Parametric Management: an Ecological - Social Approach

by

James A. Wilson
Professor of Resource Economics
University of Maine
Orono, Maine, USA

and

Lloyd M. Dickie
Scientist Emeritus
Department of Fisheries & Oceans
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, Canada

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ABSTRACT

The immediate causes of over fishing arc usually ascribed to the harvesting of too many fish to allow adequate spawning, recruitment, and sustainability. We argue that the actions that lead to over fishing are most probably to be found in the broader parametric effects of fishing on the whole biotic and environmental system. Fishing activity leads to a degradation of the biotic or physical environment of desirable species, upsetting their feeding patterns and disrupting normal life cycle sequences. These reduced opportunities for growth, reproduction and survival alter the capacity of the whole system to maintain the organization of energy flows on which the fishery depends. However, the fundamental cause of over fishing lies in social institutions that either cannot conceive the complex biological interactions, or have insufficient authority to control the inputs. From a management perspective, this changed view of the over fishing problem suggests: (1) a shift to rules designed to address the parametric effects of fishing rather than the species-specific effort controls of traditional management. and (2) creation of a multi-level governance system (of basic federalist structure) in order to match the scales and minimize the potentially large transaction costs of system wide governance. Additionally, the difficult problem posed by uncertainty - our limited ability to tie particular restrictions to particular outcomes - means that hierarchical governance processes are needed to develop the basic requirements of credibility, incentive alignment and individual assurances.

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Introduction

In the current approach to fisheries management, the rate of fishing mortality on the stock of a particular species relative to its rates of reproduction and growth is held to be the chief cause of changes in population size and catch. This theory predicts that when fishing removes too many fish before they have had a chance to produce eggs, the adaptive, density-dependent mechanisms that can compensate for moderate rates of fishing arc no longer capable of restoring the productivity on which sustained catches depend. Management addresses the problem by reducing fishing mortality to permit the stocks to rebuild.

In contrast, parametric management draws attention to a different and more comprehensive explanation for the declines. It implies that the failures in recruitment of fish stocks arc not simply the result of changed variables controlling production of individual stocks. It argues that fishing activity leads to a degradation of parts of the biotic or physical environment of desirable species, upsetting their feeding patterns, and disrupting normal life-cycle sequences. These reduced opportunities for growth, reproduction and survival alter the capacity of the whole system to maintain the organization of energy flows on which the fishery depends. They may lead to a situation in which a reduction in fishing mortality can no longer guarantee the recovery of a particular fishery.

Parametric management also recognizes that the scales at which we address management problems may need to be altered. Emphasis on the mortality effects of fishing directs management attention to the large scales and the need for a uniform reduction in fishing pressures oxer the stock range. Some management rules may need to apply to all parts of a fisheries system. But it is primarily necessary to ensure a minimum disruption of production on the scale at which natural production processes are controlled. Rather than legislating for the entire stock range, the important need may be to consider very local phenomena. Local factors, such as the special vulnerability of fish on their migration routes and the integrity of local spawning grounds, equally have to be the concern of parametric management.

The need to address biological phenomena at many different scales implies a need to develop management institutions scaled to the biological phenomena they are designed to address [(32)] . Even the scale at which scientific information is acquired needs to be questioned. Traditional knowledge gained by generations of fishermen addresses many of the biotic and abiotic factors of concern to parametric management. This knowledge is essential to the setting of the framework of fishery system interactions within which testable scientific hypotheses can be set. A challenge posed by parametric management is to find practical means to wed traditional and scientific sources of understanding into a system of governance that meets the immediate needs of fishing communities and protects the long-term health of fisheries.

Parametric management is necessary because biological evidence shows that abundance of species varies in relation to parametric constraints so that individual species arc not independently controllable entities. This leads us to inquire about the kinds of rules appropriate to parametric management and the social organization appropriate to this wider approach. We suggest a hierarchical social organizational structure, incorporating the basic elements of co-management (see the paper by Fell. McCay and Neis in this volume) and whose scales of operation parallel the scales at which biological events occur.

Evidence **for** Ecosystem Controls on Fish Production

Many important effects of Fishing are not measured in mortality rate calculations. For example, fishermen in the Gulf of Maine estimate that because of improvements to roller gear and navigation they can fish fifty percent more territory than they could even ten years ago. In Canada, newly ice-capablc and mobile draggers and long-liners can fish grounds in seasons that were once naturally immune from disturbance. These changes in fishing technology allow the fishing-out of pockets of the "different" elements in the populations, elements that contribute to the resilience of stock production. As a result, while gear has improved, disruptions of local, seasonal patterns of distribution of the fish have made it more difficult to catch them.

Changes have not been confined to the commercial stocks. Non-fished species have commonly increased their abundance and distribution to fill areas once occupied by desirable species. The abundance of dogfish and skates on Georges Bank is only one example of changes in the species composition of stocks that have been seen world-wide, wherever there are intense fisheries. In the Great Lakes after the salmon, lake trouts and whitefish had been virtually eliminated, massive quantities of small fish appeared. In the mid 1970's off Peru, the anchovies were replaced by sardines, and in the North Sea a generation of European fishermen has experienced abrupt and unexpected collapses of traditional pelagic and demersal stocks and increases of "industrial" fish. To appreciate these changes requires the parametric, ecosystem view.

Science has no uniquely objective methodology for composing new models of fishery systems. Like all of our understanding, it depends on "analogy" and "metaphor" to incorporate relevant ideas [(27)]. This is why inclusion of fishermen's knowledge is critical to developing a comprehensive view. The special strength of science rests in its ability to study the larger consequences of our experience of the interrelated local changes that are identified. Two ecological lines of enquiry are relevant to the parametric perspective: the study of large-scale climatic parameters, that help explain production changes within the system, and the study of the whole biological community underlying fisheries, which shows how its ecological balance means that changes in one species are certain to have effects on others.

Large-Scale Parametric Effects

Changes in the North Atlantic climate are common knowledge and the distribution and spawning of the cod, haddock, herring, and seals that are mainstays of the fisheries have been affected for over a century by environmental parameters. However, fishery changes began before the most recent climatic trends, and similar past changes have had lesser effects on catches. Large area correlations obscure important variations within and between stock units, so that factors related to heavy fishing are also involved in the trends [(16)]. A joint responsibility between environmental parameters and fishing variables was also found in the collapse of the Peruvian anchovetta fishery, once the largest in the world [(5)]. and in other smaller fisheries world-wide [(14)].

The mortality effects of fishing have been obvious for over 20 years. By 1973 the Arcto-Norwegian cod fishery was removing more biomass than could be resupplied by the density-dependent responses of production by the fish [(9)]. Calculations for the Northern cod fishery [(13)] have confirmed that fishing is more important than environment in its collapse; that the fishery would soon have collapsed even without environmental change. Similar calculations explain the collapse of the California sardine fishery, and the collapses of the Norwegian and North Sea Down's herring stocks [(4)]. Clearly, environmental changes have contributed to the current fisheries crises by amplifying fishing-related demographic changes in populations.

It appears however, that both climatic and fishing changes take place within a large framework of ecosystem balance. Studies in the Great Lakes of North America, were the first to show that as the rate of fishing increased, the large and valuable species, such as trout and whitefish species, that dominated catches in the 19th century were replaced in the 20th by an abundance of small "trash" fish [(26)]. Despite markedly increased fishing, total landings changed little over the century: the major changes were in the species available.

A similar phenomenon was detected in the commercial statistics for Georges Bank [(10)]. These statistics cannot reflect the whole fish community, however, special research vessel surveys of the Shelf from Cape Hatteras to Georges Bank have now shown, over a 25-year period of high fishing rates, large changes in species composition, but a stable density by body-size of the whole fish community [(18)]. Data for the Scotian Shelf over 22 years show the same thing [(7)]. That is. as fishing intensity has increased, species vary in abundance, but biological density and production of body-sizes in the total fish community remain constant. The same holds true for the whole biological system. Data on the body-size spectrum of the biomass from plankton to fish for several major ecosystems. including Georges Bank, the North Sea. and the Scotian Shelf, have all shown that total biological production is constrained by nutrient input, but the resulting biomass and production is distributed among body-sizes of organisms, including fishes, in the same way in all ecosystems [(2)]. The compelling conclusion from this research into ecosystem balance is that when one part of the system is reduced, the other parts capitalize on the opportunities opened up to them. Fishing on one species affects the whole biotic environment, not just the species of interest[31]. Management of one part is critically dependent on management of the rest [10].

Small-Scale Parameters

Compensatory changes among species and size elements that stabilize ecosystem energy flows imply organizational interactions that, if upset, may lead to unpredictable changes within the species hierarchies. Some of these implications of system organization have become appreciated through specialized scientific models, such as the complex community organization models of cod. herring, capelin and seals. Model predictions that fishing will create unexpected changes in species balance, arc amply borne out by experience of the corresponding real systems in both Norway and Newfoundland as well as the multi-species fisheries of the Great Lakes. Georges Bank and Scotian Shelf. In all cases the species structure is highly variable and apparently sensitive to small changes in the initial populations conditions. It follows that when alteration in a species clement of the system goes beyond a certain point, there is no guarantee that an original balance can be restored simply by reducing the level of fishing. In the Great Lakes, for example, the lake trout defies persistent efforts to re-establish it. while the introduced species of salmon from the West Coast have become highly successful predators on small fish.

The growing knowledge of real system behavior helps us appreciate the instinctive apprehension of fishermen at the alterations in the biological and physical environments they know by experience. An example is afforded by the migrations of fish within the continental shelves. Massive migrations are known to characterize almost all major oceanographic current systems as adult fish move to "up-stream" spawning areas where the newly-hatched young feed on locally high biological productivity, before being carried back to the areas where the adults live. However. these migrations are not well know scientifically and are rarely allowed for in marine management rales. This is in contrast to the smaller but better known, hence more highly regulated fisheries for salmon in Pacific Ocean rivers [6].

Fishermen's livelihoods depend on knowing these patterns, including the precise times and locations of runs. Thus, they understood relations between the offshore and inshore fisheries in many areas before it could be established scientifically. They also recognize the importance of details, such as that the older, larger, spawners migrate further and at different times than smaller spawners. This know ledge led them to be alarmed when certain "runs" of fish disappeared with heavy fishing, years before mortality measurements showed the effects, and before scientific studies established the importance of such special stock elements to year-class success. They recognize that fishing disperses spawning fish, and that migrating fish arc especially vulnerable at particular places along their path.

As fisheries science has come closer to an appreciation of ecosystem characteristics known to fishermen, there has emerged a growing consensus that intense fisheries cannot be managed on the large-scale generalities of single-species stock dynamics alone. To be fully responsible, management institutions have to develop a means of identifying the relevant parametric features in system organization, additional to controls on mortality. The need for special protection at sometimes Local scales requires attention to new ways of utilizing fishery information and new methods of measuring effects within the whole system. Failure to protect special features of populations can vitiate the efforts to improve yields through control of mortality rates.

Social/Organizational Implications for Fisheries Management

There are a number of obvious conclusions about what is required of parametric management on the largest scale. A perception of almost everyone touched by the current fisheries crises is that the general level of fishing is too high. However, through parametric considerations, it becomes evident that reductions in the overall intensity of fishing need to be coupled with attention to details of the methods and timing of the fishing. The need to find the means of bringing about appropriate reductions before blanket closures arc forced upon all fisheries, is paramount.

No one can ever know the significance of all local features to fishery survival. Each environment has special features, and each ecosystem faces unique disturbances. However, the sciences of ecology, economics and sociology are rich with knowledge and methods that help establish whether historical and local observations can explain the results of interaction. With the different sources of knowledge we arc increasingly able to determine the consequences of neglecting certain classes of details in management. Our problem may then be primarily one of adaptation(12) in which we work to find the organizational rules that bring the diverse sources of information and policy formation together with the means of implementation and evaluation.

Detailed responses to heavy fishing vary among areas, but the trend of the last 25 years is now very clear. Remarkably, it is only in the face of the catastrophic adjustments within the biological system that we seem ready to reach consensus on the problem. This, as much as anything else, must alert us to the need to re-think organization of the management system in relation to what we hope to achieve through it.

The social rules that fall out of this reorganization depend critically on our sense of the biological bases of overfishing. In general, parametric change implies a need to shift the focus of management to both broader and finer scales of detail than are considered in the overall control of fishing mortality. We need to adapt our social institutions to our perception of the environment in which they arc embedded. As our perception of that environment changes, so too does our sense of the appropriate institutions for management.

In traditional species-specific approaches to fisheries management the problems of long run sustainability are well addressed by institutions that restrain total catch of that species. For this reason, the broad preference for ITQ's that has emerged among managers and economists is mainly attributable to the idea that ITQ's meet the requirements for well designed institutions: that is. ITQ's provide the basis for control over catch of the species and. at the same time, generate individual incentives that arc consistent with the social object of long run sustainability of a particular species [(1)(3)]. If. however, the mechanism leading to ovcrfishing is to be found in the parametric effects of fishing, it is very unlikely that institutions like species-specific ITQ's will lead to long run sustainability. ITQ's address the wrong problem.

The Scale Problem in Management

The parametric hypothesis regarding the effects of fishing identifies numerous non-species specific externalities occurring at various spatial and temporal scales. In other words, the problems of degradation of habitat, disruption of basic life cycle processes, removal of essential 'patches' and so on. that occur at lower levels in the system hierarchy are associated with discrete acts at particular times and places and all have an impact on system structure. Changed ecosystem organization, manifested in species composition changes that beset heavily fished systems, then reinforces the lower level effects, leading to so-called "non- linear" effects.

From the perspective of appropriate management institutions, the parametric hypothesis delineates three broad classes of problems that must be addressed by management: (1) the multiple scales at which overfishing arises. (2) the non-species specific nature of the factors that control production, and (3) the uncertainty of the outcomes of management actions [(1)]. Together they suggest why it is so very difficult to encompass the relevant externalities within the present model of a government agency acting as a sole owner with or without limited entry or ITQ's.

In the last two decades social scientists have made important progress in institutional design [(8)(19)(30)]. The broad elements can be quickly summarized. In the context of parametric overfishing. the successful institutions must be able to:

(1) Fully encompass the causes of overfishing within their control: that is. the restraining rules have to be applied to all relevant behavior. This requires that the management rules: (a) control total effort at a level consistent with total system productivity, (b) control the many interacting phenomena at a variety of spatial and temporal scales, (c) apply to all the users in the governance process, and (d) avoid creating a situation in which control at one scale leads to undesirable results at other scales or sites. If the causes of overfishing lie outside the institution's control, it will fail.

(2) Credibly tie the application of rules to an intended outcome. This is likely to be especially difficult in a complex environment like fisheries where there is always uncertainty about cause and effect. It is therefore critical that there be a sense among users that a rule is reasonable. Participants must be

convinced that restraint on their part will likely lead to the intended result. But equally, if it appears that the intended result is not forthcoming, it must be clear that a reasonable process of revision and new rule development will take place [17]. Institutions must go through a continuous learning process complete with active feedback about failure or success, a learning process very similar to the scientific process. To the extent that credibility and an on-going learning process cannot be established, administrative and enforcement costs will rise and the success of the institution decline.

(3) Align private and social incentives. That is. the rules must be seen as in the long run best interests of both society and the individual participants [19]. In the face of the uncertainty, either the rules themselves or the process of arriving at and changing them must generate an atmosphere of belief that they are worthwhile. Where individual interests cannot be harmonized with social interests, enforcement costs will rise.

(4) Provide individuals with reasonable assurance that others will follow the rules or face effective sanctions: the process of rule development and negotiation should lead to reduced uncertainty about the intent of other participants with regard to compliance with negotiated rules and agreements [22]. To the extent these assurances cannot be generated, the effectiveness of the institution declines or its enforcement costs rise.

(5) Efficiently carry out the transactions required of management. Maintaining exclusive control through measurement, monitoring, and enforcement, developing credible rules and maintaining harmonious incentives and assurances will require extensive and intensive transactions. The ability to minimize the time and financial costs of these transactions will determine, more than any other criterion, a workable institutional structure [30]. To the extent that transactions cannot be conducted effectively and efficiently, all functions of the institution will suffer.

No institution can perfectly meet these criteria. But there can be better and worse institutional solutions. If property rights embedded in the resource, as in a species specific ITQ or limited entry license, do not confer complete or meaningful control over those factors that determine sustainability. a property right holder is not in a position to influence the factors that contribute to the asset value of the right. As a result economic behavior may be no different from that found under open access. The properly right becomes nothing more than privileged access with no corresponding capability or incentive to deliver conservation.

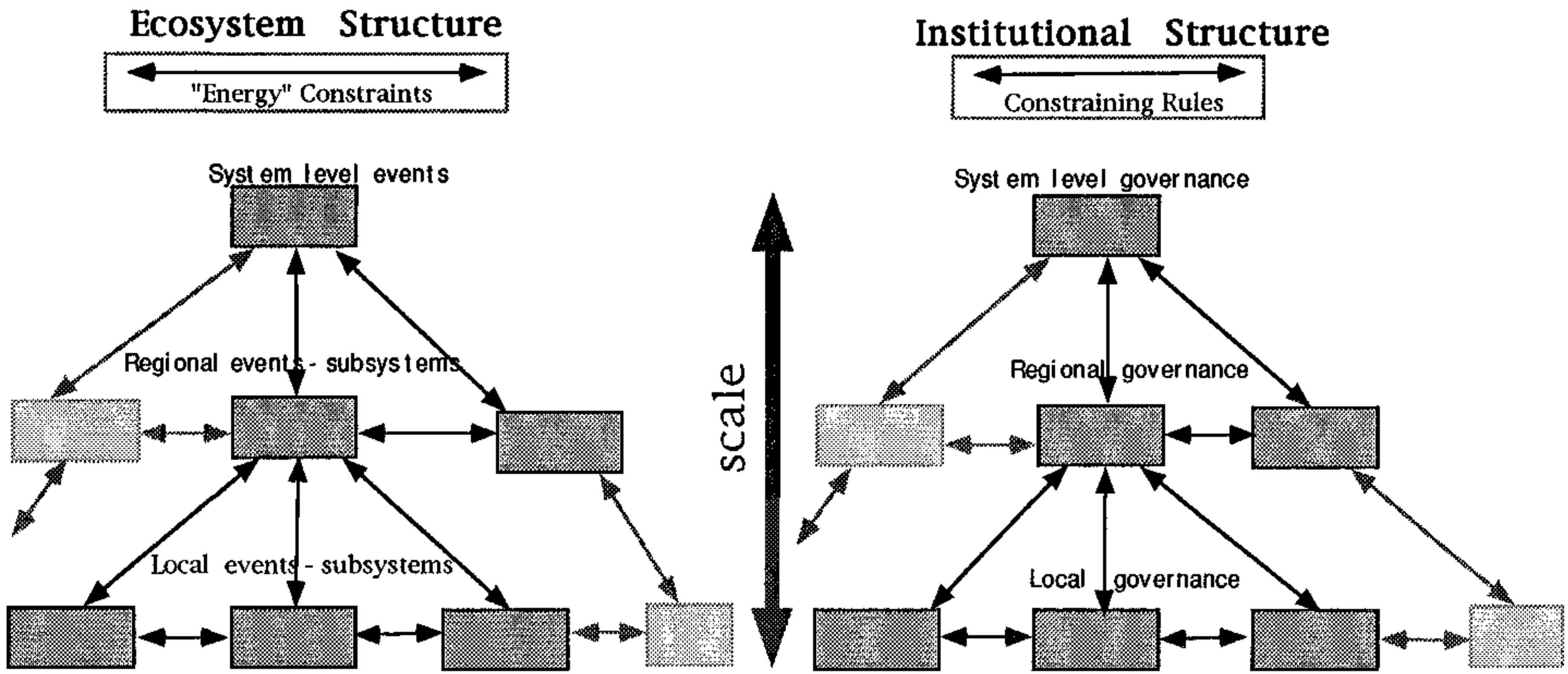
The alternative of full property rights, accorded to a government agency or a private corporation and administered through limited entry, has led to a similar lack of control, apparently because of an inappropriate alignment of incentives, related to transactional impairments that a single entity encounters in dealing with a complex system. The detail occasioned by uncertainty, multiple scales and non-species specific nature of the problem seems to lead to either an overwhelming information problem, if the entity remains centralized, or severe problems of inharmonious and conflicting incentives if the entity adopts a decentralized organizational structure [8] [30]). It seems clear that a workable solution does not rest in these approximations of the sole ownership ideal.

Towards a Solution - An Hierarchical Approach

The problems posed by parametric control of fisheries are very similar to those we face in the everyday governance of human activity. There we have to manage a great many human interactions, at widely differing spatial and temporal scales and with various levels of certainly with regard to cause and effect. Outcomes from public policies are never unambiguous; we have to devise rules that people feel will reasonably address the various problems at their appropriate scales and we have to do all this through a process that people find reasonable and that assures participants that there is a reasonably uniform, fair and equitable application of laws as well. We resolve what might otherwise be a monstrous transactions problem, leading to inefficiency and corruption, by erecting federalist type hierarchies in which responsibility for rule making and enforcement is assigned to the lowest possible unit in the hierarchy and beggar-thy-neighbor activity is constrained by a set of rules governing interactions among the various units in the hierarchy [20][21].

Parametric managernent calls for a similar approach in fisheries. The complexity of the fisheries and their derivative uncertainty, put a premium on the solution of the very human problems of generating credibility . developing assurances and aligning incentives while minimizing transaction costs. Such a governance process involves all stakeholders from the bottom up. Some form of co-management seems most likely to be the mechanism that can efficiently address these problems .

Parallel Ecological and Institutional Hierarchies



In order to address both the scale problem and these very human aspects of organization, we suggest a federalist organization at three or more levels starting with fairly local governance units, going through sub-regional and finally regional units [32]. To illustrate this structure consider the kinds of rules that might be required with parametric management.

A. With regard to sustaining the fishery:

1. Higher level system rules: Rules to restrain the total fishing effort on all species together, so that the effective mortality will be at or below the total biomass recovery rate. This may include rules to help control species balance.
2. Species specific rules related to life cycle and behavior: e.g.. minimum age of capture, no capture during spawning or along certain migration routes, etc.
3. Lower level environmental rules: e.g.. closed areas, refugia. gear types and restrictions, (when, where and how).

B. With regard to human activity

1. Human interaction rules: e.g.. gear and territorial conflicts, etc. at all levels.
2. Governance rules: e.g.. enforcement, assignment of responsibilities to various governance levels, the process of development of new or changed rules, voting, representation, rights transfers, etc. at all levels.

At a local level, to take an example, rules restricting fishing in particular habitats may be required for the purposes of protecting spawning grounds or nurseries. Under most circumstances it is not likely that clear, unambiguous evidence will connect these rules with a particular outcome in the fishery. Their intent and effect is to create a more hospitable environment for the fishery as a whole. Because restrictions encroach upon the present profitability of fishing, the development of credibility, assurances and incentive alignment becomes very dependent on the process by which the rules are developed. Because a local or community-level governance process brings to the table the varied interests and know ledge of users and advisors, and creates an arena where assessments of individual intentions can be made, it is much more likely to address the human side of the problem than a centralized institutional arrangement. And to the extent that that can be done, the likelihood that the choice and design of rules will conform with what are thought to lead to the best collective outcomes is increased. Users who are knowledgeable about local circumstances (both biological and human) arc not likely to agree to rules they feel are pointless with regard to results, that they feel will be wantonly disregarded by others, or that contain incentives which pit the individual against the collective well-being. Furthermore, to the extent that purely local problems can be dealt with at the local level, higher levels in the governance structure arc not deluged with overwhelming detail resulting in large gains in transactional efficiency.

At sub-regional levels, rules of two sorts can be expected to develop. First there arc the rules governing externalities relevant to biological phenomena occurring at the sub-regional level. For example, for a particular species it may be desirable to have a single minimum size of capture or there may be habitat problems at the sub-regional scale that need to be addressed. Here again the process can be expected to follow much the same pattern as at the local level but most probably with representatives of local areas rather than direct involvement of all users. A second and very important kind of rule required at the sub-regional level concerns the prevention of beggar-thy-neighbor behavior between units at the local level. For example, fish that grow in local nursery areas may leave those areas before they arc (catchable) adults: as a result, local fishermen may have little incentive to protect such areas. Consequently, general rules regarding the local treatment of region-wide externalities are also required.

Parallel kinds of rules would be required at the full regional level. But at this level a unique rule requirement might arise if. in fact, it was felt necessary to restrain total biomass removals or to constrain total effort consistent with biomass recovery rates. In this instance, a market in. for example, tradablc generalized inputs, might well complement the governance structures required for the other kinds of externalities. However, since other rules at other scales, such as refugia, gear design and so on. have clear economic impacts and consequent limits on the total amount of effort in the fishery, it is not clear that total effort controls would be necessary.

In general, it should be clear how a federalist approach can adapt to the various scales at which the fishery problem occurs. Less obvious is an equally important aspect of a governance process - the continuity or repetitiveness of the process itself. This would appear to be especially important in the uncertain environment of fisheries for two reasons - to suppress or minimize individual strategies that defect from the common interest (i.e.. individual gain at the expense of conservation) and to encourage learning about the environment. In both these cases, feedback about the experience of individuals is essential. For example, one would expect as a normal course of events that some actors in this environment would attempt to avoid the effect of restraints that impinged on their immediate well being. This might occur during the process of rule making or afterwards: it might be the result of deliberately cynical behavior or perhaps more likely a wishful belief that restraints are unnecessary. Whatever the source of the belief, if incorrect, there must be ways for the institution to flush it out (or reinforce it if correct). For this to occur. however, there must continuing and repeated decisions that allow individual's to recognize the patterns of behavior of one another. Then defection can be sanctioned. Decentralized governance processes strongly increase the likelihood of this outcome because of the direct and continuous feedback they provide.

Similarly, with regard to institutional learning, over the long haul the great danger to the governance process (or any other institution) comes from an inability to demonstrate or actually create a situation in which the restrictions on individual actions produce the desired results. (This is why. for example, we would expect ITQ's to fail as a credible institution if and when it became apparent that the sources of sustainability lie outside the species specific factors governed by the 1TQ.)[1] In the case of parametric management this is a potentially large problem, especially because our state of knowledge of ocean ecosystems is fairly rudimentary and under any circumstance, as we have mentioned several times above, the complexity of these systems will always make it difficult to unambiguously connect cause and effect. We can expect and must anticipate mistakes. Consequently, the long term legitimacy of **the** process will depend to a great extent upon a continuing process of learning with the full involvement of users (12). In this instance also, decentralized governance structures provide the kind of direct and continuous feedback that is likely to generate the information necessary to make institutional learning workable 2

Conclusions

The immediate causes of overfishing arc usually ascribed to the harvesting of too many fish to allow adequate spawning, recruitment, and sustainability. We argue that the actions that lead to overfishing are most probably to be found in the broader parametric effects of fishing on the whole biotic and environmental system. However, the fundamental cause of overfishing lies in social institutions that either cannot conceive the complex biological interactions, or have insufficient authority to control the inputs. From a management perspective, this changed view of the overfishing problem suggests (1) a shift to rules designed to address the parametric effects of fishing rather than the species-specific effort controls of traditional management, and (2) because of the non-species-specific characteristics and various scales at which these rules must operate, creation of a multi-level governance system (of basic federalist structure) in order to minimize the potentially large transaction cost problem. Additionally, the difficult problem posed by uncertainty - our limited ability to tic particular restrictions to particular outcomes - means that hierarchical governance processes arc needed to develop the basic requirements of credibility, incentive alignment and assurance.

FOOTNOTES

[1] The monopoly or cartel like benefits that accrue to ITQ holders in this circumstance might, however, provide sufficient incentive for collective enforcement.

[2] Fishermen carry a great deal of knowledge about this environment, but as they would all readily admit it is knowledge that could be greatly supplemented, refined and even overturned by good scientific work. Deliberate steps taken to incorporate a scientific component within the governance structure would undoubtedly enhance the usefulness of fishermen's knowledge and the feedback necessary for management success.

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