ASSESSMENT OF THE SEA CUCUMBER (ECHINODERMATA: HOLOTHUROIDEA) AS POTENTIAL FISHERY RESOURCE IN BANCO CHINCHORRO, QUINTANA ROO, MEXICO

Ma. Gabriela de la Fuente-Betancourt, Alberto de Jesús-Navarrete, Eloy Sosa-Cordero and Ma. Dinorah Herrero-Perez

ABSTRACT

The abundance, distribution, size, structure, nutritional quality and feasibility of exploitation of a sea cucumber population, an alternative fishery resource for Banco Chinchorro (Mexican Caribbean) were evaluated. Sampling was conducted during the three main climatic seasons: rainy (September 1998), cold front (December 1998) and dry (April 1999). Five sampling sites were chosen to cover the three major habitats: seagrass (north, central), reef patches (north, south), and shallow sandy-bottoms. Three species and a hybrid were identified: Holothuria thomasi, H. mexicana, H. floridana, and H. floridana × H. mexicana. H. floridana was the most abundant (mean density = 0.12 ind m$^{-2}$). Growth and natural mortality parameters, and maximum sustainable yield (MSY), were estimated using simplified protocols commonly predicated for the assessment of tropical fisheries, all assuming equilibrium conditions. Banco Chinchorro was hit by Hurricane Mitch following the first survey; estimated abundance during the second survey (after the hurricane) was only 14% of the pre-hurricane survey. Based on this study case we discuss (1) the shortcomings of methods assuming equilibrium, (2) the need for specific life-history data, and (3) the research opportunities provided by the response of populations to natural disturbances or to harvesting.

Sea cucumber fisheries have reached high levels of exploitation in China, Japan and some other Asian countries (Conand, 1990; Ferdouse, 1999; Seeto, 1999). In Mexico, the only developed holothurian fishery began 10 yrs ago with Isostichopus fuscus as the target species. In 1994 the species was declared endangered (Norma Oficial Mexicana, 1994), although there was no supporting information. A research project on reproductive biology and growth, as well as a brief description of the fishery in the Gulf of California, were conducted to that end. This study demonstrated that the species was not in real danger, and that it can still be exploited under controlled regimes (Reyes-Bonilla, 1997). Currently, some other species are being fished as an alternative resource in the Sea of Cortés. In the Caribbean, Isostichopus badionotus has been recently exploited in Venezuela (Buitrago and Boada, 1996).

Fishermen in Quintana Roo, Mexico have shown interest in sea cucumber as an alternative fishery resource because the main species currently fished, conch (Strombus gigas) and spiny lobster (Panulirus argus), have been presumably overexploited (Sosa-Cordero et al., 1993).

The main purpose of our study was to assess holothurian populations in Banco Chinchorro, off Quintana Roo (Mexico), in order to determine their abundance, the potential for the development of a fishery, and the nutritional value of the product.
Banco Chinchorro (BCH) is an atoll-like reef complex located off the southern coast of Quintana Roo (18°47′–18°23′N, 87°14′–87°27′W). It has an elliptic shape (internal area = 561 km²), measuring 46 km long and 15 km wide; the reef-lagoon—its perimeter defined by coral reefs—ranges in depth from 1 to 12 m (Fig. 1) (Aguilar and Aguilar, 1993). Three fishery cooperatives are allowed to operate on the bank, their main fishery products being queen conch (S. gigas) and spiny lobster (P. argus). Reef-fish, contributing a lesser income, is undertaken by independent fishermen (Sosa-Cordero et al., 1993).

STUDY AREA

Sampling.—Sampling was conducted during each of the three main climatic seasons: rainy (September 1998), cold front (December 1998) and dry (April 1999). Five sampling sites were chosen attending to the general topography: north and central sea grass meadows, north and south reef patches, and shallow sandy-bottoms (Fig. 1) each with an area of 87.11, 33.43, 91.61, 217.61 and 114.75 km², respectively. A sampling unit consisted of all the sea cucumbers within a large circular plot (100 m²); sampling units were GPS-referenced. A longitudinal transect (100 m, always in the east-west direction) was staked in each sampling stratum; three sampling units (circles plots) were obtained at locations randomly selected along each transect. The number of sampling stations...
(transects) varied among survey dates: 29 transects (67 plots) in September 1998, 52 transects (156 plots) in December 1998, and 59 transects (165 plots) in April 1999. The specimens in each plot were measured in situ from mouth to anus with flexible tapes. Thirteen specimens were taken to the lab for further identification on the basis of calcareous ossicles (Hendler et al. 1995), and for biochemical analysis.

**DATA ANALYSIS.**—Size frequency data (grouped in 4 cm intervals) were analyzed to estimate the parameters of the von Bertalanffy growth model (Ricker, 1975) using the computer package FiSAT (Gayanilo et al. 1995). Asymptotic length ($L$) and the growth coefficient ($k$) were estimated using the methods of Powell-Wetheral and Shepherd. The natural mortality coefficient was calculated based on growth parameters (Pauly and Morgan, 1987; Sparre et al., 1989; Gayanilo et al., 1995; Rosenberg and Beddington, 1988; Basson et al., 1988; Galluci et al., 1996). Assuming that the population follows a ‘Fox dynamics’ (Garcia et al., 1989), and that fishing mortality at the maximum sustainable yield (MSY) level equals natural mortality ($F_{MSY}=M$) (Die and Caddy, 1997), Garcia et al. (1989) expressed MSY for non-exploited resources as:

$$\text{MSY} = M B_0 e^{-1}$$

where $M$ is the instantaneous per capita rate of natural mortality (usually expressed in yr$^{-1}$), and $B_0$ is virgin biomass. In non-exploited resources (this study case) total mortality rate, $Z$, and $M$ are equivalent. We estimated $M$ from the size frequency data and $B_0$ through field surveys.

In order to estimate biomass we used design-based approach. It consists of a stratified random sampling scheme, where the mean biomass values calculated for each stratum of the reef lagoon are pooled according to specific rules. This approach allows estimate holothurians densities considering differences due to areas and habitat heterogeneity between strata without overestimation of the resource (Conde and Díaz, 1985; Conquest et al., 1996).

**Nutritional Value.**—The specimens collected were analyzed to determine nutritional content. The phenol-sulfuric method was used in order to determine total carbohydrates (Dubois et al., 1956). Fat, moisture and ash were evaluated according to the Association of Official Analytical Chemists (AOAC, 1998). For the nitrogen and protein assessments a modified Kjeldahl method was used (Aguilar et al., 1987).

**RESULTS**

**IDENTIFICATION.**—Examination of the ossicles indicated that three species were represented in the collections: *Holothuria (Halodeima) mexicana* Ludwig, *H. (Thymiosycia) thomasi*, and *H. (Halodeima) floridana* Pourtalès. A hybrid, *H. floridana × H. mexicana*, was also present; it showed spicules characteristic of both *H. mexicana* and *H. floridana*.

**SIZE STRUCTURE.**—Only two specimens of *H. thomasi* were observed (both in September 1998) but were not measured. Few specimens of *H. mexicana* (n = 7) were observed during the three surveys, their total length (TL) varying from 17 to 51 cm. Hybrids were also scarce (n = 4), with total length ranging from 20 to 51 cm. Through the rest of the text results pertain to *H. floridana* only, as the other species were poorly represented. In September 1998, TL for 83 individuals of *H. floridana* varied from 9 to 51 cm. In December 1998, TL of 29 individuals varied from 16 to 35 cm, and in April 1999, 54 individuals ranged from 9 to 51 cm (Fig. 2). Considering the size structure of *H. floridana* we assumed that the size of full recruitment is TL = 31 cm.

**DENSITY.**—In September 1998, observed density varied in the range 0–12 individuals per plot, which corresponds to 0–0.12 ind m$^{-2}$ (Fig. 3A). Density ranged from 0 to 0.02 ind m$^{-2}$ during the cold front season (December 1998) and from 0 to 0.03 ind m$^{-2}$ during
the dry season (April 1999). Abundance was highest in the central sea grass stratum, in September 1998 (before Hurricane Mitch hit BCH). The difference in density between each season has a dramatic repercussion on the concentration profiles (Fig. 3B).

GROWTH PARAMETERS.—Parameters of the von Bertalanffy growth model, estimated for *H. floridana* with the Powell-Wetherall and SLCA methods, were $L = 57.9$ cm (TL), and $k = 0.21$ yr$^{-1}$, the lineal regression achieved a $r = 0.83$ score. Natural mortality rate ($M$) estimated by the censored version of the Beverton-Holt equation (Ault and Ehrhardt, 1992) was 0.72 yr$^{-1}$.

BIOMASS ESTIMATION AND MSY.—Mean stock density of *H. floridana* estimated was 21 ind ha$^{-1}$. Considering the fully recruited individuals (41.7%), each strata area and the mean weight (876 g), the stock global size during this asses is 438 mt. Whereas in September 1998 was 560 mt. It diminished drastically after the hurricane to 170 mt (December 1998) and recovered to 491 mt for April 1999. Applying the García et al. (1989) equation to the global biomass, the MSY is a 116-mt catch per year.
Applying to the same equation the partial biomass data, the MSY is 148, 45 and 130 mt respectively for each season.

**Nutritional Content.**—Values of carbohydrate, nitrogen, moisture, fat and ash content for all the four species are shown in Table 1, which also presents the nutritional composition of the dried product reported by Sachthananthan (1979). The nutritional values found in this study refer to the raw product; percentages of protein, fat and carbohydrates are given for dehydrated samples.

Table 1. Nutritional content of sea cucumber in Banco Chinchorro and Beche de mer (reported).

<table>
<thead>
<tr>
<th>Species</th>
<th>Protein</th>
<th>Moisture</th>
<th>Fat</th>
<th>Ash Minerals</th>
<th>Ash Insoluble</th>
<th>Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>H. mexicana</em></td>
<td>74.17 ± 6.65</td>
<td>73.4 ± 4.9</td>
<td>0.91 ± 0.25</td>
<td>9.6 ± 2.8</td>
<td>0.08 ± 0.0040</td>
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<td>(n = 4)</td>
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<tr>
<td><em>H. floridana</em></td>
<td>68.17 ± 3.15</td>
<td>76.3 ± 3.4</td>
<td>1.11 ± 0.26</td>
<td>13.0 ± 5.39</td>
<td>0.080 ± 0.0006</td>
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<td>(n = 5)</td>
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<tr>
<td>Hybrid</td>
<td>70.47 ± 7.55</td>
<td>75.1 ± 3.5</td>
<td>0.84 ± 0.05</td>
<td>12.6 ± 4.7</td>
<td>0.008 ± 0.0006</td>
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<td>(n = 3)</td>
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<tr>
<td><em>H. thomasi</em></td>
<td>46.36</td>
<td>90.00</td>
<td>1.70</td>
<td>18.3</td>
<td>0.08</td>
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<td>(n = 1)</td>
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<tr>
<td>Beche de mer</td>
<td>43</td>
<td>27</td>
<td>2</td>
<td>21</td>
<td>7</td>
<td>–</td>
</tr>
<tr>
<td>(Sachthananthan,</td>
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<td>1979)</td>
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DISCUSSION

Size of commercial sea-cucumber species varies from 20 to 70 cm (total length, TL), with a body-wall thickness of 8–20 mm and a maximum live weight of 6 kg (Sachthananthan, 1979; Conand, 1990). In Banco Chinchorro the maximum size (TL) measured was 51 cm, and the maximum weight 1.87 kg. *H. floridana* is well within the marketable size range for sea cucumbers. Hydrodynamics plays a primarily role in holothurian distribution. Sea cucumbers, in general, prefer low energy waters that favor organic sediment accumulation (Kerr et al., 1993; Barkai, 1991; Conde, 1997; Mosher, 1980). Consistently, in our study we found that they were most abundant in seagrass meadows. The stratified random sampling approach allowed the estimation of density attending to differences due to spatial and habitat-related heterogeneity, without overestimating population size (Conde and Díaz, 1985; Conquest et al., 1996). Density of *H. floridana* in Banco Chinchorro (all sampling dates combined in the analysis) was 20 ind ha\(^{-1}\). This figure may appear low, but falls within range of some commercial species. Density of *I. fuscus* in Baja California ranges from 13 to 23 ind ha\(^{-1}\) (Reyes-Bonilla, 1997). Conand (1990) reported average densities of commercial species of 50, 80 and 1000 ind ha\(^{-1}\) for reefs in (respectively) New Caledonia, Papua New Guinea and Australia. Thus, the density of *H. floridana* in Banco Chinchorro is towards the lower end to those reported for other commercial sea cucumbers fishing grounds. This comparison, however, should be taken cautiously, as definition and bounding of fishing grounds must certainly vary among studies.

Harvesting sea cucumbers could be a complementary item for the commercial diving fishery, which currently targets queen conch and spiny lobster. High protein content (higher than reported by Sachthananthan (1979)), and low fat and ash content (few calcareous ossicles), contribute to a high quality product (Conand, 1990).

Obviously, the holothurian stock diminished drastically after the first survey was conducted, most likely due to the effect of hurricane Mitch. Then, the calculated MSY could
be under-estimated for a stock in equilibrium and over-estimated under conditions of recovering after hurricane. The estimated MSY must be considered as a limit, not as a target. If a fishery were authorized, we suggest that a quota of only ~50% of the MSY should be allowed, and suspend after a catastrophic event (e.g., a hurricane).

In addition to this ‘low abundance’ one must consider the concentration profile (Fig. 2B), because the reproductive success depends on it (Lawrence, 1987; Sewell and Levitan, 1992; Orensanz et al., 1998; Prince and Hilborn, 1998).

Notwithstanding, more precise studies on reproduction and population dynamics are needed in order to determine whether the species can be exploited or not and to determine the most adequate regimes of exploitation. Other studies are required on its characteristics (appearance, color, flavor, odor, and taste) of the processed product.

Annual surveys of this holothurian stock are needed and would provide much information on the aggregated dynamics (incorporating growth, mortality and recruitment). Stock logistic-type models could then be fitted to the recovery trajectory.

ACKNOWLEDGMENTS

The authors express their gratitude to the following persons: the Artisanal Fisheries Group (J. Oliva, N. Quintero, T. Valtierra and V. Valencia) for their collaboration in field work. To the fishermen ‘Chandez’, ‘Vidal’ and ‘Sami’ for their help during fieldwork, and to A. Zavala for laboratory assistance. Special thanks to L. Orenzans, Y. García-Baello and B. Schmook for their comments on this manuscript. This project was financed by ECOSUR (Fishery Ecology Project), and by PATM (Programa de Apoyo a Tesis de Maestría). Special thanks to ECOSUR for two years of scholarship support for MGFB.

LITERATURE CITED


Seeto, J. 1999. Bêche-de-mer processing - A little more effort to get much more money while saving precious resources. SPC Bêche-de-mer Info. Bull. 11: 2–3.

**DATE SUBMITTED:** December 1, 1999.  **DATE ACCEPTED:** July 24, 2000.

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