Resource Mismanagement Versus Sustainable Livelihoods: The Collapse of the Newfoundland Cod Fishery

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The term "sustainable development" is only half of the gestalt of sustainability, the other being "sustainable livelihoods." The collapse of the Northwest Atlantic cod fishery off the province of Newfoundland, Canada, provides a case study of the interacting biophysical and socioeconomic elements that can decimate a once-abundant natural resource. This collapse has resulted in the devastation of livelihoods, and the long-term impact on the Northwest Atlantic ecosystem remains unknown. This article analyzes the collapse as the first step in suggesting a rational fisheries management based on effective stewardship of the resource. This evaluation provides the knowledge base vital for guiding and improving fisheries policy. Several strategies are suggested to bolster a policy goal of sound conservation and management of fisheries for the benefit of the livelihoods dependent on healthy stocks. The strategies are predicated on the concept that living marine resources belong to complex adaptive systems, and are therefore best managed by decentralized rather than conventional, scientific, and top-down management schemes.

Keywords artisanal fisheries, CPUE, NAFO, chaos, cod, complex systems, EEZ, equity, fisheries policy, indigenous knowledge, Newfoundland, parametric management, straddling stocks, sustainable development, sustainable livelihoods, TAC

"Fishing industry fades, as does a way of life in Newfoundland ports," ran a front-page story in the *Wall Street Journal* in May 1998 (Chipello 1998), encapsulating the reality of resource collapse: the demise of sustainable livelihoods, the often overlooked counterpart to sustainable development. Fortunate to be living in a prosperous nation, Newfoundland fishers have, since 1993, been bailed out by a Canadian federal-level income-support program. Increasingly uncomfortable with the drain on the national treasury, many Canadians are unwilling to continue supporting a way of life widely viewed as a bygone relic. Yet at present Newfoundland has few options beyond a reliance on natural resources, be they fish, timber, or metals. The unemployment rate at 17% is double that of the rest of Canada, prompting a westward migration that has resulted, for the first time in Canadian census records, in a net drop in the province's population.

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Mirroring Newfoundland's upheaval, overexploitation of fisheries elsewhere in the world also results in a flux of environmental refugees. In most developing nations, however, these people go from one poverty-stricken household economy to another. Mostly lacking education and financial resources, households are faced with the choice of either joining the rural-to-urban migration that is so rapidly increasing the population of cities in the developing world, or moving to unoccupied (and often marginal) tracts in the rural hinterlands. In the former case, conditions in overcrowded urban slums are often appalling, and wage labor sporadic or non-existent. In the latter, households may eke out a living by becoming farmers or laborers, but often at the expense of the local environment and biodiversity as land-scapes are converted by the ax, plow, or hoe. In neither case is "sustainable development" a top priority, and often the "development" that takes place is likely to lead to future crises and more environmental refugees.

This article focuses on how the interaction of Newfoundland's biophysical and social elements inexorably acted on the cod fishery to cause its collapse, devastating both livelihoods and the marine ecosystem. I begin, however, by placing this Newfoundland case study into a global context, discussing the widespread reliance on marine fisheries and their overexploitation. For Newfoundland itself, I set the collapse of the cod fishery into its historical context, then proceed to outline how an international incident precipitated a deep sense of crisis in Newfoundland. To understand the biophysical aspects of the fishery's collapse, I offer a brief summary of chaos and complexity in marine ecosystems, and the ramifications of these concepts with respect to decision making. Finally, I recommend several strategies for the future management of fish stocks.

The strategies for the future are applicable worldwide, but with the following caveats. In contrast to Canada, which has since 1977 rigorously regulated its fisheries, most developing nations have few means to assess, implement, and enforce policy within their 200-mile (322-km) exclusive economic zones (EEZs; Peterson and Teal 1986). Also, where fish stocks "straddle" (exist partially in) the EEZs of two or more nations, or one or more nations plus the high seas, actions taken by one nation may affect both the resource and the outcome of its neighbor's plans.

The Global Perspective

By the beginning of the 1990s, almost 70% of the world's conventional fish species were overexploited, fully exploited, or already depleted (FAO 1995), with major ecologic and economic damage already visible. Fish stocks are imperiled from overfishing, pollution, destruction of coral reefs and spawning habitat such as estuaries and wetlands, and human ignorance. Excess fleet capacity and overinvestment stimulate overfishing, undermine fisheries conservation and management efforts, and threaten the sustainability of fisheries in the medium and long term, thereby detracting from the contribution that fisheries can make to food security, especially in developing countries (FAO 1995). Commonly, subsidies offset economic losses, which may reach US$50 billion annually.

As fisheries decline, millions of households around the world will become vulnerable to food insecurity; fish provide 29% of the total animal protein of Asians, 18.6% of Africans, and 7.6% of Latin Americans. Around 1 billion people in Asia rely on fish as their primary source of animal protein (International Agricultural Development 1995). Regardless, sustainable livelihoods rarely factor into scientific assessments of quotas, nor into the calculus of total allowable catch (TAC).

Routinely ignored by politicians, sustainable livelihoods assume importance only when social upheaval erupts, as has occurred in Newfoundland, the island comprising the easternmost of Canada's Atlantic Provinces.

Newfoundland

Since its discovery by Europeans, Newfoundland has been treated as an extractive-reserves colony (Hamilton and Seyfrit 1994). Little changed once the island joined the Dominion of Canada in 1949: It continues to provide natural resources for a modern, developed nation. Fisheries directly or indirectly supported half the population of 600,000. But in August 1993, Canada's federal government placed a total moratorium on catches of Northwest Atlantic cod (*Gadus morhua*), economically the most important of the commercial fish species.

Canada prided itself on applying the world's most-sophisticated, "best" fisheries science to its harvesting regimes. In spite of the likely truth of this statement, the collapse of codfish stocks was the end result of a series of poor management decisions made over a three-decade period coupled with an inadequate understanding of the marine ecosystem.

Rational Management of Codfish Stocks and the *Kristina Logos* Incident

Since cod is a migratory species with a large inshore breeding component, management of the Northwest Atlantic cod fishery exemplifies aspects of cooperation and competition among nations. In the case of the Georges Bank, divided by the boundary between the United States and Canada, the quarrel between the two nations was resolved by the International Court of Justice in 1984 (Gough 1993). Disputes still erupt from time to time, but differences are quickly resolved (Serchuk and Wigley 1992; Schneider 1993; Gough 1993; Facts on File 1994). A 1992 arbitration between Canada and France resolved the long-standing overlapping claim of jurisdiction by France, based on its control of the islands of St. Pierre et Miquelon (SPM; Gough 1993).[1]

On a broader level, the first steps to comprehensively manage the Northwest Atlantic's fish stocks were taken in 1949. While the International Commission for the Northwest Atlantic Fisheries acquired data on fish abundance and location, and established mild restrictions on the total catch, it lacked both the power of enforcement and the political will to take effective measures (Gough 1993; McCay and Finlayson 1996). In 1978, the Northwest Atlantic Fisheries Organization (NAFO) came into being. NAFO manages fisheries beyond the 200-mile limit, coordinating management of migrating and straddling stocks. While NAFO has adopted quotas, conservation measures (such as minimum mesh sizes and by-catch levels), and a scheme of joint international enforcement (Churchill and Lowe 1988), it has no means to cope with nations that willfully overfish (Gough 1993).

In 1994, Canada began policing the high seas. In April, Canadian enforcement officers boarded and seized the *Kristina Logos*, a Portuguese-crewed vessel sailing under a Panamanian flag of convenience, 45 km outside Canada's EEZ. In May, Canada's Parliament formally and unilaterally authorized the seizure and confiscation of any foreign vessel outside Canada's EEZ found to be in violation of NAFO regulations (Weber 1994). In August, Canada seized two U.S. scallop boats (Andrews 1994), precipitating U.S. trade threats.

Canada adopted its policing stance only after cod stocks plummeted by 95% over 4 years (Cox 1994), compelling the Federal Department of Fisheries and Oceans (DFO) to close the cod fishery first to large "dragger" vessels (trawlers that drag their nets along the ocean bottom) in 1992 and to artisanal fishers (small boats operated by one or two fishers using traditional techniques) in 1993. The French overseas territory of St. Pierre et Miquelon, an enclave within Canada's EEZ, was forced to follow suit, idling its three large draggers, though it allowed its 15 or so artisanal fishers to continue fishing for cod.

To comprehend the magnitude of the disappearance of cod, consider that in 1920 dip nets lowered alongside a dory would come up "filled with big, lively codfish" (Roberts 1993). Early explorers of the Newfoundland coast such as John Cabot found fish so plentiful that they could be caught merely by dipping a bucket into the water. For some 400 years, until 1993, people had made their living from the sea. Canada's 1993 total moratorium on cod fishing directly impacted 30,000 livelihoods, with the provincial government estimating indirect effects on 10 times as many.[2] While the fishers and their families are in no danger of starvation, thanks to a generous compensation package, a way of life has ended. There are over 700 coastal communities in Newfoundland, few of which will have any reason to exist over the long term if the fishery does not resume, which it may never do at its former scale (McCay and Finlayson 1996).

Under these conditions, the *Kristina Logos* was an outrageous insult to many Canadians. In the government's view, the ship's crew were modern-day pirates stealing Canadian cod. She was one of scores of foreign vessels operating on the Grand Banks just outside Canada's 200-mile EEZ. Uncontrolled by NAFO because of her Panamanian registry, the *Logos* ignored all the minimum-size rules. The average undressed weight of codfish in her catch (Government of Newfoundland and Labrador 1994a) was 467 g (just over 1 lb), of plaice 351 g (12.4 oz), and of redfish 226 g (8.0 oz). By using small-mesh-size nets, the *Logos* was targeting and catching juvenile fish for the Portuguese market, thereby helping to destroy the fishery and very directly affecting the lives of Newfoundlanders.

Where Did All The Fish Go? Chaos and Complexity in Marine Ecosystems

During the past decade, both the Federal Department of Fisheries and Oceans (DFO) and the Newfoundland Inshore Fisheries Association (NIFA– primarily concerned owners of small inshore-reliant fish-processing plants) commissioned reports investigating DFO's management of the fisheries. NIFA suspected DFO fisheries science of being faulty, and requested a review by faculty at the Memorial University of Newfoundland. The resultant Keats Report (Keats et al. 1986) was bluntly condemnatory of DFO science, and opined that the TAC needed to be reduced immediately. Reaction to the Keats Report was swift and unprecedented. Under heavy political pressure, the Minister of Fisheries commissioned a full-scale review of fisheries science; the Alverson Report (Alverson et al. 1987) was mildly critical of DFO, but essentially agreed with DFO's methods and assessments. But external criticism continued to mount, and the Minister of Fisheries ordered yet another assessment of the state of fisheries science. The Harris Report (Harris 1990) reached quite different conclusions than the Alverson Report; in fact, it magnified the grim outlook of the original Keats Report, and added considerable detail. Harris's 1989 Interim Report, summarily rejected by DFO, had recommended curtailing the TAC by around 50%. Ultimately, even DFO acknowledged reality: In

1992, the first-ever moratorium imposed on the Newfoundland fishery went into effect. In retrospect, the Harris Report was remarkably prescient, for it had predicted the collapse of the cod fishery.

These reports, however, shared a flawed presumption: that stock assessment science is valid. All traditional fisheries management theory assumes predictability (Wilson et al. 1990). But conventional theory has proven inapplicable (Wilson et al. 1994), for it assumes that the resilience of an exploited species is a function of very large reproductive capabilities able to accommodate fishing and other disturbances (Wilson et al. 1996). Conventional "single species" models of recruitment are based on inflexible equations, and presuppose a compensatory effect as a consequence of fishing mortality (Wilson et al. 1994). These models inadequately and inaccurately describe the response of an exploited population.

For multispecies fisheries, such as cod–herring–capelin interactions, circumstances are more complicated. Traditional single-species models have been modified to preserve a balance among the component stocks, allow interactions among species, and account for predator–prey relationships. However, long-term model predictions of community behavior are highly sensitive to biotic and abiotic initial conditions, resulting in a behavior that is largely indeterminate. For example, Gomes's (1993) complex models could not predict 80% of the species interactions for the Grand Banks, where biological surveys show that species composition is relatively persistent in time and space. But whether single-species or multispecies, such models remain myopic.[3]

Recent work in population dynamics modeling suggests that any traditional modeling effort may be ultimately futile. Simulations with a deterministic, age-structured, five-species model indicated the presence of chaos within the system (Wilson et al. 1990). Such chaotic patterns imply that the stock level of an individual species has no equilibrium tendency, but instead varies unpredictably within limits (Wilson et al. 1994). Subsequent simulations by Hastings and Higgins (1994) indicated that: (1) Populations oscillate between cyclic and chaotic behaviors for marine species with pelagic larvae (e.g., cod); (2) on a time scale of 100 to 200 years, neither population dynamics nor spatial distribution was predictable; (3) population dynamics remained unpredictable over a long period after a major disturbance;[4] and (4), continual disturbances may prevent the system from *ever* attaining predictability.

Chaos, however, is just one attribute of marine ecosystems. Yet another departure from conventional theory– complexity– further confounds modeling efforts. Relatively new, complexity theory seeks to predict the general properties of organization across all spatial scales (Waldrop 1993). In brief, complexity theorists contend that the Second Law of Thermodynamics (i.e., entropy is always increasing) fails to predict the tendency of matter to organize itself.

Emergence is the property that organized systems are more than the arithmetical sum of their parts. In ecology, emergence is the proclivity of organisms to cooperate, compete, and coevolve, thereby forming an ecosystem. Further, *connectionism* suggests that sophisticated outcomes can arise from simple nodes that interact. Ecosystems may "learn" and evolve through two possible changes in the connections among nodes: leaving the connections in place, but modifying their relative strengths; and more radically, transforming the connecting network itself– a risky proposition, and most likely irreversible (Waldrop 1993). Evidence suggests that the marine ecosystem off Newfoundland resembles this node-connection model. Northern cod consists of distinct populations with different migratory patterns

(McCay and Finlayson 1996). Cod form migration aggregations and spawning columns, and migrate along "highways" (Rose 1993).

Subsystems can be considered analogous to nodes. Multiple, functionally equivalent subecosystems create redundancy and translate into ecosystem resilience (Wilson et al. 1996). If catastrophic local events destroy one or several subsystems, rebuilding can ensue if and only if the connections to proximate subsystems remain intact. The collapse of northern cod suggests impairment of both nodes and connections. With the transformation of the connecting network for cod, the ecosystem may have "learned" a new state that may be near-irreversible. Evidence from Georges Bank off Maine and Nova Scotia suggests this to be the case (Wilson et al. 1996): Dogfish and skate have replaced other groundfish species, including cod.

But whether marine ecosystems are chaotic and/or complex explains only why conventional scientific methods failed to predict the true state of the fishery. Neither chaos nor complexity accounts for the collapse of the fishery; the crisis is better interpreted by considering the volatile mix of politics, economics, and faulty science that promoted institutional paralysis. In particular, the evolution of technological precision embodied in modern trawler fleets destabilized the system. Subsequently, nearly all parties involved in the fishery operated under a business-as-usual maxim. The net result is that scarcely anybody heeded the warning signs until far too late.

The Interplay Between Policy, Politics, Profits, and Resource

Conflicting explanations of what has caused the collapse of the northern cod stocks can be found and refuted in the literature: excessively cold water (Cox 1994) versus dismissals of this thesis (McCay and Finlayson 1996); removal of larger cod leaving only immature fish "[who] may not know how to be codfish" (Rogers 1994); and depredation by harp and hooded seals, whose populations are estimated to have doubled since the cessation of large-scale sealing in the early 1980s (Crosbie 1992). But such explanations fail to address the inherent biophysical complexity overlain by institutional and political frameworks that even today only inadequately understand complex biological systems and how these can be managed.

What, then, is responsible for the collapse of the cod fishery? Many of the Newfoundlanders I interviewed vented their anger and dismay over the resource collapse and the demise of their livelihood at specific targets: the federal and provincial governments, foreign and Canadian dragger fleets, processing-plant owners, seals. Such finger-pointing is overly simplistic, for it is the interplay between biophysical and social elements, on which I elaborate next, that ultimately led to resource collapse.

Policy: Federal-Level Decision Making

The DFO sets Canadian TAC and sectoral quotas in harmony with the findings of its own and independent scientists.[5] Yet DFO's internal sociopolitical environment assured competitiveness among scientists, and compounded the difficulty of cooperatively obtaining the correct answer– perhaps even of adequately framing the questions. Consequently, DFO acquired a tendency to develop conceptual and operational inertias, which (1) predetermined the collective reality of its members, (2) discouraged rather than supported free and open debate of controversial issues, and (3) inhibited and punished internal dissent and criticism (Finlayson 1994). Bernard Brown, DFO's Information Officer in St. John's, opined that DFO "always made a big deal that our science is the best in the world, or among the best, but what we've learned in the past few years is that our science is abysmal. When you look back from today's perspective, the disappearance of the codfish was inevitable" (personal communication, July 1994). Inevitability was assured when scientists calculated catch-per-unit-effort (CPUE) from unreliable statistics supplied by technology-heavy dragger vessels. Increased search and harvesting efficiencies misled cod biologists, who wrongly believed that growing CPUE indicated an expanding stock (Hilborn and Walters 1992).

Encouraging the widespread use of modern technology was among the gravest errors of DFO, which endorsed a view that better technology leads to greater efficiency (Antler and Faris 1979; House 1988). But technology improperly contained or managed can eventually lead to the demise of a resource precisely because its efficiencies and externalities are unbounded.[6] "The DFO 'line' is using the technology correctly; my response is that we can't seem to figure out how to do that. Technology carries its own dynamic" (Brown, personal communication, July 1994).

Vessel cost is one dynamic of the dragger fleet; a US$1 million price tag is not uncommon for a 65-ft (20-m) longliner, guaranteeing that a great deal of fish must be captured to pay just the interest on the loan. DFO's Assistant Deputy Minister of Science clarified the link between TAC and bank payments as follows (Finlayson 1994): "People's lives are affected by the number that's given for the TAC. And because people's payments on their gear and their boats are fixed– and are dealt with with great certainty by the bank– they are under pressure to have a catch and cash-flow that has equal certainty… . That translates into pressure on this department [DFO] to produce (a) certain numbers, and (b) consistent numbers over a period of time to avoid fluctuations, and (c) *to provide increasing numbers because decreasing numbers are punishing*" [emphasis added]. As long as DFO's annual stock assessments reflected the conventional wisdom of a growing stock (1977–1989), and quotas reflected that growth, few people paused to query whether the data were valid or the modeling/analytical methods robust.

As well as setting TAC and quotas, DFO is charged with issuing fishing licenses in tidal (i.e., marine) waters. In essence, DFO placed no restrictions on entry into the artisanal cod fishery, a policy that increased the number of fishers officially eligible for the moratorium compensation package. Newfoundlanders themselves recognize that the entire fisheries quota system became enmeshed in federal unemployment insurance scams, and many people I spoke with further condemned DFO policies that failed to impose meaningful sanctions on license or quota violators.

Politics: The Ineffectiveness of NAFO

DFO, however, operates only within the confines of Canadian jurisdiction, and is powerless to set or enforce policy in international waters. The 1950s saw the introduction of fleets of freezer-trawlers to the Grand Banks. By the late 1960s, the foreign offshore catch had reached the unprecedented and unsustainable level of 800,000+ tonnes per year. Predictably, stocks collapsed, prompting Canadian leadership in developing the Law of the Sea Convention. The establishment of NAFO in its current form under the provisions of the convention divided the cod fishery in two as of 1977: Inside Canada's EEZ, fisheries management is a Canadian responsibility; outside the Canadian zone, NAFO regulations apply.

By the mid 1980s, NAFO had proven ineffective. Spain and Portugal joined the European Union (EU), but were prevented from deploying their massive longdistance fishing fleets in European waters. To accommodate Spain and Portugal, the EU began to play a disruptive role in NAFO (Government of Newfoundland and Labrador 1994b). Independently, these fleets began to openly disregard NAFO quotas, and also (as with the *Kristina Logos*) started reflagging their vessels in non-NAFO countries to avoid NAFO regulations. Finally, the EU began to blatantly ignore NAFO quotas, establishing its own unilateral quotas by the late 1980s. Between 1986 and 1992, the EU's NAFO quota was set at 136,000 tonnes, but its reported catch exceeded 700,000 tonnes. EU vessels operating under "flags of convenience" additionally caught about 250,000 tonnes. On this basis, the EU catch exceeded its quota by 800,000 tonnes, or almost 600%.

Profits: The Dragger Fleet Decimated the Resource

While foreign dragger fleets were operating in a free-for-all manner off Canadian waters, Canada's response was to join the frenzy. The Canadian dragger fleet was created by the investment of hundreds of millions of taxpayers' dollars (Sinclair 1988; Andersen 1979a). "Greed, short-term profit-taking, a gold-rush mentality and political corruption did the rest" (Myers 1994). Every winter through the 1980s, Canadian draggers sailed to the offshore spawning grounds. Only the biggest fish were kept. "Hundreds of millions of undersized dead and dying fish were ruthlessly dumped overboard in order to maximize corporate profits. It was only when the stock was exhausted that a moratorium was declared" (Myers 1994).

Technology today allows draggers to detect and capture even small aggregations of fish, conferring an ability to vacuum the ocean. But that is not all, for the heavy gear is drawn across the bottom of the ocean, disturbing and damaging the substrate not just for cod but for all groundfish species. There *were* timely warnings of the cod fishery's impending failure issued, but these came from nongovernmental social scientists, not from DFO's fisheries biologists. In 1973, Antler and Faris (1979) warned that decreasing catches from all sources made very apparent the need for stringent restrictions on dragger operations. Andersen (1979a) also forecast the collapse, writing that if a massive interception of cod migrating onshore occurred, then "one may easily imagine the wide ramifications of unrestrained fishing offshore." Some inshore fishers had expressed concern over severe resource depletion as early as the 1960s (McCay 1979).

Political Economy (1): The Provincial Government and Fish-Processing Plants

The provincial government's Department of Fisheries (DOF) has jurisdiction over the issuance of fish-processing plant licenses and the provision of fiscal "incentives" to fishers. As Canada built up its own dragger fleet to exploit its 200-mile EEZ after 1977, the bonanza of fish exceeded the available processing facilities. The provincial government became mesmerized by the promise of industrial jobs in what is still largely an extractive economy. "The harsh reality is that outside the fishery, it's very difficult to create meaningful long-term jobs" (L. Dean, DOF, personal communication, July 1994). DOF therefore welcomed all plans to construct new fish-processing plants, eventually issuing permits for 220. Each crewmember on a trawler generates approximately 10 processing-plant jobs, and each new processing plant in turn generated an increased demand for fish. The promise of new jobs and their actualization generated a feedforward cycle, where the ultimate losers were first the fish, then the very jobs that had once impelled the cycle.

Resource wastage in the name of quick profits was common. "I worked in Catalina [the largest fish-processing plant in Newfoundland] for 11 years. I was told to register fish as flounder when they were cod, sometimes by the foreman of the plant, sometimes by the production manager. This happened a good many times while I was weighmaster. I *know* there was a lot more cod brought in than the [allowed] bycatch. In the mid 1980s, Catalina couldn't handle the inshore fish– they were max'ed out with the draggers. So thousands of pounds of cod were dumped. The government never saw what was going on in the plant" (Alvin Hobbs, fisherman, personal communication, July 1994). Palmer and Sinclair (1996) report other instances of cheating and deliberate misreporting.

The thoughtless disbursement of fish-plant licenses by the provincial government certainly contributed to such waste and abuse. The relationship between the fish-plant operators and the provincial government on the one hand, and the operators and the union on the other, was mutually rewarding. Wealth was broadly and openly peddling its influence.

Political Economy (2): The Fishers' Union

The Fishermen, Food and Allied Workers Union (FFAW) claims to represent all Newfoundland fishers. But over the past 10 to 20 years, according to Bernard Brown at DFO, the union took no political action to deflect the fishery collapse. Rather than focusing on long-term sustainable livelihoods and the sustainability of the fishery itself, it was instead concerned with the short-term income of its wealthier members. For example, the union opposed DFO's proposed increase in the mesh size of cod traps, demanding compensation for income lost by fishers who use this capture method. Only belatedly did the union become involved with resource conservation issues. The union is now committed to conservation and rebuilding of fish stocks, and acknowledges Newfoundland's need for sustainable livelihoods; simultaneously, however, it contends that "there is a tendency in the fishery to over-regulate" (FFAW n.d.).

Perhaps more disturbing is the union's unquestioning acceptance of the provincial government's suggestion that the basis for sharing cod stocks in the future should be the historical allocation between the inshore artisanal sector and the offshore draggers (FFAW n.d.).[7] In terms of sustainable livelihoods, consider the following: The average annual catch for the "outport" (a small, often isolated coastal community adjacent to fishing grounds) of Francois prior to 1990 fluctuated around 500 metric tonnes. A single dragger will return to harbor with 500 metric tonnes after just 3 voyages, each of 10 days or less duration– and the dragger will usually have discarded (and in the process, killed) significant numbers of subsize and "trash" (wrong species) fish. The annual catch in Francois supported 40 households, the equivalent monthly catch of the dragger just 13 households.[8] Influence within FFAW is skewed toward the officers of the draggers and executives of the processing plants. Wealthier than the inshore fishers, they paid larger dues to the union and had greater political clout within both the FFAW and the provincial government. In the milieu of such influence, it is unsurprising that neither the resource nor artisanal livelihoods were well protected.

Political Ecology: The Undervaluation of Traditional Knowledge

Francois's inshore fishers suspected that something was seriously amiss with the cod fishery as early as 1990. On the south coast, where Francois is located, winter and spring were traditionally the most productive seasons. Figure 1 (top) shows that from 1984 to 1989, 53–66% of Francois's total annual catch derived from these two seasons. By 1990, winter and spring provided only 20% of the annual catch. Figure 1 (bottom) shows the magnitude of the collapse in terms of the mass of the catch. These charts depict a radical change in ocean ecology after 1989: The winter fishery had been replaced by a summer fishery.

The weekly data that went into these charts were compiled not by a fisheries official, but by the community's dockside weighmaster. The fishers were very aware of the change in seasonality of the resource. They tried to warn federal and provincial fisheries officials and policymakers that something was awry. There were, however, few if any people prepared to listen to them and take action. Since numeri–

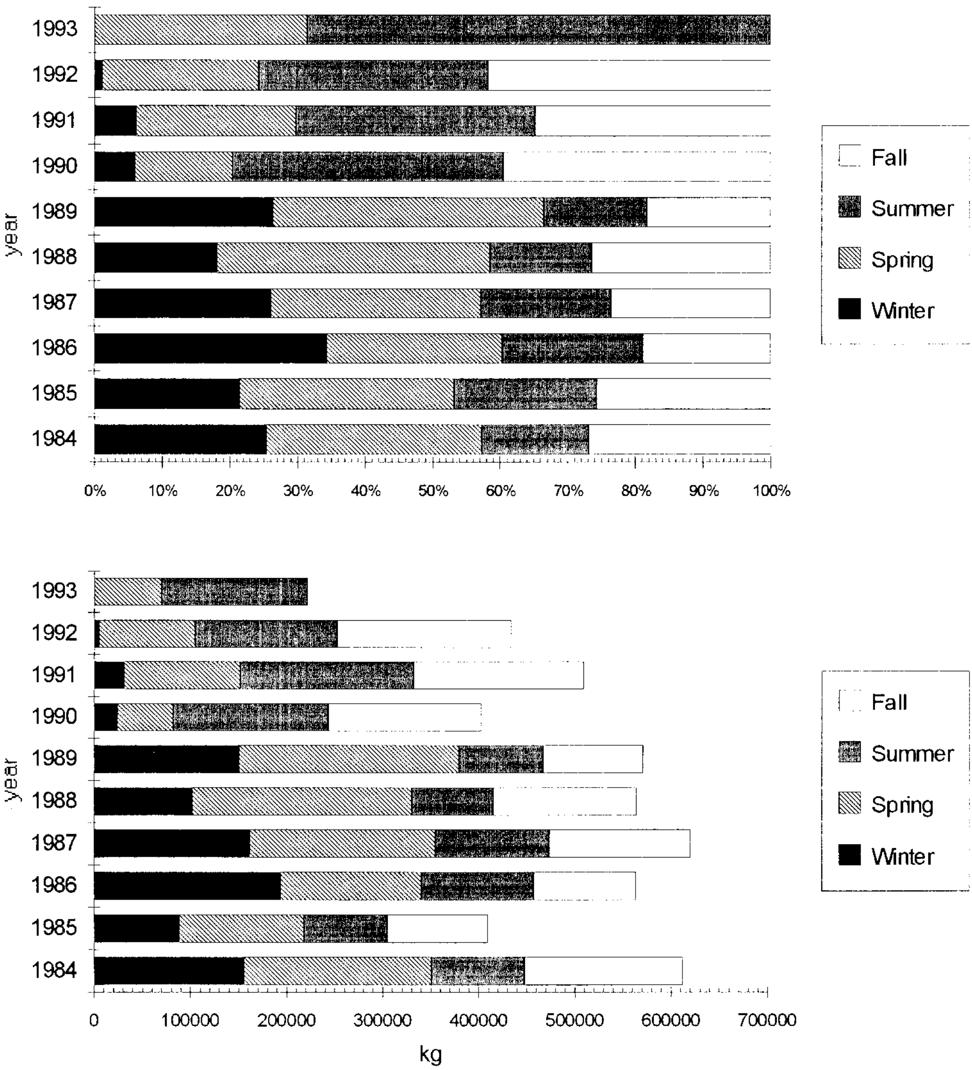

FIGURE 1 Francois, Newfoundland. Top: Percent of annual total of codfish catch sent to fish–processing plant, by season. Bottom: Total codfish sent to fish–processing plant (kg), by season. Source: Ross Fudge, weighmaster, Francois.

cal models showed nothing unduly amiss, scientists derided the fishers' alarm, referring to it as "merely anecdotal." Meanwhile, owners of every boat with a fishing license logged and submitted a weekly summary of activities. DFO was inundated with data on a weekly basis for no organizationally relevant use, for it was institutionally oblivious of weekly catch data. The forms were archived, the data unentered into any database. Only token DFO resources were ever allocated to the logbook program (Finlayson 1994). Data thus existed supporting the thesis that the inshore fishery was in trouble, but scientists and policymakers deemed them irrelevant or too inaccurate to be usable.

The Fisheries Resource: Stewardship Ethics Are Rare Among Artisanal Fishers

Almost every exploitable species of marine life off Newfoundland is under attack, including lumpfish (for roe), capelin (the primary food source for cod), lobster, shrimp, snow crab, turbot, redfish, and halibut. Several species are becoming increasingly difficult to find, especially lumpfish (*Cyclopterus lumpus*), capelin (*Mallotus villosus*), and lobster (*Homarus americanus*).

There are few fishers who do not understand the consequences of their actions, and many who regard the lumpfish fishery as wasteful and ludicrous. Many fishers I spoke with were equally adamant in regard to capelin, calling for a total closure of this fishery. Individual capelin are diminishing in size, and the fish are migrating inshore successively later every year– early indications of a potential problem. Fishers face a conundrum, however, for if they see their neighbors setting out to fish for lumpfish or capelin, they feel a twofold obligation to conform. First, there is a strong work ethic among Newfoundlanders, and it is shameful to be regarded as lazy. Second, in the words of Alvin Hobbs, lumpfisher, "One person goes out, then I have to too, or else the other person gets it all. It's stupid. Only one entity can stop it– DFO."

Reliance on DFO is not necessarily the only way to protect the fisheries. Institutionalizing some form of local common-property management regime among inshore fishers has the potential to be a successful protection strategy. Convincing people to subscribe to such a regime may be difficult, however, because the cult of self-reliance has assumed mythical proportions in Newfoundland (Andersen 1979b; Martin 1979). This intrinsic value of self-determination clashes with the ethos of "work community" needed for managing common-property resources.

Strategies for the Future

Fisheries policy is normally expressed in terms of what is best for society: "wisest/best/optimal use," "greatest benefits," "wise stewardship," or "sound conservation/management" (Sylvia 1992). However, definitions of what is "best," "wisest," or "optimal" are rarely explicitly justified. Management of fisheries has, to date, depended on scientific stock assessments from which TACs and quotas are derived. As discussed earlier, neither TAC nor quotas are sound measures in fisheries. Quotas are frequently political compromises based on naive models fed by questionable data. Quotas focus on tonnage, disregarding one of the indicators of overfishing– a decrease in size that results in the harvest of much greater numbers of fish (Christie et al. 1994)– and resource collapse is possible, perhaps inevitable, if fishing mortality rates are high. Unraveling the intricacies of the collapse of the cod fishery is therefore the first step in characterizing a rational fisheries policy, one that takes new conceptual approaches to managing depletable resources.

A robust understanding of the uncertainties inherent in complex adaptive systems has been lacking in fisheries policy. Such awareness would provide a theoretical base from which to search for a balance between two operationalizable goals: (1) long-term resource sustainability, and (2) the protection of livelihoods dependent on healthy stocks. With these two outcomes in mind, several strategies emerge as both desirable and feasible. Grouping the strategies under the categories of conservative, regulative, or allocative (Hanna and Smith 1993) advances recognition of specific policy goals, and directs choices from among the following options.[9]

Conservative

1. Revamp the scientific basis of fisheries management. Models and the data that feed them have proven inadequate, and the models fail to account for chaotic and complex adaptive marine ecosystems. The focus on resilience of fish stocks as a function of population size can be replaced by considering *ecosystem resilience*, a function of the fraction of subsystems degraded or removed. Subsystem *parameters* are the basic biological processes that maintain the fishery within the normal bounds of chaotic variation. "Parametric management" (Wilson et al. 1994, 1996) posits the relevant parameters to include habitat, migration, spawning, growth, and predation. The relative stability of ecosystem parameters means that data do not have to be constantly updated, in sharp contrast with stock assessment techniques.
2. Operationalize parametric management. Conceptually, parametric management requires development of fishing restraints that emphasize "how" fish are caught rather than "how many" are taken. Pragmatically, parametric management requires the introduction of refuges, temporary or permanent closures for spawning and nursery activities, and the choice of place and time of use of different gear types. It does not imply retrogressing to the days of sail, but does entail the decentralization of top-down management schemes (strategies 10 and 14) and the willingness to restrain technology so that system structure and productivity remain intact (Wilson et al. 1996).
3. Accommodate traditional ecological knowledge into parametric management. Local communities are often already cognizant of the "when" and "where" aspects of a fishery, and thus a framework for fusing traditional ecological knowledge with parametric management requires development (Ommer 1993).[10] Examples include the proposed replacement of the multiple-linear regression techniques used by fish biologists to ascertain the "best habitat" for fish by local knowledge of the *actual* location of such best habitat. Fishers will trace temporal changes in fish assemblages, helping scientists understand multispecies interactions.
4. Incorporate social scientists into parametric management. It is not possible or even desirable to separate the biological and socioeconomic aspects of parametric management (Wilson et al. 1994). Incorporation of social science perspectives will bring balance to the process, interjecting a degree of real-world rationality into the realm of mathematical modeling and decision making.[11]
5. Raise the level of knowledge of ocean ecology, starting in grade schools. Environmental education will encourage youth to conserve resources and appreciate local history, and it will also lay the foundation for the professionalization of local decision making processes. Concomitantly, it will raise

the prestige of fishers, enhance the value of traditional ecological knowledge, and enable participation in comanagement schemes (strategy 14).

6. Start a consumers' education campaign. Consumers are borrowing from the future when they expect to have access to inexpensive fish to eat and cheap fishmeal to fertilize fields.

Regulative

7. Reassess the technology in use, even among artisanal fishers. In the absence of effective resource management, government encouragement of an intermediate technology among inshore fishers can exacerbate overfishing and undermine extant controls over access to the resource (McCay 1979). Without institutional change, intermediate technologies cannot be regarded as synonymous with "appropriate technologies." Fishing technologies must be adapted to avoid the taking of nontarget species. For example, traps that are designed to catch capelin and accidentally take small, unsellable codfish should be banned. Feather lures on longline hooks attract smaller fish than do hooks baited with fish, so these too should be banned. Some fishers suggest the banning of traditional cod jiggers, which, they say, injure far more fish than they catch.
8. Recognize that artisanal fishers must pursue a wide range of opportunities. Successful fishers possess the flexibility to adapt and take advantage of whatever opportunities are present. Limited-entry licenses (e.g., the crab, lobster, and salmon fisheries) define a set of rights granted the licensee by the state. With the aim of forcing inshore fishers to specialize in particular species, such licensing is contradictory to the flexible adaptations traditionally practiced (House 1988; McCay and Finlayson 1996). Current limited-entry and personal-registration licenses can be replaced by a system that awards licenses based not on prior participation in a fishery, but rather on earned eligibility based on education, experience, and career development.
9. Ensure that rules violations are stiffly penalized. Observers are needed at all points in the fishing process. If political expediency mandates the continuance of the dragger fleet, at least two observers must be allocated to each vessel. Dockside observers should be stationed at all processing plants and transhippers.[12] Violations are therefore likely to be spotted, and deliberate violations must be much more stiffly penalized than at present.
10. Establish/recognize forms of common property resource management at the local level. Historically, interference by the state in the inshore fishing communities' own regulatory structures has proven detrimental to the resource. Instead, the state might focus on controlling access while formally allocating each community the property rights to its local fishing grounds and the determination of access rules.[13] In so doing, the state recognizes existing community regulatory practices and embeds them within a regulatory framework. It also explicitly declares that common property rights are synonymous with community property rights (Matthews 1993; McCay and Jentoft 1996; Davis and Bailey 1996).
11. Acknowledge Canada's interim right to protect straddling stocks on the high seas. Until the Convention on Straddling Stocks goes into effect, Canada has the right to expect that signatories to NAFO will abide by its provisions. To date, there has been considerable reticence by fishing nations to ratify the treaty. John

Efford, Newfoundland's Minister of Fisheries and Agriculture, on November 30, 1998, stated that: "It was three years ago this week that [the Convention] was opened for ratification. To date, only 18 of the 30 nations required have ratified the agreement. ... It is essential that Canada return to its leadership role on international fisheries issues and begin by ratifying [the Convention] quickly, and then to press other nations of the world to do the same" (http://www.gov.nf.ca/releases/1998/fishaq/1130n03.htm). To the extent that nations willfully do not, or attempt to skirt responsibility by reflagging vessels under flags of convenience, Canada is justified in interdicting and seizing violators.

Allocative

12. End (phase out) all subsidies. It is imperative to rationalize the fishing industry, especially the offshore sector. Ending government subsidies to the dragger fleet will force (1) market prices of fish to rise, more truly reflecting current scarcity, and (2) the retirement of a significant fraction of the fleet. A reduction in fleet size favors the rebuilding of commercial and nontarget fish stocks, and will also reduce the degree of competition and conflict with artisanal fishers.
13. Make paramount the issue of sustainable livelihoods. The federal and provincial governments need to reach consensus on the issue of sustainable livelihoods. There are many more artisanal fishers who can extract a reasonable living from the sea than there are crew members of dragger vessels. If for no other reason than the number of jobs potentially restorable in the inshore sector, consideration should be given to withdrawing dragger vessels from a future cod fishery. In the case of Newfoundland, sustainable livelihoods dovetail with overall sustainability: The small-scale inshore fishery was more ecologically sound than the offshore fishery; and as for economic viability, while the offshore fishery may have had large returns in some years, the inshore fishery was comparable in terms of returns per dollar invested.
14. Consider ecosystem comanagement. If dragger vessels are withdrawn from a future fishery, management of the resource could conceivably be assigned to the fishers themselves. Strategy 1 summarizes why quotas are an unsound management practice, and strategy 10 suggests that common-property resource management schemes could be strengthened. In concert with ecological education (strategy 5), comanagement offers options that mesh with the concept of parametric management (strategy 2). State intervention would occur only upon request, to restrain and penalize violators (strategy 9). Inshore fishers may be able to attain consensus on the status of "their" assemblage, monitoring it in real time as the example of Francois showed, adapting their harvest to local conditions. Comanagers responsible for their own future livelihoods are likely to be predisposed to conserving, rather than decimating, fisheries resources.

Notes

1. Other instances of international conflict over fisheries resources are discussed in Peterson and Teal (1986), Westing (1986), *Jane's Defence Weekly* (1995a, 1995b, 1996), and Cobb (1996).

2. See Bailey and Pomeroy (1996) for a general discussion on resource-dependent communities.

3. Ecological factors may be at least partially responsible for the collapse of the cod fishery. If such environmental factors as excessively cold water are of critical importance, then the ability of managers to control stock size through model output may be far less than they would like to believe.

4. One such disturbance imposed on the cod population was 1968's 800,000 metric tonnes harvest, about 4 times the annual average catch over the previous three centuries (McCay and Finlayson 1996).

5. However, the TAC is actually set by the Federal Minister of Fisheries– a politician. While scientists placed caveats on their projections, the minister routinely stripped and discarded caveats from reports. At the executive level, ambiguity and uncertainty were not regarded as useful (Finlayson 1994).

6. Organization theory has documented many instances of unboundedness leading to unexpected results. See for example Gattiker (1990), Horgan (1995), and Demchak (1996).

7. Inshore fishers operate at a small scale. Being self-sufficient, they may retain more of a smaller income than other sectors of the fishery: They operate without a paid crew, they have low overhead, and if a partnership, they share labor and equipment. For the Canadian Great Lakes, Berkes and Pocock (1990) showed that the small-scale fishery obtained almost twice as much fish per unit of fuel energy use, and created three times as many fishing jobs per unit of investment, compared with larger scale operations.

8. The numbers do not include fish processing plant workers, but since the draggers have not resulted in sustainable employment, including these workers in the calculus is moot.

9. Conservation decisions assure resource sustainability; regulation decisions set the rules for fisheries operations; and allocation decisions focus on quota-setting for various user groups.

10. However, not all fishers are aware of ecological linkages. Felt (1994) illustrates this point with a case study of Atlantic salmon in two different areas of Newfoundland.

11. Recognizing the value of a more participatory and inclusive decision making process, in 1993 the Minister of Fisheries and Oceans created the Fisheries Resource Conservation Council (FRCC), comprised of scientists, academics, leaders of industry groups, and other experts outside of DFO. Final authority for resource assessments, quota recommendations, and other conservation strategies was removed from the Science Branch of DFO and is now vested in the FRCC (McCay and Finlayson 1996). Note, however, that no advocate of the inshore fishers' interests is seated in the FRCC.

12. A partial dockside observer program for snow crab went into effect in 1994. Organized by the FFAW, it levied a tax of 1 cent per pound to pay for itself, and was welcomed by fishers.

13. Communities refrain from administration except to report violators, but formulate and amend their own access regulations. Enforcement is by local fisheries officers (Martin 1979).

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