Fishers' Knowledge Role in the Co-management of Artisanal Fisheries in the Estuary of Patos Lagoon, Southern Brazil.

Daniela C. Kalikoski[1,2] & Marcelo Vasconcellos[2]
[1]Institute for Resources and Environment, University of British Columbia, Vancouver, BC, Canada, V6T 1Z3, Email: danielak@furg.br
[2]Departamento de Oceanografia, Fundação Universidade Federal do Rio Grande, Rio Grande, R.S., Brazil 96201-900,
Email: Marcelo.Vasconcellos@fao.org

Abstract

This paper analyses the ecological knowledge of small-scale fishers in the estuary of Patos Lagoon, obtained from interviews and questionnaire surveys, and discusses its potential role in the local co-management of artisanal fisheries. This study demonstrates that fishers' knowledge can provide a valuable set of information about the characteristics of practices, tools and techniques that led a more sustainable pattern of resource use in the past. Such knowledge can contribute to the formulation of present management plans to better adapt rules to local social and environmental conditions. However, the use of fishers' knowledge in the co-management of artisanal fisheries was shown to be hampered by three identified factors: the low expectations among scientists and decision makers of the value of fishers' knowledge for management; the lack of incentives for fishers to act according to their ecological knowledge due to problems in the definition of property rights; and the contradictory paradigms in place about the role of scientific and local knowledge in the management of the estuarine ecosystem.

Introduction

Worldwide crises in fisheries management have triggered changes in the process of governance and in the approach to study of common property resources (CPRs). The co-management theory and the theory of the commons have played an important role in restructuring the field of fisheries CPRs management (Berkes 1989; Pinkerton 1989; Ostrom 1990). The essence of co-management, as defined by Pinkerton (1989), is the involvement of fisher's organizations and fishing communities in management decision-making through power sharing: sharing both between government and locally-based institutions, and among differently-situated fishers. It represents a way to decentralize decisions, delegate rights and roles to communities and move towards a joint decision-making process.

One of the strongest aspects of fisheries co-management that differentiates it from other models of participatory management is the knowledge of the environment and resources that fishers pursue. Fishers' knowledge is used here interchangeably with Local/Traditional Ecological knowledge (TEK) to refer to the cumulative body of knowledge, practice and beliefs, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings with one another and with their environment (Berkes 1999; Neis and Felt 2000). TEK contains empirical and conceptual aspects, is cumulative over generations, and is dynamic, in that it changes in response to socio-economic, technological and other changes (Berkes, 1999). It is well known that the knowledge held by fishers in many areas of the world, especially in small-scale traditional societies, may be extremely detailed and relevant for resource management (Berkes and Folke 1998). In fact studies have shown that it is the complimentary characteristics of local knowledge and scientific knowledge that make co-management stronger than either community-based management or government management (Pomeroy and Berkes 1997).

Artisanal fisheries in the estuary of the Patos Lagoon, located in the Southern Brazilian coastal zone, are going through a tragedy of the commons. Fisheries resources are decreasing sharply, compromising the livelihood of more than 10,000 small-scale fishers (Reis 1999). The failure of past historical institutions to manage these resources triggered the establishment of new institutional arrangements in 1996, redefining rules and rights by which to manage the resources (Reis and D'Incao 1998; Kalikoski *et al.* in press). A co-management forum (Forum of Patos Lagoon) composed of different stakeholders was established to (1) discuss and develop alternative actions to mitigate and/or resolve the problems of the fishers and the crisis in the artisanal fisheries sector, (2) recover the importance of artisanal fisheries and (3) share decisions to address problems more effectively. The role of small-scale fishers' knowledge in this new institutional arrangement has not yet received the required attention, and the exchange of knowledge between fishers and scientists has not yet been explored to its full potential.

The present scarcity of information raises the question if it is possible to identify an informal knowledge system used by small-scale fishers that could improve co-management in the estuary of Patos Lagoon and hence help in the maintenance of local ecosystem resilience. The assumption is that, in the context of the Patos Lagoon co-management Forum, such knowledge may contribute to developing or re-formulating local management plans to better adapt them to local social and environmental conditions. This paper aims to contribute to the subject by analysing two questions: 1) how has the local social system developed management practices based on ecological knowledge for dealing with the dynamics of the ecosystem in which it is located?; and 2) what are the current barriers and opportunities to using TEK in the Forum of Patos Lagoon co-management?

Methods

Fieldwork in the estuary of Patos Lagoon was carried out from April 2000 to August 2001. Data were obtained from primary and secondary sources. The primary sources were (1) researcher observations of the Forum of Patos Lagoon meetings, (2) informal conversations, (3) in-depth semi-structured interviewing, and (4) a questionnaire survey. Details of interviews and survey procedures are described in Kalikoski *et al.* (in press) and in Kalikoski (in prep.). Supplementary data were obtained from secondary sources including analysis of scientific publications, local newspapers, meeting minutes, laws, decrees and policy statements from national profile sources such as: Federal Institute for the Environment (IBAMA) and the Federal Sub-Secretary for Fisheries Development (SUDEPE).

Interviews and questionnaires focused on four levels of analysis, consistent with the description of TEK as a *knowledge-practice-belief complex* as proposed by (Berkes 1999). Level one relates to the local knowledge of the animals and ecosystems, such as the behavior and habitat of fish, and the timing of fishing seasons. Such local knowledge may not, in itself, be sufficient to ensure the sustainable use of resources. Therefore, level two refers to the existence or sophistication of a resource management system that uses local environmental knowledge to devise an appropriate set of practices, tools and techniques for resource use. However for a group of fishers to manage resources effectively, appropriate institutions or a social organisation must exist for co-ordination, co-operation, rule making and rule enforcement (Ostrom 1995; Berkes 1999). Accordingly, the third level of analysis is about institutions – the set of rules in use to coordinate the management of the resources. Lastly, the forth "worldview" level represents the system of belief that "shapes human-nature relations and gives meaning to social interactions" (Berkes 1999). As put by the author distinctions between the levels of management systems and institutions are sometimes artificial, and although the four levels are hierarchically organised, there is often feedback between the knowledge levels such that worldviews may themselves be affected by changes occurring, for instance, with the collapse of a management system.

The estuary of Patos Lagoon ecosystem

With an area of approximately 10,000 km^2, Patos Lagoon is recognized as the world's largest choked lagoon, stretching from 30^{o}30' to 32^{o}12' S near the city of Rio Grande where the lagoon connects to the Atlantic Ocean (Figure 1). The estuarine region encompasses approximately 10% of the lagoon, and is occupied by diverse and abundant flora and fauna. The estuary is shallow, with variable temperature and salinity depending on local climatic and hydrological conditions (Castello 1985). The dynamics of estuarine waters are mainly driven by the wind and rain regime with only minor influence of tides. The Patos lagoon system communicates with the ocean via a channel between a pair of jetties, about 4 Km long and 740 m apart at the mouth. All the estuarine dependent marine organisms enter and leave the estuary through this channel for nursery, reproductive and feeding purposes. Of the more than 110 species of fish and shellfish species that occur in the estuary (Chao *et al.* 1985), four represent important fisheries resources, and have sustained artisanal fisheries for more than a century. Short descriptions of these species life-cycle and dynamics are provided in Table 1.

Different species' life history characteristics create a well defined seasonal variability in the diversity and abundance of resources in the estuary and also in the availability of resources to artisanal fisheries (Figure 2). Artisanal fisheries landings have declined steadily since the mid-1970s, to ca. 5,000 tonnes in the late 1990s, the lowest landings recorded in the last 50 years. Fisheries landings also present a marked interannual variability, with a period of approximately 6 years, which seem to be related to the occurrence of strong ENSO events. Figure 3 uses Holling's (1986; 1992) model to represent the dynamics of artisanal fisheries resources in the estuary of Patos lagoon by accounting for four major phases in resource life cycles in the estuary and coastal areas. The phases are: *exploitation*, in which fisheries resources enter the estuarine environment for growth or reproduction purposes, leading to the *conservation* phase in which resources increase in size and maturity. Adults leave the estuary in the *release* phase to spawn and recruit in the marine environment closing the cycle with the *renewal* phase. The influence of climatic conditions is conspicuous in the transition from the *renewal* to *exploitation* phases because of its effect on recruitment success and on the migration/dispersion of resources towards the estuarine environment.

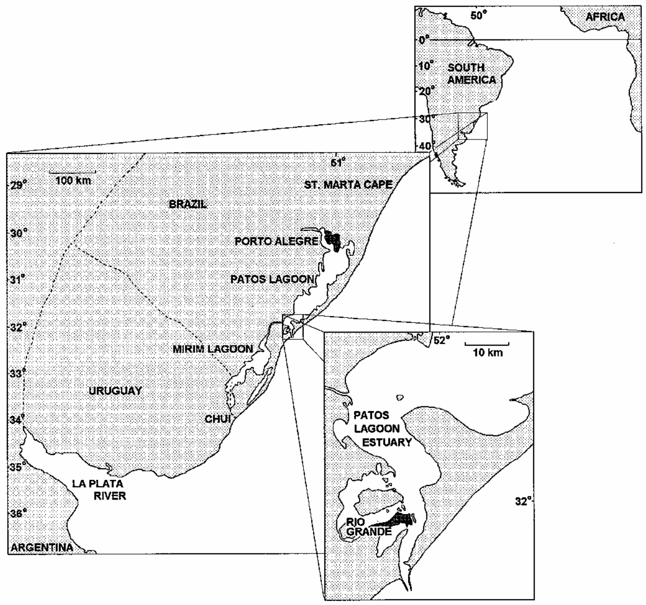

Figure 1. Location of the Patos Lagoon estuary in Southern Brazil (source Seeliger *et al.*, 1997).

Table 1. Summary of biology and life-cycle of main artisanal fisheries resources in the estuary of Patos lagoon (sources Reis, 1986; D' Incao, 1991; Vieira and Scalabrin, 1991Haimovici, 1997;).

Pink shrimp, *Farfantepenaeus paulensis*	Estuarine dependent species. Adults spawn in shelf waters below 50 m deep, producing demersal eggs that hatch into planktonic larvae. When approaching estuaries the larvae develops a benthic habit settling in shallow areas where they will grow for a few months until reaching the pre-adult phase when they migrate to the ocean reinitiating the cycle. The growing phase in the estuary may last between 4 and 10 months when they reach ca. 7 cm of length. Larvae enters with varying success into the estuary all year round but mainly in the spring and summer depending on environmental forcing of wind and freshwater outflow.
Marine catfish, *Netuma barba*	Slow-growing, anadromous species with a calculated life span of approximately 23 years, though adults may occasionally attain 36 years of age and a total length of 98 cm. At the end of the winter the species migrates into the Patos lagoon estuary. Reproduction takes place in early spring in the estuary followed by spawning in the coastal waters. *N. barba* has low fecundity and after the reproduction the males incubate the eggs for up to 2 months in the bucal cavity. Between spawning seasons, adults disperse over the entire shelf.
Croaker, *Micropogonias furnieri*	Species depends on the estuary of Patos lagoon as a nursery and feeding ground. Croackers spawn during spring and summer in coastal waters under the influence of freshwater runoff from the Patos lagoon. Adults normally migrate into the estuary in September-October and leave the area in December-January. Young and subadults croacker occur throughout the year near the coast and in the estuary of Patos lagoon. Adults are dispersed over the shelf and migrate from Uruguay to southern Brazil during the fall and winter and towards Uruguay in the summer.
Mullets (mainly represented by *Mugil platanus*	Mullets occur year round in the Patos lagoon and adjacent coastal waters. Juveniles are more abundant in the winter and spring in nursery areas of the lagoon. In the fall, adult mullets leave the estuary and initiate their reproductive migration. Spawning occurs in warmer offshore waters at about 27°S between the end of the fall and winter. Eggs and larvae are transported from spawning ground towards the surfzone, followed by long-shore migration to the estuary of Patos lagoon.

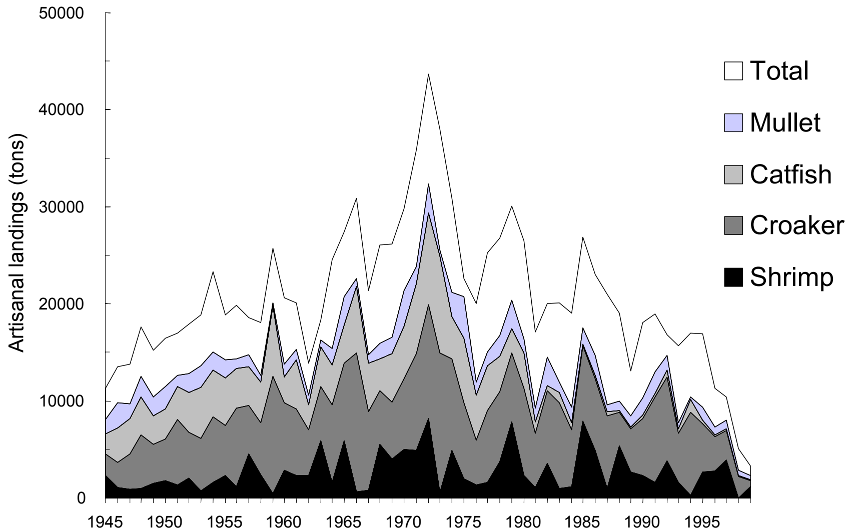

Figure 2. Artisanal fisheries landings in the estuary of Patos lagoon.

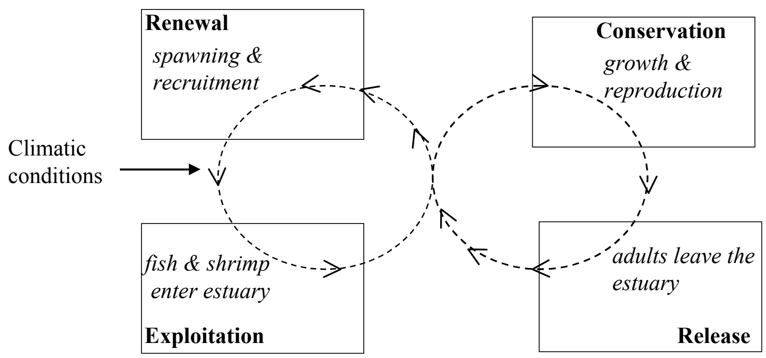

Figure 3. Four phase model of estuarine and coastal fisheries resource dynamics (adapted from Holling, 1986; 1992). During the cycle of exploitation, conservation, release and renewal, biological time flows unevenly. It is slow from the exploitation to the conservation phase, very rapid to the release, rapidly to renewal and back to the exploitation phase.

FISHING PRACTICE AND ECOSYSTEM RESILIENCE

The fishing calendar

One of the single most important characteristics of estuarine artisanal fisheries is the fishing calendar. Since the time when practically no formal rules existed for fisheries management (before 1960s), artisanal fisheries followed a calendar of activities (rules in use) determined by the abundance of different fisheries resources during the year and by the fishing technologies in use. The calendar was based on the experience of local fishers. As such it represents a form of traditional ecological knowledge with important consequences for the resilience of artisanal fisheries because it created natural limits to the exploitation of CPRs.

From January to May, fishers captured shrimp and mullets. Mullets were fished mainly in two periods: in January when the adults were returning from the spawning grounds in the sea, and during the spawning runs, which normally occur between the months of April and June. The catfish season normally began in July and lasted until early November. This fishery targeted the large catfish entering the Lagoon to reproduce and also on the spawning grounds in the upper estuary. The fishery during this period captured mostly fish of good weight and with well developed gonads. A less extensive fishery also occurred during the summer months, especially in February, when catfish migrate back to the sea and the males were incubating the young in their mouth. Few fishers were involved in this fishery because catfish was normally "thin" and did not have a high value, and also because other fisheries, such as shrimp and mullet, were more attractive at that time. The croaker season started in October or right after the catfish season and normally lasted until early summer.

According to fishers, the fishing calendar in the estuary of Patos Lagoon is strongly influenced by the strength of the intrusion of salt water and the rainfall regime. Many fishers consider saltwater to be the single most important factor controlling artisanal fisheries activities. This influence is particularly conspicuous in the shrimp fishery, as shrimp are thought to be more influenced by climate than other fisheries resources. A good fishing season usually occurs if the salinity of the estuary is ideal in the period from October to December; the earlier the estuary is replenished with saltwater the earlier will be the shrimp season. A similar relationship between rainfall regime and shrimp production was demonstrated by Castello and Moller (1978). Fishers also view a warm winter as beneficial for the shrimp season. The moon is also considered an important factor in determining the timing and success of a fishery. For instance, the full moon usually determines good catches of shrimp but it is not good to capture croaker, as explained by a fisher: "*When the moon is bright the croaker is more active and difficult to catch with gillnets*". The last quarter moon is considered excellent for mullets; normally, according to fishers, the last quarter moon of May triggers the schooling behavior of mullet spawners.

Resource use by small-scale fishers in the estuary of Patos Lagoon was and still is to a large extent conditioned by the availability of the resources in the estuarine environment which is in turn controlled seasonally by the influence of the weather and also affected by the influence of the moon on the behavior of the fish. As explained by a fisher:

> " *...nature makes its own fishing closure with the moon, the bad weather, and also the fish, because if it is too windy the fish don't move and you cannot catch them. For instance, if the mullet sees the net it does not enmesh. If it is not the right time, and the fish do not want to be captured, you cannot catch them*".

But, as will be shown in the next section, resource use practice changed markedly as new fishing technologies were introduced and as the industrialisation of fisheries brought exploitation beyond the limits of the carrying capacity of resources.

Changes in fishing practice and resource conditions

In the past 50 years, fisheries in the estuary of Patos Lagoon and coastal areas experienced changes in fishing technologies and materials that significantly altered resource exploitation and the sustainability of artisanal fisheries. Artisanal fisheries were initially based on a beach seine fishery at the mouth of the estuary and in other specific locations along the migratory route of the species inside the Lagoon (Barcellos 1966; Costa 2001). The nets were approximately 300 meters long and were utilised to encircle the fish schools of mullet, croaker, black drum, catfish, and even shrimp, close to shore. The mullet fishery was carried out in two main places in the mouth of estuary on either side of the channel. Each fisher had his turn on a specific day of the season, which was sorted out among fishers of each community. It was common to capture over 60,000 fishes (ca. 90 tonnes) in a single shot, and in order to handle the large catch volume, the fishery was often carried out by groups of 20 to 30 fishers.

Older fishers recall that the beach seine fishery remained important until approximately 1964 when gillnet fishing intensified (this is also confirmed by Barcellos 1966). Gillnets were the most appropriate type of technology to be used in the large areas of the lagoon where fish were naturally more dispersed than at the mouth of the estuary. The intensification of gillnet fishing in turn decreased the viability of the beach seine fishery.

The introduction of motors and the widespread use of gillnets allowed fishers to start fishing mullets in the lagoon as early as October. This gillnet fishery was considered unsustainable by elders who believe the lagoon functions as a nursery area. Unlike the beach seine fishery, which captured only adult fish during a short time window, the gillnet fishery targeted immature fish, and lasted for a longer time, over larger areas including those where the resource was vulnerable to exploitation. Today croakers and catfish as well as mullets are mainly fished using gillnets.

Many assume that the increase in the number of artisanal fishers and the changes in fishing practice and technologies in estuarine fisheries increased pressure on resources which became gradually less abundant to the point of collapse of some important fish resources of the past, e.g. catfish (Reis 1986; Rodrigues 1989). However, fishers and scientists agree that one of the main causes of decline of fisheries CPRs in southern Brazil is the intensification of industrial fisheries observed during the 1960s and 1970s (Haimovici *et al.* 1989; Haimovic, 1997). The fishing areas and technologies employed by industrial fisheries, as viewed by fishers, have a much greater impact of resources because of the amount of fish caught, and the fishing time. These fisheries operate in areas of the continental shelf that were before (and still are) inaccessible to artisanal fishers for most of the time. Fishers recall that since these industrial vessels started fishing, the fish that used to enter the lagoon are disappearing, and to balance the decrease in production, artisanal fishers, in turn, started to increase the amount of gear in the estuary and intensify their shallow coastal water fisheries (many stated that, when weather permits, the coastal area is visited regularly during the croaker fishing season, capturing the fish before they enter the lagoon). The end result has been an overall decrease in fisheries production.

The pink shrimp fishery has also experienced marked changes in fishing technologies and practice in the last few decades. The shrimp fishery was initially carried out along the Lagoon beaches and shallow areas using a manual trawl net dragged by two to four people, or beach seine nets. The manual trawling nets were later (in the mid-1950s) modified into fixed nets (bag nets). Bag nets were fixed around the channels, the mouth of the net placed facing the ebb currents of the estuary, so that shrimp were caught passively through the currents. Beginning in the 1960s, otter trawling from boats became widely used in the shrimp fishery. Most of the trawling was done in deeper waters of the estuary and in areas with "cleaner" bottom (although fishers acknowledge that many of them used to trawl also in shallow nursery areas). Stownets, introduced in the 1970s, are now the dominant type of gear used in the estuarine shrimp fishery. Stownets are fixed in shallow areas of the lagoon and operate by attracting shrimp to the net with light produced by gas lamps. The fishing operation with stownets has changed over the years. The nets were initially placed close to small inlets, because *"shrimp was initially caught in the currents*". Now the nets are placed mostly in the shallows where according to fishers, the young/smaller shrimp are caught before migrating from the nursery areas.

Fishers maintain that the introduction and widespread adoption of stownets impacted negatively on the operation of other types of fishing technologies (such as bag nets and trawling) because a large proportion of the shrimp is caught before they are able to migrate to the channel areas and lower parts of the estuary. It also triggered an intensification of trawling in the estuary to compensate for the decreasing yield of shrimp. The end result has been an increase in fishing effort and the over-exploitation of shrimp in the estuary. D'Incao (1991) estimated that the intensity of the stownet shrimp fishery in the estuary of Patos Lagoon is so high that few shrimp leave the Lagoon to complete the species life cycle.

Fishers interviewed cited stownets and trawling as fisheries that frequently produce high bycatch rates. According to them, artisanal trawling can produce little bycatch depending on the area of the estuary and also on the characteristics of the otter board and the height of the net – the higher the net in the water column the higher the bycatch. Fishers have found ways to reduce the amount of bycatch (if not for conservation reasons, for practical reasons since bycatch increases the handling time on the catch on board) by decreasing the height of the net, and also avoiding trawling in areas with high bycatch rates, such as shallow estuarine waters and specific locations off the coast which are known as nursery areas. Despite fishers' knowledge of trawling methods with low bycatch, since the introduction of stownets in the estuary, all types of trawl fisheries became forbidden without any scientific evaluation of potential impacts on the ecosystem.

MANAGEMENT LESSONS FROM TRADITIONAL PRACTICES

What can be learned from the above forms of resource use? When resources were still abundant, the fishing calendar worked in a way that allowed fishers to benefit from the most abundant resources in a season while limiting the amount of fishing pressure (time) over a particular species and/or a critical period. For instance, fishing for catfish was normally discouraged during the summer months when the males are incubating the young. It was also unnecessary, given the availability of other resources such as croacker and shrimp. Similarly, the capture of large amounts of shrimp below the optimal size (between late spring and early summer) was in part prevented by the type of fishing technology in use, and also by the existence of alternative fishing resources. A failure of a fishing season, normally due to low shrimp abundance, resulted in a re-distribution of fishing effort to the other resources available in the period, but never to the point of over-exploitation because the characteristics of the fishing practice were more compatible with the carrying capacity of the system and a smaller number of people was involved in the activity.

An informal fishing calendar was still in place until the mid-1990s, but to a much lesser extent than in the past. Figure 4 shows the changes in fishing calendars of the main artisanal fisheries resources between the 1960s and the early 1990s. Species such as mullets, that were fished mostly in late fall (April to June) during the spawning run, in the early 1990s were fished almost equally throughout the year. For other resources, such as catfish, the collapse of the stock brought a change in the fishing calendar from spring to winter months when the few remaining catfish sustain a smaller-scale fishery in the upper estuary. The change in technology (from beach seines to gillnets) also made fishers capture croakers during the same period as mullets, since both species are present in the estuary at different life stages throughout the year and are vulnerable to the same gear.

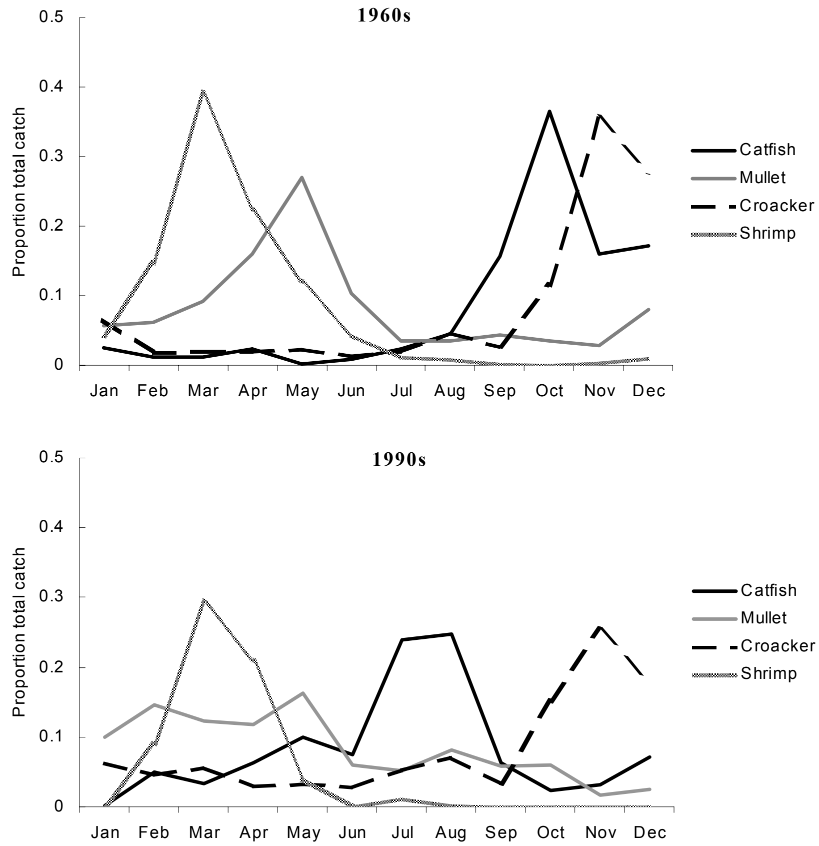

Figure 4. Fishing calendar of artisanal fisheries in the estuary of Patos lagoon and coastal waters during the 1960s and 1990s. The lines represent the proportion of the total annual catch of each species obtained in a single month.

Also, before the advent of industrial fisheries, a large proportion of the species habitat in the Patos lagoon and in the southern Brazilian shelf worked as *de facto* spatial refugia, since artisanal fisheries were limited to specific areas of the estuary of Patos lagoon and adjacent coastal shallow waters. Thus, the increasing competition between artisanal and industrial fisheries and the technological improvements in resource location and capture undermined important factors that made artisanal fisheries resilient in the past, i.e., the limited time and areas of resource exploitation**.** The fishing technologies and resource use practice in the past were intrinsically dependent upon nature, through the influence of the moon, the behavior of the fish, and weather conditions, which created natural mechanisms for limiting excess exploitation by artisanal fisheries. Referring back to Holling's 4 phases model (Figure 3), artisanal fisheries were practically limited to two phases in the resources dynamics: the *exploitation* phase, when resources such as croaker, catfish and mullets were entering the estuary, and the *release* phase, when all these species and pink shrimp were leaving the estuary to the shelf waters. The other two phases (*renewal* and *conservation*) were not targeted by fishers until technological advances and the industrialisation of the fisheries which in turn made the resources available to be exploited at any time and area. In conclusion, the hypothesis put forward here is that up to a certain point in time, the pattern of resource use by artisanal fisheries in the estuary of Patos

Lagoon served conservation purposes because it made resources less vulnerable to over-exploitation while helping maintain the cycle of resource renewal. Besides serving conservation purposes, the fishing practices adopted by artisanal fishers sustained a very productive fishery from the early 1900s until practically the late 1980s (Reis 1999). For instance, in 1960 artisanal fisheries were responsible for over 80% of the total fisheries landings in southern Brazil (ca. 27,000 tonnes/year; IBAMA).

The above analysis of the fishing practices adopted by artisanal fishers in the estuary of Patos Lagoon showed that indeed there was an informal knowledge system used by fishers to deal with the dynamics of the resources. These fishing practices were part of an informal resource management system that helped maintain a productive and resilient small-scale fishery. Resource use practice in the estuary of Patos Lagoon has been changing over time in response to changes in technology, increasing fishing pressure and influences from internal and external (mostly from government agencies) institutional transformations that shifted the management of fisheries CPRs from informal community-based, to central government-based, and to the present situation of co-management (Kalikoski *et al.* in press).

The Patos Lagoon estuary experience has shown failures in both decentralised (community-based) and centralised (government-based) forms of resource management due, to a large extent, to the mismatch between local knowledge and social institutions (Kalikoski *et al.*, in press). The local, informal, decentralised management system present until the 1960s failed because it was never formally institutionalised. Therefore the attempts to control access and attenuate the over-harvesting problem with locally devised rules never reached higher levels of decision making. This system was easily eroded by the external influence of economic development policies aimed at the industrialisation of local fisheries and by a centralised management model adopted by the federal government after the late 1960s (Kalikoski *et al.*, in press). By relying on a system of economically driven policies, this centralised management disregarded the sustainable resource use practices by small-scale fishers and drove many resources to over-exploitation and collapse.

The artisanal fisheries management situation in the estuary of Patos Lagoon called for a cross-scale linkage between local institutions and government. Steps towards a co-management arrangement were taken in 1996 with the creation of the Forum of Patos Lagoon (Reis and D'Incao 1998). This study demonstrates that fishers' knowledge can provide a valuable set of information about the relationship between fishers and the local environment, and about the characteristics of practices, tools and techniques that led a more sustainable pattern of resource use in the past. Local knowledge can broaden the knowledge base needed for management and hence improve institutions that mediate the interaction between communities and their use of the resources. However, the co-management of fisheries CPRs in the estuary of Patos Lagoon is still at its infancy. There are barriers to be overcome before fishers can play a significant role in management decisions.

It is possible to identify 3 inter-related factors influencing the use of local knowledge in the co-management of estuarine resources:

1) *Illiteracy and socio-economic marginalization create low expectations of the management value of fishers' knowledge among scientists and decision makers*. There are many myths about artisanal fishers that still haunt management arenas and hinder a more productive interaction between scientific and local knowledge. Diegues (1995) paraphrased some of the most common myths about artisanal fishers in Brazil:

> *"artisanal fishers are beach beggars, they are a social problem that needs to be treated by social aid programs"; "artisanal fisheries are in transition to industrial, capitalist fisheries, and therefore are doomed to disappear"; "artisanal fishers are unintelligent and resist the technological innovations"; "artisanal fishers are predators, individualists and are not able to organise themselves"*.

Over time, these myths helped to exclude fishers from decision-making and consequently made them more vulnerable to the management process. As put by Pauly (1997) the marginalization of fishers and their limited formal education have often blinded managers and scientists to their ecological knowledge which is used in many successful common property systems as basis for traditional community-based management.

Despite their limited formal education, artisanal fishers developed resource use practices that maintained a productive fishery in the estuary of Patos lagoon until the late 1960s when their informal systems of management practices were eroded by formal top-down management procedures. Fishers' knowledge of sustainable fishing practices were also identified during interviews and meetings of the Forum of Patos lagoon in the form of requests for changes in local fisheries management. Fishers' requirements mirror many of the principles one can read in higher level environmental institutions, such as the FAO Code of Conduct for Responsible Fisheries (Table 2).

2) *Misfit between institutions and the characteristics of common property resources hinders fishers' stewardship of resources and the use of their knowledge to that effect.* Although they recognise the need for management, fishers still do not comply with the management rules in place in the estuary (such as the fishing closure in the winter months and the banning of trawling). In a condition of scarcity and competition, fishers' stewardship of resources is an important yet difficult aim to achieve. Where stewardship of resources exists it is in the best interests of those who control it not to overfish. As put by Johannes (1981) in this case "self-interest thus dictates conservation". Users' interest in working towards the sustainability of the particular resource is conditioned to the benefits they expect to achieve (Ostrom *et al.* 1999). However, solving fisheries CPR problems involves two distinct elements that are important to the husbandry of the resources: restricting access and creating incentives for users to invest in the resource rather than overexploit it.

Limiting access alone can fail if resource users compete for shares, the resource can become depleted unless incentives or regulations prevent over-exploitation (Ostrom *et al.* 1999). Besides, as can be observed in Table 2, traditional users of the estuary of Patos Lagoon feel threatened by sharing access rights with the more recent industrial users group. Resources outside the mouth of the estuary are still open to be freely caught by industrial purse-seiners as there are no rules regulating this activity in the coast, despite the damage it may cause. This creates a dilemma inside the estuary as small-scale fishers complain that the resources they do not catch today will not be available to them in the future but rather will be fished by industrial fishers outside the estuary. Efforts to exercise stewardship in such circumstances are unlikely to succeed.

Examples of CPR management worldwide has shown that although the development of local ecological knowledge is a necessary condition, it is usually insufficient in itself to achieve sustainability if it does not become accepted and legitimized by management institutions (Johannes 1981; Berkes 1999; Castro 2000; Seixas 2000).

Table 2 Comparison between selected principles of the Code of Conduct for Responsible Fisheries (FAO, 1997) and adjustments to local fisheries management suggested by small-scale fishers during interviews and Forum of Patos Lagoon meetings.

Principles of Responsible Fisheries (FAO)	Adjustments to fisheries management according to fishers knowledge in the estuary ofPatos Lagoon
• *Control of gears that are damaging to the ecosystem*:	- Stop industrial trawling in the coast because it kills large quantities of fish that are discarded. - Switch trawling nets by gillnets with large mesh sizes, which are more selective and less damaging. - Forbid or reduce artisanal fisheries in the nursery shallow waters of the estuary (such as stownets and trawling) because they capture large quantities of juvenile fish and shrimp. - Adapt artisanal otter trawling nets to reduce bycatch (implementing by-catch reduction devices) and restrict the use of artisanal trawling only in the channel areas of the lagoon;
• *Monitoring and enforcement*	- Increase enforcement in the estuary all year round and not only during the shrimp season; - Increase enforcement in the 3 miles zone along the coast, where many industrial trawlers operate illegally.
• *Marine protected areas*	- Close the inshore area around the mouth of the lagoon (specially to industrial purse seiners). This is an area that according to fishers fish concentrate before entering the lagoon. By turning it into a protected area fishers believe that more fish will make their way to nursery and reproduction areas in the lagoon. The establishment of marine protected areas is also congruent with a precautionary approach to fisheries management.
• *Adaptive management*	- Adjust fishing calendars according to the environmental conditions and resource abundance. An intricate system of time/area openings has been suggested by fishers as a way to accommodate management rules to the characteristics of the shrimp fishery.

A fundamental incentive to conserve relies on the definition of property rights to common property resources (Ostrom 1990). As long as property rights to resources remain open, no one knows what is being managed or for whom, and any incentive to conserve will disappear because there is no guarantee that the benefits of any management action will be accrued by the same individual or group that practice conservation.

3) *The difficult transition to a "civic science" in the management of coastal resources.*
Two types of paradigms about the role of science and local knowledge are evident in local environmental management institutions. The first, which has been the dominant, is based on the idea that scientific knowledge is objective and factual, and provides the 'truth' on which decisions should be made (Holling *et al.* 1998). This paradigm has no room for local traditional knowledge, for uncertainties, or for a systemic view of the problems. This conventional way of conducting science has been shown to act against sensitive and precautionary environmental management by drawing decision makers to examine only those phenomena where cause and effect can be either proven or shown to be reasonably unambiguous (O'Riordan 2000).

The second paradigm is based on the recognition that conventional science is value-laden, and that information and decisions can be manipulated by powerful vested interests. It acknowledges that knowledge about the ecosystem is incomplete, therefore uncertainties are high and surprises (when actions produce results different to those intended) are inevitable (Holling *et al.* 1998). It calls for the integration of different forms of knowledge (scientific and local) in order to better understand the nature of complex problems and to reduce uncertainties, where possible. More importantly, this paradigm recognises that management of CPRs should not rely merely on science but on a *civic science* (Lee 1993), that is "deliberative, inclusive, participatory, revelatory and designed to minimise losers" (O'Riordan 2000).

By stimulating the exchange of information and knowledge between scientists and fishers, the Forum of Patos lagoon is creating the conditions for a transition towards a civic science in the co-management of artisanal fisheries. One important indicator of this move is the process of defining and revising rules to regulate the fisheries of the Patos Lagoon estuary from the bottom-up, with inputs from small-scale fishers (the rules devised locally were legitimised by the federal government as decrees IBAMA 171/98 and 144/01). However, while Forum decisions that relate to small-scale fisheries management are triggering the transition towards a civic science paradigm, the overall process of governance of other resources and activities within the coastal zone of the Patos Lagoon is not. Instead, the overall coastal zone governance system is still locked into a top-down management system based on a conventional scientific approach (*sensu* Holling *et al.* 1998) (Asmus *et al.* 1999). An example of this approach is seen in the Environmental Impact Assessment of the enlargement of the jetties in the mouth of the estuary of Patos Lagoon (FURG 2000). The EIA study had many uncertainties which were not made explicit or communicated. The project had many outcomes that are not well defined and there are many questions that still remain unanswered, such as the ones raised within the Forum:

> "*will the project impact the amount of shrimp entering the Lagoon? What will be the impact of the project on the behavior of the fish that migrate through the channel of Rio Grande? What will be the impact of the project on the estuarine ecosystem? How will the project affect navigation conditions for small-scale fishing boats off the mouth of the estuary?*"

As defined by O'Riordan (2000), the above characteristics create a mix of uncertainties and ignorance about the possible consequences of the project which calls for a civic science approach. Contrary to civic science's principles of inclusivity and participatory research, neither the small-scale fishers' communities of the estuary of Patos Lagoon directly affected by the project nor the Forum of Patos Lagoon were consulted during the EIA.

Therefore, although the Forum is moving slowly towards a civic science approach to artisanal fisheries management inside Patos lagoon, activities in the estuary, with a direct effect on artisanal fisheries, are not taking into account bottom-up or participatory approaches. However, because many of the 21 institutions that participate of the Forum represent interests beyond fisheries (e.g. Public Ministry, Environmental Agency), opportunities are being created for the Forum to challenge decisions which impact artisanal fisheries, thus empowering local institutions and fishers' communities to call for better governance of the natural resources in the region. In this sense this study put forward that small-scale fishers and their knowledge – including the set of practices, tools, techniques and appropriate informal institutions embedded in a different world view system – may represent a future oriented concept for sustainable resource management in the estuary of Patos Lagoon.

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