A new approach for measuring *Holothuria mexicana* and *Isostichopus badionotus* for stock assessments

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Abstract

Body length and wet and dry weight measurements of *Holothuria mexicana* and *Isostichopus badionotus* collected in shallow water (< 4 m) habitats were assessed. A new approach for measuring length consisted of submerging specimens in cold (~ 8° C) seawater, where they reached maximum contraction in less than 10 seconds. After about a minute, individuals were measured and weighed and then released into their habitat. Our method was compared with that of Yingst (1982), who proposed hand-rubbing specimens until maximum contraction was achieved, in order to measure contracted length. Although there were no significant differences between the two methods (t = 1.65), the new approach resulted in trustworthy body measurements and was adequate for rapid assessment of size distribution in the field. It also diminished the time that individuals were removed from their habitat, and the disturbance caused by handling-related factors. Regression equations correlating biometric characteristics for both species were determined and can be applied to estimate biomass and stock assessment in field studies that do not require sacrificing sea cucumbers.

Introduction

Obtaining accurate body measurements of soft-bodied animals is a difficult task that can lead to biased data. In many invertebrates, weight is often a function of the cube of the length, thus linear measurement errors are magnified when determining weights (Crisp 1990). This situation is evident in holothurians due to their high contractibility (Pérez-Ruzafa and Marcos-Diego 1985; Conand 1990, 1993a), difficulties in distinguishing contracted adults from elongated juveniles (Laboy-Nieves 1997), and the sparse information on their biohistory and behaviour (Cutress 1996).

The sediment feeding sea cucumbers *Holothuria mexicana* and *Isostichopus badionotus* are among the largest and most common holothurians inhabiting shallow waters in the Caribbean Sea. They coexist as conspicuous settlers on seagrass beds, muddy bottoms in mangrove impoundments, and channels and sandy substrates next to coral reefs (Laboy-Nieves 1997; Guzman and Guevara 2002). Their distribution range comprises the circumtropical coasts of the Atlantic (Hendler et al. 1995).

Holothurians have been harvested for centuries in the Indo-Pacific region (Conand 2004; Muthiga and Conand 2006), and there is evidence of population declines and some local extinctions (Samyn et al. 2005). Since the depletion of sea cucumber harvesting grounds in Asia, fishing efforts have focused on the Americas. Uncontrolled exploitation of holothurians peaked during the infamous "Pepino War" at the Galápagos Islands, which drew worldwide attention in 1994–1995 (Conde 1996; Toral-Granda and Martínez 2004). In Mexico, *Isostichopus fuscus* was harvested for more than 10 years before being banned because of the alleged endangerment of the species (Fuente-Betancourt et al. 2001). In Panama, uncontrolled harvesting resulted in overexploitation of the species (Guzman and Guevara 2002). Holothurians — including commercially valuable species — have important functions in nutrient recycling, which increases the productivity of coral reef ecosystems. Removal of holothurians through fishing may reduce the overall productivity of affected coral reefs (Uthicke et al. 2004).

Although a number of authors have reported body length measurements of *H. mexicana* and *I. badionotus*, the available information is mainly restricted to average values. Only Laboy-Nieves (1997) and Guzman and Guevara (2002) have presented a relationship between length and weight of these species that could be useful for field monitoring and stock assessment. However, the authors' main concern is the variety of methods employed for measuring tropical sea cucumbers. This situation presents several dilemmas: 1) it is difficult to establish comparisons, 2) most methods require the mechanical disturbance of specimens, 3) relaxing sea cucumbers after immersion in a $KMnO_4$ solution is very time-consuming, and 4) measuring length underwater may be prone to errors. The aim of this paper is to: 1) provide a simple and cost-effective method for field stock assessment by measuring contracted length of these species, and 2) determine the relationship between length and weight to establish regression equations among those variables.

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Methodology

One hundred individuals from each species were randomly collected by hand during daytime from shallow water (< 4 m) habitats in Morrocoy National Park, Venezuela (10°52'N, 68°16'W, average water temperature around 29° C, Laboy-Nieves 1997). A field balance and calliper were used to measure wet weight and contracted length, respectively. Length was determined by modifying the method described by Yingst (1982). Instead of hand-rubbing specimens to attain maximum contraction (Yingst 1982), length was measured from the mouth to the anal podia through the lateral aspect, after immersing specimens in a bucket of cold seawater and ice. The dorsal aspect was not considered because *H. mexicana* hosts a complex epibiota and other adhered materials (*I. badionotus* did not exhibit epibiota). The ventral ambulacra were not considered because both species increase their arc after attaining maximum contraction. An assay to determine which water temperature triggers the fastest contraction of sea cucumbers was performed, rendering body contractions after about five seconds for water 10° C or less. Both methods were compared.

Specimens were placed in a submerged bucket close to the boat, then immersed individually into the bucket containing cold seawater. Contracted length was measured. Once measured, the echinoderms were released into their habitat. Thirty specimens were sacrificed in order to estimate dry weight after removing visceral tissues and epibiotic material, and oven dried at 80° C for two days. Gutted weight was not considered because specimens were initially sampled for an ongoing study on nutrient content and trace element bioaccumulation. Regression equations were determined by correlating these measurements.

Results

Holothuria mexicana and *Isostichopus badionotus* exhibited significant differences in body size. Nearly 88.8% of *H. mexicana* (wet weight) corresponded to water and fecal material; for *I. badionotus* this value was 95.6%. Table 1 shows the descriptive statistics of the contracted length and wet weight for both species. It was found that the length and weight of *H. mexicana* was 172.1% and 273.7% higher than that of *I. badionotus*, respectively (Table 1). Most specimens (74%) of *H. mexicana* exhibited a contracted length between 20 and 30 cm, while for *I. badionotus*, 77% of the values were between 10 and 20 cm (Fig. 1). Adult individuals (x > 6.5 cm, Cutress 1996) accounted for about 95% of the specimens examined. The only juveniles collected were *I. badionotus*.

All specimens achieved maximum contraction in less than 10 seconds after submersion in cold water. Smaller individuals shrank faster than larger ones. It took nearly one minute to weigh and measure the length of each individual. Once measured, the holothurians were released into their habitat where they resumed normal activities after about 10 minutes. Some individuals (seven *H. mexicana* and four *I. badionotus*) spawned after been reintroduced into warm water.

Table 2 shows the regression equations and correlation coefficients for biometric variables for *H. mexicana* and *I. badionotus*. Contracted length and wet weight were significantly correlated in both species. It was observed that contracted length was significantly and directly proportional to wet and dry weight for *H. mexicana* and to wet weight for *I. badionotus*. In the case of wet and dry weight, only *H. mexicana* exhibited significant differences.

There were no significant differences (ts = 1.65, p = 0.121) after comparing the contracted lengths using Yingst's method and the procedure used by the authors of this paper. Yingst's method requires hand-rubbing individuals until the contracted length is achieved, however, handling can damage the soft epidermis of *I. badionotus*, and is followed by evisceration in some individuals. For *H. mexicana*, hand-rubbing resulted in the removal of epibiota and other marine debris fragments attached to the skin. For the handler, Yingst's method sometimes resulted in minor abrasions and small injuries, because of the hard materials (shells, pebbles, coral fragments) attached to the body of *H. mexicana*. Our method for immersing specimens in cold water was less harmful than Yingst's, because animals were not exposed to handling-related disturbances except for the collection from the substrate.

Discussion

The lack of a standardised method for measuring the length of holothurians, and thus their biomass as required for modelling and stock assessment, presents difficulties for comparing data and following variations. Although each author aims at the most objective data (Pérez-Ruzafa and Marcos-Diego 1985), the variety of methods, and relative complexity of some of them, defeats the attempts of normalisation. Conand (1989), cited by Dalzell et al. (1996), faced several problems in determining linear size measurements of sea cucumbers because of their plasticity. She further preferred using the ratio of wet gonads to drained body weight (Conand 1993a) or weight to express size frequency (Conand 1995). Conand and Byrne (1993) acknowledged that the diversity of techniques used to sur-

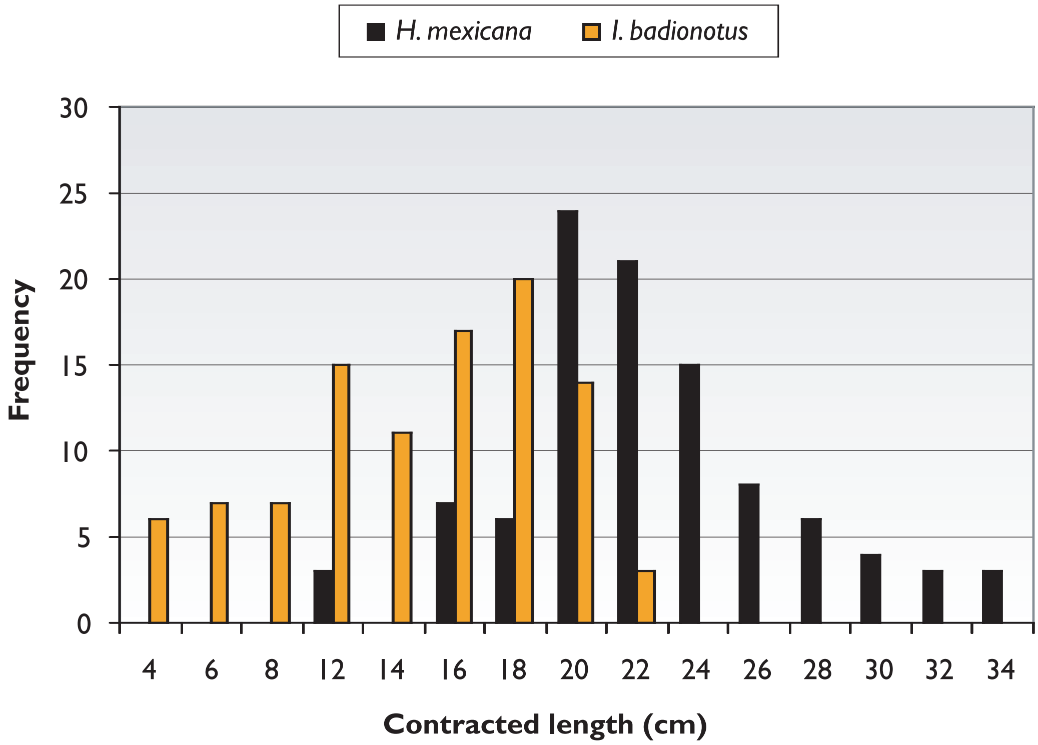

Figure 1. Contracted length distribution of *Holothuria mexicana* and *Isostichopus badionotus* (ANOVA F = 260.37 **).

Table 1. Contracted length (cm) and wet weight (g) for *Holothuria mexicana* and *Isostichopus badionotus.*

	Holothuria mexicana		*Isostichopus badionotus*	
	Length	Weight	Length	Weight
Mean	23.4	561.9	13.61	204.8
(stand. dev.)	(4.64)	(212.3)	(4.26)	(62.3)
Range	12.2–5.6	163–1205	4.1–21.3	79–355

Table 2. Regression equations for the contracted length (CL), wet weight (WW) and dry weight (DW) of *Holothuria mexicana* and *Isostichopus badionotus*. Significant values (0.01 < P < 0.05) are indicated by an asterisk (n = 30, except for contracted length and wet weight: n = 100).

	Holothuria mexicana	*Isostichopus badionotus*
Contracted length and wet weight	CL = 11.514 + 0.021 x WW r = 0.97**	WW = 27.505 + 13.034 x CL r = 0.89**
Contracted length and dry weight	CL = -70.610 + 5.724 x DW r = 0.76*	DW = 4.226 + 0.371 x CL r = 0.24
Wet weight and dry weight	DW = -15.613 + 0.143 x WW r = 0.84**	DW = 1.630 + 0.037 x WW r = 0.54*

vey holothurians limits data comparisons and that adequate statistics should be standardised. Like the authors of this paper, Conand (1993b) established biometric paired relationships between total length and total wet weight, but did not specify the method employed to measure total length.

In the particular case of *Holothuria mexicana* and *Isostichopus badionotus*, Sloan (1979) employed biomass instead of linear measurements. Hammond (1982) measured the average elongated length, Yingst (1982) preferred contracted length after hand-rubbing specimens, Sambrano (1987) anesthetised specimens to further measure maximum elongation, and Guzman and Guevara (2002) submersed sea cucumbers in magnesium permanganate and waited about five minutes to measure elongation.

Yingst's (1982) original method provides a handy approach for rapid monitoring in the field. Although there were no significant differences in the results obtained by our study, our new approach has some advantages over Yingst's because it is simpler, faster, and harmless to the animals and the handler. Only a bucket with cold water is needed for the contraction of specimens, which shrank immediately after immersion. These factors allow for sampling or processing more specimens when time and resources are limited.

With regards to the methods used by Sambrano (1987) and Guzman and Guevara (2002), our method is an improvement, because it does not require exposing sea cucumbers to chemicals. And, unlike Hammond's method (1982), our procedure reduces the time for determining measurements because there is no need to wait for specimens to achieve an average elongated length. Measuring specimens at normal (~ 29° C) sea temperature in tropical areas is difficult because individuals may eviscerate upon handling, show erratic contraction and elongation, and increase their respiration rate (pers. observ.). One benefit of our method is that immersing individuals in cold water triggers an immediate contraction that consequently stops cloacal respiration and provokes the halting of body movements in less than 10 seconds. Therefore, the handling and measuring of specimens is faster and does not require the use of gloves or chemicals to rub or tranquilise individuals. Besides, the typical epibiota of *H. mexicana* was not mechanically altered; nor was the fragile epidermis of *I. badionotus* broken, as happened with Yingst's method, while rubbing the animals. Our method is an improvement for the data collector, because it diminishes the risk of contact with eviscerated materials and fluids, and injuries from rubbing species covered with hard debris, such as broken shells. This method could also be used for harvesting sea cucumbers when there are legal live size limitations.

Bruckner (2005) emphasised that minimum sizes should be based on the size at first sexual maturity. This is advantageous for managing an export fishery, because enforcement can be done at the marketplace. The disadvantage of this approach is that rejected undersized animals are already dead, and represent a loss to the reproductive capacity of the stock as well as an economic loss to fishermen (Richmond 1996). Another disadvantage of using minimum sizes is that this method does not guarantee that the maximum sustainable yield will be harvested, and it does not predict how many sea cucumbers will be harvested. In fisheries managed solely by minimum size, the initial quantities harvested will be large, as all the individuals larger than the minimum size will be subject to harvest. Over time, the largest individuals will become scarce, and the annual fishery will depend on how many animals grow to legal size.

Australia, Papua New Guinea, Fiji and Tonga have minimum size restrictions for the harvesting of sea cucumbers, but their rules are based either on the live or dried length, which technically could be inconsistent. Bruckner (2005) stated that minimum size requires a significant amount of data and the primary burden is placed on fishermen, who must determine if each specimen collected meets the minimum established size requirement, a difficult task when live sea cucumber length is so dependant of the animal behaviour (contracted or relaxed). The method described here (measuring contracted length) could be a practical approach for standardisation of length measurements. Further studies should be conducted to compare contracted length with sexual maturity.

The low size variation found in this study shows that populations of *Holothuria mexicana* and *Isostichopus badionotus* are largely composed of individuals of similar sizes. It has been reported that juveniles inhabit deeper waters or occupy other habitats in shallow waters (Cutress 1996). This could occur because of interspecific and intraspecific competition, predation and availability of food (Laboy-Nieves 1997), marked environmental heterogeneity (Laboy-Nieves et al. 2001), and different physiological responses to pollution (Laboy-Nieves and Conde 2001). For logistical reasons, all specimens were collected during daytime, a period when juveniles may not be active or exhibit cryptic behaviour (Cutress 1996).

The contracted length of each species was significantly correlated to its wet and dried weight. Although there are specific differences in the strength of the relationships of these variables, regression equations can be applied to estimate or predict biomass in studies that do not require sacrificing these animals. However, it is crucial to consider biology as well as statistical significance, because no statistics can relieve our responsibility for the biological conclusions drawn from biometric data.

The fact that all individuals resumed activities around 10 minutes after being released may imply that the 5 second thermal shock did not alter their health. The very few spawnings that were observed after reintroducing the sea cucumbers into warm water is consistent with the thermal stimulation effect reported by Mosher (1982), Baskar (2004) and Laxminarayana (2005).

Members of the Stichopodidae family have been commercially overexploited in South America (Powell and Gibbs 1995). Furtive extraction of *I. badionotus* was observed by the senior author and has been reported by Conde (1996). Therefore, human factors might introduce a bias in field observations of natural populations of any other commercially valuable holothurians. In eastern Venezuela, *I. badionotus*, was the object of supervised exploitation for a brief period, but fishing rights were discontinued due to the scarcity of information relevant to management, such as body size and weight distributions (Buitrago and Boada 1996). These examples illustrate the urgent need to evaluate stocks to assess the sustainability of sea cucumber fisheries.

To promote more reliable data and further establish size classes or categories, the above factors as well as other that could affect body size, for instance gonads development (Conand 1993a), or temperature and dissolved oxygen (Laboy-Nieves 1997), ought to be considered. Meanwhile, the method herein described can prove to be a valuable tool for fast stock assessment of shallow water sea cucumbers. Stock size and indications of stock status are two useful parameters on which to base robust management strategies. These parameters can then be used to indicate future catch levels that allow for sustainable development of the sea cucumber fishery. Management regimes for aquatic species vary in complexity from stock assessment models relying on extensive catch and monitoring data, to the application of relatively simple measures such as closed areas and minimum size limits. Depending on the nature of the resource, an effective management regime may not necessarily require the most extensive and complex measures to be applied to support a sustainable fishery. There is, however, a fine balance between allowing a harvest at levels that are probably sustainable and being precautionary enough to ensure the survival of the species is not at risk.

Acknowledgements

The authors thank Carlos Carmona for his valuable help during bibliographic searches, and Antonio Boada and Edlin Guerra for their field assistance.

References

Bruckner A.W. 2005. Management and conservation strategies and practices for sea cucumbers: p. 1–35. In: Bruckner A.W. (ed). The Proceedings of the Technical workshop on the conservation of sea cucumbers in the families Holothuridae and Stichopodidae. NOAA Technical Memorandum 44. 239 p.

Buitrago J. and Boada J.A. 1996. La pesca de la holoturia *Isostichopus badionotus* en el oriente de Venezuela. Memorias de la Sociedad de Ciencias Naturales La Salle 61:33–40.

Conand C. 1989. Les holothuries aspidochirotes du lagon de Nouvelle-Calédonie: biologie, exploitation. Études et théses. OSTOM, Paris.

Conand C. 1990. The fishery resources of Pacific island countries. Part 2: Holothurians. FAO Fisheries Technical Paper No. 272.2. 143 p.

Conand C. 1993a. Reproductive biology of the characteristic holothurians from the major communities of the New Caledonia lagoon. Marine Biology 116:439–450.

Conand C. 1993b. Ecology and reproductive biology of *Stichopus variegates*: An Indo-pacific coral reef sea cucumber (Echinodermata: Holothuroidea). Bulletin of Marine Science 52(3):970–981.

Conand C.1995. Asexual reproduction by fission in *Holothuria atra*: variability of some parameters in populations from the tropical Indo-Pacific. Oceanologica Acta 19(3–4):209–216.

Conand C. 2004. Present status of world sea cucumber resources and utilization: an international overview. p. 13–23. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J-F. and Mercier A. (eds.). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463. 425 p.

Conand C. and Byrne M. 1993. A review of recent developments in the world sea cucumber fisheries. Marine Fisheries Review 55(4):1–13.

Conde J.E. 1996. Pepinos-do-mar. sobre sushi, sedimentos e cobiça. Ciencia Hoje 20(117):36–42.

Crisp D.J. 1990. Energy flow measurements. p. 284–372. In: N.A. Holme and A.D. McIntyre (eds), Methods for the study of marine benthos. Blackwell Scientific Publications. London.

Cutress B.M. 1996. Changes in dermal ossicules during somatic growth in Caribbean littoral sea cucumbers (Echinoidea: Holothuroidea: Aspidochirotida). Bulletin of Marine Science 58(1):44–116.

Dalzell P., Adams T.J.H. and Polunin N.V.C. 1996. Coastal Fisheries in the Pacific Islands. Oceanography and Marine Biology: an Annual Review 34:395–531.

Fuente-Betancourt M.G., Jesús-Navarrete A., Sosa-Cordero E. and Herrero-Perezrul M.D. 2001. Assessment of the sea cucumber (Echinodermata: Holothuroidea) as potential fishery resource in Banco Chinchorro, Quintana Roo, Mexico. Bulletin of Marine Science 64:59–67.

Guzman H. and Guevara C.A. 2002. Population structure, distribution and abundance of three commercial species of sea cucumbers (Echinodermata) in Panama. Caribbean Journal of Science 38(3–4):230–238.

Hammond L.S.1982. Patterns of feeding and activity in deposit holothurians and echinoids (Echinodermata) from a shallow back-reef lagoon, Discovery Bay, Jamaica. Bulletin of Marine Science 32:549–571.

Hendler G., Miller J.E., Pawson D.L. and Kier P.M. 1995. Sea stars, sea urchins, and allies: Echinoderms of Florida and the Caribbean. Smithsonian Institutions Press. Washington, D.C. USA. 390 p.

Laboy-Nieves E.N. 1997. Factores que limitan la distribución y abundancia de *Isostichopus badionotus* y *Holothuria mexicana* en el Parque Nacional Morrocoy. Doctoral Dissertation. Instituto Venezolano de Investigaciones Científicas. Caracas,Venezuela. 279 p.

Laboy-Nieves E.N. and J.E. Conde. 2001. Metal levels in eviscerated tissue of shallow-water deposit-feeding holothurians. Hydrobiologia. 459(1–3):19–26.

Laboy-Nieves E.N., Klein K., Conde J.E., Losada F., Cruz J.J. and Bone D. 2001. Mass mortality of tropical marine communities in Morrocoy, Venezuela. Bulletin of Marine Science 68(2):163–179.

Laxminarayana, A. 2005. Induced spawning and larval rearing of the sea cucumbers *Bohadschia marmorata* and *Holothuria atra* in Mauritius. SPC Beche-de-mer Information Bulletin 22:48–52.

Mosher C. 1982. Spawning behavior of the aspidochirote holothurian *Holothuria mexicana* Ludwig. p. 467–468. In: J.M. Lawrence (editor), International Echinoderm Conference. A.A. Balkema, Rotterdam.

Muthiga, N and Conand, C. (eds) 2006. Regional sea cucumber project: Proceedings of the start-up workshop, Mombasa Kenya, 26–29 January 2006. 20p.

Pérez-Ruzafa A. and Marcos-Diego C. 1985. Técnicas de recolección y estudio en la clase *Holothuroidea* y generalidades, sistemática, ecología, biología y comportamiento. Anales de Biología 3:13–35.

Powell J.R. and Gibbs J.P. 1995. A report from Galápagos. Trends in Ecology and Evolution 10(9):351–354.

Richmond R.H. 1996. Suggestions for the management of sea cucumber resources in Micronesia. Results of the workshop "A Regional Management Plan for a Sustainable Sea Cucumber Fishery for Micronesia". Technical Report 101. University of Guam Marine Laboratory. 68 p.

Sambrano A. 1987. Actividad sedimentívora de *Holothuria mexicana* e *Isostichopus badionotus* (Echinodermata: Holothuroidea) en bajos de *Thalassia.* Tesis de Licenciatura. Universidad Simón Bolívar, Caracas, Venezuela. 135 p.

Samyn Y., Vanden Spiegel D. and C. Massin. 2005. Sea cucumbers of the Comoros Archipelago. SPC Beche-de-mer Information Bulletin 22:14–18.

Sloan N.A. 1979. Microhabitat and resource utilization in cryptic rocky intertidal echinoderms at Aldabra Atoll, Seychelles. Marine Biology 54:269–279.

Toral-Granda M.V. and Martinez P.C. 2004. Population density and fishery impacts on the sea cucumber *Isostichopus fuscus* in the Galapagos Marine Reserve: p. 91–100. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J-F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463. 425 p.

Uthicke S., Welch D. and Benzie J.A.H. 2004. Slow growth and lack of recovery in overfished holothurians on the Great Barrier Reef: Evidence from DNA fingerprints and repeated large-scale surveys. Conservation Biology 18(5):1395–1404.

Yingst J.Y. 1982. Factors influencing the rates of sediment ingestion by *Parastichopus parvimensis* (Clark), an epibenthic deposit-feeding holothurian. Estuarine and Coastal Shelf Science 14:119–134.