The Impact of Lobster Fishing on Sea Urchins and Coral in Galapagos

Elaine Albertson, Sophomore College 2008

October 10, 2008

Abstract

In Galapagos the pencil sea urchin *Eucidaris thouarsii* is a "corallivore" that greatly influences the ecological structure of Galapagos subtidal marine communities. While *E. thouarsii* does not commonly feed on coral elsewhere, in Galapagos it tends to diversify its diet to include large amounts of coral. Overfishing of lobsters – predators of Galapagos sea urchins – allows *E. thouarsii* populations to boom, in turn causing the decimation of coral by sea urchin overgrazing. In order to protect the delicate Galapagos coral reef ecosystem, sea urchin populations must be controlled. Sustainable management of the Galapagos lobster fishery through strategies including the implementation of an ITQ system is the most effective method of sea urchin control.

Introduction

Pencil urchins in rock crevices in Galapagos (courtesy of Nick Wenner).

The Galapagos archipelago is uniquely located at the confluence of several major ocean currents including the Humboldt current, which carries Antarctic water north up the coast of South America, and the Cromwell current, which upwells cold deep water to the surface at the archipelago. Due to these cold water currents, the ocean surrounding the islands is

LEFT:A beach in Galapagos composed mainly of organic material including washed-up spines of *E. thouarsii*. BOTTOM: A sea turtle grazes on algae next to a pencil urchin (courtesy of Nick Wenner).

generally cooler than it is at other equatorial islands. This cool ocean temperature pushes the lower limit for the growth of reef-building corals, making the Galapagos a marginal habitat for coral reef development (Chornesky 1985: 1523). Furthermore, during El Niño periods water temperature changes drastically, rising above 25ϒC throughout the archipelago for up to a year (Edgar et. al. 2004: 1107). Even ahermatypic (non reef-building) corals undergo temperature stress during El Niño periods. Due to naturally occurring adverse oceanographic conditions such as extreme temperatures, coral development in Galapagos is limited.

The natural fragility of Galapagos coral renders it vulnerable to changes in its environment. In 2007 three endemic Galapagos coral species were placed on the World Conservation Union's Red List (Science Daily 2007). Ecological changes that favor the growth of corallivorous sea urchin populations may be catastrophic to Galapagos coral. On the coast of mainland Ecuador the urchin *Eucidaris thouarsii* is selected for smaller size and a uniform diet because it has many predators (Stewart 2007: 147). However, in Galapagos the urchin *E. thouarsii* grows larger and diversifies its diet to include coral

(Chornesky 1985: 1523). Thus, anthropogenic coral destruction may occur in Galapagos as a result of the overfishing of sea urchin predators such as lobsters. This paper aims to identify the most effective method of controlling sea urchin populations in Galapagos in order to protect Galapagos coral from overgrazing; as well as to analyze issues in the lobster fishery that allow overfishing to occur.

Hypotheses

The first hypothesis of this paper is that successful management of the lobster fishery in Galapagos is the most effective and sustainable method of sea urchin population control. Other methods of sea urchin control such as physically removing the organisms or allowing them to starve are less effective and unsustainable.

The second hypothesis is that successful lobster fishery management depends on replacing the current total allowable catch (TAC) quota system with individual transferable quotas (ITQs).

Methods

A thorough search of relevant science and social science literature was conducted in order to gather data on: coral, sea urchin and lobster populations in Galapagos; current Galapagos fishing policies; relevant documented case studies of coastal ecology and fisheries. Literature was synthesized in order to draw conclusions in relation to the two initial hypotheses.

Findings

Addressing Hypothesis 1: Methods of Sea Urchin Control

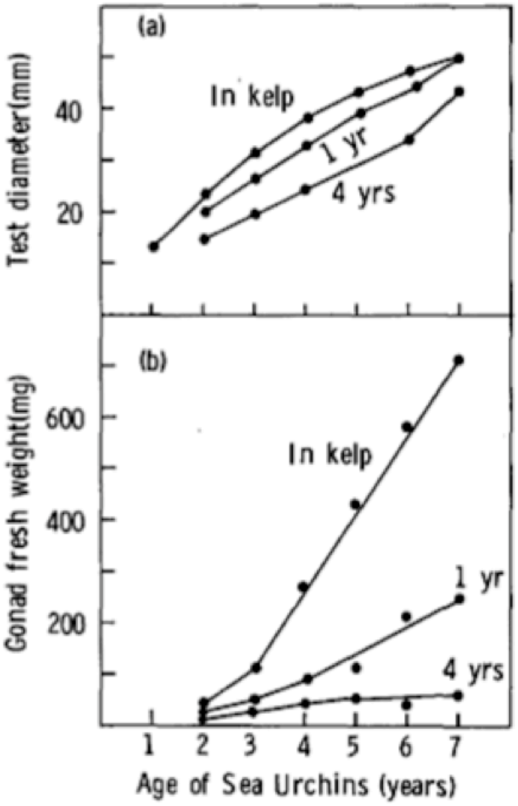
One possible method of sea urchin population control is physical removal of the urchins, either with chemicals such as Quicklime or by removing them by hand from their environment. While this method of physical sea urchin control is effective, it may yield undesirable effects.

In a case study of the removal of the herbivorous sea urchin *Strongylocentrotus franciscanus* from southern Californian waters, Quicklime was used to effectively control urchin populations. However, because this experiment aimed to control sea urchin populations in a kelp environment, it warns that "If Quicklime were used…experiments must be conducted to ascertain what other organisms might be injured by use of the chemical on coral reefs" (North and Pearse 1970: 209). Using a chemical such as Quicklime to remove sea urchins from coral environments in Galapagos may be an undesirable method of sea urchin removal due to the associated risk of unintentionally damaging the ecosystem.

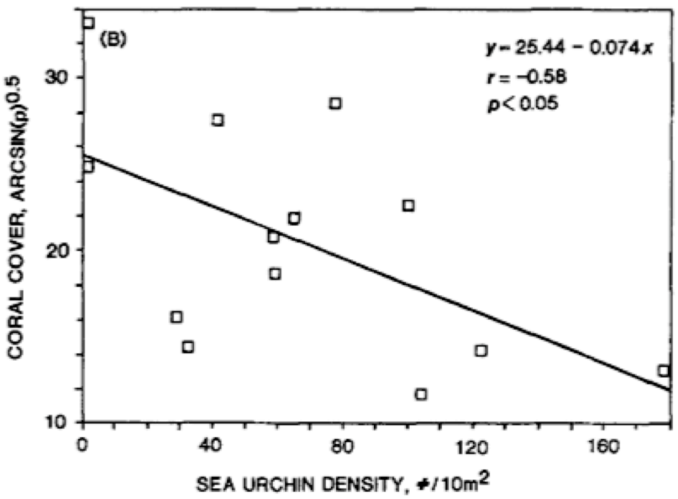
Removing urchins by hand, with no chemicals, might prove less damaging to other organisms. However, urchins are difficult to remove (Miller 1985: 278). Any method of by hand removal would require much time and labor, rendering this method of urchin population control undesirable. Furthermore, the removal of an indigenous Galapagos species such as *E. thouarsii* from its natural habitat may be a damaging political move for conservation efforts in Galapagos due to the U.N.'s declaration of Galapagos as a "World Heritage in Danger" in 2007 (UNESCO). Physically removing urchins, by hand or with chemicals, would be an unpopular method of urchin population control. It is likely that this unpopularity would render this urchin control method unsustainable.

A second potential method of sea urchin population control would be to allow the urchins to "starve out." That is, to allow the urchins to overgraze and completely destroy their main food source, coral. In theory, urchin population would then decline for lack of food, allowing the main food source the opportunity to re-grow. However, case studies show that this method of sea urchin population control is not ideal.

A study of populations of the sea urchin *Strongylocentrotus droebachiensis* in St. Margaret's Bay, Nova Scotia revealed that even four years after total destruction of its kelp food source the urchin continued to inhabit the barren site. Years after consuming its entire main food source, the urchin population still had steady larval recruitment and continued to grow (Lang and Mann 1976: 321). Even without an obvious food source urchins were able to successfully subsist on microalgae such as diatoms (Chapman 1981: 309). Assuming that urchin overgrazing in a kelp environment is analogous to urchin overgrazing in a coral environment, this case study suggests that attempting to starve *E. thouarsii* out of locations where it is threatening Galapagos coral would be an ineffective



Strongylocentrotus droebachiensis (a) Comparison of growth curves, and (b) comparison of individual gonad size, in populations before and after destruction of kelp beds. "In kelp" signifies data from sea urchins in kelp beds; "1 year" and "4 years" signify time since destruction of kelp beds (Lang 1976: 325).



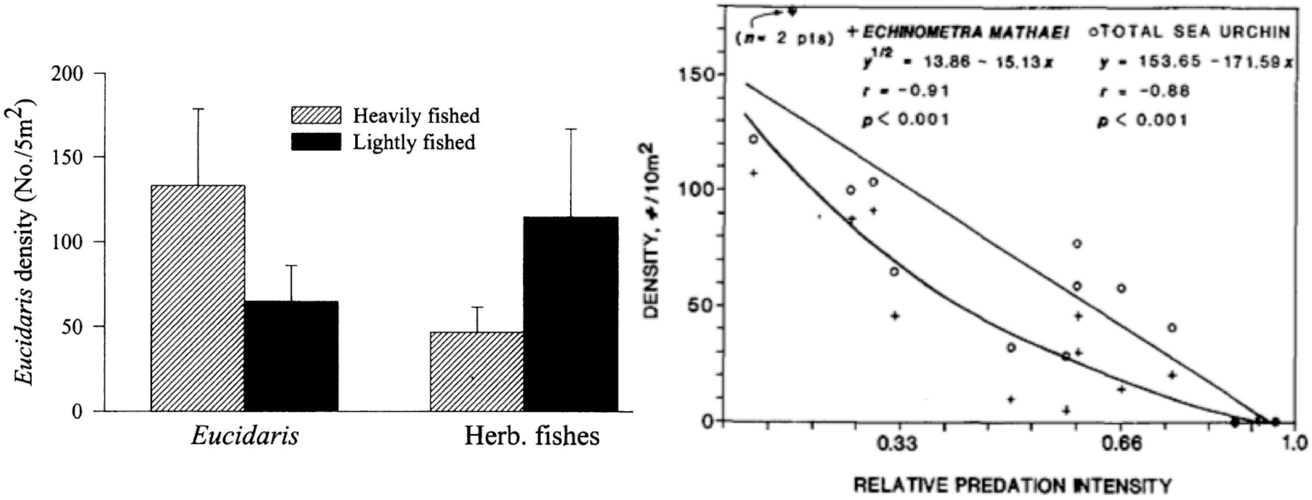
TOP: Arcsine transformed coral cover plotted against the total sea urchin density. As sea urchin density increases, coral cover decreases (McClanahan 1990: 367). BOTTOM: An urchin barren in Galapagos (courtesy of Nick Wenner)

method of sea urchin population control. Populations would persist for years after the total destruction of coral by sea urchins. Furthermore, this method requires allowing the urchins to decimate their coral environment, a clearly undesirable result of a plan meant to preserve coral.

A third potential method of sea urchin population control in Galapagos is to combat the source of the overpopulation by ending overfishing of sea urchin predators. It has been shown that in Galapagos, the removal of urchin predators causes “barren grounds” to replace previously diverse coral habitats (Okey et. al. 2004: 397). Case studies confirm that maintaining sufficient populations of urchin predators is an effective and sustainable method of sea urchin population control.

Arcsine transformed coral cover plotted against the total sea urchin density (McClanahan 1990: 367)

In a case study of kelp destruction by sea urchins in southern California, “the persisting high population densities may be the result of (i) destruction of their main predator, sea otters” (North and Pearse 1970: 209). Similarly, a case study of kelp



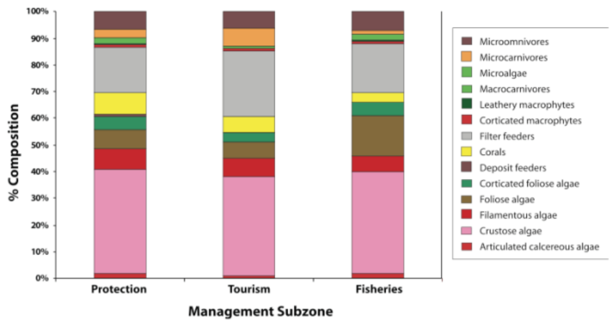
LEFT: Densities of the sea urchin *Eucidaris thouarsii* and a guild of herbivorous fishes in heavily and lightly fished sights (Ruttenberg 2001: 1698). RIGHT: Total sea urchin and *Echinometra mathaei* densities plotted against relative predation intensity at 14 sites (McClanahan 1990: 366).

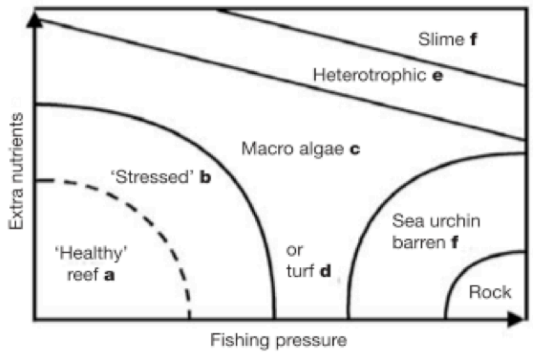
environments in the Aleutian Islands revealed that "otters effectively control sea urchin populations, and the absence of grazing pressure allows vegetation communities to flourish. Reducing the population of sea otters makes it possible for the sea urchin population to increase" (Estes and Palmisano 1974: 1059). In a situation analogous to that in Galapagos, urchin populations depended on the population density of their predators. The fewer predators present, the larger the urchin population, and the greater the flourishing of the vegetative community.

In Galapagos, lobsters are key sea urchin predators and are overfished. The Galapagos rock lobster fishery, which features the spiny lobster *Panulirus penicillatus* and the slipper lobster *Scyllarides astori*, is overexploited and in decline. In 2002, 667 lobster fishers caught 51.4 metric tons of lobster. Under a comparable fishing policy in 2004, 657 lobster fishers caught only 25.7 tons (Castro 2005: 70). This marks a 50% fishery decline in two years. Spiny lobster catches have declined steadily since 2000 (Galapagos Report 2006-2007: 126). This spiny lobster fishery decline has spurred the development of a poorly regulated and overfished slipper lobster industry (Hearn 2005:

88). Lobster overfishing in Galapagos is directly linked to high population densities of *E. thouarsii*. A study of artisanal fishing in Galapagos revealed that *E. thouarsii* densities are higher in heavily fished areas than in lightly fished areas (Ruttenberg 2001: 1698). It follows that in heavily fished areas where urchins are more populous, coral would be in decline. Indeed, in fisheries areas coral composes a smaller percentage of the sea floor than in protection or tourism areas (Galapagos Report 2006-2007: 131).

Figure 4. The composition of the sea floor (benthic environment) over all 66 sample sites

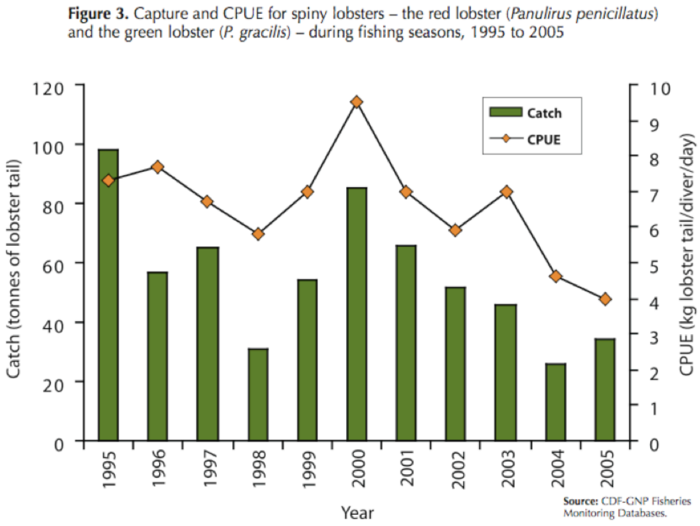




TOP: The composition of the sea floor (benthic environment) over 66 sample sites. The lowest percentage of coral cover occurs in fisheries areas. (Galapagos Report 2006-2007: 131). BOTTOM: A conceptual model showing human-induced transitions between alternate ecosystem states based on empirical evidence of the effects from fishing and excess nutrients. Sea urchin barrens occur at high fishing pressures (Bellwood 2004: 828).

Addressing Hypothesis 2: Methods of Successful Fishery Management

It is commonly asserted that the Galapagos lobster fishery is in decline because its design is not conducive to successful common property management (Hearn 2008: 567). The base of current fishery design is the Special Law for Galapagos, passed in 1998. The Special Law established the Galapagos Marine Reserve (GMR) as the area up to 40 miles off of the coastline of the archipelago and ruled that in the GMR the only allowed industries are tourism and artisanal fishing (INGALA). The lobster fishery operates within the GMR as such an artisanal industry, and is managed by a top-down total allowable catch (TAC) quota system in which there is no division of property amongst fishers. This lack of



Lobster catch and catch per unit effort in Galapagos (Galapagos Report 2006-2007: 126).

property leads to a “tragedy of the commons” in the lobster fishery, causing the quota to be too quickly filled. In the past this quota has been based on total tons of lobster caught in the fishery. However, more recent management has limited lobster fishing by designating a certain number of months in which lobster can be fished, rather than by designating a weight of lobster that can be caught (Castro 2005: 70).

Studies have shown that implementing a system of individual transferable quotas (ITQs) in place of the current TAC system would counter lobster overfishing in Galapagos. An ITQ system would allocate portions of the TAC to individual fishers or groups of fishers so that each fishing operation would have its own quota to fill. Allocations would be proportional and based on past catch data. ITQs could be bought or traded within the industry, although the TAC would not change. There is a high probability that ITQs would be economically beneficial to retiring vessel owners who would choose to sell their quota allocations for monetary compensation (Alvear 2006: 8).

However, an ITQ system would not be established without problems. Fishers who chose to sell their allocation and retire from the lobster industry would, along with their employees, face a lack of alternative economic opportunity in Galapagos (Alvear 2006: 9). Furthermore, the lobster fishery suffers from “serious enforcement difficulties”

(Hearn 2005: 95). Without certain support from the industry, such as enforcement support, an ITQ system would not create a more sustainable fishing industry. Support of the GMR's recent attempt to create a participatory fishery management system in which all fishers play a part in regulating the industry would also be necessary for an ITQ system to be successful (Alvear 2006: 9). Moreover, the exponential population growth of Galapagos also contributes to overfishing. New immigrants need jobs, and next to tourism fishing is the biggest industry of the archipelago (Bremner 2002: 307).

Conclusions

As proposed by the first hypothesis of this paper, successful management of the Galapagos lobster fishery appears from this research to be indeed the most sustainable and effective method of sea urchin control in the archipelago. Other considered methods of sea urchin removal included physical removal, and starving the urchins out. However, these methods were shown to be ineffective, unsustainable, or both. Neither of the two refuted methods would result in the protection of coral from sea urchin overgrazing.

However, findings did not fully support the second hypothesis that introducing an ITQ system would lead to successful management of the lobster fishery. To forge a sustainable lobster fishery, much more than a new quota system would be required. Social, political and economic support would be needed in addition to such

A Galapagueno selling fish in Puerto Ayora on Santa Cruz Island.

reorganization of the quota structure.

Recommendations

To end lobster overfishing in Galapagos, many facets of the industry must be addressed. These include but are not limited to the following:

Social support must be provided to the Galapagos fishing community. More accessible education opportunities must be provided to fishers in order to foster a culture of sustainability and conservation, especially among recent immigrants. Fishers must also be encouraged to participate in the management of the fishery in order to create a sense of ownership.

Political support must be provided to ensure enforcement of fishing laws. More stringent legal limitations on immigration in Galapagos may decrease overfishing by limiting the number of potential fishers. Furthermore, a more clear definition of artisanal fishing than that in the Special Law may prove beneficial by limiting the number of large fishing vessels in Galapagos.

Economic support must also exist for fishers who decide to leave the fishing industry. Permits that give ex-fishers advantages in the tourism industry may be effective incentives to motivate fishers to pursue other lines of work.

The goals alluded to in these recommendations are among those addressed in the Charles Darwin Foundation Strategic Plan 2006-2016. Fiscal and institutional support of the Charles Darwin Foundation will be required from both domestic and international forces if a sustainable lobster fishery is to be created.

Sources

Alvear, Santiago A. Bermeo, 2006. Modelling an ITQ Scheme in the Galapagos Marine Reserve Spiny Lobster Fishery. New Zealand Agricultural and Resource Economics Society Conference.

Bellwood, D.R., et. al., 2004. Confronting the coral reef crisis. Nature 429, 827-833.

Bremner, Jason M.P.H., Perez, Jaime, 2002. A Case Study of Human Migration and the Sea Cucumber Crisis in the Galapagos Islands. Ambio 31, 306-310.

Castro, Xavier, 2005. Analysis of the current Socio economic situation of the "Galapagos Artisanal Fishing Community. Project for the Conservation of the Galapagos Marine Reserve in the Republic of Ecuador.

Chapman, A.R.O., 1981. Stability of Sea Urchin Dominated Barren Grounds Following Destructive Grazing of Kelp in St. Margaret's Bay, Eastern Canada. Marine Biology 62, 307-311.

Charles Darwin Foundation Strategic Plan 2006-2016. Charles Darwin Foundation.

Chornesky, Elizabeth A., 1985. A Reef System. Science 228, 1522-1523.

Edgar, G.J., Banks, S., Farina, J.M., Calvopina, M., Martinez, C., 2004. Regional biogeography of shallow ref. fish and macro-invertebrate communities in the Galapagos archipelago. Journal of Biogeography 31, 1107-1124.

Estes, James A., Palmisano, John F., 1974. Sea Otters: Their Role in Structuring Nearshore Communities. Science 185, 1058-1060.

Galapagos Report 2006-2007. Galapagos Conservancy.

Hearn, Alex, 2005. Life history of the slipper lobster *Scyllarides astori* Holthuis 1960, in the Galapagos islands, Ecuador. Journal of Experimental Marine Biology and

Ecology 328, 87-97.

Hearn, Alex, 2008. The rocky path to sustainable fisheries management and conservation In the Galapagos Marine Reserve. Ocean & Coastal Management 51, 567-574.

INGALA. http://www.ingala.gov.ec/galapagosislands/index.php.

Lang, C., Mann, K. H., 1976. Changes in Sea Urchin Populations after the Destruction of Kelp Beds. Marine Biology 36, 321-326.

McClanahan, T.R., Shafir, S.H., 1990. Causes and consequences of sea urchin abundance and diversity in Kenyan coral reef lagoons. Oecologia 83, 362-370.

Miller, R.J., 1985. Succession in sea urchin and seaweed abundance in Nova Scotia, Canada. Marine Biology 84, 275-286.

North, Wheeler J. and Pearse, John S., 1970. Sea Urchin Population Explosion in Southern California Coastal Waters. Science 167, 209.

Okey, Thomas A., et. al., 2004. A trophic model of a Galapagos subtidal rocky reef for evaluating fisheries and conservation strategies. Ecological Modelling 172, 383-401.

Ruttenberg, Benjamin I., 2001. Effects of Artisanal Fishing on Marine Communities in the Galapagos Islands. Conservation Biology 15 (6), 1691-1699.

Science Daily, 2007. Corals Added To IUCN Red List Of Threatened Species For First Time. http://www.sciencedaily.com/releases/2007/09/070912094029.htm.

Stewart, Paul D., 2007. Galapagos The Islands that Changed the World. Yale University Press.

UNESCO, 2008. Galapagos Islands. http://whc.unesco.org/en/list/1.