*Caribbean Journal of Science,* Vol. 38, No. 3-4, 230–238, 2002


# Population Structure, Distribution and Abundance of Three Commercial Species of Sea Cucumber (Echinodermata) in Panama

HÉCTOR M. GUZMÁN[1] AND CARLOS A. GUEVARA

*Smithsonian Tropical Research Institute, PO Box 2072, Balboa, Republic of Panama.*

**ABSTRACT.—Overfishing due to high demand in Asian markets, have encouraged illegal fisheries of sea cucumbers in non-traditional areas of the tropical Caribbean. This work assesses the population structure, distribution, and abundance of three commercially important Caribbean species (*Isostichopus badionotus*, *Holothuria mexicana*, and *Astichopus multifidus*) in 47 158 hectares of shallow habitats in Bocas del Toro (Panama), from May to October 2000. Mean size class distribution was unimodal; 26.5 cm in *I. badionotus* and 16 cm in *H. mexicana*, and dominated by adult individuals of 25-30 cm for both species. Body wall wet weight (gutted) showed a similar distribution, with a higher number of individuals between 200-300 g, but with a lower mean in *I. badionotus* (214 g) than in *H. mexicana* (258g). A total of 6017 individuals of *H. mexicana*, 4431 *I. badionotus* and 208 *A. multifidus* were quantified, with mean densities of 161.8 ind./ha, 117.4 ind./ha., and 4.9 ind./ha, respectively. Based on these results and the total area of the archipelago, we estimated a stock of 7 630 164 individuals for *H. mexicana*, 5 536 349 for *I. badionotus*, and 231 074 for *A. multifidus*. This assessment is discouraging because during the 1997 30-day legal fishing period, a catch of ca. 750 000 holothuroids was estimated for the archipelago.**

## INTRODUCTION

Commercially processed sea cucumber (bêche-de-mer) is fished in the Indo-Pacific, North Pacific, and Western and Central Pacific countries. In these areas, holothuroids are not part of subsistence diets and are harvested for commercial reasons by artisanal fishermen. The final product is considered a delicacy and aphrodisiac in China and in other countries of southeastern Asia, where the most important world markets are located. The market of bêche-de-mer was so profitable a few years ago that, for instance, the Solomon Islands increased their exports from 8 metric tons in 1985 to 622 metric tons in 1992; representing 62 % of the country's exports and an income of US$3.4 million (Richards et al., 1994).

Since 1992, bêche-de-mer exporters in the Pacific region have noticed a decrease in the catch of sea cucumbers paralleling the overexploitation of some species and the lack of resource management (Conand and Byrne, 1993; Preston, 1993; Powell and Gibbs, 1995). The statistics of the mid-90s indicated a world catch of sea cucumbers of up to 120 000 t per year, worth over US$60 million. Due to poor management, conflicts between fishermen and local governments increased, as did signs of overexploitation in many Pacific countries. Predictably, pressure on holothuroids has become greater in non-traditional fishing areas like the eastern Pacific and the Caribbean (e.g., Conand, 1997; Rodríguez-Milliet and Pauls, 1998; Herrero-Pérezrul et al., 1999).

Management and conservation problems caused by this fishing industry in Ecuador (Powell and Gibbs, 1995) led Asian entrepreneurs to look for alternatives in the region. They managed, in a short time and without much government control, to promote this fishery along the Pacific and Caribbean coasts of some countries in tropical America. A systematic exploitation began at the level of small fishing localities, where entire populations of sea cucumbers were decimated in a matter of months without population assessments. In the Caribbean, exploitation ventures without management began in at least various localities in Ven-

[1]Corresponding author: Smithsonian Tropical Research Institute, Unit 0948, APO AA, 34002-0948, USA. guzmah@naos.si.edu

ezuela (Buitrago and Boada, 1996; Rodriguez-Milliet and Pauls, 1998) and Mexico (Fuente-Betancourt et al. 2001).

Three species of sea cucumbers of the families Stichopodidae and Holothuriidae may be the most highly commercially valued species in the region. *Isostichopus badionotus*, *Holothuria mexicana,* and *Astichopus multifidus* have broad distributions in the Caribbean, and are abundant in shallow and calm waters with sandy bottoms. These species are important components of the fauna associated with coral reef habitats and seagrass beds composed mainly of *Thalassia* and *Syringodium* (Sloan and von Bodungen, 1980; Hendler et al., 1995). Coastal tropical holothuroids are mainly deposit feeders that constantly digest particles of sediments rich in nutrients and of variable grain size (Hammond, 1983). The three species are easy to catch and can reach 50 cm in length and 2.5 kg in weight (Hendler et al., 1995). *Astichopus multifidus* reaches a larger size and prefers deeper or calmer reef environments than the other two species (Hendler et al., 1995).

Few comprehensive studies of these three cucumber species are available for the Greater Caribbean. Available information usually resulted from behavioral studies or unpublished reports, making it difficult to compare populations. Partial information is available for Bermuda (Sloan and von Bodungen, 1980), Jamaica (Hammond, 1981), Venezuela (Sambrano, 1987; Bitter, 1988, Buitrago and Boada, 1996; Rodríguez-Milliet and Pauls, 1998), and Mexico (Fuente-Betancourt et al., 2001). This study in the Bocas del Toro archipelago (Panama) evaluates the abundance and distribution of *I. badionotus*, *H. mexicana,* and *A. multifidus*. Species densities were compared among depths and habitat type (e.g., seagrass meadow, coral reefs, interspersed seagrass and reefs). We also assessed population structure for the first two species. We attempted to provide baseline information about the population status of holothuroids exploited in Panama, thus assisting authorities on the use and management of the local fishery.

## Materials And Methods

### *Study area*

The Province of Bocas del Toro is located on the western side of the Republic of Panama, between 8°30′ and 9°40′ North, and between 82°56′ and 81°8′ West. It has an area of ca. 8917 km$^2$, with a narrow continental shelf. The coastal zone has maximum depths of 20-50 m, and is divided into two large lagoons, Bahía Almirante and Laguna de Chiriquí, in addition to an archipelago composed of seven large forested islands and hundreds of small mangrove cays (Rodríguez et al., 1993).

Winds, tides and swells have little influence inside Bahía Almirante and Laguna de Chiriquí because the insular and barrier reef systems on the northern shore of the archipelago create a leeward lagoon-like environment, with marine currents of variable direction governed by inconsistent daily winds. Tides are semi-diurnal in the archipelago, with 2-15 cm amplitude and internal current speeds below 40 cm/sec. Waves and tides have a greater effect outside the archipelago, where the conditions are oceanic and the development of reef and seagrass habitats is limited. The main coastal current that affects Panama runs east (apparently year round) coming from northern Nicaragua and Costa Rica, and is probably more influential between June and August because it runs closer to the coast of Bocas del Toro (Greb et al., 1996; Guzmán and Guevara 1998).

### *Population structure*

A total of 475 *I. badionotus* and 479 *Holothuria mexicana* were collected in Pondsack (09°17′19″N - 082°19′43″W) and Punta Quarys (09°16′10″N - 082°23′18″W) in the Bocas del Toro archipelago. *Astichopus multifidus* was not collected because of its low density. Sea cucumbers were placed in buckets containing 10 l of seawater with $MgSO_4$ (5-10 g), and were left for 5-10 min until completely relaxed, thus facilitating measurements (Sewell and Chia, 1994). Length was measured in totally relaxed and drained individuals (precision 1 mm), and body wall weight (precision 0.01 g) was obtained from gutted individuals. Thirty-nine small (<20 cm) *H. mexicana* and 17 *I. badionotus* were collected to measure size and were then released.

*Population distribution and abundance*

To evaluate population abundance and distribution, sampling sites were identified in a 1:50 000 scale map with the entire subtidal 10 m contour area demarcated regardless of the dominant habitat (sand, seagrass meadows, and coral reefs). This shallow area was divided into continuous and shore-parallel grids of 2-km$^2$ (240 grids for the whole archipelago). Subsequently, 120 grids were randomly chosen as sampling sites, representing the existing shallow subtidal habitats of the archipelago. The area encompassed the continental and insular coasts from Boca del Drago to Punta Península Valiente.

The survey consisted of counting individuals of each species, adults and juveniles (>5 cm accuracy), and considering a maximum work depth of 10 m. Two sampling depths of ca. 0.5-5 m and 5-10 m were established at each site. Three replicate band-transects of 100 m × 6 m were run parallel to the coast per depth, totaling a sample of 1800 m$^2$ (0.18 ha) per depth and 3600 m$^2$ (0.36 ha) per site. Two divers carried a six-meter long PVC pipe along the transect, with each diver evaluating a band 3 m wide. A compass was used to keep a fixed direction along transects. Habitat was recorded and classified as seagrass, coral reef, or heterogeneous areas (interspersed corals and seagrass).

The density distribution of the three species was mapped using Geographical Information System (GIS). A digital classification for the study area was based on a combination of digital images from three sources: topographic maps at scale 1:50 000, color aerial photographs at scale 1:25 000, and LANSAT TM-5 satellite images. Satellite images were processed using the ERDAS Professional Imagine V8.5 program. Density data were integrated using MIP V3.1 (Map and Image Processing System) and ArcView V3.0.

All data sets were analyzed using non-parametric statistics. Spearman Rank Order Correlation analysis was used to test for relationship between biometric variables (body weight and size). A Mann-Whitney Rank Sum test was used to compare density differences between depths. A Krukal-Wallis One-way ANOVA on ranks and a posteriori Pairwise Dunn's Multiple Comparison procedures were used to assess habitat differences.

## RESULTS

*Population Structure*

The relationship between size and weight was weak but significant for *H. mexicana* and *I. badionotus* (Fig. 1). Size differed between these species ($T= 156\ 996.5$, $P< 0.001$), with a mean length of 27.4 cm (SE ± 0.2) and 32.9 cm ± 0.2 respectively. Mean adult weight also differed between species ($T= 197\ 911.0$, $P< 0.001$), being higher in *H. mexicana* (256.8 g ± 3.8) than in *I. badionotus* (223.9 g ± 2.9).

Size distribution was unimodal for both species (median of 26.5 cm in *I. badionotus* and 16 cm in *H. mexicana*) but was markedly dominated by adults (size range of 25-30 cm for both species- Fig. 2A). Mean size was 25.8 cm ± 0.2 and 15.9 cm ± 0.4, respectively. Body wall weight showed a similar unimodal distribution for both species, with a greater number of individuals between 200-300 g, but with medians lower in *I. badionotus* (214.4 g) than in *H. mexicana* (258 g) (Fig. 2B). Mean weight in these populations was 223.9 g ± 2.9 and 256.8 g ± 3.8, respectively.

*Population distribution and abundance*

Density varied significantly between depths for *H. mexicana* ($T= 5693.5$, $P= 0.002$) but not for *I. badionotus* ($T= 6565.0$, $P= 0.904$) and *A. multifidus* ($T= 6976.0$, $P= 0.209$). Sampling sites were heterogeneous and contained different biological communities and habitats; 55.8 % of the sites were interspersed seagrass beds and corals, 30.8 % were exclusively sea grass meadows, and 13.4 % were coral reefs. The population

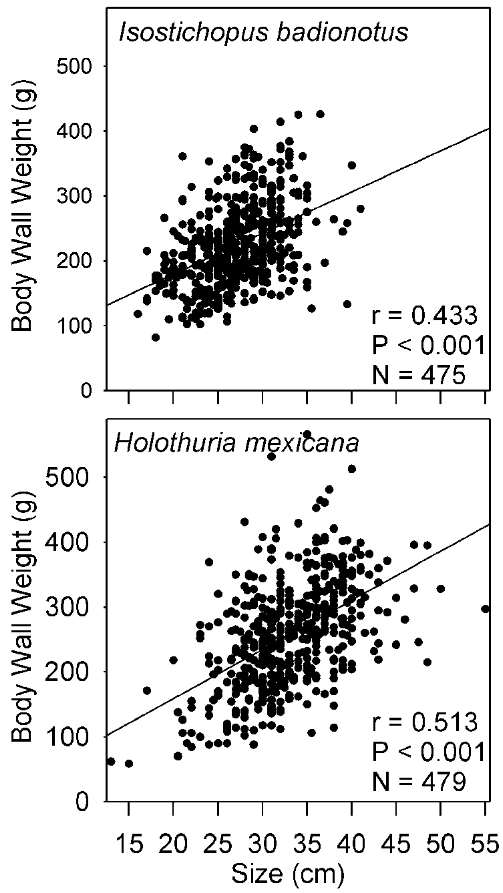


FIG. 1. Size (cm) and body wall weight (g) relationships of *Isostichopus badionotus* (upper plot) and *Holothuria mexicana* (lower plot).

density of *Holothuria mexicana* differed among habitat types (H= 14.389, *P*< 0.001); the median of 127.78 ind./ha obtained for interspersed habitats was significantly higher than the 27.77 and 44.44 ind./ha obtained for coral reef and seagrass respectively (Dunn's test). Median densities between habitats were different for *I. badionotus* (H= 7.338, *P*= 0.026); they were significant among interspersed areas (102.8) and seagrass areas (27.8), but were similar in coral reefs (47.2). It was difficult to relate density with any specific habitat for *A. multifidus*.

*Holothuria mexicana* was the most abundant and broadly distributed species in the archipelago; however, it was absent in 31.7 % (ca. 14 900 ha) of the total surface (Fig. 3A). This absence was concentrated in seven areas (red color on map), but mostly occurred toward eastern (10 134 ha) and western (2265 ha) Laguna de Chiriquí, northwestern Isla Colon (Bocas del Drago; 1418 ha), and northeast Cayo Agua (515 ha). In 59 % of the area (ca. 27 576 ha located mainly toward the insular and central sectors of the archipelago- Fig. 3A) we recorded the lowest densities (orange color) with an average of 115.8 ind./ha ± 10.6 (range 3-392 ind./ha). Nine sectors with intermediate densities (blue) covered 3636 ha and represented 8 % of the total area. Most of these sectors, with average intermediate densities of 525.8 ind./ha ± 28.9 (439-789 ind./ha), were composed largely of relatively small areas located mostly in the southern side of Isla Loma Partida (628 ha), eastern Isla Popa (433 ha), and Punta Pondsack (438 ha) along the continental margin of Bahía Almirante. Lastly, the highest densities (green) for *H. mexicana* were located in three sectors in the middle of the archipelago, with the greatest area (480 ha) located within the limits of the Parque Nacional Marino Isla Bastimentos (PNMIB), 284 ha around Crawl Cay, and 250 ha on the south of Isla Popa (Fig. 3A). The average density among these three sectors was 956 ind./ha ± 97.6 (806-1139 ind./ha).

In general, *I. badionotus* had lower densities than *H. mexicana* and a slightly lower area (15.2 %) with total absence of individuals (Fig. 3B). This absence occurred particularly around Cayo Agua (1922 ha), the western sector of Laguna de Chiriquí (1543 ha), and Peninsula Valiente (1048 ha). *Isostichopus badionotus* was strikingly absent in the eastern sector of the PNMIB, Cayos Zapatillas (1216 ha). Lowest densities, with an average of 105 ind./ha ± 8.2 (3-300 ind./ha), were evenly distributed in 81.6 % of the total area of the archipelago (Fig. 3B). Intermediate-density distribution was scattered, averaged 439.5 ind./ha ± 32.1 (342-600 ind./ha), and covered ca. 3.1 % of the area, mostly in the northwestern sector of the archipelago (Bahía Almirante). Only one high-density sector was found on the southwestern side of Isla Cristóbal, formed by 44 ha (0.1 %) with an average of 814 ind./ha (Fig. 3B).

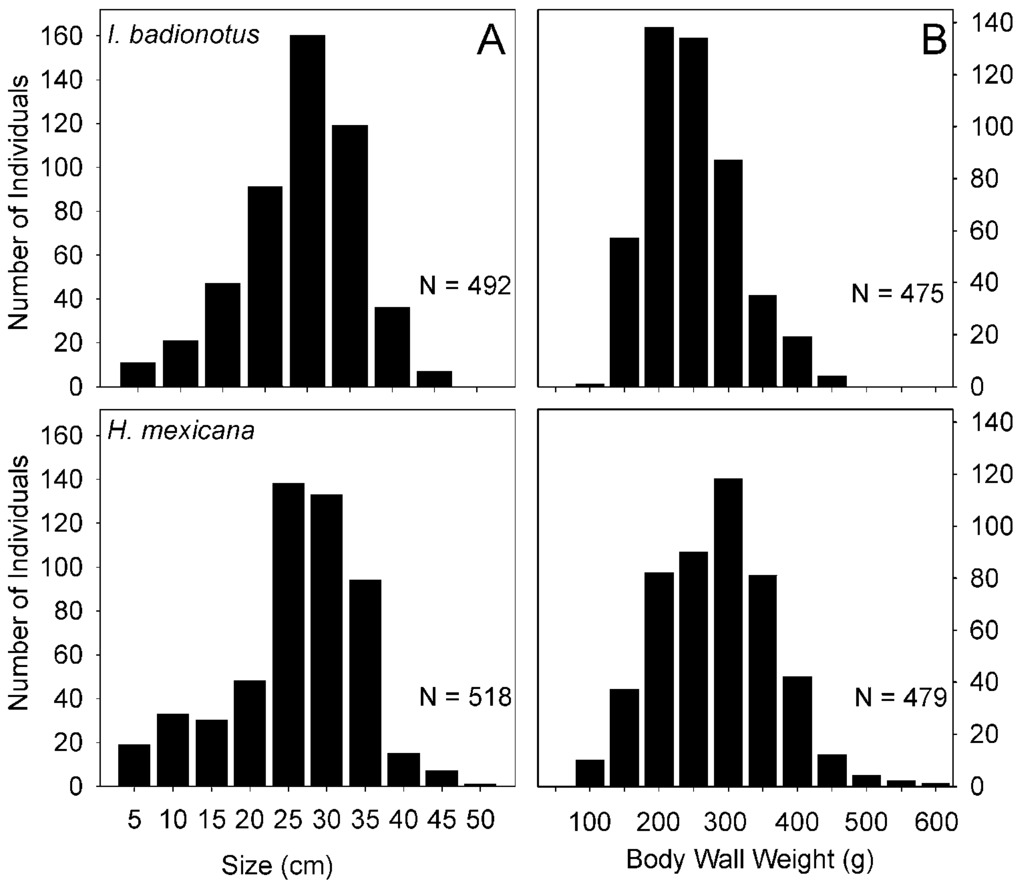


FIG. 2. Size-frequency every 5 cm (A) and weight-frequency (B) distributions of *Isostichopus badionotus* (upper plot) and *Holothuria mexicana* (lower). Size analysis included all collected individuals.

*Astichopus multifidus* was absent in 80 % of the study sites (Fig. 3C) and was not found in 84 % (39 609 ha) of the total area of the archipelago. The average highest density (131 ind./ha) was seen only in one sector of 227 ha (0.5 %), close to the southeastern boundary of the PNMIB (Fig. 3C). Two main sectors of the archipelago appeared to host the remaining populations, with average low densities of 8.6 ind./ha ± 1.7 (3-31 ind./ha) in 11 % of the total area and intermediate densities of 62.2 ind./ha ± 9.5 (36-94 ind./ha) in 4.5 % of the total area. These two sectors were located in Peninsula Valiente (719 ha) and in Bahía Almirante (3741 ha). The greatest surface area with low-intermediate densities was observed in and around the PNMIB (Fig. 3C).

We found a total of 6017 individuals of *H. mexicana*, 4431 of *I. badionotus* and 208 of *A. multifidus* in 36 randomly sampled hectares, with average densities of 161.8 ind./ha ±18.7, 117.4 ind./ha ±12.4, and 4.9 ind./ha ±1.6 respectively. By extrapolating the previous data to the total worked area with shallow habitats in the archipelago (ca. 47 158 ha), we estimated a total stock or abundance of 7 630 164 individuals for *H. mexicana*, 5 536 349 for *I. badionotus*, and 231 074 for *A. multifidus*.

## DISCUSSION

Socio-economic surveys conducted among local fishermen reveal a striking preference for *Astichopus multifidus* and *Isostichopus badionotus* in the Bocas del Toro

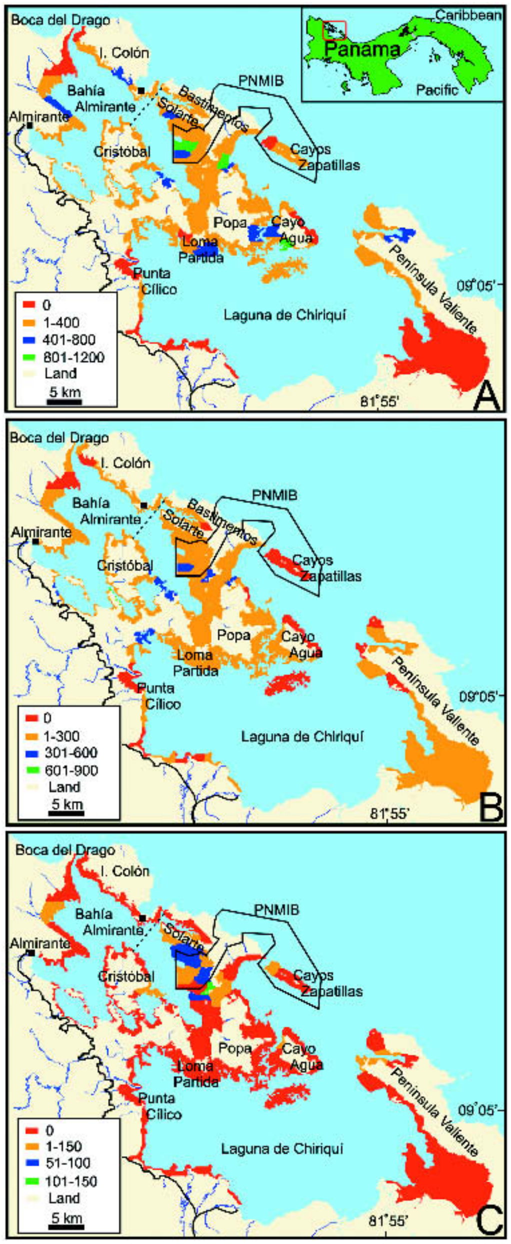


FIG. 3. Map of the Republic of Panama (upper right insert) showing the location of the Bocas del Toro archipelago and the distribution and density of *Holothuria mexicana* (A), *Isostichopus badionotus* (B), and *Astichopus multifidus* (C), from Boca del Drago to the northern point of Peninsula Valiente. Density ranges (individuals per hectare) are shown in four colors (lower left box) along the coastal zone and to a maximum depth of 10 m. Solid line polygon indicates the limits of the marine protected area (PNMIB) and dashed line indicates limit for hydrographic regimes in Bahía Almirante.

region (Cruz, 2000; this study). This preference, which is due to these species' softer and less rigid texture, occurs also in other Caribbean localities (Rodríguez-Milliet and Pauls, 1998). Locally, *Holothuria mexicana* has the lowest economic value, but it is harvested due to the decrease in the other species' populations (Cruz, 2000; this study).

Due to previous exploitation, current abundance may not reflect the natural behavior of the studied populations. The degree of disturbance of the natural populations we studied precluded any rigorous analysis of density-distribution under different hydrographic regimes within the archipelago. Based on the densities reported here, the 1997 fishery considerably affected the populations of *Isostichopus badionotus* and *Astichopus multifidus*, particularly the latter. The average density reported here for *A. multifidus* (4.9 ind./ha ±1.6) may indicate current critical overfishing levels.

The unimodal population structures of *Isostichopus badionotus* and *Holothuria mexicana* in Panama were mainly composed of adult individuals (25-30 cm), similar to the ones observed for some holothuroid species in other localities (Conand, 1993; Chao et al., 1995). We cannot ensure that this structure represents the natural state of the populations in Panama; perhaps it reflects the growth of the juvenile population that survived the 1997 exploitation. Although authorities did not gather information about the size range of the individuals harvested commercially in Panama, reports from fisheries in Venezuela indicate sizes between 10-30 cm for *H. mexicana* (Rodríguez-Milliet and Pauls, 1998) and 11-32 cm for *I. badionotus* (Buitrago and Boada, 1996; Rodríguez-Milliet and Pauls, 1998). The Venezuelan reports suggest that the fishery was based on individuals somewhat below minimum reproductive age, estimated at 18 cm for *I. badionotus* (Rodríguez-Milliet and Pauls, 1998). For Panama, we estimated a minimum reproductive size of ca. 13-15 cm (150 g) for both species.

Both species in Panama had the best possible sex proportion of 1:1 (Guzmán et al., in prep.), which would be advantageous to ensure the reproduction and subsistence of the populations. However, the densities we recorded suggest that recovery may take many years. D'Silva (2001) indicates that the recovery of overfished stocks takes a long time, in part because these species are gonochoric broadcasters, which decreases fertilization and perhaps recruitment, to a few areas with high-density populations. The decline in density by overfishing observed here for *A. multifidus* and in *I. badionotus* might impair fertilization and reduce the reproductive success of the remaining individuals in isolated populations (see Levitan and Young, 1995).

*State of populations at regional versus local levels*

Table 1 compares the abundance obtained in Panama with the average numbers reported for other localities in the Caribbean. In general, natural and human-disturbed areas sustained larger densities of *H. mexicana* than of *I. badionotus*. In addition, *H. mexicana* had average densities 50 times lower in Panama than in the rest of the Caribbean, while for *I. badionotus* it was 56 times lower.

The Parque Nacional Marino Isla Bastimentos (PNMIB) has 11 596 hectares of marine protected area, comprised of ca. 40 % (4638 ha) of shallow coral reef and seagrass environments (< 10 m). Similar habitats occur within the protected area of the Parque Nacional Morrocoy (PNM) in Venezuela (Conde, 1997; Bitter, 1999). A comparison of population densities for these areas (in which fishing holothuroids is prohibited) with Panamanian populations in the Bocas del Toro archipelago reveals the extent of population reduction due to overfishing (Table 1). Average densities of 10 125 ind./ha and 11 854 ind./ha for *H. mexicana* and *I. badionotus* have been recorded inside the PNM (Table 1); these values are notably high when compared to the maximum averages of 1139 ind./ha and 814 ind./ha recorded in the PNMIB for both species. Furthermore, *Holothuria mexicana* showed a maximum density of 956 ind./ha in 480 ha representing only 10 % of the shallow protected area within the PNMIB, while *I. badionotus* and *A. multifidus* were strikingly absent in 95 % of the protected insular area around Cayo Zapatillas, suggesting that nearby fishing communities have extracted this resource from the park. Still, inside and near the PNMIB, holothuroid populations were observed in low density but in healthier condition than in the rest of the archipelago.

*Status of the local fishery*

Panama has are large extensions of coral reefs and seagrass meadows that may allow sustainable harvesting of these three species of holothuroids. If properly managed, this activity can benefit the Ngöbe-Buglé Indian coastal communities. However, exploitation of sea cucumbers began in an unplanned way, with a permit

TABLE 1. Density comparison between *Isostichopus badionotus* and *Holothuria mexicana* in four Caribbean countries, showing populations within marine protected areas (*) and previously fished areas (**). Jamaica and Panama not considered for the overall average.

| Country | Density (individual/hectare) | | Reference |
|---|---|---|---|
| | *I. badionotus* | *H. mexicana* | |
| Bermuda | 2300–3950 | No Data | Sloan and von Bodungen (1980) |
| Jamaica | 70 | 70 | Hammond (1981) |
| Venezuela* | 3600–7600 | 7000–9400 | Sambrano (1987) |
| Venezuela* | 300–7800 | 1400–19700 | Bitter (1988) |
| Venezuela** | 90–590 | No Data | Buitrago and Boada (1996) |
| Venezuela* | 7667 | 9400 | Conde 1997 |
| Venezuela** | 530–1100 | 110–210 | Rodríguez-Milliet and Pauls (1998) |
| Venezuela* | 24500 | 13500 | Bitter (1999) |
| Panama** | 117.4 | 161.8 | Present study |
| Overall Mean | 6585 | 8362 | |

granted by the government in 1997 for harvesting and processing bêche-de-mar in Bocas del Toro. The negative effect of this unmanaged extraction occurred immediately and the permit was revoked 30 days later. Nevertheless, we conservatively estimate that 750 000 sea cucumbers of the three species were caught during the period (based on 25 fishermen extracting an average of 1000 cucumbers a day, and maximum reports of up to 1500/day). This quantity represents a biomass of ca. 180 tons (based on average body wall wet weight of 240 g) or equivalent to ca. 9 tons if the average dry commercial weight of 12 g reported for Venezuela is used (Rodríguez-Milliet and Pauls, 1998).

Density data (Fig. 3) indicates that overfishing occurred mainly in the coastal perimeter of Laguna de Chiriquí, from the point of Península Valiente through the southern section of Isla Popa and Cayo Agua. This small distribution pattern coincided with the fishing information gathered through socio-economic surveys (Cruz, 2000). Pressure from Chinese businessmen to obtain permits from the government has not decreased and illegal fishing continues mainly in the same sectors of the archipelago where the activity began in 1997 (Cruz, 2000). If the fishing pressure of 1997 is maintained or permitted, our estimated stocks for the three species of holothuroids would collapse within a short time (305, 221, and 9 days for *H. mexicana*, *I. badionotus*, and *A. multifidus*, respectively, based on a catch effort of 25 000/day).

*Management Recommendations*

Some control is needed for the management of the holothuroid fishery in Bocas del Toro, Panama. There are no fishing restrictions within the archipelago, where 48 % of the fishermen view marine resources as an unlimited source of wealth (Cruz, 2000) and 49 % favor the establishment of seasonal bans and regulations. We propose the following management alternatives for holothuroid fishing in this region: 1. Prohibit the fishing of *A. multifidus* and *I. badionotus* in the entire archipelago for 3-5 years. 2. Establish no-touch fishing protected zones, allowing the monitoring of natural populations; these areas could be part of the PNMIB or may be located close to fishing communities willing to protect the resource. 3. Capture many adult *A. multifidus* and transfer them to a special protected area reserved for the study of the species and dedicated to increasing gamete fertilization and natural propagation (sensu Levitan and Young, 1995). 4. Allow the catch of *H. mexicana* with the following restrictions: a. control the size of the fishing fleet (number of boats); b. set quotas to limit annual catch (see Mannina, 1997; Iudicello et al., 1999); c. limit the length of the fishing season; d. set the minimum size and weight of captured individuals to 25 cm and 300 g wet-gutted; e. restrict fishing in particular areas of the archipelago (notably, the western coastal areas of Laguna de Chiriquí and Peninsula de Valiente, due to lowest densities recorded and the continuation of illegal fishing there; Cruz, 2000); and f. prohibit the use of SCUBA diving.

*Acknowledgements*.—This research was partially funded by the Fundación Natura, the Fundación PROMAR, and the Smithsonian Tropical Research Institute. A. Domingo, A. Gonzalez, I. Hernandez, L. Partridge and W. Pomaire provided invaluable assistance in the field and in the laboratory. Special thanks are due to C. Manosa for assistance in preparing the manuscript. C. Muñoz from ANCON developed the map in GIS. We thank the Government of Panama for providing all necessary permits to work in the country.

## LITERATURED CITED

Bitter, R.S. 1988. Análisis multivariado de la comunidad asociada a *Thalassia testudinum* en el Parque Nacional Morrocoy. PhD. Thesis. Universidad Central de Venezuela, Caracas, 153 pp.

Bitter, R.S. 1999. Benthic communities associated to *Thalassia testudinum* (Hydrocharitaceae) at three localities of Morrocoy Nacional Park, Venezuela. Rev. Biol. Trop. 47: 443-452.

Buitrago, J., and J.A. Boada. 1996. La pesca de la holoturia *Isostichopus badionotus* en el oriente de Venezuela. Memoria Sociedad de Ciencias Naturales La Salle. 146: 33-40

Chao, S.M., C.P. Chen, and P.S. Alexander. 1995. Reproductive cycles of tropical sea cucumbers (Echinodermata: Holothuroidea) in southern Taiwan. Mar. Biol. 122: 289-295.

Conand, C. 1993. Ecology and reproductive biology of *Stichopus variegatus* and Indo-Pacific coral reef sea cucumber (Echinodermata: Holothuroidea). Bull. Mar. Sci. 52: 970-981.

Conand, C. 1997. Are holothurian fisheries for export sustainable? Proc. 8th Int. Coral Reef Symp. 2: 2021-2026.

Conand, C., and M. Byrne. 1993. A review of recent development in the world sea cucumber fisheries. Mar. Fish. Rev. 55: 1-13.

Conde, J.E. 1997. Après les bébés phoques, les concombres de mer. La Recherche. 304: 61-64.

Cruz, L.G. 2000. Campaña de educación ambiental para la conservación y protección del pepino de mar (Echinodermata: Holothuroidea) en 15 comunidades del Archipiélago de Bocas del Toro y Península Valiente. Msc. Thesis, Universidad Santa María La Antigüa, Panamá, 145 pp.

D'Silva, D. 2001. The Torres Strait beche-de-mer (sea cucumber) fishery. South-Pacific Commission Beche-de-mer Information Bulletin # 15. 4 pp.

Fuente-Betancourt, de la G.M., A. Jesús-Navarrete, E. Sosa-Cordero, and M.D. Herrero-Perezrul. 2001. Assessment of the sea cucumber (Echinodermata: Holothuroidea) as potencial fishery resource in Banco Chinchorro, Quintana Roo, Mexico. Bull. Mar. Sci. 68: 59-67.

Greb, L. et al. 1996. Ökologie ind sedimentologie eines rezenten rampensystem an der Karibikküste von Panama. Profil, Band 10, Universität Stuttgart, 168 pp.

Guzmán, H.M., and C.A. Guevara. 1998. Arrecifes coralinos de Bocas del Toro, Panamá: I. Distribución, estructura y estado de conservación de los arrecifes continentales de la Laguna de Chiriquí y la Bahía Almirante. Rev. Biol. Trop. 46: 601-622.

Hammond, L.S. 1981. An analysis of grain size modification in biogenic carbonate sediments by deposit-feeding holothurians and echinoids (Echinodermata). Limnol. Oceanogr. 26: 898-906.

Hammond, L.S. 1983. Nutrition of deposit-feeding holothuroids and echinoids (Echinodermata) from a shallow reef lagoon, Discovery Bay, Jamaica. Mar. Ecol. Prog. Ser. 10: 297-305.

Hendler, G., J.E. Miller, D.L. Pawson, and P.M. Kier. 1995. Echinoderms of Florida and the Caribbean Sea Stars, Sea Urchins and Allies. Smithsonian Institution Press, Washington, 390 pp.

Herrero-Pérezrul, M.D., H.R. Reyes-Bonilla, F. García-Domínguez, and C.E. Cintra-Buenrostro. 1999. Reproduction and growth of *Isostichopus fuscus* (Echinodermata: Holothuroidea) in the southern Gulf of California, Mexico. Mar. Biol. 135: 521-532.

Iudicello, S., M. Weber, and R. Wieland. 1999. Fish, Markets and Fishermen. Island Press, Washington, 192 pp.

Levitan, D.R., and C.M. Young. 1995. Reproductive success in large populations: empirical measurements and theoretical predictions of fertilization in the sea biscuit *Clypeaster rosaceus*. J. Exp. Mar. Biol. Ecol. 190: 221-241.

Mannina, G.J. 1997. Is there a legal and conservation basis for individual fishing quotas? Ocean and Coastal Law J. 3: 5-56.

Powell, J.R., and J.P. Gibbs. 1995. A report from Galapagos. TREE. 10: 351-354.

Preston, G.L. 1993. Bêche-de-mer. *In* A. Wright and L. Hill (Eds.), Nearshore Marine Resources of the South Pacific, pp. 373-410. Forum Fishery Agency-Institute of Pacific Studies.

Richards, A.H., L.J. Bell, and J.D. Bell. 1994. Inshore fisheries resources of Solomon Islands. Mar. Pollut. Bull. 29: 90-98.

Rodríguez-Milliet, E., and S.M. Pauls. 1998. Sea cucumbers fisheries in Venezuela. Proc. 9th Inter. Echinoderm Conf. 513-516.

Rodríguez, E., R. Almanza, and R. Alvarado. 1993. Situación biofísica y ambiental de la Provincia de Bocas del Toro. *In* S. Heckadon-Moreno (Ed.), Agenda Ecológica y Social para Bocas del Toro, pp. 55-72. Impresora Continental, S.A., Panamá.

Sambrano, A. 1987. Actividad sedimentivora de *Isostichopus badionotus* e *Holothuria mexicana* (Echinodermata: Holothuroidea) en bajos de *Thalassia*. Trabajo Especial de Grado, Universidad Simon Bolívar, Caracas, Venezuela, 131 pp.

Sewell, M.A., and F.S. Chia. 1994. Reproduction of the intravarian brooding apodid *Leptosynapta clarki* (Echinodermata: Holothuroidea) in British Columbia. Mar. Biol. 121: 285-300.

Sloan, N.A., and B. von Bodungen. 1980. Distribution and feeding of the sea cucumber *Isostichopus badionotus* in relation to shelter and sediment criteria of the Bermuda platform. Mar. Ecol. Prog. Ser. 2: 257-264.