

Comparative study of the lobster fisheries in Maine and Belize:
Possible causes for success and failure

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ABSTRACT

Lobster is an important source of income in many coastal areas. The lobster fisheries in Maine and Belize have been described in the literature as success stories in terms of their social organisation. Here, I compare their success as social-ecological systems. The information from Belize is derived from interviews with actors in the industry, fisheries statistics, the scientific literature and other documents. The Maine information is based on scientific publications. Through a complex history of resource management the Maine system seems to have been able to develop social mechanisms for responding to environmental feedback and embed those into their institutional structure. The development of a “conservation ethic” among fishers towards resource use and the emergence of political entrepreneurs, or leaders, are examples of such features. The Belize system seems to lack social mechanisms for responding in an effective fashion to environmental feedback as lobster catch per fisher has been in decline since the 1980s. Five factors were attributed to the decline in catch per fisher during interviews in Belize: natural fluctuations, hurricanes, loss of grounds to marine reserves, too many fishers, too much effort, and lack of enforcement. Self-enforcement in Maine was possible as the members of the “harbour gang” knew that free-riding was controlled, the improvement in catch indicated their efforts were having an effect, and their property rights assured them access to lobster grounds. A precondition for success is that institutions and their organisational structure incorporate the resource’s ecology and provide a social context for learning and adaptation to deal with change.

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INTRODUCTION

Environmental problems emerge from the failure of institutions to internalise the externalities of our actions (McKean 1996). This is partly attributed to a lack of response to feedback from the environment by governance bodies (Berkes and Folke 1998). External driving forces, such as export markets and new technology, which are not controlled by the governing institutional framework, may exacerbate this failure (Barbier et al. 1994). Large centralised governing bodies tend to react to signals limiting resource use rather than signals from the resource (Gunderson et al. 1995). Furthermore, as the resource is an integrated component of ecosystems, institutions should manage at the ecosystem level to sustain the flow of resources (Berkes et al. 2003).

According to Hanna and Jentoft (1996), one of the goals of social institutions is to reduce uncertainty but uncertainty can never be fully controlled (Wilson et al. 1994). Governance systems need to have the capacity to deal with change and surprise (Gunderson 2003). With present rates and scales of change as a result of human interaction with the environment (Steffen et al. 2004), the need to tighten feedback between social systems and ecosystems becomes apparent (Berkes and Folke 2002). This requires monitoring that can provide feedback in a useful form (Christensen et al. 2003). The incorporation of ecological information in turn requires institutions with the capacity for learning (Lee 1993). That is, the governance system should be able to incorporate new knowledge into its management practices and institutional structures and be flexible and adaptive to change (Berkes et al. 2003, Dietz et al. 2003).

Groups in both Maine and Belize have mobilised for collective action. Individuals in these groups aim to maximise their benefits (Ruttan 1998), in this case lobster yields, while their organisations, directly and indirectly control the group's behaviour. The "harbour gangs" of Maine and the fisher co-operatives of Belize are examples of socially resilient organisations with different effects on fishing. "Harbour gangs" developed a "conservation ethic" (Acheson 2003) in response to reduced lobster abundance while co-operatives developed measures to maintain or increase yields (Huitric in revision).

This paper focuses on social responses among resource users to environmental feedback. The objective is to compare lobster fishing in Maine, USA with lobster fishing in Belize, Central America in this context. These two cases are interesting as they are often cited as collective action successes with high yields compared to their neighbours (Sutherland 1986,

Acheson 1997, Brown and Pomeroy 1999). Both have large grounds that cannot be surveyed from land, target a mobile resource that fluctuates in abundance, fished by a large number of individual users that can access more or less all of the grounds, and directly supply export markets.

Figure 1. Map of Belize, Central America.

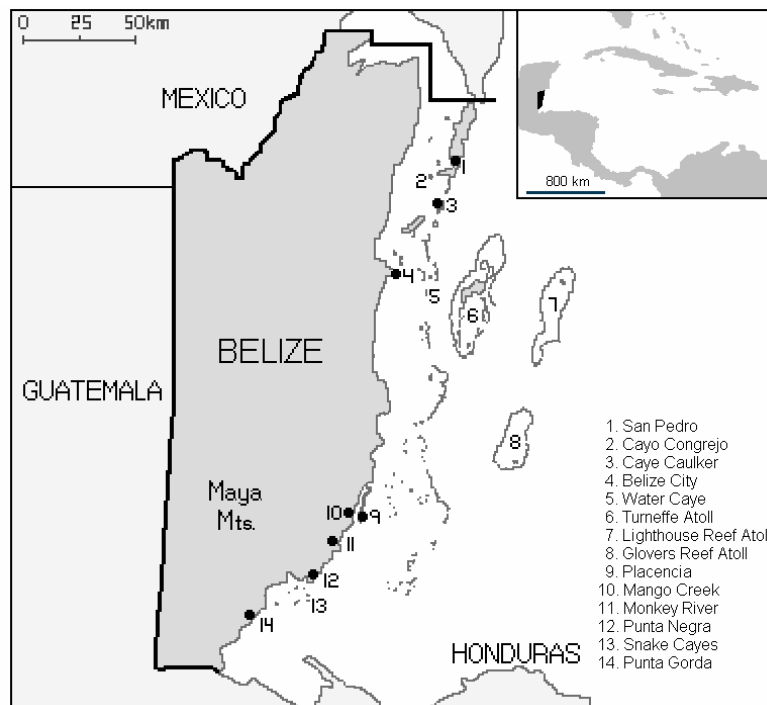


Figure 2. Map of Maine, USA.



Social responses to resource and environmental fluctuations in the lobster fisheries of Maine have been described and analysed in several publications (Acheson 1997, 2003). In this sense, the Maine example seems to show features of a social-ecological system that are successful in terms of sustainable resource use (Olsson et al. 2004a). There have been studies of the social dimension of the Belize lobster fisheries (Gordon 1986, Sutherland 1986, King 1997), but few studies have addressed the interactions between the fishery, the resource and the environment. Huitric (in revision) finds that when the resource dimension is included in the analysis, the Belize fisheries follow a pattern of sequential exploitation and unsustainable resource use. The 'successful' social organisation for the fisheries industry may, in fact, have contributed to exacerbating this pattern, in particular through rent seeking co-operatives.

The first part of the paper describes the methods and data used for the comparison. The results section is divided into three parts: changes in catches and possible causes; management of the resource; and the fishing community and governance. Similarities and differences are presented and then further discussed in relation to conservation and fisheries, management of the social dimension and social responses for dealing with change.

METHODS

Belize

Catch and export statistics were used to compile a time series for production (figure 3a). Export statistics were used, when available, as a substitute for missing production data for the period 1923-1968. The colonial government collected little fisheries data until the 1950s. As lobster was consumed in small quantities in the colony (Wilk 1999), the bulk of production was most likely exported and, therefore, accounted for in export statistics. During the 1930s the industry closed down due to the depression, an unsettled market in the USA and later World War II, after which it re-opened. From 1977, production data are available from the Fisheries Department. These data exclude catch sold on local markets, to restaurants and illegally across the border (Daly Price 1986, King 1997, Jacobs 1999, Heyman and Graham 2000). Co-operatives offer the best prices for lobster as they supply the export market so production data is expected to be a good representation of total production, until the 1980s, as the local market for lobster was limited. Since the 1980s, tourism has boomed and increased the number of restaurants. This has been a market for illegal catch, previously consumed by fishers and their families (King 1997), and more recently they have begun to offer competitive

prices with the co-operatives and so the size of the production that is missed in official statistics is growing.

The number of fishers are estimates from the colonial government, the literature, and statistics from the Fisheries Department (1946-55: (Colonial Government 1947, 1954, 1955, 1957); 1957, 1960s, mid-70s (Gordon 1986), 1973: (Baird 1973); 1985: (Daly Price 1986); 1989: (Pinto and Vasquez 1989); 1993-1998: Fisheries Department Statistics in (CSO 1999); 1999: Fisheries Department Statistics in: (CZMAI 2000). Estimates are thought to underestimate the number of fishers due to bias on the north in the literature and as there is no explanation as to how estimates were made. Until the mid 1960s, the lobster fishery was largely situated in the north and estimates until then may be less erroneous for the number of lobster fishers, compared to the total number of fishers in the colony. Due to the limitations of these data, even at a national level, it was not possible to calculate changes in catch per unit effort (CPUE). Previous scientific studies were used to identify changes in catch CPUE (see Appendix I - Espeut 1994, Jacobs 1999, Heyman and Graham 2000, Huitric et al. 2003).

To complement these other sources of information, interviews were carried out to gather qualitative data on changes in catch over time. Interviews and meetings with various stakeholders were conducted during five field visits between 1998-2002. In 2002, qualitative and semi-structured interviews (Kvale 1996) were performed with key informants. Qualitative and semi-structured interviews were chosen to provide detailed accounts of change, which was particularly relevant for building up a history of the fishery and key events in its past.

From 1998-2000 interviews and discussions with various stakeholders in the fishery were carried out including fishers, co-operative board members, NGOs, and Fisheries Department officials. The goal of these meetings was mainly to provide background information on the fishery and these informants provided a wealth of information on past and recent events in the fishery at both local and national scales. Informants were often chosen randomly. Co-operative board officials interviewed in Belize City, and later in San Pedro, Placencia and Punta Gorda, were randomly selected as it depended on who was available at the time. These key informants were re-visited during subsequent field visits. Fishers were interviewed in Belize City at the landing sites at the two co-operatives and on the local market. These fishers were also randomly chosen. On Caye Caulker, due to limited time and details of fishers on the island. Fishers were selected using snowball sampling (Bernard 1994). A researcher on the island recommended the first fisher. Subsequently, each identified fisher was

requested to recommend three other fishers. Usually only one of these was interviewed, however three were requested in case people were unavailable or at sea.

In 2002, thirteen key informants were interviewed. All had experience (at least over ten years) with the lobster fishing industry. Some of these were familiar interviewees from Belize City. A goal of these interviews was also to collect data on the development of the fishery in the south. Interviewees in Punta Gorda were recommended by an NGO. Five interviewees were from local NGOs that were working closely with local fishers. Three of these were former fishers themselves. Five of the interviewees were co-operative board members. Board members had information on environmental and economic changes and provided both personal observations, as most were or had been fishers, as well as observations from their membership at local and national scales. Interviews usually consisted of two meetings. Interviewees were asked about their personal history in the industry, changes in catches and causes, and, changes in gear, boats catch, grounds and numbers of fishers. In order to protect the identity of interviewees who chose to remain anonymous, all interviewees are anonymous.

All data used for Maine are from published literature. The main sources have been (Acheson 1988, 2003, Steneck and Wilson 2001).

RESULTS

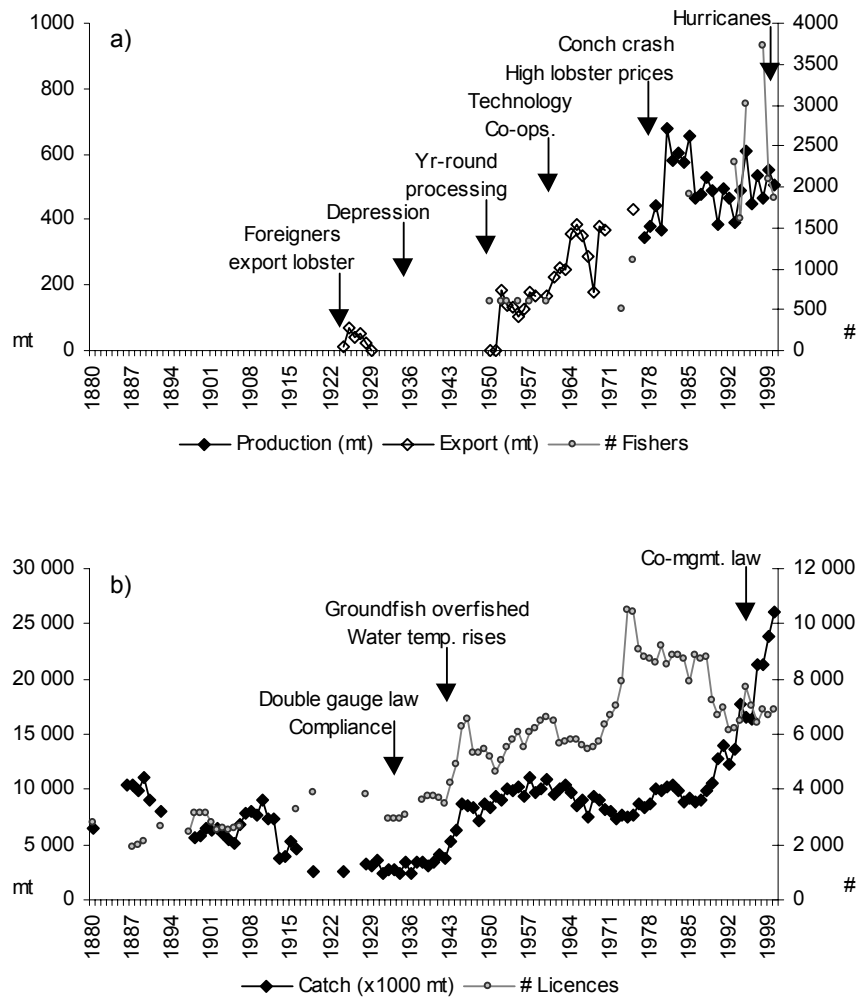
In Maine, only traps can be used to fish lobster in the inshore. In Belize, the main methods for lobster fishing are skin diving with a hook-stick and traps. At present there are around 2700 lobster fishers in Belize (FAO 2003) and around 7000 fishers in Maine (see figure 3b). I present the results in three main sections – how catches have changed and possible causes, how has management protected lobster from overfishing and how this has been structured and enforced. I identify similarities and differences between present-day Belize and the crisis period in Maine, and how problems in Maine were resolved.

Change in Catch & Causes of Change

Belize's national catch peaked in the early 1980s and has been relatively stable since the mid-1980s (figure 3a). There have, however, been reports of local declines in catch in the north since the 1920s (Daly Price 1986, Sutherland 1986). Interviewees reported similar patterns for the southern fishing grounds. In the mid-1980s "lobster nets" (baited gillnets) were introduced to fishers in Monkey River (figure 1). This resulted in a boom in lobster catch

for two to three years that then declined: “fishermen did great, built houses and bought boats at the end of the seasons... (fishers) continued to invest in more nets but they were not getting half the catch.” A second interviewee, a former fisher, also reported that he could fish: “...over 30, 000 pounds (lobster) in Monkey River”. When their productivity fell, these nets were gradually replaced by lobster traps (these differ in design and use from those used in the north): “Then ... fishermen began using both nets and traps and now they only use traps”. In Punta Gorda an interviewee related the large yields when he and his partner first fished lobster in the Snake Cayes (figure 1). These cayes had remained unexploited for lobster until the 1960s but “now it’s not worth it to go to these banks”. At a national scale, the average catch per fisher has been falling since the 1980s despite increased effort.

Figure 3. Lobster catch and number of fishers in a) Belize and b) Maine. Key events for each fishery are labelled. Sources: a) see Methods; b) Official state figures 1880-2000, in Acheson 2003 pp.17-18.



The main measures used to increase effort have been to increase the number of traps per fisher, the area fished and the size of the engine. Several interviewees reported that fishers in the lagoon area behind Caye Caulker and San Pedro have increased the number of traps they set without increasing their yields. In Placencia (figure 1), a co-operative board member explained that many fishers have invested in larger (60 hp) engines to get to the reef faster with tourists but nevertheless their production has fallen. Other studies have also found that the average size of lobster has decreased (see Appendix I).

Most of the interviewees named hurricanes as a cause of reduced catches. Until 1998, there had been no hurricanes since 1978 (Belize National Meteorological Service), but between 1998 and 2001 three hurricanes hit Belize. In 1998, Hurricane Mitch affected southern Belize, in 2000 Hurricane Keith hit the northern cayes and in 2001 Hurricane Iris struck between Placencia and Punta Negra (figure 1). All of these hurricanes had storm surges that, to different extents, caused structural damage to forereefs along the coast (see for example Mumby 1999), and in the case of Hurricane Keith, in the lagoon behind the barrier reef. Interviews with co-operative board members reported that this area had accounted for 40% of the co-operative's lobster production, which is confirmed in earlier studies (Baird 1971, Daly Price 1986), but fell to 10% following Hurricane Keith. In the months following Iris, when the interviews took place, divers in the affected area were more affected than trappers. Trappers had suffered gear loss but those who were out fishing were bringing in good catches, but the divers were not. These hurricanes also caused extensive material damage on land that affects fishing directly, due to damaged gear, and indirectly with the destruction of homes, businesses and infrastructure. Hurricane Iris ravaged the villages in its path and many fishers were on land repairing the hurricane's damage (personal observation 2002).

All of the stakeholders involved with the fishery (Fisheries Department officials, co-operative board members and fisher) reported that marine reserves competed with fishers for space and/ or were not improving catches. The view of marine reserves was well summed up by a co-operative board member: "you need to protect the life out there but it's displacing the fishermen". Interviewees also reported that the reserves were not resulting in spillover. A former fisher, now tour guide, in San Pedro reported: "The reserve (Hol Chan Marine Reserve) is not working for the fishermen. There are lots of fish inside the reserve but they're not coming out," a view shared by co-operative board members in San Pedro and Belize City.

Several attributed the change in lobster yields to natural fluctuations (see also Appendix 1). Two co-operative board members explained that the lobster catch has a cycle of two good years followed by a bad year. One interviewee, from Belize City, reported that this began in the 1960s and another, from Placencia, in the 1980s. One co-operative board member believed that the reduced lobster abundance was due to lobster moving into deeper waters.

Increased effort was directly and indirectly named as a cause in the declines during the interviews. A co-operative board member commenting on the fishing grounds in the north said: “There are now so many traps between the beds and the reef that very few lobster are making it out to the reef”. Another board member in Belize City claimed, “...most would agree that there has been too much effort in some areas like Lighthouse Reef (Atoll) which is a small fishing ground with many fishers.” Other studies have identified fishing as a cause for the decline (Appendix 1).

Lack of compliance with and/or enforcement of conservation rules (see also Appendix 1) were also considered to be affecting the catch. Two co-operative board members, felt that the existing rules were good, and were responsible for the presence of lobster at all. A former fisher in San Pedro, when asked why yields remained low despite the decrease in number of fishers in this area (due to tourism), replied: “Probably because we overfished in the past. Mistakes were made like taking gravid females at the start of the season.” Taking of shorts was reported to be common as early as the 1970s (Baird 1973). Illegal fishing appears to have been widespread in Belize. Interviewees in the south reported that fishers have regularly sold catch across the border if prices were higher or during the closed season. The use of shorts and illegal catch in restaurants is reported in the north (King 1997). Illegal fishing by fishers from Guatemala and Honduras was also reported by most interviewees in the south, but was not reported in the north. In 2002, the Fisheries Department had three boats for monitoring the fishing grounds. Two were based in Belize City and one in Punta Gorda (figure 1). During the 2002 fieldwork, the boat in Punta Gorda had been docked for one and a half months due to a broken down engine (personal observation 2002).

In Maine, the size of lobster decreased in the 1870 and 80s and the catch began to fall in the 1880s until the 1920 and 30s (figure 3b). The catch recovered between the end of WWII and the 1980s and has since boomed (figure 3b). The causes identified for the decline are

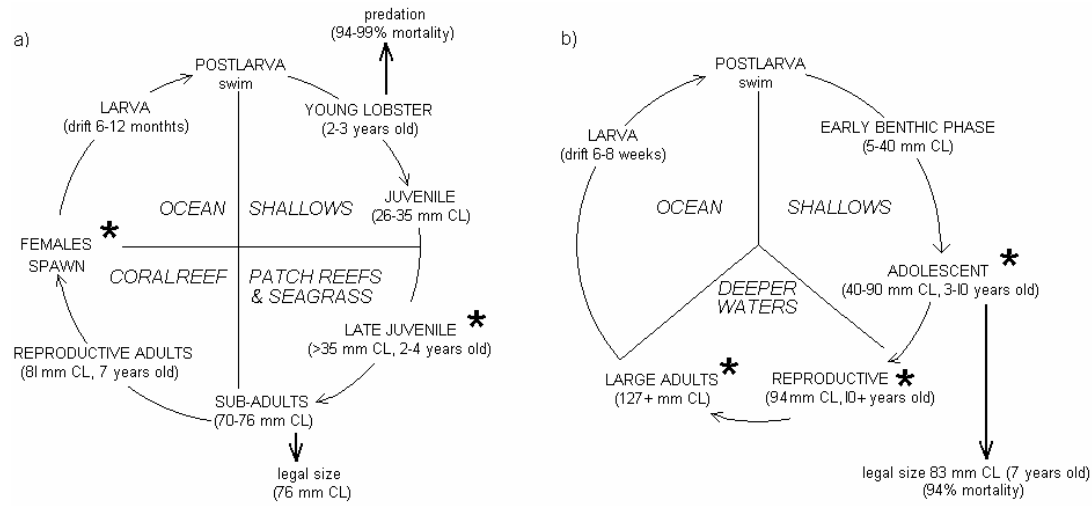
illegal fishing of short and berried lobsters and changes in predator populations (Acheson and Steneck 1997). The recovery is attributed to compliance with the conservation rules from the 1930s onwards and higher water temperatures (Acheson and Steneck 1997). Larval settlement is best at water temperatures at or above 15°C and sea-surface temperatures explained 54% of the variance in lobster landings between 1946-86 (Acheson and Steneck 1997). The boom since 1986 has occurred throughout the northwest Atlantic which rules out the above factors and suggests oceanographic regime shifts (Steneck and Wilson 2001).

Lobster Ecology & Management

Despite differences between these two lobsters' lifecycles (figure 4), they are affected by similar factors. By abundance, I refer to the abundance of legal-sized lobsters. Abundance is positively correlated to settlement of young lobster. Settlement depends on the number of eggs released and subsequent larvae survival. The number of eggs released is related to the number of females that reproduce in a year and their fecundity. Fecundity increases with the age and size of females (Morgan 1980, Acheson 1988). Survival of larvae depends on physical and chemical conditions (temperature, currents) and predation. Larvae can also be widely dispersed. In Maine, lobster population densities are lower in the east than the west, which may reflect current-related larval transport (Steneck and Wilson 2001). Long distance dispersal of lobster larvae in the Caribbean has been demonstrated (Silberman et al. 1994), although how this affects lobster in Belize is unknown. In Belize, the main current to the east of the atolls is northward flowing, however the current in front of the barrier reef and in the lagoon is southward flowing. Also, to the east of Glovers Reef Atoll (figure 1) a gyre forms (Heyman and Kjerfve 1999) that might even make this atoll self-seeding (Glaholt and Seeb 1992). These currents may mean that Belize's lobster population is to some extent self-seeding.

Young spiny lobster are prone to predation, with up to 99% mortality within the first year of settlement (Butler et al. 1997). Predation has also been an important limiting factor for the American lobster (Acheson 1988), however, these predators have been absent from the inshore since the 1940s and there is very low mortality of the young due to predation (Steneck and Wilson 2001). As lobster increase in size, predation decreases in importance. As adults, spiny and American lobsters have few to no predators respectively.

Figure 4. Life-cycle of the a) Caribbean spiny lobster *Panularis argus*, and b) the American lobster *Homarus americanus*. (*stages protected from fishing by regulations)



Conservation rules for lobster in Maine and Belize are summarised in table 1 (see also figure 4). In Belize the minimum size (76 mm carapace length) is very close to the Caribbean's average size at first maturity¹ (FAO 2001). In Maine, about 12% of females are mature at the minimum size, and up to 94% of lobster reaching legal size are fished within that year (Acheson and Steneck 1997). Belize has a four-month closed season to protect an annual peak in mating activity and to reduce fishing pressure (FAO 2001).

Table 1. Conservation rules and measures in Belize and Maine.

Measure	Belize	Maine
Minimum size	X	X
Maximum size		X
Protection of berried females	X	X
Protection of V-notched females		X
Protection of soft-bodied lobster	X	
Closed season	X	
Marine reserves	X	

¹ The average size in the Caribbean at first maturity is 78-83 mm carapace length (CL). Cuba had the smallest size, 67mm CL, at first maturity with 50% reaching maturity at 81mm CL and 100% at 97mm CL.

Both Maine and Belize protect berried (gravid) females from being fished throughout the year. In Maine berried females can be further protected if a “V” is notched in their tails, as V-notched lobsters cannot be fished. This protects known reproductive females when not berried. Maine has an additional size limit protecting large, more fecund lobster. This size limit together with the V-notch is calculated to increase the number of eggs in the water (Wilson 1997).

Additional conservation measures taken are gear restrictions and marine reserves. Regulations in Maine require that traps have a biodegradable hatch to stop ghost fishing by lost traps and an escape vent for under-sized lobster to escape from the trap (Acheson 1988). Belize’s regulations ban the use of traps and nets on the reef. Belize has established marine reserves to protect habitat and maintain a breeding stock within its boundaries to restock surrounding waters. The first marine reserve was established in 1987 and in 2000 there were twelve (CZMAI 2000).

The Fishing Community & Management

The fisheries in both Belize and Maine (pre-1995) are legally state governed. Decision-making and enforcement are carried out by a central government body and its enforcement unit: the Fisheries Department (FD) and the Conservation Compliance Unit in Belize, and the Department for Marine Resources (DMR) and the Marine Patrol in Maine.

Access to the national/state grounds is limited to licence holders, who must abide by the above regulations. In Belize, licences are reserved for Belize nationals, and there is no limit on the number of licences issued. Until recently, the number of licences issued in Maine was also unlimited. Since 1995, however, the state requires licence applicants to undertake an apprenticeship period to become eligible for a licence (Acheson 2003). In 1995, the DMR passed a law that zoned the inshore waters and established a Zone Council for each zone (Acheson 2003). The latter were to establish additional rules to limit entry (Acheson 2003).

Rules for the lobster fishery in Belize were first established in 1948. Rules were first established in Maine in 1872, over 30 years after the first cannery was established and over 50 years since lobster was exploited for local consumption. These were widely ignored until the 1930s (Acheson 1988). During the 1930’s crisis in catch the “double gauge rule” was established, that is a minimum and maximum size, and compliance increased (Acheson 1988). By the 1950s, rules in Maine were largely self-enforcing among fishers (Acheson 1988, 1997).

Organisations in the Fisheries

Trap fishers from Caye Caulker and San Pedro have an informal territorial system, meaning that it is not recognised or enforced by the Fisheries Department, which has existed at least since the 1950s (King 1997). These fishers use the northern part of the lagoon behind the barrier reef and Turneffe Atoll's lagoon (figure 1). Fishers own pieces of water from which they exclude others. This limits entry to these grounds as they can only be divided among a certain number of fishers. There are no limits on the number of traps that fishers can set and illegal fishing of shorts is reported to be common (King 1997). A co-operative board member, and recent research (King 1997), reported that this system is breaking down.

In the 1960s, fishers organised into co-operatives to increase fishers' income by removing middlemen who had been exporting lobster, and in time to diversify their exports to other fisheries products although lobster remains the most important. This succeeded and now "Belizean fishermen get some of the best prices for their catch in the world", which has allowed them to invest in other industries such as tourism and send their children through higher education. According to a co-operative board member, Caye Caulker's fishers are part-time fishers as almost all are involved in tourism. This is increasingly the case among Placencia's fishers. Declines in catch have encouraged fishers to move to tourism, which guarantees a pay cheque at the end of the day.

Despite this success, the co-operatives are having increased problems with loyalty among members who do not sell their catch or repay their loans to the co-operative. An example of loan abuse is fishers applying for loans that are not invested in fishing. A board member of one of the main co-operatives in Belize City estimated that 70% of the membership was in debt. All of the co-operative board members interviewed reported declines in the number of producing members. Fishers can sell their catch on local markets, to restaurants, to other co-operatives and to their own co-operative via another member. Two reasons emerged to explain why co-operative members sell their catch elsewhere: to avoid loan repayment and to get a better price, usually at another co-operative. The two large co-operatives in Belize City are now limiting entry and dealing with the Co-operatives Department to establish limits on the size of loans and measures to increase repayment.

The selling of catch to other co-operatives is a result of the competition for yield among the co-operatives. As a co-operative board member in Belize City said "they are working with (other co-operatives) and have good relations but at the end of the day we are still competitors". This competition began when co-operative yields stabilised in the 1980s (figure 3 a, b), and the catch per fisher began to decline. The co-operatives have responded by

competing for increased catch and following Hurricane Keith by opening receiving stations in more remote areas. In 2001, a receiving station for Northern Co-operative was opened in Mango Creek (figure 1), which was competing with the co-operatives in Placencia and Punta Gorda. Placencia Co-operative estimated that they had lost 50% of their production to the co-operative to the receiving station (this was also as it had opened faster after Hurricane Iris).

Each co-operative is represented on the Fisheries Advisory Board, which advises the Minister of Agriculture, Fisheries and Co-operatives. This is the only formal rule-making arena that formally involves representatives from the fishing community.

In Maine, access to the fishery and its grounds has been controlled informally. Fishers work in territories associated with their local harbour. Access to these grounds is reserved for the members of the “harbour gang” (Acheson 1988). There are four categories of lobster territories (table 2). Entry to “harbour gangs” is also limited, and both the number and the criteria to be eligible to join vary among “harbour gangs”. For example, a perimeter-defended territory had had 9 boats in its territory since the mid-1950s (Acheson 2003). Some “harbour gangs” developed additional conservation rules to those implemented by the state (Acheson 1988). Sanctioning is carried out by fishers and culminates in cutting traps. This is illegal and invokes a large fine and possibly loss of licence if caught by the Marine Patrol. This changed in the 1980s as the number of fishers increased (figure 3b), which introduced the need of a new scale of management.

As “harbour gangs” extended the range of their fishing territories, these changed from perimeter-defended to nucleated territories and, in time, to mixed fishing grounds. Increased demand for access to the grounds decreased the tolerance of these sanctions by new fishers. This resulted in dependence on the Marine Patrol for enforcement (Acheson 2003). This resulted in the Co-management Law that zoned the state’s waters and established a new management level, the Zone Councils, that bridged the central government agency with the local harbour gangs. Both fishers and officials are involved in decision-making.

Table 2. Territory categories in Maine’s inshore lobster fishery (Acheson 1988).

Territory	Boundary	History
Perimeter-defended	Clearly defined and aggressively defended	All territories were originally perimeter-defended
Nucleated	Clearly defined and aggressively defended near shore, decreasing with distance from shore	Expansion of the territory as “harbour gangs” grew
Mixed fishing	Shared area between 2 or more gangs where their boundaries have overlapped	When territory boundaries became too costly to defend
Open access	No enforced boundaries or limited entry	Beyond the territories where enforcement costs are high and congestion low

Acheson (2003) identified four arenas for rule-making in the Maine lobster fishery.

- 1) The territories, which have resulted from the competition between “harbour gangs”.
- 2) The “harbour gangs” that have established rules to limit entry and effort.
- 3) The state government, where fisher communities and state units come together to establish rules.
- 4) The federal government, where state and federal government units establish rules (fishers do not take part in this arena).

DISCUSSION

Conservation & Fisheries

Ecological systems are complex and dynamic (Levin 1999), and an understanding of the structures and processes of the lobster stock within its ecosystems is needed in order to explain changes in lobster abundance. The catch data from both fisheries shows that there are annual fluctuations (figure 3 a, b) that are assumed to reflect patterns in the population vs. in fishing effort that is expected to be relatively constant. In Belize the national yield has been relatively stable since the 1980s, however, the interviews and previous studies have found a general decline in catch per fisher since the 1980s and a decrease in the average size of lobster. This suggests that the lobster population is changing to a younger stock, which is not visible in the national catch data. Five factors were attributed to the decline in catch per fisher in Belize: natural fluctuations, hurricanes, loss of grounds to marine reserves, too many fishers and/or too much effort, and, lack of enforcement.

The annual fluctuations in catch in Belize may be due to changes in larval and/or post-settlement survival, which would suggest changes in environmental conditions such as

temperature, currents and salinity. The hurricanes since 1998 may have caused recent falls in production, but as no hurricanes hit Belize since 1978 they cannot account for annual fluctuations or the decline. It is also unlikely that marine reserves account for the reduced lobster catch as no-take zones have taken about 1% of Belize's territorial waters (CZMAI 2000) and less than 4% of the fishing grounds of Belize (Gibson et al. 1993). An interviewee attributed the decline in catch per fisher to migration of lobster to deeper waters. Trap fishers in the north fish the shallow waters behind the reef and have been the most important producers of lobsters, which does not support the hypothesis that lobster have migrated to deeper waters. Fishing appears to have affected lobster abundance, this may also be affected by environmental changes though this could not be assessed, and may be beyond the scale of interviewees' scope. This was true too in Maine where fishers were unaware of the positive effects of higher temperatures on the recovery of lobster production (Acheson and Steneck 1997).

Management cannot control larval and post-settlement survival. However, it can aim to maintain the number of eggs released into the water by targeting brooders (Wilson et al. 1994). In both fisheries, the proportion of females that is sexually mature when they enter the fishery may not be large enough to maintain larval supply. During a conversation, a fisher on Caye Caulker explained that the start of the lobster season was good and then slowed. At the end of the season fishers increased activity to catch the lobster that had been just below minimum size at the start of the season. I assume that the fishery in Belize has a comparable efficiency in fishing as in Maine, and therefore that a small proportion of lobster of legal size survives to adulthood. Together with decreased average size of lobster that reduces fecundity, this may cause positive feedback speeding the decrease in number of eggs.

In both cases additional rules are in place that should compensate for reduced larval supply due to fishing of reproductive and juvenile lobster. The four month closed season in Belize should act as an insurance measure by protecting a known period of higher abundance of berried females and mating, and produce a pulse of eggs provided there are no disturbances during this period. Maine's protection of first V-notched females, which ensures marked females will mate at least once more and second, large lobster protecting more fecund females, and together increase the average number of eggs released per lobster (Acheson and Wilson 1996). Gear restrictions limit indirect effects of fishing on these measures. Belize's regulations for gear target habitat damage but do not control the effects on lobster, such as ghost fishing or unselective fishing by divers. Divers often cannot see the lobster being fished, which are often maimed or killed when hooked but to what extent is unknown. This limits the

implementation of the existing conservation rules. Belize has established marine reserves that should also protect spiny lobster. Reserves need to include suitable habitats for the different life-stages as well as a design that can manage for mobility in lobster (Acosta 1998, 1999). Marine reserves should have boundaries that are large enough to prevent lobster from emigrating, or consist of a network of reserves to increase the probability that emigrating lobster will enter another reserve (Stockhausen and Lipcius 2001).

It is also necessary to be able to distinguish between natural and human-induced change as well as synergies. There have been local boom-and-bust catches and sequential exploitation of grounds at a national scale in Belize (Huitric in revision). The low catch in the 1930s in Maine might have been due to direct and indirect effects of fishing. Fishing reduced the average size of lobster, which increased the proportion of lobster lost to predation, further reducing lobster abundance. In Belize, fluctuations in lobster catch have become bigger and more frequent since the 1980s (figure 3a), which could be an environmental effect or such a synergy between environmental factors and fishing.

All of the shallow fishing grounds in Belize are accessible to most fishers in Belize, and it appears that fishing has had an effect on these populations. The fishery is now dependent on conservation measures to maintain this stock (up to 30m deep in the lagoon and on the reef), as there are no more *de facto* reserves due to access limitations. This is also true in Maine. The conservation rules in Belize depend on the success of the minimum size to maintain the population. With the knowledge that this measure may not allow enough reproduction, the other rules may become redundant as they assume that enough females will reach maturity before or shortly after entering the fishery. There are also many gaps in the knowledge of the lobster stock compared to Maine. The size at which females become mature is not included in the regulations, and the proportion of new recruits to the fishery that are able to reproduce more than once is unknown. The efficiency of fishers at removing lobster as they enter the fishery is unknown, although it is assumed to be high as the average size has decreased. The reports that there is no spillover from the reserves in Belize could be due to a lack of enforcement, the reserves being too young (the first was established in 1987), large-scale factors affecting the population that are beyond reserves' control, and/or poor communication between reserves and the fishing community. An implication of marine reserves, as well as of conservation efforts targeting the reproductive stock, is the need for knowledge of spatial variation as these measures are more dependent on conditions at local scales (Acheson and Wilson 1996). At present reserves have small no-take areas that are

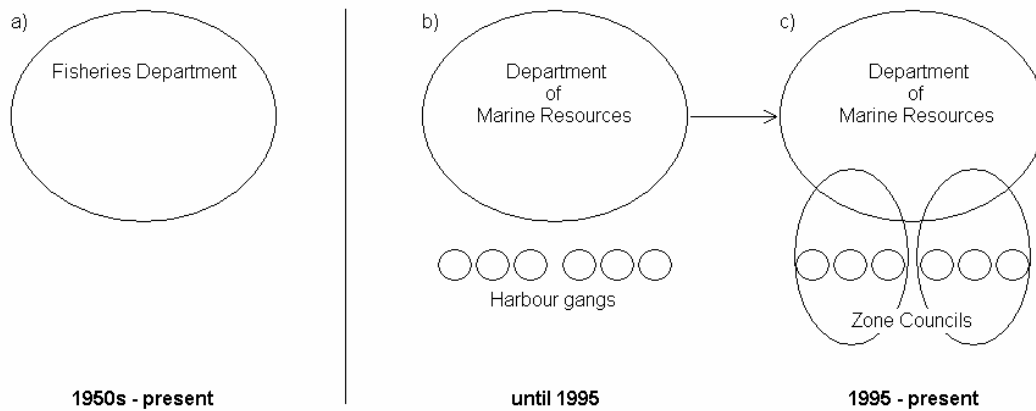
unlikely to protect lobster efficiently. This maintains the dependence on conservation rules in the fishery.

Managing the Social System

As Finlayson and McCay (1998) observed “managers control people not fish”. Both fisheries have been formally under the jurisdiction of a central government body (figure 5) responsible for decision-making, monitoring and enforcement. However, until recently property rights, and their enforcement, in Maine were *de facto* informal and enforced at the harbour gang level (figure 5b). Harbour gangs’ territories were small and clearly defined, with limited entry and members enforced both state and local rules. Unlike the Belize fisheries, where few fishers remained dependent on local resources after the 1960s, Maine’s fishers remained dependent on local resources until the 1980s, over 100 years of commercial fishing. The costs of invading territories and of travel to open access grounds beyond territorial areas (Acheson 2003) appear to have slowed sequential exploitation.

Conservation rules require an institutional structure that can enforce these in order to have an effect. The changes in catch in Belize could be due to lack of enforcement of conservation rules rather than overfishing. Lack of compliance with conservation regulations prior to the 1930s in Maine reduced the number of brooders and, therefore, subsequent recruitment (Acheson 1988). Enforcement in Belize is by an external police. This body cannot, however, afford the costs of full enforcement, which is an example of a mismatch of scales between the governance system’s structure and the fishery’s (Brown 2003). Enforcement assures fishers that there are no free riders and can enhance compliance, which reduces enforcement costs. Variables that affect enforcement costs in Maine and Belize are the number of users and the size, and complexity, of the fishing grounds. Self-enforcement in Maine was possible as the members of the “harbour gang” knew that free-riding was controlled, the improvement in catch indicated their efforts were having an effect (as they were unaware of the environmental conditions like temperature) and their property rights assured them access to these lobster. This local scale management was necessary for enforcement as the DMR had been unable to enforce regulations prior to the 1930s (Acheson 1988).

Figure 5. Schematic representation of the organisations in the governance structures that are actively involved in monitoring users in Belize a) and in Maine b) and c).



Responding to & Dealing with Change

As expected, the fisheries in both Maine and Belize have responded to changes in the natural and social-economic systems. From a sustainable resource use perspective, however, their responses have been very different. I begin this section by presenting environmental changes that have occurred in each case and then compare the responses taken.

Two changes in lobster abundance have been selected from Maine: the crisis in catch in the 1930s and the recovery of the catch from the 1940s onwards. Both of these occurred throughout the state affecting all fishers. In Belize there have been local declines in catch that have affected local fishers throughout the fishery's history. During the 1980s the co-operatives' catch stabilised, and since the 1980s fishers have on average caught smaller amounts of lobster. In Belize the territorial system in the north has also limited entry but, as in Maine prior to the 1930s, it has not controlled effort. Yet this area has dominated the industry until recent hurricane-induced changes to the grounds. In the 1930s, Maine's fishers accepted regulations and eventually incorporated these into their own property rights regimes. Declined yields in Belize, however, have been solved at the fisher level by increasing effort and technology. The co-operatives responded by increasing their capitalisation in the fishery and the subsidies offered to the members. The most costly subsidy has been the offer of loans and taking on members' increasing debt. The increase in lobster abundance from the 1940s onwards in Maine led to the development of additional rules to protect the fishery, both at the state level as well as informally in some harbour gangs. While there was an increase in the number of fishers, this was not large enough to change the governance system among the

harbour gangs until the 1980s. In contrast, increases in abundance in Belize, for example on the atolls and with the introduction of skin diving on the reefs, have led to influxes of new fishers and increases in exploitation. This was particularly true at the end of the 1950s with the introduction of skin diving, engines and in the 1960s the co-operatives. Within ten years few fishers depended on local resources.

The fisheries have also been affected by changes in the socio-economic system. The crisis in Maine was also an economic one related to the depression of the 1930s that lowered prices and demand for lobster. This period also affected the fishery in Belize that closed until the 1940s. A second period of change in Maine was the gradual increase in number of fishers and traps set in the grounds. The increase in number of fishers and pressure on the territory boundaries increased monitoring and enforcement costs as it was more difficult to identify cheaters and conflict was more common. The increase in number of traps per fisher increased entanglements with others' traps and increased individuals' costs, as they spent more time and fuel tending to traps. This began to threaten the territorial system and could have resulted in *de facto* open access to the resource as fishers would no longer be guaranteed future rewards of present restraint and lose the incentive to maintain rules. Instead, fishers responded by lobbying the DMR to take over enforcement, as well as to protect harbour gangs' "rights" (Acheson 2003). The loss of the territories would also have led to a loss in diversity of rules.

In Belize the establishment of the co-operatives was a very successful collective action endeavour to increase equity in the lobster (and later fisheries in general) export industry. This succeeded, through the much higher prices that fishers received. However, this also led to an uncontrolled influx of fishers, both to the co-operatives as well as independent fishers who could sell to the co-operatives, and eventually resulted in the loyalty problems described during the interviews. The co-operatives were taking action at the time of the interviews by limiting entry and taking legal measures to control loan abuse and repayment. These measures will reduce debt issues in the co-operative but will not reduce fishing effort as co-operatives continue to purchase landings from non-members.

Governance systems should be able to adapt their structures and institutions in response to change in both the natural and social systems. Response often takes time, particularly if means of monitoring feedback are missing. The crisis in Maine culminated after about 40 years of falling yields and ten years of low yields. Fishers' attitude to conservation rules is affected by their dependence on the resource, knowledge that reduced effort will increase future yields and that access to these future yields is reserved for them. In Maine,

prior the 1930s, fishers did not perceive taking shorts and berried females as a crime or as contributing to the change in catch, despite their dependence on the local resource. Once this perception changed, however, conservation rules could be incorporated into the local property rights regime. Whereas a formal/ trusted means of communicating information and knowledge about the industry were missing, the property rights appear to have acted as brakes on rapid changes in the industry and allowed time, and created space, for learning. A key factor was the limited entry to the fishery, even in times of abundance. This effectively controlled fishing pressure. This property right system was also the means of implementing formal regulations and allowed fishers to start incorporating their own observations in the grounds into knowledge of the grounds and transforming this knowledge into institutions – by developing conservation measures.

This common property resource management system contributed to ecological resilience, but changing social-economic conditions changed their ability to successfully manage the resource. The growing numbers of fishers in the 1980s gradually weakened the capacity of the territorial system to control users. This is explained in the common properties literature (Ostrom 1993), as the number of fishers and/or the area fished increase, compliance decreases and social sanctioning becomes more difficult. This is similar to the changes that have taken place in the co-operatives and the fishery in Belize.

Maine's nested structure creates institutional diversity. The complexity and scale issues of the fishery demonstrate the value of organisational diversity. The diversity in the organisations acted as an insurance and latent knowledge that was necessary for the structural changes of the Co-management Law. As in adaptive management (Walters 1997), the present zoning has increased the opportunity to experiment with different management approaches. The organisations in Maine's governance system overlap in roles for rule making and monitoring both of the resource and of the users, and provide forums for these levels to meet. This has formally created space for learning in the governance system, as it provides channels for feedback at appropriate scales. It would be "natural" to take advantage of Belize's existing organisations and incorporate the co-operatives in the governance structure. This will require, however, that members and non-members agree to this, as well as the co-operatives themselves and that the Fisheries Department is willing to delegate responsibility (Berkes et al. 2001).

The cause for the shift in Maine in the 1930s is unclear – there was a crisis in yield, although yield per fisher was equally low in the 1970s without the same exodus from the industry statistics in (Acheson 2003), there was an economic crisis affecting demand and

prices, and the head of the DMR of the time was a respected leader trusted by the industry. Whatever the cause, the change in perception of conservation measures set the path for the development of the “conservation ethic” and new vision for the fisheries. This resulted in the establishment of additional conservation rules, adapted to local conditions and/or desires.

Belize has not yet reached a crisis at a national scale, but has now experienced twenty years of declining yields per fisher. It was not possible to determine whether or not this is a result of overfishing or illegal fishing. However, since individuals cannot afford to reduce their catch, management may need to reduce the number of fishers. Furthermore, if Belize’s grounds are indeed self-seeding, then fishers in Belize will benefit more from their conservation measures. Can they avoid a crisis, or do they need one to learn? It seems like an overall vision for management and governance is still missing. A vision like the “conservation ethic” of Maine may need to emerge. Recent literature suggests that leaders and other key individuals with trust among fishers are central in developing such a vision in successful social-ecological systems (Westley 2002, Olsson et al. 2004b). Such “political entrepreneurs” were identified in Maine (Acheson 2003) and may transform management and develop a governance system in tune with ecosystem feedback.

CONCLUSIONS

With today’s scale of exploitation the fisheries in Belize and Maine are very dependent on the success of the conservation regulations in place. The responses from interviews with actors in the Belize lobster fishery and past studies confirm that there are changes in the lobster population, which indicate that fishing pressure is too high. Based on existing knowledge of the ecology and life cycle of the spiny lobster I conclude that there are shortcomings in existing regulations, particularly in the minimum size, as well as in the dependence on marine reserves as insurance in Belize. Based on Maine’s success in restoring lobster catches through its conservation rules, rather than controlling effort, I recommend the reviewing the goals of the existing rules in Belize.

Environmental feedback management is essential for sustainable resource use. Governance systems and their structure affect the capacity to learn and develop ecological knowledge for responding to changes in the resource. I attribute the co-operatives’ responses to the declines in lobster in Belize to their being organisationally de-linked from the environment. The failure of existing rules to match lobster biology and the failure to enforce

and comply with these rules suggests that the governance structure and the stakeholders in the fishery are de-linked from their resource base. There is a governance gap and lack of incentives for sustainable resource use. The Maine lobster industry seems to have been able to develop a governance system with vision, trust and rules that created incentives for ecosystem management and connected actors across scales. A precondition for success is that institutions and their organisational structure incorporate the resource's ecology and provide a social context for learning and adaptation to deal with change.

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APPENDIX I

Summary of results from the past studies 1) Jacobs 1999, 2) Heyman and Graham 2000, 3) Espeut 1994, 4) Huitric et al. 2003, 5) the present study.

	1	2	3			4	5
Study area (District/ Town)	Stann Creek, Toledo	Toledo	Belize City	San Pedro	Punta Gorda	Corozal	National
# Fishermen interviewed	75	37	102			25*	13**
	%	%	%	%	%	%	N
Lobster stocks							
Fewer; Smaller	88; 24	49; 43	82; 37	86; 45	79; 53		6***
Concerned about population			72	83	68		
Previous good grounds empty/ worse			61	41	58	92	
Causes of decline							
Weather change			96	100	79		
Hurricane						44	5
Bleaching						4	1
Lobster smarter/ location changed		27	24	21	32		1
Nets too many/ destructive		76	37	14	68		
Too many fishermen/ Overfishing		89	26	66	37	44	1
Increased effort							6
Reserves take space						24	4
Minimum size too small			50	48	84		
Illegal fishing by locals			59	66	58		4
Illegal fishing by foreigners			76	31	79		5
Smuggling & crossborder fishing		86					1
Illegal fishing						4	
Limited enforcement		49					2
Mangrove destruction/ Habitat damage		8	32	66	68		
Proposed Remedies							
Gear restrictions		68	39	66	63		
Restrict fishing in sensitive times & areas	21	73	70	62	84		
Marine reserves/ Fish sanctuaries	80		67	83	90		
Size restrictions	15		85	97	100		
Enforce existing laws/ more patrols	41	97					
All fishers must have licenses			94	100	95		
Fines for fishers without license			93	97	68		
Limit numbers of fishermen			22	28	11		