Sustainability Issues for Resource Managers

Daniel L. Bottom
Gordon H. Reeves
Martha H. Brookes

Technical Coordinators

U.S. Department of Agriculture
Pacific Northwest Research Station
Forest Service
General Technical Report PNW-GTR-370
November 1996

In Cooperation with:
Oregon Chapter, American Fisheries Society

Historical Interdependence Between Ecology, Production, and Management in the California Fisheries

Arthur F. McEvoy

ARTHUR F. McEVOY is a professor, School of Law, University of Wisconsin, Madison, Wisconsin 53706.

The organizing topic of this set of papers was "the nature of our obligation as fishery professionals to present and future generations." Entailed in that organizing topic, so the symposium's organizers informed the participants, were three subsidiary questions. Those questions were, first, what is it that fishery managers are trying to sustain and why? Second, what social, political, or scientific problems undermine sustainable fisheries management? Finally, how might fishery managers undertake the intensive management of commercial resources without irreversibly altering the ecosystems upon which these and other resources depend? This article is an effort to address those questions from the perspective of the historical record of fisheries management in California, since it began to be actively concerned with the health of its fishery resources in the late nineteenth century (McEvoy 1986, 1988).

Fisheries management is an object lesson in John Muir's aphorism about Nature, to the effect that once one begins pulling at any particular aspect of the natural world, one inevitably finds it hitched to everything else in the universe (Teale 1973). What stands out from the history of the fisheries in this one jurisdiction are, first, the truth of Muir's notion that everything is connected to everything else and, second, how richly textured that truth is. That history suggests short answers to each of the three questions the conveners of this symposium put forward, in reverse order. How do we manage commercial resources without altering the ecosystems in which they are embedded? The answer to this one is easy: it's not possible. What social, political, or scientific problems undermine sustainable management? The answer to this one is easy, too: all of them. The first question—What is it that we're trying to sustain, exactly?—is the really interesting one. Moreover, the way in which one approaches the second and third questions depends a lot on how one answers the first one.

Many of our problems in sustaining fisheries historically have stemmed from the fact that managers have traditionally understood their task as one of sustaining a flow of wealth from something they identify as a "resource" into something they identify as "the market," both of those things conceived of as distinct from one another and each from their environments. The history of California fisheries management makes clear that, as a matter of fact, everything is connected to everything else and that people have problems when they try to treat things as if they were not.

What a fishery is, descriptively, and what management ought to try to sustain, prescriptively, is an interaction between three variables: an ecosystem, a group of people working, and the system of social control within which the work takes place. Each of the three variables has a good bit of its own independent dynamism, but each varies continually in response to changes in the other two. So it is not possible, in the nature of the case, to manage a resource as if it could be described and manipulated at arms' length. The best that fisheries managers can do is to monitor and adjust the interaction between a volatile ecology, a creative economy, and society's understanding and control as they go along.

Ecology

The ongoing history of fisheries management is best understood as an ecological one, consisting of a tripartite system of ecology, production, and management as it has moved through time. In California, the data for such a history are as variegated as the state's fisheries are themselves.

There are, first, a lot of useful historical data on California ecology, both on land and offshore. Army and Weather Service records of temperature and precipitation date back to the 1840s (McAdie 1903); we know from these records, for example, that the period between 1880 and 1920 tended to be cooler than the periods before and after. We also know that the decades between 1910 and 1940 were significantly drier than average. We know, finally, that significant climatic anomalies, probably associated with the El Niño-Southern Oscillation occurred in the mid-1950s, in the early 1920s, in the early 1880s, and the mid-1860s. All of these anomalies were associated with serious crises in the fishing industry, in response to which industry pressed for some political solution (Hubbs 1948, Radovich 1961, Cane 1983).

We also have an interesting set of geological data developed by the Scripps Institution from fish scales deposited in anaerobic sediment in the Santa Barbara Channel (Soutar and Isaacs 1974). These sediments are annulated, like tree rings, because winter sediment from the coast is darker and thicker than summer sediment; what the people at Scripps did was to take cores out of the sediment, date the layers, count the number of scales from different kinds of fish in each layer, and calibrate those measurements to modern estimates of those stocks' populations. The end result of all that work is a census of the major pelagic schooling species in the system (sardine anchovy, and mackerel) that goes back some two millennia (Smith 1978). We know from these data that the aggregate biomass of these schooling fishes has varied widely and continuously: it was extremely high in the 1830s, and again at the turn of the twentieth century, when the major industrial fisheries of this century (for salmon, sardine, and tuna) were first developed. We also know that since the sardine fishery collapsed in the late 1940s, the aggregate population of such fishes has remained far below any numbers in the geological record.

In this record, further, is an interesting relation between populations of sardine and anchovy. These two species are ecologically very similar, except that the anchovy has a shorter life span and breeds at a higher rate than the sardine does. What this knowledge does for us is to provide an index of the relative volatility of conditions in the system: highly unsettled conditions favor a species like the anchovy that turns its population over more rapidly; more stable conditions tend to favor the sardine (Smith 1978, Smith and Lasker 1978). We thus know that the system was both highly stable and productive in the 1860s, the 1890s, and the 1930s. The first period was when the sardine fishery was in its heyday. The system was in disequilibrium in the 1880s, when government fishery management began in California, during the World War I decade, and during the late 1940s and early 1950s, when the sardine fishery collapsed. On the whole, the California Current system is extremely volatile and all of the fisheries in them are vulnerable to random environmental shock. In sum, clearly a great deal of change takes place in the system, some of it quite drastic, whether people are working it or not. People who develop expectations about a fishery's productivity in good times may be caught by surprise a few years down the road.

Contemporary observations provide a wealth of more traditional historical data. We know, for example, that massive die-offs of sardine occurred off the southern end of Baja California in 1602 and off Monterey during the last week of May 1858, the first because the Spanish explorer Vizcaino noted it in his diary (Wagner 1928), and the second because the Monterey newspaper reported that a lot of Indians had come from inland to gather the fish for drying. We know that when Richard Henry Dana visited Santa Barbara in the 1830s, little or no kelp grew along that stretch of coast (Dana 1841), but in 1888 the kelp was so thick that coastal steamers had to have channels cut for them before they could come into port (USFC 1888). This last item tells us a lot about the system that we can correlate with the histories of the sea otter trade, the Chinese abalone fishery, and the near-shore market fisheries whose staples were yellowtail, barracuda, sea bass, and other kelp-living species (McEvoy 1986).

Finally, more-or-less systematic observations were taken by scientists, most of them on government payrolls, from time to time beginning in the 1860s. In all, direct observations by scientists and lay people provide good evidence as to what kinds of fisheries were prospering at what times, and which ones were doing poorly. It is thus possible, given current knowledge about the dynamics of the California Current system, to compare what modern science suggests was really going on in the system with what people at the time thought was going on and what they did about it. Perhaps not surprisingly, correlation between what people thought was happening to them at the time and what the data suggest was really happening is usually rare.

Production

All of these measurements tell us something about the ecology leg of the tripartite system. The second leg is that of production. The most striking characteristic of the industry's economic history is the familiar, cyclical pattern of boom-and-bust: new resources are discovered or come within reach of developing technology, harvests grow exponentially for a while, they level off, and the fishery collapses. The story, told in a single iteration, is unremarkable. What is remarkable about it is the innumerable quantity of its historical iterations and the seeming inability of people to do anything to prevent it.

One interesting aspect of this cycle as it has played out in California, however, has to do with the nature of economic development in the fisheries, both extensive (in the sense of geographic expansion) and intensive (in the sense of technological development). That is, that more or less coherent agglomerations of capital and labor tend to persist through the industry's history, shifting to new stocks or moving to new waters for new supplies of old stocks or changing their techniques in the service of either strategy when they deplete their old ones. One very interesting example of this phenomenon concerns the Sacramento River salmon fishery of the late nineteenth century.

The Sacramento River salmon fishery was established in the late 1860s by a couple of men from coastal Maine; these people were refugees from a salmon fishery that their families had worked since before the American Revolution but had since begun to decline under the impact of agriculture, industry, and other competing uses of water (Dodds 1959, Merchant 1989). Once established on the Sacramento, salmon fishing continued sporadically until the late 1870s, when the climate suddenly changed from a hot and dry "continental" regime to a cool and wet "marine" pattern. Suddenly, the runs of salmon in the system were unbelievable. At its peak, the fishery probably took 10 million pounds of chinook salmon out of the Sacramento River each year between 1879 and 1883. The runs were so heavy between September 15 and 17, 1880, that fishers at Sacramento simply threw 9,000 dead chinooks back into the river because no one would buy them. The boom phase of this fishery lasted exactly four years, or one modal chinook life span.

As the industry collapsed, most of its capital and labor moved northward, more or less bodily, first to the Columbia River, then to Puget Sound, and then to Alaska, depleting each fishery in turn. The industry behaved a little like a group of slash-and-burn farmers, except that enough people stayed behind at each place, making their average cost and no more, as the economics of the "tragedy of the commons" would predict, to make sure that the stocks got no chance to recover (Crutchfield and Pontecorvo 1969).

One California salmon processor moved from Sacramento to Monterey at the turn of the century and did two things: he outfitted a few motorized boats and began trolling offshore for salmon, which boosted the harvest but intensified the pressure on the Sacramento stocks; and he modified his cannery and a few of his boats and began fishing sardine. The sardine industry spread north along the coast to British Columbia, boomed during the twenties and thirties, and collapsed after 1945. In the early fifties, the sardine industry moved bodily, canneries and boats and even a few scientists, to Peru (Paulik 1971, Clark 1977).

The economic history of this part of the California fishing industry is thus one of a more or less coherent aggregation of labor, capital, and technology that endured nearly two centuries, from the 1770s to the 1970s. The industry had a kind of malignant ecological unity as it moved through two centuries and into three oceans. The same kind of story can also be told about whales and tuna (McEvoy 1986). The point is about the nature of technological and economic change in the fishing industry that comes to light only when one looks at it from an ecological and historical perspective.

Another interesting thing about fisheries in general and those in California in particular is the remarkably high degree of informal order under which they operate. Until about World War I in California, the fishing business as a whole consisted of a handful of disaggregated sectors, each made up of a different ethnic group fishing target species with which they had been familiar in their home countries. Chinese fished squid and abalone, New Englanders fished salmon, Italians fished nearshore market varieties, Portuguese hunted whales, and so on. Given the relative weakness of the state's fishery management apparatus before World War I, each of these disaggregated fisheries operated under its own law, more or less independently of the others and certainly from the state. The one Indian group that survived into the twentieth century more or less intact, those people who fished salmon in the Klamath River, likewise retained a great deal of power to order its harvest in its own, traditional ways.

These regimes could be quite vigorous. In the words of the San Francisco Chronicle in 1907,

> if anyone imagines that it is possible for a Chinese or member of any other nationality than an Italian to catch crabs in this bay for the market, let him try it. If any Italian thinks it is possible to catch crabs for the market without joining the Association, let him try it.

"Everything is governed by laws which the fishermen have made for themselves," reported David Starr Jordan some years earlier (Goode 1887).

Would-be competitors of these ethnically proprietary fisheries certainly seldom saw anything of substance in these arrangements except monopoly and piracy. Modern economists usually pay little attention to them either, as do law enforcement officials except when, as in Indian treaty fisheries, the courts force them to. The record suggests, however, that these tight little ethnic or tribal associations served an ecological function by linking the allocation of access to the resources to the long-term welfare of the group, and that their management record, historically speaking, in many cases looks at least as good and sometimes a lot better than that of the bureaucratic, scientific agencies that superseded them.

Similar groups that exist today, among the Cree Indians of James Bay, Canada, for example, or among lobster fishers in parts of Maine, likewise close off access to their fisheries, maintain a similarly high degree of order in their harvest, and tend to generate more net social income on a more sustainable basis than neighboring groups not so highly organized (Acheson 1975, Berkes 1977, McGoodwin 1990). In California, the very cohesiveness of these groups and the relative prosperity that they derived from that cohesiveness incited the envy of less organized competitors, who called on the political machinery of the state to destroy them, thus exposing those fisheries to the market failures that make up tragedies of the commons. The point here is a relatively conservative one, that a systematic, ecological, mutually reinforcing relation exists between the social and cultural organization of harvesting groups and the ecology of their target stocks.

Thus, a reciprocal, interactive relation exists between the ecological processes that determine a stock's productivity and the social and cultural processes that make fishers behave in the ways they do—that is, between the ecological and productive parts of my tripartite model of the fisheries. For a long time, of course, people thought that no such interactive relation existed; that is, that nature was essentially a passive store of resources from which harvesters could always take more and it would grow back. We know better than that now, although the idea persists, frequently hidden deep in the assumptions we make about what fisheries management is all about. Nowadays, the notion manifests itself whenever people act as if nature were resilient enough to take whatever burdens they can put on it, that some technical way of making nature produce more than it seems willing to will always be found, or that what all fishers want, when they resist outside intervention into their affairs, is to get more for themselves, beggar their neighbors.

Management

The reciprocal relations between the ecology of resources and the economic use of the resources is relatively easy to grasp. Fishers go where nature makes resources available to them; nature, in turn, changes its character whenever human use has an appreciable impact on it. Less intuitive is the reciprocal interrelations between management and both industry and ecology. Management, including both lawmaking and the scientific research that (at least ostensibly) informs it, clearly has some impact on the structure of the fishing industry and consequently, as the industry works in a responsible environment, on the ecology of the resources. At the same time, however, management is itself a product of the historical interaction between production and ecology, between fishers and fished.

Frequently, lurking deep within our assumptions about fisheries management is an assumption not unlike the one that postulates a sharp, hermetic distinction between ecology and production. Here, fishery managers frequently assume that the regulatory process goes on in isolation from the interaction between nature and production that it is supposed to monitor and regulate. This assumption about the management process, in turn, has two aspects to it. One facet of the assumption is the idea that lawmaking goes on in isolation, unaffected by the struggle for resources in the marketplace. The other aspect is the common assumption that the scientific information on the basis of which lawmakers regulate the fisheries comes to them as objective truth, free of political charge either in its generation or in the manner in which lawmakers put it to use. Both of these preliminary assumptions are wrong; both science and law are inextricably knit into the systematic interaction between ecology, production, and regulation that constitutes fisheries management in the real world.

The first incorrect assumption is that lawmaking somehow goes on in isolation from the struggle for resources that leads to fishery depletion. What lawmakers are theoretically supposed to do, whether they are regulators, legislators, or judges, is to identify market failures that lead to "tragedies of the commons" like fisheries depletion; once they discover these market failures, their job is to fashion regulations to correct them (Christy and Scott 1965, Hardin 1968, Cheung 1970). Market failures stem from a number of readily identifiable sources: free rider problems, jurisdictional incoherence, overly high discounts placed on future income from renewable resources, poor accounting of uncertain risks to the resources, and the difficulty of translating ethical or otherwise nonmonetary values into measures that can be balanced against the economic costs of fish left uncaught.

Lawmaking, however, is subject to all of the same kinds of market failures that the unregulated economy is. The legal system is a kind of market for legal entitlements to use resources in certain ways; inasmuch as people struggle in that legal market for rights to use resources, "the law" and "the market" are simply different modes of bargaining between economic actors (Hurst 1982). It is certainly true that much of what passes for resource management amounts to little more than one well-organized interest group or another pressing the state to give its members access to resources while denying it to others. Most restrictions on fishing gear fall under this head: the controversies between people who troll for salmon offshore, those who fish salmon inshore for recreation, and the Indian tribes should come immediately to mind.

California history is replete with examples of this kind of struggle for resources displaced from the market into the legal system. The California Fish and Game Commission spent most of the first 30 years of its history engaged in a process whereby it commissioned one or another scientific study of fisheries problems, noted the near-uniform conclusion that the one-third of the state's fishers who were Chinese were to blame for those problems, and with little trouble urged the state legislature to burden the Chinese fisheries with season restrictions, gear restrictions, export prohibitions, and so on.

As it turns out, Chinese fishing had little or nothing to do with any of the problems that led fishers of European background to demand that the state take legal action against them. In the 1880s, Chinese abalone hunters did well and Italian market fishers did poorly, for example, not because of any ecological link between the two, but because the fur industry had by that time wiped the California Current system clean of sea otters, which allowed populations of intertidal mollusks to bloom and thereby led to a depletion of the kelp forests that provided habitat for the market fishers' targets. Indeed, the record hints that, by the late 1880s, Chinese gathering had depressed populations of abalone and sea urchin enough that the kelp forests were reviving in those neighborhoods where the Chinese were active (McEvoy 1986). To contemporary observers, however, Italian trouble and Chinese success, plus the instinctive notion that Nature herself had only a passive role to play in the human economy, led to a political result in which resources management amounted to a struggle between harvesters only, in the state capitol no less than on the water itself.

Perhaps a more dramatic example of this reciprocal interaction between lawmaking and market struggle comes from the sorry history of the California sardine fishery. Here, California assembled the world's most sophisticated research-and-regulatory apparatus to manage what at the time was the most intensive fishery the world had ever seen (Thompson 1919). By the late 1920s, the California Fish and Game Department had identified all of the then-accepted signs of overfishing in the stock and recommended a catch limit of 250,000 tons (Clark 1939). Later research indicated that this was close to the fishery's sustainable yield at the time, even with discounting for occasional years of reproductive failure built in (Murphy 1966, MacCall 1979).

The problem was that the state legislature had the legal authority for regulating commercial, as opposed to recreational, fisheries: what happened was that the Fish and Game apparatus had to join the commercial fishery and (especially) its allies in the state's poultry industry in a political struggle over allocating access to the fishery. As a result, the fishery went essentially unregulated. In 1935, Oregon and Washington responded to California's inability to rein in its fishers by giving theirs unlimited access to the stock as well. By the end of the thirties, the sardine fishery was seriously overcapitalized and catches had leveled off; it collapsed suddenly in 1945-46 and again in the early 1950s, never to recover. Here was a particularly clear example of the reciprocally constitutive interaction between production and lawmaking: the "tragedy of the commons" reproduced itself, more or less unchanged, in the very regulatory processes that were supposed to correct its evil effects in the market.

If market struggle shapes the regulatory process by influencing the outcome of political bargaining in legislatures and administrative agencies, it also does so by influencing the character of the scientific information made available to lawmakers as a basis for their allocations. This in turn, takes place in two arenas, both by determining the kinds of questions that scientists are given to answer about a resource and by influencing the ways in which lawmakers respond to whatever information their scientists are able to generate for them.

In the nineteenth century, both state and federal fisheries science concentrated single-mindedly on increasing the flow of resources from the environment into the market. One way to do this was through prospecting for new resources; a great deal of this kind of activity occurred at all levels of government in the last three decades of the century.

Another way to maintain the flow of resources into the market was to enhance the productivity of declining fisheries through applied science. Government scientists, then, restocked depleted waterways with exotic species of fish and propagated particularly valuable species like salmon and trout artificially, in government hatcheries. As it turned out, a few successful transplants of exotic fishes to California waters (shad and striped bass) were at least counterbalanced by the baleful effects of others (German carp and brown catfish, most notoriously) (Smith 1895, Elton 1958). Observed increases in the salmon harvest at the turn of the twentieth century, meanwhile, were almost certainly due, not to the hatchery work, but rather to changes in climate, changes in the distribution of the salmon's prey species, the opening of an offshore troll fishery for immature salmon, and the steady decline of pollution from the mining industry inshore (Larkin 1979, McEvoy 1986). The state, however, claimed in 1900 that "by the efforts of this Commission, the salmon has been restored to our state" (California Fish and Game Commission 1900).

Not only to harvesters, then, but also to the public officials whose job it was to oversee the industry, fish were like gold nuggets: valuable commodities to be recovered from their state of nature and transformed into cash for the one, a valuable source of political capital for the other. So long as government apparently maintained the supply and drove unwanted competitors out of the business, further inquiry into the biology of valuable fisheries seemed to have little point. Nature was thoroughly plastic and could be manipulated in the service of enterprise to the limits of human ingenuity and political will. That observed changes in the fishing business might have been due to the collective behavior of the harvesters, to changes in other industries, or even to the weather was simply not a legally meaningful question. Inasmuch as most fishery research was paid for through political appropriations, moreover, it was not a scientifically meaningful one, either.

The second way in which the interaction between lawmaking and market struggle influences the role of fisheries science in management has to do with the effects that knowledge has on the regulatory process. Here again, a telling example comes from the history of the sardine industry. The sardine is very vulnerable to environmental change in its first few days after hatching: if conditions aren't just right while fish are in the larval stage, the whole generation will die (Smith 1985). What happened was that conditions were good for sardine recruitment between 1900 and 1940, while the sardine fishery was in its growth phase, but when conditions turned bad in the 1940s, the stock could no longer sustain such a heavy draft as the industry was placing on it and collapsed. What extinguished the sardine, then, was the interaction between an overcapitalized fishery and a volatile ecology (Murphy 1966, MacCall 1979). Precisely the same thing happened in Peru some 30 years later (Clark 1977).

Until the mid-1960s, one could take either of two positions in the political controversy over regulating the sardine fishery. One could say that observed fluctuations in the harvest were caused by "environmental" conditions, meaning that fishing had nothing to do with the collapse and that the collapse would have taken place even had no fishing been done at all. Alternatively, one could take the position that observed fluctuations in the harvest and the ultimate collapse were due to overfishing (Croker 1954, Clark and Marr 1955).

Although some people had pointed to possible interactions between fishing and environmental change, they were unable to bring that reasoning to bear on the political process because neither casual synergy nor predicting the future on the basis of random-variable analysis were meaningful concepts in the culture at large. By the mid-1960s they were, thanks largely to the work of Rachel Carson in popularizing the ecosystemic effects of chemical pesticides and to the way in which fallout from atmospheric nuclear weapons testing had familiarized the American public with food chains. Computer modeling for predicting the weather, the outcomes of elections, and the public health effects of this or that pollutant also contributed to educating the public about the ecological and cybernetic concepts that underlay what is now generally accepted as the explanation for the sardine failure, first published in 1966.

Also coloring the debate over the sardine collapse in the mid-1960s was an industry campaign to open the state's anchovy fishery to commercial harvest (McEvoy 1986). The anchovy had apparently grown abundant as it filled the ecological niche left vacant by the depleted sardine (Murphy 1966). The industry argued that the state could promote the eventual recovery of the more valuable sardine by allowing it to fish down the anchovy population. At this point, one important scientist wrote to a friend in the industry that the time had come to switch sides on the sardine issue: not only would that open up the anchovy fishery, but, in his words, "the sardine case is beginning to look too sound to me for us to either hide from the public or to escape the conclusions of." This statement was only partly about the scientist's knowledge of the world; the scientific judgment here was primarily an assessment of the political consequences of admitting the truth of one or the other position in a scientific debate. An end to the sardine controversy was made possible by some absolute advance in the scientific knowledge about the fishery, but the legal cognizability of that knowledge was a political function. In the event, the pro-development scientists traded a moratorium on sardine fishing for an experimental anchovy fishery; so enthusiastic was the legislature for this new approach to fisheries management that it enacted similar moratoria on a number of other depleted fisheries without any real scientific basis for doing so.

Conclusion

Our scientific knowledge of the world, then, emerges out of a complex interaction between ecology, economic production, and the legal system. What "science" is, then, is a struggle among those who do research and between researchers and those who put their findings to work over what will count as "reality." Lawmaking, in turn, consists of a struggle between people wanting to allocate access to resources in particular ways, whether to commercial use, recreational use, or for "natural" uses. Production, for its part, is a complicated function of technology, the sociology of user groups, the structure of legal entitlements to access, and the availability of resources. Nature is, finally, at any point to no small degree the product of past and present human impacts on it, which impacts in turn are determined in no small way by the sociology and the legal structure of the market.

As Muir had it, everything is connected to everything else. Historically, fishery managers have made trouble for themselves when they have assumed, usually unconsciously, that this statement is not true. Although theory and technology of fisheries management have advanced a great deal since the late nineteenth century, some of these conceptual divisions between lawmaking and the private market, between science and politics, and so on persist, usually in ways of which scientists and lawmakers are not even aware. Those assumptions are, indeed, so powerful precisely because they are made instinctively, unthinkingly. Their unseen power is all the more reason why fisheries managers should be careful to watch out for them when they ask themselves such questions as, "What exactly are we trying to sustain here?"

To conclude, one way of answering the organizing question for the symposium is to say that, to the extent that fisheries managers approach their task as if they were trying to maintain sustainable yields of guppies from a well-maintained aquarium, they are doing it wrong. Coming up with a better way of thinking about the problem is hard because all the dualisms that underlie our traditional thinking about the world, between culture and nature and law and markets and so on, are so deeply embedded in our culture and our legal system that it is sometimes hard to tell when they are at work in our thinking. Some lessons, however, may be worth taking away from this excursion into the history of California's fisheries.

At a minimum, mathematical certainty about the state of the resources, or about the likely effects of whatever regulations a government might actually impose on a fishery, is simply not attainable. This lack of certainty is partly because of the important role that random shocks play in the environment and should play in our thinking about it. It is also because of the sheer complexity of the tripartite system of ecology, production, and management, in which we are inextricably embedded; our knowledge of the system will always be imperfect because we will change it every time we act in it.

Another thing that may be said is that traditional strategies for management, insofar as they assume any of these dualisms, are likely as not to raise as many new problems as old ones that they solve. Public agencies will of course have to do a certain amount of prospecting work, and they will always have to balance competing claims for access to resources. But they should never delude themselves into thinking that all of that, even taken together, is "management" in the way that it really should be approached.

Finally, what we ought to sustain when we approach fisheries management is not the size of a particular stock nor even the prosperity of a particular harvesting group over the near or long term. Rather, the most important target is the long-term health of the interaction between nature, the economy, and the legal system. We can recognize that diversity and balance in the system, insurance against an uncertain future, the social cohesion of user groups, the attachment that fishers feel for their work, even the moral unease we feel when we contemplate the extinction of a species, all those difficult-to-quantify things do in fact play integral roles in the tripartite interaction between ecology, production, and management, and perhaps more significant ones than the more "objective" measures to which we usually look for guidance. We can recognize that, because everything is connected to everything else, every step we take will change the system in which we live in some way. When we make choices, then, we can keep an eye on what kind of interactive relation we want to maintain with the rest of Creation and make our choices accordingly.

References

Acheson, J.M. 1975. The lobster fiefs: economic and ecological effects of territoriality in the Maine lobster industry. Human Ecology. 3: 183-207.

Berkes, F. 1977. Fishery resource use in a subarctic Indian community. Human Ecology. 5: 289-307.

California Fish and Game Commission. 1900. Annual report. [Location of publisher unknown].

Cane, M.A. 1983. Oceanographic events during El Niño. Science. 222: 1189-1195.

Cayan, D.R. 1980. Regimes and events in recent climatic variables. CalCOFI Reports. 21: 90-101.

Cheung, S.N.S. 1970. The structure of a contract and the theory of a non-exclusive resource. Journal of Law and Economics.13: 49-70.

Christy, F.R.; Scott, A. 1965. The common wealth in ocean fisheries: some problems of growth and economic allocation. Baltimore: Johns Hopkins Press.

Clark, F.N. 1939. Can the supply of sardines be maintained in California waters? California Fish and Game. 25: 172-176.

Clark, F.N.; Marr, J.C. 1955. Population dynamics of the Pacific sardine. CalCOFI Progress Report. 4: 12-48.

Clark, W.G. 1977. Lessons of the Peruvian anchoveta fishery. CalCOFI Reports.19: 57-63.

Croker, R.N. 1954. Loss of California's sardine fishery may become permanent. Outdoor California. 15(1): 1-8.

Crutchfield, J.A.; Pontecorvo, G. 1969. The Pacific salmon fisheries: A study of irrational conservation. Baltimore: Johns Hopkins Press.

Dana, R.H. 1841. Two years before the mast. Reprint. New York: New American Library.

Dodds, G.B. 1959. The salmon king of Oregon: R.D. Hume and the Pacific fisheries. Chapel Hill: University of North Carolina Press.

Elton, C.S. 1958. The ecology of invasions by animals and plants. London: Methuen.

Goode, G.B. 1887. The fisheries and fishery industries of the United States. Tenth census, Washington, DC.

Hardin, G. 1968. The tragedy of the commons. Science. 162: 1243-1248.

Hubbs, C.L. 1948. Changes in the fish fauna of western North America correlated with changes in ocean temperature. Journal of Marine Research. 7: 459-482.

Hurst, J.W. 1982. Law and markets in United States history: Different modes of bargaining among interests. Madison: University of Wisconsin Press.

Larkin, P.A. 1979. Maybe you can't get there from here: a foreshortened history of research in relation to management of Pacific salmon. Journal of the Fisheries Research Board of Canada. 36: 98-106.

MacCall, A.D. 1979. Population estimates for the waning years of the Pacific sardine fishery. CalCOFI Reports. 20: 72-82.

McAdie, A.G. 1903. Climatology of California. Weather Bureau Bull. [Location of publisher unknown]: U.S. Department of Agriculture.

McEvoy, A.F. 1986. The fisherman's problem: ecology and law in the California fisheries, 1850-1980. New York: Cambridge University Press.

McEvoy, A.F. 1988. Toward an interactive theory of nature and culture: ecology, production, and cognition in the California fishing industry. In: Worster, D., ed. The ends of the earth: new directions in environmental history. New York: Cambridge University Press. 289-305.

McGoodwin, J.R. 1990. Crisis in the world's fisheries: people, problems, and policies. Stanford, CA: Stanford University Press.

Merchant, C. 1989. Ecological revolutions: nature, science and gender in New England. Chapel Hill: University of North Carolina Press.

Murphy, G.I. 1966. Population biology of the Pacific sardine *(Sardinops caerulea)*. Proceedings of the California Academy of Sciences, 4th series, 34.

Paulik, G.J. 1971. Anchovies, birds, and fishermen in the Peru current. In: Murdock, W.W., ed. Environment: resources, pollution, and society. Stamford, CT: Sinaur: 156-185.

Radovich, J. 1961. Relationships of some marine organisms of the northeast Pacific to water temperatures, particularly during 1957 through 1959. Fish Bull. 112. [Location of publisher unknown]: California Department of Fish and Game.

Smith, H.M. 1895. A review of the history and results of attempts to acclimatize fish and other water animals in the Pacific states. U.S. Fish Comm. Bull. 15. [Location of publisher unknown].

Smith, P.E. 1978. Biological effects of ocean variability: time and space scales of biological response. Rapports et Proces-Verbaux des Reunions, Conseil International pour l'Exploration de la Mar (Denmark). 173: 117-127.

Smith, P.E. 1985. Year-class strength and survival of 0-group clupeoids. Canadian Journal of Fisheries and Aquatic Sciences. 42: 69-82.

Smith, P.E.; Lasker, R. 1978. Position of larval fish in an ecosystem. Rapports et Proces-Verbaux des Reunions, Conseil International pour l'Exploration de la Mar (Denmark). p. 77-84.

Soutar, A.; Isaacs, J.D. 1974. Abundance of pelagic fish during the 19th and 20th centuries as recorded in anaerobic sediments off the Californias. Fishery Bulletin U.S. 72: 257-273.

Teale, E.W., ed. 1975. The wilderness world of John Muir. New York: Houghton-Mifflin.

Thompson, W.F. 1919. The scientific investigations of marine fisheries as related to the work of the Fish and Game Commission in southern California. Fish Bull. 2. [Location of publisher unknown]: California Fish and Game Commission .

[USFC 1888]. U.S. Fish Commission. 1888. Annual report. [Location of publisher unknown].

Wagner, H.R. 1928. Spanish voyages to the Northwest coast in the sixteenth century, Chapter XI—Father Antonio de la Ascenscion's account of Vizcaino's voyage. California Historical Society Quarterly. 7: 295-394.