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ALAIN BODOY*

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ABSTRACT

A reprint from

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ABSTRACT

A quantitative, ecological study was carried out on several populations of the bivalve *Tridacna maxima*, in order to assess the changes due to the collection of this species. Four transects were made across fringing reefs which differed from their accessibility, but exhibiting the same orientation and wave exposure.

In an undisturbed area, the number of individuals found along a transect was 63, the average length, 134 mm and the biomass, expressed in dry weight of tissues and related to one metre of shore, 88 $g.m^{-1}$. In seldom utilized area, those parameters were 19 individuals, 113 mm and 18.6 $g.m^{-1}$ respectively, while, in an area subjected to intermediate exploitation, 40 individuals were found, with an average size of 69 mm and a biomass of 5.7 $g.m^{-1}$. At a highly utilized beach, only 6 individuals were found, with an average length of 82 mm and a biomass for one metre of shore of 1.5 $g.m^{-1}$.

The effect of such human impact is discussed, according to the ecology and the biology of this species.

(*) Permanent address: Laboratoire Cultures Marines IFREMER B.P. 190,17 390 La Tremblade, FRANCE.

INTRODUCTION

Among the different species of invertebrates colonizing coral reefs in the Indo-Pacific area, the giant clams of the genus Tridacna are a dominant feature of the shallow waters were they are living (Rosewater, 1965). They are probably the largest bivalves which have ever existed, and the Pacific species, T. gigas, can reach one metre in length. From a biological point of view, their association with symbiotic algae, which was studied by several authors (Yonge, 1936; Jaffrey and Haxo, 1968; Goreau et al., 1973 and others), enables us to consider species of the genus Tridacna as phototrophic, primary producers. Indeed, the metabolism of the zooxanthellae contributes to their nutrition (Ricard and Salvat, 1977).

They are also of an economic interest, since they are eaten in many countries and the adductor muscle has a very high commercial value in South-East Asia (Munro and Gwyther, 1981). Some attempts were made to evaluate their aquaculture feasibility (Beckvar, 1981; Munro and Heslinga, 1983), and the possibility of rearing of tridacnid's larvae (La Barbera, 1975; Jameson, 1976; Gwyther and Munro, 1981).

In spite of being essentially reef-top inhabitants, relatively few works have been carried out on their growth, population size and biomass (Salvat, 1971; McMichael, 1974; Richard, 1977 and 1981; Alcala, 1981; Beckvar, 1981).

Along the coasts of the Red Sea, two species are usually found, T. maxima and T. squamosa (Hughes, 1977; Mergner and Mastaller, 1980), the first one being the most abundant. These species are submitted to heavy exploitation in the vicinity of Jeddah, Saudi Arabia, and they are often collected on the reef flat, both for food and for decorative purposes.

The present study aims to assess on quantitative basis the human impact on *T. maxima*. Therefore, abundance and biomass were estimated for several populations of this species living in areas differing for their accessibility. Similar studies, following the same goal, have been carried out on corals (Antonius, 1984) and on fishes (Oakley, 1984).

MATERIALS AND METHOD

The analysis of different populations of *T. maxima* has been carried out using a transect technique. Four different transects were studied in sites differing in the extent to which they are affected by human impact (Fig. 1). The site located North of the port of Tuwwal, because of its military importance, is strictly protected by the coast-guard, and may be considered to be an undisturbed area. The second site studied is about 180 km South of Jeddah. Both the distance and the state of the road leading to it make its access difficult. A third site was on the reef, North of Sharm-el-Abhur, which is one of the favourite beach spots for Jeddah people during week-ends, and the last transect was studied on Jeddah northern Corniche, 3 km North of the desalination plant. The latter area, turned into an artificial beach, is very popular, due to its easy access. Since this work was carried out, a development scheme on the reef flat has destroyed the studied area.

Each transect consisted of a band, 10 m wide, across the reef flat, from the shore-line to a depth of 2 m at the beginning of the outer slope. Along each transect, all the individuals of *T. maxima* were counted and the maximum antero-

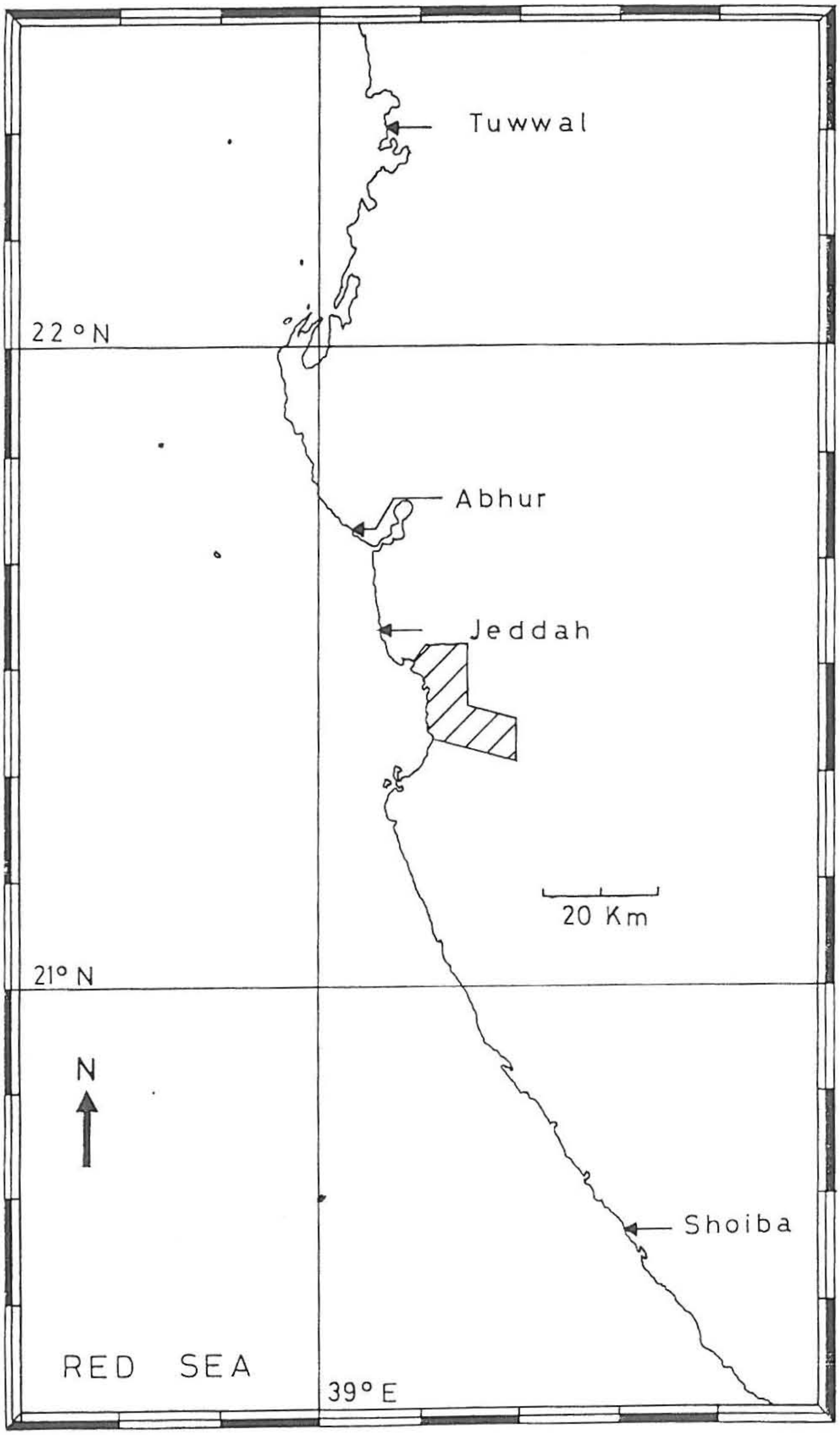

Figure 1. Location of the four transects along the coasts of the Red Sea.

posterior length measured with a margin of error of ± 2 mm. The transect was divided into five metres wide sections, each of 50 m^2 area.

About 20 individuals, chosen as so to cover the whole span of length found in the field, were also sampled in order to establish the relationships between length and weight leading to measures of biomass. For that purpose, the specimens were drained, to obtain a total weight accurate to 0.01 g, and then opened. The flesh was weighed to obtain the fresh weight and then dried for 24 hours at 85°C and reweighed, to get the dry weight. The logarithmic relationships between length and total weight, fresh weight and dry weight were calculated using regression techniques. The values of biomass were then calculated for each unit area of 50 m^2. To improve on the accuracy of these quantitative data, additional perpendicular transects were carried out in areas of high density, such as the edge and the inner flat, near the algal crest.

Length-frequency distributions of the clams were calculated by including all the animals for each main transect.

RESULTS

The constants in length-weight relationships are shown in Table 1. Using these coefficients, the dry weight of each animal was calculated from its length. Fig. 2 shows the results for the undisturbed area of Tuwwal, including the number of individuals obtained for each unit area of 50 m^2 along the transect, the biomass (dry weight) of T. maxima corresponding to each unit area (in $g.m^{-2}$), and the depth profile of the reef flat.

From a morphological point of view, the reef flat neighbouring the shoreline is composed of a sandstone tile,

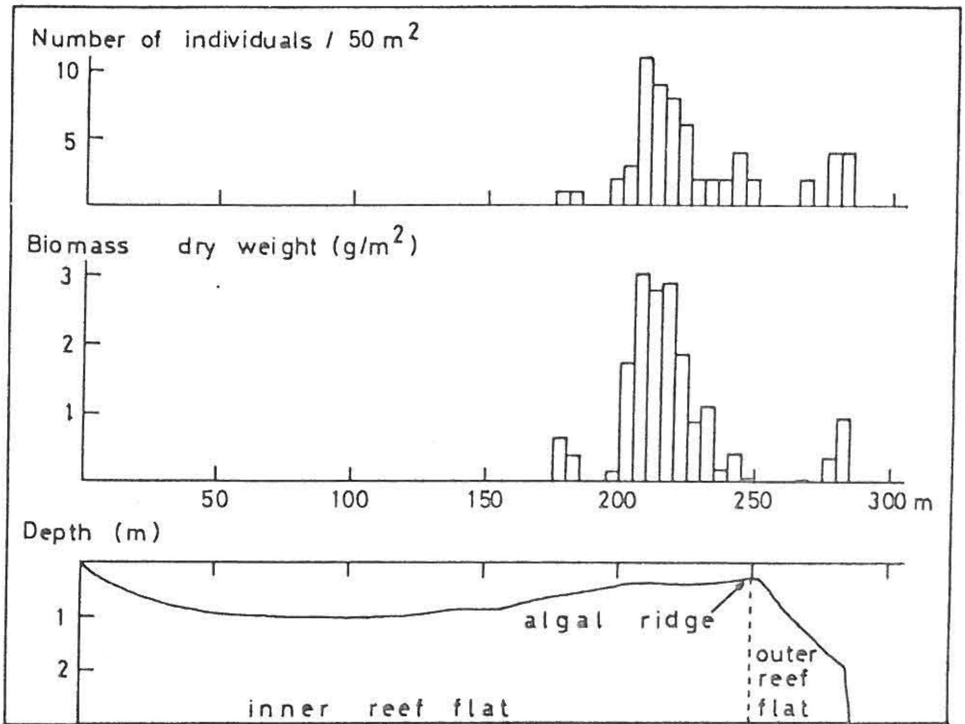

Figure 2. Abundance and biomass of Tridacna maxima along a transect across the reef flat in the undisturbed area (Tuwwal).

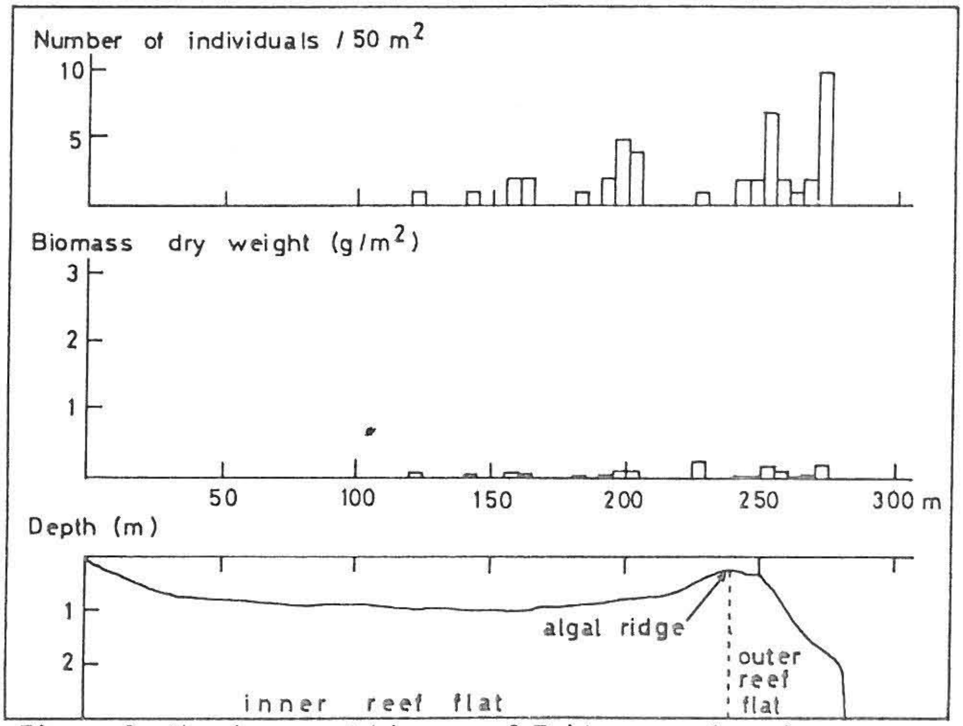

Figure 3. Abundance and biomass of Tridacna maxima along a transect across the reef flat in a slightly disturbed area (Shoiba).

slightly covered with silt, and is populated with Caulerpa racemosa, which first is scattered and then becomes more numerous as one gets nearer the end of the sandstone tile (150 m). Rocks, unevenly scattered and surrounded by sandy patches, were then found, as were the first T. maxima. Further towards the open sea, rock formations become denser while C. racemosa disappears. The highest densities of T. maxima were found in this zone, between 200 to 240 m from the shore. Further on, a very dense belt of seaweeds (Sargassum sp.) is located at the top of the algal ridge (Fig. 2), as defined by Battistini et al. (1975), and no T. maxima were found there. However, at the end of the outer reef flat (Fig. 2), individuals were settled. The external slope, not studied here, was sometimes inhabited by scattered, large individuals.

The total number of individuals found along this transect was 63, the majority of which were on the reef flat. The largest one measured 23 cm, and the smallest, 6 cm. The average size for the whole of the transect was 13.4 cm, whereas for individuals from the inner reef flat (Fig. 2), betwen 195 and 250 m, it was 13.6 cm. The average size of those living beyond the ridge was 11 cm. The highest biomass was 3.06 $g.m^{-2}$.

If one considers a band of one metre width, perpendicular to the shore, the biomass can be expressed in grams per linear metre of shore, which allows a comparison between fringing reefs which are not of the same extension. For the Tuwwal site, the biomass of the population of T. maxima was 88.12 $g.m^{-1}$ of shore.

The fringing reef located South of Shoiba (South of the desalination plant for Makkah city), is different in various ways. Its width is greater (505 m) and for the first 200 m from

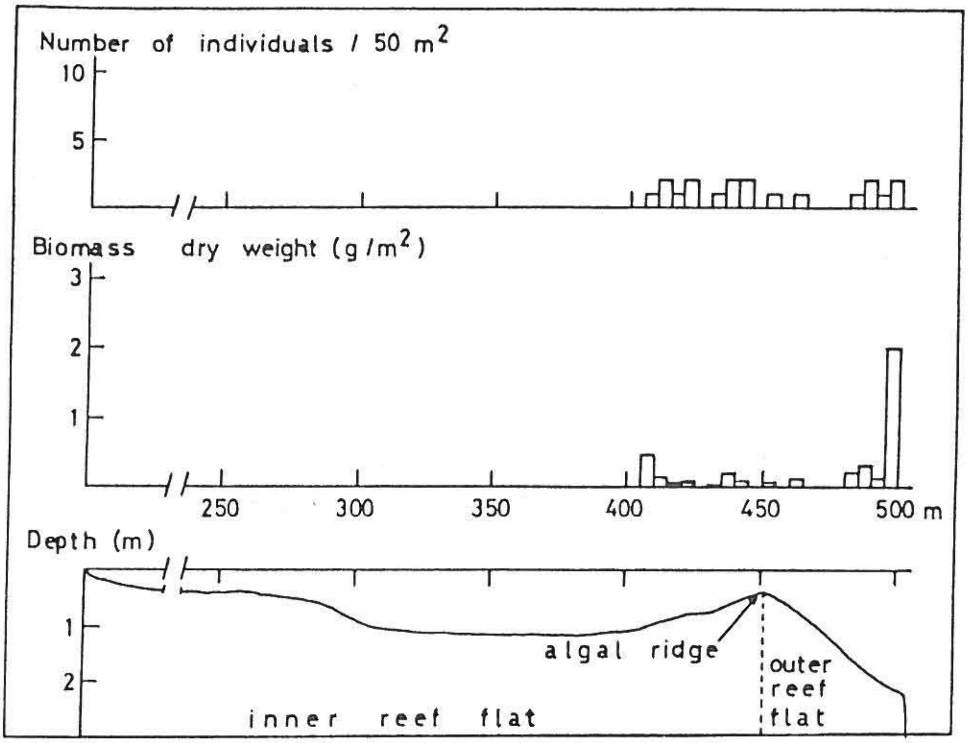

Figure 4. Abundance and biomass of <u>Tridacna maxima</u> along a transect across the reef flat in a visited area (Abhur).

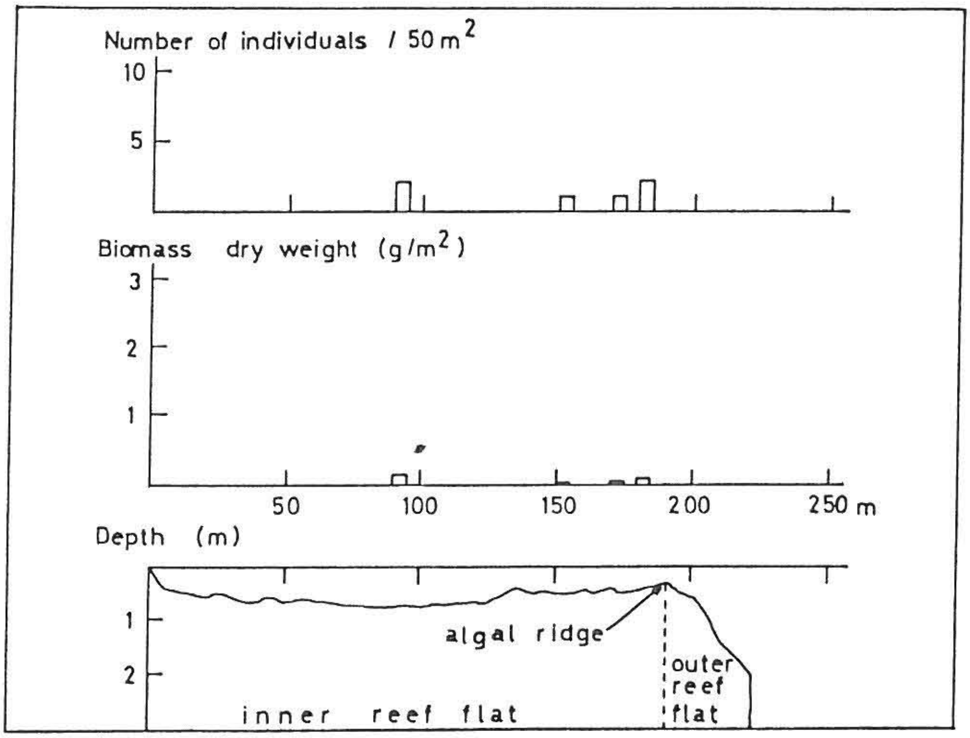

Figure 5. Abundance and biomass of <u>Tridacna maxima</u> along a transect across the reef flat in a heavily disturbed area (Jeddah).

Table 1. Coefficients for the linear relations, $(y = ax + b)$ between the logarithm of the length (y) in mm and the logarithm of the different weights (x) in g. Number of samples = 20. a = slope of the straight line. b = intercept. r = correlation coefficient.

	a	b	r
Total weight (live animal)	3.8043	-1.5834	0.9914
Fresh weight (organic tissues)	3.0739	-1.7238	0.9639
Dry weight (organic tissues)	3.2237	-2.5890	0.9715

the shore, there is a zone of intense sedimentary accumulation, with a large proportion of fine particles. This fine substratum has not been colonised by seaweeds. At 300 m, a population of green filamentous algae (cf. *Enteromorpha*) appears. The algal belt of *Sargassum* is absent and is replaced by a population of *Turbinaria cf. triquetra*. The outer fringing reef consisted of patches growing from a step 15 m deep, whereas, in the other locations, the reef flat ended with a precipitous slope.

The distribution of the number of individuals and the biomass along the transect are shown in Fig. 3. The population of *T. maxima* was concentrated over the last 100 m of the transect, and only 19 individuals were found. The *Enteromorpha* zone had particularly few clams. The average length of this was population was 11.3 cm, but some individuals were up to 25 cm long. The average biomass per linear metre of shore was 18.6 g.m^{-1}, and the highest biomass (2 g.m^{-2}) was found on the outer flat of the fringing reef.

The third transect was carried out on a popular beach, a few kilometers North of Abhur creek. The width of the fringing reef was 275 m. After a zone of back reef, composed of a sediment of a fine sand covering a flagstone, there were populations of the algae Padinia pavona and C. racemosa (Fig. 4).

The first individuals of T. maxima were found at 120 m from the shore. On the top of the algal ridge, where a very dense belt of Sargassum sp. was located, only one individual was found. The total number of individuals was 46 over the whole transect, while the biomass, expressed in grams per linear metre, was 5.7 $g.m^{-1}$. All the individuals however, were very small, with an average length of only 6.9 cm. The largest individual measured 14 cm. Apparently, the distribution of the animals along the transect was not size-related. The highest densities were found on the outer edge, and just after the algal ridge on the outer reef flat. The highest biomass was 0.16 $g.m^{-2}$.

The last transect, carried out on the North Corniche in Jeddah, was 285 m long (Fig. 5). For the first 50 m, the bottom was made of a flagstone covered with a very fine coat of silt and blue-green algae. Further on, the algal cover consisted in the main of P. pavona, T. cf. triquetra and C. racemosa. The belt of Sargassum sp. was well developed. The coral populations were recovering slowly after having been heavily choked up with mud, when the Corniche Road was built two years ago (Antonius, pers. comm.).

The population of T. maxima was very scattered. The absence of valves from dead individuals leads one to think that the small size of the population was not due to a mortality resulting from the mud. Only 6 individuals were found, averaging 8.2 cm in length, the largest one measuring 11 cm. The biomass per linear metre of shore was the lowest of the four transects:1.5 $g.m^{-1}$ The highest biomass was 0.14 $g.m^{-2}$.

Figure 6 shows the quantitative data for the population of the four studied areas. The average biomass indicates that these four areas can be classified in the same way. The low number of individuals found in Shoiba can be related to the presence of

Enteromorpha sp., which usually indicates either natural or man-induced alterations in the quality of the marine environment. The average size of the populations from Abhur and Jeddah varies only within 5%.

The analysis of those different populations carried out using criteria of density (number of individuals per 50 m^2), of longevity (average size of the population), and of standing stock (dry weight) enables a classification of these populations to be obtained, corresponding to the order established in term of their accessibility. Since T. maxima is a sessile species, it is likely that its scarcity in the most visited areas is mainly due to excessive collection.

The analysis of length-frequency distributions for the four transects (Fig. 7) leads to confirm these results. Big individuals, larger than 15 cm, were found on the undisturbed reefs of Tuwwal and to a smaller degree, of Shoiba. In both sites, the distributions are polymodal. In the two other areas, only individuals smaller than 15 cm were found, and the shape of the distribution is much simpler. In Jeddah, the number of T. maxima found along the transect is too low to allow any comments on a preferential exploitation size, but the large number of young individuals found in Abhur transect clearly indicates a size-dependant collection upon the largest animals.

DISCUSSION

Much attention has been paid to the symbiotic relationships between the zooxanthellae and tridacnids. But few studies have been carried out on the ecology of related species. The density of T. maxima can reach up to 224 individuals per square metre, in the atoll of Reao (Salvat, 1972), but this species may be scarce in other atolls (Salvat, 1971). McMichael (1974) found

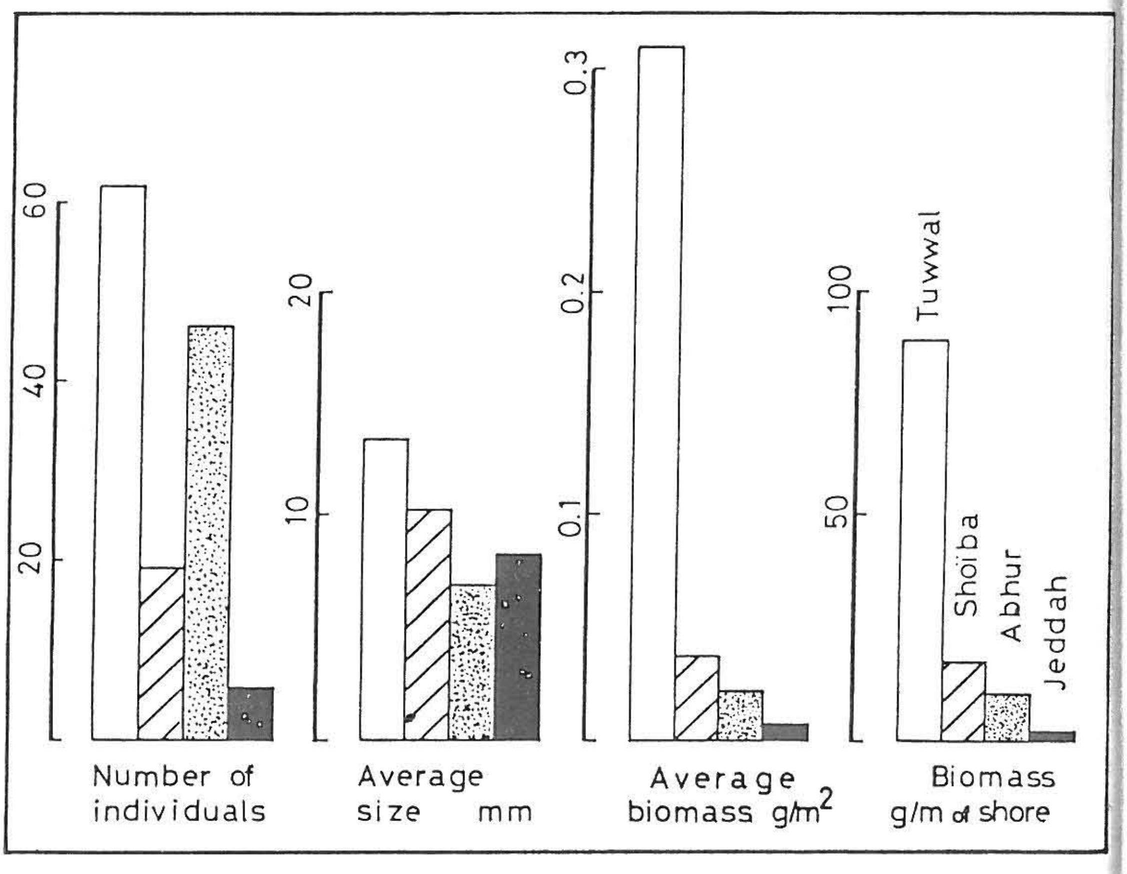

Figure 6. Abundance of <u>Tridacna maxima</u>, average size, average biomass in $g.m^{-2}$, and average biomass for one metre shore in $g.m^{-1}$ for the four sites.

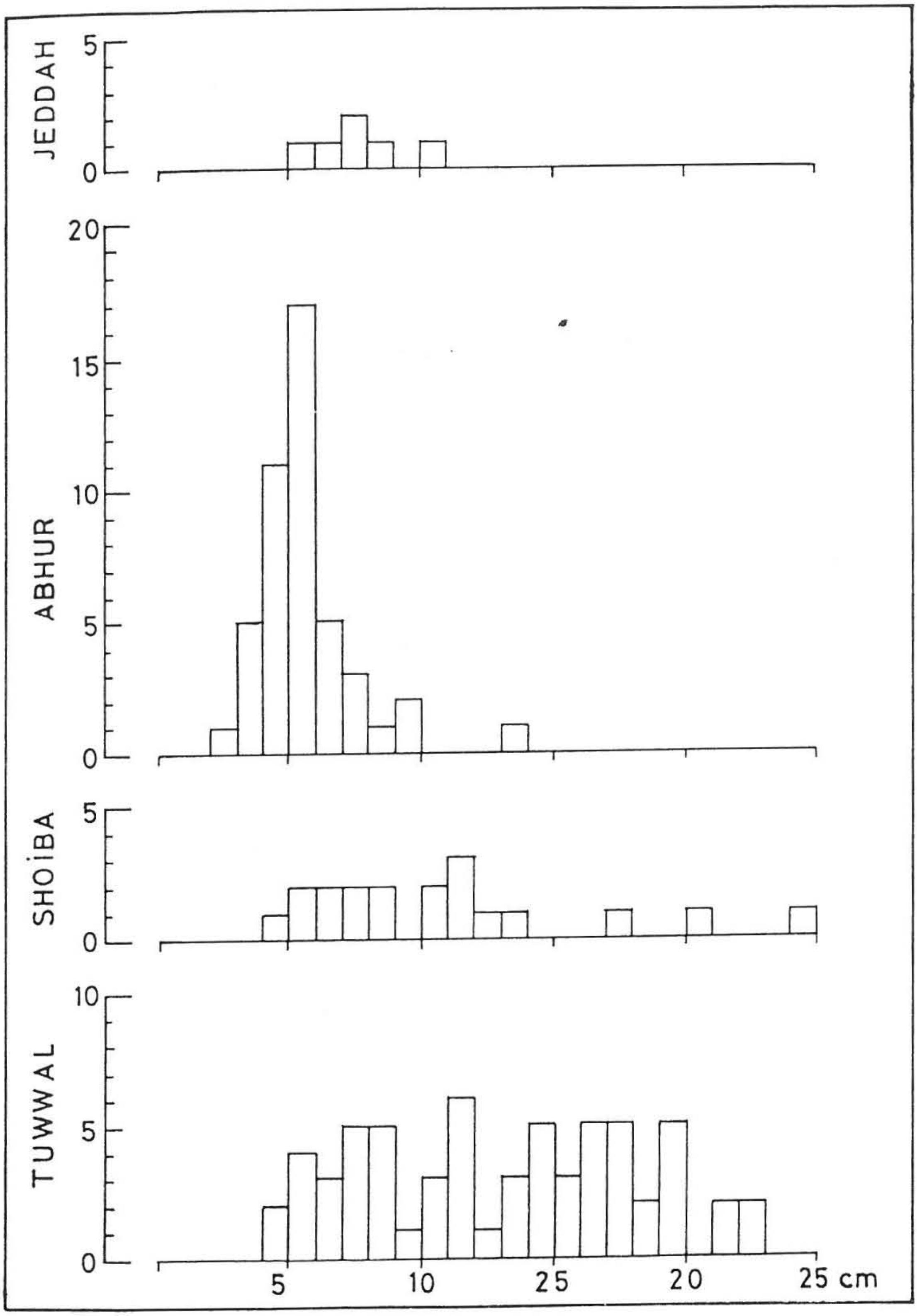

Figure 7. Length-frequency distribution of Tridacna maxima for the four studied sites.

an average density of 0.8 T. maxima per square metre, at a site on the Great Barrier Reef.

These densities are higher than in our study, since the highest density recorded was 0.22 individuals per square metre, in Tuwwal. In the Pacific Ocean, T. maxima often settles in the shallow waters of lagoons, e.g. in the atoll of Takapoto (Richard, 1977). In the Red sea, settlement in sheltered, shallow waters close to the shoreline was not recorded in any of the four transects. This and the low average density can be explained by the peculiarities of the Red Sea coasts. During the winter, cold winds can lower the water temperature on the shallow, inner reef, sometimes down to 11°C (Hughes, 1977), which could be a letal temperature for many tropical species. On the other hand, loose sediments, acted by waves, might limit settlement of Red Sea populations.

The exposure can affect the quantitative distribution of T. maxima. Salvat (1970) encountered this species on the windward side of the barrier reef of Gambier Islands, but not on the other, sheltered, leeward side. In our case, for all the transects, the reefs showed similar, North-South orientation, and received the prevailing winds from the same direction. Therefore, these ecological factors should not affect the results.

Only very few empty shells were found, and since these were always large, one can assume that most of the mortality is mainly due to collecting. This collecting rate seems to vary with the difficulty of access. Several authors have estimated the asymptotic length (l_∞), corresponding to the average maximal size in the growth equation of Von Bertalanffy, for different areas. These data are summarized by Munro and Hesling (1983). The values are ranked from 12.4 cm from a population coming from an atoll of French Polynesia (Richard, 1977 and 1981), to 30.5 cm in New Guinea (Munro and Gwyther, M.S). Other values of this estimated asymptotic length are 24.3 cm (Munro and Gwyther, 1981), 27.5 cm (McMichael, in Munro and Heslinga, 1983) and 30.5 cm (McKoy, 1980, in op.cit.) For all these populations, the longevity was more than 20 years. Assessments on such longevity, based on shells rings counts, agree with such results for Red Sea populations (unpubl. data). In these localities, the asymptotic length was calculated to be within 20-23 cm, if the transect of Shoiba was excluded, were individuals up to 25 cm were observed. According to Rosewater (1965), the maximal recorded length is 35 cm.

The growth equations given by McMichael (1974), Munro and Gwyther (1981) and Richard (1981), indicate that T. maxima would reach a length of 12 cm in 6-13 years. Therefore, to regenerate an overcollected population to a normal level (e.g. in Tuwwal), will take many years, once collecting stops.

Another problem, related to the reproduction, has to be mentioned. T. maxima is a protandric hermaphrodite. Richard (1982) gave the following scheme for a Polynesian population: sexual maturity is reached for a size of 5 cm; after a male phase, up to 7 cm, simultaneous hermaphrodites form the population between 7 and 15 cm. The larger individuals would have only female gonads. But, for most of the other populations, those large animals remain simultaneous hermaphrodites. According to Jaubert (1977), T. maxima can reach a depth of 15 m, after which there is not enough light for the zooxanthellae to photosynthesize. These specimens have often a large size, and such big individuals were observed in the four localities, after the end of the transects, deeper than 2 m. It seems that very few bivalves are collected deeper then the edge of the outer reef flat, were they are only accessible by diving.

This preserved stock of large tridacnids should allow to avoid any long-term disappearance of the species by over-collecting, as long as it remains untouched.

ACKNOWLEDGEMENTS

I would like to thank Dr. J.L. Munro, both for his scientific comments and for suggesting improvements of the English language.

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