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Economic reasons, ecological actions and social consequences in the Mexican sea cucumber fishery

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Introduction

Increasing attention is being given to the effects of international trade on the environment, especially in situations where biodiversity conservation is opposed to export-led industries such as fisheries. Even many small-scale fisheries are not an exception. When a natural resource represents high revenues to artisanal fishermen, fishing effort rapidly increases and fish stocks become overexploited. This is what Grainger and Garcia (1996) call the 'boom and bust' cycle of fisheries. When an open-access fishery develops, it passes through four phases:

- Undeveloped: the fishery commences and stocks remain under-exploited.
- Developing: the catch keeps on growing and the industry flourishes.
- Mature: the level of captures becomes constant but more and more fishing effort is needed to maintain these levels.
- Senescent: captures decrease in spite of increasing fishing effort. The stocks become overharvested and a number of jobs are put at risk.

Once this cycle finishes, a new fishing ground, a new stock, or a new fishery is developed, and the cycle starts all over again. Sea cucumber fisheries around the globe have gone through this cycle (Conand 1998, 2001). In order to find a solution to this problem, the United Nations organised the 1992 Conference on Responsible Fishing, which

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was held in Cancun, Mexico as a follow-up to the Rio Declaration on Environment and Development. The Mexican government then became committed to protecting marine biodiversity. One of its actions was to impose a total closure for the *Isostichopus fuscus* fishery. In this paper, we present a brief description of how this fishery was constrained by biodiversity conservation concerns, and by the high international price. We discuss as well few recommendations for its management.

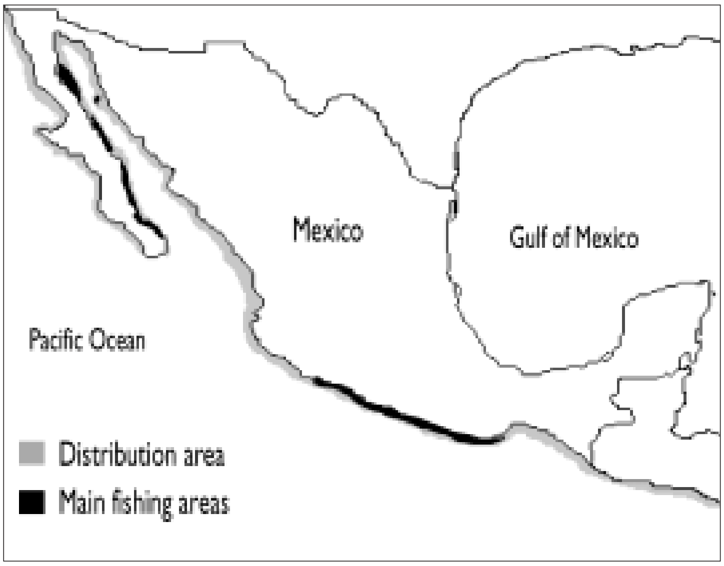

Figure 1. **Distribution of *Isostichopus fuscus* in Mexico**

The Mexican sea cucumber fishery

The sea cucumber fishery is a small-scale fishery that started in the late 1980s in response to elevated prices in Asian markets, which especially favoured a Mexican species: *I. fuscus*. The international price rose from 11 USD per kilo in 1989 to 25 USD per kilo in 1993 (Fajardo-León and Vélez 1996). Although intermediaries paid a much lower price to fishermen, the latter obtained attractive benefits as their cost of capture was very low. Usually, fishermen process their catch either as whole, gutted and dried, boiled, semi-frozen, or as raw-fresh muscle (Castro 1995). Once processed, they sell the product to intermediaries who export it to California where it is re-exported to the main markets: Hong Kong, Taiwan and Singapore (Conand 1998, 2001).

In only three years, captures in Baja California Sur state — the main fishing area (Fig. 1) — reached an historic high of nearly 2000 t in 1991, decreasing steadily afterwards. The fishery showed typical signs of the fisheries cycle as described above, developing faster than the ability of authorities to implement precautionary management measures. Even when the stage of exhaustion appeared, little information was available, hampering reliable evaluations of population parameters (Reyes-Bonilla and Herrero-Perezrul 2002).

Given that information on the biology of *I. fuscus* was very limited, the real level of abundance was unknown. Consequently, the Mexican government, trying to comply with biodiversity conservation principles, declared this species as threatened with extinction and imposed a total closure to the fishery in 1994. A Mexican legal provision (the official standard NOM-059-ECOL-94) was enacted and published in the Official Diary of 16 May 1994. However, this decision did not take into account that *I. fuscus* is distributed from California to Ecuador, and that Mexican law defines a threatened species as 'a species whose distribution areas or population size have been dramatically diminished, putting at risk its biological viability along its whole distribution range'.

Because fishermen were opposed to such a suddenly-implemented measure, they did not stop fishing, and sea cucumber stocks continued to be exhausted as enforcement costs were prohibitive for the environmental enforcement agency — Profepa. Fajardo-León and Vélez (1996) argue that fishermen were willing to cooperate with scientists and managers in order to preserve stocks and to benefit from the high international price. However, with no controls or monitoring of captures, *I. fuscus* stocks reached a level of approximately two per cent of the original estimated population in Baja California state in 1997, according to the research fisheries agency (INP). It was evident that the permanent closure did not solve the problem of stock depletion.

An experimental approach with the aid of fishermen

Milliman (1986) demonstrated, using certain assumptions, that with illegal fishing, the costs of the transgressors increase as enforcement spending increases. However, in the case of the sea cucumber fishery, officers of Profepa cannot afford to survey the entire area where the fishing takes place. Another option is to distribute the costs of enforcement and surveillance among users. Nevertheless, managing a fishery is not just a matter of costs, fishermen need to have a feeling of stewardship for the resource (Young 2001). Involving fishermen in both biomass assessments (e.g. the level of the populations) and management measures has been a successful way to deal with several shellfish fisheries in Latin America (Castilla and Defeo 2001). Yet the lack of reliable biomass assessments remains a serious problem. Perry et al. (1999) have proposed an experimental design for sea cucumber fisheries and other sessile organisms. It consists of following the behaviour of the population using known exploitation rates by defining reference areas subject to different levels of harvesting, and leaving one area as a no-take area in order to have a control for allowing further comparisons. Biomass assessment would be made in cooperation with fishermen, discussing with them ways to achieve a certain biomass level.

Assigning territorial rights to fishermen cooperatives could be a complementary option. The idea behind this is that once fishermen have defined sea cucumber fishing areas, they will have an incentive to survey the biomass level and keep it sustainable, thereby reducing the problem of uncontrolled open-access fisheries. Such systems of territorial rights are already applied 'de facto' for lobster fisheries in Mexico (Castilla and Defeo 2001). This may lead to more efforts on mariculture as another good option for stock rebuilding (Gutierrez-Garcia 1999) and, as Conand (1998) puts it, a way for achieving economic sustainability.

It should to be noted that, for carrying out such a management programme, the category of threatened species for *I. fuscus* has to be changed, which would then end the permanent closure, and allow for commercial fishing. In fact, in March 2000, a modification to the official standard (NOM-059-ECOL-94) took place, placing *I. fuscus* as 'species under special protection', authorising scientific monitoring to be carried out by both fishermen and government scientists. Although it can be reckoned as a first step in the right direction, the implementation of cooperative surveys in the harvesting areas has not yet been achieved at a large scale, and the illegal fishing continues.

Final considerations

We described in this paper how export prices for sea cucumbers induce fishermen to overharvest the resource in a short period. However, a drastic measure such as a total closure did not alleviate fishing pressure on stocks. The government chose to protect a species without taking into account other options for fishermen and, except for illegal middlemen, no one was better off. A high export price will continue to be an incentive for illegal fishing, losing valuable information on biomass levels. If fishermen participate in: experimental fishing designs, management measures for enforcement, and commercialisation channels, and have the exclusive access to defined fishing areas, the sea cucumber fishery may become a rewarding activity in economic, ecological and social terms. Participatory management of the sea cucumber fishery in the Galapagos Islands, as described by Martinez (2001), may be a promising example.

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Hatchery research sheds light on problems in sea cucumber aquaculture

Andrew D. Morgan

Hatchery research on the reproductive biology and culture of *Stichopus mollis* has given great insight into some of the problems facing the sea cucumber aquaculture industry. During four months of the reproductive season, some 60 or more spawning trials were conducted, and 300 dissections and 300 biopsies performed. Morphometric measurements were made on 5000 larvae spread across eight replicated experiments. A number of bulk rearing trials of 30,000 to 50,000 larvae each were conducted.

Reproductive behaviour and spawning

Considerable problems in developing hatchery technology for sea cucumbers have stemmed from the fact that it is difficult to control reproduction. A semi-lunar rhythm of reproduction and spawning was found for *Stichopus mollis* over a four-month period, both in a wild population and in captivity. This coincided with the gonad index (body wall weight to gonad weight ratio), which fluctuated depending on when spawning events occurred. Asynchrony between males and females also occurred with the gonad index of one sex often peaking before the other sex every few weeks. However, gonad index was not an accurate reflection of spawning condition.

Animals were collected from the wild every two weeks and held under controlled conditions in the laboratory. In captivity, spawning trials were always conducted at dusk as this was when their natural spawning behaviour occurred. Broodstock were always kept for two weeks, similar to the semi-lunar rhythm of gonad index and reproductive condition occurring in natural populations. Spawning also occurred naturally and with a predictable rhythm in broodstock holding tanks and lasted approximately 45 minutes.

Three spawning trials a week were conducted to determine the pattern of spawning in relation to the lunar cycle. During a trial in which animals spawned the synchrony of spawning was increased to greater than 80 per cent by placing animals in a temperature shock bath about 3–5°C above ambient. Individuals of both sexes often spawned across several days. Some asynchrony in spawning was observed as males often spawned in the days preceding a major spawning event, as did females on occasion.

Reproductive condition and gamete viability

Dissections and wet mounts of gonad tissue under microscopic examination indicated that the reproductive condition of broodstock was similar to that of natural populations. Under macroscopic examination, ripe male gonad often contained a visible lumen as did the female gonad.

Another problem facing the industry is that in a lot of cases the use of temperature shock does not induce large numbers of individuals to spawn. To investigate why this may occur, all individuals collected every two weeks from the wild for spawning trials were biopsied (a strand of gonad was extracted using a hypodermic needle and syringe) and the gonad tissue samples examined microscopically to compare differences in sperm and egg quality between spawners and non-spawners. A section of gonad tissue was also stored for later histological examination.

The index of sperm quality provided an accurate tool for assessing readiness to spawn. Predicting the readiness of females to spawn was more of a problem. With no differences in egg size and often