2. GENERAL INFORMATION ON HOLOTHURIANS AND THEIR EXPLOITATION

2.1 Holothurians

2.1.1 General characteristics

Holothurians, or sea cucumbers, form one of the five classes of the marine phylum of echinoderms. They possess the main characteristics of this subdivision, as described in detail by Hyman (1955), Boolootian (1966) and Meglitsh (1975). Certain aspects of their anatomy, physiology and ecology will be discussed as an introduction to this paper. Echinoderms are characterized by their lack of segmentation, an endoskeleton of calcareous ossicles and a spacious coelom with complex chambering which is the source of the haemal and water-vascular or ambulacral systems. The latter system is hydraulic, comprising ambulacral tube feet or podia, in which the functions of respiration, locomotion and sensory reception are combined. The typical pentaradial body symmetry is mirrored by secondary bilateral symmetry visible on the body surface, where five radial ambulacral tracts, which usually bear the tube feet, alternate with five intermediate trunks. The alimentary canal is complete, the nervous system is not centralized and the reproductive system is simple. Embryonic development proceeds by a series of larval stages.

2.1.2 Anatomy and biology

The Class Holothurioidea, consisting of approximately 1,200 species, features a soft, cylindrical body, elongated along an axis from mouth to anus which rests on the trivium, that is to say, the three ambulacral "ABE zones" of the Carpentier system, and a reduced endoskeleton formed of microscopic spicules embedded in the body wall. The six orders of this class, Dendrochirotida, Dactylochirotida, Aspidochirotida, Elasipodida, Apodida and Molpadiida are distinguished by the presence or absence of tube feet, the shape of the mouth tentacles and the presence or absence of oral retractor muscles, respiratory trees and cuvierian organs. Most commercial species belong to the order Aspidochirotida, whose general characteristics are described and illustrated in Figure 2.

These holothurians have many oral tentacles (multiples of five, up to thirty) of the peltate type. On the trivium, the podia are either arranged in three rows or cover the whole creeping ventral surface or sole. On the bivium, they may occur in the modified form of wart-like processes or papillae, more or less highly developed. Their generally dull, brown, grey or black colouring is occasionally relieved by bright shades such as the green of *Stichopus chloronotus*, coloured stripes, as with *Bohadschia vitiensis*, or the blotches or ocelli of *Bohadschia argus*. Some species (*Bohadschia marmorata*, *Holothuria scabra*) show a high degree of polymorphism.

The edible part is the body wall. There is no clear dividing line between the epidermis and the softer underlying dermis, while the deeper dermis is dense, consisting of fibrous connective tissue enveloping the spicules, pigments, coelomocytes and a nervous plexus. The spicules, which form the internal skeleton, are microscopic elements which are important taxonomically. They occur in a very wide variety of shapes, from tiny rods, plates, rosettes, ellipsoids or buttons to more complex forms such as

tables with discs or arrow-heads. Species descriptions are based on spicule shape, distribution and abundance in the dorsal and ventral body wall, and on the papillae, the podia and the tentacles.

The internal skeleton also contains the peripharyngeal calcareous ring, an organ partly comparable to Aristotle's lantern in sea urchins. To this ring, formed of calcified plates differing in size and shape from species to species, are attached five longitudinal muscular bands, which contract to allow the oral tentacles to be retracted into the mouth under the oral membrane. Aspidochirotes are usually detritus-feeders, using their tentacles to gather food on the hard or soft substrate. This food passes through a long tubular digestive canal beginning with a muscular pharynx; through the calcareous ring passes an oesophagus, opening into a short stomach which is succeeded by an intestine with three loops, the first going backwards, the second forwards and the third backwards, terminating in a large cloaca opening outwards through an anus, which is sometimes ringed with calcified anal papillae (anal teeth). A recent review of available knowledge on the digestive system and nutrition appears in 'Echinoderm nutrition' (Jangoux and Lawrence, 1982).

The two branched bodies of the respiratory trees terminate, either separately or jointly, in the cloaca. They pass up through the coelomic cavity; the left-hand respiratory tree is sometimes, as with *Holothuria nobilis* (Figure 2), intertwined with the haemal system *(rete mirabile)*, which is attached to the forward loop of the intestine.

Cuvierian organs are present in some species of genera *Holothuria* and *Actinopyga*, in particular abundance with *Bohadschia*. These sticky tubules, attached to the base of the respiratory trees, are expelled through the anus towards a source of irritation. They are generally considered to be a defensive organ.

The reproductive system consists of an unpaired genital gland (contrary to other echinoderms whose pentaradial symmetry is reflected in the gonads). The sexes are usually separate. The gonad consists of one or two tufts of tubules attached to the dorsal mesentery through which the gonoduct passes, terminating in a gonopore or a genital papilla. The gametes are freely released into the sea water. Some brooding takes place with certain species of dendrochirotes and apodes but aspidochirotes are oviparous.

A special kind of behaviour occurs during spawning. The male and female animals rear upright and, attached to the substrate by the posterior podia, sway back and forth while the sexual cells are released.

After radial holoblastic segmentation, development follows a series of larval stages: the first is a swimming larva with ciliate bands, *auricularia*, which evolves into *dololaria*. The *pentacula* stage, characterized by five oral tentacles and the first podia, becomes benthic. The juvenile, initially transparent, gradually acquires adult characteristics.

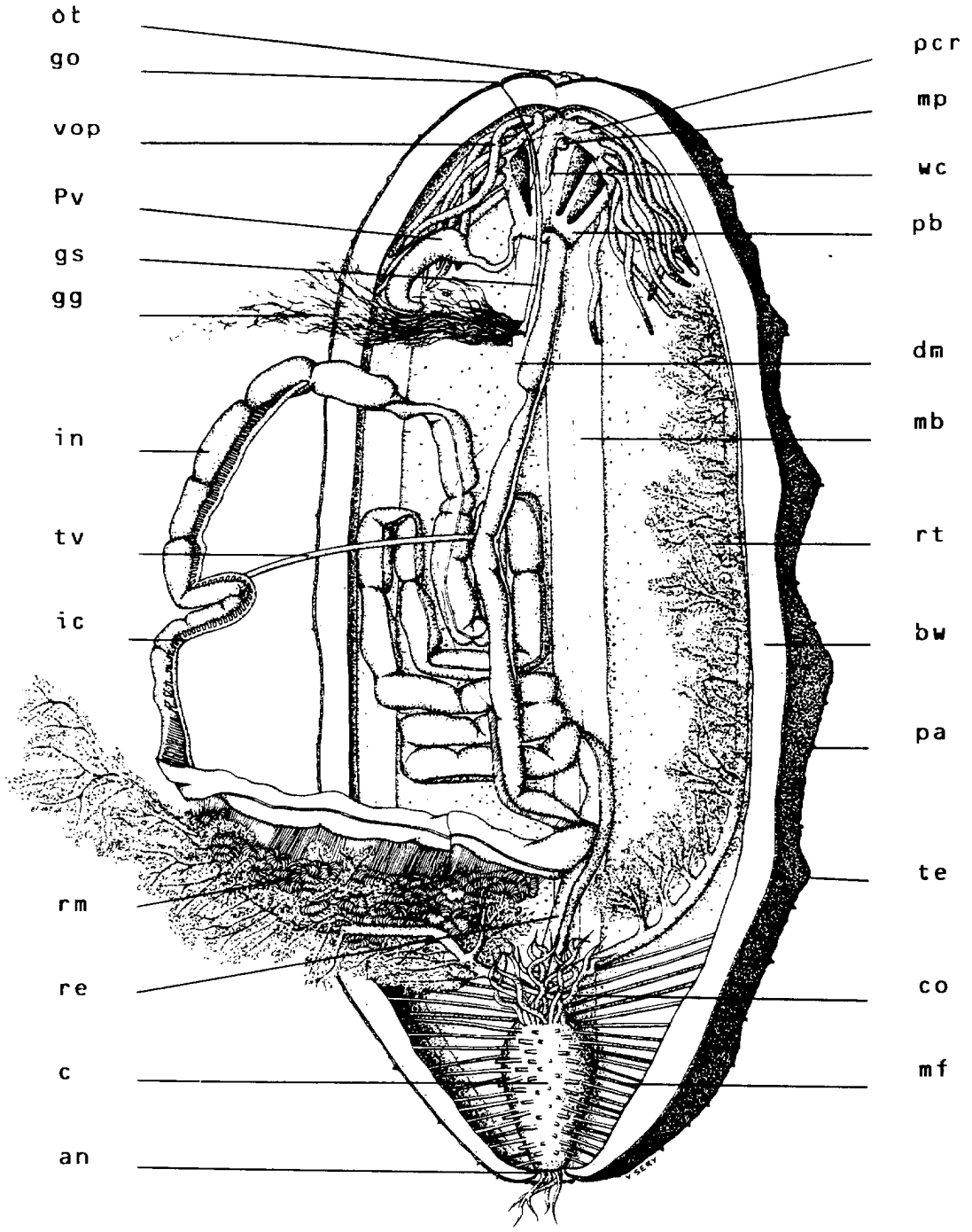

Figure 2: Anatomy of *Holothuria nobilis*

ot: oral tentacles go: genital orifice vop: vesicles of the oral podia mp: madreporite wc: water ring canal Pv: Polian vesicle pcr: peripharyngeal calcareous ring mb: radial muscular band gs : genital stolon gg: genital gland
co: cuvierian organs c : cloaca an: anus re: rectum rt: right respiratory tree pb: pharyngeal bulb rm: rete mirabile tv: transverse vessel ic: intestinal cavity dm: dorsal mesentery mf: muscle fibres bw: body wall in: intestine
pa: papillae te: teats

Asexual reproduction, by transverse binary fission, has been recorded with a number of species. In *Holothuria atra*, the incidence may be as high as 70 per cent of the population (Harriot, 1982). Evisceration and autotomy are probably processes of adaptation to unfavourable environmental conditions. These enable the individual to survive with a reduced metabolism and are followed by regeneration when normal ambient conditions are restored.

Holothurian toxicity, due to the presence of holothurin, has been tested on many organisms. The toxin is concentrated in the body wall, the viscera and particularly in the cuvierian organs. Its ecological significance is probably that it acts as a protection against predators (Bakus, 1968).

2.1.3 Distribution

Holothurians are found in many marine biotopes at all latitudes, from the foreshore to greater depths. They are usually benthic except for some pelagic Elasipodida. Although some species live on hard substrates (rocks, cavities, coral reefs) or in epibiosis on plants or invertebrates, they more regularly inhabit soft bottoms, either living on the seabed surface or, temporarily or permanently, in the sediment.

The distribution of the various groups in coastal zones shows the predominance of Aspidochirotida between the tropics and of Dendrochirotida in temperate and higher latitudes.

The greatest degree of diversity occurs in the tropical coastal areas where genus *Holothuria,* for example, comprises 114 species (Rowe, 1969). Much disparity is evident in the surveys carried out in the Indo-Pacific area, with regard both to the purpose of the study and the methods used, which makes comparisons difficult. This difficulty is exacerbated by the wide variety of biotopes. Holothurian densities, whether mean or maximum, may be as high as several hundred animals per square metre. This aspect will be investigated in more detail in Chapter 5, which deals with resources.

In deep-water zones, holothurians account for a high percentage of total biomass, where their abundance was discovered by the 'Challenger' expeditions. More recent papers have concentrated on their quantitative distribution in relation to environmental parameters (Sibuet, 1985) or to their life cycles or behaviour (Tyler, et al., 1985).

2.2 The holothurian as a commodity

2.2.1 Consumption of fresh sea cucumber

The consumption of holothurians, either raw or after very simple preparation, is common in Japan and Korea.

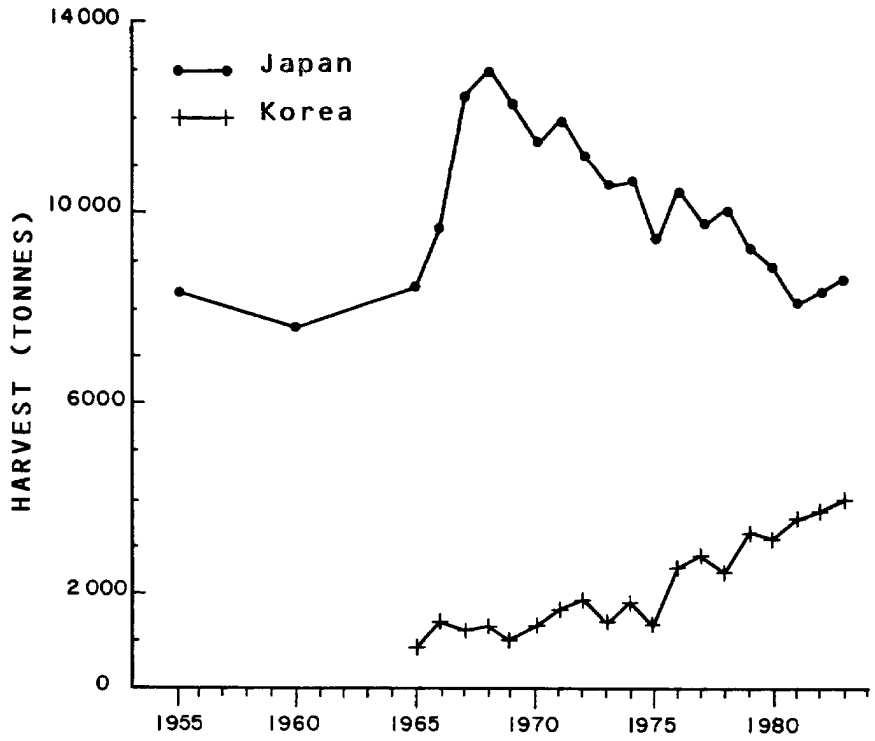

Figure 3: Evolution of the *Stichopus japonicus* fishery

Table 2: Estimates of the world harvest of holothurians for preparation as bêche-de-mer and geographical distribution, by area

AREA	1978	1979	1980	1981	1982	1983
Southern Pacific (%)	8	4	4	2	4	4
Central Pacific (%)	54	65	68	77	75	76
Northern Indian Ocean (%)	11	9	10	9	9	10
Western Indian Ocean (%)	26	21	17	11	12	8
Total (MT, fresh weight)	10 860	10 540	15 370	13 300	13 600	14 450

In Japan, the body wall, 'namako', is eaten raw, in slices soaked in a mixture of vinegar and soya sauce. Other organs are also considered delicacies: the ovaries, either dry, 'konoko', or salted and fermented; the intestines, 'konowata', and even the respiratory trees, 'minowata'. A dry product, known as 'iriko', is also traditionally produced. Choe (1963) refers to this product as an export to China along with abalones and sharks' fins, but this trade has now declined to less than ten tonnes per year. Market prices are generally much higher for the viscera than for the body wall (Mottet, 1976). According to documentation communicated by Dr Ishida, referring to two locations in Aichi prefecture in 1976, 'konowata' was fetching between 13 and 20,000 yen per kilogram, while 'namako' was priced on average at 1,000 yen per kilogram; seasonal price fluctuations were very marked, being dictated by the availability of the various organs.

In 1983, the sea cucumber harvest totalled around 8,700 tonnes, confirming a gradual downward trend since 1970, when it exceeded 12,000 tonnes (Figure 3). According to the annual statistics for 1978, the geographical distribution was very uneven; for example, the 8,970 tonnes collected in 1980 consisted of 42 per cent from the Seto Naika Sea, 16 per cent from Hokkaido, 15 per cent for the Pacific region, 18 per cent from the Sea of Japan and 9 per cent from the China seas. According to Suguri (1965) in Mottet (1976), fishing regulations were determined by the prefectural authorities and the cooperatives and were based on closed seasons and quotas. The timing of fishing bans varied from region to region; during the spawning season of *Stichopus japonicus,* fishing was forbidden for periods varying from two months, the shortest, to eight months, as at Aichi. April-to-December is the breeding and estivation season. During the summer, this species stops feeding, its intestine atrophies and the body wall loses weight; these occurrences are more pronounced with specimens aged three years or over. Attempts to increase stocks have traditionally been made either by using artificial reefs or by transplanting adults or juveniles.

The next most prolific *Stichopus japonicus* harvest is recorded in the Republic of Korea. FAO statistics for this country are shown alongside those for Japan (Figure 3).

This species is also harvested in the extreme eastern portion of the USSR, in Peter The Great Bay. In a work on the biology, fisheries and uses of *Stichopus japonicus,* Levin (1982), presented catch data since the early part of the century; these are incomplete and sometimes contradictory; approximately 6,000 tonnes had been collected by 1935. After 1970, reliable data reveal a decline in the harvest from 274 tonnes in 1970 to 33 in 1978. To this figure should be added the harvest taken by private individuals with a taste for this animal, which is probably of equivalent size. Fishing is regulated by quotas and a summer closed season. Hopes for a future production increase are being pinned on aquaculture (Mokretsova, 1978).

A dry product, 'Hai-som', is prepared from this species in China and a number of recent articles have dealt with artificial reproduction and larvae breeding (Shuxu and Gongchao, 1981; Shui Xi-Lin *et al.*, 1984). This activity is carried out by the people's communes, who sell their catch to the government. The local market absorbs the production estimated at 60-100 tonnes dry weight per year.

2.2.2 The bêche-de-mer industry - world statistics and the importance of the South Pacific

On the whole, it is difficult to find statistics on small-scale artisanal fisheries in the South Pacific region. The sea cucumber is chiefly gathered in the seas of tropical countries with limited technology and where, in some cases, part of the harvest is consumed locally, in countries with a large ethnic Chinese community. Some evaluations refer to the catch (fresh weight), and others to the processed, dry product; in the latter case, figures have to be multiplied by ten (cf. section 6.2) to obtain the approximate equivalent fresh weight.

Catch estimates were made using the results of a survey carried out by ORSTOM which consulted French embassies and local fisheries departments in countries where this activity had a long history, and the FAO's statistical yearbooks (1978 to 1983).

Holothurian fishing grounds throughout the world exploited for bêche-de-mer production can be divided into various groupings, determined by the geographical area and the species concerned (Conand and Sloan, in press), as follows:

- the western central Pacific, itself subdivided into the central Pacific and the southern tropical Pacific, where the activity is chiefly centred on Fiji, the Solomons and New Caledonia; some other islands produce small quantities or would be interested in resuming this activity (cf. section 3.5). The major bêche-de-mer producers are to be found among the states of the central Pacific area - the Philippines, Indonesia and Malaysia - but their statistics are not always accessible. Generally speaking, a number of different species are harvested in each of these countries.

- another traditional fishery area is the Indian Ocean, especially for the species *H. scabra*. This zone may be split into eastern Africa and south-west Asia, including India and Sri Lanka. The main east African countries involved are Madagascar, Mozambique, Tanzania and Kenya.

- The north-eastern Pacific, British Columbia, Washington and California have recently begun developing fisheries for two species (Sloan, 1986); these operations remain modest, representing less than one per cent of the world market and will therefore not be detailed.

The table gives a summary of the harvest, area by area, in recent years.

The total annual harvest ranges from 10 to 15,000 tonnes and would appear to be following a slight upward trend in recent years. A study of the Hong Kong and Singapore market statistics would yield a more accurate picture, but the substantial tonnages of bêche-de-mer re-exported from these centres make interpretation of these figures difficult. Indeed, the same product may crop up in a number of markets one after the other (cf. Chapter 7).

The Philippine and Indonesian fisheries are by far the biggest and the southern tropical Pacific only accounts for 10 per cent of the world catch.