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Fleet dynamics and fishermen behavior: lessons for fisheries managers

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Abstract: We review fleet dynamics and fishermen behavior from an economic and sociological basis in developing fisheries, in mature fisheries near full exploitation, and in senescent fisheries that are overexploited and overcapitalized. In all cases, fishing fleets behave rationally within the imposed regulatory structures. Successful, generalist fishermen who take risks often pioneer developing fisheries. At this stage, regulations and subsidies tend to encourage excessive entry and investments, creating the potential for serial depletion. In mature fisheries, regulations often restrict season length, vessel and gear types, fishing areas, and fleet size, causing or exacerbating the race for fish and excessive investment, and are typically unsuccessful except when combined with dedicated access privileges (e.g., territorial rights, individual quotas). In senescent fisheries, vessel buyback programs must account for the fishing power of individuals and their vessels. Subsidies should be avoided as they prolong the transition towards alternative employment. Fisheries managers need to create individual incentives that align fleet dynamics and fishermen behavior with the intended societal goals. These incentives can be created both through management systems like dedicated access privileges and through market forces.

Résumé : Nous analysons la dynamique des flottes et les comportements des pêcheurs des points de vue économique et sociologique dans des pêches commerciales en émergence, des pêches en plein essor près de leur exploitation maximale et des pêches en déclin souffrant de surexploitation et de surcapitalisation. Dans tous les cas, les flottes de pêche se comportent de façon rationnelle dans les limites des structures réglementaires imposées. Les pêcheurs généralistes qui réussissent bien et prennent des risques sont souvent ceux qui initient les pêches en émergence. À ce stade, les règlements et les subventions tendent à encourager un excès de nouveaux exploitants et d'investissements, ce qui crée un potentiel pour un épuisement en cascade. Dans les pêches en plein essor, la réglementation restreint souvent la longueur des saisons, les types de bateaux et d'engins, les aires de pêche et la taille des flottes, ce qui cause ou exacerbe la course pour les poissons et l'investissement excessif; cette réglementation ne réussit généralement pas sauf lorsqu'elle est combinée à des privilèges d'accès ciblés (par exemple, des droits territoriaux et des quotas individuels). Dans les pêches en déclin, les programmes de rachat de vaisseaux doivent tenir compte du potentiel de pêche des individus et de leurs bateaux. On devrait éviter les subventions parce qu'elles prolongent la période de transition vers des emplois de rechange. Les gestionnaires de la pêche doivent créer des incitations individuelles qui ajustent la dynamique des flottes et le comportement des pêcheurs aux objectifs fixés par la société. Ces incitations peuvent être mises au point, tant par les systèmes de gestion comme les privilèges d'accès ciblés que par les forces du marché.

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Introduction

A fishery consists of two essential elements, populations of fish in their ecosystems and humans capturing the fish. It has often been noted (e.g., Wilen 1979; Hilborn 1985; Hilborn and Walters 1992) that we rarely manage the fish, and almost all regulatory action affects the fishing fleets pursuing the fish. Therefore, studying fishing fleets and their behavior should be as important a part of fisheries science as studying the ecology and population dynamics of the fish. Although the study of fish continues to dominate the funding by management agencies and the publications in scientific journals dealing with fisheries, over the last 25 years a significant literature on fishing fleets has developed.

The literature on fishing fleets is highly interdisciplinary, with publications by ecologists, economists, anthropologists, sociologists, and mathematicians. Few fisheries managers or scientists have had the opportunity to assimilate the collective knowledge regarding fishing fleets. Nevertheless, anyone involved in managing fisheries needs to be aware of the lessons of history in how fishing fleets begin, develop, and respond to regulation and closure, i.e., the dynamics of fishing fleets. The purpose of this paper is to fill this gap by reviewing the broad literature on the dynamics of fishing fleets: what determines where fishermen fish, how much they fish, how they invest in new fishing gear, and how they respond to regulation and enforcement. This field of study on fleet dynamics is essentially an analysis of the population dynamics of fishing fleets, of which there have been no reviews. Salas and Gaertner (2004) reviewed the literature on small-scale fisheries, but in this literature review we will concentrate on lessons learned from the major commercial fisheries of the world.

The universal societal goals for fisheries are to maintain healthy fish stocks to ensure sustainable fisheries, that is, to sustain the jobs, income, and food that flow from the act of harvesting fish (e.g., Pew Oceans Commission 2003). Accordingly, key words used in the Magnuson–Stevens Fisheries Management and Conservation Act include "optimum yield" and "take into account the social and economic needs of the States". Here we see the fundamental blind spot of fisheries management and policy; although the objectives are to achieve the long-term health and viability of fisheries, the prescription is to protect marine ecosystems with no words or thoughts to the dynamics of fishing fleets, including their economics and behavior. In general, fisheries management has operated under the paradigm that if you take care of the fish, you will manage fish well.

There are few formal discussions of the tradeoffs needed between different objectives in fisheries management. For instance, is the main objective to generate employment or economic efficiency? How much are we willing to overharvest less economically important species to maximize the harvest or profit from more important species? What value do we assign to commercially unimportant species such as birds and marine mammals? In the US, a few of these issues are settled in legislation such as the Endangered Species Act and the Marine Mammal Protection Act, but many other issues remain unaddressed.

We have organized this review around the cycle of fisheries development as classified by Grainger and Garcia (1996). They divided the world's major fisheries into developing, mature, and senescent, broadly displaying increasing, stable, and declining catch series; later work has suggested that 24%, 52%, and 24% of the world's fisheries fall into these three categories, respectively, and that over time, fewer and fewer fisheries will be classed as developing (United Nations Food and Agriculture Organization (FAO) 2004). During the discovery and growth phase of fisheries, the primary dynamics are the entry of new participants, the expansion of fishing capacity, and the exploration of new fishing grounds. Regulations are usually minimal during this development phase, yet during the growth phase, conditions that are set can encourage subsequent overcapitalization and economic decline. As fisheries mature, management tends to become more intrusive, limited entry is usually introduced, and stock assessments become critical. Finally, it is all too common that fleets become too large, fish become too rare, and fisheries senesce. Management actions then often include attempts at fleet reduction and rationalization, and it is important to understand how individuals and fishing fleets respond to subsidies, buybacks, and dramatic total allowable catch (TAC) reductions. During each of these phases, understanding the behavior of fishing fleets is essential to achieving reasonable long-term biological and economic management.

The problem of the race for fish

No review of fleet dynamics would be complete without at least a brief discussion of the implications of many fisheries being a common-property (or open-access) resource. Under these conditions, individuals receive all of the economic benefits of taking more of the resource (the income from fishing), while the consequences of their actions (stock depletion) are shared among all resource users, resulting eventually in the tragedy of the commons (Hardin 1968). The consequences are that fishermen (if allowed) will continue to enter a fishery as long as revenues minus costs remain above zero, until ultimately the net revenue of the entire fleet is zero — the bionomic equilibrium (Gordon 1954). At this equilibrium the resource is depleted as far as economics will allow and fishermen will move to alternative fisheries, resulting in the sequential depletion of fish stocks (e.g., Hilborn et al. 2003). Furthermore, at the bionomic equilibrium, any stock that has low harvest costs compared with revenues will be overexploited and overcapitalized or, in extreme cases, will become commercially extinct (Gordon 1954). There are wider implications of this theory, for example, reducing season length will result in a more frantic and overcapitalized race for fish (e.g., Gordon 1954; Pautzke and Oliver 1997), and adding subsidies will result in even greater overcapitalization and overexploitation of the fish stocks (e.g., Mackinson et al. 1997). The open-access race for fish, subsidies, and overcapitalization results in annual economic wastage of US$2.9 billion in US fisheries and US$60 billion worldwide (Christy 1997).

Management issues for new and developing fisheries

Few new fishing resources remain undiscovered (Hilborn et al. 2003). For those that remain, managers walk a delicate line in providing incentives that encourage the development of new fisheries while ensuring that those fisheries will be effectively managed if and when they mature. Minimizing regulatory interference will encourage individual entrepreneurs to experiment in new fisheries but may lead to an open-access situation with the attendant problems of massive increases in fishing effort and depletion of the stock (e.g., Gunderson 1984). If the regulations are cumbersome and expensive, this will tend to discourage attempts to develop new fisheries (Miller 1999). It seems reasonable to restrict the number of initial participants for a specified time period and review the progress of the fishery if catches exceed a threshold level (Boyer et al. 2001). This will ensure that the initial entrepreneurs are guaranteed a return on their investment in exploratory fishing and new gear and techniques and that depletion does not occur too soon.

In a new fishery, the rate of entry and the types of fishermen that will be attracted will depend on which fishermen think they will be better off, as predicted by standard economic utility theory. Utility theory assumes that people are rational and will attempt to maximize their happiness or satisfaction by (if possible) gaining more of whatever goods or services they desire. Bearing this in mind, we examine who enters new fisheries, how managers confront uncertainty in new fisheries, and why both biological and economic management are essential for the successful development of fisheries.

Who enters new fisheries?

Fishermen are not identical. Some will be generalists that give up some efficiency to gain the ability to fish in multiple fisheries, and others will be specialists who invest heavily in a particular fishery but cannot easily switch to another fishery (McKelvey 1983; Smith and McKelvey 1986). Both types can be active in a given fishery because generalists will be drawn into that fishery in years of high catches. Fishermen can also be divided into “stochasts” and “Cartesians” (Allen and McGlade 1986). Stochasts are willing to lead the fishery in new directions and to take risks to explore new resources, whereas Cartesians follow the leaders to exploit resources after they have been discovered. Thus stochasts may be willing to accept significant risk in exchange for high rewards, whereas Cartesians are willing to forgo occasional high returns for a steady, but lower, income.

If many different types of fishermen do exist, one would expect to see wide variation in catches among fishermen. Some (termed “highliners”) would repeatedly catch large quantities of fish, whereas others would consistently obtain smaller catches. Highliners are usually stochasts and are likely to be the first people to develop new resources (Allen and McGlade 1986; Holland and Sutinen 2000). They are also likely to be generalists that are constantly exploring a range of fisheries. Over time, technology may develop to increase the efficiency (and usually the costs) of operating in that fishery, and then the specialists start to predominate; thus well-established fisheries primarily consist of specialists (Smith and McKelvey 1986). Perspectives will tend to differ among fishermen: generalists are often more focused on short-term gains relative to other opportunities, whereas specialists may be more interested in ensuring the long-term sustainability of their fishery (Smith and McKelvey 1986). The degree to which vessels and skippers each determine catching power has been debated (e.g., Pálsson and Durrenberger 1982; Hilborn and Ledbetter 1985; Squires and Kirkley 1999); however, highliners will be active in exploration whether catching power is due to vessel or skipper characteristics.

Although risk-loving behavior might be thought to be more common among fishermen exploring new fisheries, it appears to be relatively rare in the literature. This may be because it is difficult to accurately classify fishermen into the categories of risk-loving and risk-averse: fishermen may appear to be risk-loving but are actually just making bad decisions, relying on poor information, or are unlucky. When risk-loving behavior has been identified, it is generally displayed by only a portion of fishermen (e.g., Dupont 1993; Mistiaen and Strand 2000), perhaps reacting to the news of a few highly successful trips instead of average income (Holland and Sutinen 1999). Risk aversion is much more common and may contribute to a bias towards staying in the same fishery despite favorable alternatives elsewhere (e.g., Hilborn and Ledbetter 1979; Dupont 1993). However, it should be noted that high switching costs (Hilborn and Ledbetter 1979; Dupont 1993) or great uncertainty about catches outside known areas (as in the historical Swedish longline fishery; Poulsen 2005) might result in a rational response to eschew exploration.

The first entrants into a new fishery would therefore be expected to be generalists who are drawn towards opportunities with an expected high payoff, but are not necessarily risk-loving. These conclusions are, however, largely based on theory and not fisheries case studies.

Factors influencing entry and exit decisions

Entry and exit decisions in fisheries cannot be considered in isolation. Individuals may enter a fishery because it is a new fishery or as a result of spillover effects caused by the collapse of existing fisheries. There is limited literature studying these entry–exit decisions. Although numerous case studies exist about the development of new fisheries, only two studies were found that examine the relative earnings of fishermen that enter, remain in, and exit fisheries. Pradhan and Leung (2004) explored entry–exit decisions in the Hawaii longline fishery, which targets tuna and swordfish. In this fishery, earning potential, fleet size, and resource abundance affected entry–exit decisions, and fishermen were more likely to stay in the fishery if the vessel owner was a resident of Hawaii. Furthermore, annual revenue, number of trips, and days at sea was highest for those who remained in the fishery and lowest for those who exited.

Entry–exit behavior was also examined in the Gulf of Mexico shrimp fishery (Ward and Sutinen 1994). In contrast to the results of Pradhan and Leung (2004), new entrants to the fishery had the highest average catches, 1053 kg per trip, whereas those who remained in the fishery averaged 762 kg per trip, and exiting vessels averaged only 583 kg. The probability of exiting was most affected by harvesting costs and ex-vessel prices.

Culture and hierarchy also matter. In Iceland, low catches are considered to be humiliating, so leaving the fleet to explore new fishing opportunities is only possible for successful captains with close bonds to crew (Pálsson and Durrenberger 1982). The costs and benefits of search may vary for different fishermen.

The above analysis fails to really capture the "who" of a new fishery. Some evidence suggests that it is highliners, but we do not have a clear theory or pattern to explain the type(s) of fishermen expected to predominate in new fisheries. More research tracking fishermen before and after they enter a fishery is needed to better understand the particular characteristics of fishermen in new fisheries.

The role of uncertainty in managing developing fisheries

Managing and tolerating uncertainty is a key aspect of fishery management. What happens depends on biology, economics, and management institutions. How one controls access will clearly have large effects on what happens in a fishery. Hilborn and Sibert (1988) found that most fisheries do not have the institutional capacity to restrict fishing effort when necessary, an essential component of effective management.

New fisheries may develop from a sideline fishery, previously discarded bycatch, or from fish previously unknown to fishermen. Technology may also be developed or imported that makes a particular type of fishing or processing viable (e.g., US West Coast shrimp processing). New species may also be added to a suite of fishable species, as in the US West Coast trawl fishery (Gunderson 1984), which may change the dynamics of the fishery to encourage new entry and present new management challenges. For bycatch and sideline fisheries, managers should assess what conditions changed to cause the fishery to be targeted: have the market conditions changed for the previously nontargeted fish or is this stock part of a process of sequential depletion? If a new stock is "found" or "discovered", as stocks of orange roughy (*Hoplostethus atlanticus*) and swordfish (*Xiphias gladius*) commonly are, a different set of conditions may apply. The fishery may be extremely valuable and could suffer rapid and irreversible depletion if it is not carefully regulated.

Many factors drive the degree to which fishermen will enter a fishery as it develops. Available capital and fishing equipment, knowledge about the fishery and the institutions that govern it, and market conditions for the fish will all affect entry. There may be investment lags between the decision to enter and actually entering the fishery, and in some cases, the initial years may be unprofitable (Pradhan and Leung 2004). However, one has to carefully weigh these investment trade-offs with the benefits of capturing rents (economic returns that exceed the minimum required to induce entry to a fishery) in a newly developing fishery. The first entrant in a new fishery may develop highly profitable, near-monopoly power if the demand for the fish is strong. Given the depleted condition of many existing fisheries, it is more likely that a developing fishery will experience a rapid influx of new entrants, thus the survival of a fishery often depends on swift action well before any signs of stock decline emerge (Walters 1998).

Several examples illustrate how quickly fisheries can decline. The Namibian orange roughy fishery expanded and declined within 6 years (Boyer et al. 2001). The story of this fishery is not one of inattention, but rather highlights the problems of uncertainty and optimistic interpretations of the biological state of the fishery. The fishery followed "best practices", but managers did not pay adequate respect to uncertainty in all aspects of management, which led to the rapid decline of the fishery. With a long-lived species such as orange roughy, recovery will be extremely slow and the overly optimistic management of the fishery was costly.

Widow rockfish (*Sebastes entomelas*) on the US West Coast are another example of how one can "miss the boat" in a very short period of time. Excessively optimistic interpretations of data led to the collapse of this fishery in just 3 years and therefore "imprecise assessments necessitate coarse controls, with ample protection against damage to the resource base from overharvesting" (Gunderson 1984). Subsidies for new boats combined with declining alternative stocks and nonscientific allowable catch levels contributed to overfishing and rapid exhaustion of the widow rockfish fishery.

Managing both the biology and economics of new fisheries

Many new fisheries have included an initial period in which managers made concerted efforts to understand the biology of the fish being exploited. What has almost always been missing from this period, however, is an effort by managers to control the economics of the fishery. The key point here is that even if a fishery is managed ideally from a biological perspective, most of its benefits will be squandered if the fishery operates under open-access conditions.

Exploratory fishing often results in lower catch rates (e.g., Rijnsdorp et al. 2000). If fishermen knew that they would have greater catch by exploring, they would explore all of the time instead of continuing to fish in known grounds. However, because open access leads to rent dissipation in established fisheries, new fisheries present the best opportunity for fishermen to capture positive resource rents.

The wreckfish (*Polyprion americanus*) fishery in the southeastern US provides an example of how management can fail both biologically and economically, leading to the benefits of a fishery being lost to open access. The wreckfish fishery was discovered when swordfish longliners were recovering pieces of pelagic longline gear (Gauvin et al. 1994). From 1987 to 1990, the wreckfish fishery expanded from less than 13.6 t to 1800 t, and the fleet grew from two to more than 20 vessels. An intense derby-style fishery in 1990 resulted in the entire TAC being caught within 2 months. Prices plummeted because of the resulting glut of product on the market. In 1992, individual transferable quotas (ITQs) were implemented and the severe open-access problems were addressed (Gauvin et al. 1994). However, the implementation of ITQs did not solve all the problems in the fishery because the TAC was set too high and overfishing continued up to 1994, leading to declining catch rates, and as a result, the catches decreased steadily to 10% of the allowable quota in 1998 (Vaughan et al. 2001). Given the long reproductive lives of wreckfish and uncertainty about their population status, it is unclear whether or not the population is currently being overfished, despite low catch levels. During the short time when there was a strong market for wreckfish and high catch rates, many of the rents were lost because of open access. Despite belated attempts to be biologically responsible, a failure to quickly address the economic problems and to conservatively assess the biological potential of the fishery led to the loss of most of the possible economic gains from the fishery. Although ITQs can much better capture the economic benefits of a fishery, ITQs cannot revive a severely depleted fishery, nor can they ensure that favorable market conditions will continue.

Implications of fishermen behavior in the management of new fisheries

In summary, a relatively limited amount of research has been conducted about entry–exit behavior in fisheries, and little empirical analysis has been conducted about what types of fishermen enter new fisheries. Nevertheless, we can suggest a number of practical rules for managing new and developing fisheries.

Joint biological and economic management is crucial when starting a new fishery. It is insufficient to aim solely for biological sustainability at the start of a fishery, because there is great uncertainty about what catch levels will be sustainable, and because a rapid buildup in the fleet size could swiftly deplete the fish stock. Conversely, it is insufficient to aim solely at maximizing economic benefits from the fishery, because in some cases, the greatest benefits are obtained by rapidly depleting the stock (e.g., Clark 1973), and legal mandates for conservation render this option unacceptable. Instead, managers of new fisheries should concentrate on controlling both fishing mortality and fishing capacity to ensure biological and economic sustainability.

Research about the fishermen involved in new fisheries also has several implications. Fishermen exploring new fisheries are likely to be generalists and highliners who are more willing to tolerate risk than other fishermen. Managers of new fisheries might therefore reasonably focus their attentions on a limited class of fishermen most likely to participate in new fisheries. The risk of economic overexploitation (i.e., wasteful overcapitalization) will increase when there are few alternative fisheries and large amounts of latent fishing capacity suited for generalist fishing. The risk of biological overexploitation will be highest when the species is valuable, costs little to exploit, is easily caught, and is both long-lived and slow-growing.

Unfortunately, fisheries have a long history of sequential depletion, readily evident in the history of whaling, in which fishermen focused on increasingly less commercially valuable species of whales (Hilborn et al. 2003). Rapid responses to the development of new resources are necessary to prevent fishermen from repeating this pattern throughout the world's fisheries.

Mature or established fisheries

In established fisheries, managers tend to concentrate on how to assess the status of the stocks and how to control fishing effort. In many fisheries, attempts have been made to control fishing effort by restricting season length, vessel and gear types, and fishing areas and by limiting the number of boats. These options generally cause or exacerbate a race for fish and excessive investment. Managers and researchers have therefore displayed considerable interest in alternative management systems such as granting dedicated access privileges to specific user groups.

Fisheries stock assessments

In all stages of fisheries development, but perhaps particularly in established fisheries, stock assessments are used to estimate the current status of fish stocks. Typically, stock assessments rely on a combination of information obtained from fisheries, such as commercial catch-per-unit-effort (CPUE) indices, catch length frequencies, and catch-at-age data, and fisheries-independent data obtained from standardized trawl or acoustic surveys. Clearly fleet dynamics and fishermen behavior do not affect fisheries-independent surveys or the data they produce, thus we concentrate on their influence on commercially obtained data.

Commercial length and age frequencies

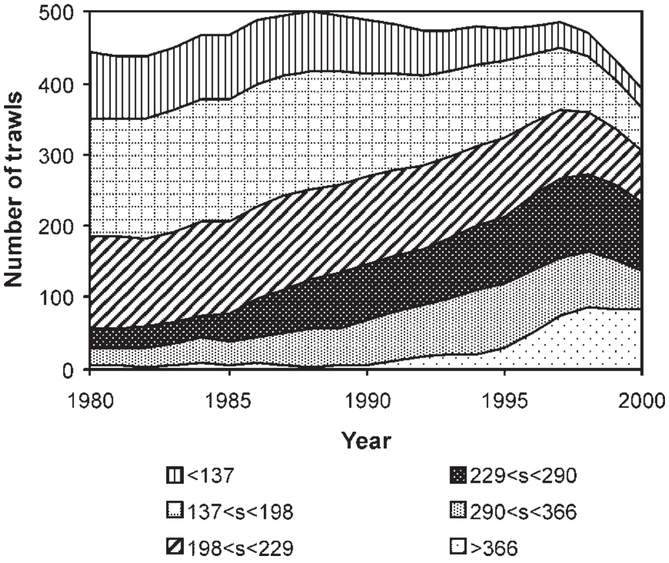
Length and age frequencies are most useful if they are representative of the entire fish stock and not merely the commercially caught component of the fishery. However, it is surprisingly hard to get representative samples of population size structure because of gear selectivity (size classes, sexes, and species may be differentially selected by the fishing gear), spatial changes in distribution with increasing size, and the difficulty in obtaining random samples from catches (Hilborn and Walters 1992; Pennington et al. 2002). As fisheries develop, fishermen may alter fishing gears, expand into deeper waters (containing larger fish), start fishing in different areas, or target different components of the population (spawning aggregations vs dispersed individuals) (Hilborn and Walters 1992). At a minimum, it seems prudent to analyze length- and age-frequency data separately for each gear type and area fished and to downweight age- and length-frequency data used in stock assessment models by assuming that effective sample sizes are much smaller than the actual number of fish measured (Pennington et al. 2002).

CPUE indices

The analysis of CPUE plays a disproportionately large role in fisheries stock assessments because CPUE data is relatively cheap and easy to collect compared with other stock assessment inputs. The simplest assumption in using CPUE data is that trends in CPUE are linearly related to abundance. Unfortunately, CPUE is the most likely of all data inputs to be influenced by fleet dynamics and fishermen behavior, including increases in fishing power, information sharing, switching between target species, and many other factors. Only a brief summary of this subject is included here, as it would be better treated in a separate paper.

Fishing power tends to increase over time for various reasons, depending on the fishery involved; thus it is naïve to expect restrictions on nominal effort to constrain actual fishing mortality. In the Finland herring fishery, for example, the number of fishing trawls remained constant, but improvement in net design resulted in their average size increasing by a factor of 2.7 over two decades (Fig. 1) (Rahikainen and Kuikka 2002). In the Australian northern prawn fishery, despite nominal effort reductions of 39%, adopting GPS (global positioning system) and plotter increased fishing power by 12% in 5 years through more accurate targeting and charting of fishable areas (Robins et al. 1998). Stock assessments should therefore take into account the disparity between nominal effort and true fishing power, while management

Fig. 1. Number of trawls of different sizes (*s*; m) employed in the Finland herring (*Clupea harengus*) fishery. Modified from Rahikainen and Kuikka (2002).



policies should attempt to constrain actual fishing mortality and not nominal fishing effort.

Information transfer allows fishermen to reduce the time they spend searching for aggregations. If the fish stock declines, but search time remains low, CPUE will hardly decline, breaking the assumption of proportionality between CPUE and abundance. Information transfer is widespread but varies greatly depending on the size of the fishing community, relatedness of participants, differences in ethnicity, and the biology of the species involved (sedentary or mobile). Active information transfer is when direct communication is used between fishermen, typically between close relatives and long-standing friends, such as that observed in the Maine lobster fishery (Palmer 1991) and the southeastern Alaskan salmon purse-seine fishery (Gatewood 1984*a*). Passive information transfer occurs when fishermen observe other fishermen and is most common when targeting highly migratory or mobile species; in such cases, a combination of exploration and following other vessels will increase catch rates (Mangel and Clark 1983; Vignaux 1996; Ruttan 2003).

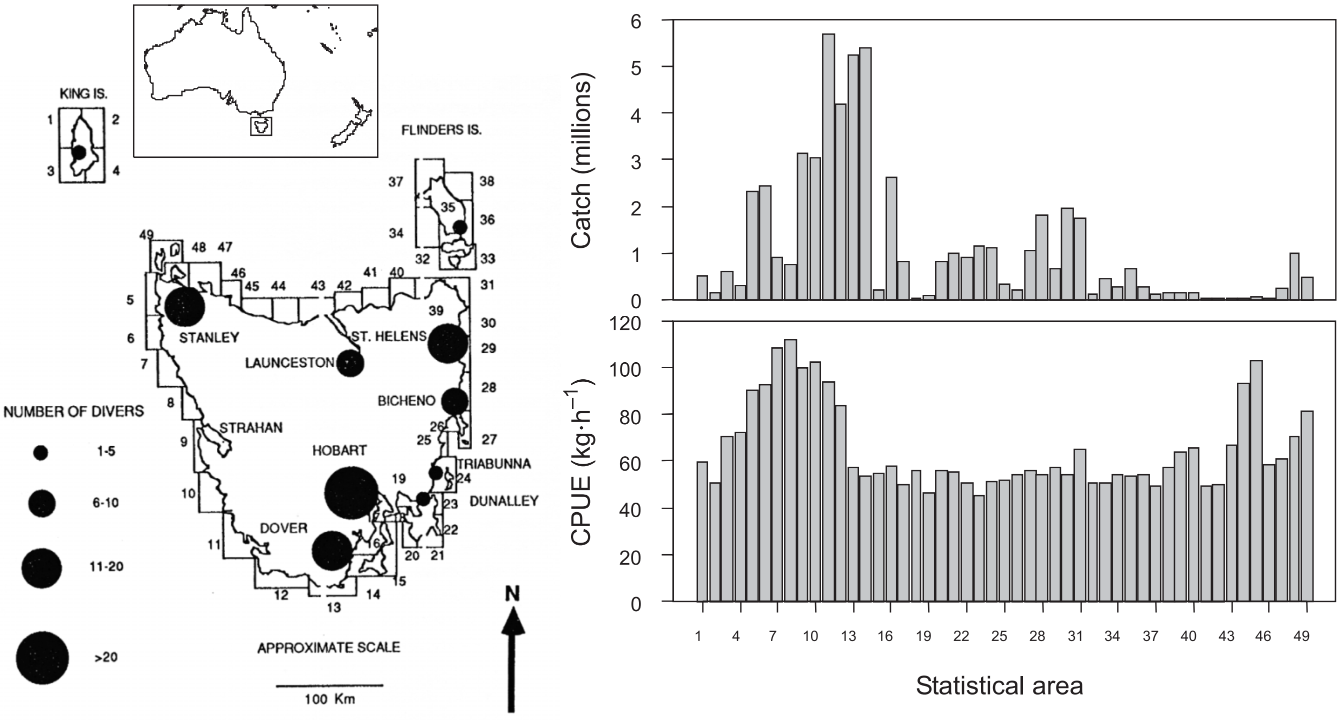
In multispecies fisheries, the target species may change from trip to trip or even from trawl to trawl, making it difficult to estimate CPUE for any individual species. In the Danish fishing fleet, for example, there are 25 vessel groups targeting 54 fisheries, and there was evidence for shifting between gears and areas, especially in secondary fisheries (Ulrich and Andersen 2004). Fishermen will target the most valuable species where possible, but fluctuations in market prices and allowable catches of particular species could result in the targeting of different size classes (e.g., Béné 1996) or different species (e.g., Holland and Sutinen 1999), complicating the analysis of CPUE.

It might be thought that spatial patterns in CPUE can be examined to determine where fish are present at highest abundances and hence where productivity is greatest, but CPUE turns out to be surprisingly constant over large spatial areas in fisheries ranging from oceanic longline fleets to crabbers to abalone divers (e.g., Prince and Hilborn 1998; Fonteneau and Richard 2003; Swain and Wade 2003). The theory of the ideal free distribution (IFD; Fretwell and Lucas 1970) explains this phenomenon. The IFD predicts that when foragers have perfect knowledge about resources in a number of different areas and there is no cost to choosing among areas, then the attempts of each forager to maximize their profitability will result in an equalization of profit rates in all areas. At this equilibrium, the number of foragers (fishermen or fishing effort) in each area will reflect the abundance better than the profit rate (CPUE). Fisheries research in this field has been reviewed by Gillis (2003). It turns out that although fishermen do not have perfect knowledge and the average fishery is not in equilibrium, these assumptions are sufficiently well approximated in fisheries for the IFD to hold. A classic example is the Tasmanian abalone (*Haliotis rubra*) fishery (Fig. 2) in which CPUE is equalized among accessible areas, despite catches differing by several orders of magnitude (Prince and Hilborn 1998). CPUE was greater only on the west coast of Tasmania (Fig. 2), reflecting that region's inaccessibility and worse weather, which combine to reduce the number of days on which fishing can occur (Prince and Hilborn 1998). Thus, deviations from IFD predictions generally point to violations of the underlying assumptions of free movement and perfect information, due to fuel costs, difficult terrain, poor weather, and other factors (Hilborn and Kennedy 1992; Prince and Hilborn 1998; Swain and Wade 2003).

There are thus many factors related to aspects of fleet dynamics and fishermen behavior that can reduce the comparability of CPUE among years and areas and obscure the relationship between CPUE and biomass levels. To detect CPUE signals, it has become common practice to standardize CPUE data to remove trends in vessel characteristics, fishing season, fishing ground, and other factors unrelated to stock abundance (Maunder and Punt 2004). However, even when CPUE series were standardized, a meta-analysis examining CPUE paired with independent research abundance estimates showed that in most cases (70%) there was evidence of hyperstability (when CPUE remains high while stock abundance declines) (Harley et al. 2001). An extreme example of this phenomenon occurred in the northern cod (*Gadus morhua*) fishery in which CPUE actually increased as the stock declined, leading to misleading stock assessments, unsustainable fishing mortality, and the eventual collapse of the stock (Rose and Kulka 1999). Hyperdepletion (when CPUE declines faster than abundance) is also a possibility when intense localized depletion of dense aggregations depreciates catch rates but does not greatly affect overall abundance (e.g., Sosa-Lopez and Manzo-Monroy 2002; Fonteneau and Richard 2003). Accordingly, the claims by Myers and Worm (2003) that the biomass (they actually examined CPUE) of oceanic predators was reduced by 80% within 15 years of industrialized fishing have recently been questioned (Polacheck 2006) because these rapid CPUE declines occurred during a period of historically low effort and catches, suggesting hyperdepletion.

In conclusion, either hyperstability or hyperdepletion should be suspected in every fishery because of the interaction between fleet dynamics and the spatial distribution of the resource. At a minimum, fisheries managers and scientists need to standardize CPUE data, to split CPUE series

Fig. 2. Catch (millions of abalone) and catch-per-unit-effort (CPUE; kg·h^{-1}) in the statistical areas of the Tasmanian abalone (*Haliotis rubra*) fishery (statistical areas shown in lower map; location of Tasmania off the southern coast of Australia shown in upper inset). Catches are summed over 1965–1986, CPUE is averaged over the same period. Modified with permission from Prince and Hilborn (1998).



when technology or fleet behavior changes, and to treat the resulting series with a healthy dose of skepticism.

Input controls

Stock assessments provide recommendations on what level of removal is appropriate for fish stocks, but fisheries managers must choose how to control catches. Management often starts with input controls, including restrictions on season length, engine horsepower, tonnage, hull construction, gear types, the number of crew members on board, and vessel entry. However, input controls almost always result in a less efficient fishery (both technically and economically) because they restrict methods of catching, instead of restricting catch directly. Changes in fleet dynamics can result in annual changes in the relationship between input controls and resulting catches, which can result in unpredictable annual catches, leading to overharvesting, and variation in fisheries employment levels. Furthermore, it must be borne in mind that under input controls, fishermen will try to maximize their share of the catch in a race for fish, leading to excessive investment in fishing technology.

Restrictions on season length

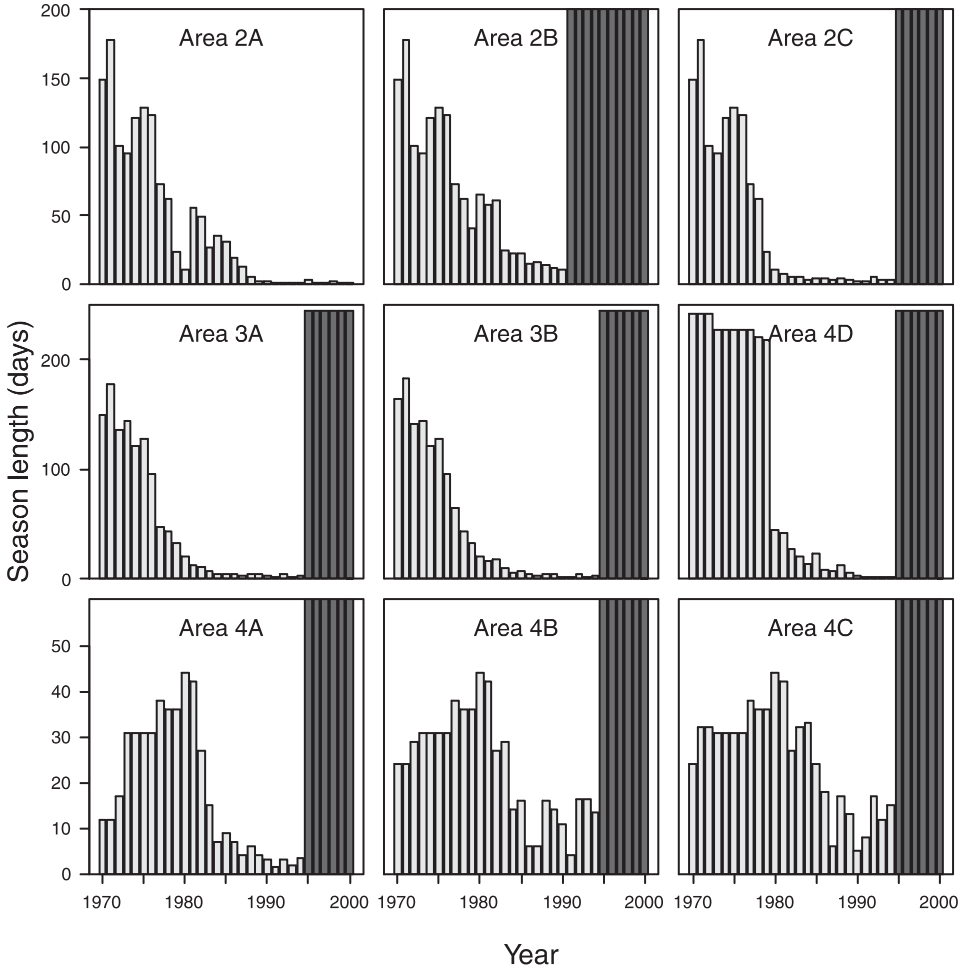
Closed seasons may be imposed to protect spawning periods and to limit catches. Experience shows that season-length restrictions are insufficient to control total fishing effort, especially in profitable fisheries. The incentives that were present under open access remain: new fishermen will continue to enter the fishery and existing fishermen will continue to increase their fishing efficiency and capacity, requiring further season-length restrictions. This pattern has been widely repeated in many fisheries, including those for Alaskan halibut (*Hippoglossus stenolepis*), with season lengths in each area decreasing from 40–230 days to just 1–11 days (Fig. 3), and for Alaskan sablefish (*Anopoploma fimbria*), with season length declining from 254 to 60 days in the Central Gulf and from 180 to 20 days in the Eastern Gulf (Pautzke and Oliver 1997).

Shortened fishing seasons have many negative effects. They disrupt the natural evolution from generalists towards specialists by preventing year-round fishing. They cause market gluts during season openings, which reduce the prices paid to fishermen and decrease the availability of fresh product to consumers (Pautzke and Oliver 1997). During the short, intense seasons, fishermen have to operate regardless of weather conditions, which may put boats and crew at risk. Fishermen may engage in capital stuffing (excessive investment in capital equipment) to maximize catch rates, dissipating profits. Finally, during the race for fish, excessive amounts of gear may be set but not retrieved or lost in the rush. Lost gear is a financial burden and also contributes to stock declines through “ghost fishing”, because fish continue to be caught and killed by abandoned gear. The International Pacific Halibut Commission (IPHC 2000) estimated that almost 900 t of Pacific halibut, worth US$3.2 million, were killed in 1990 in abandoned gear (Hartley and Fina 2001). In summary, restrictions in season length may constrain total mortality, but the resulting intense race for fish leads to many negative outcomes.

Vessel and gear restrictions

Fisheries managers may attempt to reduce fishing effort by placing restrictions on vessel and gear characteristics. These restrictions directly reduce the economic efficiency of

Fig. 3. Changes in season length in nine management areas of the Pacific halibut (*Hippoglossus stenolepis*) fishery during 1970–2000: light bars, periods when fishing effort was controlled by season length; dark bars, management under individual transferable quotas (ITQs). Area 2A (Washington) is still managed by season length. The *y* axes differ for each horizontal row of graphs and the ITQ season lengths were 213–259 days in all cases. Sources: annual reports of the International Pacific Halibut Commission (e.g., IPHC 2000).



the fishing fleet, lowering profitability, and provide incentives for fishermen to invest capital in unregulated input dimensions (e.g., increasing vessel length when regulations restrict engine horsepower). When a fleet-wide TAC limits fishermen, they will overinvest in vessel improvements and in technology that may not be the most efficient for the fishery, resulting in suboptimal fishing practices (Wilen 1979).

One of the best examples of indirect regulations leading to economic inefficiency is the Bristol Bay sockeye salmon fishery (Metzner and Ward 2002). The fishery was originally valued at US$350 million but is now worth less than 10% of that because of a combination of overcapitalization and an increase in farmed salmon on the market (resulting in reduced prices). Initially, the number of vessels in the fleet was limited to reduce fishing pressure. Fishermen responded with vessels that were larger and faster than their predecessors. When restrictions were placed on vessel length, fishermen increased vessel width and engine power. The net result was that much of the potential profit in the fishery was lost to fuel costs and vessel improvements. In the late 1990s, more than 2000 high-powered boats caught the same amount of salmon as fewer than 1500 sailing vessels in the 1920s (Link et al. 2003).

Technical efficiency is a measure of how efficiently fishermen conduct harvest (the goal being to maximize the CPUE) and will be reduced by limiting vessel or gear characteristics. In Australia's northern prawn fishery, a vessel replacement program was started in 1985, with the limiting metric of each new vessel being a sum of engine power and hull size. In response, fishermen increased an unregulated input control (the length of the gear headrope), decreasing the average technical efficiency of the fleet (Kompas et al. 2004). Technical efficiency also decreased with vessel size in the Dutch beam trawl fishery when mesh size and beam length were restricted (Pascoe et al. 2001).

Gear restrictions may have unintended consequences. In the Alaskan red king crab (*Paralithodes camtschaticus*) fishery, the introduction of pot limits unexpectedly shifted wealth from large vessels to small vessels (Greenberg and Herrmann 1994). In the Maine lobster (*Homarus americanus*) fishery, pot numbers actually greatly increased after pot limits were imposed because good economic conditions favored entry, and part-time fishermen who formerly used small numbers of pots ended up increasing their pot numbers to the maximum allowed because they were concerned about the potential for future freezes in pot numbers (Acheson 2001). Finally, gear restrictions are vulnerable to the creativity of fishermen. For instance, when trawl nets were banned in the Florida finfish fishery, fishermen responded by fishing with tarpaulins instead of nets (Metzner and Ward 2002).

If vessel or gear restrictions are to be considered for controlling fishery effort, they must be enforceable and leave no unregulated inputs. The economic, biological, and social consequences must be considered, in addition to the inefficiency resulting from each restriction. Such considerations may limit the degree of overcapitalization and rent dissipation.

Limited-entry programs

Limited entry may be intended to prevent further increases in effort, to increase economic efficiency, or to protect local fishermen from outside competition and risk. However, limited entry rarely ends up reducing or limiting fishing effort. In the New Jersey (US) blue crab (*Callinectes sapidus*) fishery, for instance, a limited-entry program in 1993 did not restrict the number of pots allowed per boat, and by 1995, the total number of pots deployed in the fishery had actually increased by 8% (Stehlik et al. 1998). Studies of diverse types of fisheries catching lobster, salmon, and halibut have also demonstrated increases in fishing effort following the introduction of limited-entry regulations, even when limited entry is combined with vessel or gear restrictions (e.g., Fraser 1979; Meany 1979; Trumble et al. 1993; Townsend and Pooley 1995).

One problem with limited-entry programs is capital stuffing. When the total catch of the fleet is limited, each individual stands to increase their share of the catch by fishing harder, for example, by increasing the size of their vessels or by upgrading their engines when they replace their vessels. Although the 1969 limited-entry program in the British Columbia salmon (*Oncorhynchus* spp.) fishery decreased the number of vessels in the fleet (appearing to decrease effort), Fraser (1979) showed that gill-netters and trollers (employing 1–2 crew) were being replaced by purse-seiners (employing 4–5 crew) and by vessels with multiple sets of gear. This switch required an investment of capital in vessel improvement, increasing fishing costs and causing overcapitalization in the fishery. The Bristol Bay limited-entry program in 1974 resulted in similar vessel modifications, particularly for vessels with owners who were not local to the Bristol Bay area (Koslow 1982).

It should not be thought that limited entry offers no hope. On the contrary, limited entry is a necessary step in constraining overall fishing power, especially in profitable fisheries. The problem is that limited entry is typically introduced only when there is already evidence of overcapitalization or overfishing. An exception is the Western Australian prawn fisheries, in which limited entry was introduced during the exploration phase and economic rents were still being generated 15 years later (Meany 1979). In that case, a few large companies owned the entire fleet, which may have limited vessel improvements to those that would improve fishery-wide profits.

Although some limited-entry programs have been designed to protect local fishermen from competition, transferability of permits may reduce the protection offered. In the Bristol Bay salmon fishery, 6% of the original limited-entry permits were transferred from local residents to nonlocal fishermen between 1975 and 1979 (Koslow 1982). These changes occurred because residents were poorer and less economically flexible than nonresidents and thus tended to sell permits during economic crises when prices were lowest. Consequently, 41% of outsiders said their income increased under limited entry compared with only 4% of residents.

A limited-entry program needs to be designed in combination with season length, area, vessel, and gear restrictions to have even a chance of being successful (Adasiak 1979). If only a single aspect of the fishery is regulated, fishermen will likely increase effort using unregulated dimensions of the fishery, which may result in unintended consequences. If limited entry is intended to protect local fishermen, managers should consider whether to issue permits to individuals or vessels and whether permits should be transferable (Adasiak 1979). Inactive permits may become problematic if vessel buybacks are proposed, but requiring permits to be fished may lead to fishing even when the fishery is not economically viable (Townsend and Pooley 1995).

Area-based management

Spatial controls have long been part of fisheries management and are exercised over a wide range of scales. Catch, effort, vessel and gear restrictions, exclusions, and temporary or permanent closures are commonly specified by area. Spatial management may be based on existing political boundaries, species distribution, or the distribution of fishing effort. It seems intuitive that successful spatial management regimes would account for the behavior of fishermen.

Area-based management actions will impact the spatial allocation of effort by fishermen, because fishing location choice is an important component of fishermen behavior (e.g., Branch et al. 2005). Spatial allocation of effort is often related to distance from home ports (Sampson 1992; Caddy and Carocci 1999) and to other costs associated with different fishing areas (Prince and Hilborn 1998). Species profitability, catch rates, quota limits, and the relative desirability of specific fishing locations are all factors that may drive changes in fishing location (e.g., Hilborn and Ledbetter 1979; Gorfine and Dixon 2001; Salas et al. 2004).

Spatial management will have a more pronounced impact on fishermen who are area specialists (fish only in one area) than on fishermen who are movement specialists and fish in multiple areas (Hilborn 1985; Hilborn and Ledbetter 1985). In the British Columbia salmon purse-seine fleet, area specialists performed well in one area and poorly in another, reflecting a lack of knowledge about other areas (Hilborn and Ledbetter 1985). In contrast, movement specialists tended to be highly successful at finding fish regardless of the location (Abrahams and Healey 1990). Hilborn (1985) notes that a proposal of area licensing in the British Columbia salmon purse-seine fishery was met with strong opposition by some parties: “many fishermen have devoted years to learning which weeks are best for which areas, and area licensing would deny them the opportunity to use that information to their advantage".

Area-based management is often used to spread out fishing effort or to rotate effort between open and closed areas. Even without explicit management, fishermen may distribute their effort in this manner. Among abalone divers in Australia, incentives to maintain high catch rates led to patterns of effort rotation on individual reefs that mitigate against high exploitation rates (Gorfine and Dixon 2001). Fishermen may develop their own mechanisms to spread fishing out, avoid repeated harvesting, and reduce conflict, as has happened informally in the Aleutian Islands golden king crab (*Lithodes aequispinus*) fishery (Criddle et al. 2001) and formally in the stake-net fishery in Itoman, Japan (Akimichi 1984). Such examples demonstrate a tier of self-governance beyond that controlled by management regulations.

Reactions of fishermen to spatial management measures may be predicted through analysis of real data (e.g., Salas et al. 2004) or through fisheries models (e.g., Little et al. 2004). For example, Marchal et al. (2002) assessed the impact of the "plaice box", an area of restricted fishing in the North Sea. Although the fishing efficiency of some vessel classes increased inside this area, others did not, perhaps because of many other area-dependent factors besides the management action.

Marine protected areas (MPAs), or marine reserves, have been in use for over a millennium (Johannes 1978) and are a special case of area-based management. There has been growing momentum to set aside 20%–30% of the world's oceans to protect against human activities, including fishing, at an estimated cost of US$5–19 billion (Balmford et al. 2004). Proponents argue that closed areas will protect some portion of a stock from fishing pressure, increasing individual sizes and their contribution to spawning biomass, and that catch rates will increase outside MPAs through migration and larval dispersal. However, commercial fishermen are often opposed to marine reserves, fearing that any improvement in harvest levels outside reserves will be insufficient to offset the loss of former fishing grounds included in the reserves. The results depend largely on what happens to the displaced fishing vessels: do they exit the fishery (in which case they are worse off) or intensify fishing pressure outside the reserve (depleting fish stocks outside the reserves)? The IFD predicts that effort should move to places of highest catch rates, i.e., near the reserve perimeters where spillover effects are greatest, termed "fishing the line". Relatively little empirical evidence for this effect has yet been published. In the California Big Creek reserve, no evidence was found of fishing the line (Wilcox and Pomeroy 2003), but area closures off the northeastern US resulted in high levels of effort within 5 km of the MPA boundary, which corresponded to a doubling of revenue per hour within 4 km of the reserve boundaries (Murawski et al. 2005). Nevertheless, fishing the line could be important: Palumbi (2004) notes that fish spillover (a major reason for implementing MPAs) has only been well documented a few times and may be dependent on the intensity of fishing immediately outside the reserve.

When considering MPAs and other forms of area-based management, managers should therefore consider enacting short-term reductions in overall fishing effort to avoid the potential for depletion of fish stocks outside MPAs caused by displaced effort (Hilborn et al. 2004*b*). In addition, some compensation may be necessary to win support from fishermen who specialized in fishing areas that would be closed under any regulations.

Dedicated access privileges

There are many benefits to ending the race for fish that exists in open-access fisheries and changing the incentives in input-controlled fisheries that lead to capital stuffing and inefficient fishing. One solution is output controls through "dedicated access privileges" (US Commission on Ocean Policy 2004), in which a share of the TAC is allocated to specified participants or groups of participants and they can then choose when to catch their share. Dedicated access privileges include territorial rights, cooperatives, community development quotas, and individual transferable quotas.

Territorial rights

Systems of territorial rights include informal fishing territories, customary marine tenure, and territorial use rights in fisheries (TURFs). In all these cases, groups of fishermen have formal or informal rights to harvest fish in a particular area and to exclude other fishermen.

Informal fishing territories typically arise where it is possible to defend territories. In the Maine lobster fishery, groups of fishermen called "harbor gangs" have exclusive fishing rights near their harbors or around the islands from which they operate (Acheson 1975). Territories are defended initially by verbal threats but this may escalate into trap cutting if these warnings are ignored. In territories that were more rigorously defended, lobsters were larger, a greater percentage reached maturity, and profits were greater than in areas where territories were less well defined (Acheson 1975). More formal territorial arrangements have arisen in the Japanese Itoman stake-net fishery, in which more than 200 fishing locations are shared among fishermen according to a series of complex rules (Akimichi 1984).

Customary marine tenure systems are undergoing a resurgence in Oceania (Johannes 2002), despite premature reports of their demise (Johannes 1978). Many countries in Oceania have allowed customary village regulations to be accorded legal authority. As a result, villages have declared marine reserves, excluded outsiders from fishing in their waters, banned or restricted certain types of gears, and banned fishing on certain species. A number of success stories have arisen; for example, in Vanuatu, many villages have chosen to cease fishing for trochus for several years between harvests to maximize their income (Johannes 2002), a solution that would not be possible without tenure rights to the resource. Marine tenure systems bear similarities to Japanese-style cooperatives and are more likely to be enforced and supported by fishermen than top-down regulations imposed by central governments.

TURFs are a formal mechanism of assigning exclusive use rights over a particular fishery area to an individual or group (Christy 1982) and have been used in a diverse range of fisheries (e.g., Criddle et al. 2001). Their best-known application is in Chile, where a network of TURFs has been implemented to manage the gastropod loco with great success (Bernal et al. 1999). When TURFs were established, the former race to exploit locos over a very short season was replaced by a yearlong fishing season, resulting in a higher quality product fetching greater and more stable prices. TURFs allow for the rational exploitation of resources and, through ownership, provide incentives to maintain a sustainable fishery and to prevent poaching.

These types of territorial rights provide the long-term incentives for the resource owners to sustainably manage their resources and will work best if the owners have the ability to prevent outsiders from harvesting their resources.

Cooperatives

Fishery cooperatives are groups of individuals, each of which are allocated a share of the TAC. Individual allocation decisions are made within each cooperative, usually by agreement. Each cooperative is able to choose when and how to harvest their share of the TAC, halting the race for fish and preventing overcapitalization. In addition, the cooperative's knowledge of fish distribution, processing, and marketing can be used efficiently to improve profitability. Furthermore, cooperatives are effective at devising and enforcing self-imposed regulations that will be supported by local social norms (Townsend 1995). Cooperatives have been successfully employed in Japanese fisheries and in the US Pacific whiting (*Merluccius productus*), Bering Sea and Aleutian Islands (BSAI) pollock (*Theragra chalcogramma*), and Chignik Lake salmon fisheries (Kitts and Edwards 2003).

Since 1948, all Japanese fishermen must belong to cooperatives that allocate licenses and manage resources in specific coastal zones and often provide support services such as loans (Yamamoto 1995). Their overall success must be balanced against the possibility that allowable catches may not be sustainable and the lack of protection for migratory stocks that visit multiple zones (Yamamoto 1995).

In the BSAI pollock fishery, each company decides how many boats are necessary to catch their portion of the TAC. This has resulted in a 30% reduction in fleet size and a longer and more relaxed fishing season (North Pacific Fishery Management Council 2002). Instead of attempting to maximize catches, fishermen now target particular schools more accurately, deliver a higher quality product, and have increased product recovery rates for catcher–processor vessels by 35%.

In the Lake Chignik sockeye salmon (*Oncorhynchus nerka*) fishery in Alaska, 77 of the original 100 vessels formed a cooperative, agreeing to share their profits, and were allowed to catch 77% of the TAC in 2002. Only 22 of the 77 vessels were used to catch the same quantity of salmon, greatly increasing profitability and resulting in changed harvesting practices allowing for the transport of live salmon directly to the processors, ensuring higher fish quality for consumers. Lake Chignik salmon are now marketed as a special brand, Castle Cape Reds, and command premium prices (Babcock and Weninger 2004). Furthermore, the more relaxed and efficient fishing process has also allowed the fisheries manager to fine-tune the escapement levels in a much more responsive manner than before (G.S. Gislason & Associates Ltd. 2004).

Cooperatives avoid the problems of the race for fish while encouraging fishermen to abide by the regulations through common ownership and self-management. They are most applicable to fisheries with a limited number of participants, creating circumstances where social pressure can ensure sustainable fishing practices.

Community development quotas (CDQs)

When dedicated access privileges are granted to communities, these are termed community development quotas (CDQs). CDQs embody the concept that fishing communities have interests in fishing that go beyond just the harvesters and processors involved in the fishery (Ginter 1995). In the BSAI pollock fishery, 55 remote villages were initially allocated a total of 7.5% of the TAC as CDQs (Ginter 1995). Most villages rented out their CDQs to commercial companies to obtain additional revenue or required the employment of local labor in the fishery in exchange for their catch shares. The CDQ program provided many benefits to the remote villages, basically through the transfer of fishing wealth to meet social objectives.

Individual transferable quotas

Individual transferable quotas are a form of dedicated access privilege allowing maximum flexibility. Each ITQ holder is allowed to harvest a portion of the TAC in a given year and can transfer this right (or privilege) to other entities by leasing or selling it (Christy 1973). ITQ systems have been introduced in many countries and are the default choice of management in Iceland (Arnason 1996) and New Zealand (Sissenwine and Mace 1992; Annala 1996). Although it is deceptively simple to describe ITQs, their consequences are far-reaching and have been detailed in a series of reviews (e.g., Squires et al. 1995; Grafton 1996; National Research Council (NRC) 1999).

The key difference between ITQs and other forms of dedicated access privileges is transferability, which encourages less efficient owners to sell their quota to more efficient owners and leave the fishery, reducing overcapacity (e.g., Crowley and Palsson 1992; Wertheimer and Swanson 2000). Through payment for their quota, exiting vessel owners are compensated without requiring the public funds typically used in vessel buyback programs.

Under ITQs, fishermen have the most flexibility in choosing when and where to fish. A classic example is that of the Alaskan halibut fishery (Wertheimer and Swanson 2000; Hartley and Fina 2001). In this fishery, management by season-length restrictions resulted in capital stuffing, ever-shortening fishing seasons, gluts of halibut on the market, unsafe fishing conditions, and overcapitalization as fishermen competed against each other for the highest possible share of the TAC (Fig. 4). After ITQs were introduced, season length increased by one or two orders of magnitude (Fig. 3), the number of search and rescue missions decreased by 66%, the number of active vessels declined by 40% in the first year, and most of the halibut could be marketed fresh instead of frozen. In addition, catches were consistently kept under the TACs, and "ghost fishing" was reduced by 75% (Fig. 4).

The Icelandic summer spawning herring (*Clupea harengus*) fishery offers an example of the kinds of changes to be expected under ITQs (Fig. 5). Since this fishery reopened in 1975, total spawning biomass and landings have increased dramatically (although this is not directly due to ITQs). The

Fig. 4. The effects of individual transferable quota (ITQ) implementation (dark bars) on overharvest percentages, number of vessels, and estimated tonnage of fish caught by lost or abandoned gear (ghost fishing) in the Alaska halibut (*Hippoglossus stenolepis*) fishery, and search and rescue missions in the Alaska halibut and sablefish (*Anopoploma fimbria*) fisheries. Sources: National Research Council (1999), Hartley and Fina (2001), Wertheimer and Swanson (2000).

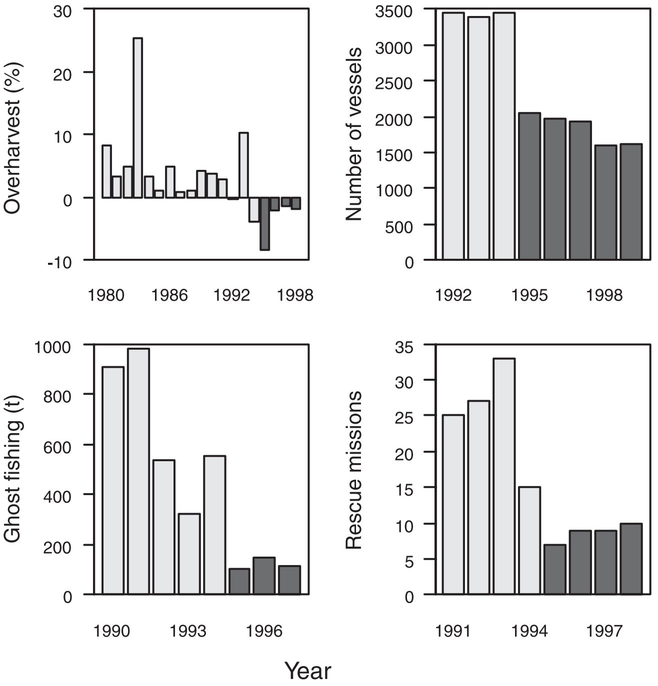
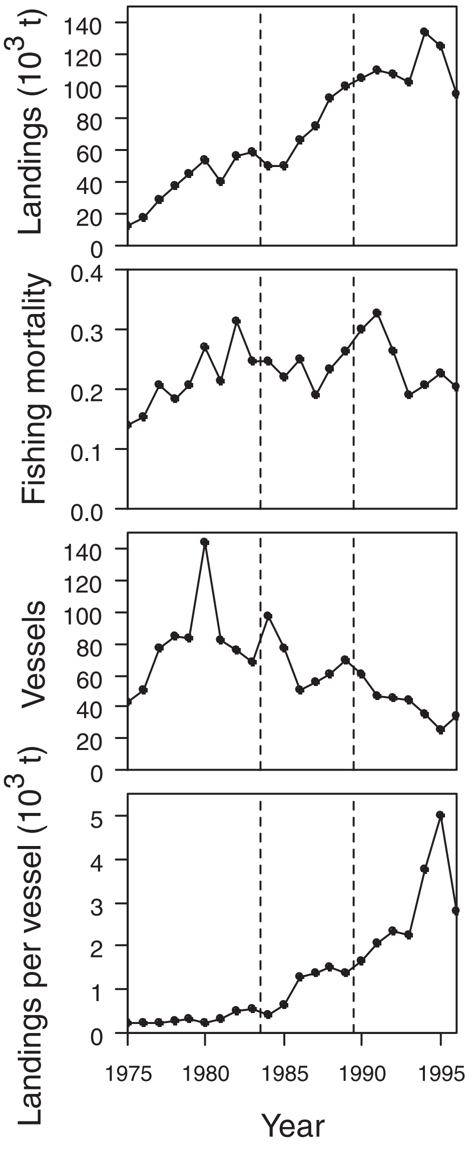


Fig. 5. Landings (10^3 t), fishing mortality, number of purse-seine vessels, and landings per purse-seine vessel (10^3 t) in the Icelandic summer-spawning herring fishery (*Clupea harengus*) during 1975–1996. Entry was not restricted before 1982. In 1982–1983, a lottery was used to halve the fleet size. Periods with no individual quotas, limited transferability of individual quotas (1984), and full transferability (i.e., ITQs, 1990) are divided by broken lines. Modified from Jakobsson and Stefánsson (1999).



number of vessels initially increased threefold, but when individual quotas were introduced, this increase reversed. The decline in vessel numbers accelerated when fully transferable ITQs were introduced in 1990, despite further increases in landings. In an open-access fishery, the opposite pattern in vessel numbers would be expected. As a result, landings per vessel increased by an order of magnitude (Jakobsson and Stefánsson 1999).

Under ITQs, biological sustainability is controlled by the TAC, while economic success is not only allowed, it is encouraged. Fishermen change their behavior in a variety of positive ways to maximize their profits. They typically aim for higher prices by increasing the quality of their product, changing the product form from frozen to fresh, adding value to the product, fishing when market prices are high (which may increase fishing in dangerous conditions), or changing fishing patterns to obtain a broader mix of species (Casey et al. 1995; Batstone and Sharp 1999).

The increased security granted by ITQs may also lead to unexpected behavior. ITQ shares become a valuable asset that approximates the long-term value of the fishery, and fishermen try to maximize this asset value. In the Gisborne rock lobster (*Jasus edwardsii*) fishery in New Zealand, ITQs were implemented in 1990 but catch rates continued to fall, partly due to the robbing of lobster traps by nonquota holders, but also because of octopus mortality on sublegal-sized lobsters held in the traps (Breen and Kendrick 1997). After 3 years of ITQs, the quota holders proposed halving the TAC to rebuild the stock, moving to a winter season when poor weather would reduce trap robbing and reducing the legal size to decrease octopus mortality (because allowing the retention of a greater proportion of legal-sized lobsters decreased the number of trap hauls needed to catch the TAC). The resultant changes have been remarkable: catch rates increased fivefold, the size and numbers of lobsters increased, illegal poaching diminished, and the value of ITQ shares increased sixfold.

ITQs may provide the correct incentives for fishermen to maximize profits without overfishing, but they also provide incentives to cheat. Fishermen can increase profits if they exceed their quotas, either through illegal fishing or by misreporting catches (Copes 1986). In addition, ITQs may provide incentives to increase high-grading and discarding (defined below), especially in multispecies fisheries where constraints on TACs for some species would restrict catches of other species and there is no individual accountability for discards (Copes 1986; Arnason 1994; Annala 1996). Fishermen may speculatively enter new fisheries, anticipating that a history of high catches may result in them being granted a large ITQ share in the future, and once an ITQ fishery is declared, vessels exiting the fishery may create a spillover effect of excess capacity into unrestrained fisheries (NRC 1999; Macinko and Bromley 2002).

Many social changes occur under ITQs. Quota owners generally have increased bargaining power compared with crew members, processors, and fishing communities, which may lead to fewer (but often better paid) crew members (Crowley and Palsson 1992; Wertheimer and Swanson 2000), processors being worse off than under a race for fish (Matulich et al. 1996; Matulich and Clark 2003), and fishing communities losing their quota (Eythórsson 2000). ITQs may also lead to increased concentration of quotas in the hands of a few people or large companies (Eythórsson 2000; Stewart and Callagher 2003). A combination of these issues has led to widespread dissatisfaction with the ITQ system in Iceland, including strikes by crew members protesting the low wages offered by quota holders under ITQs (Eythórsson 2000). These social changes are an inevitable consequence of the greater economic performance achieved under ITQs.

Thus, although ITQs offer many benefits to fisheries managers, modifications may be required to reduce some of their social impacts. A sensible list of recommendations is made by the NRC (1999) and includes improved monitoring and enforcement, restrictions on quota transfer and leasing, including crew members and fishing communities in initial allocations (e.g., through CDQs), and setting control dates for catch history well in advance to discourage speculative fishing. These modifications generally restrict the transferability or ownership rights conferred under ITQs, providing a trade-off between economic efficiency and societal goals.

Advantages and disadvantages of dedicated access privilege systems

All dedicated access privilege systems allow fishermen greater flexibility in deciding how to fish compared with alternative management structures. These systems therefore promote economic efficiency, improve profitability, reduce overcapitalization, and result in a better quality of product. By restricting access and fishing privileges to particular groups, they provide incentives for resource stewardship. However, the process of granting fishing privileges is often contentious, and this can cause social impacts related to the creation of a class of people that have control over fisheries access. Nevertheless, if such systems are designed carefully, they provide appropriate incentives for fishermen to balance resource stewardship, economic efficiency, and social welfare.

Bycatch, discards, and high-grading

Bycatch, discarding, and high-grading may affect the management of fisheries in a variety of ways. We define "bycatch" as the unintended catch of nontarget species, "discarding" as caught individuals that are returned to the sea, and "high-grading" as the practice of discarding less valuable grades of fish in order to fill quotas with more valuable grades. Discarding occurs in most fisheries (and may even be required) because fishing is imperfect: some caught individuals are too small, others are the wrong species, and still others may be diseased or damaged.

Estimates of worldwide discards of fish have decreased substantially from the widely quoted 27 million t per year in the late 1980s and early 1990s (Alverson et al. 1994) to current estimates of 7.3 million t in 1992–2001 (Kelleher 2005). The prime culprits are trawl fisheries, particularly for shrimp but also for demersal finfish (Kelleher 2005). In shrimp fisheries, discards are generally small fish with little value that would be more profitably harvested when larger (Hall et al. 2000).

High-grading occurs in fisheries that have individual output controls, such as bag limits, trip limits, and individual quota systems, in which there is also a price differential between different sizes of fish and little effort is needed to catch fish to replace those discarded (e.g., Arnason 1994; Gillis et al. 1995). High-grading was regarded as a problem in the New Zealand snapper (*Pagrus auratus*) fishery (managed by ITQs) in which some fish met the strict criteria for the lucrative *ike jime* Japanese market and could be sold for US$3 per kg more than those destined for the domestic market (Boyd and Dewees 1992). Increased enforcement and severe penalties reduced the level of high-grading in this fishery, and fishermen reacted by altering their handling and fishing practices to increase the proportion of *ike jime* fish; however, problems with misreporting and black market sales of the lower-value fish remain.

In multispecies fisheries managed with individual output controls, discarding problems may be exacerbated as fishermen have incentives to discard when quotas are exceeded so that they can continue fishing for another species (Copes 1986; Pikitch et al. 1988). One solution is seen in the multispecies British Columbia groundfish fishery in which there is 100% observer coverage and deduction of discard mortality from individual quotas and vessels are prohibited from bottom trawling for the remainder of the year if their individual quotas are not covered by leasing quota (Turris 2000). This system has led to near-zero discards of marketable fish (Branch et al. 2006).

Bycatch can be reduced using bycatch reduction devices (BRDs), gear modifications that attempt to exclude bycatch species from the target species' gear (Hall et al. 2000). BRDs can be beneficial to fishermen: in Australia's northern prawn (*Penaeus* spp.) fishery, studies showed that fishermen installing BRDs would increase their profits, as a result of a reduction in prawn damage from large bycaught animals (worth US$1 million fleet-wide), reduced time required to sort out small fish, and an easing of pressure from conservation groups (e.g., Salini et al. 2000). BRDs were subsequently made mandatory in the northern prawn fishery (Salini et al. 2000). In this and other prawn fisheries of Australia, the majority (100% in one fishery) of fishermen have adopted BRDs developed in conjunction with industry even before they were required by regulations (Kennelly 1999). Of course, if BRDs reduce catches of the target species and decrease fishing profitability, it is likely that fishermen will experiment with or modify these devices or resist their imposition

(Moberg and Dyer 1994). Thus the predicted reductions in bycatch may not in practice be realized.

Bycatch species may be charismatic and popular (e.g., dolphins and turtles). In the 1960s and 1970s, hundreds of thousands of dolphins were killed annually by purse-seine fleets fishing on tuna associated with dolphin schools in the Eastern Tropical Pacific. Public outcry and concern about declining dolphin populations led to the passage of the US Marine Mammal Protection Act in 1972. This Act capped the annual mortality of dolphins, placed observers on US vessels, and changed fishing gear and practices. Annual dolphin mortality declined from 500 000 to 20 000 in the late 1970s. However, the increased costs associated with these restrictions encouraged many US vessel owners to register their vessels with other countries that imposed fewer restrictions, and dolphin kills soared to 133 000 in 1986. However, a consumer boycott of dolphin-unfriendly tuna (starting in the late 1980s), the implementation of individual vessel quotas for dolphin bycatch (replacing fleet-wide limits), and 100% observer coverage on large vessels combined to reduce annual dolphin kills to 1877 in 1998 (Fig. 6), i.e., less than 0.1% of any dolphin population (Hall et al. 2000). The lesson from this case study is that although methods existed even in the 1970s that could reduce dolphin mortality, there were no economic incentives for fishermen to implement these methods. The key developments in this fishery were the creation of individual accountability of dolphin catches, increased market pressure from the dolphin-friendly tuna campaign, and 100% observer coverage on vessels.

Senescent fisheries

Fisheries that are heavily depleted require drastic management action, which may include fleet reductions, catch cuts, or even fishery closures. The costs of reducing fishing effort may be considerable and may include vessel buyback programs and the payment of unemployment insurance to ease the blow to fishermen and fishing communities.

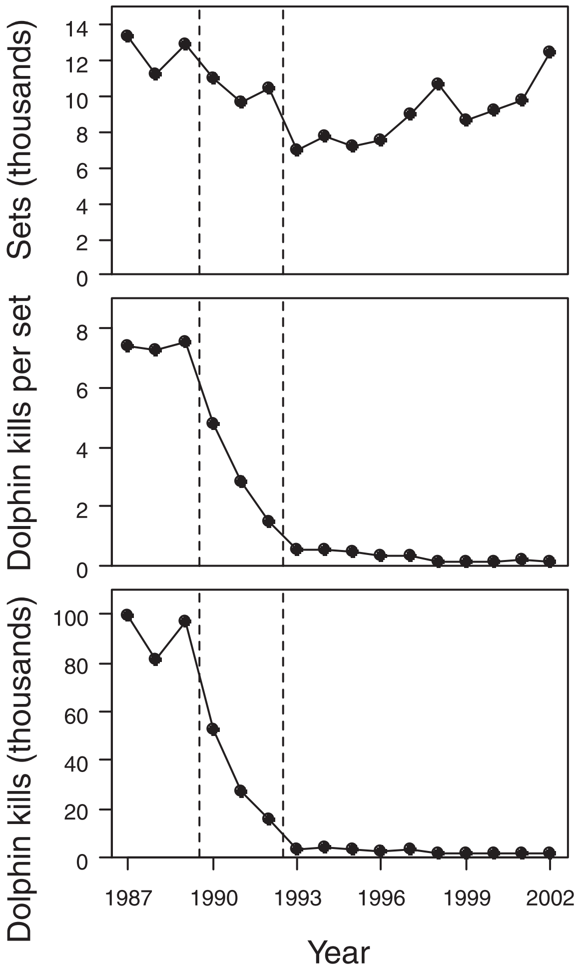
Vessel buybacks

Vessel buyback programs are widely used to reduce overcapitalization in depleted fisheries. The majority of academic attention has focused on how to remove the greatest fishing capacity for the lowest price. We examine the extent to which capacity is actually removed in buyback programs and the behavioral response of fishermen to these programs.

One common assumption is that removing vessels with the highest catch history for the lowest cost will be optimal (Holland et al. 1999), but the effectiveness of this approach may be undermined if vessel characteristics are not the most important determinant of catching power. If the vessel operator explains most of the variation in catch rates instead (the “skipper effect”), then any effect of removing vessels may be counterbalanced by these skilled individuals re-entering the fishery on other vessels.

Although the skipper effect is “widely recognized in the fisheries literature” (Squires and Kirkley 1999), Pálsson and Durrenberger (1982) found that among Icelandic cod fishermen, the size of boats and number of trips explained most of the variance in catch and that years of experience were not correlated with fishing success. Their thesis sparked intense debate (e.g., Gatewood 1984*b*; Pálsson and Durrenberger 1984). In response, Hilborn and Ledbetter (1985) found that “skipper, crew and net effects” accounted for 20%–24% of the variance in catch among British Columbia salmon fishermen, whereas vessel attributes including length, tonnage, and horsepower accounted for only 10%. Moreover, when localized skills specific to an individual fishing area were considered, the skipper effect accounted for almost half of the variation in catch. Pálsson and Durrenberger (1990) concluded the debate by contending that they began their research from the perspective of the Icelandic “folk model”, which holds that skipper ability is responsible for nearly all of the variation in catch, and found less skipper effect than predicted by such a model, whereas Hilborn and Ledbetter (1985) “started with an opposite folk model — a model held by biologists who insisted that individual differences among skippers were unimportant — and showed that they were more important than the model suggested”.

Fig. 6. Number of purse-seine sets, dolphin kills per set, and total dolphin kills in the Eastern Tropical Pacific purse-seine tuna fishery, 1987–2002. Major events indicated by broken lines include the 1990 decision by the three biggest tuna buyers to accept only dolphin-friendly tuna in response to a consumer boycott, and the 1993 La Jolla agreement that implemented vessel-specific dolphin catch limits. References: Gosliner (1999), Inter-American Tropical Tuna Commission (2003).



The obvious policy recommendation is to require buyback participants to leave a fishery altogether. Indeed, allowing vessel buyback participants to remain in a fishery may negate the effects of the buyback in unexpected ways as buyback participants may use the money that they receive to upgrade remaining vessels that they own. In the 1975 buyback in the Washington state salmon fishery, "nearly 40% of the participants in the program sold an unwanted license or vessel, upgraded vessels and gear, and remained in the industry" (Kurt and Muse (1984), personal communication, cited in Holland et al. 1999).

An additional problem of vessel buybacks is that they do not remove the incentives for the remaining fishermen to engage in capital stuffing, such as improved navigation aids, larger nets, more powerful winches, and greater fishing capacity (Clark and Munro 2002). Holland et al. (1999) raise an additional concern that even if fishermen and vessels depart from the fishery, "human capital" can still be passed on to the remaining fishermen in the form of logbooks, electronic records, and plotters that record the speed and location of vessels.

Buyback programs may also cause a "spillover effect" into other fisheries (Clark and Munro 2002). The vessels that are bought back are typically prohibited from future involvement in some sphere surrounding the fishery of interest, which may include that fishery, fishery management zone, state, or nation. However, buyback vessels may be sold or moved outside that sphere of influence. It is common knowledge that many Canadian "buyback seiners" have been purchased in the past decade by American fishermen for use in Alaska's decidedly overcapitalized salmon fisheries.

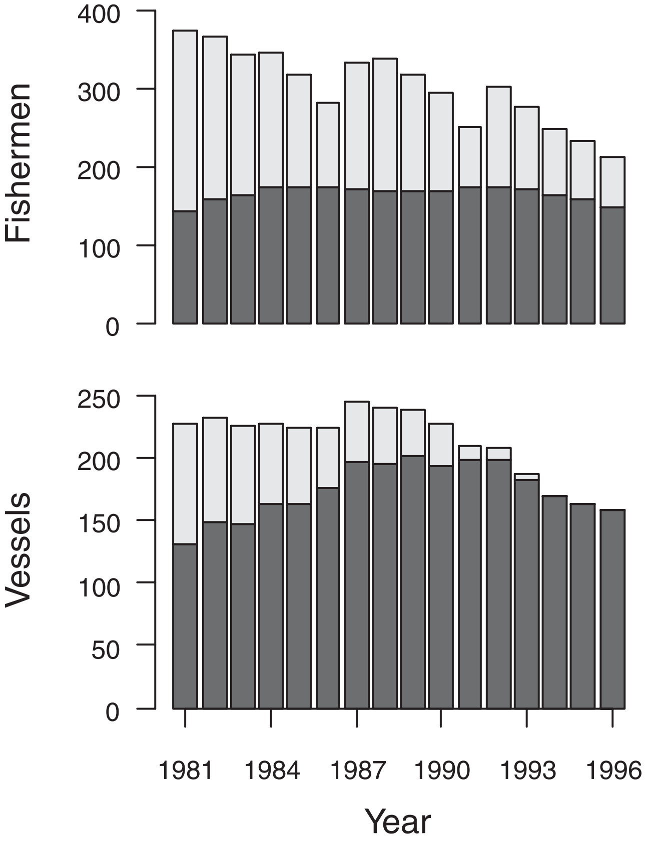
In summary, many buyback programs are not adequately structured to ensure the actual removal of fishing capacity along with the removal of vessels. Whatever capacity is removed may be compensated for by capital stuffing in the fishery or exported to cause overcapitalization in other fisheries. Additionally, buybacks increase the long-term incentives to build boats because they create an expectation that the reduction of excess capacity will be compensated in the future (Clark and Munro 2002).

Fishery closures and disaster relief

Moratoria and drastic catch reductions have been implemented repeatedly, along with a wide array of social programs, including subsidized loans, unemployment benefits, subsidized alternative employment, and "retraining" programs. With the exception of unemployment insurance, scant attention has been focused on the incentives created for fishermen by these measures.

Fishery participants have met proposed fishery closures and severe reductions in catches with responses ranging from intense opposition to cooperation. In the case of the New England groundfish fishery, participants have consistently opposed plans aimed at rebuilding the stocks, despite expected long-term increases in fishery output (Hilborn et al. 2004*a*). The authors pointed out that only a fraction of the fishing licenses were active, and hence a rebuilt stock would cause the activation of more licenses, canceling any benefits from stock rebuilding gained by the current participants. On the other hand, Irish-moss harvesters in the southern Gulf of St. Lawrence became keenly interested in conservation when depletion of the stock became evident (Pringle 1985). They voted against allowing the use of a piece of equipment designed to increase efficiency on the grounds that it might enable the clandestine use of a similar, ecologically destructive device. The main goal in this fishery was not to increase efficiency and profitability, but to ensure that as many fishermen as possible could continue working in the fishery for part of the year, thus qualifying for unemployment insurance during much of the remainder of the year.

Fig. 7. Numbers of registered full-time (dark bars) and part-time (light bars) fishermen and vessels registered to full-time and part-time fishermen in nine fishing communities in northeastern Newfoundland, Canada. The northern cod (*Gadus morhua*) moratorium was imposed in July 1992. Modified from Woodrow (1998).



After the collapse of the Canadian northern cod fishery (and despite a moratorium), only 10% of full-time fishermen surrendered their groundfish licenses in a buyback program, far short of the expected 50% (Woodrow 1998). One of the important reasons for retaining a license was that income support from relief packages depended on owning a license, and a minimum of 12 weeks of annual employment was required to qualify for unemployment insurance. Instead, fishermen increased effort on other species, such as crab and flatfish, and only part-time fishermen left the fishery (Fig. 7). The remaining crew members each work the minimum amount of time necessary to qualify for unemployment insurance and then quit to make room for others to do the same (Schrank 2005). Similar practices exist in the processing sector so that "the union ensures these people get their 12 weeks" (Woodrow 1998).

In summary, the full effects of disaster relief programs have not been thoroughly analyzed, but unemployment insurance acts as a subsidy that keeps fishermen in a fishery regardless of its profitability.

Compliance and enforcement issues

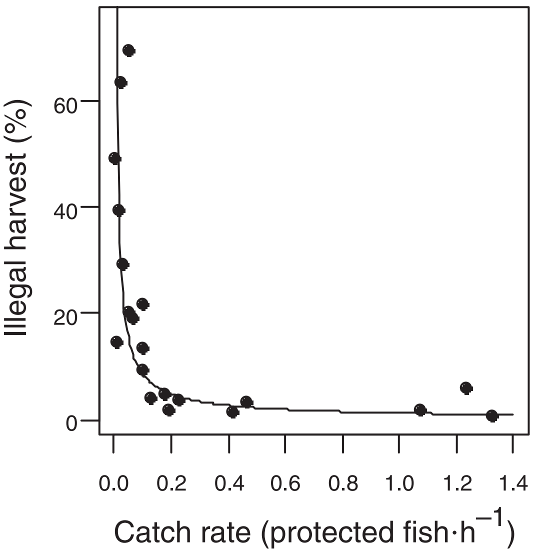
Given that fisheries management is about managing fishermen and not fish, the absence of an effective enforcement regime is likely to doom even the most robust fisheries management systems (Randall 2004). Therefore, management schemes that minimize the incentive for noncompliance and facilitate effective enforcement are ultimately the most successful at achieving fisheries management objectives.

The reasons for noncompliance are poorly understood and vary between different fisheries and the individual fishers themselves. Although economic incentives are undoubtedly important, fisheries managers need to also examine how normative and social factors influence fishermen behavior and response to enforcement. Incentives for illegal harvesting also vary with the status of the stocks, increasing when stocks are at low levels. In recreational fisheries, for example, Sullivan (2002) found illegal harvest increased sharply at low catch rates (Fig. 8), thereby placing further pressure on already depleted fish stocks. This has serious implications for fisheries managers attempting to protect declining fish populations, because just when effective protective regulations are needed most, the typical response of many fishermen is increased noncompliance.

Designing an enforcement system that elicits the desired behavior from fishermen requires intensive monitoring and high penalties for offenders, which are difficult and expensive to implement. For example, Namibia has expended considerable resources in enforcement of its exclusive economic zone, combining maritime surveillance, high levels of observer coverage, intensive port monitoring, and the seizure of numerous vessels (Bergh and Davies 2004). These measures greatly increase the risk of being caught fishing illegally in Namibian waters and make the expected costs of noncompliance so high that rational participants will choose to comply. Similarly, intensive measures employed in the British Columbia groundfish trawl fishery (Turris 2000) have also resulted in low levels of noncompliance (Ainsworth and Pitcher 2005).

The deterrent penalties in many fisheries are, however, inadequate to modify fishermen behavior (Blewitt et al. 1987). In such cases, crime pays, and many fishermen view monetary penalties simply as a cost of doing business (Frailey and Taylor 1987; Sutinen et al. 1990). Increasing the severity of penalties reduces the incentives to fish illegally but also results in more vigorous opposition to paying fines and fishermen taking “greater pains” to hide their illegal activity (Frailey and Taylor 1987). Fishermen can be highly creative in evading regulations: in the Atlantic sea scallop (*Placopectin magellanicus*) fishery, skippers have even built false bulkheads and storage compartments to hide illegal catches (NOAA 2004), in addition to the more mundane activities of skippers and processors conspiring to under-report catches and falsify records (NOAA 2005). In the absence of effective enforcement and compliance, routine violations may indicate that a norm of noncompliance has become established in a fishery (Sutinen et al. 1990).

Fig. 8. Relationship between catch rate and illegal harvest rate in 20 walleye (*Sander vitreus*) fisheries in northern Alberta, Canada. Fish are “protected” by minimum size limit or slot limit regulations. Modified from Sullivan (2002).



In short, despite management’s best efforts, the determined violator can circumvent nearly any monitoring system employed to manage and enforce a fishery. Enforcement will be easier when it is in the interests of the fishermen to comply, either because the penalties are high or because of a long-term interest in the fishery. Simple regulations that are easy to enforce are most likely to avoid the development of a norm of noncompliance in a given fishery.

Summary

What has been learned

The central thesis of this review is that fisheries management is people management, and fisheries managers need to understand how individuals and fleets behave in response to regulation in order to design fisheries management systems that will achieve the desired social, economic, and biological objectives.

Individuals and fishing fleets act rationally to maximize their individual well-being. If we understand the economic and social circumstances of the fishery, we can usually explain and indeed predict the consequences of policies. The classic “perversities” of fisheries (overcapitalization, increasing investment in technology, shortening fishing seasons, and political pressure for higher catches) are in fact rational behaviors that should be expected and can be predicted in the types of fisheries management systems that predominate worldwide.

At the core of the fisheries problem, and the first challenge for understanding fishermen behavior, is the race for fish. The race for fish is a natural consequence of individuals making decisions to maximize their well-being and will be expected to occur in any system in which individuals can obtain a larger portion of the catch by fishing more or fishing more efficiently.

A wide range of techniques have been employed by management agencies to try to achieve economic and biological sustainability, with most fisheries in industrial countries going through periods of unregulated open access, TAC-managed open access, and TAC-managed limited entry. It is now recognized that the natural dynamics of fishing fleets during this sequence of regulatory systems lead to most fisheries being overcapitalized, heavily exploited, and neither economically nor biologically sustainable. Within all of these management systems, individuals can increase their catch by fishing more or more efficiently, and all lead to a race for fish. We have reviewed the range of alternative governance systems that are currently under consideration, or in use, to try to move from the "senescent" state of overcapitalized and overexploited to a more desirable state. The successful governance systems all have at their core a change in structure so that there is no race for fish.

The use of subsidies and buyback programs has generally not been successful, whereas various "dedicated access privileges" have been more successful. Subsidies and buybacks leave the race for fish intact, providing continued incentives for those remaining in fisheries to fish more or more efficiently. The more successful buyback programs have been associated with a move between a race-for-fish management and a dedicated access system, with the buyback being part of a total package that in the end eliminates the race for fish. Dedicated access systems include territorial fishing rights, cooperatives, community development quotas, and various forms of individual fishing quotas (e.g., ITQs). In each of these systems, allowable catches are allocated to individuals or groups to eliminate the incentives associated with the race for fish, and the participants naturally act in a fashion that maximizes their well-being, with generally desirable consequences. Problems have been identified with dedicated access systems, particularly for ITQ systems, which are the most common and best studied. Although ITQ systems do generally appear to achieve many of the economic objectives of fisheries management, concentration of ownership, negative impacts on processors, and other issues have been noted. Again, these outcomes are natural consequences of individuals acting rationally, and managers need to determine what the objectives of the system are and design the rules of the dedicated access system to provide incentives to achieve the management objectives.

Ecological and economic theories provide powerful tools to predict many aspects of fleet behavior. For example, the IFD generally explains the distribution of fishing effort across space and the consequent distribution of catch rates (e.g., Gillis et al. 1993). Given the importance of catch rates in the economics of vessel operation and the analysis of fisheries catch and effort data as indices of stock abundance, this theory has a particularly important place in the analysis of fishing fleet behavior.

Another recurring theme in the history of fisheries is the evolution of catching efficiency and the ability of fishing fleets to increase their fishing power despite attempts by management to prevent it. This is again a natural consequence of the incentives provided in systems with a race for fish and should always be expected. Although there are a number of statistical methods of "standardizing" catching power, the more challenging problem is determining the underlying relationship between catch rates and actual abundance.

Discarding, bycatch, and mortality of protected species is an area of growing concern, and the incentives provided in dedicated access systems that stop the race for fish do not generally provide appropriate incentives to reduce these actions. Successes in reducing these problems have involved additional incentives, such as bycatch quotas and prohibitions on discarding. These incentive systems almost always involve intense at-sea monitoring, which may indeed turn out to be essential for successful management of many fisheries.

Compliance and enforcement are often the neglected aspects of fisheries management, yet in many fisheries, illegal harvesting may be the major conservation issue. Our review suggests that the same forces are acting: individuals act rationally, and when the economic or social benefits of illegal activities exceed the costs (probability of detection and arrest combined with penalty size), illegal activities will be common. Successful fisheries management systems must find ways to reduce the benefits of illegal activities and increase the costs. Dedicated access systems have a good track record of making legal harvesting more profitable, increasing the potential deterrence (because access privileges can be revoked), and providing incentives for long-term stewardship of the resource. As such, dedicated access systems may be considered a good step towards better compliance. It is clear that good enforcement measures do significantly deter illegal activity and should be considered an integral part of any fishery management system.

The overall lesson that we have found in this review is that the behavior of fishing fleets and fishermen can be guided towards desirable actions by providing appropriate incentives. Responses of individuals and fishing fleets to management systems can be predicted based on individual utility maximization, and managers need to understand the economic and social forces affecting individual behavior when designing management systems. There are a range of governance structures that have provided appropriate incentives to stop the race for fish and reduce discarding and bycatch. Fisheries managers around the world need to learn from these lessons and move to systems with appropriate incentives.

What remains to be done

While much has been learned from the lessons of the past, there still remains much to be discovered. We are lacking models for the rational development of new fisheries. How do we balance incentives to develop and explore, while still capturing much of the economic value of these new fisheries for the public owners? Perhaps there are more lessons available than we have been able to ascertain in this review, and a review of lessons from developing fisheries should be initiated. What has emerged is that there is a need for biological caution in new fisheries, as these are low information resources. There are also strong arguments for the use of closed areas to protect a significant portion of the resource during fisheries development.

Another important area for research and exploration is the dynamics of group size and self-regulation in various dedicated access systems. Although we have examples of success in cooperatives, ITQs, TURFs, and CDQs, there is much to be learned about governance structures that work and those that do not. For instance, under what circumstances will these groups act as a single utility maximizing agent rather than collections of individuals? When will groups be effectively self-enforcing? How do we obtain the benefits of harvesting cooperatives without seriously disadvantaging existing processors?

The interaction between fisheries management systems and compliance and enforcement needs more study. There is a miniscule literature on this problem, perhaps reflecting the fact that branches or agencies separate from fisheries managers almost always conduct compliance and enforcement activities, and the compliance and enforcement agencies have traditions (for good reasons) of secrecy rather than publication of results and case histories. Studies that simply document the compliance systems and expenditures on compliance would be a good first step.

Perhaps the greatest problematic area is that of international and high-seas fisheries. These fisheries are often the last frontier of the unregulated fisheries of the past, inheritors of the “freedom of the seas” ethic. Designing international governance systems that provide appropriate incentives is an outstanding challenge. Where international governance is impossible, the power of public opinion and market pressure has in the past been successfully harnessed to prevent the overexploitation of depleted resources. There are many examples of nongovernmental organizations or campaigns that have had a major impact on international fisheries. The Greenpeace-initiated “Save the Whales” campaign played a major role in altering public opinion about whaling, which ultimately resulted in a moratorium on international whaling. The “dolphin-friendly” tuna movement resulted in a major change in tuna purse-seining operations and reduced dolphin deaths by several orders of magnitude. Finally, recent efforts by the Marine Stewardship Council to certify sustainable fisheries and by the Monterey Bay Aquarium (and others) to rate marine fisheries by sustainability may also have major impacts on the profitability of certain fisheries, perhaps forcing changes in fisheries exploitation even in international waters.

Fisheries managers are learning from experience, and in many countries, the lessons of the past have been absorbed and managers are moving to implement governance systems and incentives that eliminate the race for fish. However, the rate of learning is slow because of limited documentation of the lessons learned. Although this review will, we hope, be a substantial resource, a single review article is no substitute for a major body of case histories documenting the range of fisheries experience. We suggest that an international effort should be made to provide a broad range of case studies of fisheries management successes and failures that specifically explore the incentives of the management system and how individuals and fishing fleets have responded. Only by learning from the past will we do better in the future.

Fisheries management is people management, and the people involved in fisheries, be they harvesters, processors, scientists, or managers, act within a social and economic structure established by the governance systems. If we wish to achieve economically and biologically sustainable fisheries, we must recognize that people will act to maximize their individual well-being. Ludwig et al. (1993) argued that greed is the driving force behind fisheries overexploitation and collapse. Greed is really nothing more than an unrestricted desire to maximize individual well-being. We need to restrict and harness this “greed” to achieve socially desired outcomes. The lessons of the past suggest that appropriate incentives can do this and that individuals maximizing their well-being within an appropriate governance system should be an essential part of sustainable fisheries.

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