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Towards Sustainability of Data-Limited Multi-Sector Fisheries

Editors
Stephen J. Newman, Daniel J. Gaughan, Gary Jackson,
Michael C. Mackie, Brett Molony, Jill St John and Patricia Kailola

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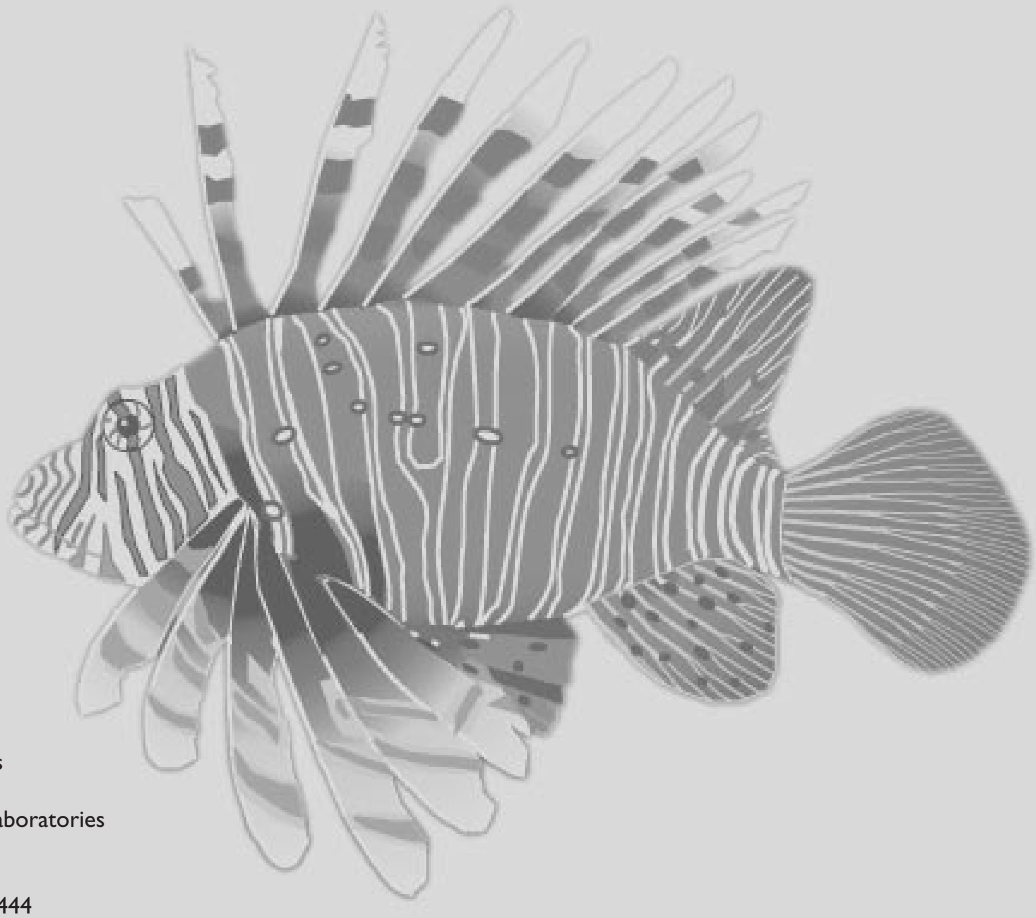

Department of Fisheries
Research Division
WA Marine Research Laboratories
PO Box 20
North Beach WA 6920
Telephone (08) 9246 8444
Facsimile (08) 9447 3062
Website: http://www.fish.wa.gov.au

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KEYNOTE ADDRESS

Diving for shellfish and data: incentives for the participation of fishers in the monitoring and management of artisanal fisheries around southern South America

Ana M. Parma, J.M. (Lobo) Orensanz, Inés Elías and Gabriel Jerez

Ana Parma, Lobo Orensanz and Inés Elías can be contacted at the Centro Nacional Patagónico, 9120, Puerto Madryn, Argentina. Gabriel Jerez works at the Instituto de Fomento Pesquero, Valparaiso, Chile. Email: parma@cenpat.edu.ar

Abstract

The conventional approach to fisheries management requires reliable estimates of stock size and fishing targets, and strong compliance with fishing regulations. Lack of data and poor enforcement are widespread among small-scale coastal fisheries, especially those that target spatially-structured benthic resources. Spatial heterogeneity in the dynamics of the stock and of the fishing process complicates data collection and assessment and limits the effectiveness of catch and effort controls. Where landing sites are spread out along the coasts, accountability and enforcement are impossible. Overall, the centralised monitoring, assessment and control of these fisheries are unrealistic. It is only through providing the right incentives for the fishers to participate in all stages of management that sustainability is possible. Two co-management initiatives involving commercial diving fisheries in South America illustrate these points. The implementation of territorial use rights in the shellfish fishery of Chile has delegated much of the monitoring and management to the local fishers' organizations, which now find in their own best interest to conserve their resources. In the shellfish diving fishery of northern Argentine Patagonia, a co-management experiment involves fishers, scientists and managers in the development of sustainable management plans.

Introduction

Many artisanal fisheries along the coastal zones of the world rely on a potpourri of spatially-structured stocks associated with the seabed. These fisheries, which support the livelihood of hundreds of thousands of fishers and their families, are often regarded as a nightmare from the viewpoint of stock assessment, and hence unmanageable. One difficulty frequently invoked is the scarcity of data, particularly of the type needed to estimate stock abundance and productivity trends. The cost of collecting these data is prohibitive given the need to capture the spatial heterogeneity of both the resource and the fishing process at a meaningful scale. Yet, would these fisheries be more manageable if those data were available? Not necessarily. Lack of data is just one of the obstacles to the implementation of conventional, assessment-based management approaches in small-scale coastal fisheries. There are other, perhaps more fundamental difficulties, which result from the very nature of the resources and the fishing operations. On the one hand, the spatial structure of the population, the preferential allocation of effort to highest density grounds and the fact that fishing effects are local bring into question the effectiveness of catch and effort controls at the scale of the whole fishery (Orensanz and Jamieson 1998). On the other, the implementation of catch or effort quotas are generally fraught with difficulties: where thousands of fishers land their catch anywhere along the coasts, accountability and enforcement may be simply impossible.

In this paper we argue that (i) centralised monitoring, assessment and control of spatially-structured coastal fisheries is unrealistic, (ii) there is a wealth of empirical information that can be used to develop precautionary management guidelines for such coastal fisheries, and (iii) it is only through providing the right incentives for the fishers to participate in all stages of management (monitoring, analysis of the information, decision-making, and enforcement) that sustainability is achievable. We illustrate these points describing the results of two co-management initiatives involving commercial diving fisheries in South America. These results are the large-scale implementation of territorial use rights (TURFs) in the multi-species shellfish fishery of Chile, and a small test co-management experiment involving a shellfish diving fishery in northern Argentine Patagonia. While still in their infancy, these co-management systems show promise compared to the conventional approaches tried in the past. We discuss their advantages and our caveats, and identify some key problems that need to be addressed in order to consolidate these initiatives.

S-Fisheries: where conventional management approaches do not work

We focus on a particular category of fishery, which can be described by several ‘S’ words:

- *small-scale*, in terms of the size of the fishing units (small boats typically less than 10 metres long), but not necessarily small in terms of the aggregate landings nor of the economic value of the catch;
- targeting *sedentary stocks*, typically structured as ‘metapopulations’, in which subpopulations of relatively sedentary adults are interconnected through larval and/or juvenile dispersal; and
- *spatially-structured*, where the structure of the stock is persistent (relative to pelagic fisheries or fisheries that target more mobile species) and the behaviour of fishers is dominated by spatial heterogeneity.

S-fisheries are very common along coastal zones of the world. Typical examples are diving and trap shellfish fisheries, and hook-and-line reef fin-fisheries. In some cases these fisheries support very lucrative export-oriented industries or touristic/recreational activities[1], while in others the fishery’s significance is not due to its monetary output but to its being a source of labor, often the sole means of support of thousands of fishers and their families.

The limited mobility of the organisms and the heterogeneity of the coastal seascape shape the dynamics of both the stock and the fishing process. Population processes related to growth, reproduction and recruitment are dominated by local effects (both environmental and density-dependent) and tend to vary dramatically over small spatial scales in the order of metres. Fishing tends to effectively remove patches of highest density, modifying the concentration profile of the harvested population in the exploited grounds (Orensanz et al. 1998). The effects of fishing operations are locally persistent, resulting in local depletion of accessible fishing grounds, followed by spatial shifts in effort allocation. In the end, the process can lead to serial depletion of large geographic areas[2]. Because of the small size of the fishing units, port infrastructure requirements are minimal, therefore landing sites tend to be dispersed along the coasts. This non-concentration of landing sites has implications on data collection and enforcement, as discussed later.

[1] Good examples are the geoduck fisheries from Washington and British Columbia (Orensanz et al. 2001) or the artisanal ‘loco’ snail and sea urchin fisheries from Chile (Castilla and Fernández, 1998; Andrew et al., in press).

[2] The Chilean sea urchin fleet moved towards the southernmost regions (XI and XII) following depletion of the grounds in region X (Barahona and Jerez 1998).

S-fisheries are in sharp contrast to the industrial, centralised fisheries after which classical fishery theory was developed (Table 1). The paradigm behind the conventional management approach corresponds to a unitary stock of highly mobile organisms, where population dynamics processes are spatially homogeneous and the local effects of fishing are diluted in a dynamic pool. Fishing mortality can be controlled by placing limits on the total amount of catch that can be taken or the number of units of fishing effort that can be spent on a season. These limits are commonly determined on an annual basis by applying some harvest strategy or control rule (generally defined in terms of target and threshold reference points) applied to best point estimates of stock size or fishing mortality (for example, Figure 1). For this approach to work, stock assessments must be reliable, reference points must be meaningful in terms of the stock and the fishery dynamics, and catch or effort controls must be effectively implemented. This conventional approach is data-thirsty; not many fisheries in the world are able to meet the required information standards.
S-fisheries rarely do.

Dealing with data-poor fisheries

Different approaches have been proposed over the years to deal with data-poor situations. They include:

- *Adjust conventional assessment-driven approaches and work with what you have*

Many methods fall into this category, from the use of rules of thumb to derive fishing mortality reference points (e.g., set fishing mortality equal to natural mortality) to over-simplified methods of stock assessment popularised in the 1980s (Pauly 1983), made available through accessible and user friendly software (Sparre and Venema 1992). Collectively, these methods strive to provide the same management parameters as can be estimated in data-rich situations using conventional analytical assessments based on long-term data series. Short-cuts and simplifying assumptions need to be made to do so (e.g. equilibrium), many of which are often inappropriate, resulting in a degraded product and a dangerous illusion of success.

- *Set conservative fishing targets*

The standard prescription under the Precautionary Approach (Food and Agriculture Organisation 1996) is to acknowledge the uncertainty in the estimates of stock size and reference points and reduce harvest rates appropriately. In some cases, generic rules for adjusting fishing targets as a function of uncertainty have been proposed (e.g. Thompson 1992); in others, precautionary advice is derived from fisheries-specific evaluations of performance of alternative harvesting strategies in simulations considering a wide range of possible scenarios consistent with experience.

- *Use robust strategies that work in the absence of stock-assessments*

Under this category are the use of precautionary size limits to protect reproduction (Myers and Mertz 1998) and the implementation of closed areas to directly limit harvest rates (Lauck et al. 1998, Walters 1998).

The last two prescriptions are not mutually exclusive: both are valuable components of a precautionary approach to management in data-poor situations. Other axes of the management problem, however, are key to the success of any approach (Hilborn et al. 2001, Orensanz et al., in press).

Data poverty generally has some structural correlates

Uncertainty and information quality can be viewed as a continuum ranging from very data-rich situations to total lack of information. In theory, harvest targets could be adjusted along this gradient according to any given degree of risk-aversion. Consideration of other fisheries attributes beyond data availability, however, shows that data-poor cases are not a random set of all fisheries. Rather, data poverty tends to be associated with some structural features of the system, which compound the management problem and require qualitatively different solutions. S-fisheries, in particular, are a case in point. Due to the structural features described in Table 1, S-fisheries tend to be data-poor because:

- catch and effort statistics are difficult or impossible to collect and mis-reporting is commonplace;
- even when catch rate statistics are collected, they are only meaningful locally and not representative of the aggregate abundance; and
- in most cases, total abundance can only be assessed through direct surveys, which are difficult and expensive.

Before we place much weight on the need to collect data we should ask how the data would be used and whether the fisheries would be more manageable if those data were available. Although the answer to these questions is fishery specific, it is generally true that data poverty is symptomatic of more fundamental problems that need to be addressed. The same structural features that explain why S-fisheries are data-poor also result in fisheries that do not fit within the conventional fishery paradigm. In these fisheries:

- the unit-stock concept does not hold: stock dynamics and the fishing process need to be analysed in a spatially-explicit context;
- comprehensive catch or effort controls may not be meaningful; and
- top-down enforcement of catch quotas, effort, or other regulations is often difficult or impossible.

Altogether, this means that centralised monitoring, assessment and control of these fisheries are unrealistic. The only feasible way to obtain the information required to support meaningful management plans at the appropriate spatial scale and to achieve compliance with management regulations is through the cooperation of the fishers. Thus, the key to sustainability is to provide the right incentives for the fishers to participate in all stages of management (monitoring, analysis of the information, decision-making, and enforcement). Excessive focus on data shortage may obscure these more fundamental limitations.

Lessons from S-fisheries in South America

Two co-management initiatives involving commercial diving fisheries in South America illustrate the points discussed above. The first is a large-scale implementation of territorial use rights (TURFs) in the benthic fisheries of Chile (Castilla and Defeo 2001, Castilla and Fernández 1998, Orensanz et al., in press, Stotz 1997); the other is a test co-management experiment involving a small shellfish diving fishery in northern Argentine Patagonia (Figure 2). In both cases, fishers' participation appears to be the only feasible alternative not only to gather the data required to make informed management decisions at the appropriate spatial scale, but also to achieve compliance, driven by self-interest as opposed to top-down enforcement.

1. A mega-experiment with TURFS: benthic fisheries in central and northern Chile

The Chilean shellfish fishery is a large and significant industry, with an aggregate catch in the order of 150,000 tons per year (worth about US$170 million per year) (Castilla et al. 1998, Castilla and Fernández 1998) and enormous social and cultural importance. More than 10,000 commercial divers, based in about 250 fishing communities known as "caletas"[3] (Figure 3) are currently registered with the country's National Fisheries Service (SERNAPESCA). The divers target many species of seaweed and invertebrate, most significant among them 'loco' (*Concholepas concholepas*, a carnivorous snail superficially resembling abalone), sea urchin (*Loxechinus albus*) and key-hole limpets (*Fissurella* spp). Throughout central and northern Chile caletas are spread along approximately 3,000 kilometres of a quasi-linear coastline, spanning over 24 degrees of latitude. Administratively the country is divided into 12 regions (Figure 4, centre), with regions I-IX corresponding roughly to the north-central zone. This zone is the domain where a mega-experiment with TURFs was launched during the 1990s.

Until the late 1980s, fishers harvested overlapping 'historical grounds' in what was essentially an open-access fishery. At about that time, scientists and managers became concerned about the possible overfishing of loco and the fishery was nominally closed for three years (1989-92) (Figure 5, Castilla and Fernández 1998). Fishing never ceased however but became illegal, with disastrous consequences for fishing communities. Economic hardship and social tensions created by the closure motivated the search for management alternatives. The current Fisheries Act, approved by the legislature in 1991, contemplates three regimes for the management of benthic shellfish:

1. **URFs**
2. **Open Access** of historical fishing grounds (outside TURFs) to all artisanal fishers listed in a National Registry compiled by region, and
3. **Total Allowable Catches (TACs) and Individual Quotas (IQ),** the latter granted to all registered divers for resources considered 'fully-exploited'.

In general, artisanal fishers are entitled to operate only in the region where they are registered. The National Registry was closed in 1995, leading *de facto* to a ***limited** entry* system. The Act also contemplates management tactics such as size limits and fishing seasons, and a system of marine reserves.

Interestingly, implementation of the Fisheries Act of 1991 allowed two different management regimes to coexist for the loco fishery. When the fishery was reopened in 1993 loco was considered fully-exploited; therefore, TACs and individual quotas were introduced to limit harvest rates. TACs, however, proved to be unenforceable and the system of tickets used to implement the IQs was ineffective, leading to a black quota market and a distortion of the limited entry program. Hence the system as a whole was considered a failure and was effectively terminated in 2000. Only landings from TURFs have been allowed since then.

Implementation of the TURF system, on the other hand, started in 1996 and gradually increased in importance to absorb the whole fishery, as discussed below. TURFs are granted to officially recognised fishers' organisations, which request them voluntarily. Benthic resources within a TURF are co-managed by the central authority (the Under-Secretary of Fisheries, responsible for fisheries management in the country) and the local fishers' organisation that was granted the TURF, with assistance from a technical consultant

[3] 'Caletas' are sites along the coast which serve as operational bases for local artisanal fleets. In rural areas, caletas are equivalent to fishing villages; in urban areas, fishers and their families are part of larger communities.

hired by the fishers' organisation. The requesting of a TURF is a long and demanding process (Montecinos 2000; Orensanz et al., in press): a detailed base-line survey of the grounds is required, including a map of habitat types and estimates of abundance of all target species. A two-year management plan has to be approved by the central managers and, once a TURF is functioning, annual reports of management performance, including trends in estimated abundance, have to be presented.

So far the TURF system appears to be successful. Overall there is not the sense of crisis that led in the past to drastic policy swings or draconian management measures. On average, the abundance of target species is stable or increasing in the TURFs that have been monitored for the last few years (C. Tapia and J. Garrido, pers. comm.). Marketing style has changed dramatically, from unstructured deals to sales pre-arranged before shellfish are harvested.

Yet there are many problems to be solved. TURFs are taxed on a per-area basis, the rate being the same along the entire coastline. This equal tax encourages requests for small TURFs (Figure 6) and provides an incentive for transporting loco from the open grounds into the TURFs (a practice known as 'apozamiento') that inflates local abundance at the expense of open-access grounds. A more perverse problem is the illusion of self-containment of a TURF (in terms of its sustainability) that often results from the sedentary nature of benthic shellfish. Because local areas are open to recruitment originating in other areas (i.e., each TURF is an open population) the incentives for conserving a reproductive stock within a TURF may be weakened. Mismanagement of one TURF will have consequences for the others and vice versa, even if these effects are not detectable over short temporal scales.

These and other problems were discussed during a workshop conducted in Valparaiso, Chile, in 1999 to evaluate the implementation aspects of the TURF system, then at an early stage of development. The workshop involved representatives of all the sectors that participate in the management system, plus an independent international panel[4]. At the end, the panel produced a consensus report with the following conclusions and recommendations:

1. Coexistence of TURFS and the open access fishery is not viable
   - The system of TURFS should expand to encompass the whole fishery
2. The implementation process is too complex
   - It should be designed so that it can be implemented in hundreds of TURFs
   - It should be understood by the fishers
   - It should not be too costly
3. The data collection system is unnecessarily demanding
   - The information required should be simplified
4. The implementation of the system was judged too 'top-down'
   - Fishers' organisations must be empowered
   - Education is needed so that fishers and managers can participate in management decisions on an equitable basis

[4] The members of the panel were Prof. Loo Botsford (U. of California - Davis), Prof. Ray Hilborn (U. of Washington), Dr. Glen Jamieson (Pacific Biological Station, DFO, Canada), Dr. Jean LeFur (ORSTOM, Montpellier, France), Dr. Robert Pomeroy (World Resources Institute, Washington DC), Dr. Jeremy Prince (Biospherics Inc., Australia), and Prof. Steve Thompson (Pennsylvania State University). A copy of the report is available from the authors upon request.

Guidelines for the implementation of the TURFs have been simplified in recent years and the system keeps expanding at a fast pace. The number of TURFs increased explosively, especially in some regions (Figure 4, Montecinos 2000). By 2001, 264 had been assigned, encompassing 43,200 hectares of seabed; and of those 80 were being implemented. Although the TURFs are generally small (Figure 6) the percentage of the total catches that they contribute increased rapidly over time. A three-year moratorium on fishing in 'historical grounds' was sanctioned in June 2000, putting a *de facto* end to the TAC-based 'benthic regime'. Since then, loco fishing in regions I-IX has been allowed only within the TURFs. In 2000 a controlled ('research') fishery was allowed in regions X-XI, but this did not re-open in 2001.

This loco fishery is an interesting case study in the context of this symposium because knowledge and implementation have provided feedback to each other in many ways. Knowledge about the benthic fisheries of central and northern Chile, and particularly about loco, is exceptional for an S-fishery from the developing world. Three major **paths** to this knowledge can be recognised: scientific knowledge, stock-assessment models based on fishery statistics, and folk knowledge.

PATH 1 corresponds to work conducted by Chilean scientists over the years, including studies on the basic biology of commercial species, experimental work on benthic communities, and experimental and comparative studies on the dynamics of localised harvested populations (Castilla and Defeo 2001). Experimental work conducted in the 1980s elucidated key aspects of the response of benthic communities and stocks to harvesting (Moreno et al. 1984, Castilla 1999). Based on those results, scientists and fishers collaborated in local stock-rebuilding experiments in a few well-organised caletas from central Chile, and these were granted exclusive fishing rights over adjacent sectors of the sea bed between 1987 and 1992. Local abundance was rebuilt after two or three year closures and closely monitored by participating fishers (Castilla 1997, Castilla et al. 1998). It is most remarkable that these studies were a major input for the inception of TURFs in the Fisheries Act of 1991 in what has been called the 'institutionalization of scientific knowledge' (Castilla 1994).

PATH 2 was the dominant input to management after the moratorium on the loco fishery was lifted in 1992 when management was based on TACs and individual quotas. A TAC had to be estimated for each of the 12 administrative regions. This was done using a state-of-the-art statistical catch-at-length stock-assessment model. Path 2 corresponds to the provision and use of information (data + models) in the classical tradition of industrial fisheries assessment and management. Although the model was internally consistent, the full list of problems with assessment, implementation and enforcement that typically afflict S-fisheries worked against the success of the TAC regime (A. Zuleta, pers. comm.). The situation was worst in the central and northern regions, where catch statistics are poorest due to the lack of centralised landing sites. Abundance estimates were meaningless in those areas.

PATH 3 corresponds to folk or empirical fishers' knowledge, a source of information whose significance has been acknowledged only in recent years (Johannes et al. 2000). This information is most often of pure observational nature. Chilean fishers, for example, are knowledgeable about the natural history and distribution of harvested species, as well as about the dynamics of recovery of harvested patches. A program of interviews conducted by the Chilean *Instituto de Fomento Pesquero* (IFOP) to gather empirical information in the sea urchin fishery (regions X-XI; Barahona et al. 2001) has produced very important information, including criteria for the design of reproductive reserves (Orensanz et al., in press). Yet, what is most exceptional in Chile is that many fishers' organisations have attempted manipulative experiments such as self-imposed temporal or spatial closures, removal of alleged predators and competitors ('limpiezas'), transplantation of loco to sites where prey are abundant and protection of the latter, and closure of patches with high density of loco recruits ('maternidades'). Some of these experiments did not produce the expected results: for example, in one case (O. Avilés, pers. comm.) the removal of black sea urchins (*Tetrapygus niger*, a species of no commercial value and a supposed competitor of the commercially valuable white sea urchin, *Loxechinus albus*), resulted in the development of macroalgal beds that smothered benthic communities. Although experiments are not designed according to scientific standards and are often ill-conceived, they are significant because fishers have been willing to invest time and labour in experimental probing, on occasions at substantial spatial scales.

This rich tapestry of knowledge has influenced important elements of the management system and guided their implementation. Paths 1 and 3 paved the way towards the inception of TURFs in the Fisheries Act of 1991, which incorporated inputs from scientists as well as from fishers. The fact that Chile has a very strong tradition in benthic ecology was a major factor in the course taken by the implementation process (Montecinos 2000), as many managers and consultants have been trained in that field. This strong tradition is reflected in the level of ecological detail required by baseline studies, management plans and annual follow-ups, which demand a substantial investment in the acquisition of data that is generally not used for management decisions. The 1999 external panel actually concluded that (1) too much emphasis had been placed on collection of ecological data, (2) information requirements were too complex, and (3) complexity required the hiring of consultants as primary knowledge-providers, which increases implementation costs. Data are being collected faster than they can be analysed by managers. The central administration is bogged down scrutinising individual base-line studies and management plans, and they lack the resources to look at the dynamics of the system as a whole.

Beyond the specific contents of the information assembled, there are indirect positive effects of the influential role of Path 1 in the implementation process, as follows.

- Information requirements have created a sense of institutionality and order in the transition between the 'open access' and the TURF systems.
- Many consultants (e.g. IFOP) have worked very closely with fishers' organisations in the collection of data required for base-line studies, management plans and annual follow-ups. These activities have included the participation of the local fleets in surveys, and the training of monitors within communities. Participation of fishers in monitoring and surveys creates trust in the system, and reduces the costs.
- In a further development, some caletas have retained quasi-resident biologists as regular consultants. These come close to the 'barefoot ecologists' profiled by Prince (in press) as ideal primary producers of information in S-fisheries.

While demanding of ecological information, the implementation of a TURF largely ignored Path 3. Baseline studies, for example, paid no attention to the exploitation history of the area, even though this is a significant piece of information for management, and one on which fishers are generally very knowledgeable. Structured interviews or other forms of gathering empirical knowledge are not a regular part of data acquisition protocols.

The strong tradition in experimental ecology in Chile has created expectations about various forms of experimental and/or adaptive management, particularly considering that the many TURFs along the coast could be managed differently (in a planned way) with a consequent gain in insights about population responses to exploitation. This, however, would apply only to post-dispersal processes, because of the lack of dynamic independence among the TURFs discussed above.

An evaluation of the sustainability of the system at the scale of the whole fishery will require a considerable effort to consolidate the massive amount of information generated into a form that facilitates the analysis. A synthesis above the level of individual TURFs should examine performance in terms of key indicators and consider the different axes of sustainability (Charles 2001): biological (e.g. trends in abundance and recruitment, size compositions), economic (e.g. yields, sales, sale prices, profits), community (e.g. level of organisation, distribution of labour and benefits) and institutional (e.g. participation of fishers in management). Such a synthesis would help to develop criteria for designing suitable harvesting strategies (e.g. harvest rates, size limits) and for coordinating management plans of individual TURFs at a regional scale – a role that would correspond primarily to the central fishery administration responsible for the sustainability of the fishery as a whole.

This overview of data, information and knowledge of Chilean benthic fisheries points to some aspects requiring further attention. They are:

- the need to gather folk knowledge in a systematic way, and the convenience of utilising it;
- the importance of involving fishers in surveys and monitoring; and
- the possible value of promoting 'barefoot ecologists' as primary providers of knowledge in place of external consultants.

More generally, this case illustrates why more information does not necessarily mean better management. This applies both to some of the data currently required by the baseline studies and to the assessment models used as part of the TAC regime. It was not the costly accumulation of information but rather the introduction of appropriate incentives to the fishing communities that created sustainable options for the fishery.

2. *A test co-management initiative in the diving fishery of the San José Gulf in northern Argentine Patagonia*

Small-scale coastal fisheries of Argentine Patagonia are very small due to the large amount of exposed and inhospitable coasts, where artisanal fishing is only possible in a few places. Among these, San José Gulf (Figure 2), a productive semi-closed body with an approximate surface area of 800 km^2, is the most significant. Shellfish and finfish resources currently support an estimated 110 artisanal fishers and their families, many of them organised in a professional association ('Asociación de Pescadores Artesanales de Puerto Madryn', APAPM[5]). A commercial hookah-diving fishery for scallops (*Aequipecten tehuelchus*) developed in the mid 1970s, following the 'boom-and-bust' cycle of a scallop dredge fishery in the adjacent San Matías Gulf (Orensanz et al. 1991). Because of the demonstrated unsustainability of that fishery, dredging was banned in San José Gulf (then designated as a Provincial Marine Park) out of concerns over the negative impact of the gear on the bottom and the potential destruction of habitat considered suitable for settlement of scallop larvae (Orensanz 1986). A hookah diving fishery operated after that, targeting several clam and mussel species in addition to scallops. Fishing units are boats less than 10 metres long equipped with compressors and outboard motors, typically operated by a crew of one deck assistant and two divers. These units are able to land the catch at many locations along unpopulated coastlines (Figure 3b).

[5] For further information see http://www.apamadryn.com.ar

In contrast with the Chilean system, coastal fisheries are under provincial jurisdiction: San José Gulf fisheries are managed by the fishery administration of Chubut Province. Under open access, the artisanal fleet grew to approximately 30 units (60 divers) by 1995.

A weak peso favoured exports and divers responded by taking higher risks to work in deeper waters, thereby lowering the density threshold considered profitable and violating size limit regulations. All existing reproductive refuges disappeared, landings rose to approximately 1,200 tons per annum. The fishery collapsed soon after, and remained closed for three years (Figure 7). Fishing was resumed in 1999 at a rather modest level. However, a crisis in the off-shore industrial hake (*Merluccius hubbsi*) fishery in 2000 cascaded into the coastal zone. Social pressure on the provincial fishery administration to issue new permits mounted as a way of absorbing fishers displaced from the off-shore sector.

This critical scenario led in 2000 to discussions for solutions between the fisheries administration of Chubut Province, artisanal fishers, environmentalists and scientists.

Unlike the case of central and northern Chile (discussed above), the implementation of a TURF system is not an option for this fishery because:

- Fishers generally do not live close to the fishing grounds. Only two permit holders live along the coasts of San José Gulf, where there is a permanent moratorium on the establishment of new human settlements[6]. Most fishers live in Puerto Madryn, about 60 km away from the gulf. Enforcement of territorial rights would therefore be difficult.
- The fishers' organisation is weak, although this is in part a consequence of the historical open nature of the fishery.

Instead, a test co-management experiment was initiated. It emphasises flexibility and allows for input from all the parties, open discussion of options and feedback from short-term learning.

- A technical advisory team was formed with participation of the APAPM, technical staff from the provincial administration and scientists from CENPAT[7].
- Artisanal fishers received an intensive four-month course covering aspects related to the ecology and natural history of target species, conservation and environmental effects of fishing, assessment techniques and management.
- The technical advisory team prepared short-term management guidelines for the scallop fishery and for a newly-developed geoduck (*Panopea abbreviata*) fishery.

Management recommendations for 2001 were relatively straightforward in the case of scallops, because a pre-season survey had indicated very high abundance of pre-recruits (one year old scallops, smaller than the minimum legal size of 60 mm) in several grounds along the coast of the San José Gulf. The technical advisory team considered that protection of this cohort would be enough to guarantee successful reproduction during the upcoming season. Emphasis was thus placed not on the overall TAC but on the protection of sublegal animals, and on the close monitoring of the fishing season.

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6 San José Gulf is part of Península Valdés, designated by UNESCO as Natural World Heritage Area in 1999. The main motivation is that this and neighboring coastal areas are mating/calving grounds for the southern right whale, Eubalaena australis. During the l990s there was friction between fishers and conservationists concerned about interference of fishing with whale behaviour.

7 CENPAT (National Patagonian Center) is a regional research facility that reports to Argentina's National Council for Scientific and Technical Research (CONICET).

In contrast to the scallop, the data available to guide management decisions in the case of geoduck were very scarce. No information about total biomass existed, nor would it be feasible to survey the entire grounds. Instead, information from two sources was used to develop a management plan.

1. Information was borrowed from the North American species (*Panopea abbreviata*), which supports a lucrative fishery in Washington and British Columbia (Orensanz et al. 2001). Due to its very high longevity (maximum recorded age in the order of 160 years) and apparently low productivity only a very small fraction (around 2%) of the biomass is exploited annually. We assumed that the local species would be similarly long-lived with a comparable productivity.
2. Fishers' knowledge about geoduck availability, gathered while they explored potential yields from different grounds, was also utilised.

Although patchy, the information from these sources was sufficient to select a robust harvesting strategy, at least for the short-term. The key elements of the plan were:

- to limit harvest rates by opening up only a small fraction of the overall grounds;
- to rotate fishing areas annually; and
- to assess pre-harvest biomass in the area to be opened and monitor depletion over the fishing season with cooperation from the fishers.

The rotational strategy was proposed by the fishers, as was also the area opened in 2001. The plan was developed within the technical advisory team and after several meetings of the APAPM. Overall, the process resulted in trust between fishers, scientists and technicians from the fishery administration, and all sectors felt that the plan was theirs.

For the longer term, strategic management plans will need to be designed and management procedures fine-tuned. In a most significant development the APAPM petitioned a limited entry program for the diving fishery. In response, the fisheries authority froze the number of permits. During the 2001 season, only 'historical fishers' were allowed to fish scallops (15 diving teams) while about the same number were not given any quota. While still far from a formal limited entry program, these first steps have encouraged a conservative attitude on the part of the permit-holders and have facilitated the collection of detailed catch and effort statistics by fishing ground. At the same time we are developing operating models of the fisheries, which will be used to evaluate alternative regulatory tactics and information needs for implementation.

Discussion

Experience with the cases discussed here, and more generally with small-scale coastal fisheries, has led us to conclude that *the key limitation for management of data-poor fisheries is not lack of data.* S-fisheries are typically data-poor, but this is only one of the difficulties faced by management. More fundamentally, shortage of data commonly comes together with spatial heterogeneity in the dynamics of both the resource and the fishing process, inadequacy of overall catch and effort controls, and unenforceablility of management regulations. In these circumstances, the conventional top-down approach to fisheries management based on TACs or effort quotas determined from analytical stock assessments would fail even if all the standard input data were available.

A qualitatively different approach is needed; one that is based on participation. While solutions will need to take into account the peculiar characteristics of the exploited system in terms of resource dynamics and fleet behaviour, and the geography of fishers' communities, some general prescriptions can be offered to address management of data-poor fisheries.

- *Use empirical information for developing management plans*

Shortage of scientific data may preclude conducting standard analytical stock assessments, but it does not mean absence of information. There is usually a wealth of empirical knowledge that may be gathered, organised and used for the development of management guidelines (Johannes 1998). As discussed by Berkes et al. (2001), the challenge is to find ways of combining information coming from multiple sources into an understandable and communicable form, so that it can be used in support of decision-making. Although the value of empirical information has been appreciated only during the last decade or so, experience is rapidly accumulating (Johannes et al. 2000, Neiss et al. 1999).

- *Fishers themselves can collect the data needed to assess exploited resources*

Fishers can be motivated to get involved in monitoring and data-collection programs once they understand the value of the knowledge that they can contribute. Appreciation of that knowledge by scientists, managers and other stakeholders empowers fishers, fostering their participation in the management process. Simple protocols need to be designed for the regular collection of fishery data (catch, effort, size composition and quality of the catch) at the appropriate spatial scale, a process for gathering and archiving the data, and software to facilitate data visualisation and analysis. Shortcomings of CPUE data to monitor abundance trends are well known (Hilborn and Walters 1992) and should not be overlooked. However, the idea here is to use CPUE as a relative indicator of the local status of the resource in the different grounds, and not necessarily as an index that is proportional to abundance as assumed in conventional assessment models. Also, CPUE is one of the determinants (often the most significant one) of the suitability of locations or grounds as perceived by the fishers. Other determinants of suitability include perceived abundance, exposure, depth, distance to harbour, type of bottom and quality of the shellfish. The costs of collecting scientific data at an appropriate spatial scale, on the other hand, may be prohibitive in S-fisheries.

- *Educate the fishers, and in the process of so doing enlighten the scientists*

Benefits will be maximised if fishers have an adequate understanding of the different elements that support management decisions, from the biology of the resources to the dynamics of the fishing process, to basic concepts about fisheries management and conservation. Investing in education, rather than in expensive scientific surveys, results in broader benefits to the management process and, in the end, a more sustainable monitoring system. It is our experience that scientists are enlightened themselves in the process of educating the fishers.

- *Use the experience gathered with similar systems elsewhere*

Whether informally or using formal approaches for meta-analysis (e.g. Myers et al. 2002), information gathered about related species or fisheries elsewhere should be considered in the development of management plans.

- *Work in association with fishers and other stakeholders including managers and scientists to develop management plans*

The best way to appreciate the value of collecting fishery data, both scientific and empirical data, is to make use of the extended knowledge base in the development of management plans that make sense to all the sectors involved with the fishery: managers, scientists and other stakeholders. It is essential that a participatory and transparent process be established for the analysis of the information and the evaluation of alternative management approaches. To work, management plans do not require a formal stock assessment and estimation of absolute stock abundance. In the absence of analytical assessments, precautionary guidelines can still be developed (Berkes et al. 2001, Mahon 1997). Simple harvest rules can be developed that do not strive for optimality, but may still provide 'pretty good yields' (Hilborn et al. 2002).

- *Promote management systems that provide the right incentives*

In order for the fishers to participate in monitoring and management in an effective way they need to be genuinely interested in the sustainability of the fishery. This will only happen when fishers have secure long-term access rights to the fishery (Orensanz et al., in press). It is only by providing the right incentives that fishers will be motivated to spend the time it takes to participate in resource monitoring, provide unbiased information about stock status, cooperate with enforcement and organise themselves to contribute effectively to management discussions and decision making.

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Table 1. Contrasts between S-fisheries and the type of fishery addressed by the classical theory. ITQ: individual transferable quota; IVQ: individual vessel quota; IEQ: individual effort quota; CDQ: community development quota.

	S-fisheries	The classical fishery
Nature of the physical world		
	Coastscapes and inshore waters, heterogeneous	Offshore waters, perceived as homogeneous
Target populations		
Stock structure	Metapopulation, composed of heterogeneous subpopulations	Unit stock, spatially homogeneous, dynamic pool
Life style	Sedentary	Mobile
Stock–recruitment	Subpopulations open to recruits originating in other subpopulations; processes involved decoupled by the dispersal phase	Unitary stock–recruitment relationship
Growth and mortality	Spatial gradients (often very steep) within subpopulations	Homogeneous within a stock
Small-scale spatial processes	Spatial location of individuals relative to others is significant[8]	Spatial location of individuals ignored
Fleets and fishing process		
Fishing units	Small-scale, artisanal	Large-scale, industrial
Fishing effects	Locally persistent	'Diluted' in the dynamic pool
Fleet behaviour	Central for the design of spatially explicit management strategies (reserves, rotation, etc.)	Secondary significance, academic interest
Landing sites	Dispersed along the coasts	Consolidated industrial ports
Stock assessment		
Direct estimation of total abundance	Always too costly, often technically unachievable, and in many cases irrelevant	Facilitated by sampling surveys (e.g. hydroacoustics, trawling)
CPUE as an index of abundance	Often useless except at very local scale, yet important in the analysis of the fishing process	Useful, with due caveats
Catch-at-size/age methods	Often useless due to spatial patchiness in age composition and gradients in size-at-age	Usual approach to estimating stock abundance
Mark-recapture methods	Non-mixing of tagged and non-tagged individuals violates basic assumptions	In many cases a reasonable alternative
Aggregate biomass models	N/A	Part of the core theory
Stock–recruitment relation	Pre- and post-dispersal processes decoupled; pattern cannot be captured using an aggregate function	Can be reasonably modeled as an aggregate relationship

[8] This corresponds to concentration, which may affect rates of fertilization, settlement, growth, etc. (Orensanz et al. 1998).

Table 1. continued.

	S-fisheries	The classical fishery
Management options		
Control of catch and effort	Generally N/A, as they require reliable abundance estimates and enforcement	Main option
Spatially explicit strategies	Important options include rotation and closed areas	Often not an option due to individual movements
Manipulation of productivity	Feasible even at the local scale of a TURF: habitat manipulation, control of predators and competitors, thinning and restocking	N/A
Experimental management	Spatially defined treatments and controls possible involving post-dispersal processes	Generally N/A
Access rights	Mostly TURFs; limited entry	Typically based on catch or effort quotas (ITQs, IVQs, IEQs, CDQs).
Conflict with other users or stakeholders	Very common, involving pollution, habitat degradation, recreational/tourism uses, urban development and military use. Conflicts often constrain options	Rare

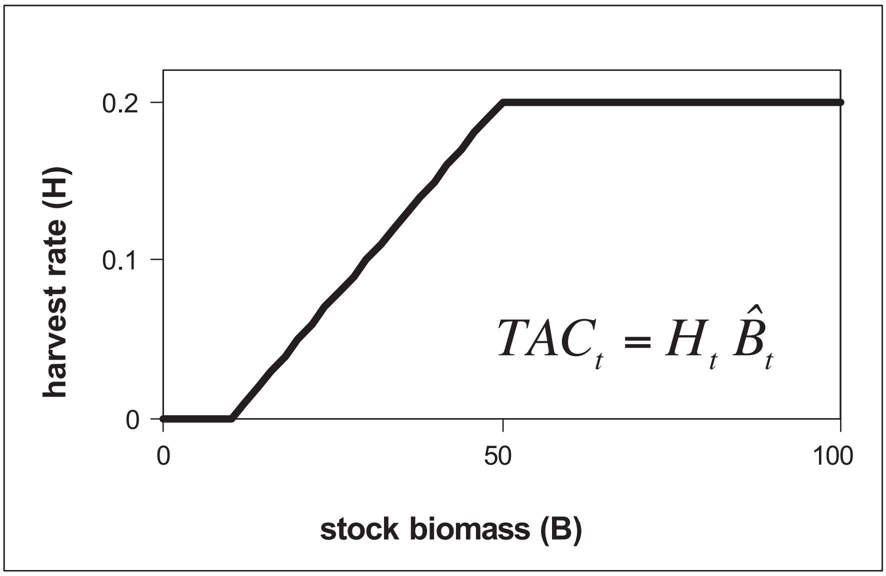

Figure 1. Generic control rule specifying the target harvest fraction in year *t*, H_t as a function of the estimated stock size $\hat{B}_t$, both used to set the Total Allowable Catch *(TAC)* for that year.

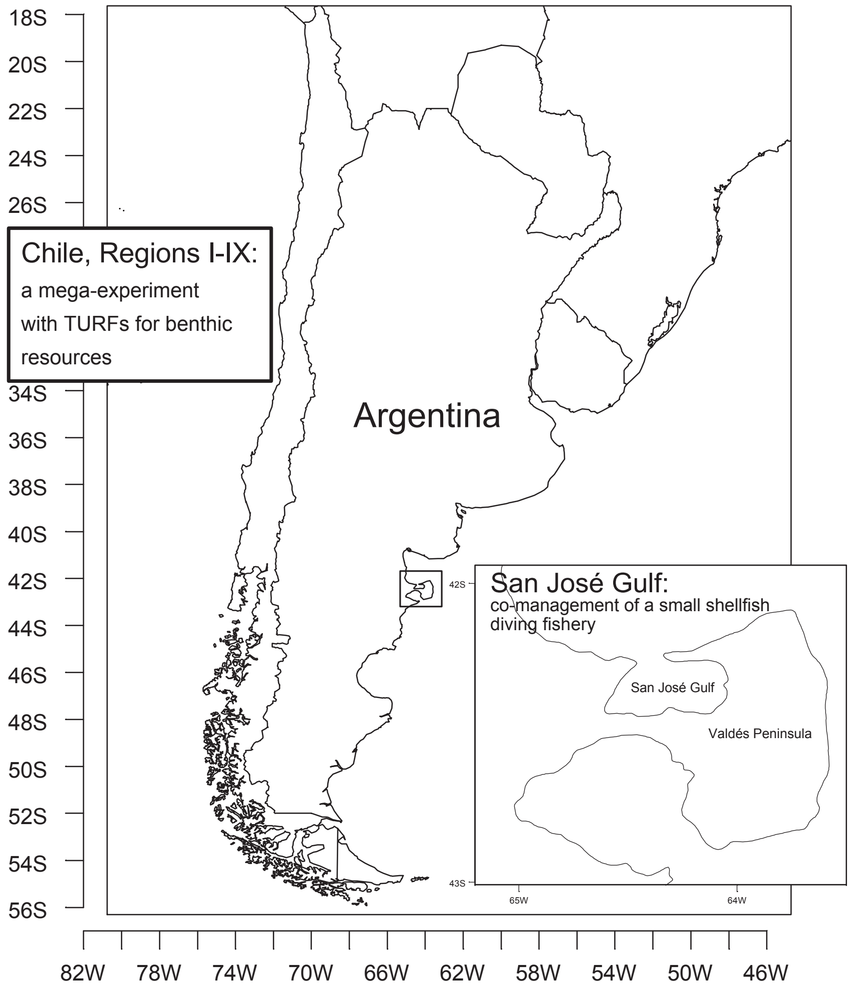

Figure 2. Map of southern South America showing the extensive coastline of Chile, where a mega-experiment on Territorial Use Rights has been launched, and San José Gulf, Argentina, where a test co-managemnt project is being conducted, both involving artisanal shellfish diving fisheries.

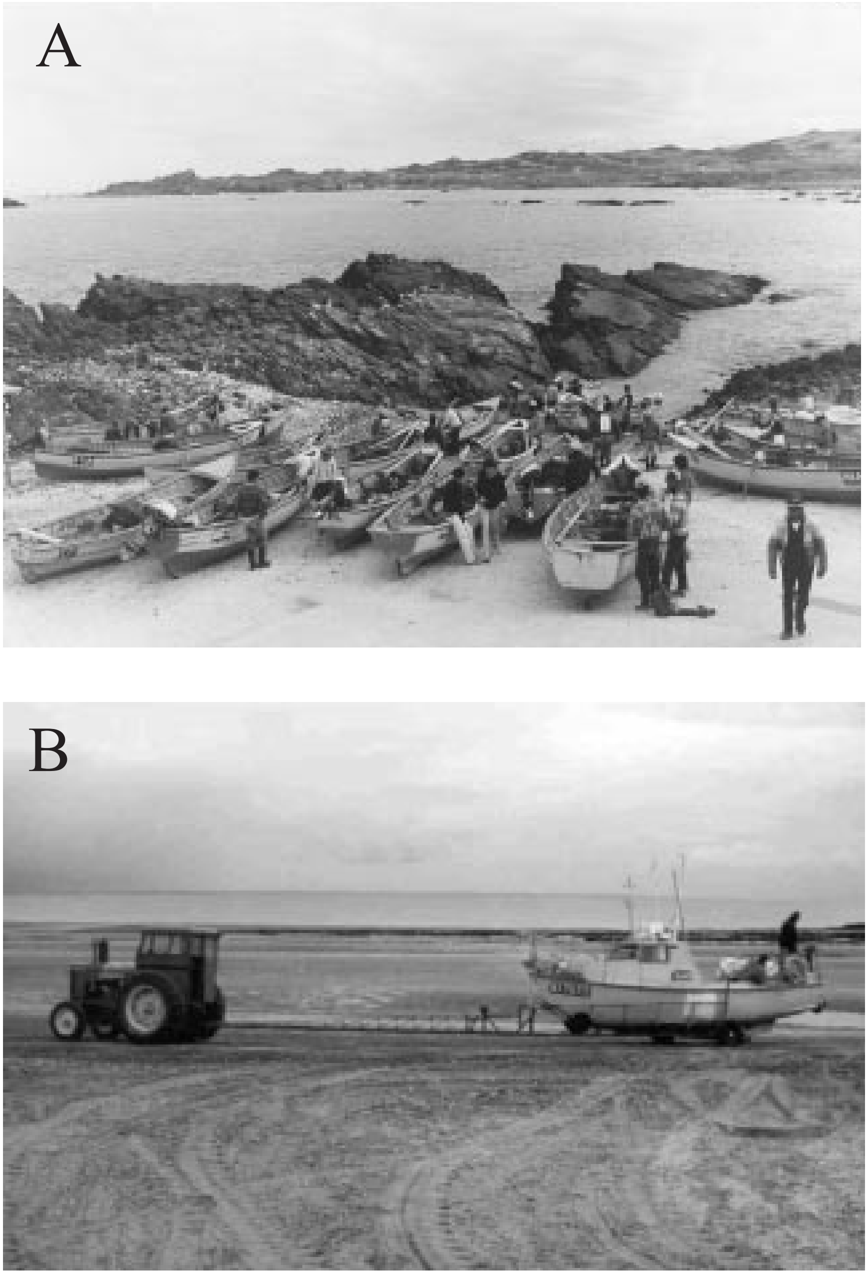

Figure 3. Artisanal fleets can land the catch at many locations along extensive coast lines. (A) Caleta Totoralillo Sur in region IV of central Chile; (B) vessel geared with diving gear, pulled by a tractor in San José Gulf.

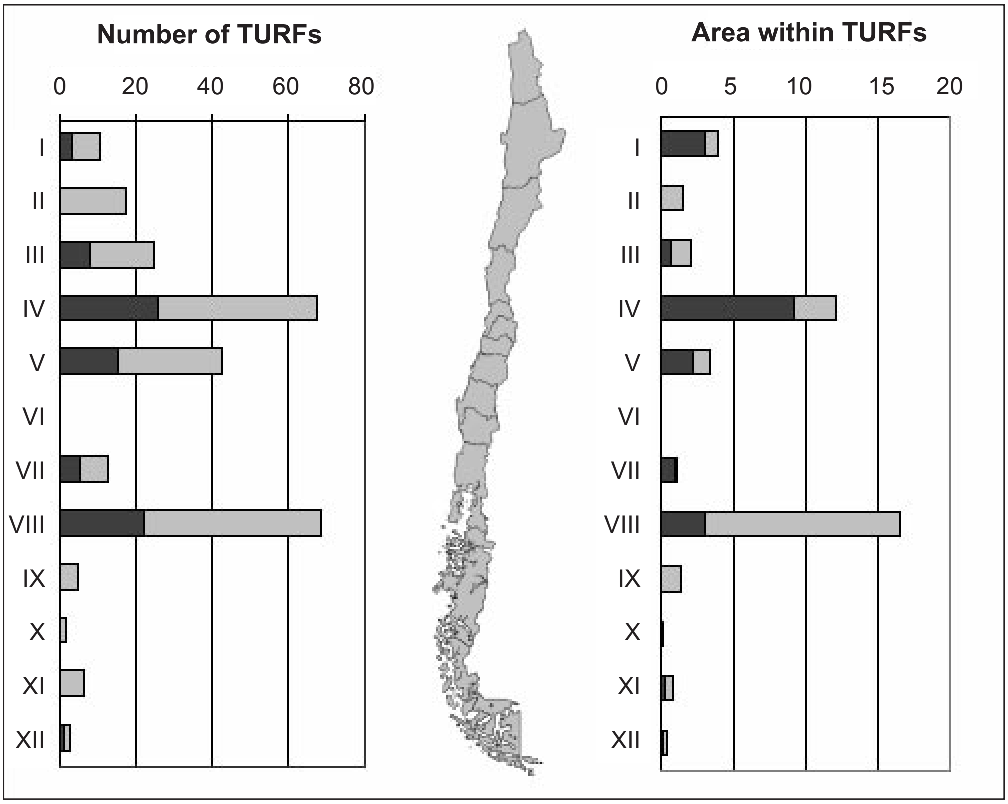

Figure 4. Number of approved TURFs and thousands of hectares within TURFs by Region, number in correlative order from I in the north to XII in the south. Light bars: assigned TURFs; dark bars: TURFS with approved management plan.

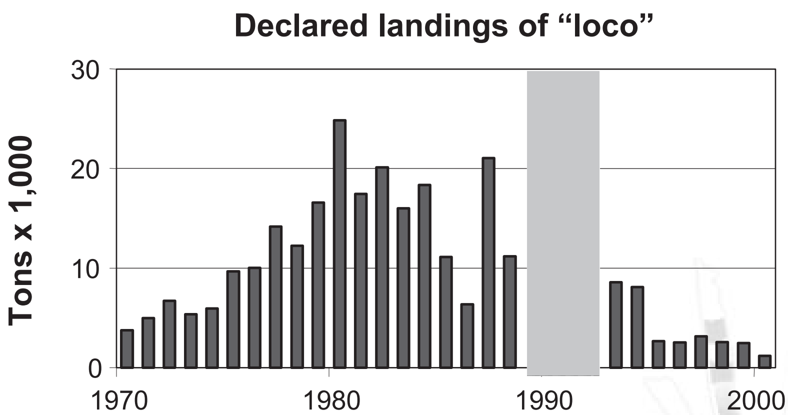

Figure 5. Trends in landings of loco *(Concholepas concholepas)* from the artisanal diving fishery in Chile. Shaded areas indicate periods when the fishery remained closed.

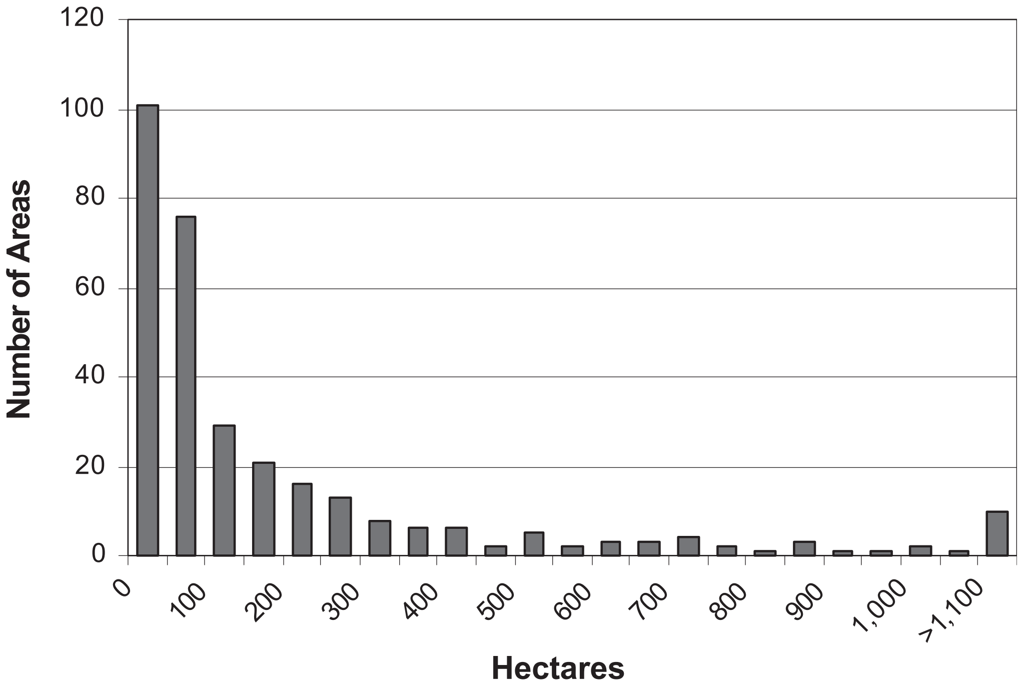

Figure 6. Chilean TURFs: area frequency distribution.

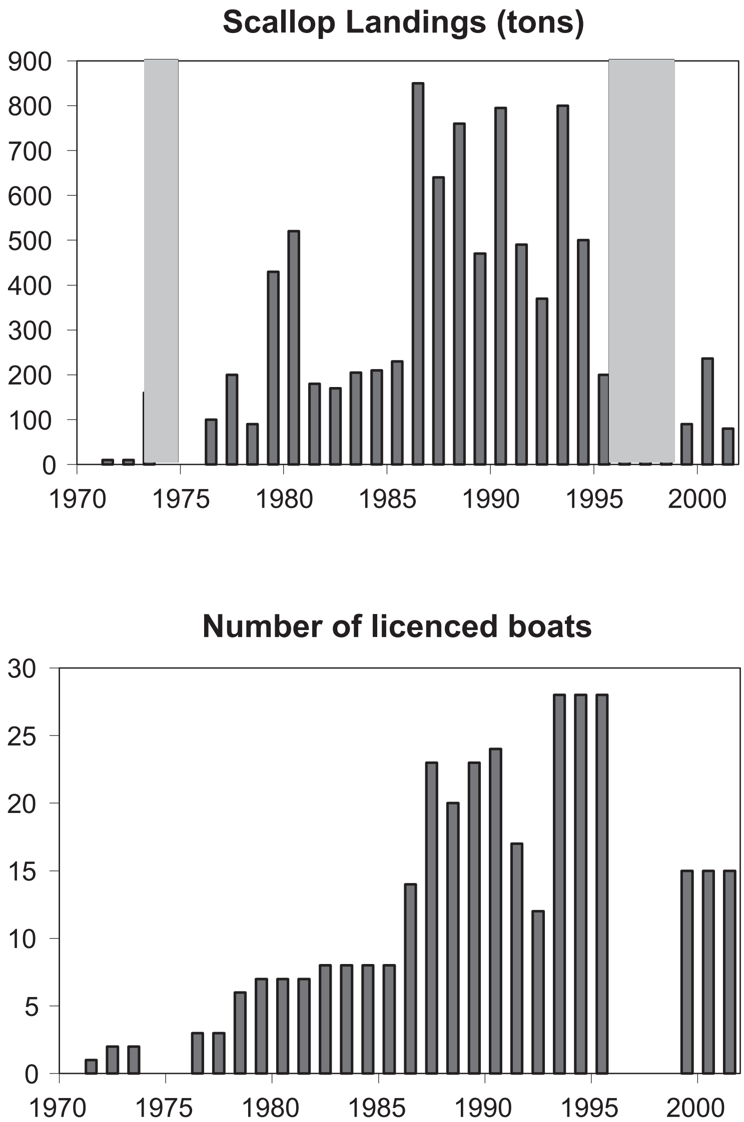

Figure 7. Landings of the techuelche scallop *(Aequipecten tehuelchus)* from San José Gulf, Argentina, and number of boats with permits to participate in the fishery. Shaded areas indicate periods when the fishery remained closed.