Abundance of the brown sea cucumber *Isostichopus fuscus* at the National Park Bahia de Loreto, México

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Abstract: The Natural Protected Area Parque Nacional Bahia de Loreto, including five adjacent islands, was created in 1996. The park presents rocky and sandy shores, mangrove areas and small patches of reef corals, which have been used for fishing and ecotourism activities. The fishery of the brown sea cucumber *Isostichopus fuscus* is one of the most peculiar in the Gulf of California since early nineties and in the Park the fishery takes place since 2000 under special permits known as UMAS (units for wildlife management). However, little is known on the abundance of the resource in natural populations in México, crucial information to determine total allowable catch. The objective of this study was to assess the abundance of *I. fuscus* in the National Park Bahia de Loreto, Gulf of California, during the fishing season 2005-2006. Abundance was estimated through belt transects (25 x 2 m). A total of 29 sites or "banks" were visited, mostly sites where the fishery occurs. Data were analyzed to determine homoscedasticity and normality using the Levene and Kolmogorov-Smirnoff tests, respectively. To detect differences between the islands we used a one way ANOVA (model II; α=0.05) considering the islands as factors. We used linear regressions to detect geographic clines between population density and geographic location. The average abundance of *I. fuscus* in the PNBL was 1.41 $\pm$0.02 individuals/transect, with an average density of 0.028 $\pm$0.0004 ind/m^2. Density was slightly higher in the southern banks. The lowest value was found at isla Montserrat, which is close to the coastline of the Baja California Peninsula, where most of the fishery occurs. No relationship was found between population density and latitudinal gradient, nor with the distance from the coastline. We concluded that even though density levels were low in PNBL, the situation of *I. fuscus* does not seem critical to populations. Rev. Biol. Trop. 56 (Suppl. 3): 265-271. Epub 2009 January 05.

Key words: *Isostichopus fuscus*, holothurians, abundance, density, National Park Bahía de Loreto, UMAS.

The holothurian, *Isostichopus fuscus* (Ludwig 1875), is a common inhabitant of coral and rocky bottoms in the tropical eastern Pacific. It is found in shallow waters (0 to 40 m depth) from the northern Gulf of California to Ecuador, including the oceanic islands Revillagigedo, México and Galápagos, Ecuador (Maluf 1988). It is also considered the most relevant commercial species from the American continent (Jenkins and Mulliken 1999). Nearly 2 000 t of *I. fuscus* were exported to Asian countries, with profits over two million dollars between 1989 and 1993 (Espinoza *et al.* 2001) and fishing activities benefit many families in México, Costa Rica and Ecuador (Jenkins and Mulliken 1999, Herrero-Pérezrul and Chávez 2005). However, since *I. fuscus* is a slow-growth organism, with late first

maturity and that can live up to 17 years old (Herrero-Pérezrul *et al.* 1999, Herrero-Pérezrul and Chávez 2005), is prone to overfishing. These life-traits mean that populations do not recover easily after fishing activities, as it has been demonstrated for sharks and other species (Jennings *et al.* 1997, 1999, Frisk *et al.* 2001, Denney *et al.* 2002). The fishery of *I. fuscus* was in difficult situation during the early nineties in México and Ecuador due to over explotation. Catch diminish drastically and authorities closed the fishery to protect its populations (Anonymous 1994, Sonnenholzner 1997, Hearn *et al.* 2005) and promoted investigations on the species. Ecuador included the brown sea cucumber in Appendix I CITES (Sant 2006). The fishery of *I. fuscus* is currently allowed under strict regulations in both countries (Anonymous 2001).

To date, *I. fuscus* is been well studied. There are reports of its distribution range (Brusca 1980, Solís Marín *et al.* 1997, Holguín-Quiñones *et al.* 2000), growth rate and reproductive cycle in the Gulf of California (Fajardo-León *et al.* 1995, Herrero-Pérezrul *et al.* 1998, 1999). Some work has been done on its potential for aquaculture (Gutiérrez-García 1999). On the other hand, Fajardo-León and Vélez-Barajas (1996) and Herrero-Pérezrul and Chávez (2005) analyzed the fishery and estimated yield based on fishing effort and age at first maturity. In Ecuador most of the studies addressed the effects of overfishing, but there are good data on the biology, and larval studies (Sonnenholzer 1997, Hamel *et al.* 2003, Toral-Granda and Martínez 2004, Hearn *et al.* 2005).

Notwithstanding, little is known on the abundance of the resource in natural populations, and in Mexico those studies date from the early nineties (Herrero-Pérezrul *et al.* 1999). This does not mean that there is no data. Since the year 2000 government agencies and fishing cooperatives assess the populations in fishing designated areas, mostly in the southern Gulf of California, however, this information is used only to determine total allowable catch (TAC).

The objective of this study was to assess the abundance of *I. fuscus* in the National Park Bahía de Loreto, in the Gulf of California, México during the fishing season 2005-2006.

MATERIALS AND METHODS

The Parque Nacional Bahía de Loreto (PNBL) is located in the western coast of the Gulf of California (Fig. 1). This Natural Protected Area of 206 580 ha in size (~798 square miles) was created in 1996. The park presents rocky and sandy shores, mangrove areas and other type of wetlands, and also small patches of reef corals. Loreto Bay and five adjacent islands (Carmen, Catalina, Monserrat, Coronado and Danzante), are located within the PNBL boundaries. The marine communities of the islands have been used for fishing and ecotourism activities during many years (Anonymous 2000).

Holothurian fishery was opened in PNBL in 2000, the park was divided in equal parts and

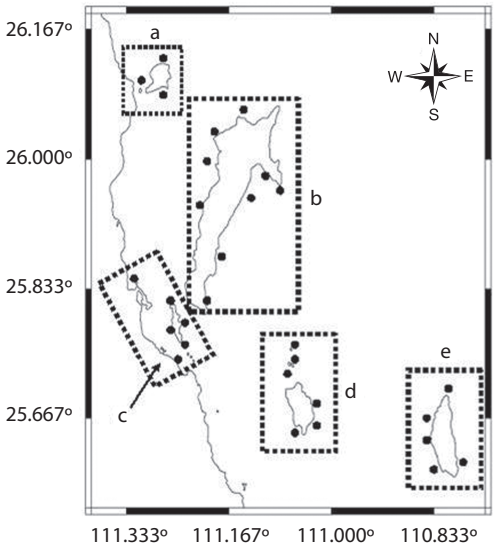

Fig. 1. Location of the Parque Nacional Bahía de Loreto. Sampling sites are represented with dots. A) Isla Coronados; B) Isla Carmen; C) Isla Danzante; D) Isla Monserrat; E) Isla Catalina.

four fishing cooperatives obtained special permits called UMAS (Unidades de manejo para la vida silvestre or Units for wildlife management) until 2006. We visited 29 "banks", sites where the fishery occurs (Fig. 1). A total of 60 belt transects (25 x 2 m) were established, two per bank in average. As sea cucumbers can be hiding in rock crevices and therefore difficult to count, the diver scanned the area in search for pellets, which indicate the presence of *I. fuscus*. Fishermen mentioned that sea cucumbers are active after the sunset and that assessment should be done by night, but the park authorities stated that in order to determine an estimate of population density and TAC in a precautionary way, assessment was to be done during daytime.

Each bank was assigned to specific area (Fig. 1) and density was calculated for each site and region. Data were analyzed to determine homoscedasticity and normality using the Levene and Kolmogorov-Smirnoff tests, respectively. To detect differences between the islands we used a one way ANOVA (model II; α=0.05) considering the islands as factors (Zar 1996). We used linear regressions to detect geographic clines between population density and geographic location, such as latitude, longitude and the distance from the coastline.

RESULTS

The average abundance of *I. fuscus* in the PNBL was 1.41 ± 0.02 individuals/transect (Fig. 2), with an average density of 0.028 ± 0.0004 ind/m^2. Density values ranged between 0 and 5 ind/transect (0 and 0.1 ind/m^2, respectively).

The valves at specific areas ranged from 1.08 ± 0.41 ind/transect (at Isla Montserrat) to 2.00 ± 0.38 (at Isla Catalina), however, no statistical differences were detected ($F_{4, 53}$=0.67, p=0.62). The regression analysis showed no relationship between population density and latitude (ANOVA for the regression: $F_{1,27}$=0.863, p=0.361; Fig. 3A), nor with the distance of the islands from the coastline (ANOVA for the regression: $F_{1,27}$=3.806, p=0.062; Fig. 3B). However, we noticed that density was slightly higher in the banks found in the southernmost islands, and no holothurians were found at Isla Coronados and Isla Carmen, the latter being to the city of Loreto.

The results of the ANOVA test comparing densities between islands (Fig. 2) and the regression between bank location and abundance (Fig. 3) did not reject the null hypothesis. This means that individual numbers per unit area were distributed homogeneously along the

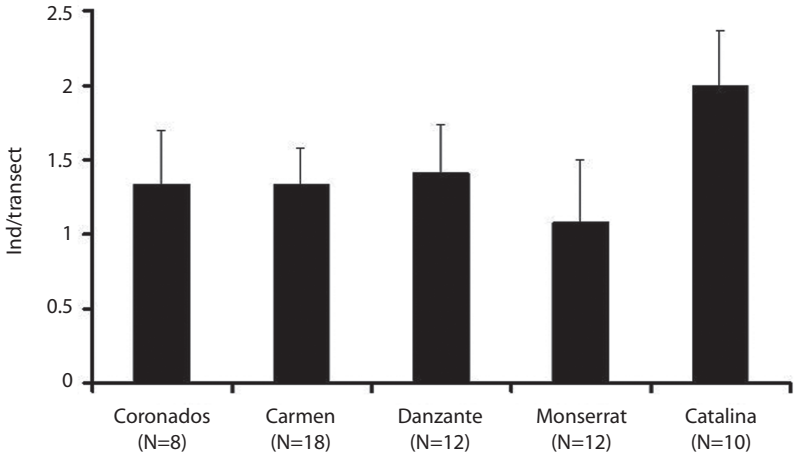

Fig. 2. Population density (average ± typical error) of *Isostichopus fuscus* in the islands from Bahía de Loreto. N = number of transects.

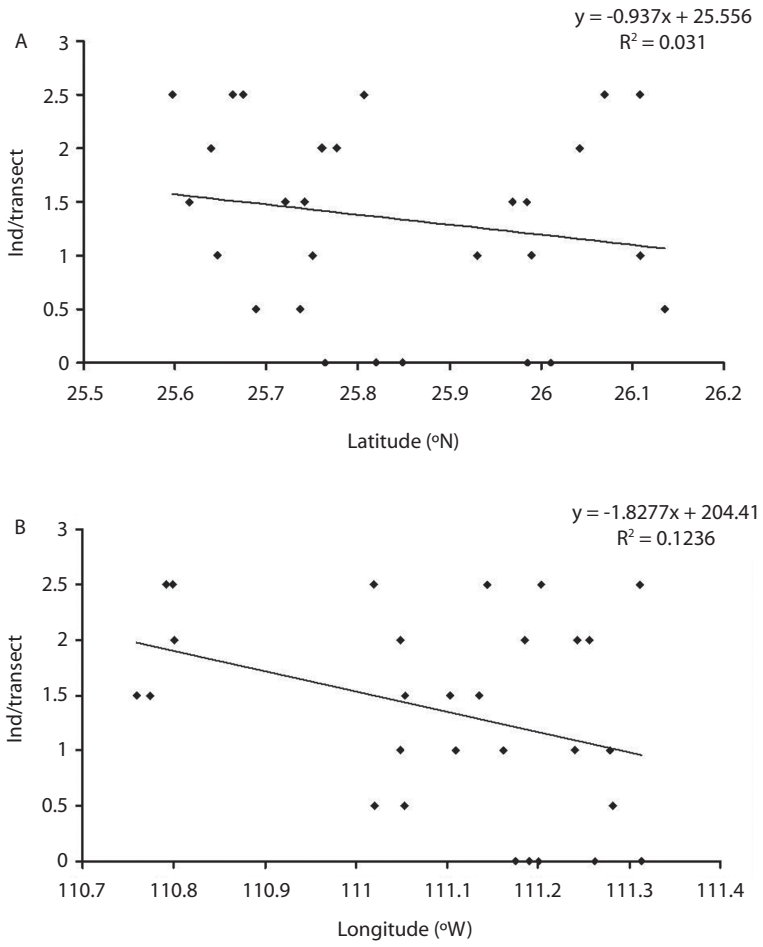

Fig. 3. Population density's regression versus latitude (a) and longitude (b) in the PNBL.

study site regardless of geographical gradient. The habitat and suitable conditions for the species must be similar within the PNBL, and also fishing activities.

We observed that on each degree of longitude the number of holothurians decreased 1.8 units per transect as sampling approached the coastline of the peninsula. The highest density was found at Isla Catalina, the most remote (Fig. 1, 2), and the lowest at Isla Montserrat, which is near the coastline and where most of the fishery occurs.

DISCUSSION

This is the first study addressed to analyze the status of the brown sea cucumber *I. fuscus* in Loreto Bay, and it is also the first analysis of population density after the turn of the century when fishery reopened (Herrero-Pérezrul *et al.* 1999, Ramírez Soberón *et al.* 2001). The first record of the presence of this holothurian in Loreto belongs to Steinbeck and Ricketts (1941), who observed hundreds of individuals in Puerto Escondido (located south of the PNBL). Years later, between 1989

and 1993, population density in the southern Gulf of California (25° N to 27° N, area which includes Loreto) ranged from 0.03 to 0.30 ind/m^2 (Fajardo-León and Vélez-Barajas 1996). The lower limit is similar to that found in our study (Fig. 2). Later on, Holguín-Quiñones *et al.* (2000) estimated values lower than 0.02 ind/m^2 at Isla Carmen, Coronados and Danzante during 1997 and 1998, a reduction which they attributed to overfishing. It is important to mention that in the early nineties, illegal catch was high. The increase in density observed in our study denotes a recovery on the population numbers, probably helped by the establishment of the UMAS and others regulations. Despite the limited data, it appears that the average density of *I. fuscus* in Loreto is proven to be similar during the last decade, meaning a certain stability of the populations on the long term.

Estimates of density in other banks from the eastern Pacific such as the productive northern Gulf of California and the Galápagos Islands, showed values of 0.1 ind/m^2 (Fajardo-León and Vélez Barajas 1996, Hearn *et al.* 2005), higher than those obtained during 2006 in the PNBL; but in other areas from the Mexican Pacific, density was estimated in 0.01 ind/m^2 (Nuño-Hermosillo 2003). These data support the evidence of a latitudinal cline in *I. fuscus* abundance, possibly related to ocean productivity, and it may indicate that food is a limiting factor for the species. Despite the low values found in PNBL during this study, densities are still higher than those reported for other commercial holothurians (Shiell 2004, Uthicke 2004). The critical situation of the west Pacific sea cucumber fishery can explain why Mexican exports have increased from 0.1 % in 1998 to 2.6 % in 2001 (Vannuccini 2004).

All the evidence points to the fact that there are changes in *I. fuscus* populations related to the distance from populated areas, and hypothetically, to the effort level within the park. This must be taken in consideration for future management plans.

According to Shepherd *et al.* (2004), in order to achieve a 50 % success in the fertilization process of *I. fuscus* in the Galápagos, a minimum density of 1.2 ind/m^2 is required and that Toral-Granda and Martínez (2004) suggested that local populations with densities lower than 0.4 ind/m^2 faced to a notorious decline in recruitment. Despite the fact that densities of this holothurian in Ecuador are higher than in México (0.023 ind/m^2), it seems to be a common trait in our country (Fajardo-Léon and Vélez Barajas 1996, Herrero-Pérezrul *et al.* 1999, Nuño-Hermosillo 2003), and populations have adapted to this conditions. Many holothurians gather to reproduce (Rodgers and Bingham 1996), which increases the probability of fertilization. Besides, the Galápagos is a unique group of islands where due to the confluence of warm currents from the north (26-29 °C) and cool waters from the southwest (20-22 °C), cause nutrient-rich upwellings favoring high abundances of holothurians (Lawrence 1987, Okey *et al.* 2004). On the other hand, Toral-Granda and Martínez (2004) support the hypothesis that populations in this region do not receive external supply of larvae, which we believe is unlikely, since holothurians larvae takes a nearly a month to settle, time spent in the water column (Lawrence 1987, Hamel *et al.* 2003). However, genetic studies would prove that hypothesis.

We concluded that even though density levels were low in PNBL, the situation does not seem critical to populations.

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RESUMEN

En el Parque nacional Bahía de Loreto la época de pesca de *Isostichopus fuscus* abrió en el año 2000 bajo permisos especiales denominados UMAS (Unidades de manejo para la vida silvestre). Poco se conoce sobre la abundancia del recurso en las poblaciones silvestres de México, información crítica para la determinación de cuotas de captura. El objetivo de este trabajo fue evaluar

la abundancia de *I. fuscus* dentro del parque durante la temporada 2005-2006. Se realizaron dos transectos de banda de 25 x 2 m en 29 bancos. Para detectar diferencias, se utilizó un ANOVA de una vía (modelo II; α=0.05) considerando a las islas como factor. Se efectuó un análisis de regresión simple considerando la densidad de pepinos y la latitud y longitud del banco para detectar la presencia de clinas geográficas. La abundancia y densidad promedio fueron de 1.41 ± 0.02 individuos/transecto, y 0.028 ± 0.0004 ind/m^2, respectivamente. No se detectó una relación entre el número de individuos y el gradiente de latitud, además de la cercanía de las islas con la bahía de Loreto, sin embargo, la densidad fue ligeramente mayor en los bancos más lejanos al sur del parque y menor en las islas cercanas a la costa. Se concluye que los bajos niveles de densidad de *I. fuscus* probablemente no representen una situación crítica para las poblaciones.

Palabras clave: *Isostichopus fuscus*, holotúridos, abundancia, densidad, Parque Nacional Bahía de Loreto, UMAS.

REFERENCES

Anonymous. 1994. Determinación de las especies y subespecies sujetas a protección especial y especificaciones para su protección. NOM-059-ECOL-1994. Diario Oficial de la Federación, Mayo 16, México: 2-59.

Anonymous. 2000. Programa de Manejo Parque Nacional Bahía de Loreto. Comisión Nacional de Áreas Naturales Protegidas, Baja California Sur, México. 125 p.

Anonymous. 2001. Análisis de la densidad poblacional y estructura de tallas del pepino de mar (*Stichopus fuscus*) en el archipiélago de Galápagos durante Abril 2001. Informe preparado para la Autoridad Interinstitucional de Manejo. Sector Pesquero Artesanal de Galápagos, Servicio del Parque Nacional Galápagos, Estación Científica Charles Darwin e Instituto Nacional de Pesca, Ecuador. 45 p.

Brusca, R.C. 1980. Common intertidal invertebrates of the Gulf of California. University of Arizona, Tucson, Arizona, USA. 513 p.

Denney, N.H., S. Jennings & J.D. Reynolds. 2002. Life-history correlates of maximum population growth rates in marine fishes. Proc. R. Soc. Lond. B. 269: 2229-2237.

Espinoza, E., J.C. Murillo, M.V. Toral-Granda, R.H. Bustamante, F. Nicolaides, G.J. Edgar, J. Chasiluisa, C. Yépez, M. Barreno, J.C. Shepherd, S.A. Viscaino, J. Villalta, M. Andrade, R. Born, A. Figueroa, L.P. Guerrero & M. Piu. 2001. Fisheries in the Galapagos: a summary of the main indicators for 2000. Galápagos Report. Fundación Natura y el Fondo Mundial para la Naturaleza (WWF), Quito, Ecuador. 78 p.

Fajardo-León, M.C., E. Michel Guerrero, J. Singh Cabanillas, A.J. Vélez Barajas & A. Massó Rojas. 1995. Estructura poblacional y ciclo reproductor del pepino de mar *Isostichopus fuscus* en Santa Rosalía, B.C.S., México. Cienc. Pesq. México 11: 45-53.

Fajardo León, M.C. & A. Vélez Barajas. 1996. Pesquería del pepino de mar, p. 151-165. *In* M.C. Casas-Valdéz & G. Ponce-Díaz (eds.). Estudio del potencial pesquero y acuícola de Baja California Sur. SEMARNAP/CICIMAR, México.

Frisk, M.G., T.J. Miller & M.J. Fogarty. 2001. Estimation and analysis of biological parameters in elasmobranch fishes: a comparative life history study. Can. J. Fish. Aquat. Sci. 58: 969-981.

Gutiérrez García, A. 1999. Potential of culture of sea cucumber in México. SPC Béche de Mer Inf. Bull. 11: 26-29.

Hamel, J.F., R. Ycaza Hidalgo & A. Mercier. 2003. Larval development and juvenile growth of the Galapagos sea cucumber *Isostichopus fuscus*. PC Béche de Mer Inf. Bull. 18: 3-8.

Hearn, A., P. Martínez, M.V. Toral-Granda, J.C. Murillo & J. Polovina. 2005. Population dynamics of the exploited sea cucumber *Isostichopus fuscus* in the western Galápagos Islands, Ecuador. Fish. Oceanog. 14: 377-385.

Herrero-Pérezrul, M.D. & E.A. Chávez. 2005. Optimum fishing strategies for *Isostichopus fuscus* (Echinodermata: Holothuroidea) in the Gulf of California, México. Rev. Biol. Trop. 53 (suppl. 2): 357-366.

Herrero-Pérezrul, M.D., H. Reyes-Bonilla & F. García-Domínguez. 1998. Casual hermaphroditism in gonochoric *Isostichopus fuscus* (Ludwig, 1875) (Echinodermata: Holothuroidea) of the southern Gulf of California, México. Bull. Mar. Sci. 63: 611-615.

Herrero-Pérezrul, M.D., H. Reyes-Bonilla, F. García-Domínguez & C.E. Cintra-Buenrostro. 1999. Reproduction and growth of *Isostichopus fuscus* (Ludwig, 1875) (Echinodermata: Holothuroidea) in the southern Gulf of California, México. Mar. Biol. 135: 521-532.

Holguín-Quiñones, O., H. Wright-López & F.A. Solís-Marín. 2000. Asteroidea, Echinoidea y Holothuroidea en fondos someros de la Bahía de Loreto, Baja California Sur, México. Rev. Biol. Trop. 48: 749-757.

Jenkins, M. & T. Mulliken. 1999. Evaluation of exploitation in the Galápagos Islands, Ecuador, sea cucumber trade. TRAFFIC Int. Bull. 17: 107-118.

Jennings, S., J.D. Reynolds & S.C. Mills. 1997. Life history correlates of responses to fisheries exploitation. Proc. R. Soc. Lond. B. 265: 333-339.

Jennings, S., S.P.R. Greenstreet & J.D. Reynolds. 1999. Structural change in an exploited fish community: a consequence of differential fishing effects on species with contrasting life histories. J. Animal Ecol. 68: 617-627.

Lawrence, J. 1987. A functional biology of echinoderms. Croom Helm. Great Britain. 340 p.

Maluf, L.Y. 1988. Composition and distribution of the Central Eastern Pacific Echinoderms. Nat. Hist. Mus. Los Angeles. Tech. Rep. 2: 1-242.

Nuño-Hermosillo, A. 2003. Ecología poblacional, ciclo reproductivo e historia de la pesquería del pepino de mar *Isostichopus fuscus* (Ludwig, 1875) (Echinodermata: Holothuroidea) en Bahía Chamela, Jalisco, México. M.Sc. Thesis. Centro Universitario de Ciencias Biológicas y Agropecuarias, Universidad de Guadalajara, Guadalajara, México. 111 p.

Okey, T.A., S. Banks, A.F. Born, R.H. Bustamante, M. Calvopiña, G.J. Edgar, E. Espinoza, J.M. Fariña, L.E. Garske, G.K. Reck, S. Salazar, S. Shepherd, V. Toral-Granda & P. Wallen. 2004. A trophic model of a Galápagos subtidal rocky reef for evaluating fisheries and conservation strategies. Ecolog. Model. 172: 383-401.

Ramírez Soberón, G., M.C. Fajardo León, J.A. Massó Rojas, A. Aguilar Ibarra & A. Gutiérrez García. 2001. Pepino de mar. p. 851-874. *In* M.A. Cisneros Mata, L.F. Belendez Moreno, E. Zarate Becerra, M.T. Gaspar Dillanes, L.C. González, C. Saucedo Ruiz & J. Tovar Ávila (eds.). Sustentabilidad y pesca responsable en México: Evolución y manejo. IPN-SEMARNAP, México, D.F.

Rodgers, S.A. & B.L. Bingham. 1996. Subtidal zonation of the holothurian *Cucumaria lubrica* (Clark). J. Exp. Mar. Biol. Ecol. 204: 113-129.

Sant, G. 2006. CITES and sea cucumbers, p. 104-121. *In* A.W. Bruckner (ed.). Proceedings of the CITES workshop on the conservation of sea cucumbers in the Families Holothuriidae and Stichopodidae. NOAA Technical Memorandum NMFS-OPR 34. Silver Spring, M.D.

Shepherd, S.A., P. Martínez, M. V. Toral-Granda & G. J. Edgar. 2004. The Galápagos sea cucumber fishery: management improves as stocks decline. Env. Cons. 31: 102–110.

Shiell, G.R. 2004. Density of *Holothuria nobilis* and distribution patterns of common holothurians on coral reefs of northwestern Australia, p. 231-237. *In* A. Lovatelli, C. Conand, S. Purcell, S. Uthicke, J.F. Hamel & A. Mercier (eds.). Advances in sea cucumber Aquaculture and Management. FAO Fish. Tech. Paper. No. 463, FAO, Rome, Italy.

Solís-Marín, F.A., H. Reyes-Bonilla, M.D. Herrero-Pérezrul, O. Arizpe-Covarrubias & A. Laguarda-Figueras. 1997. Sistemática y distribución de los equinodermos de la Bahía de La Paz. Cienc. Mar. 23: 249-263.

Sonnenholzner, J. 1997. A brief survey of the commercial sea cucumber *Isostichopus fuscus* (Ludwig, 1875) in the Galápagos Islands. SPC Béche de Mer Inf. Bull. 9: 11-15.

Steinbeck, J. & E.F. Ricketts. 1941. Sea of Cortez. Viking, New York, USA.

Toral-Granda, M.V. & P.C. Martínez. 2004. Population density and fishery impacts on the sea cucumber (*Isostichopus fuscus*) in the Galápagos Marine Reserve, p. 91-100. *In* A. Lovatelli, C. Conand, S. Purcell, S. Uthicke, J.F. Hamel & A. Mercier (eds.). Advances in sea cucumber Aquaculture and Management. FAO Fish. Tech. Paper, No. 463, FAO, Rome, Italy.

Uthicke, S. 2004. Overfishing of holothurians: lessons from the Great Barrier Reef, p. 163-171. *In* A. Lovatelli, C. Conand, S. Purcell, S. Uthicke, J.F. Hamel & A. Mercier (eds.). Advances in sea cucumber Aquaculture and Management, FAO Fish. Tech. Paper, No. 463, FAO, Rome, Italy.

Vannuccini, S. 2004. Sea cucumbers: a compendium of fishing statistics, p. 397-412. *In* A. Lovatelli, C. Conand, S. Purcell, S. Uthicke, J.F. Hamel & A.Mercier (eds.). Advances in sea cucumber Aquaculture and Management, FAO Fish. Tech. Paper, No. 463. FAO, Rome, Italy.

Zar, J.H. 1996. Biostatistical Analysis. Prentice- Hall, Upper Saddle River. 918 p.