survey period. Chandran's 1988 revised estimated populations of 3.0 million and 0.6 million, respectively, were based on 46 *B. marmorata* in one of seven sites and 7 *A. echinites* in two of seven sites.

The most abundant commercially-valued sea cucumber in the Saipan Lagoon, i.e., excluding *Holothuria atra,* is *Stichopus chloronotus* with a 1996 estimated population of 146,600, with the majority of the individuals present on the lagoon slope of the barrier reef flat and on the barrier reef. One 100 m^2 circle consisted of 14 small individuals, with a mean length of 11 cm, or an estimated population of 384,000 individuals within the 2.74 km^2 of one of the barrier reef habitats. Chandran's 1988 revised estimates of 2.4 million (i.e., 0.080 per 1 m^2) seems high, since he only observed 29 individuals in his seven sites; the 1996 survey documented 42 individuals in 8 of the 20 habitats.

The 1996 population estimate of approximately 20,000 *Actinopyga mauritiana* (surf redfish) in the Saipan Lagoon seems plausible, since this species is mainly found on the seaward reef margin and slope in the surf zone. A total of 15 *A. mauritiana* was counted in one of the 20 habitats, i.e., the edge of the leeward fringing reef off Managaha Island. Only one specimen each of *Holothuna axiologa* and *Holothuria edulis* was found in the lagoon.

The one specimen of *H. edulis* allowed a projection of approximately 900 individuals inhabiting the lagoon; R. Chandran never encountered this species in the Saipan Lagoon during his extended studies.

Since the specimen of *H. axiologa* was found outside of the sampling circle, a population estimate was not prepared. The low estimate of 5,317 *Actinopyga miliaris* encountered in the Saipan Lagoon may be attributed to mistaken identification while counting *Holothuria atra.* The population estimate for *Bohadschia argus* at approximately 6,000 also seems low.

Future surveys should target four species within the Saipan Lagoon, i.e., *Stichopus chloronotus, Actinopyga echinites, Bohadschia marmorata* and *Bohadschia argus.* Population counts of *Actinopyga mauritiana* can be obtained from the commercial harvesters when they initiate harvesting within the confines of the lagoon.

Distribution and abundance of beche-de-mer on Torres Strait reefs

by Brian Long & Timothy Skewes [1]

Introduction

Beche-de-mer is once again an important fishery in Torres Strait after a 50-year lull. Historically it has been a very valuable fishery with annual catches earlier this century sometimes greater than 500 t, and continued to be a prominent fishery up until the Second World War (Shelley, 1985). Torres Strait, a shallow stretch of treacherous reef-studded water situated between Australia and Papua New Guinea, was a wild frontier for pearl and beche-de-mer fishing entrepreneurs at the turn of the last century. This spirit is still evident in the recent gold rush for beche-de-mer in Torres Strait which started on the reefs on the Papua New Guinea side of the border in the early 1990s and has since spread to the reefs on the Australian side (Queensland Fisheries Management Authority (QFMA), personal communication).

One consequence of the enthusiastic fishing has been the recent closure of the beche-de-mer fisheries on both sides of the border because of concerns of overfishing (Lokani et al., 1996; QFMA, pers. comm.). Currently, beche-de-mer is a very important fishery on the PNG side of Torres Strait with catches reaching 192 t dry weight (approximately 3,000 t wet-weight) in 1991 (Lokani, 1996). With the renewed interest on the Australian side between 1,200 to 1,400 t wet-weight of beche-de-mer were collected in 1995 (QFMA, pers. comm.). The fishery at the turn of the last century was based on black and white teatfish (*Holothuria nobilis and H. fuscogilva*) whereas the fishery now is mainly sandfish, *H. scabra*. Over the last couple of years there has been, however, an increasing number of lower valued species such as *Actinopyga* spp. reported in the catch.

Although research on the PNG side of Torres Strait has shed some light on the stock in PNG waters (Lokani et al., 1996), very little is known about the distribution and abundance of beche-de-mer in Australian waters of Torres Strait. The CSIRO Division of Fisheries recently conducted a survey of the marine resources of Torres Strait reefs on behalf of

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the Australian Fisheries Management Authority (AFMA) to map reef habitats and quantify commercial resources. One of the resources sampled during the survey was beche-de-mer.

Torres Strait

Torres Strait has more than 585 reefs ranging in size from 975 m^2 to 165 km^2 covering a total area of 2,426 km^2. Torres Strait has a wide range of benthic shallow water habitats on the reefs and inter reefal areas which are structured by a diverse array of interrelated environmental factors such as water turbidity, sediment composition, freshwater discharge, strong tidal currents and complex bathymetry (Long & Taranto, 1997; Long et al., 1996a).

There are significant patterns in the spatial distribution of substrate types: live coral, soft sediment, rubble, consolidated rubble, pavement and boulders on the tops of the reefs in Torres Strait. The percentage cover of live coral on the reef top, averaged by reef, decreased significantly from the south-east to the north-west corner of Torres Strait whereas seagrass cover on the reefs showed a significant increase (Long et al., 1996b).

Field Survey

The large and conspicuous holothurians on the reefs in Torres Strait were surveyed in February 1995, November 1995 and February 1996. A total of 1,272 sites were sampled on the tops of 46 reefs and 374 sites were sampled along the edge of 44 of these reefs. On the reef top, the primary sampling unit was a 700 m x 700 m square and we subsampled this area with a 20 m x 2 m transect. A grid of potential sample sites centred in the squares were superimposed on all reefs in Torres Strait. For each day's sampling, 50 sites were randomly selected from the complete list of sites and a team of three divers used a small dinghy fitted with a Global Positioning System receiver (GPS) to locate the sites in the field.

At each site on the reef top a diver laid out a 20 m transect line and swam along the line collecting all holothurians within a metre either side of the transect line and placing them in a nylon-mesh divers bag. All holothurians were returned to the surface and individually weighed in the dinghy. For each transect the percentage cover of live coral, seagrass and algae and the relative proportions of the dominant taxa were also estimated. Other variables measured at each site were the percentage cover of the dominant sessile megabenthos and the percentage cover of sand, rubble, consolidated rubble, boulders (>0.5 m) and hard smooth coralline algal.

Consolidated rubble was distinguished from pavement by the presence of reticulated crevices and holes in the substrate. The vertical structure of each site was described as low (0 to 0.5 m), moderate (0.5 to 1 m) or high (>1 m).

On the reef edge, sites were sampled at regular intervals along the edge of the reef. At each site a 4 m wide transect orientated perpendicular to the reef was sampled down the reef slope to the base of the reef or to a depth of 15 m, whichever came first. When sampled this way the average transect length for the reef edge sites in Torres Strait was 40 m. The sites along the edge of the reef were sampled with the same techniques used for the reef top except that information was recorded for every 10 m interval along the transect.

Holothurian distribution and abundance

A total of 2,287 holothurians from 12 commercial species were identified and counted during the survey: three species of high-commercial value (see Conand, 1990), *Holothuria scabra*, *H. nobilis* and *H. fuscogilva*; two species of medium commercial value, *Actinopyga miliaris* and *A. echinites*; and seven species of low commercial value, *Holothuria atra*, *H. edulis*, *H. axiologa*, *Stichopus chloronotus*, *S. variegatus*, *Bohadschia argus* and *B. marmorata*.

The regional distribution of most commercially important species showed strong spatial patterns in Torres Strait. The current target species, *Holothuria scabra*, was only found in central Torres Strait, with highest abundances recorded on the Warrior reefs (Fig. 1).

In contrast, both *H. nobilis* (black teatfish) and *H. fuscogilva*, the other two species with high value, were found in the north-eastern part of Torres Strait. However, whereas *H. nobilis* had a wide distribution and were mainly found on the tops of the reefs in this area, *H. fuscogilva* had a very narrow distribution and were mainly found along the edge of the reef (Figs. 2 & 3). *Holothuria atra*, the most abundant species, was widely distributed throughout Torres Strait (Fig. 4).

At a habitat scale there were significant correlations between holothurian abundance and characteristics of the habitats such as substratum type and seagrass cover. The abundance of *Holothuria scabra* increased significantly with increase in the percentage cover of seagrass ($P < 0.001$).

In contrast, *H. nobilis* were more abundant in areas with higher percentage cover of live coral and coralline algal pavement ($P < 0.01$). *H. fuscogilva* were more abundant at deeper than shallower sites ($P < 0.05$). *H. atra* were significantly more abundant in shallow water ($P < 0.001$) with high cover of soft sediment ($P < 0.001$) and low cover of live coral ($P < 0.001$). The abundance of most of the remaining species were also significantly correlated with one or more of the habitat variables measured.

Holothuria scabra fishery

The current beche-de-mer fishery in Torres Strait occurs mainly on the Warrior Reef complex and is based almost exclusively on *H. scabra*. Size frequency of the population on the Australian side of the border suggested that the breeding year classes (larger than 18 cm total length, 2-years old and older) were heavily depleted whereas the recruiting year class (one-year old) was relatively abundant (Fig. 5a). Fisheries managers were advised that the recruiting year class needed to be protected from over-exploitation to allow the juvenile *H. scabra* to grow to legal size (18 cm) in the latter half of 1996 to spawn in the 1996/97 summer (Long et al., 1996c). On the basis of this information and catch statistics the Australian Fisheries Management Authority imposed a minimum size limit of 18 cm and a total allowable catch of 260 t.

In contrast, new recruits (one-year old) of *H. scabra* were noticeably absent on the Warrior reefs in Papua New Guinean waters (Fig. 4). This fishery has been closed for most of the last four years (Lokani, 1996). The lack of a conspicuous recruiting year class during the present survey means that this fishery will require close monitoring and management for a sustainable recovery. The focus of future research will be on the *H. scabra* stock on the Warrior Reefs as this is the commercially important species now fished. The depleted breeding year classes sampled during the survey indicates that there is a chance that there will be weak larval settlement to the fishery during the summer of 1995/96 . This could be assessed by a survey of the recruiting year class (one-year olds) in early 1997 and this information would shed some light on the stock recruitment relationship which could be used for management arrangements in 1997. If a weak

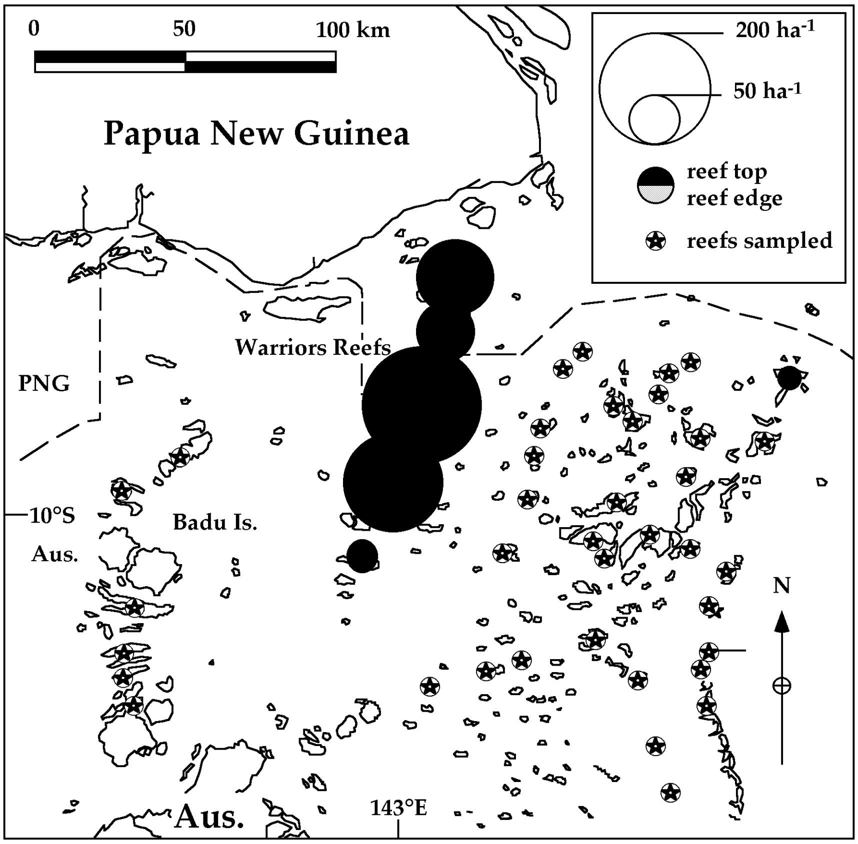

Figure 1: Pie bubble plot of abundance of *Holothuria scabra* (ha^{-1}) sampled on the top of the reefs in Torres Strait (dotted line: international border)

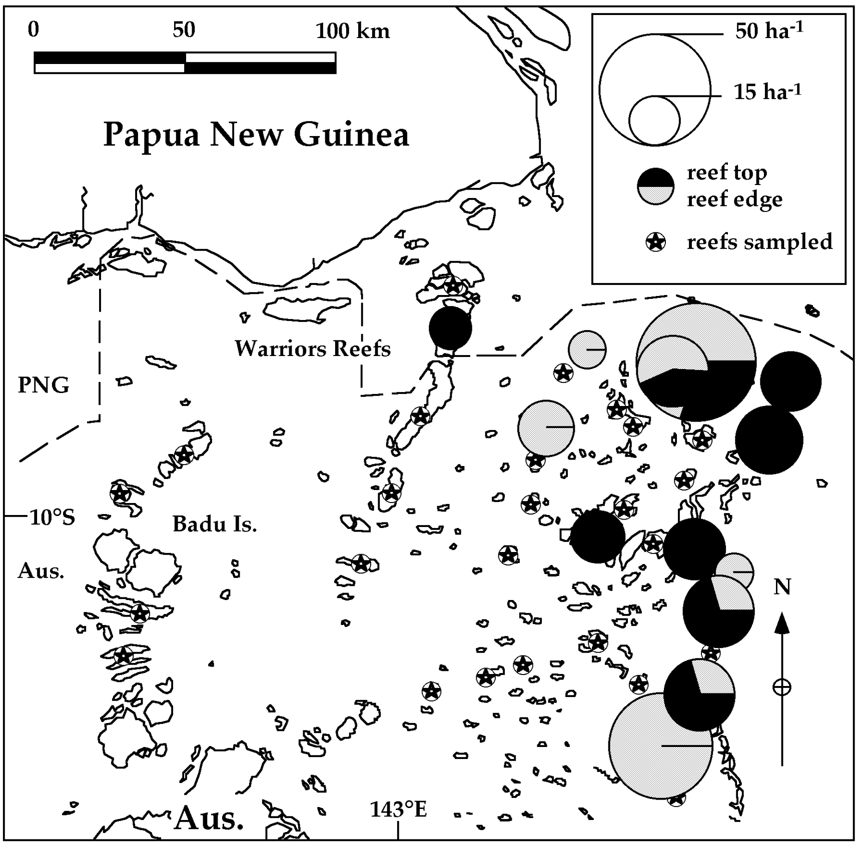

Figure 2: Pie bubble plot of abundance of *Holothuria nobilis* (ha^{-1})

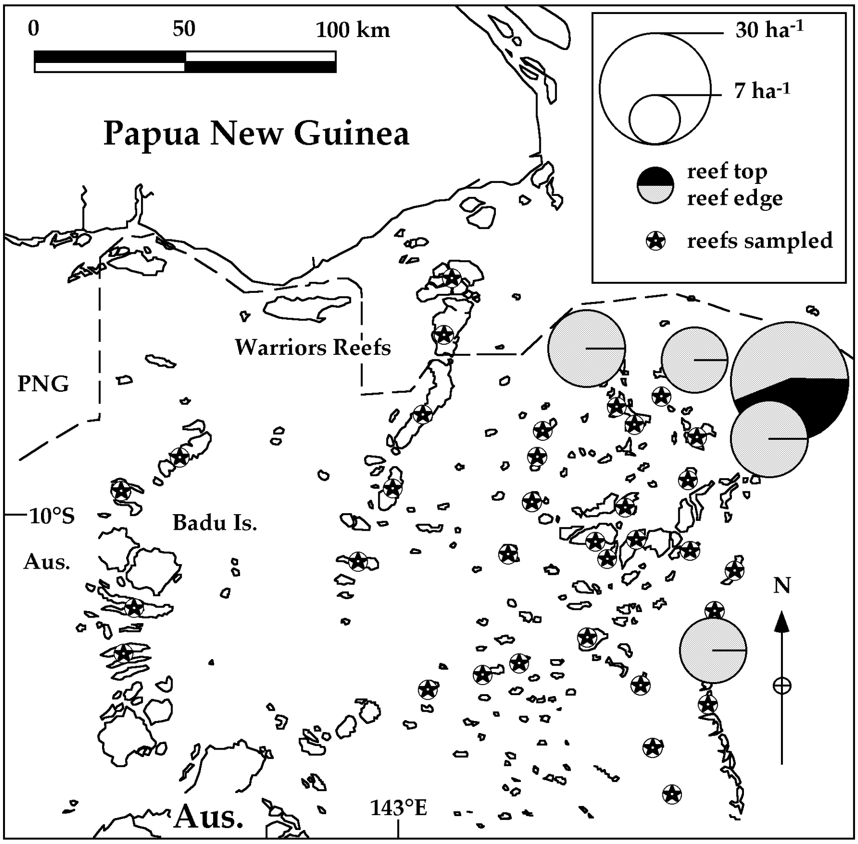

Figure 3: Pie bubble plot of abundance of *Holothuria fuscogilva* (ha-1)

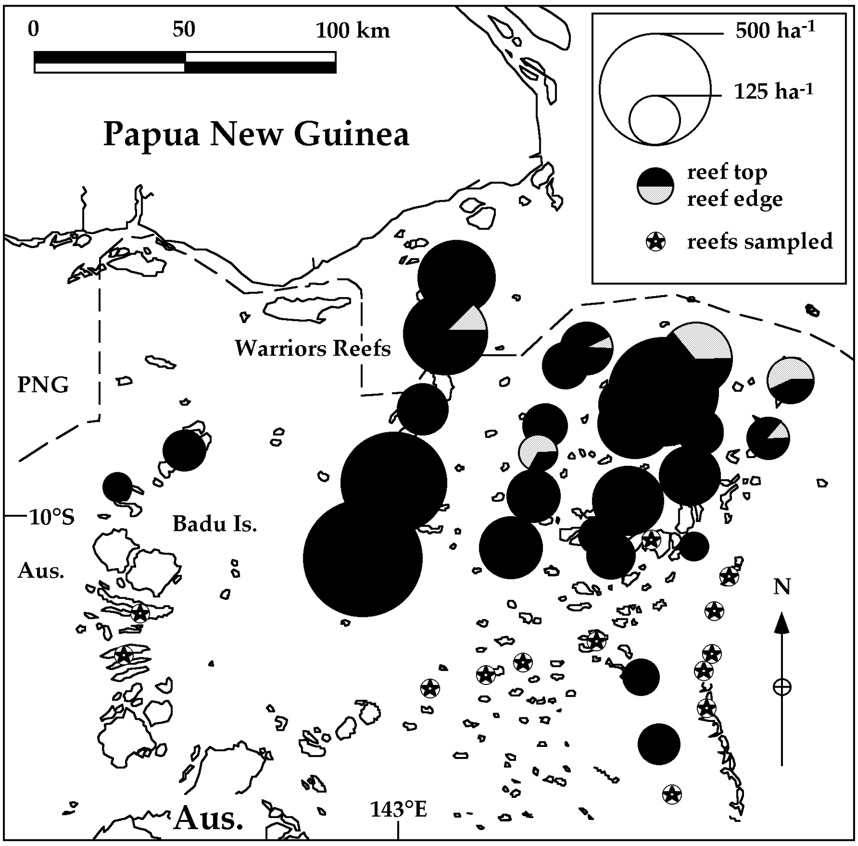

Figure 4: Pie bubble plot of abundance of *Holothuria atra* (ha-1)

recruitment results from this years breeding stock, then further measures such as a lower total allowable catch (TAC) and/or closed seasons may need to be taken to protect the breeding stock in 1997.

Potential new fishery for beche-de-mer in Eastern Torres Strait

The preliminary results of this survey indicates that there are substantial resources of beche-de-mer on the unfished reefs of Eastern Torres Strait principally made up of high-value *Holothuria nobilis*, *H. fuscogilva* and medium-value *Actinopyga miliaris* and *A. echinities*. This resource may provide an important future beche-de-mer fishery for Torres Strait. At present we do not have enough information about the stock to provide useful fishery advice and a full survey is required to assist fisheries managers to develop plans for sustainable exploitation of this resource.

Conclusions

Although the survey did not specifically target beche-de-mer the results have provided valuable ecological and fisheries information for this resource at both the regional and habitat-level spatial scale. There were large scale regional patterns in the distribution and abundance of many of the holothurians sampled in Torres Strait during the survey. A striking example of this was the absence or very low abundance of holothurians on most of the reefs in western Torres Strait whereas holothurians were abundant on the reefs of eastern and central Torres Strait. Only one individual of *Bohadschia argus* was collected from more than 400 sites on the 12 reefs sampled in western Torres Strait between the Australian mainland and Badu Island.

Furthermore, low abundances only of *Holothuria atra* were sampled on the reefs north of Badu Island. We cannot explain this difference in terms of habitat alone as the reefs in western Torres Strait are similar in many respects (e.g. percentage cover of seagrass) to the Warrior reefs—reefs which do have high abundance of holothurians.

Moreover, the correlations between habitat characteristics such as seagrass cover and substrate type and holothurian abundance, although significant, were generally low (Pearson's R < 0.3). Thus factors other than habitat type are also important for explaining the regional patterns in distribution and abundance. One hypothesis being investigated is that the differences are due in part to the relationship between larval source, supply and delivery (supply side ecology) and the complex tidal hydrological system experienced in Torres Strait (Skewes & Long, in prep.).

The significant correlations of most species of holothurians and habitat variables do, however, match up with research findings elsewhere. In Torres Strait, *Holothuria scabra* was found mainly on the Warrior reefs that are influenced by terrigenous sediments carried into Torres Strait by large rivers on the adjacent Papua New Guinea mainland. *H. scabra* have been shown to prefer reef flat areas with a high terrigenous influence (Conand, 1990).

Also, *H. nobilis* in Torres Strait had a wider distribution and a shallower mean water depth than *H. fuscogilva*; a finding also reported for other areas by Conand (1990). Moreover, *H. fuscogilva* was found on reefs at the eastern edge of Torres Strait in an area under the oceanic influence of the Coral Sea. *H. fuscogilva* in particular is usually found in reef passes that have a high oceanic influence (Conand & Chardy, 1985; Conand, 1990).

In both Torres Strait (this study) and other tropical reef systems, *H. atra* has a widespread distribution (Conand 1990). The survey of the Warrior reefs of Torres Strait also provided very useful information for fisheries managers. The results indicated that there were important differences in the size structure of the population of *H. scabra* fished on the Australian versus the Papua New Guinean sides of the border on the Warrior reefs. These differences are most easily explained in terms of differences in fishing pressure; Papua New Guinea has been fishing beche-de-mer on the Warrior reefs for a longer period than Australia. There is little evidence today that the fishery has recovered despite the extensive closure periods on the Papua New Guinea side over the last four years.

The information from the survey is being used by fisheries managers to prevent a similar occurrence in the Australian fishery. Without these data the managers may not have been able to halt the rapid decline of beche-de-mer stocks from over-fishing using catch statistics alone, as shown by what happened on the Papua New Guinea side of the border and in other tropical nations (Conand, 1990).

The broad scale patterns of distribution of many species of commercially important holothurians combined with the significant correlation of abundance with characteristics of the main habitats of Torres Strait reefs provides powerful information for designing cost-effective sampling programmes to estimate the standing stock of beche-de-mer in Torres Strait.

Stratification of the reef top based on reef and dense seagrass habitat for the Warrior reef complex improved the precision of the estimate of the abundance of *Holothuria scabra* (sandfish) by 38 per cent, because there was a significant difference in the abundance of *H. scabra* between reefs, and also because there was a significant correlation between the abundance of *H. scabra* and the percentage cover of seagrass (Long et al., 1996c).

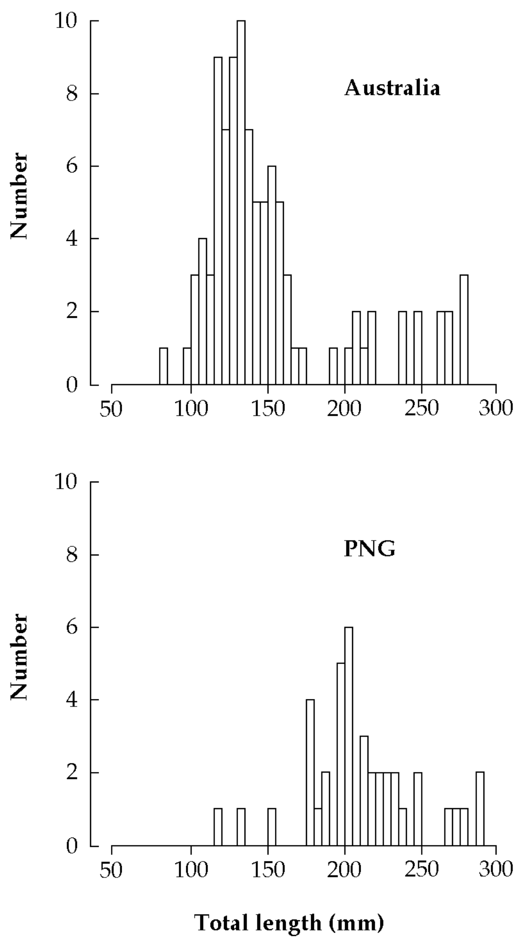

Figure 5: Length frequency distributions for the sandfish *Holothuria scabra* collected in Australian waters and Papua New Guinea (PNG) waters on the Warrior Reef complex. Total lengths were derived from wet weight using a biometric relationship total weight versus total length, given by Conand (1990).

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Total catch by species of beche de mer for the Queensland east coast fishery, July 1995 – June 1996

Information given by the Queensland Government and sent by Robert Lowden, President of the East Coast Beche-de-mer Industry Association (QECBIA). Please note that this information does not include the Torres Strait, 10°41'S to the Papua New Guinea border.

Month	Black teatfish	Sandfish	White teatfish	Prickly redfish	Black lolly	Deep water redfish	Other	Total (kg)
Jul. 95	5,346	3,810	32	556	0	0	64	9,808
Aug. 95	6,294	3,659	32	556	0	0	54	10,595
Sep. 95	7,809	3,433	33	558	0	0	55	11,888
Oct. 95	9,518	1,511	90	378	66	0	235	11,798
Nov. 95	24,544	3,270	43	605	88	13	455	29,018
Dec. 95	6,434	1,117	80	1,179	0	14	186	9,010
Jan. 96	14,294	3,474	0	114	0	9	0	17,891
Feb. 96	23,329	4,729	25	1,546	0	0	741	30,370
Mar.96	22,373	935	230	492	0	13	405	24,448
Apr. 96	25,036	7,798	188	3,192	0	23	725	36,962
May 96	13,483	8,081	69	397	0	36	180	2,246
Jun. 96	15,451	5,779	1	0	0	0	0	21,231
Total (kg)	**173,911**	**47,596**	**823**	**9,573**	**154**	**108**	**3,100**	**235,265**