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Management, Adaptation and Large-Scale Environmental Change

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MANAGEMENT, ADAPTATION AND LARGE-SCALE ENVIRONMENTAL CHANGE

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INTRODUCTION

Fisheries have long been agents of ecological change, often altering ocean environments to their own disadvantage. McGoodwin (1990) cites examples of overharvesting by maritime cultures ranging from the Pleistocene era through pre-Columbian America to the present, concluding that "modern examples of overfishing are so numerous as to be pattern rather than anecdote." Data from the Food and Agriculture Organization (FAO) of the United Nations indicate that most of the world's fisheries are presently exploited at or beyond their sustainable limits, with catches recently declining in 13 of the 15 principal marine fishing regions (Weber 1994). Pauly and Christensen (1995) estimate that a surprisingly high fraction of the oceans' primary production (24−35% on continental shelves) is currently being removed by fisheries, a clearly nonsustainable practice that is driving ocean ecosystems towards a composition "increasingly dominated by lower trophic levels" (Beddington 1995:213).

The social mechanisms of formal or informal fisheries management can, in principle, control fishing so that it does not overshoot sustainable limits and collapse. In practice, such control proves difficult to achieve. Fisheries are complex and dynamic systems of interaction between humans and their biophysical environment. Understanding or managing such systems *as a whole* presents great challenges, and is rarely if ever attempted. Instead, we deal with more tractable but isolated parts of a fisheries system. The results have been poor, as fisheries crises attest. In these crises, we often see that management did not work as planned.

Catching too many fish of course depletes targeted fish populations — the most common scenario for fishery decline. Less obviously, fisheries affect the food web and predator-prey relations, and may physically disrupt seafloor habitat. Oceans are naturally dynamic anyway, however, and human activities outside of the fisheries add new sources of change including habitat loss, contamination and greenhouse gases. Fishing pressure interacts with other environmental conditions in determining fish populations. Fishers' actions do not always deserve full blame if a fishery declines, or full credit if it does not.

Management decisions may have unintended social as well as environmental consequences. The particular form of fishing restrictions (on licenses, quotas, species, gear, seasons, areas...) affect different fishers in different ways, so that any change creates winners and losers. This prospect often affects what restrictions get adopted in the first place. Furthermore, fishers can respond to restrictions not just by compliance, but also by leaving, shifting to new economic activities, cheating or exerting political-legal pressures to ease the restrictions. The social consequences of management decisions sometimes undercut their primary goals. Social scientists have rightly argued for the need to consider social variables, but they sometimes then commit the opposite mistake by losing sight of fisheries' biophysical aspects.

To keep various aspects of a system "in sight" requires an image of what it looks like. In this paper we propose a simple model for a fishery system. The model is not intended to be definitive or complete, but does help to integrate discussion of selected fisheries issues. Specific propositions from the model, and directions for future research, are illustrated using examples from northwest Atlantic fishing communities.

A FISHERY SYSTEM MODEL

Where need and technology are sufficient, uncontrolled fisheries tend to consume resources in a pattern of serial depletion: exhaust the most accessible or valuable stocks first, then move to the next stock, and so on. **Figure 1** illustrates with data on 20th-century whaling. Other whale species had been substantially reduced in earlier centuries, but populations of fast-swimming rorqual whales remained relatively intact. The advent of faster ships and harpoon guns allowed steep reductions in populations of blue whales, fin whales and sei whales, in that order. Whaling paused for World War II, and since 1946 has faced increasing restrictions from the International Whaling Commission, culminating in a partly effective moratorium as of 1986.

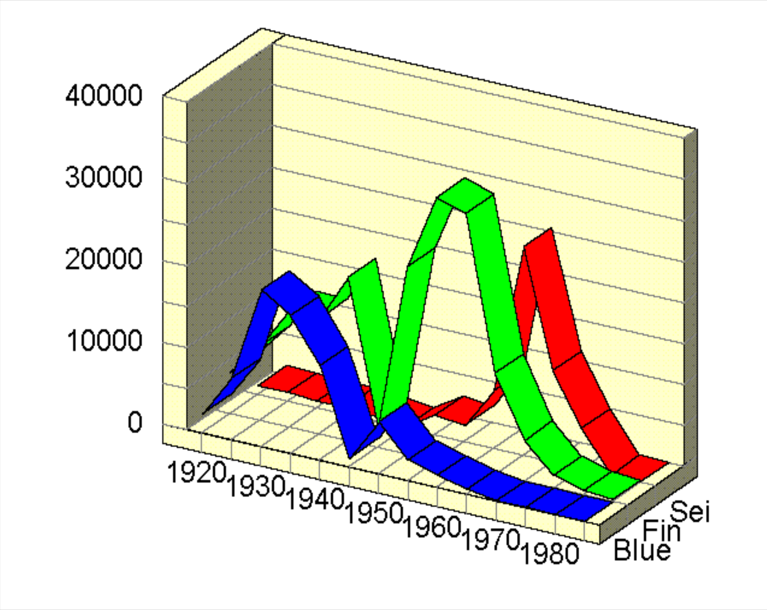

Figure 1: Serial depletion of rorqual whales, 1920–1985.

A popular view of whales as special creatures deserving protection helped motivate the IWC moratorium, but marine fish and invertebrates lack similar appeal. To avoid serial depletion and fishery collapse, we count on management. **Figure 2** outlines fisheries management as a simple feedback system having four endogenous variables:

Fish catch — the actual quantity of fish caught, both landed and thrown away.
Fish stock — the actual, but unknown, size of the fish population of interest.

Stock estimate — what participants, scientists or decision makers perceive about the size of that fish population.

Restrictions on catch — *formal or informal* social controls intended to limit the amount fishers catch.

These variables are connected by arrows indicating causality. For example, fish stock is positively (+) related to stock estimate: the larger the population, the larger the estimate should be. But stock estimates are also affected by other factors, exogenous to this model but represented by the arrow from Uestimate. Uestimate includes such things as the adequacy of the data and model upon which estimates are based, the assumptions of people making the estimates, and perhaps any external pressures favoring higher or lower estimates. Stock estimates in turn affect restrictions on catch, but negatively (−): the higher the stock estimate, the more lenient restrictions are likely to be.

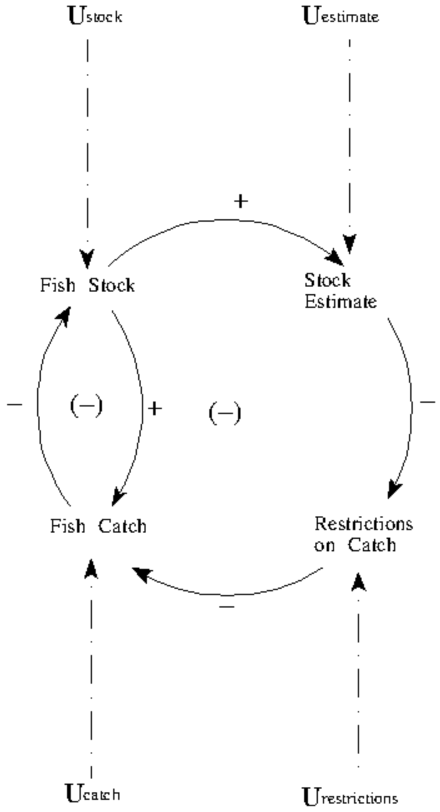

Figure 2: Fisheries management as a simple feedback system.

Two negative feedback loops appear in Figure 2. A negative loop occurs when the sequence of arrows from one variable back to itself includes an odd number of negative paths. Negative feedback is self-limiting because a change in one variable sets in motion other events that eventually change that first variable in the opposite direction. For example, suppose the fish stock declines due to natural reasons or overfishing. An accurate stock estimate would then decrease too, motivating stronger restrictions on the fish catch. If fishers comply with these restriction, their catch decreases, allowing the fish stock to increase — reversing its earlier decline. This loop describes the principle of fisheries management, whether it is self-regulation based on folk knowledge or government management based on science.

But we know that in practice, management may not succeed. The “unintended consequences” mentioned earlier, and relegated to the exogenous U terms in Figure 2, must include relationships that defeat the simple self-limiting loop. To make our model more realistic, we need to specify further variables and linkages. **Figure 3** takes a step in this direction by elaborating several aspects of the system.

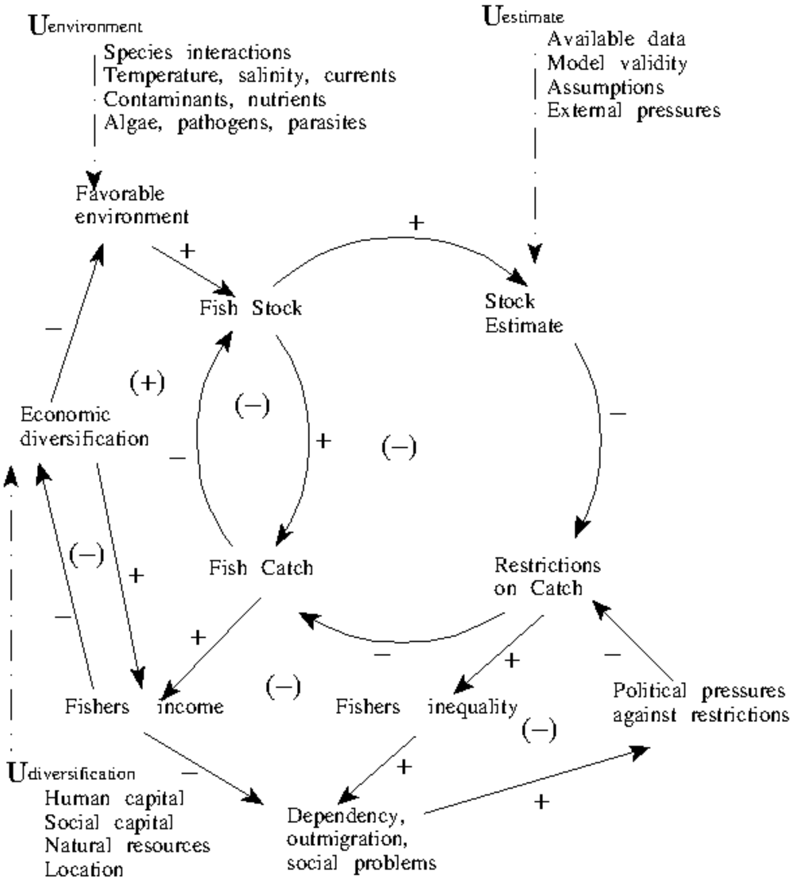

Figure 3: A fishery system including social variables.

U terms are still needed for every variable in Figure 3, since nothing is completely determined within this system. To avoid crowding, however, only three U terms are drawn. We also list a few things those U terms might encompass. Other changes from Figure 2 include the addition of a subsystem involving the social consequences of declining fish catch (bottom), which feed back into fishing restrictions; and another for the environmental consequences of economic diversification (left side), which feed back into fish stocks.

Further elaborations could be proposed, such as distinguishing between alternative management strategies (e.g. traditional, co-management, or “top-down”) that may achieve different rates of compliance; alternative economic diversification strategies, some of which do not harm the environment; or more realistic models including multiple fish species and human communities. E_{catch} could be elaborated by specifying other influences such as fishery product market values, excess catching/processing capacity, governments’ need for foreign exchange, or fishing’s role as “employer of last resort.” A sociologist of science might conceive a subsystem for the process generating stock estimates, to replace $U_{estimate}$ in Figure 3. $U_{environment}$ represents linkages between fishery systems and the global environment, for which system models already exist.

Although incomplete, Figure 3 encompasses many of the topics discussed in this volume, and outlines some interconnections between them. This model helps to frame thinking about the unintended consequences of management change, or about other systems implications of findings from more narrowly focused research.

STOCK ESTIMATION

As Figures 2−3 assert, management decisions depend not directly on fish stocks but rather on perceptions of fish stocks, provided by scientists who study the signs and/or by fishers who note changing abundances in their nets. Calculations of maximum sustainable yield (MSY, in principle an ecosystem parameter), maximum employment, optimum yield (more vaguely defined, but taking into account social and economic needs) or other numerical targets may follow from these estimates, and contribute to the setting of catch restrictions. Any estimates inevitably contain some error, however, and even the best estimates may be ignored in management decisions. Either wrong estimates (attenuating the fish stock−stock estimate path) or ignored estimates (attenuating the stock estimate−restrictions on catch path) can weaken the negative feedback loop that effective management presumes.

Stock estimates failed spectacularly in the case of Newfoundland, a story told from a sociology-of-science perspective by Finlayson (1994). Following years of fishing based on estimates that turned out to be overly optimistic, the major fisheries collapsed in 1992 and have not yet recovered (**Figure 4**). More accurate estimates were ignored in New England, where cod and other stocks declined over this period as well (Collins 1994). As cod and haddock disappeared from New England waters, their ecological niche was taken over by unwanted “trash” species — dogfish and skates (**Figure 5**). The new dominant species may now suppress the recovery of cod and haddock. Both the Newfoundland and New England stories illustrate an important point: disturbed ecosystems do not necessarily rebound to their previous state, once the disturbing pressures (e.g., fishing) have eased.

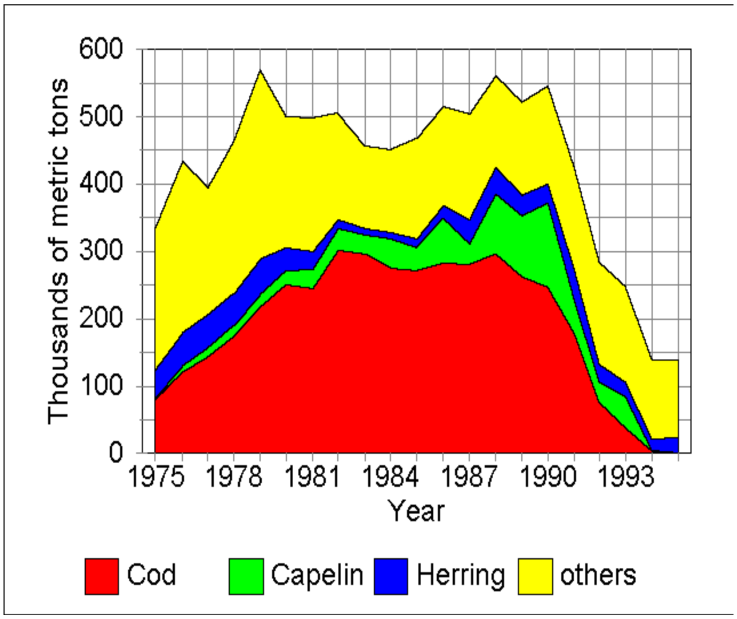

Figure 4: The collapse of major Newfoundland fisheries, 1975−1994.

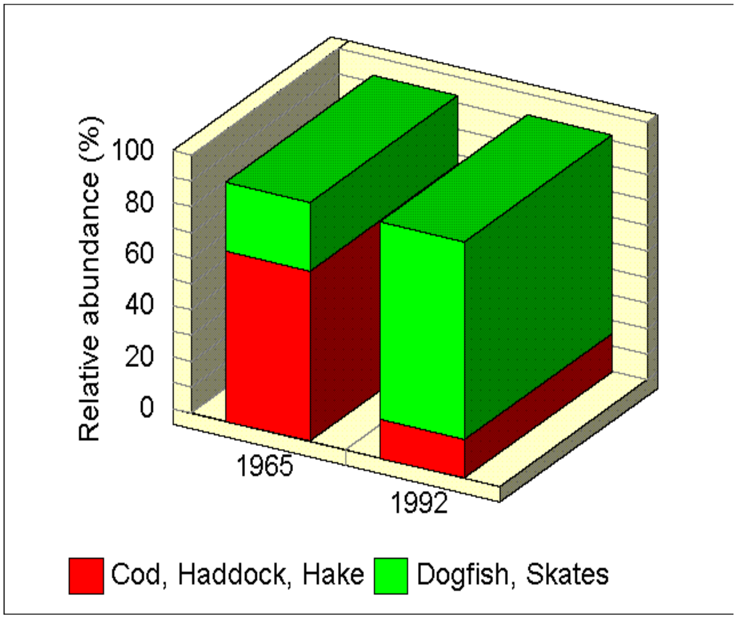

Figure 5: Ecological replacement of New England groundfish, 1965−1992.

Ecosystem dynamics make accurate prediction difficult in any event. Gomes (1993:167), experimenting with computer models of Grand Banks food webs, concludes that due to incomplete knowledge and unpredictable ecological events, long-term predictions are “highly sensitive to initial conditions...rendering the behavior of the community to a large extent indeterminate.” Sensitivity to initial conditions and unpredictable outcomes also characterize chaotic systems, an insight with some appeal to those frustrated with fisheries prediction. Wilson et al. (1994) suggest shifting management efforts from controlling the numerical abundance of various species, where variation appears chaotic, to more stable habitat and biological-process parameters (also see rejoinder by Fogarty 1995).

Numerical forecasting models depend upon the quality of data inputs. One readily available source, commercial catch reports, tends to systematically understate bycatch and discards, so that forecasters relying on them may start out with incorrect estimates of fishing mortality and age structure (Alverson et al. 1994). More expensive scientific surveys obtain less biased data, although they remain subject to sampling errors and controversy.

Attempts to control marine fish stocks tend to focus mainly on the activities of fishermen. Certainly their catch is a key variable, and must be addressed directly. Fish populations also respond to other variables, however. Fisheries management efforts, as presently conceived, have no way to address broader environmental problems that happen to affect fish. Indeed there exist few if any national or international management structures for atmosphere/watershed/ocean ecosystems.

LINKS TO LARGE-SCALE ENVIRONMENTAL CHANGE

Fish populations vary for many reasons besides the fish catch. General environmental conditions can cause population decline to continue, even as fishing is halted or reduced. Furthermore, the effects of fishing pressure may be much different under relatively favorable and unfavorable environmental conditions. Environmental change disrupts the feedback loop of fisheries management by weakening the path from fish catch to fish stock, and by requiring a difficult fast response in stock estimates and catch restrictions.

Variations in water temperature, salinity and currents naturally affect marine life. Cod, for example, cannot long survive in water below 2° C. Newfoundland’s codfish collapse in 1992 followed decades of overfishing, but it also coincided with an unusual spread of the 0° C core of the Labrador Current. This cold-water intrusion both stressed and concentrated the remaining fish, making it easier for trawlers to catch a dangerously large fraction of the remaining stock (Martin 1995). Historical records provide other instances of climate/ocean changes affecting fisheries. Cod were common off southwest Greenland at the time of the Norse settlements, but vanished in subsequent centuries as the climate cooled. Other Atlantic cod fisheries failed in the 17th−19th centuries during the “Little Ice Age,” including that of the Faeroe Islands (1625, 1629 and for some years after 1675), Norway (1695 and after) and Iceland (especially 1685−1704 and 1744−1759). During warmer periods, cod expanded their range northwards, as they did up the west coast of Greenland after 1917. The same warming also pushed seal populations farther north, reducing their availability to Inuit settlements. As an economic alternative to seal hunting, the Danish government established a commercial cod fishery. After 1950, however, west Greenland waters cooled again and the northern limit for cod moved southward (Grove 1988). Today Greenland’s cash economy depends heavily on shrimp, making the cod-oriented settlement pattern problematic. In the central North Atlantic, changing abundances of cod and salmon over the past decade have been linked to changes in water temperature, salinity and wind/current conditions (GLOBEC 1993; Flanders, Hamilton and Duncan 1995; Friedland et al. 1993; Friedland 1995).

The atmospheric buildup of greenhouse gases and other industrial effluents is increasing the likelihood of large-scale climate change. Current models predict increases in the global average air temperature on the order of 1 or 2°C, but for specific geographical regions — particularly at high latitudes — changes could be more drastic (Houghton, Callender and Varney 1992). Circulation throughout the world's oceans is driven by the sinking and deep southward flow of cold, high-salinity water in the northern Atlantic. A rise in polar temperatures will melt ice, increasing the flow of fresh water into the Arctic Ocean. This could decrease the salinity of northern Atlantic surface waters, and thereby disrupt the "ocean conveyor" that controls our present climate. Since this conveyor system includes the warmer north-flowing surface currents that keep Europe's climate temperate, global warming might in fact produce radical cooling in the eastern North Atlantic (Broecker 1995).

Ocean-atmosphere models have suggested that by interfering with Atlantic thermohaline circulation, relatively small changes in temperature could lead to large climatic changes over just a few years (Rahmstorf 1995). Data from glacier and marine sediment cores indicate that such rapid and large-magnitude climate shifts have in fact occurred repeatedly in the past. **Figure 6** graphs an index of "polar circulation intensity" derived from Greenland ice cores (GISP−2), covering the past 20,000 years. It shows the climate changing not gradually, but with periods of wild variation (an order of magnitude greater than any historically experienced) and abrupt shifts from one state to another. For example, we see the end of the last glacial period (about 15,000 years before present), and a subsequent event called the Younger Dryas (about 13,000 ybp) during which climate returned to near-glacial conditions (Mayewski et al. 1994). The onset of the Younger Dryas took less than two years. Recent data from Antarctic ice cores have confirmed the Younger Dryas' rapid onset and worldwide scale (Mayewski et al. 1996). Sudden fresh-water intrusions into northern seas, changing the Atlantic conveyor and worldwide circulation patterns, appear to be the immediate cause of such rapid climate shifts (Broecker 1995; Manabe 1995).

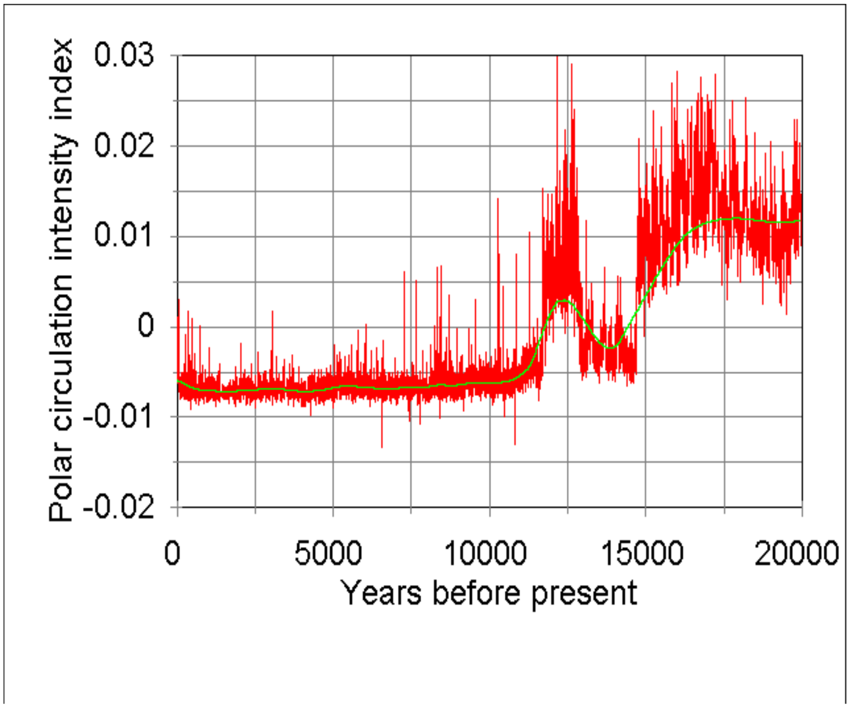

Figure 6: Changes in polar circulation intensity over the last 20,000 years, inferred from Greenland ice core (GISP-2) samples.

Some efforts have been made to envision the agricultural consequences of global change, focusing on an expected gradual rise in temperature and sea level (e.g., Chen and Kate 1995). Comparable efforts regarding fisheries are still at an early stage (e.g. GLOBEC 1993; Beamish 1995). Fisheries consequences seem likely to be severe, partly because much fishing takes place at high latitudes where climate changes are amplified, and where key species are near their environmental limits already. Even at lower latitudes the changes could be ecologically massive, as suggested by recent reports of a 70% reduction in zooplankton following a 1.5°C warming in the California Current (Roemmich and McGowan 1995a, 1995b). Moreover, we now understand that climate change involves not just temperature change but also basic shifts in ocean/atmosphere circulation — changing temperature, sea level, winds, currents, oxygen and nutrients in the water, wave height, ice and the frequency of extreme weather. If such changes seem too large and too unpredictable to plan for, they also make fisheries-dependent regions direct stakeholders with respect to worldwide emissions of greenhouse gases. Their vulnerability might be compared with that of low-lying and small island nations, where governments have become outspoken international advocates for greenhouse gas reductions.

Greenhouse gases are only one of many ways in which large-scale environmental change, originating beyond the scope of fisheries management, threatens to impact fisheries. Other examples affecting marine food chains or life cycles include ozone depletion; long-range transport of airborne pollutants; water-borne contamination from agricultural, urban and industrial runoff; and the loss of rivers, wetlands, mangrove swamps, reefs and other near-shore habitats due to exploitation or development. Microbiological changes present another area of human impact. Examples include nutrient-encouraged algae blooms and spread of pathogens affecting mollusks, fish, marine mammals and humans (Garrett 1994). As with climate change, the causes of these environmental changes may be distant from the fisheries, but fishing communities will bear their consequences and so have an interest in the larger environmental debates.

ENVIRONMENTAL FEEDBACKS FROM ECONOMIC DIVERSIFICATION

Declining income from fishing stimulates the search for economic alternatives. Successful diversification can boost incomes again, but sometimes with the result of further environmental change detrimental to fish stocks. This creates the only positive (+) or self-amplifying loop in Figure 3, a route by which fisheries decline can accelerate. (Truly “sustainable development,” often mentioned as a goal for fishing communities, would not have this dynamic and could appear as a separate negative-feedback loop in Figure 3.) When economic diversification is pursued with a sense of urgency, environmental consequences seem of secondary importance. Fishing communities seeking economic diversification face a range of choices, but three possibilities usually head their list: underutilized species, aquaculture and tourism.

The most immediate targets for diversification, since they require the least change, have usually been “underutilized species”: previously unwanted marine resources that can be harvested once the preferred stocks are gone. This may just involve shifting from higher-value fish such as flounder and cod, to lower-value fish such as herring or capelin. With a less valuable catch, however, more biomass must be removed to earn the same income. Experience has shown that vertebrates such as sharks, marine mammals and seabirds that have low reproductive rates can be reduced quickly under commercial exploitation. On the other hand, stocks of invertebrates such as crab, shrimp or squid, with their comparatively high reproduction rates, may survive longer despite heavy fishing mortality. Whether fishing pressure moves to lower or higher trophic levels, the newly-targeted species will decline too unless the basic problems underlying the collapse of earlier stocks have been solved. Moreover, depleting any species can have unexpected ecological effects due to predator-prey interactions.

Fishing communities sometimes exist near sites suitable for aquaculture. Where it succeeds, aquaculture can generate income and provide new livelihoods with some resemblance to fishing, but it has different social and environmental effects. Environmentally, the concentration of many fish in a small area leads to buildup of wastes, which threatens benthic life, water quality and local carrying capacity. Food for the farmed fish typically comes from high-volume capture fishing elsewhere, so that fishery too is part of aquaculture’s environmental footprint. Because crowded fish are susceptible to disease, their food is often mixed with antibiotics, creating a breeding ground for antibiotic-resistant bacteria. Finally, biologists have expressed concern that escaping farmed fish are mixing with wild populations, reducing the latter’s chances to survive.

Aquaculture competes directly with capture fisheries for markets, holding prices down. Lower prices necessitate that more fish, captured or farmed, be extracted per unit of income — another economic and ecosystem feedback. Aquaculture as a mode of production employs fewer people per ton of fish produced, but also requires more constant year-round effort and risky capital investment. The character of the workforce and communities it can support would therefore change, even if the environment did not.

Tourism, the third commonly-named hope for economic diversification, might be organized in ways that have low or high environmental impact. Large-scale development such as shorefront hotels and cruise ships tend to degrade water quality, and construction may displace wetlands and create runoff that has further habitat effects. Smaller-scale tourism, although creating fewer jobs, could more easily be designed for minimal impact. In that case its feedback to the fishery need not be positive (fishery-reducing) as depicted in Figure 3. It might even be negative (fishery-enhancing) because new jobs, if they go to local residents, should draw pressure away from fish stocks. Like aquaculture, a tourist industry will have different labor-force characteristics than fishing. It provides mainly service jobs, and places more value on education including foreign language fluency.

Other avenues for economic diversification vary by location, as does the likelihood of feedbacks affecting fisheries. Industrial development or new resource-extraction industries present major opportunities but also environmental risks. *Fish vs. Oil: Resources and Rural Development in North Atlantic Societies* (House 1987) collects papers on this topic from North Sea and Atlantic Canada. Emissions from industry may contribute to large-scale as well as local environmental change. Like aquaculture and tourism, industrial and large-scale resource development require a different kind of labor force than fisheries and so transform the social environment too.

SOCIAL INFLUENCES ON ECONOMIC DIVERSIFICATION

One author has written, concerning the prospects for economic diversification on Newfoundland's Great Northern Peninsula:

> "Anyone endeavouring to put together a plan for the development of the Peninsula will find little with which to work. The climate is harsh, the landscape rocky and forbidding, the people offer little by way of special skills." (Canadian Institute for Research on Regional Development 1995:93)

His observation highlights the fact that available physical and social resources constrain efforts to broaden the economies of fishing regions. The $E_{diversification}$ term in Figure 3 expresses this idea. "Human capital" refers to skills and education; individuals and communities with higher human capital tend to find more choices available, and their efforts more effective, in adapting to change. In many places, however, fishing communities have comparatively low human capital, making adaptation to environmental or economic change problematic. Other things being equal, we might expect that communities with better-educated populations will find more ways to diversify their economies and adapt to fisheries decline. This testable proposition illustrates one direction for future research: empirically identifying what community characteristics affect the likelihood of sustainable adaptations.

The problems facing those dependent on fisheries, whether at the household level, community level, or national level, are problems that require collective action. Social capital provides one key to the course collective action takes. Coleman (1990) defines social capital as social resources — relationships characterized by trust and commitment — that enhance individuals' development. Recent years have seen a growing appreciation of its role in enhancing human capital and in propelling economic development (Coleman 1990; Duncan 1995; Flora and Flora

1993; Loury 1987; Portes and Sensenbrenner 1993; Putnam 1993). Growth and development are more likely where norms of trust and habits of cooperation exist, and where social institutions are inclusive across social classes. Applied to fisheries, social capital theory suggests several testable propositions:

1. Communities where people families have long-standing habits of cooperation and participation may be better prepared to develop new rules for resource management, be more open to change, and more ready to experiment with new economic activities. They would bring both skills at working together and confidence that they could trust one another to be fair.
2. People in communities where outside forces — such as creditors or distant government bureaucracies — have controlled access to resources and determined "the rules of the game" may be less trusting of one another and of outsiders and "experts." They will be suspicious, and if they have had less experience working together to manage community affairs, they may lack the institutional resources and habits of decision making necessary to develop and carry out alternative strategies.

Independent of most fisheries research, there exists an extensive literature on the problems of boom-bust cycles, human and social capital, dependency and underdevelopment in natural resource dependent communities or NRDCs (e.g. Bunker 1989; Freudenburg 1992; Freudenburg and Gramling 1994, 1995; Johnson and Stallman 1994; Rural Sociological Society Task Force on Persistent Rural Poverty 1993). Recent empirical work in this vein includes a challenge to the "conventional wisdom" by Freudenburg and Gramling (1995), who show that renewable resources can be depleted faster than nonrenewable resources; and that extractive industries often boom and bust without spurring more general economic development.

To what extent do the generalizations from forestry, mining and oil community studies in the NRDC literature apply to fishing communities? Specific examples of such generalizations (from Freudenburg and Gramling 1994; Humphrey 1995) include:

1. Many NRDCs have experienced persistent, long-term poverty. Resource extraction industries did not link to other industries to produce broad economic growth, nor did most of their workers invest in human capital sufficient to insure their prosperity in other industries or locations.
2. There has been a long-term downward trend in employment for NRDC workers, due to shifts from labor-intensive to capital-intensive extraction and processing, global competition among resource providers, and "dematerialization of manufactured goods in advanced industrial countries" (Humphrey 1995:94).
3. Resource-extraction industries' backward and forward linkages (e.g., manufacturing resource-extraction equipment, and processing raw materials into finished products) often form away from the remote geographical locations of the NRDCs themselves. This limits the local benefits that NRDCs derive from their natural-resource industries.

These generalizations about NRDCs appear relevant and testable with respect to fishing-dependent communities.

SOCIAL CONSEQUENCES OF FISHERIES DECLINE

A New England fisherwoman described how declining catches have affected her community:

> "People are getting divorced, and having major money problems. The workers employed by fishermen are hurting. Worse yet, that leaves everyone either selling T-shirts or leaving. A lot of our best and brightest have already booked it [left]. And the remaining best and brightest sit around here at the bar." (Benjamin 1996:B7)

Changes in fish catch have social consequences that feed back into the fisheries system. A catch decline immediately lowers income from fishing, and unless alternative jobs are found this will increase dependency in the community (Benjamin refers to "shaking the government's money tree").

Figure 7 illustrates with data showing a negative correlation between the fish catch value and unemployment in the province of Newfoundland. Unemployment increases as catch value goes down, or decreases as the value goes up. For this analysis, catch values are expressed in constant 1994 dollars. "Relative unemployment" was calculated by subtracting out variation due to changes in the Canadian economy outside of Atlantic Canada. Due to their limited human capital and their "boom and bust" resource economies, fishing communities often have higher rates of dependency on transfer payments, as illustrated again with Newfoundland data in **Figure 8**.

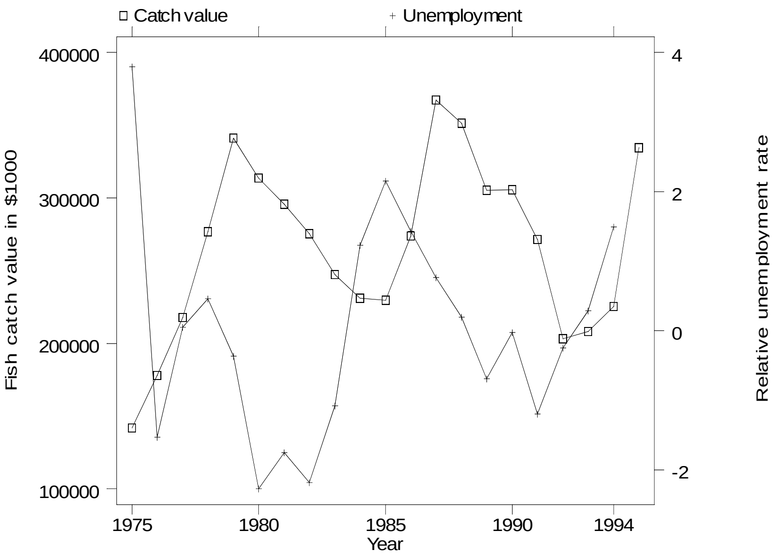

Figure 7: Newfoundland fish catch value and relative unemployment, 1975−1994.

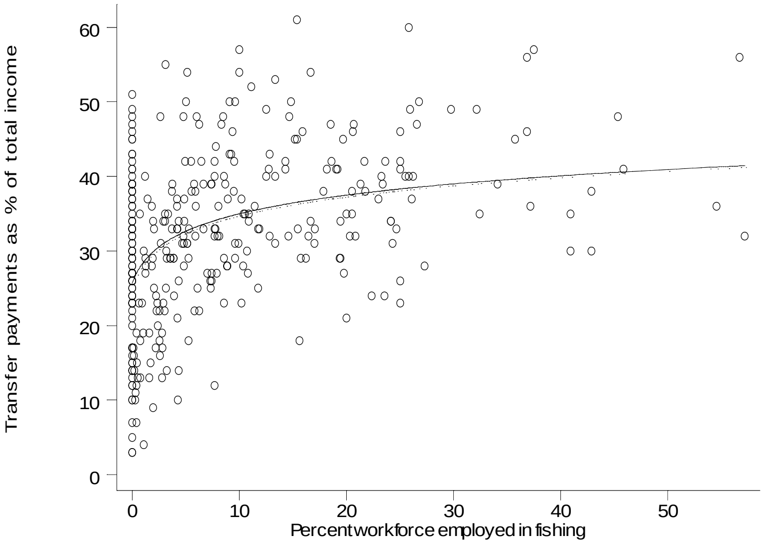

Figure 8: Transfer payments and fishing, 338 Newfoundland communities 1991.

A number of social problems accompany high rates of unemployment and dependency. The affected communities may lose population, as shown for Newfoundland census divisions in Figure 9. Outmigrants tend to include some of the more ambitious young adults, and also a disproportionate number of young women. Thus outmigration can reduce the human capital and increase the male/female ratio in fishing communities (Hamilton and Otterstad, forthcoming), both trends detrimental to their viability.

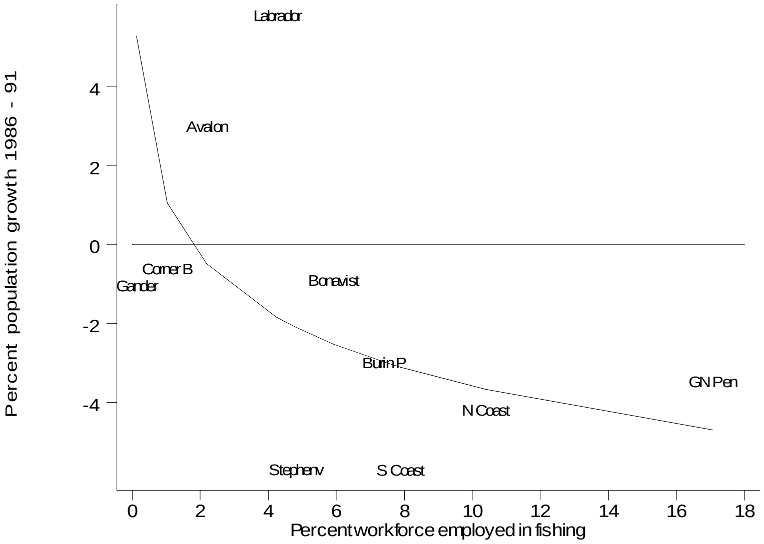

Figure 9: Population change 1986−1991 and fishing employment, 10 Newfoundland census divisions.

Just as individual and community characteristics play a key role in adapting to change, they also help control what changes will occur — including the details of fishing restrictions, government subsidies or mitigation efforts, and new economic developments. A recent thread of discussion, begun by Alan Finlayson (2/6/95) on the FISHFOLK Internet forum, concerned consequences for fishermen of Nova Scotia’s new individual transferable quota (ITQ) system. According to “Finlayson’s Theorem of Winners and Losers in an ITQ System,” the winners will be fishermen who have superior political organization, larger operations, work near the primary ports of the fleet, have completed at least high school, know lawyers and accountants, and can think and plan abstractly. Finlayson’s Theorem suggests that fishermen with the most human and social capital are likely to gain — and their opposites to lose — as the rules of a fishery change. In more general terms, individuals and communities with relationships, institutional mechanisms, and experiences in managing organizations and participating in the public sphere will have advantages in the politics of resource management.

Some fishing restrictions have the unintended effect of increasing the degree of inequality among participants in a fishery. Individual transferable quotas (ITQs), for example, might eventually become concentrated in a small number of hands. Such distributional questions are of interest to social scientists and fishers alike, so research and debate over this issue continues.

Both income loss and the accumulation of social problems exert pressures on fisheries management to ease restrictions on catch. This step completes the two negative feedback loops at bottom in Figure 3, which tend to make catch restrictions self-limiting, and hence less capable of preventing fish population decline. We earlier noted one instance, New England groundfish, where political and economic pressures against restrictions overrode advice based on stock estimates — with the environmental consequences seen in Figure 5, and the social consequences described by Benjamin.

FUTURE RESEARCH

Human and social capital influence efforts to diversify the economy of fishing communities, but they may play a more direct role in solving or perpetuating fisheries crisis as well. Garret Hardin’s 1968 article “The tragedy of the commons” has been embraced by many researchers, while criticized by others as historically and anthropologically wrong (Ostrom 1990; Bailey 1995). It retains power as a metaphor, however, and failed fisheries are routinely termed a “tragedy of the commons.” The “commons dilemma” or “free rider problem” (Olson 1965) provides a succinct economic explanation for why fishermen tend to be poor (Arnason 1994). Various writers including Arnason (1994) and McCay (1995) have considered private-property structures, notably ITQs, as possible legal solutions to commons dilemmas. Less formal communal solutions are also much discussed. Some argue that resource management based on local knowledge is likely to have greater sustainability (cf. McCorkle 1989; Chambers 1990, 1993), but others hypothesize that only communities with relatively high levels of social capital have sufficient legitimacy and sanctioning authority to control individual behavior and avert free riding or selfish depletion of common resources (Coleman 1990; Buenavista et al. 1994). These ideas may guide future research on the requirements for avoiding or adapting to fisheries decline.

The systems model depicted in Figure 3 needs both theoretical and empirical refinement. In any form, such models specify a number of propositions linking fisheries variables, which could be evaluated with appropriate data. Besides confirming the existence or sign of particular relationships, research should give us some estimate of their magnitude. Better information about the existence, sign and magnitude of causal relationships would be valuable in its own right, but would also help link fisheries variables to research on the human dimensions of large-scale environmental change. General models of ocean/atmosphere circulation are presently crude but advancing rapidly, motivated by the need to anticipate if not avert future anthropogenic changes in the planet's climate. Connecting such models to human behavior presents a worthwhile although difficult challenge.

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