Paper to be presented at the 2000 IASCP Conference, Bloomington, IN, USA

State-property, Communal-property or Open-access?

The Case of Ibiraquera Lagoon, Brazil

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Abstract

The broad objective of this paper is to investigate the dynamics of institutions and changing resource systems for building social-ecological resilience. Here, I analyze a case study, the Ibiraquera Lagoon fishing management, in Brazil, which has experienced several changes in the social as well as ecological system in the last four decades. In this case study the dynamics of ecological system and social system have different time scale. The lagoon's fishing stock and water are renewed two to four times a year due to the lagoon's connection to the ocean. On the other hand, the management system has experienced just four major changes in the last four decades. Although the Ibiraquera lagoon has always been legally a state property, in 1960's the lagoon system was 'de facto' managed as a communal property (a community-based management system); from 1970 to 1981, the system was 'de facto' in an open-access condition; from 1981 to 1994 the lagoon was 'de facto' a co-management system (between local fishers and Federal Government); and since 1994 the lagoon has becoming an open-access system again. Key factors for building social-ecological resilience are examined.

INTRODUCTION

Any resource management system has two interrelated dimensions: the social system and the ecological system. In the last decades, facing the failure of conventional ("western") resource management (Ludwig *et al*. 1993), several researchers have been investigating the dynamics of social systems and ecological systems in order to improve resource management, specially adaptive management. In this sense, the development of a common-property theory (particularly represented by the work of McCay and Acheson 1987, Berkes 1989, Ostrom 1990, and Bromley *et al.*1992) has been extremely relevant in understanding the social dimension of management systems.

[1] Sponsored by CNPq, Brazil

According to Feeny *et al.* (1990), common-property resource[2] can be managed under at least four property regimes: communal property (or community-based management), state property, private property, or open access (lack of a property regime). More recently, another property regime has also been often addressed: the co-management regime. Co-management results from a shared responsibility between the government and user groups for resource management. The degree of participation of government agencies and user-groups in the decision-making process may vary greatly according to the local features of the resource system and the local, regional and national socio-political system (McDaniels *et al.* 1994; McCay and Jentoft 1996; Sen and Nielsen 1996; Pomeroy and Berkes 1997). Co-management seems to be the most promising regime in developing adaptive management in modern societies.

In the field of ecosystem dynamics, the development of a new model – the adaptive renewal cycle – and of a new theory – the resilience of ecological systems – both proposed by Holling (1986, 1995) has also been of major importance in understanding management systems. According to Holling (1986, 1995), the ecosystem adaptive renewal cycle encompasses four stages: exploitation, conservation, release and renewal (Figure 1). An ecosystem changes from exploitation slowly to conservation, rapidly to release, rapidly to renewal, and rapidly back to exploitation. The resilience of an ecosystem is its capacity to absorb disturbances while maintaining its main behavioral processes and structure (i.e., resilience is a buffer capacity) (Holling 1995).

As ecosystems are hierarchically structured into a number of levels, many adaptive renewal cycles are linked through time and space scale in nature - a process termed panarchy by Gunderson *et al*. (1997) (Figure 2). According to these authors, at least two features of panarchy (products of cross-scale interaction) may contribute for understanding resilience: (1) disturbance in small-scale system can cascade to broader scale and (2) broader-scale system can provide resources (by remembering or carrying over elements through its release phase) for the renewal phase of smaller-scale system.

More recently, research efforts have focused in understanding the dynamic interactions between the social and ecological dimensions of resource management system (as presented in the work of Gunderson *et al.* 1995, Hanna *et al*. 1996, Gunderson *et al*. 1997, and Berkes and Folke 1998). One of such effort is a project of the Resilience Network[3] organized by Carl Folke and Fikret Berkes which is working towards the identification of key factors that build social-ecological resilience in resource management systems (Folke and Berkes 1998). The present work is part of this project.

In this paper, I combine the common-property theory to the theory of ecosystem resilience (*sensu* Holling) to navigate the dynamics of social-ecological systems in order to identify some of the key factors that build ecological resilience in resource management systems. In a 1998 workshop, the Resilience Network hypothesized that some of these factors include: strong local institutions, accountability/ contestability across scales; good cross-scale communication; shared cross-scale acknowledgement of

[2] Common-property resources are defined as a class of resources for which exclusion is difficult and joint use involves subtractability (Berkes 1989, Feeny *et al*. 1990).

[3] The Resilence Network is about developing theories that have practical consequences for designing and managing sustainable, evolving systems. The Network is based at the University of Florida, USA, and at the Beijer International Institute of Ecological Economics, Sweden, and involves a number of researchers around the word.

facts about the status of the resource and threats to the resource; political space for experimentation; and memory/knowledge of resource monitoring, and past institutional arrangements and other past management practices (Alcorn, J. in prep.).

To explore such hypotheses, I analyze here a case study, the Ibiraquera Lagoon fishing management, in Brazil, which has experienced several changes in the social as well as ecological system in the last four decades. Particularly, I investigate changes over the years on the socio-economic system, management practices, management institutions[4] and the lagoon ecosystem dynamics. I also investigate the local ecological knowledge behind fishing practices and institutions. Research methods included open-ended key-informant interviews (cross-checking information with other people), archival research and participant observation. The fieldwork has been carried out since June 1999.

THE CASE STUDY

The Ibiraquera lagoon is located in Imbituba[5], at the Santa Catarina State, in the Southern Brazilian Coast. The lagoon is seasonally connected to the Atlantic Ocean. Pink shrimp (*Peneaus paulensis and P. brasiliensis*) fishery, especially in the hot months (from October to April), and mullet (*Mugil platanus*) fishery in the winter time (from May to July) are the main fishing activities. This lagoon is a state property. According to the Brazilian law, any fisher with a license has the right to fish on it. The problem is that fishing licenses are issued to anyone who requests it. In other words, there is no legal access restriction to this lagoon.

Today, there are about 350 fishers living in seven communities[6] around the Ibiraquera lagoon. These communities were formed mainly by descendents of Azorians, who arrived in this part of the country about 150 to 200 years ago, and also by some slaves' descendents. Until the 1960's, most communities were quite isolated living on household agriculture and subsistence fishing. Since early 1970's, changes in the local, regional and even national socio-economic systems have been affecting the lagoon management system.

To understand the interactions over the time between the social and ecological dimension of the lagoon management system, I investigate the socio-economic and ecological history of this system in the last four decades. This time interval is divided into four periods according to the occurrence of major institutional changes affecting the management system: first, the decade of 1960 – before any major change in the local socio-economic system or shift in management institutions occurred; second, from 1970 to 1981 – a period of several socio-economic changes that culminated in a crisis in the management system; third, from 1981 to 1994 – a period of major changes in fishing institutions that recovered the management system; last, since 1994 – when the fishing enforcement structure broke down and a new crisis has been emerging.

In the following sections, I first summarize the socio-economic history of the local communities, according to each period of analyses. Second, I describe the lagoon ecosystem dynamics. Third, I explore the linkages between the lagoon dynamics and the

[4] Institutions, as North (1994) defines, are any formal constraints (rules, laws, and constitutions) or informal constraints (norms of behavior, conventions, and self imposed codes of conduct) that mold interactions among human beings in a society.

[5] Imbituba is a municipality with almost 33,000 inhabitants.

[6] Ibiraquera, Barra da Ibiraquera, Arroio, Alto Arroio, Araçatuba, Campo D'Una, and Grama.

traditional fishing management. In fourth, I describe the management system in each period. Finally, I analyze the interaction of management institutions and the lagoon dynamics over these periods.

Background: The fishing communities

In the 1960's, there were few families living in communities around the lagoon. These communities had poor or none road access, no electricity, few or none market place, and no fish marketplace. The local economy was based mainly on household agriculture (manioc flour was the main product) and fishing activities was mainly for subsistence. By that time, there was no job opportunity in these communities, what pressured several young natives[7] to migrate to big cities.

From 1970 to 1981, road accesses were constructed and electricity installed in most communities. With the roads, came the tourists and the local population increased. Tourism-related activities created local job opportunities, and propitiated the return of those natives who had migrated to the big cities. With them, those natives brought money and new ideas of "development" to their communities. More marketplaces were created including fish marketplaces; and the importance of household agriculture to the local economy started to decrease.

From 1981 to 1994, the resident as well as tourist population increased. All communities had road access and electricity. Telephone was installed in most communities, and several summer cottages, hostelries and restaurants were built around the lagoon. In addition, even more marketplaces were created (including fish marketplaces). By this period, tourism related activities had already dominated the local economy, and household agriculture was been practiced mainly for subsistence.

Since 1994, communities growth continues at a high-accelerated rate, as well as the growth of the tourism-based economy. The area surrounding the lagoon and the closest beaches became a hot summer spot.

The lagoon ecosystem dynamics

The Ibiraquera lagoon is an assembly of four interconnected small basins ('Upper lagoon', 'Middle lagoon', 'Lower lagoon', and 'Sacs lagoon')[8] with a total area of approximately 900 ha, depending on the water level (Figure 3). This is a shallow lagoon; most of its area is between 0,20 m to 2,0 m deep, with few points reaching about 4 m deep. The lagoon has mainly sandy bottom and brackish water. Through a channel, the Lower lagoon is temporarily connected to the Atlantic Ocean. Naturally, the channel is open by the lagoon water pressure which increases with rainfalls and the water drained by several small freshwater streams into the lagoon (i.e., the lagoon 'explodes' into the ocean). The channel closes through sand deposition by ocean tides, which in turn allows once again the increase of the lagoon water level.

Almost all fishing resources in the lagoon come from the ocean when the channel is open. Most fishes enter the lagoon in their juvenile stage while shrimp usually enters in its post-larvae stage. That is, the lagoon fishing stock is determined, mainly, by the

[7] The local people call themselves "nativos", i.e., natives.
[8] Lagoa de Cima, Lagoa do Meio, Lagoa de Baixo, and Lagoa dos Sacos.

seasons in which the channel is open (i.e., in relation to the fish and shrimp stocks moving through the ocean in front of the channel) and by the time the channel lasts open. Naturally, fish and shrimp grow in the lagoon habitat, returning to the ocean as adults in the next channel opening. That is, the lagoon fish and shrimp biomass increases over the months after the channel is closed.

The Ibiraquera lagoon is a good example of a small ecosystem going through several adaptive renewal cycles each year. In this system, the release stage is the few hours that takes from the time the channel is open to the time the lagoon water level matches the ocean tide (i.e., the period the lagoon takes to drain its water). The renewal stage is all the rest of the period the channel is open, which can be from a few days to a few months. In this stage the lagoon salt water and fishing stock are renewed. The period encompassing the exploitation and conservation phases, usually the longest one, occurs when the channel is closed, which may last from one to several months depending on rainfall. During this period the lagoon water level arises and the fish and shrimp biomass augment (i.e. gradual accumulation of capital). When the system becomes too overconnected, the lagoon releases its water and production to the ocean, reinitiating its renewal cycle.

The lagoon system is also a good example of how adaptive renewal cycles (ecosystems dynamics) are nested one in another over time-scale and space-scale – the so called parnachy. During the lagoon release phase, the lagoon (a small ecosystem) liberates adult fish and shrimp to the ocean (a large ecosystem) where these species reproduce. In other words, the lagoon is a source of renewal for the ocean fish and shrimp stocks. On the other hand, the ocean is the source of salt water and juvenile fish and post-larvae shrimp during the lagoon renewal stage.

The lagoon dynamics and the traditional fishing management

The renewal of the lagoon fishing system depends on the season the channel is open. That is, it depends on the availability of fish and shrimp post-larvae stocks moving through the ocean in front of the channel. For this reason, instead of leaving the channel to be naturally open by the lagoon "explosion" during uncertain time, native fishers traditionally managed the channel opening to coincide with fish and shrimp post-larvae season. In a year of normal rain precipitation, the lagoon was traditionally open three times. In this circumstance, fishers opened the channel in the spring (some time between September and November) – the season of the post-larvae shrimp in the nearby ocean; in late summer (some time around February) – the season of small mullets; and in the late fall (some time between May and June) – the adult mullet season. In any channel opening several other fish species also enter the lagoon. At least 35 marine fishes and 3 salt-water shrimps occur (some only occasionally) in the Ibiraquera lagoon.

Traditionally, fishing activities take place all year around in the Ibiraquera lagoon. However, in the past, different fishing methods and management practices were used at different stages of the lagoon adaptive renewal cycle, according also to the season the channel was open.

At the time of the mullet season (from May to July), bamboo fences with a 'gate' in front of the channel was built in the Lower lagoon just before the release phase. During

the draining, the gate was closed and the fence helped to retain part of the fish stock[9] in the lagoon (i.e., to put the brakes on the release phase). During the renewal phase, the 'gate' was used to control the fish coming in and out the lagoon. The gate was open when a fish school was trying to come in and closed soon after that, so that fish would not return to the ocean in the case the channel last open for a long period.

A similar bamboo fence for the same purpose was also built in the Upper lagoon close to a small channel interconnecting the Upper and Middle lagoons. In this case, however, the fence was built not only in the mullet season, but also in any channel opening. This occurred because the Upper lagoon is the shallowest one and farthest one from the channel; therefore, it is the most affected by the draining. If no fence is built, all shrimp and fish stock run away during the draining.

In the small channels interconnecting the four lagoons, there was sometimes an elder fisher who stood up looking the amount of fish entering the lagoon; when he decided it was enough he allowed the others to start fishing.

Whenever the channel was open, gillnets could not be used in the lagoon. This happened because gillnet fishing methods produced a lot of noise in the water for entrapping fish, and this noise dispelled other fish to the ocean. While gillnets were used only during the exploitation and conservation phase, cast-nets for fish and shrimp was used inside the lagoon in all four phase of the lagoon cycle. However, fish cast-nets were not allowed in the channel and on the nearby beach (a 100 meters distance from each side of the channel's mouth) when the channel was open (the renewal phase). This was so to permit fish entrance into the lagoon.

The lagoon management system

Fishing system in the 1960's

By that time, the fishers organization Colônia de Pescadores[10] already existed but was not responsible for regulating or enforcing the fishing rules; its responsibility was just to issue fishing licenses, specially for those fishers working in coastal (not in lagoon) fisheries. Although some legal fishing rules existed, these were either unknown or not recognized by local people. Fishing rules were decided locally, and respect for old fishers was the main enforcement institution (i.e., there was no fishery inspector).

The main fishing gears included cast-net (mesh size from 3,0 cm to 4,0 cm) used for small fish and large shrimp, cast-net (mesh size of 5,0 cm or bigger) used for large fish; gillnet (mesh size of 3,5 or 4,0 cm) used for small fish, and gillnet and purse-seine net (mesh size of 5,0 cm or bigger) used for large fish. Local fishers also used kerosene lamps to attract shrimp and dugout canoes. By that time, fishing gears were handmade. Until mid 1960's when nylon (a new technology) was introduced, nets were made of cotton or *tucum* (a fiber made of palm tree). Making nets was costly regarding both the

[9] Some fishes were able to cross the fence either jumping over it, as some mullets, or passing through gaps in the fence.

[10] The "Colônia de Pescadores" was founded in 1952; its president and board of directors are elected by its members each two or three year. This organization encompasses fishers from the entire municipality of Imbituba and not only fishers living around the lagoon. Today, there are around 1,500 associated fishers including about 350 fishers living around the lagoon.

time and money spent. Cast-net, a small gear, was more affordable to most people than gillnet or seine-net (big gears). In fact, it was gear types that separated the user-groups. Native fishers were divided into two groups: *tarrafeiros* – those who use cast-nets (most fishers) – and *redeiros* – those who use gillnets or seine-nets (a few people). There was no outside fisher in that system yet.

The main fishing methods included (a) a fisher using a shrimp cast-net with a kerosene lamp, or a fish cast-net while standing in a known fishing spot close to the lagoon margins; (b) one or two fishers using fish cast-net inside a canoe moving through the lagoon surface; (c) a fisher setting a gillnet; (d) a group of fishers with at least two canoes encircling a fish school with bound gillnets, inside which they and others standing in more canoes threw cast-nets; (e) four fishers in a canoe, encircling a fish school with one stick purse seine net; and, (f) two fishers holding an open cast-net used as trap-net to catch shrimp in the water current soon after the channel was open. A new fishing method was introduced in this system by mid 1960's. Fishers started to use bound gillnets as hand-drawn beach seines for fish and shrimp in the lagoon shore.

The management practices during this period were described in the above section. The management institutions (informal rules) include: (a) respect to the elders, (b) the decision-making on channel openings and on the time to build the bamboo fences by old fishers; (c) prohibition of cast-net use in the channel and on the beach (a 100 meters distance from each side of the channel mouth) whenever the channel was open; (d) prohibition of gillnet use when the channel was open; (e) the first comer's right (but no territoriality); and (f) allowance of both gillnet and cast-net in all four basins.

Due to the low population density, fishers caught a lot of large fish and shrimp. Although there was an abundance of fishing resources all year around, there was a conflict between *tarrafeiros* (most fishers) and *redeiros* (few fishers) for resource access as *redeiros* caught more fish than *tarrafeiros*. The human effort to fish with cast-nets is bigger than to fish with gillnets. A man has to throw a cast-net several times a day to get his catch. A gillnet set in a fishing spot for many hours "fish by itself"; the only human effort is to set the net and to take it out. When gillnets are used to encircle a fish school, a few *redeiros* might catch more fish in one short trip than several *tarrafeiros* using cast-nets might catch in one entire day of work. In addition, when *tarrafeiros* fished inside the encircling gillnets, they had to give one third of their catches to the gillnet owners (*redeiros*). This conflict between *tarrafeiros* and *redeiros* had existed for decades.

Fishing system from 1970 to 1981

The road access to the communities favored the development of a fish market around 1970. At the begging native middlemen bought fish and shrimp from the lagoon and sold them in the big cities. By that time, there was a patronage system, in which a middleman used to give money or fishing gears to a fisher, who in turn had to sell his catch exclusively to the former. After mid 1970's, when the tourism started in that region, an increase of fish and particularly shrimp commercialization happened inside the local communities.

The roads also brought some outside fishers from nearby communities and municipality to explore the lagoon resources. User-groups then encompassed both natives

and outsiders who could be either *tarrafeiros* or *redeiros*. During this period, all Colônia's presidents were *redeiros*.

The main fishing gears include all used in the previous period and two other new technologies: a shrimp trap-net and a gas lamp used to attract shrimp. Another technological innovation was the use of nylon-net fences instead of bamboo fences in fishing management. Due to fishing over-exploitation as a result of market pressures, the gears' mesh-size started to diminish to the point that shrimp cast-nets had mesh size of 2,0 or 2,5 cm and fish gillnets had mesh size of 3,0 cm.

The main fishing methods include all those used in the previous period, with the intensification of hand-drawn beach seine fishery. In addition, due to market pressures, fishers started to use shrimp cast-net all over the lagoon surface moving in canoes. Other two innovations in fishing methods were the use shrimp trap-nets, instead of cast-nets, in the channel just after its opening; and the use gas lamp instead of kerosene lamp, as the former attracts more shrimp than the latter.

Most of fishing gears and methods used during this period were in fact legally prohibited. Despite the regulations issued by the Federal Fishery Agency (SUDEPE[11]) in this period[12], there was almost no rule enforcement because legal fishery inspectors (Federal agents[13]) only showed up sporadically. Hence, all formal fishing rules were disrespected.

Most of the informal fishing institutions were the same as in the previous period. The exception is that the Colônia became the fishing rule decision-maker, including the decision on the right time to open the channel. Although nylon-net fences in the lagoon was legally prohibited, it was informally allowed by the Colônia. In view of socio-economic and cultural changes during this period, the respect for elders has weakened. Fishers searching only profits confronted old fishers' decisions. Rule enforcement became partial; it seems that the Colônia's president (a *redeiro*) only called the local police to help him enforcing regulations that favored *redeiros* (e.g., prohibition of cast-net use in the open channel). In conclusion, there was almost no enforcement of informal institutions as well.

In 1971, an attempt was made to solve the conflict between *tarrafeiros* and *redeiros*. The arrangement between *tarrafeiros* and *redeiros*, made in the presence of the Colônia's president and the director of the State Department for Fishing and Hunting[14], (a) prohibited the use of gillnets in the Upper lagoon and in the Sac lagoon (gillnets could only be used in the Middle lagoon and Lower lagoon); (b) prohibited the use of cast-nets and gillnet in the channel whenever it was open; and (c) prohibited sport fishers to sell their catches. This attempt failed and the conflict reinitiated when *redeiros* started to disrespect the 1971 arrangement due to the lack of enforcement. The conflict augmented as fishing profits magnified the economic differences between *redeiros* and *tarrafeiros*.

[11] SUDEPE: Superintendência para o Desevolvimento da Pesca.

[12] The Federal Fish Agency (SUDEPE) issued several regulations for national or state territory which apply to the Ibiraquera lagoon, including: Establishment of minimum mesh size of 2,5 cm for shrimp cast-net (1970), of 5,0 cm for fish cast-net (1972), and of 7,0 cm for fish gillnet (1972); prohibition of setting gillnet longer than 1/3 of lagoon width (i.e., it also prohibit the use of nylon nets as fence close to the channel and to the Upper lagoon interconnecting channel) (1972); prohibition of trap net in lagoon channel to the ocean (1972); prohibition of hand-drawn beach seine and purse-seine (1972) and trawling (1975).

[13] Members of Federal Agencies – Capitania dos Portos replaced by SUDEPE later.

[14] Departamento Estadual de Caça e Pesca

Using big gears, *redeiros* caught more fish and made more money than *tarrafeiros*; moreover, they bought more material to make even more nets, to catch even more fish.

As a result of the use of small mesh-size gears, and particularly the intensive use of hand-drawn beach seine, in the second half of the 1970's, all fish and shrimp stocks in the lagoon were caught about one or two months after each time the channel closed. (This is the time shrimp post-larvae need to become small shrimp). The months left before the channel was reopen had almost no production in the lagoon. This pressure on fishing resources and the conflict between user-groups triggered a crisis in the fishing management system.

Fishing system from 1981 to 1994

Facing the resource over-exploitation and the on going conflict between *tarrafeiros* and *redeiros*, the *tarrafeiros* (most native fishers) organized themselves and elected in 1981 a new Colônia's president – an outside *tarrafeiro* - who promised to work towards the restriction of any net type, but cast-nets, in the Ibiraquera lagoon. The Colônia, then in hands of a strong knowledgeable leader who had good political relations with the State Government, conducted several institutional changes that helped rebuild the lagoon ecosystem resilience. As a result of the positive results of these changes, the president was reelected five times during the entire period.

The first, and perhaps the most important, institutional change was the banning of any net use, but cast-net, in all lagoon basins. Local fishers, through the Colônia's president, demanded this banning to the Federal Fishery Agency (SUDEPE) and two other State Agencies working with fishery (IPEP, ACARPESC)[15]. After a study to evaluate the lagoon fishing situation, SUDEPE agents elaborated a project upon which local fishers voted and decided to ban all net types, but cast-net, in the lagoon. The Federal Government approved this project in October 1981. The new regulation (N-027/81), specifically to the Ibiraquera lagoon, banned the use of all net types, but cast-nets with minimum mesh size of 2,5 cm for shrimp and 5,0 cm for fish (these are standard mesh sizes for multi-species coastal fishery in Brazil). This regulation also prohibited any fishing in the channel and in a small channel interconnecting Upper and Middle lagoon basins.

In 1986, a similar institutional change process took place in order to ban the use of gas lamp in the lagoon (only kerosene lamp is allowed). Gas lamp was been used with a new fishing gear – a shrimp sucker – which caught small shrimps on their feeding areas (the lagoon margins). Also, its bright light was interfering with other fishing activities as fish catching with cast-net at night. In addition, because gas lamp attracts much more shrimp than kerosene lamp, its use was promoting an uneven shrimp resource distribution among local fishers since not all fishers could afford buying a gas lamp. Again, this change was demanded by most fishers, through the Colônia, and officially approved (N-09/86) by the Federal Fishery Agency (SUDEPE).

Until 1988, the Colônia president decided when was the right time to open the channel after consulting with native fishers; yet he had to have an authorization from a Navy Commander ("Capitão dos Portos"). Since then, this decision-making was

[15] IPEP: Instituto de Pesquisa e Extensão da Pesca. ACARPESC: Associação de Crédito e Assistência Pesqueira de Santa Catarina.

transferred to the Municipal Government. From 1989 to 1992, the person in charged of the opening had no knowledge on the lagoon ecosystem dynamics. He listened fishers as well as other natives living close to the lagoon margins and whose houses' sewerage systems were been affected by the lagoon increasing water level. The decision was sometimes made to solve the sewerage problem and not in face of the fishery system dynamics, what affected the lagoon production. Since 1993, the Municipal Government returned to the Colônia the decision-making on channel openings.

Due to channel openings in wrong periods and some weather surprises in 1990 and 1991, the amount of ocean shrimp post-larvae that enters the lagoon diminished affecting shrimp production. Moreover, the natural shrimp production had became insufficient to supply the growth of fisher number resulting from local population growth and an increasing number of outside fishers. In face of these circumstances, the Colônia's president contacted the Federal University of Santa Catarina (UFSC) to develop a shrimp-stocking project in the Ibiraquera lagoon. The project, which consisted in the liberation of post-larvae shrimp in the Upper lagoon, started in 1992 and lasted until 1998[16.] A nylon net fence (mesh size of 1,0 cm) built in the Upper lagoon just before the any channel opening prevented shrimp migration to ocean.

In view of shrimp abundance year around and low catch efficiency, the project coordinators in agreement with the Colônia showed the local fishers that an increase of the cast-net mesh size from 2,5 cm to 3,0 cm could augment fishers' yields and profits (since they would catch bigger shrimp which in turn have better market price) and consequently the lagoon shrimp production. Furthermore, it could also exclude most outside fishers (who usually have only shrimp cast-nets with mesh of 2,5 cm). Accordingly, in 1993, local fishers, through the Colônia, demanded another institutional change - establishing a minimum mesh size of 3,0 cm for shrimp cast-nets - which was officially approved (N-115/93) by the Brazilian Institute for the Environment (IBAMA)[17.]

These three regulations specific for the Ibiraquera lagoon substituted most of the legal existing regulations in the previous period. Meanwhile, most informal fishing institutions either disappeared or became formal. Exceptions include the use of nylon-net fences in the Lower lagoon during the mullet season and in the Upper lagoon during any channel opening (although legally prohibited) and first comer's rights. There was almost no more respect to the elders.

All these institutional changes only attained efficacy by the reason of a strong enforcement structure. From 1981 to 1994, an agreement between the Federal Fishery Agency (SUDEPE replaced by IBAMA) and the State Government held fishery inspector positions in certain localities including inspectors exclusively for the municipality of Imbituba and a neighbor one[18]. Besides, during some time, local lagoon fishers also helped these inspectors. Nevertheless, this help had to be withdrawn later because it was generating a lot of conflicts between *tarrafeiros* and those *redeiros* who insisted in fishing with prohibited gears.

[16] The shrimp stocking project was funded by three federal Government agencies: Fundação Banco do Brasil (1992-1993); Fundo Nacional do Meio Ambiente (1994-1996); Programa de Execução Descentralizada do Ministério do Meio Ambiente (1997-1998).

[17] The Federal Fishery Agency (SUDEPE,) was extinguished in 1989 and replaced by the Brazilian Institute for the Environment (Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renovaveis – IBAMA) in the same year.

[18] Garopaba, SC

As a result of all these institutional changes and the strong enforcement, the main fishing gears used during this period were limited to shrimp cast-nets (minimum of 2,5 cm of mesh size till 1993, and 3,0 cm after that), fish cast-nets (minimum of 5,0 cm of mesh size), kerosene lamp, and gas lamp (only until 1986). As well, the main fishing methods were restricted to those using shrimp cast-net or fish cast-net in one fishing spot or all over the lagoon surface.

The modifications in fishing rules also limited user-groups to *tarrafeiros* either natives or outsiders. In addition, as a result of the dominance of tourism-related activities in the local economy, most full-time native fishers started to find jobs, specially in the construction business, hence becoming part-time fishers.

Regarding the fishing production during this period, fishers say that about two year after the net banning, the lagoon's fish and shrimp stock was recovered (i.e., there were stocks all year-round). *Tarrafeiros* were catching more than in the previous period, while *redeiros*, who were then fishing with cast-nets, were catching less. Nonetheless, on account of fishers population growth, each *tarrafeiro* was catching less than in the 1960's. Around 1990, the lagoon production was affected due to channel opening at wrong period and to weather surprises. From 1992 to 1998, shrimp production increased considerably all year around as a result of the shrimp stocking project (normally, the shrimp season is from October to April – the hot months). Furthermore, the establishment of a minimum mesh-size of 3,0 cm for shrimp cast-net in 1993 augmented fishers' catches (bigger shrimp) and the lagoon shrimp production.

The main problems affecting the fishery system during this period were: (a) the wrong decisions made (by the Municipal Government) on channel openings; (b) the increase of tourists, whose sport activities interfere with fishing activities; (c) the increase of outside fishers; and (d) the unregulated growth of summer cottages, hostelry and restaurants constructions around the lagoon, destroying the native vegetation, and several fish and shrimp feeding areas. These changes in the lagoon margins also began to fill up with earth the channel and the small channel interconnecting the Upper and Middle lagoons, making the fish and shrimp transition difficult.

Fishing system since 1994

In 1994, the arrangement between IBAMA and the State Government was broken down and the fishery inspector positions extinguished. A new arrangement was then made between IBAMA and the State Environmental Police[19]. In this new arrangement, a group of few policemen has to cover a large area encompassing several municipalities and concerning all environmental issues, including fishery. As a result, they patrol a place such as the Ibiraquera lagoon sporadically just upon denunciation of infractions. The weakening of the enforcement structure has given the opportunity for many fishers to violate regulations. As a result, in 1996, the depredation of the lagoon system was again evident, and some fishers demanded more action from the Environmental Police to avoid a new crisis. Due to the ineffective action of the Environmental Police and the IBAMA, in 1998, fishers living close to the Upper lagoon, decided to organize themselves into two groups to patrol the Upper lagoon. Nonetheless, this activity did not last long because the group was threaten with shotguns by those fishers using irregular gears.

[19] Policia Ambiental.

In addition to changes in the enforcement structure, the only other institutional change regarding fishing management since 1994 was the prohibition of engine vessel at the lagoon. In 1994, fishers organized themselves to demand the restriction of jet-ski and any engine vessel because their use was affecting the fishing practices and threatening the security of fishers and tourists in the lagoon. In 1995, the Imbituba Major issued a regulation (N-1501) prohibiting any type of engine vessels in this lagoon. Today, paddle canoe is the vessel most used by fisher; however, jet-ski and motor canoes are still been used by tourist due to no rule enforcement.

As a result of this lack of enforcement, all prohibited gears and fishing methods used before 1981 returned to the lagoon. In addition, another very destructive gear was introduced in this system: a small shrimp trawling net (*gerival*) which is pulled by a canoe. Irregular gears are used by native fishers and outsider as well. Evidently, *redeiros* fishers, although illegally, became an user-group again; yet, *tarrafeiros* are majority. In fact, probably more fishers have (or can afford buying) big nets today than in the 1970's. Fishers do not have to make their own nets today, they can easily buy industrialized nets. Because of the tourism and local economy growth today most fishers are part-time fishers; indeed, there are less than 10 full-time fishers using the lagoon.

The lack of a strong enforcement has also affected the channel openings. In the last years, instead of waiting the Colônia decision on the time to open the channel, some fishers are opening it whenever they think is appropriated. Today the interests in opening the channel are not related only to fisheries, but also to summer vacations and the sewerage problem. People living in the community close to the channel prefer the channel open in December and January, so that the lagoon water is renewal constantly and the stink in the water caused by the sewerage does not repel the tourists. The channel openings in the wrong time has been affecting the lagoon production.

As well, the use of irregular gears has also been affecting the lagoon production. On one hand, the use of small mesh size gears decreases the potential production during the months the channel is closed. On the other hand, the use of shrimp trap net (an irregular gear) when the channel opens increases the lagoon shrimp production. Since 1998, there has been a retraction of shrimp production as the shrimp stocking project ended. Today, the lagoon production is mainly commercialized in the surrounding communities (i.e., there is no exceeding production taken to big cities). Fishers either sell their product to middlemen (but there is no more patronage) or direct to local restaurants and tourists; a large proportion of fishers, however, does not sell their catches (i.e., they fish for their family own consumption)

The problems affecting the lagoon has just aggravated since the end of rule enforcement. To enlarge and to deepen the main channel and some small channels filled up with earth inside the lagoon, the Colônia in a joint work with the Municipal Government and the State Government dredged part of these channels in 1999. The effects of this dredging in the fishery system are unclear yet.

In addition to the aggravation of the problems existing in the previous period, other problems are affecting the lagoon fishing systems today. These problems are mainly caused by lack of a strong enforcement structure and include: (a) the use of irregular gears and fishing methods, (b) the use of engine vessels and windsurf boards interfering with fisheries, (c) the lagoon pollution due to the increase of tourists, (d) the increase of tourists' houses draining sewerage into the lagoon, (e) the channel openings in

wrong periods, (f) conflict between *tarrafeiros* and *redeiros*, (g) conflict between native fishers and outside fishers because of irregular fishing activities, and (h) conflict between full-time fishers and part-time fishers because of irregular fishing activities. This scenario shows that a new crisis is emerging in the lagoon management and ecosystem.

'Why is the Colônia not responding to this emerging crisis?' one may ask. 'Because the Colônia has become a 'brittle' organization', is probably the best answer. The Colônia's president is the same and has been reelected several times since 1981. According to some fishers, he has been reelected because of his achievements on banning big nets in the lagoon. Today, the president is, in fact, 'the organization'. Although, the board of directors encompasses other members, they play no real role in the Colônia; all decisions are made by the president who also acts as secretary and controls the Colônia's money.

In view of this new situation and the problems above described, the president has been losing credibility among fishers (specially the lagoon native fishers). Recently, he is training a younger man (who is 'de facto' a sport fisher and is his nephew) to run in his place next election (2001) as he is also looking for retirement. On the other hand, some fishers who have previously supported this president are also organizing themselves to run against him or his man. Meanwhile, in the past year, two of the seven communities surrounding the lagoon have re-activated their communities council[20] in face of the environment impacts the unregulated tourism growth has caused to these communities and to the lagoon system.

It seems that some major institutional renewal will occur soon. Let us wait and see!

Navigating the dynamics of management institutions and the ecosystem

The history of the Ibiraquera lagoon fishing management is particularly interesting as it shows a resilient traditional management systems (the 1960's) transforming in a non-resilient system (1970-1981), rebuilding resilience after experiencing a crisis (1981-1994), and once again transforming in a non-resilient system (since 1994).

What conferred ecological resilience until the 1960's were the traditional management practices in addition to a strong (informal) enforcement structure (respect to elders). These management practices were concentrated on the release and renewal phase of the lagoon ecosystem dynamics (Table 1). These practices helped to avoid ecological surprises and also performed as insurance mechanisms for maintaining biodiversity.

From 1970 to 1981, the management system began to lose its ecological resilience as fishing effort increased due to changes in the local economy and as the enforcement structure (respect to elders) diminished due to changes in the social system. Although fishing gears and methods used in this period were very similar to those used in the previous period, changes in the socio-economic system affected the ecosystem resilience (Table 2). Changes in the local economy also diminished the social resilience of the management system. This happened as young fishers facing only profits confronted elders' authority and as over-fishing by *redeiros* augmented the difference in socio-economic status (and the conflict) among *redeiros* and *tarrafeiros*. The lost of social-ecological resilience triggered a crisis in the management system.

[20] Conselho Comunitário de Ibiraquera e Associação dos Amigos da Praia da Barra da Ibiraquera.

The rebuilt of social-ecological resilience from 1981 to 1994 depended on a sequence of institutional changes (key factors), but two main responses to that crisis were the election of a Colônia's president willing to promote management changes and the implementation of a strong enforcement structure. Other key factors to this resilience reconstruction are examined below.

Since 1994, the ecological resilience of this system has been threatened again by the lack of an strong enforcement structure; as well the social resilience has been threatened by the "brittle" organization that the Colônia became (fishers started to lose confidence in the Colônia's president – the same since 1981).

Key factors for building social-ecological resilience in management systems

The key factors hypothesized by the resilience network that build social-ecological resilience in resource management systems are examined below according to the present case study.

Strong local institutions: During the two periods the lagoon system was resilient (the 1960's and from 1981-1994), there was a strong fishers organization, either informal (old fishers) or formal (Colônia). On the other hand, the fishers organization was not strong during the periods the system was not resilient (Table 3).

Accountability/ contestability across scales: ???

Good cross-scale communication: All three fishing regulations modifications (banning of all nets but cast-nets; banning of gas lamp, increasing of shrimp cast-net minimum mesh size) involved local resource users, the fishers organization (Colônia), State fishery agencies and the Federal Fishery Agency (both, during the study to evaluate the lagoon fishing situation as well as during the decision-making process). The banning of engine vessel in the lagoon also involved local fishers, the Colônia, and the Municipal Government.

Shared cross-scale acknowledgement of facts about the status of the resource and threats to the resource: During the process for banning all nets, but cast-net, and the process for banning gas lamp in the lagoon, knowledge generated at local level by qualitatively monitoring the resource was taken to federal level in order to change the institutional arrangement. In the first case, fishers acknowledged the resource over-exploitation; in the second case, fishers recognized the threats of gas lamp use to fishing resources as it was used to catch juvenile shrimp and as its use increases fishing effort a lot.

Political space for experimentation: The positive results of all three attempts for fishing rule modification (banning of all nets but cast-nets; banning of gas lamp, increasing of shrimp cast-net minimum mesh size) shows that, yes, there was a political space for experimentation. Although all fishing rules have to be approved by the Federal Fishery Agency, the agency was open to suggestions on rule modifications.

Memory/knowledge of resource monitoring, and of past institutional arrangements and other past management practices: This case study provides some examples in his sense: (a) Because the Colônia's president elected in 1981 was not a native but was in charged of making decisions on channel openings, he listened old native fishers on the right time to open the channel. (b) The banning of all nets but cast-nets in all four basins might had been inspired on the first attempt (the 1971 arrangement) to prohibit their use in two lagoon basins. (c) The regulation prohibiting any fishing activities in the channel and in the small channel interconnecting the Upper and Middle lagoons was probably based on the traditional management rules. (d) Although legally prohibited, the use of nylon-net fences during the mullet season channel opening (as traditionally used) was informally accepted by Colônia's president and fishery inspectors (perhaps because the fishery inspectors were lagoon natives – although State Government employees – and knew the fence importance for the fishery system).

Other key factors that seem also important in the process of rebuilding social-ecological resilience include:

Strong rule enforcement or strong authority system (either local, regional or national): During the two periods the lagoon system was resilient (the 1960's and from 1981-1994), a strong rule enforcement and authority system either informal (respect to elders) or formal (fishery inspectors) existed (Table 3). Rule enforcement is only strong when those enforcing rule are vested with authority to do so. The attempt by two groups of fishers to patrol the Upper lagoon in 1998 failed due to the lack of such authority.

Co-management between scientific and local ecological knowledge (Gadgil *et al*. in prep.): Two of the three fishing rule changes were based on local ecological knowledge and one on scientific knowledge. First, local ecological knowledge on the effect of big nets (gillnets, purse seines and trawling nets) and gas lamp use on the fishing stock was taken in account by federal agents. Second, the scientific knowledge on the effect of a larger mesh size for shrimp cast-net on the shrimp production was also considered by local fishers, who used this information to demand another rule modification.

Strong leaders with credibility among resource users and willingness to promote changes: The Colônia's 1981-elected president (an outsider *tarrafeiro*) was determined to change the fishing rules 'status quo', while the previous Colônia's presidents, all them *redeiros,* had no interest in changing the rules as they had privilege with that situation.

Institutional changes that lead to better resource distribution: The banning of big nets use in all lagoon basin, as well as, the banning of gas lamp use led to a more evenly resource distribution among fishers and throughout the fishing periods.

Resource users able to detect disturbances in the ecosystem and to percept crisis: The first example occurred when fishers detected resource overexploitation in the end of 1970's, and acted in order to reverse this situation. In another example, fishers noted the depredation of the lagoon system in 1996 and demanded more action from the Environmental Police to avoid a new crisis.

Resource users with conscience and willingness to conserve the resource system for the next generations: During fieldwork, several fishers exposed their concerns in conserving the lagoon resources for their descendents and several others were conscious of the limitation of lagoon resources.

Positive feedback from an institutional change furthering other changes: The positive results from the banning of big nets (1981) led fishers to demand other institutional changes including banning of gas lamp (1986), increasing of shrimp cast net mesh size (1993), and prohibition of engine vessel in the lagoon (1995).

Inducing critical ecosystem process, specially release and renewal, at small time scale to avoid big disturbances at large time scale: For instance, fishers open the channel (induce release) to avoid that the lagoon 'explodes' to the ocean later during a season of few or no fish and shrimp post-larvae. In another instance, fishers use fences to maintain part of fishing stock inside the lagoon (help renewal) as an insurance to the case that the ocean tides close the channel before enough fish schools enter the lagoon.

Key factors that threaten ecological and social resilience

This case study also shows some of the key factors leading to a crisis in the management system. These include:

Breakdown of traditional institutions and authority system: For instance, respect to old fishers in the 1960's and lost of confidence on Colônia's president since 1994.

Rapid changes in the local socio-economic system: The rapid changes in local economy during the 1970's impacted the social-cultural system that gives support to management institutions (formal or informal). Respect to elders (the enforcement structure) diminished when fishing profits became an issue in the system.

Rapid changes in the larger socio-economic system negatively affecting local management system (negative cross-scale interactions): For instance, changes in an arrangement between State and Federal government extinguished the fishery inspector positions. The lack of rule enforcement is leading the lagoon management system to a new crisis

Conclusions

This case study clearly demonstrates the co-evolution between social and ecological dimensions of a management system. The first conclusion one can reach, however, is that the social dynamics and ecological dynamics in this case have different time scale. While some ecosystem cycles occur each year (month-scale), major changes in the management institutional system take several years to occur (decade-scale). In fact, it was a sequence of several ecosystem's surprises (over-fishing) what has triggered a major institutional response (election of a *tarrafeiro* for the Colônia presidency).

The second conclusion is that the regime under which fishery resources are managed depends on several variables constrained by social, economic and cultural factors as well as ecological factors, which in turn change over time. Although the Ibiraquera lagoon has always been legally a state property, in 1960's the lagoon system was 'de facto' managed as a communal property (a community-based management system); from 1970 to 1981, the system was 'de facto' in an open-access condition; from 1981 to 1994 the lagoon was 'de facto' a co-management system (between local fishers and Federal Government); and since 1994 the lagoon has becoming an open-access system again (Table 3). As an ongoing study on the resilience of linked institutions and ecosystems, the Ibiraquera Lagoon case illustrates how property regimes can flip, with consequences also for the resource system.

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Table 1. Traditional (the 1960's) management practices according to each phase of the ecosystem adaptive cycle.

Ecosystem phases	**The traditional management**
Release	- Management of channel openings according to shrimp post-larvae and fish seasons (to avoid ecological surprises) - Bamboo or nylon fence in front the channel (to maintain part of the fishing stock) (insurance mechanism) - Bamboo or nylon fence in front the small channel interconnecting the Upper and Middle lagoons (to maintain part of the fishing stock) (insurance mechanism)
Renewal	- Fence gate controlling the fish coming in and out the lagoon - Prohibition of gillnet fishing methods inside the lagoon (to avoid fish return to the ocean) - Prohibition of cast-net in the channel or on the beach near the channel mouth (to allow fish entrance to the lagoon) - Old fish controlling fish coming in and out the lagoon basins
Exploitation	None
Conservation	None

Table 2. The lagoon ecosystem resilience: comparison between gears used during each phase of the ecosystem adaptive cycle, market pressures and rule enforcement in each period of analysis.

	The 1960's	**1970 – 1981**	**1981 – 1994**	**Since 1994**
Ecosystem phases				
Release				
Lagoon	cast-net /other nets	cast-net /other nets	cast-net	cast-net/ other nets
Channel	other nets	other nets	----	other nets
Renewal				
Lagoon	cast-net	cast-net /other nets	cast-net	cast-net /other nets
Channel	----	----	----	cast-net
Exploitation				
Lagoon	cast-net /other nets	cast-net /other nets	cast-net	cast-net /other nets
Conservation				
Lagoon	cast-net /other nets	--(no resource left)	cast-net	cast-net /other nets
Fishing market	None	small to median	median to large	large
Rule enforcement	Strong	weak	strong	weak
Ecosystem's resilience	Resilient	non-resilient	resilient	losing resilience

Table 3: The Ibiraquera lagoon fishing management: changes over time.

	The 1960's	**1970 – 1981**	**1981 - 1994**	**Since 1994**
Fishing rules decision-making	Local	Local	Local / national	Local /national
Fishers formal organization	Weak	Median	Strong	Median
Fishers informal organization	Strong	Weak	Strong	Weak
Rule enforcement	Strong	Weak	Strong	None
Social-ecological system	Resilient	Non-resilient	Resilience	Losing resilience
Property regimes	Community-base management	Open-access system	Co-management (users / national government)	Open-access system