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Institutions, incentives and the future of fisheries

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Fisheries around the world are managed with a broad range of institutional structures. Some of these have been quite disastrous, whereas others have proven both biologically and economically successful. Unsuccessful systems have generally involved either open access, attempts at top-down control with poor ability to monitor and implement regulations, or reliance on consensus. Successful systems range from local cooperatives to strong governmental control, to various forms of property rights, but usually involve institutional systems that provide incentives to individual operators that lead to behaviour consistent with conservation.

Keywords: sustainability; marine governance; resource management

1. INTRODUCTION

In recent years, fisheries have attracted considerable attention from the media and the scientific community, with a focus on declines, collapses (Pauly *et al.* 1998; Jackson *et al.* 2001; Myers & Worm 2003) and the negative impacts of fishing on marine ecosystems (Watling & Norse 1998). What has escaped the public media, and indeed much of the scientific community, is that there are many examples of successfully managed fisheries that are both biologically sustainable and economically profitable. Successful fisheries provide lessons on what ingredients can lead to biological and economic sustainability. We describe a range of successful and unsuccessful fisheries and compare and contrast their management institutions. We find that the primary determinants of success relate to institutional structure and incentives for participants. We argue that the key to successful management of marine resources is the establishment of appropriate institutions for governance that include a reward system, so that the individual welfare of fishermen, managers and scientists is maximized by actions that contribute to a societally desirable outcome. The majority of existing governance structures encourage fishermen to overcapitalize and overexploit and managers to elude responsibility.

2. THE DIMENSIONS OF GOVERNANCE AND INSTITUTIONS

We identify three primary elements of governance: (i) the way in which individuals are allowed access to fish resources; (ii) the decision-making structure of the institutions; and (iii) the spatial scale of management.

(a) *Access structure*

Hardin (1968) described a system of governance, the commons, in which individuals maximize their own welfare by a series of decisions that result in overexploitation (the 'tragedy of the commons'), a societally undesirable result. It is now well established that a similar pattern has been repeated in the majority of unregulated fisheries around the world (Hilborn *et al.* 2003). Many of the world's fisheries are characterized by a race-to-fish, where individual fishermen compete to catch a limited number of fish. The number caught may be limited by government regulation or by the availability of the fish, but whenever a race-to-fish occurs, fishing pressure increases until it is no longer profitable to build a larger or faster boat. This recognition has led to management systems that include specific management measures (e.g. gear restrictions, regulation of catch and effort), access rights (e.g. limited entry, ITQs, TURFs) and various forms of governance (Christy Jr 2000).

We identify four levels of access that correspond to increasingly exclusive privileges for individuals or groups of individuals. The least exclusive is open access (in a broad sense), in which any individual wishing to go fishing can do so, perhaps with the purchase of a license for a nominal fee. Most recreational fisheries of the world are open access, and most commercial fisheries go through a period of open access during their early days of development. Regulations of gear and season are often introduced in open access fisheries to reduce the level of harvest, but the most important element in open access fisheries is that anyone who wishes can participate.

The next level of exclusivity includes various forms of limited entry. In commercial fisheries this normally means there is a fixed number of licences issued, and to participate in the fishery one must either purchase a licence from an existing participant (transferable licences), or receive one through a merits ranking, or even a lottery, when someone dies or gives up his/her licence. When licences are transferable and the fishery is economically successful, the licences generally become very valuable. In the Alaskan salmon fisheries, when prices for the fish were high, licences often sold for several hundred thousand dollars. In limited entry fisheries, there is no guarantee of catch; the licences simply permit the right to participate.

Even more exclusive access is found in various forms of group or IQs, in which the licence not only allows access, but carries with it a proportion of either the total catch or

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effort. Such access privileges take two general forms, either individual or individual vessel quotas, or cooperative agreements among fishermen in a limited entry arrangement that specify allocation among individuals or companies. IQs may be transferable (ITQs) or not. When transferable they generally become very valuable. An Australian tuna fisherman recently sold his ITQ for southern bluefin tuna for *ca.* AUS$70 million (B. Jeffriess, Australian Tuna Boat Owners Association, personal communication). The most significant element of IQs is that by specifying what proportion of the fish each participant may catch, the competitive race-to-fish between participants is eliminated. The participants can then concentrate on reducing the cost of fishing and increasing the value of the product, both of which lead to increases in profitability.

In cooperatives, groups of fishermen in a limited access system agree on how to share the fish. Again, the race-to-fish is broken and individuals can concentrate on reducing costs and seek improved marketing conditions. In the past decade, cooperatives have formed for hake on the west coast of the US, pollock in the Bering sea, and salmon in the Chignik area of Alaska (At-sea-processors 2003, see http://www.atsea.org/). In all cases, the formation of cooperatives and the effective movement from limited access to IQs has led to a reduction in the number of vessels fishing and increases in quality and price.

TURFs are still another form of exclusive access, usually vested on communities of subsistence, artisanal or small-scale fishermen. Traditional management systems in the Western Pacific, based on the common law of the seas, allow communities to own the fish resources of their area and to exclude others from access (Johannes 2002). In recent years, fishing cooperatives in Chile have been granted long-term exclusive use rights over delimited portions of subtidal beds for the harvest of benthic shellfish and algae.

Strong exclusive use rights (for example, as seen in some TURFs) may come close to ownership, the most exclusive form of access. While in theory most states 'own' their fish resources, by granting fishing privileges in the form of open access, limited access, IQs or TURFs, states effectively give the resource away. In a few locations, states retain true ownership of fish resources, and grant access by auction for short periods of time. In the Falkland Islands, most fish resources are auctioned on an annual basis (Barton 2002), and in the Washington State geoduck fishery (Orensanz *et al.* 2005) rights to harvest geoducks from specified 'tracts' are sold at annual auctions. In both cases, the fish resources bring substantial incomes to the governments. Macinko & Bromley (2002) have advocated the widespread adoption of auction systems for US fisheries, but in general fishermen strongly oppose the imposition of auctions and it is difficult to envisage auctions being widely implemented in existing fisheries.

(b) *Decision making*

The second dimension of fisheries institutions pertains to how decisions are made. In many parts of the world the British Parliamentary system has left a legacy of a 'Minister of Fisheries' who wields the ultimate decision-making power. This system is most common in former parts of the British Empire (UK, Canada, Australia, New Zealand), but is also widely imitated elsewhere. In such systems, there may be varying levels of bureaucratic interaction between the fishery, science and the minister. For instance, the contrast between Canada, with its large central government located thousands of miles from the major fisheries, and New Zealand, a country 1/40 of Canada's size, is extreme. In New Zealand, the number of participants in fisheries' advice is small and direct, whereas in Canada there are more layers and less transparency (Finlayson 1994).

Another common model is for the central government to devolve authority to a board or council for decision-making. The US regional fisheries management councils are examples, where there are often a dozen or more individuals appointed by various levels of government to make management decisions. Within the US States, there is often a Board of Fisheries or a Board of Fish and Game that also controls fisheries regulations within the states. Generally, Councils or Boards work on a majority vote, although they often try to achieve consensus.

Many international fisheries are regulated by international commissions, consisting of representatives of the member countries. Examples include the Inter-American Tropical Tuna Commission (IATTC), the International Pacific Halibut Commission (IPHC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLAR). Most commissions operate on the basis of consensus, with a few setting regulations by majority voting.

In recent years, 'co-management' arrangements have received increased attention, under which management agencies and fishing communities, and eventually other stakeholders as well, vie to participate together in the decision-making process (Pinkerton 1989, 1992, 1994). These agreements became particularly popular (at least in concept) in small-scale or coastal fisheries, where top-down, centralized systems have proved inefficient. The ultimate stage in this transition occurs with the devolution of management authority to the fishing communities ('community-based management'), currently advocated as the only viable option for many coastal fisheries in the developing world. Decision-making rights vested in the owner are a natural state for state-owned fisheries.

(c) *Spatial scale*

The third dimension of management institutions is the spatial scale at which regulations are set, data collected and science conducted. The default pattern in commercial fisheries around the world is for large-scale spatial management, with regulations set on a scale of hundreds to thousands of kilometres. This was often the product of the definition of the 'unit stock', the idea that fish populations could be defined into discrete units largely disconnected from other units. Early commercial fisheries also tended to target species (from anchovies to tunas) that exhibited large spatial scales. However, spatial scale has become increasingly important as we recognize that many marine populations operate on very small spatial scales, while the regulatory structure is much larger. An extreme example is the abalone fishery in the state of Tasmania, Australia. This is an ITQ fishery where the total quota is set for the entire island, but biologically the stocks consist of thousands of discrete populations (Prince *et al.* 1998). The result is that many of the populations close to fishing ports have been depleted, while more distant populations are lightly exploited. The mismatch between the large scale of management and the small scale of the biological and fishing processes has already had devastating consequences for the abalone stocks of western North America (discussed in § 3b). More commonly, the discreteness of local populations applies to only the adult, exploited stages, while the stock-recruitment dynamics occurs at much larger spatial scales involving many local populations. Management action taken on one population of sedentary organisms may have, via larval dispersal, an effect on populations from other management jurisdictions. This is the case in most reef and benthic shellfish fisheries, in which the exploited stock corresponds to a 'metapopulation', composed of local populations of relatively sedentary adults, interconnected to varying degrees by larval and/or juvenile dispersal. In such systems, management should ideally operate at the local scale (the scale at which fishing effects are primarily noticed through local depletion) and also involve coordination at the global scale (the scale at which recruitment overfishing needs to be prevented). A system of co-management, such as is advocated by Berkes (1997) can be established to match the biologically relevant scales. In the Japanese TURF system, for example, management plans developed at the level of local communities by cooperatives are evaluated collectively at the level of the Prefecture. In the Chilean system, harvest strategies and catch quotas proposed by the fishing cooperatives that control local TURFs have to be approved by the central fishing administration, but there is still no formal strategy in place to effectively coordinate management at the global or regional scale (Orensanz *et al.* 2005).

In more mobile fish management needs to operate at larger spatial scales but still recognize the disparity of scales that may affect different dynamic processes. Management of Pacific halibut, for example, involves the establishment of separate catch quotas for nine regulatory regions in the Gulf of Alaska and the Bering Sea, under the assumption that the exploited populations within those regions are isolated. Harvesting strategies, however, are evaluated by assuming a unitary stock-recruitment relationship involving all regions within the Gulf of Alaska (e.g. Parma 2002).

(d) *Biological and economic factors*

While the major proposition of this paper is that incentives inherent in the governance system are the keys to sustainable biological and economic management, we do recognize that there are also important biological and economic factors that influence sustainability. The three that are most important in our experience are (i) the bionomic equilibrium (Clark 1985), (ii) the ability to measure the abundance of the fishes, and (iii) the lifespan of the fish.

The bionomic equilibrium is the stock size at which it is no longer profitable to fish. When the fishing gear is efficient and/or the price of the product is high relative to the cost of fishing, then the stock will be fished down to very low levels in an unregulated fishery. Such situations are much less likely to produce a sustainable biological outcome than a system where the costs of fishing are high relative to the fish price or the gear is inefficient and fishing becomes unprofitable at large population sizes.

Fish stocks that are easily and reliably monitored are more likely to be well managed simply because there is less uncertainty about the stock size. The good track record of management of Alaska's Bristol Bay sockeye salmon, for instance, is due in part to the fact that the number of spawning fish is easily counted (Hilborn 2004). While the ability to monitor abundance reliably does not guarantee sustainable outcomes, it certainly makes them more likely.

Long-lived animals can sustain low exploitation rates as compared to short-lived animals. In general, sustainable exploitation rates are in the order of the annual natural mortality rate. Natural mortality is commensurate with sustainable harvest rates, ranging (on an annual basis) from 5% in long-lived species such as orange roughy to 30–50% in short-lived fishes. The natural morality rate interacts with fishing in two ways beyond the simple sustainable harvest rate. When sustainable harvest rates are low, the abundance of fishes relative to the removals is high, and fishermen 'see' that they are taking only a small fraction of the population, leading them to believe they are not affecting it. Secondly, long-lived species have large non-sustainable surpluses available during the development stage of the fishery. This often leads to excess capitalization during the 'fishing down' phase, and the transition from large non-sustainable fishing down catches to the much lower sustainable yields is often difficult to achieve given the accumulated capital in the fishery (Hilborn & Walters 1992).

Although the above three examples of biological and economic characteristics do not tie directly into our theme of incentives, it is readily seen that the biological and economic environment of the fishes and fishery are closely integrated and incentives cannot be readily separated from these other factors.

3. EXAMPLES OF FAILURES

Before we begin a discussion of failures and successes, some criteria for classification must be discussed. In principle, a fishery could be considered a failure if either the stock has been reduced to very low levels, at which long-term yield is much lower than possible (biological failure), or when the profitability from fishing is much less than it could be (economic failure). Unfortunately, it is often very difficult to obtain economic data other than landed value. In the examples below, we will generally consider a fishery an economic failure based on widespread concern or government assistance to 'struggling' fishermen, or a success based on indications of profitability such as high values placed on licences or other forms of access privilege. Economic success may well be a general indication of biological success. When access privilege can be sold and has a high market value, this indicates that there is a belief in the marketplace that the yields and profitability from this fishery can be maintained. Of course, economic success relates to the target species and ignores any biological concerns about bycatch. We discuss this in § 5.

(a) *New England groundfish*

The New England groundfish stocks have declined since the US established the EEZ in 1978, and the scientific advice has called consistently for reduced catches throughout the 1980s and 1990s. This is, in theory, a limited-access fishery, but there are many unused licences. The primary form of regulation has been 'days at sea' limiting effort, but not absolute catch. The fishery has been in continued economic crisis throughout much of the past decade, as evidenced by repeated government concern. However, throughout this period the commercial fishing industry consistently opposed catch restrictions, which would appear to be contrary to their own interests—if they would simply reduce catches now, higher catches in the future would more than compensate. However, when one recognizes that only a small portion of the possible fishing licences are currently active, it is soon realized that if the stocks were rebuilt the benefits would be shared by a much wider group of licences (Hilborn 2000). Currently, active licences would make the sacrifice but not receive a big enough share of the future rewards to make quota reductions individually worthwhile. The current system of governance provides no incentives to engage in a stock-rebuilding plan.

We should note that major progress has been made in rebuilding some of the New England groundfish stocks by a combination of closing areas to fishing and reduced effort. Stocks of haddock and cod in the Georges Bank are increasing, but the fishery is still vastly overcapitalized, and the economic problems of the groundfish fishery continue (NMFS 2002).

(b) *Abalone along the west coast of North America*

Five abalone species (*Haliotis* spp.) found along the west coast of North America were abundant enough to support multimillion-dollar fisheries through most of the twentieth century, but stocks of all five species are now severely depleted from southeast Alaska to southern California (Muse 1998; Karpov *et al.* 2000; Woodby *et al.* 2000). The white abalone (*Haliotis sorenseni*), whose fishery peaked at 65 t in 1972, was brought to the brink of biological extinction (Davis *et al.* 1996) and is now on the USA federal endangered species list. All the commercial fisheries were closed between 1991 and 1995, and poaching is very difficult to control. California's abalone fishery is one of the best-documented examples of serial depletion and collapse (Davis *et al.* 1992; Richards & Davis 1993; State of California 1995; Karpov *et al.* 2000).

Abalone have relatively short periods of pelagic larval development (in the order of one to a few days), so local stocks tend to be self-sustaining. Longevity is high (35–55 years), suggesting that stocks can sustain only moderate harvest rates and depleted abalone populations may take years to recover; closing California's Orange County shoreline to abalone harvest in 1977 and waiting 15 years for populations to recover spontaneously was ineffective (Tegner 1992). Management regimes that focus on aggregates of local populations at a regional scale will inevitably lead to serial depletion, as fishers target local populations in a sequential way, starting with the most profitable (e.g. the closest to port, or those in shallow water or sheltered locations). These small local populations are spread along thousands of kilometres of coastlines, often in regions where enforcement is difficult or impossible. Given the high value of abalone, poaching and illegal marketing of small volumes can be very profitable. Management strategies based on a combination of management measures implemented at the regional level, without attention to the spatial configuration of populations within the region, and heavy dependence on enforcement, will predictably fail. This was the case for western North America, where (on top of a legal size limit and seasonal closures) fisheries were managed through IQs in British Columbia, bag limits (sport fishery) or limited entry (commercial fishery) in California, and 'guideline harvest rates' and effort limitation in Alaska. The collapse of the western North American fisheries has caused worldwide concern because abalone management practices elsewhere are based on the same tenets as in western North America (Shepherd *et al.* 1992).

The nature of abalone fisheries calls for territorial use rights (Prince *et al.* 1998), but these have been difficult to implement due to political or institutional constraints. In the post-collapse era, the management regime in place in North America has four components.

- (i) Emphasis on MPAs, although given the limited dispersal capability of abalone those are likely to help local populations within the MPA, with little or no effect on the potential fishery.
- (ii) Indefinite closure of commercial fisheries, *de facto* open access illegal fisheries, and limited sport fishing (California red abalone), together with costly enforcement.
- (iii) Development of aquaculture through leases or on-land operations.
- (iv) Experimental-scale reseeding of depleted areas with hatchery-produced juveniles, which may not be effective but is politically well received.

The future for natural populations of abalone outside heavily enforced, small MPAs is uncertain at best.

(c) *US west coast trawling*

The west coast groundfish fishery consists of four main sectors—commercial limited entry (subdivided into limited-entry trawl and limited-entry fixed gear), open access (fishermen without limited-entry permits and those targeting other species), recreational and tribal. It operates along the US west coast from the US–Canada border to the US–Mexico border. The Fishery Management Plan for this fishery includes 83 species of rockfish, roundfish, flatfish and sharks, although only a minority of these are managed actively. The bulk of the catch (85% by mass; 26% by value of commercial landings in 2000) consists of Pacific whiting, one of the roundfish. Other main target species are sablefish (28% of the value of commercial landings in 2000), dover sole, thornyheads, widow rockfish, arrowtooth flounder, petrale sole and yellowtail rockfish.

Twelve primary species comprised 61% of the total value of the landings by the commercial sector of the fishery in 2000 (83% of the value of the landings of species other than Pacific whiting). Five of these species have been designated as overfished at present (depleted to less than 25% of the unfished population size) and drastic fisheries closures have been implemented to reduce fishing mortality. The fishery is in biological and economic crisis as evidenced by the species listed as overfished and recent government legislation to buy back surplus fishing capacity.

Management of the west coast groundfish fishery has been based on trip limits by species and area (originally weekly, but now bi-monthly), gear restrictions (e.g. prohibitions on the use of small footropes in waters deeper than 100 fathoms), and (recently) area closures. The management regulations are selected to achieve desired levels of fishing mortality, but when an individual vessel reaches its trip limit for a given species, it can continue fishing and discard species for which the trip limit is reached. It is estimated that 40% of the commercially valuable fish product has been discarded in recent years.

(d) *Argentinian hake*

Hubbs' hake, the backbone of the Argentine fishing industry, declined to a critical state during the late 1990s, after catches rose greatly over the previous 10 years, largely exceeding the total allowable catch, and the size of the fleet of freezer trawlers almost doubled. The increase in fleet size followed the incorporation of vessels from the European fleet, allowed to fish in the Argentine EEZ under different joint venture arrangements. Signs of overfishing of the Patagonian stock were evident in the trawl survey trends and in the acoustic surveys, which were unable to locate well-formed spawning aggregations in the main spawning ground as registered in previous years. The Patagonian stock had been sustaining the fishery since the 1970s when effort was displaced south after the northern stock shared with Uruguay collapsed. Since 2000, the administration has been trying to prevent further stock declines by closing large areas of prime fishing ground, reducing TACs and displacing the freezer trawlers to waters further to the south of the hake grounds, while protecting the fresh-fish fleet. The administration's short-term, emergency-style policy has been marked by a severe social crisis in the fishing communities, acute disputes between the different fleet sectors, political pressure causing many policy swings, and a highly inefficient judiciary system, which has failed to punish violators and to prevent illegal vessels from operating. The Federal Fishery Act of 1998 mandated for the first time the adoption of a quota system based on ITQs. So far, attempts to implement the new regime have failed. The highest authority in Argentinean fisheries management is a federal council, representing the central government and the five coastal states, all of them with jurisdiction over shared marine fish resources. This council has been unable to develop a strategic plan for the country's fisheries administration. Rather, a lack of resolution of conflicts between sectors and jurisdictions, and the impossibility of achieving a parliamentary quorum has blocked progress (Verona 2000).

4. EXAMPLES OF SUCCESSES

(a) *New Zealand lobster*

In 1991, New Zealand instituted a programme of ITQs in its rock lobster fisheries. One of the problem rock lobster fisheries, based in the Gisborne area of eastern New Zealand, was plagued by low catch rates, substantial illegal harvesting, and the inability of commercial fishermen to catch their allowed quota (Breen & Kendrick 1997). A coalition of commercial and recreational fishermen, together with the Maori and government officials, developed a management plan that aimed to reduce illegal fishing and rebuild stock abundance. The key actions were a 50% reduction in the commercial catch limit, reductions in the allowed recreational harvest, and moving the fishing season to the winter. The implementation of a winter fishery was particularly important because most of the illegal fishing consisted of poachers pretending to be recreational fishermen pulling up legal commercial pots and removing the catch. During the winter, few boats are on the water and it is much harder to pull pots illegally. In addition, there is a considerably higher price for rock lobster during the winter because the major competition in the marketplace comes from the West Australian rock lobster fishery, which takes place in the summer. Thus, by moving the fishery to the winter, the higher price compensated significantly for the reduced catches. This programme of stock rebuilding was dramatically successful; the abundance of legal-sized rock lobster increased fivefold over 5 years, the value of the individual ITQ holdings increased sixfold, and by 1999 the total quota had been increased to pre-rebuilding plan levels. Because the fishermen had a substantial asset value in the ITQ holdings, they recognized it was in their interest to rebuild stock abundance. Quota reduction eliminated the 'race for fish' because each fisher was confident he could take his allotted catch in the winter when the price was high. The system of governance established a framework where rewards for individual behaviour were consistent with societally desirable outcomes.

(b) *Chilean artisanal fisheries*

The Chilean shellfish fishery targets more than 40 species that are harvested almost exclusively by commercial divers. It is a significant industry, with an aggregate catch of *ca.* 150 000 tonnes (worth *ca.* US$ 170 million) per year (Castilla *et al.* 1998). More than 25 000 fishermen are registered with the National Fisheries Service (SERNAP), based in approximately 250 fishing villages known as 'caletas'. Throughout central and northern Chile, caletas are spread along a longitudinally oriented, quasi-linear coastline; until the late 1980s fishermen harvested overlapping 'historical grounds', in what was essentially an open access fishery. At that time, scientists and managers became concerned about the possible overfishing of loco snails, the most significant species, and the fishery was closed for 3 years (1989–1992). The economic consequences and social distortions created by that draconian measure motivated the subsequent search for management alternatives. Three precedents led to the consideration of communal territorial use rights.

(i) Some caletas had experimented with spatial and temporal closures and an array of manipulative practices. Abundance increased rapidly in self-imposed spatial closures, presumably because of immigration from adjacent (open access) regions (Stotz 1997).
(ii) Substantial scientific knowledge was accumulated about the dynamic response of benthic communities and stocks to harvesting (Castilla 1999).
(iii) Between 1987 and 1992 a few well-organized caletas from central Chile applied for and obtained from the government exclusive fishing rights over adjacent sectors of the seabed, where local abundance was rebuilt through 2–3 year closures while closely monitored with participation of the fishermen (Castilla 1997). In 1991, Caleta Quintay was given exclusive fishing

> rights to harvest the first AMERB (Spanish acronym for Areas for the Management and Exploitation of Benthic Resources, a type of TURF), 57 ha of seabed (Castilla *et al.* 1998).

As a result, territorial fishing rights were incorporated into the Fisheries Act of 1991 (González 1996; Stotz 1997; Bernal *et al.* 1999), in the form of so-called 'AMERBs'. These rights can be requested by fishermens' organizations (usually known as 'sindicatos'; Payne & Castilla 1994; Minn & Castilla 1995), and are granted upon presentation of a base-line study and a management plan. The organizations became true partners in *de facto* co-management arrangements.

There is a stark contrast between the status of the stocks within the AMERBs and those in open access 'historical grounds': fishermen are highly protective of the first, while a 'tragedy of the commons' situation prevails in the latter. As a result, caletas that have requested and managed AMERBs have been comparatively successful (Payne & Castilla 1994; Castilla *et al.* 1998). Full, wide-scale implementation of the system had effectively begun by 1998. The TURF system has other positive effects: gathering of knowledge about the response of the stocks to the harvest, great improvement in marketing practices, improved product quality and reliability of supplies and, most important, strengthening of fishermen's organizations stemming from shared responsibilities and appropriate incentives (Stotz 1997).

Although promising, the system is still undergoing some adjustment, as all the parties (fishermen's organizations, managers and scientists) learn from the implementation process. Problems that still demand attention include the amount and nature of the information required from the fishermen to get a TURF, taxation, and the coexistence of TURFs and open-access areas, which still constitutes a permanent source of conflict and an incentive for overfishing in the 'historical' grounds outside the AMERBs (TURFs) (Parma *et al.* 2003; Orensanz *et al.* 2005).

However, where a disastrous situation prevailed a decade ago, there is now no sense of a looming crisis. So far, experience shows that the TURF system provides the right incentives to prevent the overfishing of benthic shellfish resources.

(c) *Canadian sablefish*

The sablefish fishery in British Columbia is managed by ITQs that are held by approximately 20 individuals. Their organization, the Canadian Sablefish Association (CSA), has engaged in an active programme of research and conservation, funding directly from levies a large-scale biological sampling programme, a tagging programme which tags over 20 000 individual fish annually for stock assessment purposes, and the stock assessments. The society has also developed an escape ring technology that permits young sablefish to escape the traps undamaged. Owing to the escape ring, young are no longer brought to the surface and then released, removing the associated risk of being caught by predators while out of their normal habitat. The society is currently working on technology that will prevent large females from entering the traps. The CSA is a successful model for commercial fishing groups' responsible behaviour and is currently negotiating with the Canadian government to assume more of the responsibility for data collection, stock assessment, management and enforcement. It is the nature of the governance system that makes this possible for a high-value asset, which is strongly affected by the perceived sustainability of the resource. Although under-reporting catch and high-grading are negative incentives often associated with ITQ systems, members of the CSA believe that it would be impossible for any individual member to systematically cheat on the system without word getting around the fishing community.

(d) *West Australian rock lobster*

The West Australian rock lobster fishery is widely regarded as one of the most successful in the world, with a long record of sustainable yield and high economic value. It was the first fishery in the world to be certified by the Marine Stewardship Council as sustainably managed. Regulated by the state government of Western Australia, it is a limited-entry fishery with each licence holder allowed to use a fixed number of units of fishing effort, which are transferable among licence holders (Phillips & Brown 1989; Morgan 2001). The effort units are defined in terms of the number of pots, which can be adjusted annually to match incoming recruitment levels (Penn *et al.* 1997). The general prescriptions for success have been the effectiveness of the pot limit in regulating fishing mortality, and the close control of a small regulatory organization with no competing institutional interests.

(e) *Gulf of Carpentaria prawns*

The Gulf of Carpentaria prawn fishery is another Australian success story, again evidenced by a long history of economic profitability and continued yield. Managed by the Australian national government, it, too, is a limited-entry fishery with tight regulations on total net width, effected through fully tradable statutory fishing rights for boats and gear. As technology has advanced, the fishery has repeatedly shortened the fishing season and reduced fleet size and the amount of net allowed (Pownall 1994); close to 100 trawlers operated in the fishery in 2002 (www.afma.gov.au).

(f) *Tasmanian abalone*

The Tasmanian abalone fishery also has a long history of high economic value (licences sell for over AUS$1 000 000), and sustained yield. It is almost unique among the abalone fisheries of the world in its long-term sustainability. It has been an ITQ fishery since 1985, with the total quota set by the Tasmanian State Government. There is good evidence that many populations close to fishing ports have been depleted and have not rebuilt, but it does appear that the total Tasmanian abalone resource is able to sustain the current level of catch (Prince *et al.* 1998).

(g) *Northeast Chatham Rise orange roughy in New Zealand*

The largest known orange roughy stock in the world is harvested on the northeast portion of the Chatham Rise off New Zealand and is currently estimated to be above the level that produces MSY (Annala *et al.* 2002). It is an ITQ fishery that is managed by the New Zealand government. As with most orange roughy stocks (Branch 2001), the stock was fished down reasonably rapidly, but survey estimates of biomass depletion were available and quotas were cut dramatically in the early 1990s so that the stock now supports a yield of *ca.* 6000 t annually. The fishery is very profitable and the ITQ value remains high. A key to the success of the northeast Chatham Rise orange roughy is the history of surveys, both trawl and acoustic, that led to reductions in quota before the stock was depleted well below MSY levels.

(h) *Pacific halibut in Canada and the US*

The North American Pacific halibut long-line fishery is managed by the International Pacific Halibut Commission (IPHC), which was established in 1923 by a treaty between Canada and the US, the countries participating in the fishery. This fishery has been generally regarded as a biological success. The resource has gone through natural abundance cycles, but the productive capacity of the stock has been protected and the IPHC has been able to adjust catches up and down as a function of estimated stock abundance, and to implement a rebuilding programme when the stock reached a historical low in the mid-1970s. Tight control of harvest levels was achieved long before there was any form of property rights in the fishery. In the US, an open-access system was in place until 1994, involving more than 3500 vessels chasing the annual TAC over a fishing season lasting only a few days. In 1995, IQs were allocated among 4830 licence holders, now down to *ca.* 3500. In Canada, a limited-entry programme had been in place before the establishment of IVQs in 1991. Fleet size was reduced from 435 at the onset of the IVQ programme to 214 in 2002. (www.iphc.washington.edu). Management success has been mostly credited to the ability of IPHC to monitor the fishery closely, to conduct a strong and independent scientific endeavour in support of management decisions, and to host an open decision-making process through which commissioners from the two countries vote on management regulations after receiving public input from the scientists, the fishermen and the processors. A long-standing tradition of high scientific and management standards has provided good incentives to the IPHC staff and the managers to maintain those high institutional standards.

(i) *US hake and pollock cooperatives*

The hake fishery on the west coast of the US and the pollock fishery in the Bering Sea have limited-entry factory-trawler fleets that have been allocated a specific portion of the TAC for these stocks. In both cases, the vessel owners have formed cooperative agreements to allocate the TAC internally, thus creating, *de facto*, an IQ-like system. This has enabled both fleets to become highly profitable by matching harvesting capacity to the TAC, and to harvest at a rate that maximizes product value rather than product volume.

(j) *Geoduck in British Columbia and Puget Sound*

The geoduck is the largest bivalve in the world and is highly prized in the Asian market, supporting highly profitable fisheries in British Columbia (Canada) and Washington State (USA). The fact that geoducks are very long-lived animals (maximum recorded age is 168 years) was recognized early in its exploitation history, and harvest rates have always been very low (*ca.* 1–2% per year) in both British Columbia and Washington (Orensanz *et al.* 2004). In British Columbia it is an ITQ fishery with the quota set by the Canadian Department of Fisheries and Oceans, while in Washington, where it is managed by the state's Department of Natural Resources, harvest rights are sold annually at auction. While in British Columbia the quotas are allocated over broad geographical regions, in Washington harvest rights are auctioned on a bed-by-bed basis. The key elements of success in both areas were the early restriction of harvest rights preventing the fleets from overcapitalizing, and the ability to monitor and manage the fishery on a small spatial scale.

(k) *Summary of cases*

Table 1 summarizes the examples presented.

It is clear that there is no single prescription for success or failure. ITQ systems do not guarantee biological or economic success: the poor performance of the British Columbia abalone fishery makes that clear. Similarly, management by committee, as in the US fisheries management councils, is not a sure prescription for failure. The Bering Sea pollock fishery and the west coast hake fishery make this evident. The mismatch of management scale in the Tasmanian abalone fishery or the British Columbia geoduck fishery is also not a fatal impediment to successful management. What does emerge is that a better outcome is more likely with the right incentives, increasingly restrictive access, simpler institutions and appropriate management scales.

5. DISCUSSION

(a) *Setting appropriate rewards*

Underlying failures and successes is the nature of incentives for the individual fishermen, managers and scientists. As Hardin (1968) noted, in open-access fisheries (the commons), there is no individual benefit from conservation. It is evident that when it is in fishermen's interests to conserve they are more likely to do so: this has been the thrust of most economic arguments for limited entry and property rights in the fisheries literature. The same arguments can be applied to the decision-making structure. When institutions are simple and there is direct responsibility, as in the state regulated Alaska salmon fisheries, the Tasmanian abalone fishery, the West Australian rock lobster fishery, and even the very simple International Pacific Halibut Commission, the managers have better incentives compared with complex organizations (US management councils, large international commissions, the EU). In more complex organizations, many competing interests cause a dilution of responsibility and incentives for good economic or biological stewardship. Ostrom (1999) has shown that small groups can, and will, organize for their self-interest when the setting is appropriate.

Fishermen clearly respond to economic incentives. The New England groundfish fishermen have opposed rebuilding because it is not in their interest to give up current catch for higher future catch shared among other licence holders. It was in the interest of Gisborne rock lobster fishermen to take catch reductions to increase their asset value more than fivefold. In many fisheries with strong access privileges, fishermen often vie for reduced or constant catch rather than catch increases because they recognize the benefits of higher stock size in terms of lower costs of fishing and that higher catches often lead to lower prices.

Table 1. Examples of different fisheries, their access system, the decision-making system and the spatial scale of management. (In large-scale systems the regulations cover an area of 1000 km across, in medium scale it is on the order of 400 km, and in local scale under 100 km.)

stock	access	decision-making	spatial scale of management
Gulf of Carpentaria prawns	strong limited entry; net width limits	national government	large
West Australian rock lobster	pot limits	state government	large
Chignik salmon	cooperative	state government	local
Canadian sablefish	ITQ	federal government	large
New Zealand lobster	ITQ	national government	local
Tasmanian abalone	ITQ	state government	large
BC geoduck	ITQ	federal government	medium
NE Chatham Rise orange roughy	ITQ	national government	small
Pacific halibut	ITQ	international commission	medium
Pacific hake US	cooperative	management council	large
Bering Sea pollock	cooperative	management council	large
Puget Sound geoduck	auction	state government	small
Falkland squid	auction	regional fisheries authority	large
Chilean artisanal fisheries	TURFs	co-management (national government–local fisher's associations)	small
New England groundfish	weak limited entry	management council	medium
West Coast trawl	weak limited entry	management council	large
West Coast abalone	all commercial fisheries closed	state (USA) or federal (BC) governments	large
Argentinian hake	weak limited entry	management council	large

An important aspect of the reward structure is the line responsibility of managers and scientists. Governance structures that include many competing interests in the data collection, stock assessment and management decision making have a poorer track record than governance structures with few institutional actors. The complex institutional structure of EU fisheries and many US councils, with overlapping state and federal authority and interest, have a terrible record of being able to regulate the catch in their area of management. By contrast, the institutional structure of small countries such as Iceland, New Zealand and Namibia, or the sole authority of the State of Alaska over Alaskan net fisheries such as Bristol Bay, the North Pacific Management Council management and NMFS stock assessment of the North East Pacific, or the two-party IPHC, have all resulted in good track records of fisheries management.

In these institutionally simple governance structures, there is a direct line of responsibility. In the Bristol Bay salmon fishery there is a manager and a research scientist who is directly accessible to the fishermen during the fishery. The fishermen know who is in charge, and who to blame when things go wrong. By contrast, many US fisheries management councils have rotating teams of scientists who perform the stock assessments—many times these assessment scientists have little, if any, experience in the fishery and know it only from the statistics in front of them. A fishery management council with 10–20 members is not conductive to individual responsibility. No one is in charge, and no one is to blame if things go wrong.

(b) *Self regulation by fishing groups and co-management*

Fishing groups in a number of jurisdictions including New Zealand, Canada and Chile are currently working with their government institutions to devolve management authority for data collection, stock assessment, catch regulation and enforcement to the commercial fishing industry. The Chilean TURF system for benthic resources described above is probably the most advanced, but in all cases, the underlying conditions are use or quasi-property rights for the commercial fishing industry and no significant competing user groups. Under such circumstances, all of the incentives are in place for the commercial fishing groups to behave in a societally desirable fashion by operating as a sole user. The long-term return to the fishermen will be maximized by good sustainable management of the resource. The fishermen will be in a position to determine the appropriate levels of expenditure on research and on enforcement. Many people have argued that such arrangements put the fox in charge of the henhouse. If the governance structures are adequate and the appropriate incentives are in place, the better analogy is putting the farmer in charge of the farm. No one argues that mussel farmers or salmon farmers should have government regulation to keep them from overharvesting their mussel or salmon farms. Why should a commercial fishing group with exclusive rights to a resource overharvest its resource?

However, there are circumstances under which exclusive rights do not guarantee responsible fishing practices. For example, the mismatch between the spatial scales of TURFs and the scales at which stock-recruitment processes operate tends to weaken the fishing communities' incentives to protect local stocks. This is because future recruitment into one TURF depends not only on its local stock but also on neighbouring populations. Overfishing of one TURF may not have such a severe impact if recruitment is still maintained by the contribution of other healthier populations outside the TURF. The maximization of yield-per-recruit within the TURF will tend to counter this effect, especially in animals of a moderate to long lifespan. In general, a co-management system will be needed to coordinate management of the different TURFs.

(c) *Where incentives are insufficient*

There remain a number of problems associated with ensuring the incentives are appropriate. Within fishing groups there is no guarantee that the group will act in its self-interest, nor is the interest of the individual within a group necessarily the same as the group's interest. The dynamics and internal governance of the groups, even if granted exclusive fishing rights, may not necessarily lead to good outcomes. In our experience, group size alone is a very important factor. The successful cooperatives in the US west coast have involved small fishing groups; the two groundfish cooperatives have less than a dozen companies, while the Chignik cooperative has 70 members.

Our focus has been on the sustainability of fisheries, but society has other priorities, like equity ('social justice') and conservation ('social justice'). Equity issues created by the introduction of user rights are well documented and have been extensively discussed in the fisheries economics and policy literature (NRC 1999).

Conservation issues are diverse: direct or indirect effects of fishing on marine wildlife, impact of mobile gear on benthic ecosystems and the bycatch of non-commercial or low-value species, among others. Many of these are very difficult to deal with. As an example, there are few economic incentives to prevent bycatch. Negative effects are exacerbated when low unit value, slow-growing species are caught in a multispecies fishery, as exemplified by Pacific ocean perch in the North American west coast mixed groundfish fishery. In such cases, an overall economic optimum may not be ecologically optimal. In the Irish Sea and the Scotian Shelf, for example, booms in valuable shellfish abundance have been attributed to the collapse of groundfish stocks. Bycatch quotas and heavy observer coverage are one form of incentive, as has been market pressure in the case of dolphin bycatch in tuna fisheries.

(d) *Governance and enforcement*

Enforcement of regulations is an often-neglected aspect of fisheries management. Setting catch regulations is of little use if they are not enforced, and in some fisheries, the illegal catch may be as high or higher than the legal catch. This is particularly true for high-value species such as abalone and lobster. In areas near urban markets, the stocks of such high-value species are often seriously depleted by illegal fishing alone. The traditional solution is a top-down response of adding more enforcement officers, a highly expensive approach that is simply not working in many jurisdictions. We believe that enforcement is one area where top-down systems such as auctions may fail, whereas TURF systems may succeed. State agencies are unlikely to be able to patrol large areas effectively, whereas locally based individuals with territorial fishing rights can and have kept the illegal fishermen away.

6. SUMMARY

The lessons discussed in this paper are primarily the result of our own personal experience in a range of fisheries. There has been very little experimental research on governance systems (Ostrom 1999 being an obvious exception), and thus many of our conclusions can be considered anecdotal. There is clearly a need for a large-scale quantification and evaluation of biological and economic successes and failures in fisheries management. Nevertheless, we do believe from our own work in many different fisheries that there are clear lessons to be drawn. The keys to success allocation, simple institutions and appropriate incentives are not sufficient conditions for success, but they do seem, to us, to be almost certainly necessary.

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GLOSSARY

EEZ: exclusive economic zone
IQ: individual quota
ITQ: individual transferable quota
IVQ: individual vessel quota
MPA: marine protected area
MSY: maximum sustainable yield
TAC: total allowable catch
TURF: territorial use right