



# Ludwig's Ratchet and the Collapse of New England Groundfish Stocks

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*The stocks of principal groundfish species off New England have collapsed, creating economic hardship and dislocation in fishing communities from Rhode Island to Maine. In this article we analyze the causes of this collapse using the "ratchet effect" described by Ludwig, Hilborn, and Walters (1993) as a framework. According to Ludwig, Hilborn, and Walters, powerful economic and political interests drive fisheries to overcapitalize and overexploit despite scientific evidence that stocks are declining. When the fishery is no longer economically viable, governments provide financial assistance to minimize economic hardship. When stocks increase there is another rush to invest, and the cycle repeats itself. The history of groundfish management in New England conforms well to this model. Optimism among fishers and government over U.S. control of this fishery in 1977 stimulated successive rounds of investment that built up excessive fishing capacity despite warnings from scientists that stocks were becoming weaker. Management regimes designed by the New England Fishery Management Council were ineffective in constraining fishing effort. Collapse of the stocks has led to severe restrictions on fishing and to government assistance. We suggest that the integration of science, management, and harvesting sectors through ecosystem-based management offers the best means of avoiding similar situations in the future.*

**Keywords** fishery management, fish stock collapse, New England groundfish

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## Introduction

The stocks of principal groundfish species off New England have collapsed and there is considerable uncertainty in the scientific community, the fishing industry, and among the general public as to when and how this resource might be brought back to productive levels of abundance (Edwards, 1999; Fogarty & Murawski, 1998; Fordham, 1996; Wang & Rosenberg, 1997). This collapse did not come about abruptly but took place over a number of years. From 1983 to 1993 there was a continuous and serious decline in the groundfish catch: cod landings declined by 55%, haddock by 94%, and yellowtail flounder by 89% (NMFS, 1994). For the New England groundfish fishery, the Massachusetts Offshore Groundfish Task Force (MOGTF, 1990) estimated that the lost potential each year due to overfishing in the late 1980s amounted to at least 137 million pounds of fish, \$350 million in gross revenue, and 14,000 jobs.

Opinions differ strongly about how the crisis developed and who is to blame. Fishers blame a regulatory bureaucracy that was too slow to act. Regulators say that they were responding to the economic concerns of the fishing industry or that they were overwhelmed by unpredictable swings in fish populations that were exacerbated by advances in fishing technology. Regulators also complain that biologists' uncertain estimates of fish populations and acceptable fishing levels failed to offer a strong enough case for tighter restrictions on fishing. What is clear is that the groundfish stock collapse is an economic disaster for New England coastal communities, such as Gloucester and New Bedford, where the social fabric has been torn apart by the loss of employment in fishing (Aguirre International, 1996). It is also clear that the collapse was a consequence of the long-standing failure of fishery managers to solve problems of chronic overfishing associated with an open access fishery (Collins, 1994, 1995).

Many have blamed the scientific community for not anticipating the impending stock collapse or, if they did, for failing to warn of the dire consequences of such a collapse in sufficiently strong terms that remedial action would be taken (O'Malley, 1998). In this article we consider the role of science and a number of other factors in the management of the New England groundfish fishery over the 21-year period from 1977 to 1997. We structure our analysis in the context of hypotheses drawn from a controversial essay in *Science* by Don Ludwig, Ray Hilborn, and Carl Walters (1993).

Ludwig, Hilborn, and Walters (1993) dismissed natural science as having any significant influence on renewable resource conservation. Instead, they argued, a series of political and economic imperatives drives the system in a downward spiral. They termed this the "ratchet effect," and we have labeled the process they identified as "Ludwig's ratchet." In this article we show that Ludwig's ratchet is sufficient to account for the demise of the New England groundfish fishery, once one of the most productive in the world. We further consider what prescription, if any, will decommission Ludwig's ratchet and permit sustainable fisheries.

Our analysis is based on information derived from interviews, reports, and documents relating to management of the New England fishery. We interviewed fishers, fish processors, present and former members of the New England Fishery Management Council (NEFMC), Council staff, and scientists at the National Marine Fisheries Service (NMFS), located at the Northeast Fishery Center in Woods Hole, MA. Between 1982 and 1996 both authors attended numerous meetings of the NEFMC at which groundfish management was discussed. We reviewed fishery management plans, minutes of Council meetings and other management planning meetings, as well as other published and unpublished documentation on the status and management of the New England groundfish fishery.

## Ludwig's Ratchet

There are four elements to Ludwig's ratchet as we adapt it to fishery management:

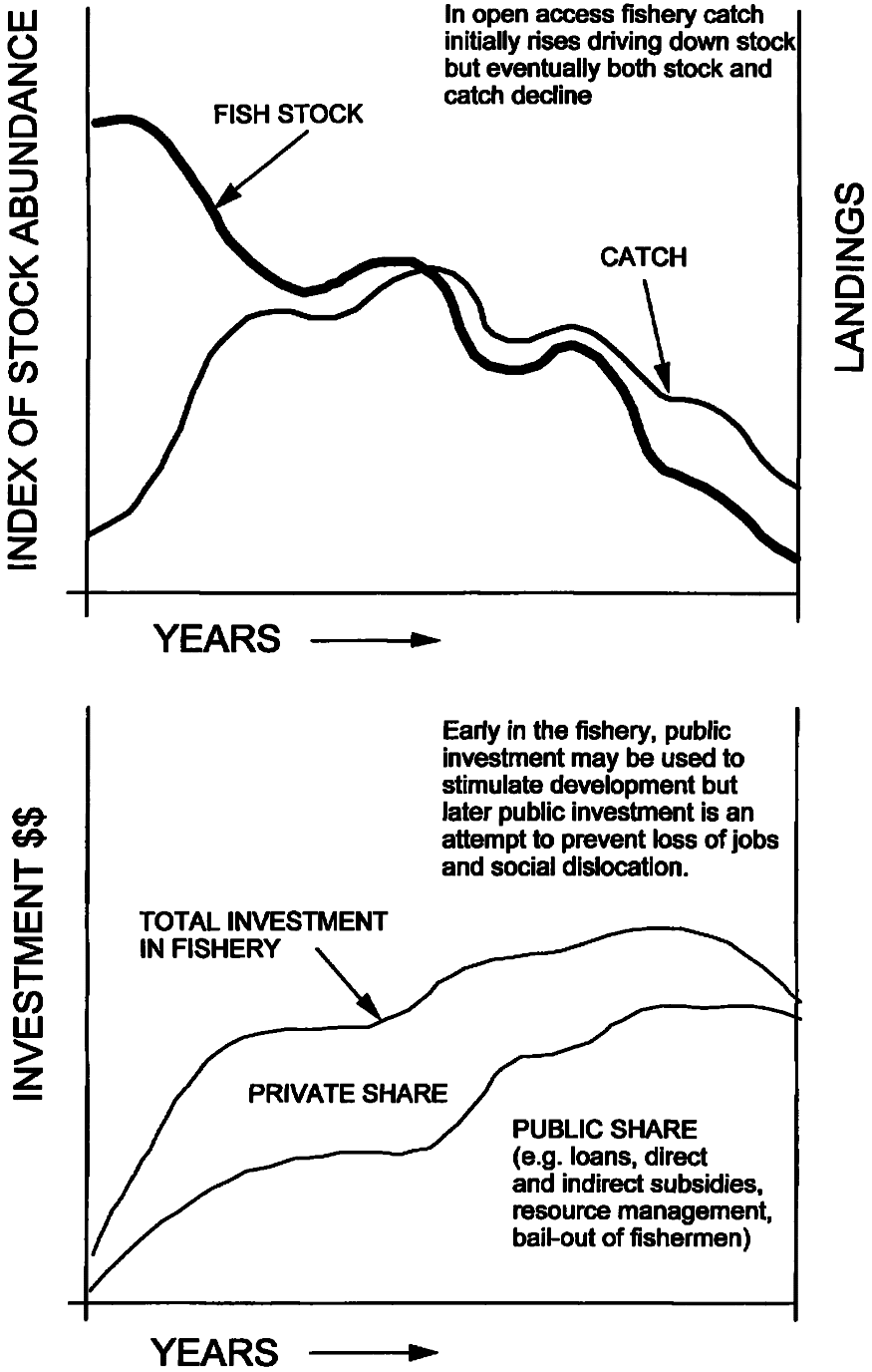
1. Profit or the promise of profit in the fishery attracts political and economic power that, in the face of uncertainty about resource abundance, drives the decision-making process.
2. Science is unable to measure the abundance of fish accurately enough or to predict future states of the fish stocks well enough to demonstrate the negative effects of overexploitation until it is too late.
3. In the face of scientific uncertainty, investment in the fishery expands to the point that rents are dissipated and the economic viability of individual fishing units becomes marginal.
4. When there is a short-term increase in fish abundance, investment in the fishery expands. When there is a short-term decrease in fish abundance, disinvestment is slow and the industry appeals to government for assistance. Assistance is typically given by the government, ostensibly as a short-term measure. In reality, the assistance tends to become incorporated into the functional economics of the fishery.

Because of 1 and 2 above, this cycle continues inexorably driving stocks downward until they collapse or fishing becomes so uneconomical that the fishery is forced to reorganize around new species or on a reduced basis. The hypothetical trends generated by this process are depicted in Figure 1. In an open access fishery, catch initially rises, driving down the fish stock, but eventually both fish stock and catch decline. Early in the exploitation of the fishery, public investment may be used to stimulate development, but later public investment is used in an attempt to prevent loss of jobs and social dislocation. Moreover, some decisions about public investment may be completely disconnected from any consideration of the state of the fish stock, as in the case of favorable tax and investment rules for fishers. Private investment tends to peak early in the process, and later, public funds may be used to compensate failed private investors.

In what follows we investigate the applicability of these arguments to the evolution of management plans and regulations developed by the NEFMC for the groundfish fishery from 1977 to 1997. We have divided this 21-year period into three phases. First was the quota management phase from 1977 to 1982, during which more than 100 changes were made in regulations (Table 1). Noncompliance was so rampant during this phase that the fishery came to resemble the humorous depictions by famous cartoonist Rube Goldberg of exceedingly complex solutions to simple problems. Second was the indirect management phase from 1982 to 1992, during which regulations dealt with closed areas, closed seasons, mesh size, and fish size restrictions (Table 1). During this phase, vessel construction loan programs, increases in fleet size, lack of enforcement, political intervention, and indecisive action by the NEFMC led to an essentially open access fishery with large numbers of vessels engaged in overfishing despite scientific evidence of serious stock decline. Third was the effort control phase from 1992 to 1997, during which the NEFMC and the federal government implemented limitations on fishing days for individual vessels with the objective of reducing fishing effort by 50% over 5 years (Table 1). This phase was initiated by legal action taken by The Conservation Law Foundation, which forced the Council and the federal government to take the fisheries crisis seriously and to prepare and implement plans and regulations that would reduce fishing effort and fleet size and rebuild the stocks.

## Fishery Management in the United States

Until passage of the Fishery Conservation and Management Act of 1976 (FCMA; later the Magnuson Fishery Conservation and Management Act [MFCMA]), the U.S. federal



**Figure 1.** Hypothetical trends in fish abundance, catch, and investment in an open access fishery cycling through Ludwig's ratchet. *Upper panel:* Expected changes in fish stock abundance and catch over time. *Lower panel:* Expected changes in public and private investment over time. See text for full explanation.

**Table 1**  
Chronology of management plan development for New England groundfish, 1977–1997

	1977	1978	1979	1980	1981	1982	1983
Emergency implementation of groundfish plan, including initial OYs	Emergency increase in OYs extended.	Emergency plan in effect	Emergency plan in effect	Emergency plan in effect	Emergency plan in effect	Interim plan implemented on emergency basis; quotas lifted (March)	Interim groundfish plan in effect
Final regulations approved.	Emergency increase in OYs extended.	Weekly landing limits in effect.	Yellowtail incidental catches increase.	Yellowtail landing limit west of 69° increased.	Petition for emergency implementation of interim plan.	Minimum cod end mesh increased to 5 1/2 in.	
Annual quota for cod in Gulf of Maine exceeded and fishery closed in June.	Emergency amendment: quota increase for haddock and cod, decrease for yellowtail.	Fishing closures rescinded. New trip limits set based on new stock assessments.	Closures not enforced.	Council submits interim plan in the fall. Interim plan approved, January 1982.	Interim plan implemented with minimum mesh for cod ends (5 1/8 in.), minimum fish sizes and area closures (October).	Amendment proposed to specify definition of cod end for enforcement purposes (September).	
Annual quota for haddock and yellowtail exceeded and fisheries closed in July.	Cod: daily trip limits imposed.	Increased OYs for cod and haddock. No combining quotas on a single trip.			Fishing year changed to March 1–Feb. 28.	Continued development of multispecies plan.	
Emergency regulations: increase OY for cod, haddock and yellowtail.	Cod and haddock: weekly landing limits imposed.	New fishing year OYs set same as 1978–1979.			Development of first multispecies plan begins.		
Quarterly quotas by species imposed.	No-discard rule imposed.	Interim plan development begins.					
	New fishing year set: Oct. 1–Sept. 30.						

(Table continued on next page)

**Table 1**  
Chronology of management plan development for New England groundfish, 1977–1997 (Continued)

1984	Interim groundfish plan in effect	1986	Interim plan in effect until September; multispecies plan implemented (September)	1987	Amendment 1 to multispecies plan (June)	1988	Amendment 1 to multispecies plan in effect	1989	Amendment 2 to multispecies plan (February)	1990	Amendment 3 to multispecies plan
1985	Secretarial amendment extending interim plan (October)	1986	Interim plan in effect until September; multispecies plan implemented (September)	1987	Amendment 1 to multispecies plan (June)	1988	Amendment 1 to multispecies plan in effect	1989	Amendment 2 to multispecies plan (February)	1990	Amendment 3 to multispecies plan
1984	Interim groundfish plan in effect	1986	Interim plan in effect until September; multispecies plan implemented (September)	1987	Amendment 1 to multispecies plan (June)	1988	Amendment 1 to multispecies plan in effect	1989	Amendment 2 to multispecies plan (February)	1990	Amendment 3 to multispecies plan
Final definition of cod end imposed (January).	Draft multispecies plan ready for review.	NOAA rejects multispecies plan (January).	NOAA rejects multispecies plan (January).	Cod end redefined for enforcement.	Cod end redefined for enforcement.	TMG report criticizes multispecies plan (June).	TMG report criticizes multispecies plan (June).	Changes to penalty system for fishing infractions.	TMG report criticizes multispecies plan (June).	Changes to penalty system for fishing infractions.	Changes to penalty system for fishing infractions.
Hague line decision. U.S. vessels now restricted to 75% of Georges Bank.	Council holds public hearings on draft multispecies plan (February).	Council resubmits multispecies plan (April).	Council resubmits multispecies plan (April).	Larger minimum mesh area for yellowtail.	Larger minimum mesh area for yellowtail.	Council holds public hearings on proposed Amendment 2.	Council holds public hearings on proposed Amendment 2.	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).	Council holds public hearings on proposed Amendment 2.	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).
NOAA holds public hearings on proposed single-mesh-aboard rule (no rule resulted).	Council submits multispecies plan for NOAA approval (August).	NOAA partial approval to multi-species plan (August); main features are: more species with minimum size limits; larger closed areas; 5/2 in. minimum mesh; exempted fisheries.	NOAA partial approval to multi-species plan (August); main features are: more species with minimum size limits; larger closed areas; 5/2 in. minimum mesh; exempted fisheries.	Small part of haddock area closed.	Small part of haddock area closed.	Council submits Amendment 2 for NOAA approval; main features: bycatch limits in exempted fisheries; yellowtail minimum size increased to 13 in.; large-mesh-only area on Nantucket shoals.	Council submits Amendment 2 for NOAA approval; main features: bycatch limits in exempted fisheries; yellowtail minimum size increased to 13 in.; large-mesh-only area on Nantucket shoals.	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).	Council submits Amendment 2 for NOAA approval; main features: bycatch limits in exempted fisheries; yellowtail minimum size increased to 13 in.; large-mesh-only area on Nantucket shoals.	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).
Continued development of multispecies plan.	Council submits multispecies plan for NOAA approval (August).	NOAA partial approval to multi-species plan (August); main features are: more species with minimum size limits; larger closed areas; 5/2 in. minimum mesh; exempted fisheries.	NOAA partial approval to multi-species plan (August); main features are: more species with minimum size limits; larger closed areas; 5/2 in. minimum mesh; exempted fisheries.	Small part of haddock area closed.	Small part of haddock area closed.	Council submits Amendment 2 for NOAA approval; main features: bycatch limits in exempted fisheries; yellowtail minimum size increased to 13 in.; large-mesh-only area on Nantucket shoals.	Council submits Amendment 2 for NOAA approval; main features: bycatch limits in exempted fisheries; yellowtail minimum size increased to 13 in.; large-mesh-only area on Nantucket shoals.	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).	Council submits Amendment 2 for NOAA approval; main features: bycatch limits in exempted fisheries; yellowtail minimum size increased to 13 in.; large-mesh-only area on Nantucket shoals.	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).	Massachusetts Offshore Groundfish Task Force submits report critical of multispecies plan (December).

1991 Amendment 4 to multispecies plan partially approved by NOAA	1992 Amendment 4 in effect	1993 Amendment 4 in effect	1994 Amendment 5 to multispecies plan in effect	1995 Emergency rules extended indefinitely by council	1996 Amendment 7 to multispecies plan in effect	1997 Amendment 7 in effect
Conservation law foundation (CLF) sues secretary of commerce over failure to conserve groundfish stocks.	Continued development of Amendment 5.	Amendment 5 completed; main features: moratorium on new fishing permits; days at sea (DAS) limits imposed to reduce fishing effort; minimum mesh size 6 in.; closed areas expanded; fishing mortality to be reduced 10%/year for 5 years (50% reduction).	NMFS scientists Special Advisory Report: stocks have collapsed and Amendment 5 insufficient to allow recovery (August).	Public hearings on Amendment 7 proposals: extended closed areas; 50% reduction in DAS by 1997; target total allowable catch levels; possession limits; minimum fish and mesh sizes.	Procedure for setting annual target for total allowable catches implemented.  50% reduction in allocated DAS.  Time and area closure in northeast, mid-coast, and Massachusetts Bay extended to all gear types.  Haddock possession limit: 1000 lb for vessels in DAS program.	Gillnet effort control program and Gulf of Main cod trip limit imposed.  Council holds public hearings on adjust- ment to DAS rules to reduce discards of cod in Gulf of Maine.  Haddock trip limits increased.
Consent decree reached in CLF suit, 28 August.			Amendment 6: 500-lb possession limit for haddock.			
Development of Amendment 5 to satisfy consent decree begun.			Emergency rules implemented; 6-month closure of 17% of Georges Bank.  Mandatory log book reporting implemented.			

government had limited authority over marine resources beyond three miles, with the exception of international fishery agreements. Under the FCMA, the United States took management control over offshore fishery resources. The FCMA specified an institutional structure for managing fisheries in the Fishery Conservation Zone (FCZ) that extends from 3 to 200 miles. The objective of the act was to achieve optimal yield for each fishery under federal jurisdiction. This was to be accomplished by management plans and regulations drawn up by eight regional fishery management councils, approved by the U.S. secretary of commerce, and implemented by the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fishery Service and the Coast Guard.

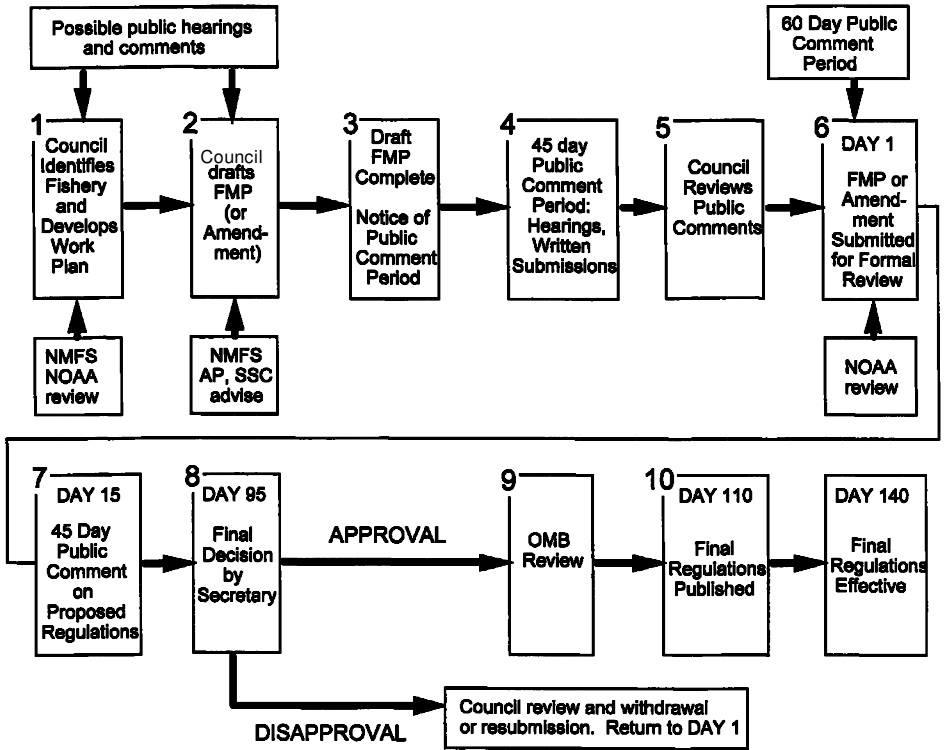
Each fishery management council is made up of the principal official with marine fishery responsibility from each coastal state, the regional director of the NMFS, and additional members equal to twice the number of member states. The additional members are appointed by the secretary of commerce from lists of nominees submitted by the governors of the member states. Nonvoting members include the regional Director of the Fish and Wildlife Service, the Commander of the Coast Guard District, the Director of the Marine Fisheries Commission and one representative of the Department of State. Decisions are taken by majority vote in council. Management councils are required to solicit public comment on proposed management plans, regulations, and amendments. Each council is also required to establish a scientific and statistical committee (S&S Committee) to give technical advice on issues such as fish stock abundance, sustainable harvests, and fishing technology changes.

Fishery management plan preparation has proven to be a lengthy and intricate process (e.g., Appolonio, 1978; Anderson, 1987; Branson, 1987; Finch, 1985; McHugh, 1990; Miller, 1987; Turgeon, 1985). It consists of a series of procedural and administrative decisions and checkpoints involving many actors and numerous levels of government. Moreover, the councils are comprised of individuals with divergent backgrounds and preferences who are charged with preparing a plan that must satisfy economic, social, and ecological criteria, as identified in 10 national standards. (The MFCMA has recently been amended and reauthorized as the Magnuson-Stevens Fishery Conservation and Management Act with the addition of the Sustainable Fisheries Act [P.L. 94-265, as amended, 16 U.S.C. 1801 et seq. and P.L. 104-295].) Figure 2 illustrates the plan development and implementation process, which, under the best of circumstances, took up to 140 days under the MFCMA. If a plan was not approved, the process could take much longer, sometimes years. Even when this process worked normally, it created considerable "lag" in the system, since fisheries continued to be managed under an old plan or under emergency measures until a new plan came into force.

### **The Quota Management Phase, 1977–1982**

On December 31, 1976, the United States withdrew from the International Commission for the Northwest Atlantic Fisheries (ICNAF), the international body that had been regulating the New England and other western Atlantic fisheries beginning 3 miles offshore, and declared exclusive rights to manage fisheries out to 200 miles offshore. Expectations were high among fishers and others in the industry that exclusion of foreign fishers from the FCZ would result in a fishing bonanza for U.S. fishers as well as better management of the stocks. Since the FCMA was not implemented until March 1977, however, the early U.S. withdrawal from ICNAF left a regulatory hiatus of two months. The NMFS and the newly formed NEFMC quickly developed a preliminary plan for managing the groundfish fishery so as to prevent unauthorized fishing within the FCZ. This fishery is quite complex, involving three principal species (cod, yellowtail





**Figure 2.** Fishery plan development and implementation process under the MFCMA. Stages prior to submission of plan to secretary of commerce for approval have no specified time frame. Once the plan is submitted, then time limits apply to each stage in the approval (or disapproval) process.

flounder, and haddock) with significant ecological and economic interdependencies as well as a variety of gear and vessel types (Fogarty & Murawski, 1998). The interim management plan prescribed quotas for the principal species based on old ICNAF records that, as it turned out, were unreliable. The fishery was pursued vigorously from the beginning of the year, and by June the cod quota was reached and this fishery in the Gulf of Maine had to be closed. By the middle of July, the haddock and yellowtail flounder fisheries were also closed, as their quotas had been exceeded (Table 1).

Fishers reacted to the closures by claiming that they were unfair (Healey & Hennessey, 1998, and unpublished interviews). Many said that the closures were unnecessary because there was an abundance of cod. Others protested that the closures came about before the small boat fishers had had a chance to begin summer fishing as the cod moved closer to shore. Still others argued that the management system favored those taking shorter trips. Thus the regulatory system, which was intended to apply equally to all harvesting groups, was having powerful distributional effects on harvesters depending on their type of vessel, gear, and tradition.

The credibility of the science upon which the quotas were based was quickly called into question. The NMFS had recommended that there be no fishery for haddock in 1977, as this species had been depleted under ICNAF rules and the stock needed to be rebuilt. By contrast, fishers were claiming that haddock were in great abundance. Later, the NMFS admitted that it was aware that a very large year class of haddock had been produced in 1975, which fishers were seeing as scrod in 1977. The NMFS argued that it

had recommended against a quota of haddock because it believed these fish should be invested in stock rebuilding, not allocated to harvest. This admission raised suspicion about the trustworthiness of NMFS scientists in the eyes the fishermen—an attitude that would continue to strengthen and that would have a corrosive affect on groundfish management in New England for the next 20 years (Hennessey & Healey, unpublished interviews).

The efforts of fishermen to maximize their profitability within the constraints of the management regime led to a series of “games” played against the regulations (e.g., see Pollnac & Miller, 1978). One such game was the “piggyback game,” in which yellow-tail flounder boats caught a trip’s worth of fish in the offshore zone (i.e., east of 69 degrees West longitude) and another trip west of the line, thereby disguising their contribution to quota harvests within each zone. There was also an “inshore-offshore game” in which the offshore vessels began fishing within three miles of the coast, where they had not traditionally fished. This stratagem allowed fishers to get their catch by making shorter trips and, thereby, to maximize their share of the quotas. Another common practice was the “Canadian game,” in which the haddock boats that traditionally fished Georges Bank instead went to fish in Canada or said that their catch originated in Canadian waters. The impact of this game was that the U.S. quota in Canadian waters was rapidly exhausted, thus limiting the amount of this quota available to the large New England vessels that traditionally fished there. In another ploy, “the racing game,” cod fishers fearful of a closure of Georges Bank raced to obtain a share of the catch before restrictions went into effect. Finally, and perhaps most serious for the fishing industry, was the “fish smuggling game,” in which fish were harvested illegally and dropped off at smaller ports that were not routinely monitored.

Many of these activities were illegal and charges were laid. However, it often took up to two years to resolve a charge (Sutinen & Hennessey, 1986; Sutinen, Reiser, & Gauvin, 1990). Beyond delays in processing cases, a major difficulty in enforcement was the fact that NMFS enforcement agents were not empowered to impound illegal catches. As a result, skippers who were charged with violations simply sold their catch, hired an attorney, and went back to fishing until their case came up. In short, adequate deterrents to illegal fishing were not in place in the early years of the management plan.

Weak enforcement tended to penalize law-abiding fishermen, as fishers who obeyed the law caught fewer fish, suffered economic hardship, lost prestige in the eyes of other fishers, and lost their credibility as effective captains (Pollnac & Miller, 1978). During 1977 and 1978, the NEFMC attempted to remedy this rapidly deteriorating situation through more than 100 changes in regulations (Healey & Hennessey, 1998). In an attempt to stretch out the quotas as long as possible, the NEFMC first implemented a quarterly allocation system (Table 1). Quarterly quotas led to “derby behavior” in which fishers raced to get the largest possible share of the catch before the quotas were taken. To combat this problem, the council established a vessel trip limit system in which the allowable catch per vessel was reduced as the quarterly allocations were about to be reached.

The changes to regulations had different impacts on different vessel classes. The inshore fishers claimed that the offshore fishers were overwhelming them and taking most of the quota. Large vessel owners, for their part, complained that they could not survive on the same allocations as the smaller vessels. The fixed-gear fishers complained that, because their fishery was seasonal, they were at a disadvantage vis-à-vis mobile-gear fishermen who could fish all year (Hennessey & Healey, unpublished interviews).

These complaints led to new proposed remedies (Table 1). The NEFMC endorsed a proposal drawn up by the Massachusetts Inshore Draggermen’s Association and the Cape Cod Fishermen’s Coalition (The MIDA-CCFC Plan) that would distribute the quarterly quotas among vessel classes based on their historical performance in the fishery. The

plan was designed to encourage competition among fishers within vessel classes while minimizing the negative consequences of competition between classes. The proposal was adopted through a series of amendments to the groundfish plan at the end of March 1978. Unfortunately, a whole new series of problems then arose. As Spencer Appolonio (1978) observed: "Vessel class distinctions are of necessity arbitrary, and the concept almost invariably leads to pressure for establishing 'special' classes each with its 'unique' problems. The incorporation of vessel class allocations implicitly set new plan objectives, neither biological nor economic, but largely sociological or at least socio-economic in nature" (p. 26).

New "games" arose with each new set of regulations as the fishers sought to improve their relative positions. Gear-type restrictions were circumvented through the "shifting gear type" game in which stern trawlers would carry tubs of gill nets to claim allocations as both a trawler and a gillnetter. Vessel trip limits evoked the "What is a trip?" game in which fishers changed their times of departure and arrival or relocated their port to undermine the intent of the regulation. Furthermore, the NMFS and the Coast Guard found trip limits extremely difficult to enforce, which in turn encouraged illegal fishing. As Appolonio (1978) noted, "the combination of quotas, allocations and trip limits amounted to hundreds of regulations of different kinds. The cumulative impact of these complex and ever changing regulations was that they induced widespread violation and non-compliance with the law and probably a significant reduction in the reliability of landing data" (p. 30).

In sum, the regulatory regime for New England groundfish during the 1976–1982 period proved to be "confusing, difficult, painful and largely ineffective" (Appolonio, 1978, p. 29). Despite the five-year record of mismanagement, however, stock assessments for 1981 indicated that the outlook for recruitment was good and that groundfish resources would remain near the long-term biomass averages at least in the near term (Clark, Overholtz, & Hennemuth, 1982; Serchuk & Wigley, 1982). The prospects for the industry looked positive, and the optimism that accompanied declaration of the 200-mile FCZ remained undiminished. Thus, the "promise of profit" persisted as a powerful driving force in the fishery.

During the quota management phase, a variety of government subsidies encouraged greater participation in the fishery (Table 2). Through these programs the U.S. government contributed substantially to overcapitalization of the fleet by providing financial assistance to fishers. The fishing vessel Capital Construction Fund (CCF), begun in 1970, and the Fisheries Obligation and Guarantee Program (FVOG) were two of the most important of these programs. Under the CCF, owners or lessors of vessels could make tax deductible contributions to a capital construction fund to replace, reconstruct, or build new vessels (Mooney, 1997). The FVOG guaranteed obligations (loans) that would aid in the financing or refinancing of construction, reconstruction, or reconditioning of vessels. These two funds were utilized extensively in the late 1970s and through most of the 1980s. They assisted many fishers to enter the fishery and existing fishers to build bigger, more efficient boats. Indeed, from 1977 to 1992 the number of vessels in New England increased by 80% and the number of fishers by 140% (U.S. Department of Commerce, 1995).

The industry profile during this phase, therefore, fits the conditions of Ludwig's ratchet, in which profit or the promise of profit attracts investment and political interest in the fishery. A large number of new vessels entered the fishery in search of profits and, initially, landed large amounts of fish. But profits began to decline in real terms as more vessels entered the fishery. It should have been clear by 1981 that without some form of limited entry, fish stocks would be depleted and revenues per vessel would continue to decline. But limited entry was strongly opposed at the time. Indeed, even

**Table 2**

Government programs providing financial assistance to fishers to improve existing vessels or construct new ones during the period 1977–1997

Program	Citation	Purpose
Fisheries Loan Fund*	16 U.S.C. 742c: 50 C.F.R. 250	Loans to commercial fishermen for financing or refinancing costs of purchasing, constructing, equipping, maintaining, repairing, or operating new or used commercial fishing vessels or gear.
Fisheries Obligation Guarantee Program**	46 U.S.C. 1271 et seq.	Guarantees obligations that aid in financing or refinancing construction, reconstruction, or reconditioning of vessels.
Capital Construction Fund**	50 C.F.R. 259	Owners of lessors of vessels can make tax-deductible contributions to a capital construction fund to replace, reconstruct, or build new vessels.
Saltonstall/Kennedy Fund	15 U.S.C. 713c-3	Federal funding for market and product development.
Tax exemptions	19 U.S.C. 1309 26 U.S.C. 4221	Exemptions from customs duties and excise taxes for fishing vessel supplies.
Tax Reform Act		Accelerated depreciation schedules for capital property.
Training grants	16 U.S.C. 760d	Grants to universities and colleges to promote the education and training of scientists, technicians, and teachers in the field of commercial fishing.
Fishermen's Protective Act	22 U.S.C. 1973 and 1977	Reimbursement to fishermen for financial charges and losses sustained as the result of seizure by a foreign country outside that country's territorial waters.

\*The Fisheries Loan Fund ceased to exist in 1986.

\*\*Part of the Merchant Marine Act.

now, when stocks have collapsed and the economics of the fishery is devastated, limited entry is not widely favored (Hennessey & Healey, unpublished interviews).

During this quota management phase the NEFMC's attitude toward scientific advice was ambivalent. Initially, quotas were set on the basis of target allowable catches (TACs) determined by the NMFS. However, once these quotas were exhausted, the NEFMC appealed to NMFS to reconsider the TACs and adjust them upward (Bockstael, 1980). The uncertainty in scientific estimates of TAC became an argument for increasing quotas.

And when NMFS's estimates of fish abundance conflicted with fishermen's perceptions, the Council was likely to side with the fishermen. Disagreements among scientists about arcane methods of stock assessment and the NMFS's admission that they had failed to alert the Council to the good year class of haddock in 1978 reinforced suspicion in the NEFMC and among fishers of the NMFS' motives and their assessments. Yet the S&S Committee, which should have been able to advise council on these matters, was never consulted (Hennessey & Healey, unpublished interviews).

### **The Indirect Management Phase: 1982–1991**

As early as 1979, the NEFMC began discussing changes in management policy to remedy the perceived failure of the original groundfish plan. The Council decided to adopt an interim groundfish plan (IGFP) that would be in effect only until a comprehensive multispecies management plan for groundfish could be developed. Virtually all participants agreed that the quota-based, command and control regulatory approach of the original plan had been a dismal failure. The IGFP allowed "open fishing" and depended on minimum fish sizes and minimum mesh sizes coupled with spawning area closures for haddock to ensure stock conservation and rebuilding (Table 1). As it turned out, without enforceable quotas or limits on vessel entries, the IGFP was unable to protect the fishery resource.

Under the IGFP, much of Georges Bank was designated a large mesh area within which only trawl nets with cod end meshes of  $5\frac{1}{8}$  in (to be increased to  $5\frac{1}{2}$  in the near future) could be used. Areas where haddock spawned and where there were often large concentrations of small fish were closed to trawl fishing on Georges Bank and Nantucket Shoals. For commercial fisheries, minimum fish sizes of 17 in for cod and haddock and 11 in for yellowtail flounder were established. Recreational fishers could keep cod and haddock as small as 15 inches.

There was a significant exception to these rules. Vessels that had traditionally fished in the large mesh area for species other than cod, haddock, and yellowtail flounder could sign on to an "Optional Settlement Program." Fishers registered under this program could fish with nets of smaller mesh provided at least 50% of their total landings consisted of small mesh species listed by the regional director of the NMFS. The amount of cod, haddock, and yellowtail in the total landings of vessels participating in the optional settlement program was not to exceed 15%. NOAA approved the IGFP in early 1982 and its implementing rules in March 1982.

Given the failure of the earlier regulatory regime, enforceability was an important consideration in the NMFS's assessment of the IGFP. The NMFS insisted that trawlers fishing within the large mesh area be prohibited from carrying small mesh nets aboard. Otherwise, illegal fishing would be very difficult to detect. This concern was echoed by the New Bedford Seafood Council. NMFS also pointed out that minimum fish sizes were not enforceable because this would require warrantless searches of markets to discover undersize fish. The Optional Settlement Program required a heavy emphasis on verification of vessel status at sea and of reported data through dockside monitoring. Budget cuts within the federal agencies made it virtually impossible to monitor a sufficient number of landings to ensure compliance. Spawning closure areas, by contrast, did not impose unacceptable costs.

The response of NOAA administrators to these criticisms revealed their failure to understand or appreciate that enforcement was an integral aspect of the management process. For example, NOAA's reply to the concerns about vessels in the large mesh fishing area having small mesh nets aboard was "there is no benefit to the fisherman who uses a small mesh net when all of the undersized fish caught will have to be

discarded" (47 FR. 43706, Oct. 4, 1982). Furthermore, NOAA stated that it was the express intent of the NEFMC to allow vessels to carry a variety of gear because of the diversity of fishing practices among New England fishers. NOAA gave a similar response to concerns that without a uniform mesh size restriction throughout the net, fishers would shorten the cod end to capture fish in smaller meshes further forward in the net. NOAA noted that no unusual practices, such as shortening of cod ends, had been observed since implementation of "the interim plan" and that the minimum fish size nullified any advantage gained by fishing in such a manner (47 FR. 43707). These comments by the responsible government administration are remarkable for their failure to understand the incentives for fishers to violate the rules.

Because of their failure to appreciate the problems of enforcement, the Council and the federal government spent the majority of their time and resources from October 1982 to May 1984 dealing with mesh size abuses, something they could and should have anticipated from the beginning. Despite overwhelming evidence that many fishers were abusing the intent of the mesh size restrictions, and after several public hearings on the matter in 1984, the NEFMC failed to incorporate regulations prohibiting possession of small mesh nets while fishing in the large mesh area.

Even though problems with enforcement under the IGFP were well known, the NEFMC proposed a similar approach to management in the Atlantic Demersal Finfish Plan (ADFP). Commenting on the draft ADFP, the NMFS Office of Enforcement concluded that three years of experience with the IGFP indicated that fishers generally ignored the minimum mesh size rules and complied with minimum fish sizes only through extensive culling and the discarding of undersize fish. By contrast, compliance with closed spawning areas was generally good. The Coast Guard concluded that many of the enforcement problems encountered under the IGFP would continue if the draft ADFP was approved without revision. The Coast Guard and the NMFS enforcement office found that: (1) minimum mesh size was very difficult to enforce; (2) minimum fish sizes were impossible to enforce dockside if they had to prove that the fish were caught in the FCZ; and (3) the exempted fishery provisions could not be adequately enforced. They concluded that fishery benefits outlined in the plan did not justify spending \$16 million on enforcement and recommended disapproval of the ADFP on grounds that it could not be adequately enforced.

While debate continued on the draft ADFP, the Secretary of Commerce approved a time extension for the IGFP to September 1986. The Council submitted the ADFP for review by the secretary of commerce in August 1985. The management measures in the plan were essentially those in the IGFP. In addition, however, the ADFP included the establishment of a Technical Monitoring Group (TMG) that would do periodic assessments and report to the Council on their findings. The ADFP was also a "framework plan" in that it had built-in provisions for adjusting management measures in response to the performance of the fishery. This was to avoid the necessity of having to submit every minor change in regulations for approval by the secretary of commerce, a lengthy process that had been a major obstacle to timely management.

The secretary of commerce disapproved the plan on the grounds that "it did not demonstrate that it did prevent overfishing, or result in benefits outweighing costs" (51 F.R. 49580, January 1986; see Table 1). The acting regional director of NMFS sent a letter requesting that the NEFMC (1) consider more restrictive management measures, including effort control, catch controls, and numerical optimum yields; (2) prepare a detailed cost/benefit analysis of the measures; and (3) reevaluate the minimum sizes for each species in light of the recent severe declines in spawning stock biomass.

The response of the NEFMC was to resubmit the ADFP in April 1986, virtually unchanged. In June 1986, NOAA published the NEFMC's proposed rules and repeated

its position regarding overfishing, the exempted fishery, and the enforceability of the management measures in the absence of additional resources. The Coast Guard recommended that the plan be disapproved on the grounds of unenforceability. The NMFS had received reports from its field officers that there was virtually no compliance with current mesh regulations, reinforcing its position that the management measures in the draft ADFP were not enforceable. Nevertheless, NOAA partially approved the resubmitted plan and published interim rules to implement the approved portions in August 1986 (Table 1).

This abrupt reversal in NOAA's position with regard to the ADFP coincided with an act of political interference in the management process (Hennessey & Healey, unpublished interviews). The congressional delegation of the New England states had signed a letter to the regional director of NMFS urging him to approve the proposed plan in order to protect the fishing industry and the jobs that depended on it. In pursuing a plan that federal authorities had stated would not address a growing conservation problem in the groundfish fishery, the NEFMC appeared to be discounting scientific advice about the status of fish stocks in order to satisfy short-term economic and political objectives of fishers and their congressional representatives. Under intense political pressure, NOAA eventually acquiesced to a plan that its fishery experts believed was fundamentally flawed.

NOAA regarded the ADFP as essentially a continuation of the IGFP, under which key groundfish stocks had continued to decline. Thus, the ADFP was inconsistent with the MFCMA requirement to prevent overfishing. The secretary of commerce approved the plan for one year on the expectation that, among other concerns, the NEFMC would address the high levels of juvenile mortality that were being caused by abuses of the mesh and size limit rules. The secretary of commerce further expressed his expectation that the TMG would address the deficiencies in the ADFP as one of its initial tasks (51 F.R. 29643 and 29645).

To meet the secretary's concerns, the NEFMC submitted Amendment 1 to the ADFP in early 1987 (Table 1). Amendment 1 tightened restrictions on mesh sizes and closed areas but made no changes to minimum fish sizes. There was considerable public support for implementation of the amendment, although there was still some concern that the provisions were insufficient to prevent overfishing. The amendment was approved at the end of August 1987, and the regional director of NMFS wrote to the NEFMC, calling the amendment a significant step in the right direction. Concern for the state of the fish stocks remained high among federal agencies, however, and the regional director requested that the NEFMC work with the NMFS to develop measurable criteria for evaluating the amended plan's effectiveness in reducing fishing mortality on the depressed stocks.

Stock status did not improve (Fogarty & Murawski, 1998), and in October 1987, the minimum size for cod was increased to 19 inches. In December, The Office of Management and Budget wrote to the NEFMC expressing its concern for the development of more effective management measures. The assistant administrator for fisheries for NOAA discussed this letter with the regional director of NMFS and requested that he develop a stock monitoring plan by February 1988 and a stock recovery plan by March 1988.

In June 1988, the Council received the report of the TMG, which concluded that the stocks and catch-per-unit-effort of the principal groundfish species were at historic lows. The TMG argued that the ADFP should be evaluated as part of a total management system that included administration and enforcement. They noted that the current plan included regulations that were unlikely to be effective because the industry was not willing to comply with them and the authorities were not able to enforce them. They concluded that the ADFP's objectives were in conflict because it was not possible to

meet the ADFP'S spawning stock biomass goals while retaining for the industry a flexible and open access fishery with minimum regulation (TMG, 1988).

In October 1988, NOAA sent out Amendment 2 for public comment. Six of the nine measures in Amendment 2 were intended to improve compliance with existing ADFP measures, and three were to enhance the ability of the existing measures to achieve their objectives. Amazingly, mesh size and the single-mesh-size-aboard rule were not among the nine measures. NOAA noted that the current level of noncompliance with mesh size regulations argued against any increase in mesh size until the Council could be assured of compliance. Instead of pushing for a single mesh size aboard, NMFS opted for a modification to the definition of "nets not available for current use." This modification was developed to accommodate vessels that either had to fish in two separate areas with differing mesh regulations on the same trip or had to traverse regulated areas on the way to areas where regulated mesh was not required. Final rules implementing Amendment 2 took place at the end of February 1989 (Table 1).

At this time, the guidelines for the National Standards of the MFCMA contained a new requirement that referred to overfishing: "Each FMP (Fishery Management Plan) must specify, to the maximum extent possible, an objective and measurable definition of overfishing for each stock or stock complex covered by the FMP" (50 CFR 602, 11(c)(1)). Moreover, "if data indicate that an overfishing condition exists, a program must be established for rebuilding the stock over the period of time specified by the council and acceptable to The Secretary" (50 CFR 602.11(c)(6)(iii)). But, as Dorsey (1994) noted, "Like the requirement for a numerical definition of overfishing, this requirement is a precondition to meeting National Standard 1, because if overfishing is already occurring, it cannot be prevented in the future unless it is first eliminated through a rebuilding program" (p. 3).

In November 1989, the NEFMC proposed that the overfishing definitions for groundfish be the biological targets contained in the ADFP, which were 20% of the maximum spawning potential for most groundfish stocks. At the same time, the NEFMC acknowledged that the targets for cod, haddock, and yellowtail flounder were not being achieved. That is to say, the Council was admitting that overfishing was taking place on all of the major species. As Dorsey (1994) observed, "This was a useful admission to get from the Council because a number of its members, as well as the industry representatives, were reluctant to face up to the facts presented by the stock assessments and The Technical Monitoring Group Report and admit that age at entry [i.e., fish size limit] controls—the heart of the plan—were insufficient to meet the conservation needs of the fishery. This new requirement [for an overfishing definition] succeeded in nudging the Council to take the first necessary step to address overfishing. It established accountability for the fishery, a critical quality that had been missing since quotas were abandoned in 1982" (p. 5).

In November 1990, the NEFMC submitted Amendment 4 to the ADFP, the first amendment since the adoption of the overfishing definitions for groundfish (Table 1). In its submission the Council acknowledged that the overfishing thresholds had been crossed for the three principal species. Yet, the amendment contained no provisions to eliminate overfishing of these stocks or to rebuild them. Instead, the Council proposed to address overfishing in subsequent amendments (56 F.R.979, 1991). The Conservation Law Foundation, an environmental group concerned with the declining state of New England groundfish, advised the Council that Amendment 4 clearly violated the MFCMA's requirement that conservation and management measures prevent overfishing in accordance with the national standards. Nevertheless, NMFS approved Amendment 4 and promulgated regulations to implement it at the end of May 1991.

A full 19 months after it had admitted that the groundfish stocks were overfished, The NEFMC had not designed a plan to reduce effort or rebuild stocks. Furthermore,



the NMFS took no action to force them to do so, despite the NMFS's legal authority to prepare a secretarial plan to address the problems.

During most of the indirect management phase, neither the NMFS nor the fish stocks they were supposed to protect had any significant supporting constituency. The fishing industry attacked anything that got in the way of their open and unfettered access to the resource. Moreover, during the 1980s, the Reagan administration, in its antiregulatory zeal, substantially cut the budget of the NMFS. Congress not only failed to restore the agency's budget but went on to expand greatly its regulatory mandate. As Collins (1994) cogently observed, "NMFS incurred the largest percentage of budget reductions of any of the federal natural resource agencies during the Reagan years. Isolated within Commerce, NMFS had little support from the Secretary's office or NOAA. Its management and enforcement budgets crumbled and, as its financial resources declined, fishing industry criticism of its science increased. Assailed on all sides, the agency attempted to isolate itself from the pressures of the fishing industry, which only exacerbated the relationships further. This led to some conservationists alleging that the New England Council and the NMFS had been 'captured' by the fishing interests they were supposed to regulate" (p. 6).

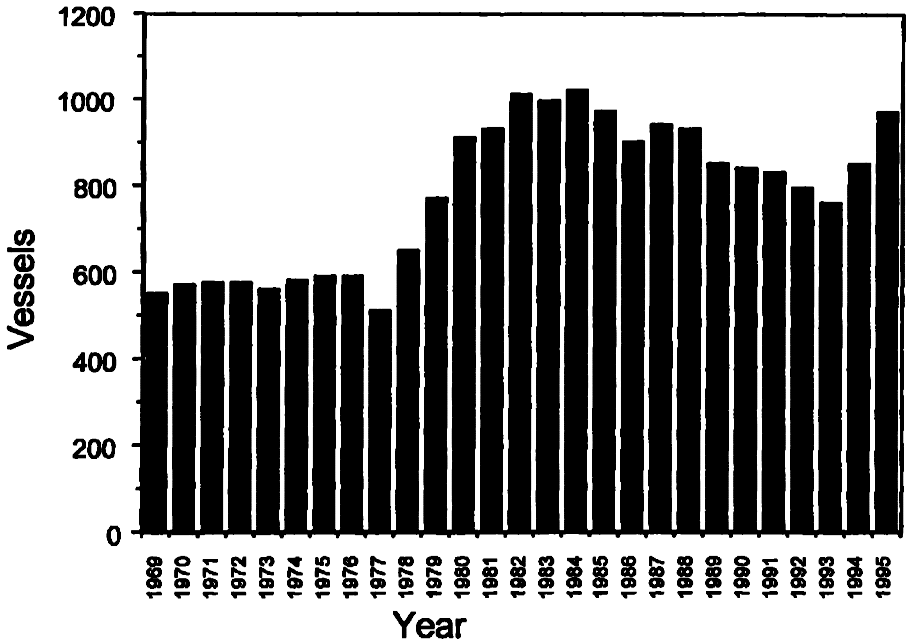
In a similar vein, Weber (1994) noted, "these circumstances led to a management system which did not effectively process scientific data and develop management options which were in the long run interests of the resource. Representatives on the NEFMC focused on their own narrow interests. The result was the evolution of 'the lowest common denominator' approach to management in which the least contentious option was usually adopted."

One of the most ecologically and socially damaging aspects of the conflicts within fisheries management was the high and increasing level of noncompliance with regulations that were developed during the 1980s (Sutinen, Reiser, & Gauvin, 1990). Sutinen, Reiser, and Gauvin identified four reasons for noncompliance:

1. *Price effects*: As stocks fell, fish prices increased, providing incentives for noncompliance.
2. *Imitation*: Previously law-abiding fishers began to imitate the economically successful behavior of illegal fishers.
3. *Weak penalties*: Often penalties were treated as a cost of doing business and they were generally much lower than the economic benefits of illegal fishing.
4. *Enforcement difficulties*: The coast guard reported that mesh size violations as well as other regulations were virtually unenforceable.

During the indirect management phase, there was a slow but continual decline in the number of otter trawl vessels operating in New England (Figure 3). By 1991, vessel numbers had declined by about 20%. Although changes in vessel numbers are important, their impact can be overshadowed by changes in fishing technology. All evidence indicates that the efficiency of individual fishing vessels increased substantially during both the quota management and indirect management phases. Roy and Gates (1991) estimated that, following implementation of the FCMA, catching power of individual vessels increased at an average rate of 1% a year in the New England otter trawl fleet. Edwards and Murawski (1993) estimated the increase in catching power to be 2% a year in the same fleet. Thus, the 20% decline in vessel numbers was more than offset by increases in vessel efficiency.

During the 1980s, declining landings created an incentive for fishers to fish longer and harder, because otherwise they could not afford to pay the deferred tax on funds they had withdrawn from their CCF account (Mooney, 1997). Nor could fishers afford to pay penalties for unqualified withdrawals from CCF accounts. Fishers could not avoid



**Figure 3.** Changes in the number of otter trawl vessels operating in New England, 1969–1995. Note that the number of vessels increased rapidly in the late 1970s and early 1980s in response to government incentives and that, despite the current poor catches, few vessels have withdrawn from the fishery. Data provided by the NMFS Northeast Fishery Center.

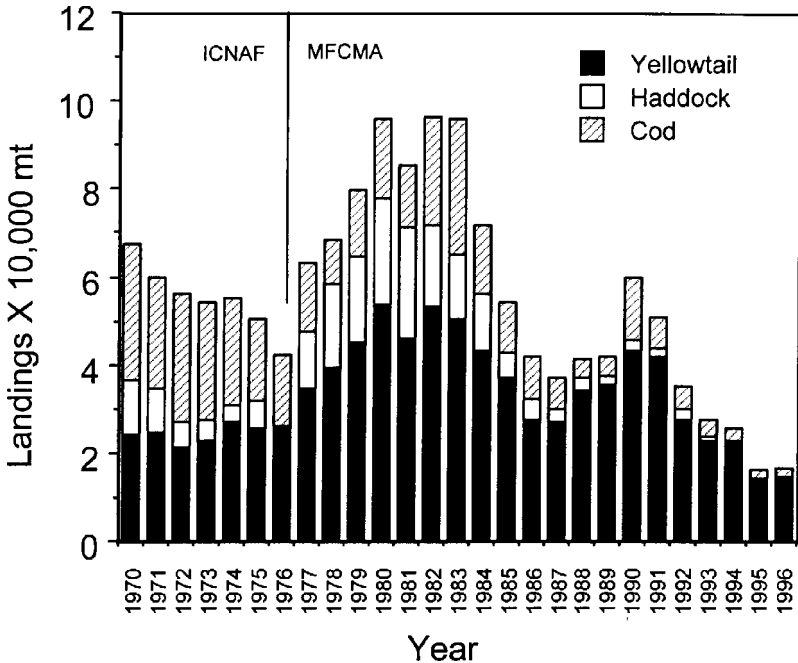
the tax problem simply by leaving the money in their CCF account until economic conditions improved because CCF accounts required that owners use the funds to construct or reconstruct a vessel within a finite period of time and many fishers were coming up against these deadlines. Thus, as fish stocks declined in the 1980s, fishers were still obligated to fulfill the requirements of the CCF to build more vessels. In a similar manner, fishers with loans through the FVOG program found themselves unable to afford the minimum payments required on their loan debts. Many borrowed more money and increased their time at sea in an effort to service their debts. This vicious circle had a destructive effect on the groundfish resource, as more powerful and more heavily capitalized boats chased fewer fish, leading to many bankruptcies and the eventual destruction of the groundfishery.

Despite these problems, there was still considerable incentive for new investment in vessels. Knowledgeable observers suggest that the accelerated depreciation provisions of the Tax Reform Act of 1980 had a dramatic effect on fleet capitalization as wealthy fishers as well as investors from outside the industry began to buy boats for tax relief (Hoagland, Kite-Powell, & Schumacher, 1996). These provisions were modified in 1986, but during the early 1980s their influence in sustaining fleet size and capitalization appears to have been considerable. Overcapitalization and the resulting overcapacity of the groundfish fleet has been identified as the single most important contributing factor to groundfish decline in New England, especially in the 1980s (U.S. Department of Commerce, 1995, p. 39).

The economic incentives for overcapitalization noted above are all consistent with Ludwig's ratchet. They underscore the willingness of government to give aid to the fishing industry during times of stock abundance and potential profitability, and their

reluctance to encourage disinvestment when stocks go into decline. Indeed, the government loan programs encouraged fishers to build new boats and increase their fishing efforts to repay the loans when the scientific and economic evidence showed that stocks, catches, and revenues from fishing were all declining. The increase in capacity, technology, and effort would have caused any remaining rents to be dissipated and the individual fishing units to be marginalized, as Ludwig's ratchet predicts, even if stocks had been stable. But stocks were declining. Under the IGFP, landings declined rapidly. Landings stabilized and increased briefly under the ADFP (due to recruitment of good year classes of cod and yellowtail) but then plummeted again in the early 1990s as first haddock, then cod and yellowtail stocks were devastated (Figure 4). During the late 1980s and early 1990s catch-per-unit-of-fishing-effort in the trawl fishery was half what it had been in the late 1970s. By 1990, the spawning biomass of the principal groundfish species had declined to the lowest levels ever recorded and the populations were at the point of collapse (Anthony, 1990, 1993; Fogarty & Murawski, 1998). Yet, new vessels were still being constructed.

During the indirect management phase an ineffective, unenforceable management regime coexisted with government subsidy programs that encouraged a continual increase in the number and power of fishing vessels. At the same time, the government was cutting to the bone the budget of the agency responsible for providing scientific advice on the state of the fish stocks and enforcement of fishing regulations. During this period, elected representatives from New England exacerbated the problems by pressuring the NMFS to approve a plan that was scientifically unsound. As a result, high rates of overfishing occurred in what was essentially an open access unregulated fishery.



**Figure 4.** Changes in catch of major species of groundfish, 1977–1996. Note the large increase in catch following U.S. declaration of 200 mile FCZ and subsequent declines in catch as stocks were depleted under various management regimes implemented by the NEFMC. Data provided by the NMFS Northeast Fishery Center.

### **The Effort Control Phase: 1991–1997**

During the period of indirect controls, conservation groups became increasingly concerned over the status of New England groundfish (Collins, 1994; Hennessey & Healey, unpublished interviews). The Conservation Law Foundation and the Massachusetts Audubon Society advised the Council that Amendment 4 was in violation of the MFCMA's National Standards, but the amendment was approved and implemented. In June 1991, the Conservation Law Foundation and The Massachusetts Audubon Society successfully sued the secretary of commerce, the director of the NMFS, and the regional director of NMFS for failure to prevent the overfishing of cod, haddock, and yellowtail flounder (U.S. District Court, 1991a, 1991b). In August 1991, the plaintiffs and the Department of Commerce signed a consent decree establishing a judicially supervised schedule for the development of an amendment to stop overfishing of cod and yellowtail flounder within five years and of haddock within ten years. The NEFMC was ordered to develop an amendment that would achieve these goals by September 1992 (Conservation Law Foundation vs. Mosbacher, 966F2nd.39, 1st Cir. 1992).

The court order for the secretary of commerce to put an end to overfishing led to law suits by industry challenging the authority of the secretary to execute the decree. These appeals were dismissed by the courts as being without merit.

The NEFMC produced a draft of Amendment 5 that met the terms of the consent decree by March 1992. When the draft went out to public hearings it was greeted with hostility by the fishing industry (Hennessey & Healey, unpublished interviews). Some of this antagonism was caused by a good 1987 year class of cod and yellowtail flounder, which began to appear in the fishery in 1990 and 1991 (Anthony, 1993; Fogarty & Murawski, 1998). Catches had improved somewhat, so that some fishers assumed the stocks were recovering. Thus, at this critical time, fishers remained highly suspicious of the validity of NMFS's scientific assessments of stock status.

Amendment 5, adopted by the NEFMC in September 1993 (Table 1), was designed to reduce fishing mortality by 50% over five years. Under the amendment, the number of days each boat could fish for groundfish was to be reduced by 10% each year, the fishery was closed to new entrants, and a moratorium was placed on some classes of new permits. The requirement to reduce fishing mortality by 50% within five years was the main revision to the old plan. The progress made in effort reduction would be reviewed after the third year of implementation, and at that time further reductions in fishing effort would be determined.

Despite its drastic measures, Amendment 5 was not designed to rebuild the stocks but only to hold the line on further reductions. Furthermore, it did nothing to reduce the size of the current fleet. Amendment 5 was approved by the secretary of commerce in January 1994 and went into effect in March 1994, more than four years after the NEFMC first acknowledged that the groundfishery was overfished (Shelly et al., 1996; see Table 1).

New information on the state of the fish stocks was provided by NMFS in December and January 1993 and again in August 1994. These assessments revealed that, to prevent further declines in cod stocks, a reduction of 60% to 70% in fishing mortality was required, not 50%, as required by Amendment 5. In December 1993, the NMFS reported to the NEFMC that Georges Bank haddock and southern yellowtail flounder stocks had both collapsed and advised that there should be no fishing on these stocks. Despite these alarming assessments, no changes were made to Amendment 5. As in the past, the NEFMC was unable to respond to new information so as to conserve the stocks.

In August 1994, NMFS's assessments showed that yellowtail flounder had collapsed throughout the region and cod was in imminent danger of collapse. On the basis of this

evidence, NMFS scientists took the highly unusual step of issuing a Special Advisory on Georges Bank groundfish. The Special Advisory declared that measures in Amendment 5 “were clearly inadequate to prevent the collapse of cod or allow the rebuilding of yellowtail flounder” (NMFS, 18th SAW, 1994, 53–54). The scientists advised that fishing mortality for these two stocks should approach zero. Thus, even before Amendment 5 could be implemented, the NEFMC was faced with the task of developing new amendments to deal with the deepening crisis in New England groundfish stocks.

Finally, if belatedly, the NEFMC decided that its objective should be to rebuild the biomass of cod, haddock, and yellowtail flounder. The Council also requested that the secretary of commerce take emergency management action to close Georges Bank and southern New England to fishing for groundfish (Shelly et al., 1996).

In January 1996, the NEFMC approved a set of measures (Amendment 7) intended to reduce fishing mortality by 80% from 1993 levels within two years, primarily by accelerating the effort reduction schedule of Amendment 5 (Table 1). But even with these drastic reductions in fishing effort, rebuilding ground fish stocks to acceptable levels of biomass could take from three to four years for yellowtail flounder and well over ten years for haddock (NEFMC, 1995, 1996). Under Amendment 7, the number of fishing days for each licensed vessel was reduced to 88 for the 1997 fishing year, with further reductions anticipated. Amendment 7 also included other management measures to assist with achieving stock rebuilding, such as area closures, minimum fish sizes, and TACs.

Consistent with Ludwig’s ratchet, the federal government has introduced a number of assistance programs to deal with unemployment and idle fleet problems associated with the groundfish collapse and subsequent regulatory actions taken under Amendments 5 and 7. The first of these aid packages, introduced in 1994, included loan restructuring, community planning grants, job counseling, and retraining grants to individual fishermen (Hamilton, Stout, & Helm, 1995). An additional \$25 million in disaster assistance was provided by the Department of Commerce to buy out fishers and retire permits and boats permanently from the New England Groundfishery (Hamilton, Stout, & Helm, 1995; Collins, 1995; Jagodzinski, 1997). By December 1996, the program had received over 164 applications, totaling \$58.25 million. The NMFS estimated that 80 vessels would be purchased and scrapped, which would reduce the fleet by 22% (Aguirre International, 1996).

Many fishers argued that the amount they would receive for their vessels in the federal buy out auctions would not pay their debts, much less compensate them for giving up their livelihood (Jagodzinski, 1997). Most fishers who considered getting out of the fishery decided to sell their vessels themselves for more money (Mooney, 1997). For many fishers, the \$25 million in the federal program was only a “drop in the bucket” compared to what was needed for a sound, large-scale fleet reduction program (Collins, 1995).

Amendments 5 and 7, as well as the buy-back program, are contentious issues in New England. Even though many members of the fishing industry are suffering severe economic hardship, many still argue that the groundfish stocks are not nearly as depressed as the scientists say. In 1998, the Multispecies Monitoring Committee of the NEFMC reported that stock status had improved for Georges Bank cod and yellowtail and Southern New England yellowtail. Fishing mortality rates for these stocks were below target levels except for Georges Bank cod. Spawning stock biomass had increased for these stocks, but was still below target levels except for Georges Bank yellowtail. Recruitments were also below long-term averages except for Georges Bank yellowtail. Thus, there is evidence of some positive response on Georges Bank but, unfortunately, Gulf of Maine cod have continued to deteriorate. Fishing mortality remains well above target levels for this stock, and both spawning stock biomass and recruitment are at

record low levels (NEFMC, 1999). Overall, these formerly highly productive stocks remain at critically low abundance, and there is no clear indication of when recovery can be expected (Fogarty & Murawski, 1998).

## Summary and Conclusions

Management decision making for New England groundfish under the MFCMA conforms remarkably well with the process we have termed "Ludwig's ratchet." As we have described, profit and the promise of profit when the United States declared sovereignty over the fisheries inside 200 miles attracted powerful economic and political interests to the fishery. These interests dominated decision making to the virtual exclusion of any meaningful influence from scientific assessments of the status of the principal stocks, at least until 1991. Furthermore, in New England and other fisheries that we have examined (Healey & Hennessey, 1998), the effects of Ludwig's ratchet have been intensified by hostility, mistrust, and poor communication among scientists, fishers, and managers and by frequent disconnection between public financing of fishing activities and the productivity and status of fish stocks. It was not just normal scientific uncertainty that weakened the influence of scientific advice in the management of the New England fishery, but scientific uncertainty coupled with low credibility of scientists among managers and fishers. And it was not just a normal emphasis on short-term gains at the expense of long-term stability that drove economic decisions in the fishery but, at times, a complete disconnect between government programs that encouraged capitalization on the one hand and the ability of the fish stocks to sustain greater harvests on the other. As a result, the fish stocks have collapsed and their capacity to generate wealth has been almost completely destroyed. Without significant changes in the approach to managing New England groundfish, there is little hope that the potential of this fishery will ever be realized. Indeed, changes in species composition on Georges Bank may militate against recovery of cod, yellowtail, and haddock even if overfishing is eliminated (Fogarty & Murawski, 1998).

In New England we have seen Ludwig's ratchet drive decision making in the fishery over two decades despite several changes in NEFMC membership as well as in government and senior officials at federal and state levels. This suggests that the problem is systemic and not related to any particular individual or philosophy regarding the fisheries. Furthermore, the downward spiral of fish stocks and the influence of Ludwig's ratchet is not confined to New England. Rather, it is a widespread phenomenon (Healey & Hennessey, 1998, unpublished data; Ludwig, Hilborn, & Walters, 1993) and probably contributed significantly to the severe overfishing of many important fish stocks in the United States and the world (FAO, 1988; Sissenwine & Rosenberg, 1993; Garcia & Newton, 1997).

Several modified and new approaches to fishery management have been put forward as ways to avoid the destructive effects of Ludwig's ratchet. These include: (1) strengthening the conservation rules governing management decision making; (2) strengthening the scientific information base to reduce uncertainty so that science can be a more effective basis for decision making; (3) confronting uncertainty and structuring decisions to reflect the reality of scientific uncertainty; and (4) allocating property rights to fish either to individuals or to communities so that public agencies are absolved of the full responsibility for conservation (Ludwig, Hilborn, & Walters, 1993; Pinkerton, 1989; Collins, 1995; Neher, Arnason, & Mollett, 1989; Ostrom, 1995; Scott, 1993; Jentoft, 1989; Hanna, 1997, 1998; Hanna, Folker, & Mahler, 1996).

In general, the solutions that demand a more strict regulatory framework are by no means guaranteed to succeed. Although we have shown that many regulations in the

New England fishery were inherently unenforceable, similar stock declines occurred off Newfoundland and in the southwest Nova Scotia groundfish fishery, which did not suffer to the same degree from unenforceable regulations (Healey & Hennessey, 1998). Experience in New England, Maritime Canada, and elsewhere shows that, if fishers do not agree with regulations, they will find ways to circumvent them (Sutinen, Reiser, & Gauvin, 1990; Angel et al., 1994). Although government intervention may at times be beneficial, we are doubtful that stricter regulations and enforcement will allow fisheries to escape Ludwig's ratchet. This is not to say that clear definitions of overfishing and sustainable fisheries, such as appear in the Sustainable Fisheries Act, are not important improvements to the institutional and regulatory framework. Such definitions are a necessary but not a sufficient basis for successful management. Nevertheless, the uncertainty in measurements of fish stock status will still permit Ludwig's ratchet to function, even in the presence of such definitions.

Successful escape from Ludwig's ratchet depends on limitation of access to the resource, meaningful incentives for fishers to conserve stocks, and meaningful disincentives for governments to invest in fisheries independent of stock performance. License limitation as a means to restrict entry is now almost universal in industrial fisheries, although still resisted by fishers and political interests in some regions. Limitation of entry remains a concern in the context of fishers' self-government, as Scott (1993) has described. However, the numerous examples showing that fishing communities are able to manage participation and harvest levels demonstrates that a community-based approach is possible (Hanna, Folke, & Maler, 1996; Pinkerton & Weinstein, 1995).

Individual Transferable Quotas (ITQs) and allocation of specific fishing rights to communities or engaging communities in comanagement have been presented as options to encourage a stronger commitment to conservation by fishers individually and collectively (McCay, Apostle, & Creed, 1998). Although transfer of quasi-resource-ownership rights to fishers has the potential to engage them more directly in conservation, experience to date has been mixed (Sissenwine & Mace, 1992; Mace, 1993; McDaniels, Healey, & Paisley, 1994; Scott, 1993; NRC, 1999a; Pinkerton, 1989; Hanna, Folke, & Maler, 1996). Furthermore, creation of additional ITQ fisheries in the United States has been delayed under the Sustainable Fisheries Act until October 2000 because of industry concerns.

In the case of ITQs, it typically rests with governments to set quotas and monitor stocks on behalf of the public (the ultimate owners of the resource). Even when these activities and the costs associated with them have been delegated in large measure to ITQ holders, the government continues to be responsible for the state of the resource. When stocks fluctuate, as they always do, government agencies can easily get drawn into cycles of conflict and investment while stocks decline, analogous to Ludwig's ratchet. This was seen in the orange roughy fishery in New Zealand and the surf clam/ocean quahaug fishery in the United States (Mace, 1993; NRC, 1999a). Implementation of ITQs does appear to reduce excessive capitalization of fisheries and improve the profitability of individual fishing vessels (NRC, 1999a). This reduction in inputs, however, comes at a cost of displaced fishers and livelihoods—a problem of fairness and equity (Nixon, 1998).

With community allocations or comanagement, two problems arise. First, a community-based infrastructure must be put into place that will administer the new responsibilities. Where there is no established tradition of such management, many false starts may be made before a workable arrangement is found. For example, of more than 100 salmon enhancement cooperatives that were initiated in Alaska in the 1980s, only 20 have done well enough to survive (Pinkerton, 1989). Implementation of a Community Development Quota (CDQ) system in Native communities of western Alaska appears to

have been quite successful in the short term, although there was one community organization (of six created) that experienced significant financial difficulty (NRC, 1999b). The CDQ system in Alaska has been criticized, however, for becoming disconnected from the participating communities (NRC, 1999b). This system also operates under strong oversight from the state of Alaska and the North Pacific Fishery Management Council and is dependent on these state and federal agencies for overall management of the fish stocks that provide the community quota. The study of successful community-based or comanagement systems has identified several principles that such arrangements should satisfy to be successful (Pinkerton, 1989; Ostrom, 1990; McDaniels, Healey, & Paisley, 1994). Not all fisheries are capable of being organized to satisfy those principles.

Second, where there are many different styles and types of fisheries harvesting from the same resources, successful community-based or comanagement implies that the community resource owners have been able to negotiate agreeable sharing of the resource between and within communities (Pinkerton & Weinstein, 1995; Ostrom, 1990, 1995). In complex fisheries (such as the Georges Bank groundfish) where the tradition is one of strong rivalry between fishers and communities, there seems little reason to believe that community allocations will foster the necessary cooperation (Scott, 1993). Some form of federal and/or state oversight will always be required to ensure that traditional rivalries do not jeopardize the resource.

Despite the problems inherent in ITQ and community-based management models, we believe that a more formal recognition of ownership rights for fishers and fishing communities has the potential to improve fisheries management and help avoid some of the most destructive excesses of Ludwig's ratchet (e.g., Hanna, Folke, & Maler, 1996; NRC, 1999a, 1999b). This will be particularly true if: (1) fishers are required to invest in the process; (2) that investment has the potential for significant economic returns; and (3) the participants can agree to an effective dispute resolution mechanism (McDaniels, Healey, & Paisley, 1994; Ostrom, 1995).

Fishery science also has a role to play in any escape from Ludwig's ratchet but not simply by reducing scientific uncertainty. For reasons well described by Ludwig, Hilborn, and Walters (1993) and Wildavsky (1979), greater scientific certainty will have relatively little influence on decision making. Of more direct benefit may be redefining institutions to integrate fishery science, fishery management, and fishery harvest more effectively. Over the past century, science, management, and harvest have evolved into three separate and largely independent solitudes (Healey & Hennessey, 1994). The recent evolution of resource management theory, however, has emphasized a new integration among these activities under the banner of ecosystem-based management (NMFS, 1999; NRC, 1999c; Hennessey, 1998; Healey, 1998). The NMFS has recently completed a report outlining how ecosystem-based management should be integrated into U.S. fishery management as mandated under the SFA (NMFS, 1999). The chief recommendation is for each fishery management council to prepare a fisheries ecosystem plan that addresses ecosystem principles, policies, and goals so as to increase significantly the sustainability of fishery systems. Although adaptive management was not specifically highlighted in the NMFS report, the increasing emphasis on adaptive management in fisheries is part of the evolution toward ecosystem-based management and is an attempt to integrate science more directly into management (Lee, 1993; Healey, 1998). The increasing emphasis on traditional and local knowledge as a basis for management and policy decisions is an attempt to integrate the knowledge systems of scientists and harvesters (Newell & Ommer, 1999). Although still tentative and untried in the modern context, this integration of science, management, and harvesting through ecosystem-based management appears to be the most promising avenue of escape from Ludwig's ratchet.



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