

## Weight-Length relationship and relative condition of the holothurian *Isostichopus fuscus* at Espiritu Santo Island, Gulf of California, México

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**Abstract:** Holothurians were heavily exploited worldwide during the last decade. The high prices of the product prompted the opening of new fishing grounds in the west coast of American countries, such as México and Ecuador. In these countries, the target species is *Isostichopus fuscus*. There is good information regarding the reproductive biology, growth and abundance of this sea cucumber, however, more studies are still needed, especially those which can supply information on the physiological condition of the individuals. The objective of this study was to estimate the relative condition of an exploited population of *I. fuscus* at Isla Espiritu Santo, in the southern Gulf of California, México. A total of 1 446 individuals were analyzed during 1996-1997. Length and weight were monitored each month. We calculated the weight-length relationship and the index of relative condition (Kn). The mean length and weight were  $23.3 \pm 0.1$  cm and  $385.9 \pm 3.9$  g respectively. The weight-length relationship showed that *I. fuscus* grew allometrically at the study site. The index of relative condition (Kn) had an average of  $1.040 \pm 0.027$ , and ranged from 0.123 to 2.816. There were no statistical differences in Kn along the year, although the highest values appeared from November to April. Kn presented a parabolic relationship with total length, and peaked at 21 cm length, the size of first maturity. This pattern may indicate that the condition of individuals is slowly improving with age up to a point and then decreases gradually, a possible evidence of aging and the first indication of senescence in holothurians. Rev. Biol. Trop. 56 (Suppl. 3): 273-280. Epub 2009 January 05.

**Key words:** *Isostichopus fuscus*, holothurians, weight-length relationship, relative condition, Gulf of California.

Holothurians have been heavily fished around the world, and reports of a decrease in world catch have become common during the last decade (Conand 2000, Hearn *et al.* 2005). In America this fishery is not traditional; nevertheless, the high price of the product prompted the opening of new fishing grounds in the west coast of Alaska, Canada, the United States, México, and the Galapagos Islands, Ecuador. In this region, the target species are *Isostichopus fuscus* (Ludwig 1875), *Parastichopus parvimensis* (H.L. Clark 1913) and *P. californicus* (Stimpson 1857) (Heizer and Hobbs 1994, Zhou

and Shirley 1996, Herrero-Pérezrul *et al.* 1999, Ramírez Soberón *et al.* 2001). *I. fuscus* is the most important commercial species in the eastern Pacific and has been so since the early nineties. After a few years of intense exploitation, the government of Mexico and Ecuador banned the fishery for many years (Anonymous 1994, Fajardo-León and Vélez Barajas 1996, Sonnenholzner 1997, Jenkins and Mulliken 1999). At the end of the decade, strong social pressure lead to the reopening of the fishery, but this time in the frame of a better legislation and knowledge of the status of the populations.

There is good information regarding the reproductive biology, growth and abundance of *Isostichopus fuscus* (Fajardo-León *et al.* 1995, Herrero-Pérezrul *et al.* 1999, Hamel *et al.* 2003, Reyes-Bonilla and Herrero-Pérezrul 2003, Hearn *et al.* 2005), used to establish basic management programs in México and Ecuador, including total allowable catch (TAC), reproductive ban (from June to September in México), and minimum weight and size of capture. Notwithstanding, more studies are still needed, especially those which can supply information on the physiological condition of the individuals, as an indication of their fishing yield. The study of condition assumes that heavier organisms of a given length are in better physical condition, therefore, condition indices are used in fishery science as indicators of the weight-to-length relationship of a population or subgroup. The physiological state of an animal is related to its evolutionary fitness, thus health status would be an indicator of reproductive success and of the ability to cope with environmental factors (Cone 1989, Jones *et al.* 1999). One of the best ways to analyze this subject is to evaluate the relationship between weight and length of a given species, and the use of the relative condition index  $K_n$  (Cone 1989). Relative condition relates individual weight to a standard population weight, which must be specified for a population or region of interest (Murphy *et al.* 1991). Consequently,  $K_n$  is limited to comparisons of individuals in a population of interest with a standard population.

Considering this background, the objective of this study was to estimate the relative condition of a population of *I. fuscus* at Isla Espíritu Santo, in the southern Gulf of California, México, where the stock was under active exploitation until 1994.

## MATERIALS AND METHODS

The population of *I. fuscus* of Isla Espíritu Santo in the southern Gulf of California, México (24°35'55" N, 110°24'17" W; and 24°24'04" N, 110°19'13" W), was monitored

during 1996-1997. Individuals were collected monthly on six shallow bays of the island (~10 m depth) where a total of 1 446 individuals were measured and weighted. Length was registered *in situ* to the closest centimeter from mouth to anus using flexible tapes (precision 1 mm), a procedure that avoided contraction of the holothurians. Each individual was collected in individual bags, transported to a boat, and weighted with spring scales (precision  $\pm 5$  g). The organisms were then returned to the general area where they resided.

With that information we estimated the weight-length relationship according to the general equation (Cone 1989):

$$W = aL^b$$

where  $W$  = weight in g,  $L$  = body length in cm,  $a$  = the ordinate,  $b$  = the slope of the curve.

Using the parameters of the equation and the observed data of weight and length, we calculated the index of relative condition ( $K_n$ ) for each specimen (Anibeze 2000). This index expresses how different is the weight of a given individual from the expected value calculated for the entire population.

$$K_n = W/aL^b$$

To describe the results we estimated the monthly mean and standard error of  $K_n$ , as well as the first and third percentile of the data (Sokal and Rohlf 1995). It has been suggested that regression-line-percentile is considered to be a proper technique when analyzing condition indices (Murphy *et al.* 1991). Finally, since data were normally distributed (Kolmogorov-Smirnov,  $p > 0.05$ ) a one-way ANOVA ( $\alpha = 0.05$ ) was used to detect differences in time of the values of  $K_n$ .

## RESULTS

The sampled population of *Isostichopus fuscus* had a mean length of  $23.3 \pm 0.1$  cm and weight of  $385.9 \pm 3.9$  g, with minimum and maximum values of 5 and 40 cm, and 15 and 830 g, respectively.

The weight-length relationship (Fig. 1) evidenced that the species grows allometrically, as it appears to be the general case in tropical holothurians (Table 1).

The index of relative condition (Kn) had an overall average of  $1.040 \pm 0.027$  and ranged from 0.123 (lowest value found in June 1997) to 2.816 (highest value in July 1997). No statistical differences were detected in the Kn values among months ( $F_{11, 1434} = 0.616$ ,  $p = 0.817$ ), although monthly mean was higher in September and August, 1996, and June and July 1997. The tendencies of Kn are also clear in the plot of the third percentile of the data, which apparently depicts an annual oscillation (Fig. 2).

The polynomial curve indicates that Kn attains its peak in winter and spring. Figure (2) evidences that condition in the studied population of *I. fuscus* is relatively homogeneous and shows two levels: high from November to May,

when the individuals are not in reproductive activity, and low from June to October.

Kn presented a parabolic relationship with total length ( $p < 0.05$ ; Fig. 3), which had its highest point (1.0961) at 20 cm length.

## DISCUSSION

According to Herrero-Pérezrul *et al.* (1999), the maximum size of *I. fuscus* (estimated as the asymptotic length  $L_{\text{inf}}$  and weight  $W_{\text{inf}}$  from the Bertalanffy growth equation) were 36.1 cm and 815.4 g, respectively. We found similar length values from other relevant commercial species for which information is available. It can be seen that the maximum length of *I. fuscus* is high, surpassed only by *Stichopus japonicus*, *Parastichopus parvimensis* and *Thelenota ananas* (Table 1). This may be one of the main reasons why Asian markets are importing *I. fuscus* from Mexico and Ecuador.

TABLE 1  
A review of the length-weight relationship in commercial holothurians

Species	Maximum length (cm)	b	References
<i>Actinopyga echinites</i>	23.1	ND	Shelley 1985
<i>A. mauritiana</i>	34	ND	Conand 1988
<i>Stichopus japonicus</i>	36.7	ND	Hamano <i>et al.</i> 1989
<i>Thelenota ananas</i>	66.3	ND	Conand 1990
<i>Holothuria scabra</i>	29	ND	Pauly <i>et al.</i> 1993
<i>H. pulla</i>	30.7	ND	Pauly <i>et al.</i> 1993
<i>Opheodesoma spectabilis</i>	32.6	ND	Pauly <i>et al.</i> 1993
<i>Parastichopus parvimensis</i>	52.5	ND	Pérez Plascencia 1995
<i>Isostichopus fuscus</i>	37.32	ND	Fajardo-León <i>et al.</i> 1995
<i>I. fuscus</i> (preserved)	29.108	1.36	Reyes-Bonilla and Herrero-Pérezrul 2003
<i>Holothuria fuscogilva</i>	18.9	2.629	Purcell and Tekanene 2006
<i>H. fuscogilva</i> (dried)	29.5	1.3054	Aumeeruddy and Conand 2007
<i>H. nobilis</i> (dried)	27	1.806	Aumeeruddy and Conand 2007
<i>A. miliaris</i> (dried)	12.2	1.365	Aumeeruddy and Conand 2007
<i>Thelenota ananas</i> (dried)	41	2.1784	Aumeeruddy and Conand 2007
<i>I. fuscus</i> (in situ)	36.1	1.83	Herrero-Pérezrul this study

ND = no data, b = allometry coefficient.

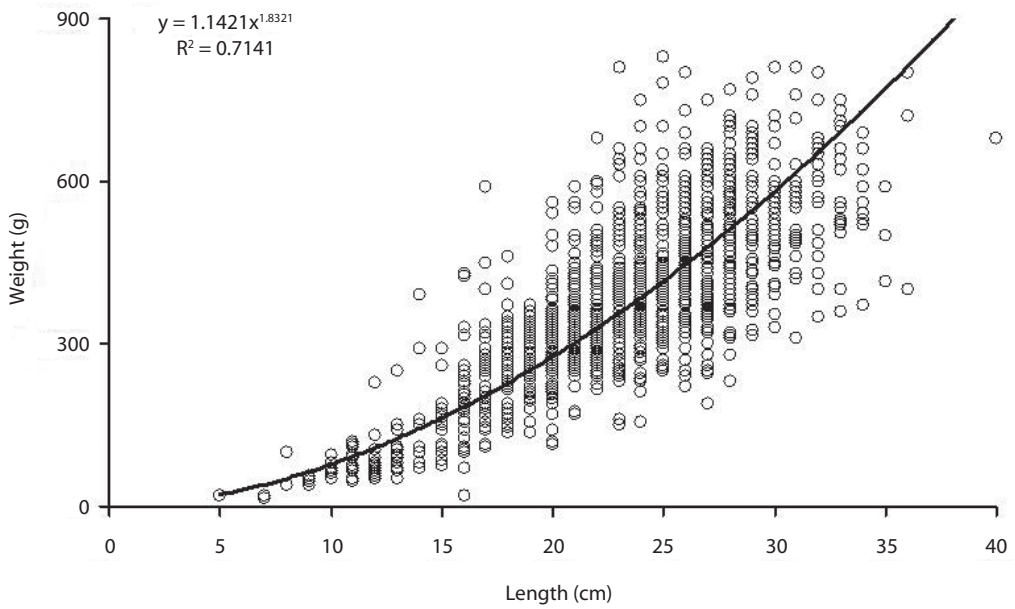


Fig. 1. Length-weight relationship of *Isostichopus fuscus* at Espíritu Santo Island, México during 1996-1997.

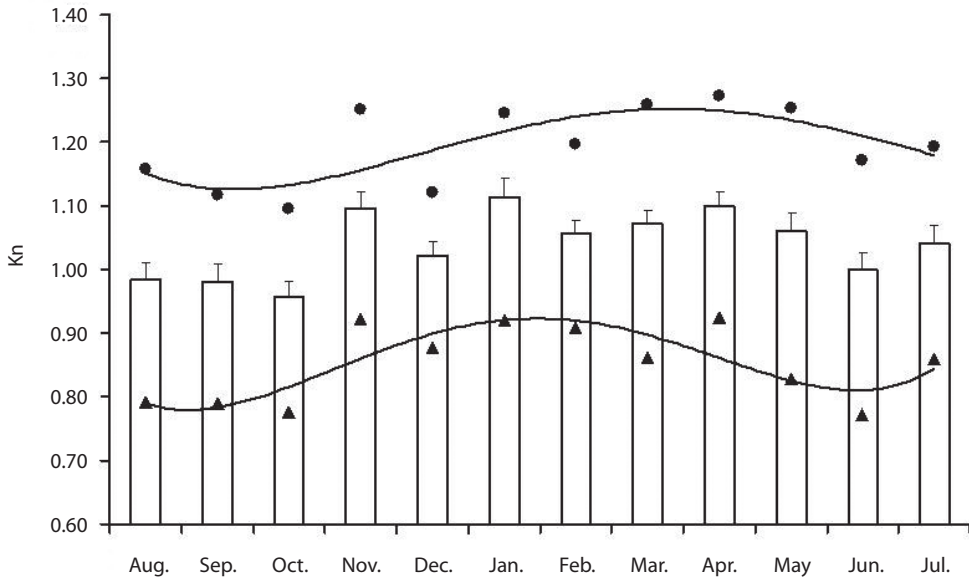


Fig. 2. Monthly index of relative condition (Kn) of *I. fuscus*. Bars indicate mean values +SE. Third and first percentile are indicated by circles and triangles, respectively; Lines show the polynomial regression curve of percentile data.

The relationship between length and weight differs among species according to their body shape, and within a species according to the condition (robustness) of individuals (Cone 1989). Condition sometimes reflects food availability and growth within the weeks prior to sampling, but is variable and dynamic. Individual size varies considerably, and the average condition of each population varies seasonally and yearly. In tropical holothurians, gonad weight is also variable along the year, with the highest values during summer corresponding to maturity stage. The gonad is reabsorbed and grown each year, reaching between 6 and 12% of the total weight (Lawrence 1987, Conand 1990, Smiley *et al.* 1991, Herrero-Pérezrul *et al.* 1999, Horeau and Conand 2001).

The polynomial curve indicates that Kn attains its peak in winter and spring, in correspondence with the initiation of gametogenesis, a process which continues throughout summer when spawning ensues (Herrero-Pérezrul *et al.* 1999). We found that during summer and fall there was more variation in the condition

of the population as specimens had high and low weight related to the mean population value (Fig. 3). This may be an indication of the changes in the condition of the holothurians at the time of gametogenesis and gamete expulsion, respectively. Relative weight has been widely applied to fish species, but does not account for seasonal changes in body condition related to reproduction (Murphy *et al.* 1991). Ideally, a change in relative weight with length would reflect a trend in feeding conditions rather than a seasonal trend in gonad weight. The values of Kn obtained in this study ( $1.040 \pm 0.027$ ), indicates good condition according to Cone (1989) and Jones *et al.* (1999).

Brooding would not occur in large species, because of spatial limitations on celomic space in relation to animal size increase (Heath 1979, Strathmann and Strathmann 1982), resulting in insufficient space for keeping the embryos, according to the allometry hypothesis. This seems to be the case of *I. fuscus*, which is a large species and whose gonad weight represent almost 12 % of total weight. The fertilization is external and they spawn small eggs ( $<150 \mu$

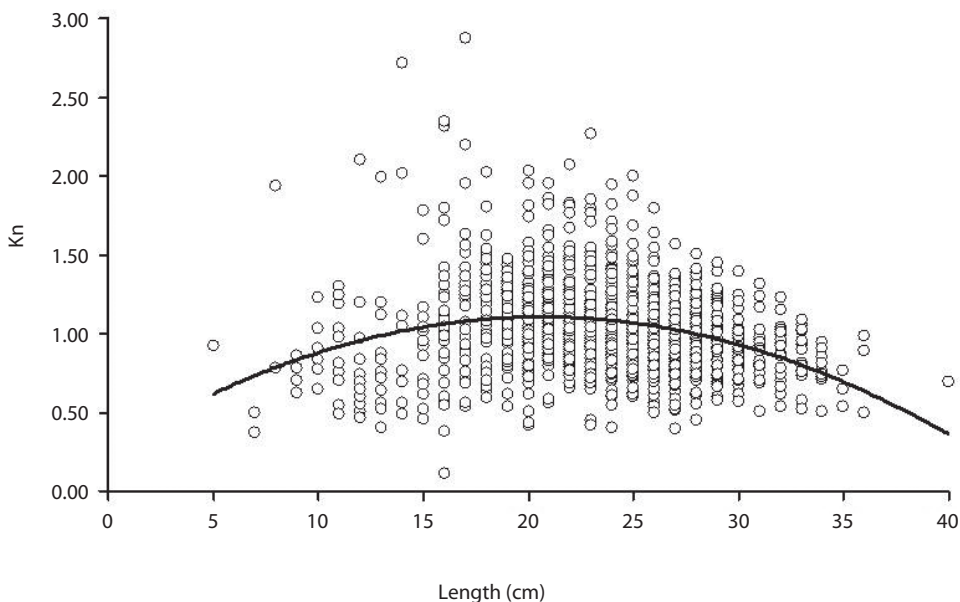


Fig. 3. Relationship between length and relative condition; the second-order polynomial regression curve of the data is shown.

diameter) which develop in to planktonic larvae (Herrero-Pérezrul *et al.* 1998, 1999, Hamel *et al.* 2003).

There are no other studies of the trends in Kn in holothurians, but comparing the mean monthly value of the index with that obtained in fishes (Anibeze 2000) and in sea urchins (T. Herrera Escalante, pers. comm. 2006), it can be seen that the mean is relatively low, indicating that *I. fuscus* do not increase their weight much above expected levels, even when they are reproductively active. Actually, the weight of the female gonad of *I. fuscus* never exceeds 12 % of total weight, and in seven months did not surpass 5 % (Herrero-Pérezrul *et al.* 1999). This could explain why Kn fluctuates so few along the year.

One interesting result was that Kn presented a parabolic relationship with total length and had its highest point coinciding almost exactly to length of first maturity (21 cm or five years, Herrero-Pérezrul *et al.* 1999). Below and above this size, the relative condition of the individuals was lower. This pattern of peak and decline in the relative health also occurs in other species behaving like K strategists, characterized by protracted growth, large size, longevity and late sexual maturity (Jennings *et al.* 1997, 1999). An interpretation of this result is that the Kn show that the "health" of the individuals improves with age up to a point, and then decreases gradually. This may point out that *I. fuscus* shows signs of aging after five years, and would be the first indication of senescence in holothurians. Further studies on Kn and analysis of growth efficiency in aquaria might be useful to test the hypothesis, which has key implications for the management of commercial holothurians worldwide.

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#### RESUMEN

La sobreexplotación de los pepinos de mar a nivel mundial ha promovido la búsqueda de nuevos sitios de captura hacia las costas de América, particularmente México y Ecuador. En estos países, la holoturia más importante es *Isostichopus fuscus*. Aunque existe valiosa información biológica sobre la especie, aún hacen falta estudios relacionados con la condición fisiológica del organismo, como lo es el factor de condición. El objetivo del trabajo fue el de estimar la condición relativa de una población explotada de *I. fuscus* en la Isla Espíritu Santo, Baja California Sur. Durante 1996 y 1997 se midieron y pesaron 1 446 individuos. Para cada mes se estimó la relación peso-longitud y el factor de condición relativa (Kn). Los resultados mostraron que la especie crece de forma alométrica en la zona de estudio. No se encontraron diferencias significativas en el factor de condición a lo largo del periodo de estudio. Los valores más altos se encontraron entre noviembre y abril. Se observó una relación parabólica entre el factor de condición y la longitud total, con un pico a los 21 cm, que corresponde a la edad de primera madurez. Este patrón puede indicar que la condición de los individuos se incrementa con la edad y luego disminuye gradualmente, lo cual puede ser evidencia de envejecimiento en la especie.

**Palabras clave:** pepinos de mar, *Isostichopus fuscus*, holoturias, relación peso-longitud, factor de condición relativa, Golfo de California.

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