5. HOLOTHURIAN RESOURCES

The exploitation of marine resources in the South Pacific was traditionally a subsistence activity. The arrival of the explorers led to an expansion in fishing for various species to be traded on outside markets. The tonnages yielded by these artisanal activities were however very irregular, being dependent on political, social and economic factors such as wars, mining booms and recessions. Some countries have recently expressed the wish to develop this traditional artisanal sector, but their isolation often hinders the development of a fishery because of the complications raised by commodity storage and transport. After processing, bêche-de-mer can however withstand a long storage period if it is kept in a dry place. This renewed interest has led to a demand for estimates of available resources and their renewal rate.

5.1 Resource assessment methods

The holothurians which are of commercial interest are sedentary mega- or macro-benthic organisms. Some species live on hard substrates, others on soft ones. These general characteristics are conducive to the use of certain quantitative sampling techniques, as described in detail in articles by Reys and Salvat (1971), Plante et Le Loeuff (1983) and in 'Coral reefs research methods' by Stoddart and Johannes (1978). Choice of technique and of a sampling strategy is at once governed by the relevant scientific aims, population parameters and material constraints (technical possibilities, cost, manpower). Although present knowledge of holothurians of reef and lagoon systems is not very thorough, various techniques have been used to assess either the size of populations or the wealth of the reef environments. Some of the methods described have already been used, while others could be adapted to this kind of research.

5.1.1 Estimation of species abundance

5.1.1.1 Utilisation of fishery statistics; catch per unit effort (CPUE)

Used in fishery population dynamics, this indirect method is based on fisheries data. Where certain factors are known, such as the number of divers working on a boat, their respective diving times, the number of specimens of each species and the tonnage harvested, it is possible to calculate 'catch per unit effort', in which the unit will be the number or fresh weight of holothurians per diving hour. The very nature of these fisheries, however, both temporary and scattered, makes data collection very difficult. CPUE can also be calculated by scientific observers.

The CPUE only provides a rough guide to the natural abundance, because its values are not related to a surface area. The main factors responsible for its variation are the following:

- harvesting method: walking at low water on a reef flat or skin diving by fishermen, to which should be added scuba-diving, a method available to scientists. In each case the following need also to be considered:

- the type of observation made; this may consist solely of counting or gathering one or more species, or both counting and harvest, or lastly an *in situ* length measurement of specimens whether or not they are subsequently harvested;

- environmental conditions, especially visibility; this is excellent at barrier reef stations but is reduced as the coast is approached, because of terrigenous influences. Hydrodynamic factors (waves and currents) may affect the harvest, as can the nature of the substrate. Specimens are clearly visible on bare sediment bottoms but are camouflaged on sediments where epibionts abound;

- the observer's experience and ability to detect specimens;

- population distribution factor: the risk of error in enumeration is greater with high-density colonies;

- species morphology: individuals of large or brightly-coloured species are easier to inventory.

To make comparisons, the exact conditions affecting the survey carried out to assess CPUE should be stated where possible. This method remains the simplest to apply and the least costly, and can be used in most biotopes including both hard and soft substrates.

5.1.1.2 Use of fishing gear

In marine ecology, qualitative studies generally use samples obtained by trawling or dragnetting while quantitative surveys employ dredge-buckets or suction dredgers. Such gear would however appear unsuitable for sampling widely-dispersed large specimens. It is ill-suited to rocky or coral bottoms and is therefore of limited use for fisheries resource assessment in coral environments.

5.1.1.3 Direct visual assessment of densities

Skin or scuba-diving, which is compatible with the various substrates encountered, is the method conventionally used in coral ecology and is efficient for the direct enumeration of specimens of the epifauna. Techniques vary according to the size of the area to be sampled:

- quadrats are areas that can be marked out by ropes or frameworks; they are sometimes drawn along radials, and may be continuous or at intervals, regular or random;

- transects are lines, often laid out according to an ecological gradient, along which enumeration is carried out. Their principal use is for coral colonies;

- measurement of distances between specimens is a method based on the linear measurement of distances between points where individuals are gathered at random.

For assessments covering wide areas or widely-scattered populations, other direct visual methods are used, particularly for enumerating large invertebrates such as giant clams, crown-of-thorns starfish (*Acanthaster* spp) or holothurians. Kenchington (1978) has summarised the survey techniques as follows:

- diving along a straight line, making an assessment comparable to CPUE;
- the 'spot check', a rapid sub-sampling technique, very useful in shark-infested waters; the observer simply leans overboard and submerges his head at regular intervals;
- the 'manta tow', where the observer, a diver, is towed behind the boat and can adjust his position in the water using a 'manta board'. In conjunction with a calibrated flow-meter, this method makes it possible to work out the distance travelled. In depths under 10 m, estimation of the density over large areas is possible with minimum fatigue for the diver. The towing speed, however, leads to under-estimation of densities by a factor of 2 to 4 (Harriot, 1985);
- diving, without a tow, remains the most widely used technique for qualitative and semi-quantitative evaluations. The introduction of a low speed flow-meter (General Oceanics) mounted beneath the board (Conand, 1985) has brought about a great improvement in quantitative assessments. Large quadrats were surveyed in this fashion in New Caledonia by two observers swimming alongside one another. The width of the quadrat, approximately 2 m. is estimated by the observer, visibility permitting. A third diver collects a sample of each species of holothurian which, after weighing, will give the mean fresh weight at the station and the biomass.

5.1.1.4 Indirect visual assessment

In order to minimise the time and energy required by dive-sampling and to attain greater accuracy than that given by blind harvesting using fishing gear, indirect visual methods were developed from around 1960. These techniques utilise underwater imagery either from photography or from an underwater cine camera mounted on a towed framework. These methods yield interesting results for shallow-water macrofauna, but their costliness and the very nature of coral environment topography seem, so far, to have restricted their use in such zones.

5.1.2 Biotope definition and mapping

5.1.2.1 Definition of biotopes

Irrespective of the area over which a benthic resource is to be surveyed, it is necessary to define and demarcate the biotopes to be mapped in the area concerned. The various coastal environments were briefly described in Chapter 1. In accordance with reef terminology (Battistini *et al.*, 1975; Thomassin, 1984), 16 main biotopes may be distinguished for high islands, which form the most diverse type of coastal environment. These are illustrated in Figure 33 and may be broken down into various <u>geo-morphological types</u>: reef structures associated with barrier reefs, islet reefs or fringing reefs and non-reef structures, subdivided into outer and inner lagoon and coastal categories. They may also be grouped as structural formations or features on the basis of their functional morphology: outer slope, outer reef flat, inner reef flat, inner slope, lagoon. Each biotope may be described (Conand and Chardy, 1985) by a number of general parameters: distance from the shore, depth, gradient, hydrodynamics (currents, exposure to swell and waves, exundation). Grain-size estimation enables 9 principal classes of substrate to be distinguished, from coral flagstones to rock or mud. The accompanying flora and fauna, consisting of coral formations and the dominant macro-benthic groups, complete the description. Their respective abundance and the degree of coverage of the varying types of substrate, may be coded from 0 to 5 on the simple scale recommended by Dahl (1981).

5.1.2.2 Mapping

The environmental data used in describing stations for mapping purposes may be obtained *in situ* by diving, by dredging or by underwater imagery. For shallow zones, aerial imagery is extremely useful in defining biotopes. Aerial photography is often used, with a varying degree of subjectivity, and can be automatically analysed by computer-assisted techniques. Lastly, recent developments in remote-sensing have greatly improved resolution; the use of satellite imagery is proving applicable for coral environments and an example will be given in Chapter 5.3.

In conclusion, it would appear that each of these methods suits specific objectives and has its own constraints and inadequacies. A general sampling plan therefore has to be outlined and the size and number of samples determined. Without going into the details of these options, which can advantageously be considered and appraised in the light of the study by Frontier (1983), it is advisable to state which choices have been made so as to enable comparisons to be made and to secure a return on the human and financial investment in data collection.

5.2 Holothurian resource survey results

The results obtained by the author from fisheries departments and environmental surveys will be reviewed. The level of knowledge about these resources varies considerably between countries, but the data collected in some areas (New Caledonia, Papua New Guinea, Queensland) should facilitate subsequent assessments.

5.2.1 Papua New Guinea (after Shelley, 1981)

This survey was conducted from 1979 to 1981, south-east of Port Moresby, at a bay in Papua New Guinea's coastal lagoon bounded to seaward by a barrier reef and by a coast lined with mangrove in places, in front of which seagrass beds were developing. There were fringing reefs in the areas exposed to the prevailing winds. Using quadrat, transect and CPUE methods, the distribution and abundance of the species *Thelenota ananas*, *Holothuria nobilis*, *H. fuscogilva*, *H. scabra* and *Actinopyga echinites* were determined, the research effort focussing particularly on the last two species. The habitats surveyed (28 stations) were mainly the slopes and flats of the fringing reefs and islet reefs; a few stations were located on the barrier reef. Results were expressed as catch per diving hour. Distribution of most of the species was characterized by the presence of aggregations where densities are fairly high (Figure 34). A more detailed survey of the aggregations of *Holothuria scabra* enabled the relation between effort and area covered to be estimated (1 diving hour = 1000 m^2 approximately) and, on this basis, the mean density was found to be 0.37 individuals per m^2, on the inner fringing reef flats. Over a 800 m^2 quadrat, sampled monthly for 13 months, the mean density fluctuated slightly around 0.29 individuals per square metre for this species; it was only 0.18 specimens/m^2 for *Actinopyga echinites*. From these values and from growth estimates, the maximum annual production was estimated at 487 kg/ha/year for

H. scabra and 497 kg for *A. echinites*. These figures must be regarded as approximations, in the absence of more detailed knowledge of the environmental parameters and those relating to the population considered.

5.2.2 Solomon Islands

The reports prepared by Crean (1977) for the Fisheries Division of the Ministry for Natural Resources provide some information, based on a one-week bêche-de-mer survey conducted on the atoll of Ontong-Java, one of the largest in the Pacific. Of the fifteen-odd species identified by McElroy (1978) in the five major biotopes, only *Holothuria nobilis* and *Actinopyga miliaris* were regularly harvested. Average CPUE, calculated for *H. nobilis* from the catches of about twenty fishermen over a period of 9 days, was 11 specimens.

5.2.3 Fiji

Assessments made by Gentle (1979) on the Suva and Levuka reefs by skin diving, concerned mainly teatfish. The white *H. fuscogilva* was abundant on these reefs, in *Syringodium isoetifolium* seagrass beds; average CPUE was 12 to 20 specimens.

5.2.4 Tuvalu

A survey by the Fisheries Division (Pita, 1979) reported an average harvest of 20 to 50 teatfish per trip, over a period of 12 weeks, which was considered insufficient for a viable fishery.

5.2.5 Truk

A report by Howell and Henry (1977) presented the results of teatfish harvests made in October 1976 and February 1977. It did not give enough information to enable CPUE to be calculated. On the basis of the distribution of individuals on the inner reef slopes near the passes, the species concerned appears to be *H. fuscogilva*. A diver's one-day harvest, which varied considerably, only rarely exceeded 30 specimens.

5.2.6 Australia

Evaluations of the potential bêche-de-mer resource were carried out by the Queensland Fisheries Department on the reefs of the central zone of the Great Barrier Reef (Harriot, 1985) and on the reefs between Cairns and Lizard Island (Pearson, in press). The method used in both cases was counting by a diver holding a board with a flow-meter and towed by a boat. The surveyed sites were zones less than 10 metres deep. Pearson's counts (226 tows), which included giant clams and *Acanthaster* in addition to holothurians, gave average values of 16.3 *Holothuria nobilis* per hectare, 15.5 *H. atra* and only 3.6 for the 3 species *Thelenota ananas*, *Actinopyga miliaris* and *A. mauritiana* combined. In the permanent 2.7 ha quadrat which he set up on Michaelmas reef, holothurian density was 108 per hectare, mainly made up of *H. nobilis* (63/ha), *Actinopyga lecanora* (13.3/ha), *A. miliaris* (10/ha) and *T. ananas* (4.1/ha). Harriot's estimations (Table 26) are more detailed. Values are presented by reef structure for each group. Among the species counted, the commercially valuable ones are shown separately: *H. nobilis*, *T. ananas*, *T. anax*, *A. miliaris*, *A. mauritiana* and *H. axiologa (= fuscopuntata)*. The author feels that these estimations should probably be multiplied by three to approach the real density. On the basis of the densities calculated for the commercially important species, she considers that 20 specimens per hectare corresponds to a relatively high abundance. These high-density stations are usually located on outer and inner reef slope biotopes where the species *H. nobilis* and *T. ananas* are predominant.

5.2.7 New Caledonia

5.2.7.1 Calculation of CPUE

In the course of a study on the biology of holothurians, the results of which were presented in Chapter 4, the abundance of certain species was calculated by CPUE: the data for certain species are given in Figure 34; for *Holothuria fuscogilva*, data obtained from a survey conducted in Suva, Fiji are also shown. This information permits comparison with Papua New Guinea. For the three species *Thelenota ananas*, *Holothuria nobilis* and *H. fuscogilva*, the CPUE, generally low, very occasionally reaches 100 per diver per hour. *Actinopyga echinites* and *H. scabra* have more variable CPUE's that may approach 1000.

At three stations in New Caledonia, during counts of a single species, a flow-meter enabled the area surveyed to be evaluated and the relationship between area and effort values to be calculated simultaneously (Table 27).

The surface area surveyed at the three stations was nearly 5 times as large as the one covered by Shelley (1981). CPUE is thus a simple method, but it remains to be standardized, to enable comparisons and stock-size assessments to be made.

5.2.7.2 Distribution and abundance of the various species

To determine the distribution of *Aspidochirota* holothurians more precisely, 216 stations were surveyed, at different times, in various parts of the New Caledonian lagoon. Direct visual evaluation of species density (counts made by diving with a flow-meter or walking over the quadrats at low tide), sampling to obtain biomass values and description of environmental parameters yielded estimations of biotope richness, the biotopes being classified by reef type, as well as by structural formation, faunal composition and abundance of the main species.

- <u>Biotope richness</u>. Although the method was imprecise, the populations highly dispersed and the biotopes variable in area, the results obtained depict an extensive and varied reef and lagoon complex. Figure 35 shows mean densities and biomasses, expressed per hectare, for the three categories of holothurian in the 16 biotopes of the reef complex. The first grouping contains the 5 high-commercial-value species. *Holothuria scabra*, *H. scabra* var. *versicolor*, *H. nobilis*, *H. fuscogilva*, *Thelenota ananas*, *Actinopyga echinites*, and *A. miliaris*. The second category comprises the species of little value, or of historical value only (cf. Chapter 4): *H. atra*, *H. edulis*, *H. fuscopuntata*, *Actinopyga mauritiana*, *Bohadschia argus*, *B. vitiensis*, *Strichopus chloronctus*, *S. variegatus*, and *Thelenota anax*. The third category consists of the 30 other species of *Aspidochirota* holothurians that were inventoried in these surveys.

Both density and biomass values were found to rise with the gradient from the open sea to the coast, as far as the classification by type of reef was concerned and from outer slopes to inner reef flats with regard to structural formation. The slopes and outer lagoon were less rich than the reef flats. The inner reef flats, in particular, and coastal zones (bays, estuaries) were the richest environments. From the point of view of densities, first-category species were least abundant on the barrier reefs, outer reef slopes and outer lagoons. They were however predominant on the inner reef flats and in the coastal zones. Biomass distribution had comparable characteristics, except for the barrier reefs and outer lagoons where the respective proportion of commercially valuable species was slightly higher; this was because of the large size of these species.

Composition of the fauna (after Conand and Chardy, 1985). Population units were determined by an inertia analysis performed on the basis of the density values for the different species of holothurians at the survey stations. The stations or "observations" and the species or "variables" were used to produce a two-dimensional table. The analysis deals with the distance between observations. Among the inertia analyses possible, analysis of correspondences was chosen because it gave a simultaneous representation of observation groupings and variables. Introduction of additional variables of "zero mass" and projection to control-points of the biotope barycentres assisted in interpreting the structures obtained. The results shown in Figure 36A correspond to the configuration obtained in the plane defined by the first 2 axes of the analysis; they allow discrimination between reef systems (flats, slopes, passes) and non-reef systems (lagoons and bays). Within the reef system, two types of organisation (by structural formation and type of reef) are distinguished. Along axis 1, corresponding to the offshore-inshore gradient, are located, firstly, the barycentres: barrier reef, island, fringing reef; secondly, the barycentres of the reef formations: slope, outer flats, inner flats. The non-reef system is well defined, except for the outer lagoon which is in an intermediate position, thus proving its affinity with the reef system. The passes, located at the tip of the V whose "branches" are the reef and lagoon biotopes, belong to both systems. The configuration of the species projection enables three main groupings to be defined:

. pass and slope species, including *Holothuria nobilis*, *Thelenota ananas* and *H. fuscogilva*, which are the commercially valuable species;

. inner reef-flat species, with *Holothuria scabra*, *Actinopyga miliaris* and *A. echinites;*

. lagoon species, with *H. scabra* var *versicolor*. The outer reef-flat species are less concentrated; while others show a twofold affinity: "lagoon-slope" or "inner reef-flat bay". Species of commercial interest can be seen to exist in very different biotopes, which explains how varied the possible exploitations are.