decisions and assure the alignment of individual incentives with corporate objectives. Ownership and decision-making authority can be safely and economically separated (Rosen 1993). In a complex environment, on the other hand, where there are multiple drivers of sustainability the discretion of individual fishermen decision-makers, especially with regard to fine-scale phenomenon such as habitat, is greatly increased, as are the costs of monitoring their behaviour. The likelihood that corrupt incentives will arise increases, as do, consequently, the dangers of separating ownership and decision-making authority. For example, a corporate employee skipper has little or no incentive to avoid towing in habitat critical to the system if he can't be monitored effectively. His catch and remuneration go up and there is no loss to him because he has no stake in the future of the system. For all practical purposes he has the incentives of a roving bandit and lacks the fundamental accountability imposed by the market (Olson 2000). Owner-operators on the other hand, can have a stake in the health of the system if their rights are systemic, if their ability to cash out of the system is constrained so that they don't become financial roving bandits and if they have some way to reach collective agreement on mutual restraint. In this sense, the agenda of co-management is the creation of basic accountability in a complex environment.

18.5 Conclusion

In this chapter, I have noted that, from an economist's perspective, the appropriate organisation of common pool institutions and the definition of individual access rights for the management of renewable resources depend critically upon the nature of the biological regime being managed. In ocean fisheries, that regime has until recently been characterised as a relatively simple collection of independent, scale-less, single species populations. Current institutions and access rights are designed with that conception of ocean ecosystems in mind. However, over the last decade and more, there has been growing reason to be sceptical about the efficacy of these arrangements. The generally very poor results of conventional management, together with the scientific evidence and theories that emphasise the spatial and temporal complexity of ocean ecosystems, strongly suggest the need to manage in a way that addresses this complexity. But recognition of complexity also requires recognition of the fact that our current institutions and rights systems are designed with a particular learning and control problem in mind, one that derives from a mental model of very simple, ecologically isolated, single-species populations. These institutions constrain the kind of science that can be done, and lead to rights systems that fail to internalise the drivers of system sustainability. In order to adapt human activity to the complexity of the ocean, that is, to introduce ecosystem-based management, it will be necessary to reform the organisation of management and of individual access rights so that it is possible to deal efficiently with the large information and learning requirements generated by these systems. Broadly, this means some form of place-based, decentralised organisation that is congruent with the multi-scale spatial structure of the ecosystem. It also means rights that are place-based; are specified in terms of access to a local sub-system (not species specific); are lodged in individual, owner-operators; and are embedded in a co-management governance arrangement that is able to assure individual accountability and mobilise the knowledge of individual users and science for the purpose of management.

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