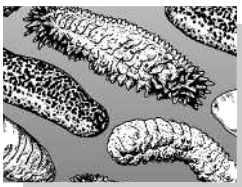

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# Baseline information on the warty sea cucumber *Stichopus horrens* in Santa Cruz, Galápagos, prior to the commencement of an illegal fishery

*Alex Hearn*[1] *and Fernando Pinillos*


## Abstract

With the depletion and collapse of the fishery for the sea cucumber *Isostichopus fuscus* in the Galápagos Marine Reserve, attention is now being focused on the warty sea cucumber *Stichopus horrens*, which has been illegally fished since 2004. This study presents the results of surveys carried out at a site in the south of Santa Cruz Island before illegal harvesting began, and constitutes the only baseline information available to date on this species. *S. horrens* displays more diurnal variation than *I. fuscus*, and may be present in densities greater than 100 individuals per 100 m$^2$ at night. Total length of individuals ranged from 9–31 cm, with a mean size of 20 cm. $L_\infty$ was estimated at 37.7 cm and $Z/K$ was equal to 4.95. No recruitment was observed. The length–weight relationship was linear but displayed considerable variation, suggesting that a minimum landing size may not be appropriate for this species. Before such a fishery is opened, lessons need to be learned from the failure to sustainably manage the *I. fuscus* fishery, and a management plan, including marketing aspects, should be developed.


## Introduction

The Galápagos Marine Reserve, created in 1998, straddles the equator at 600 nautical miles off the coast of Ecuador (Fig. 1). Its location, in the path of the warm Panama Bight from the north, the cool Humboldt Current from the south, and the nutrient-rich, cold upwelling Cromwell Current from the west make it unique in the variety of species and communities found over a relatively small area (Edgar et al. 2004).

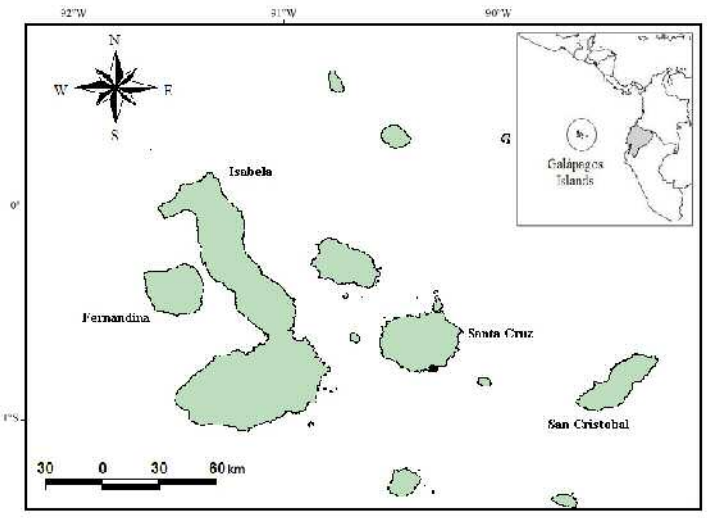


**Figure 1. Galápagos Islands.**
**The study site ( ● ) is at the south end of Santa Cruz Island.**

As a multi-use marine reserve, fishing is permitted, although this is restricted to artisanal fishing carried out by registered local fishers. In the early 1990s, as a response to the collapse of the fishery for the sea cucumber *Isostichopus fuscus* on the coast of continental Ecuador, there was an influx of fishers to Galápagos, where this species was not traditionally exploited. In 1994 an experimental fishery was opened with a catch quota of 500,000 individuals over a period of two months. However, the season was closed only six weeks later and the final catch was estimated somewhere between 8 and 12 million individuals (DeMiras et al. 1996). After four more years of illegal fishing and political pressure, the sea cucumber fishery for *Isostichopus fuscus* was finally opened on a seasonal basis with a series of regulations in 1999. After only seven years of legal fishing, despite regulations (Toral

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and Martinez 2004; Altamirano et al. 2004; Shepherd et al. 2004; Hearn et al. 2005a; Toral et al. 2005), the *I. fuscus* resource has been overexploited to the point of commercial extinction (Fig. 2), and the number of registered fishers has increased to around 1000 (Fig. 2).

As a result of the decline and collapse of the *I. fuscus* fishery, there has been increasing pressure to allow extraction of other species of sea cucumber. One alternative, which was identified by the fishing sector in 2004, is the warty sea cucumber, *Stichopus horrens* Selenka, 1867 (Fig. 3).

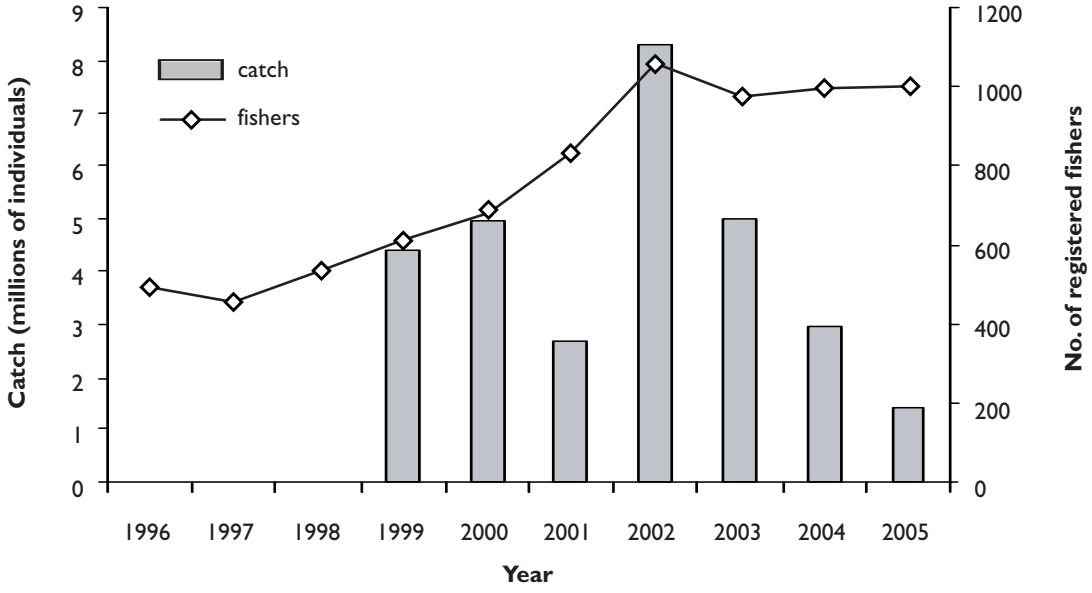


**Figure 2.** **Official annual catch of sea cucumber *Isostichopus fuscus* since the fishery was opened in 1999, and number of registered fishers in the Galápagos Marine Reserve (source: Galápagos National Park Service and Charles Darwin Foundation archives).**

**Figure 3.** **The warty sea cucumber *Stichopus horrens* (photo: Alex Hearn)**

*Stichopus horrens* is found in the Pacific Ocean, from Malaysia to the Society Islands, French Polynesia, and from southern Japan and Hawaii to New Caledonia (Massin et al. 2002), as well as in the Galápagos Archipelago, where it is found on rocky substrates from 5–20 metres depth (Hickman 1998). It is cryptic and lethargic by day, when it finds shelter in cracks, caves and crevasses in the rocky substrate. At night, it emerges to feed and may be found in large aggregations (Hearn et al. unpubl. data).

This species is subject to commercial exploitation in other parts of the world, such as Madagascar (Rasolofonirina et al. 2004) and Malaysia (Baine and Choo 1999) where it is exploited for the medicinal properties of its coelomic fluid, known as "gamat". In Galápagos, illegal shipments of *S. horrens* were detected during the *I. fuscus* fishing season in 2004. Since then, a widespread illegal fishery has developed (Hearn et al. 2004; Toral et al. 2005) and the Galápagos National Park Service has seized a number of shipments of *S. horrens* (Table 1). At the same time, the local fishing sector has applied pressure through legal channels and the local Participatory Management Board has called for a baseline study to be carried out in order to assess whether this species can sustain a fishery. However, after two years of illegal fishing, it is unlikely that any study carried out in the short-term future on size structure and abundance will truly reflect the unexploited population.

**Table 1. Illegal *Stichopus horrens* shipments and camps raided by the Galápagos National Park Service (source: Galápagos National Park Service archives).**

| Date | Site | Island | Number of *S. horrens* |
|---|---|---|---|
| 07 Oct. 04 | Puerto Ayora | Santa Cruz | 20448 |
| 03 Jun. 05 | illegal campsite | Santa Cruz | 5934 |
| 27 Jul. 05 | BP Calipso | At sea | 1355 |
| 14 Oct. 05 | illegal campsite | Santiago | 1752 |
| 19 Oct. 05 | illegal campsite | Isabela | 7141 |
| 20 Oct. 05 | illegal campsite | Isabela | 3986 |
| 09 Jan. 06 | illegal campsite | Santa Cruz | 13000 |
| 23 Feb. 06 | Bellavista | Santa Cruz | 13343 |
| **Total** | | | **66959** |

The aim of this document is to report the findings of a pilot study carried out in 2003 in the south of Santa Cruz Island as the only existing information on this species in Galápagos prior to the commencement of illegal extraction.

## Materials and methods

Surveys were carried out at a depth of 6 metres at Punta Estrada in Academy Bay, Santa Cruz Island (S 00.7622; W 090.3019), central Galápagos Archipelago (Fig. 1). The seafloor in this area is characterised by a sloping bed of lava rocks, below a coastline of cliffs.

In order to study the diurnal variability in abundance of *S. horrens* in comparison with that of the commercial species, *I. fuscus*, two permanent transects of 100 m² were established in Academy Bay. Abundance of both *S. horrens* and *I. fuscus* was determined at the following times: 00:00, 06:00, 08:00, 12:00, 18:00 and 20:00. Each transect was carried out twice for each time regime. Both datasets were normalised to show the comparative changes throughout the day for each species.

Nocturnal circular surveys covering 100 m² were carried out in September, October and December 2003 and January 2004, following the methodology of Richmond and Martinez (1993). One circular survey was carried out per month in a fixed 100-m² area, in which all individuals of *S. horrens* were collected by a diver and measured underwater in order to reduce handling, as this species is known to eviscerate immediately when gripped by hand (Kohtsuka et al. 2005). Total length (dorsal distance from the mouth to the anus) was recorded for each individual.

Approximately 25 individuals from outside the transects were collected each month and taken to the laboratory, where the following measurements were taken for morphometric analyses: total length (± 1 mm), maximum circumference (± 1 mm), total wet weight (± 1 g), volume (± 1 mL) and gutted wet weight (the total weight once the gonads, viscera and coelomic fluids have been removed, ± 1 g) (see Conand 1990).

Assuming that the population is in equilibrium, and that the size distribution is not affected by exploitation, the Powell-Wetherall method can be used to estimate $L_\infty$ and $Z/K$, where $Z$ is the total mortality rate (Powell 1979; Wetherall et al. 1987; Sparre and Venema 1992). This method is based on Beverton and Holt's (1956) equation, which estimates Z in a steady state population:

$$Z = K\,[(L_\infty - L)/(L - L')] \qquad (1)$$

Where $L$ is the mean length of individuals of size L′ and greater, and $L'$ is a length for which all individuals of that length and longer are fully exploited. There is a linear relationship between a series of arbitrary cut-off lengths $L'$ and corresponding mean lengths $L$ of fully exploited size classes, so that:

$$L - L' = a + (b \times L') \qquad (2)$$

Where $Z/K = -(1 + b)/b$ and $L_\infty = -a/b$

## Results

### *Length–weight relationship*

*Stichopus horrens* displays a high degree of plasticity and is able to rapidly shrink or elongate. Daytime specimens (not included in this analysis) were usually found in crevices or under stones and were highly contracted. The length–weight relationship for individuals in a relaxed state displays a loose positive correlation, with considerable variation around mean (Fig. 4).

### *Diurnal patterns of abundance*

During the daytime, the abundances of both *S. horrens* and *I. fuscus* were similar and low (around 7 individuals per 100 m$^2$). For both species, abundance increased at night, although for *I. fuscus* the increase was small, whereas for *S. horrens* the increase was on an order of magnitude (Fig. 5).

### *Size structure and density*

The size frequency distribution displayed by *S. horrens* each month from September 2003 to January 2004 (N = approximately 100 individuals each month) was normal and stable. The smallest individual measured 9 cm, the largest 31 cm. Mean length overall was 19.6 cm. No modal progression or recruitment events were observed (Fig. 6).

According to the size frequency distribution, the first fully recruited length group was 20–21.9 cm. Powell-Wetherall analysis of the fully recruited size groups provided estimates of $L_\infty$ equal to 37.7 cm and $Z/K$ equal to 4.95, with an $r^2$ value of 0.967 (Fig. 7).

In all four surveys, the density of *S. horrens* exceeded 100 individuals per 100 m$^2$ (Fig. 8). Individuals were generally found fully extended, on rock surfaces, and appeared to be highly mobile in comparison with the more sedentary individuals of *I. fuscus*.

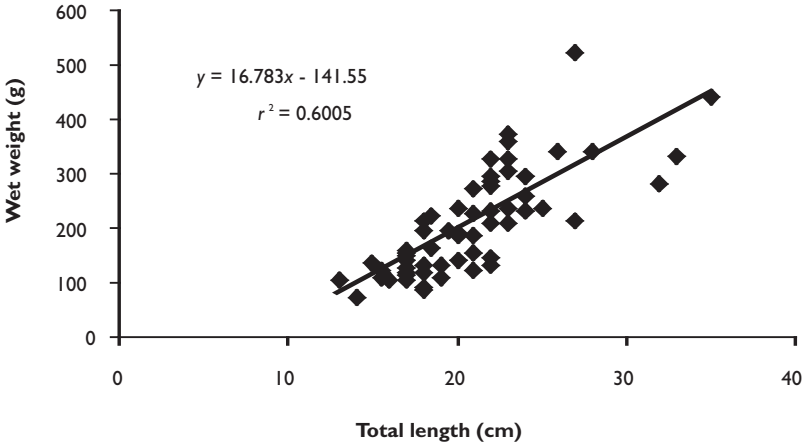


**Figure 4.** **Length-weight relationship for *Stichopus horrens* in relaxed state (n = 59).**

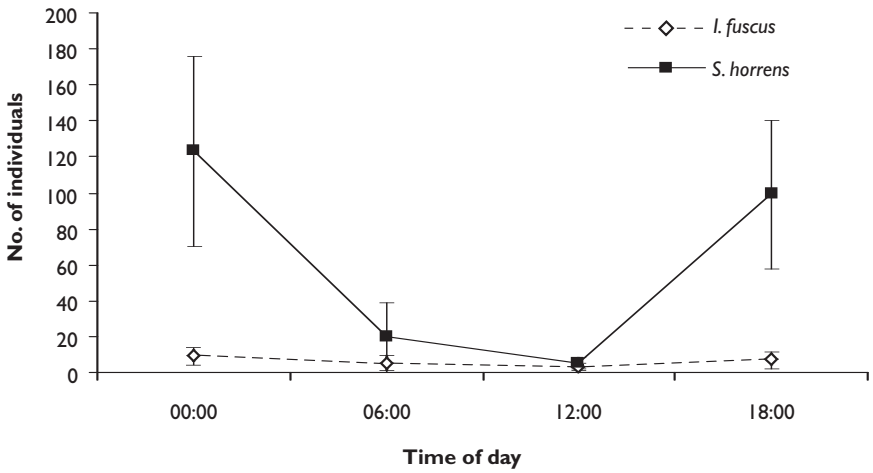


**Figure 5.** **Mean (with 95% confidence intervals) abundance of *Stichopus horrens* and *Isostichopus fuscus* over a 24-hour period in Academy Bay, Santa Cruz Island, using visual diver census.**

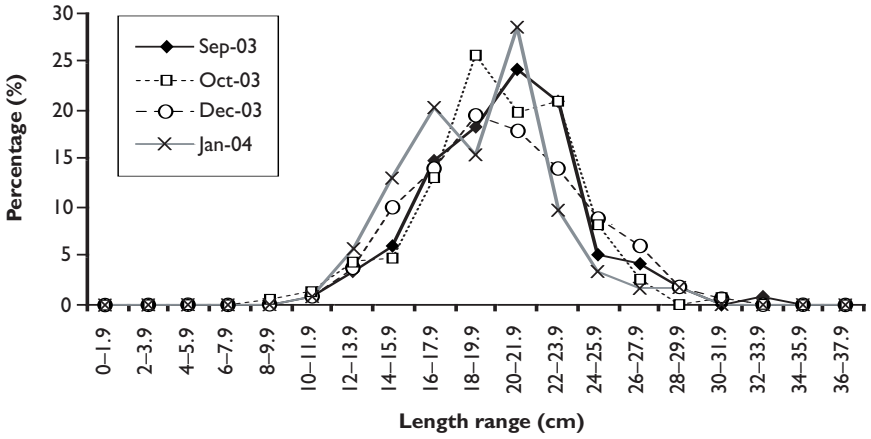


**Figure 6.** Monthly size frequency distribution for *S. horrens* at Academy Bay, Santa Cruz Island.

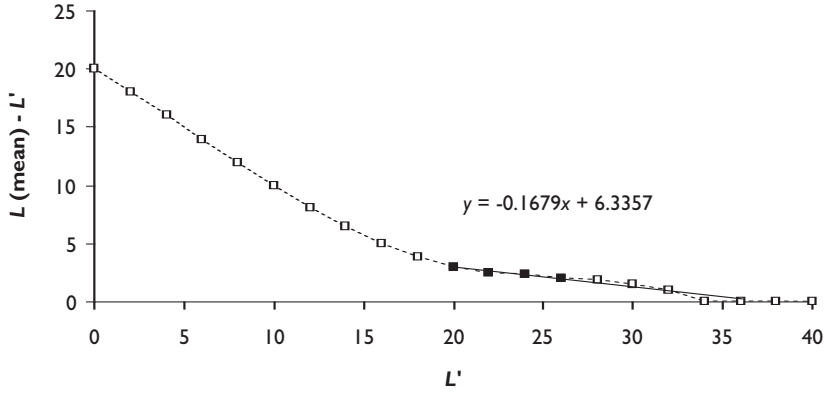


**Figure 7.** Powell-Wetherall plot for *S. horrens*, linear regression based on filled points for determination of $L_\infty$ and $Z/K$.

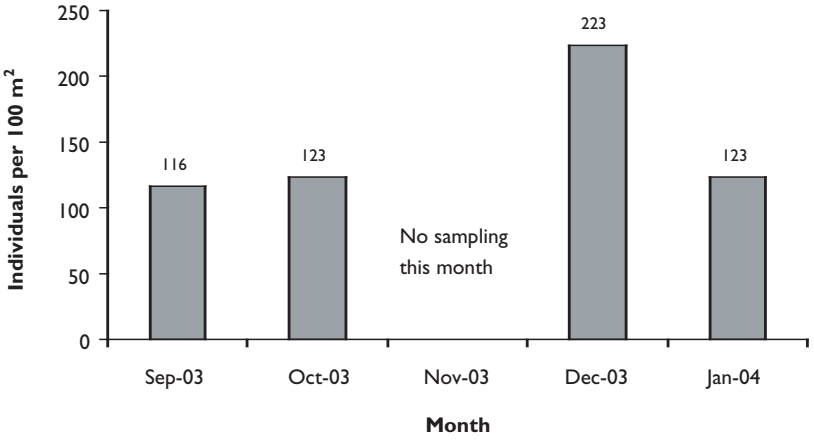


**Figure 8.** Population density of *S. horrens* in number of individuals per 100 m² area in Academy Bay, Santa Cruz Island.

## Discussion

Sea cucumber fisheries generally follow the pattern of rapid expansion followed by collapse. Included in this pattern is the serial depletion of high value to low value species (Conand 1990, 2004, in press; Uthicke and Benzie 2000). Galápagos does not appear to be an exception to this (Shepherd et al. 2004; Hearn et al. 2004, 2005a; Toral et al. 2005). The reasons behind these patterns are both biological and economical. Biologically, sea cucumbers are slow moving, easy to catch, slow growing and with poorly understood recruitment dynamics. The fishery for *I. fuscus* in continental Ecuador, which collapsed in the early 1990s, has still not recovered (Altamirano et al 2004; Toral-Granda and Martinez 2004, Toral et al. 2005), and holothurian fisheries worldwide are generally poorly managed and in decline (Lovatelli et al. 2004; Bruckner in press).

The economic activity of sea cucumber extraction in Ecuador has been promoted by investors from the Far East, who pay low prices initially for an abundant resource and often subsidise fishers' operations. As the resource declines, they are prepared to pay higher prices, and once an area is exhausted, the merchants move to a new area. This results in social and economic problems in communities that have grown to depend on an unrealistically high income for a short period of time (Christy 1995; Carranza Barona and Andrade Echeverría 1996). In Galápagos, the search for alternative employment or resources for sea cucumber fishers has been marked by unrealistic expectations, illegal activities (such as shark finning) and frequent outbreaks of civil unrest (Hearn et al. 2004; Shepherd et al. 2004).

The eventual opening of a legal fishery for *S. horrens* must be analysed against the background of the inherent governance capacity of the Galápagos Marine Reserve (GMR) and the failure to manage *I. fuscus* in a sustainable fashion. In this sense, the lack of response to the Participatory Management Board's call for the fishing sector to elaborate and present a feasibility study regarding exploitation of *S. horrens* is most likely a result of the ease with which the illegal fishery can be carried out, thus eliminating the sense of urgency for legalization. One fisherman explained to the authors that he could collect around 40 crates of *S. horrens* (equivalent to some 4000 individuals) in one night, for which he received USD 2000.

Currently, illegal *S. horrens* are processed in the same way as *I. fuscus* — boiled, salted and dried. However, in certain parts of Malaysia, *S. horrens* is used for its coelomic fluid (termed gamat water), which has medicinal uses (Baine and Choo 1999). As part of a feasibility study for Galápagos, market options should be explored, not only to determine the highest value product from the species, but also to avoid the economic dependence of local fishers on the merchants and middlemen.

The results of these preliminary surveys show a size structure characterised by an absence of juveniles, with a modal size of around 20 cm, and potentially high densities, which may compare with estimated virgin densities of *I. fuscus* (Shepherd et al. 2004). However, a management plan for the extraction of this species should consider the relative enforceability of the regulations that were applied to *I. fuscus*. Management measures such as a minimum landing size (MLS) may not be appropriate for a species that displays such high levels of plasticity, and for which a size at maturity is unknown. The provisional coastal zoning scheme (Danulat and Edgar 2002) is aimed at creating space for different stakeholders (fishers, tourism and science) and is not appropriate for the management of benthic resources. Clear rules on how to establish catch quotas from survey results should be drafted. Despite the problems associated with individual transferable quotas (ITQs) for *I. fuscus* in 2001 (Murillo et al. 2003), some form of private rights should be explored, in order to avoid the race to fish, which characterised the collapse of *I. fuscus*.

The Galápagos Marine Reserve Management Plan is based on the Precautionary Principle, and aimed at allowing sustainable use of its resources. To date, its most important fisheries are severely depleted, and little has been done to manage them sustainably (Toral et al. 2005; Hearn et al. 2005b). Unless there is a shift in awareness of the users themselves, legalising a fishery for *S. horrens* under the current management regime is likely to result in another link in the chain of successive collapses in the Galápagos Marine Reserve.

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PIMRIS

Pacific Islands Marine Resources Information System