4. BIOLOGY OF THE COMMERCIAL SPECIES FOUND IN THE SOUTH PACIFIC

4.1 Introduction

A knowledge of population parameters is a prerequisite for the rational management of holothurians. Published information on the various species is scarce despite their abundance and size, which qualify them as a significant component of the benthic macrofauna of lagoon and coral environments. Clark and Rowe (1971), in their monograph on shallow-water echinoderms of the Indo-Pacific area, gave a table of references to each species, by geographical area. Most of the published papers deal with the description and distribution of the various species, while some supply information on their ecology. A review by Bakus (1973) stressed the gaps in knowledge about their biology. Since then, much attention has been paid to the optimum exploitation of marine resources, the diversification of sources of income for fishermen and to gaining a better understanding of how coral reef ecosystems function. Recent research in the area, particularly that conducted by ORSTOM in New Caledonia, has enhanced available knowledge of holothurian populations (Conand, 1981, 1982, 1983).

Various species are harvested in the tropical Pacific for processing into bêche-de-mer. Common characteristics of the species concerned are their abundance in shallow water, the large size of specimens and the thickness and quality of their body wall. This should neither contain too many spicules nor deteriorate between gathering and processing; it should be borne in mind that, with some species, the body wall disintegrates rapidly (Tanikawa and Ishiko, 1955, in Mottet, 1976 and Motokawa, 1981, 1982). Using these criteria (and others imposed by the market), the species of commercial value can be subdivided into three main categories:

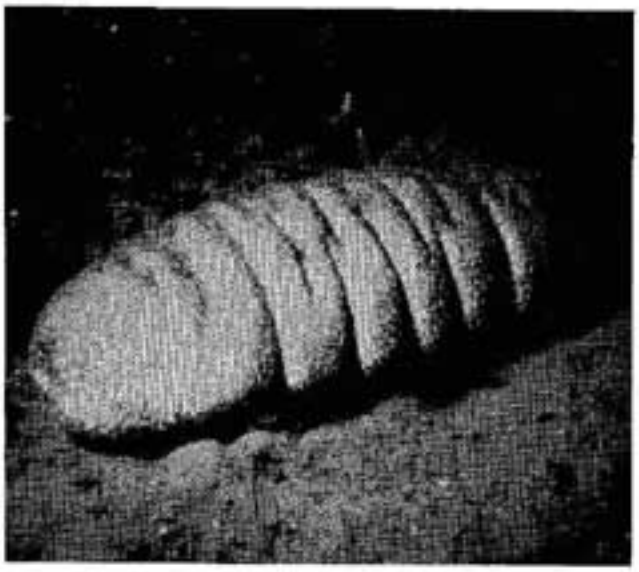
- species with high commercial value: *Holothuria scabra* and *Holothuria scabra* variety *versicolor*, the 'sandfish', and *Holothuria nobilis* and *Holothuria fuscogilva*, the 'teatfish';
- species with medium commercial value: *Actinopyga echinites*, *Actinopyga miliaris*, *Thelenota ananas*;
- species with low commercial value: *Holothuria atra*, *Holothuria fuscopunctata*, *Actinopyga mauritiana*.

Saville-Kent (1903) and Panning (1944) refer to other species: *Bohadschia argus*, *Bohadschia marmorata*, *Holothuria edulis*, *Thelenota anax*, *Stichopus chloronotus* and *Stichopus variegatus*. These are all large species, but their harvesting was abandoned for a variety of reasons: low profit margin due to very low prices, unpleasant handling caused by the expelling of the cuvierian organs the moment *Bohadschia* is handled, the deep habitat of *Thelenota anax* and, lastly, the very rapid disintegration of the body wall with the two *Stichopus* species mentioned.

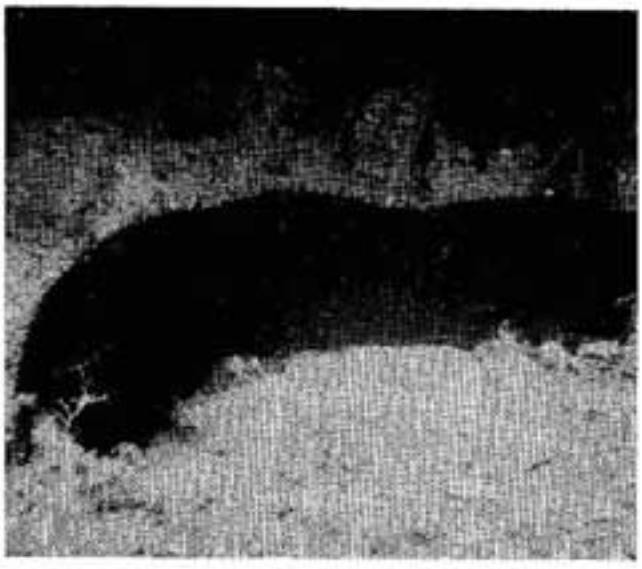
One or more species are gathered in each of the countries concerned. Present understanding of the population parameters of each species will be discussed for each commercial grade. The morphometric parameters will be given in detail because of their importance for grading processed products and for the market. One major hindrance in studying holothurians is the inaccuracy of weight and length measurements, due to the elastic consistency of the body wall, the absence of a skeleton and the variability

Holothuria nobilis

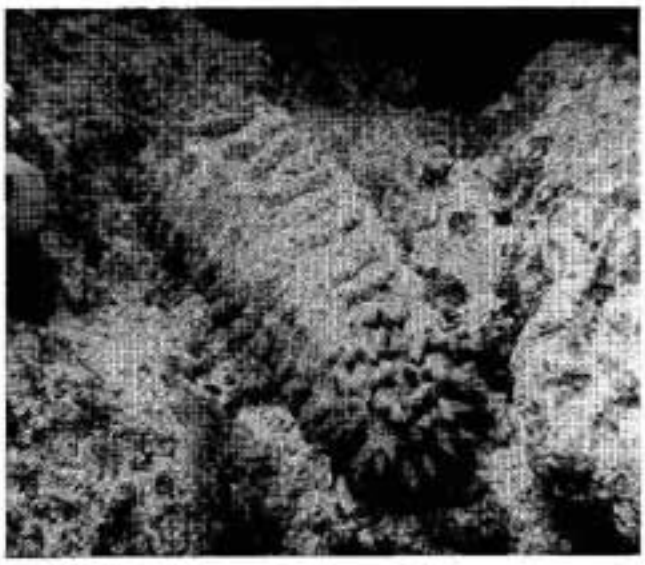
Holothuria fuscogilva



Holothuria scabra var. versicolor



Actinopyga miliaris



Thelenota ananas

Figure 7: Main commercially valuable species of holothurian (photos: ORSTOM)

of the contents of the digestive system and the coelomic fluid. The results obtained with regard to biological parameters, reproduction, growth and mobility will be discussed.

4.2 Species with high commercial value

4.2.1 Holothuria scabra (Jaeger, 1833) and H. scabra variety versicolor (Figure 7), the 'sandfish'

This species yields the second biggest catch worldwide after *Stichopus japonicus*. It accounts for the majority of bêche-de-mer exports from India, Sri Lanka and Madagascar. It is also a commodity in Indonesia, the Philippines and some tropical Pacific islands, particularly New Caledonia since 1983.

4.2.1.1 Description and distribution

Described by Jaeger in 1833, it has a wide distribution in the Indo-Pacific area; references to it may be found in a publication by Clark and Rowe (1971); Cherbonnier (1980) recorded 'its very great variability in colouring'.

From observation in New Caledonia, it would seem feasible to distinguish between *H. scabra* and *H. scabra* variety *versicolor*. Although it is not possible to describe a completely new species, in the absence of significant differences between the spicules, the calcareous ring or the anatomy, some particularities do recur regularly: the tegument colour varies with *H. scabra* from deep grey fringed with varying hues of green to very light grey on the dorsal surface. *H. scabra* shows very pronounced lateral wrinkles (Figure 7), black speckling and unpronounced papillae. Five dark lateral bands may also occur (Tan Tiu, 1981). With *H. scabra* variety *versicolor*, the colouring of the dorsal tegument is highly variable; it may be of any of the intermediate shades between light beige and unrelieved black. Some specimens show black blotches of varying size and number, but in this case the dark patches and lateral folds are absent, while the papillae and tube feet are more fully developed. The distribution of these phenotypes in New Caledonia, divided into three categories (black, speckled and beige), is given in Table 8.

The *versicolor* variety differs from *H. scabra* by its size and average weight in addition to the previous dissimilarities. It is generally (cf. Chapter 4.2.1.2) larger and heavier. There is, moreover, no difficulty whatsoever in distinguishing between a small specimen of this variety and an *H. scabra* of the same size. When specimens are being taken for monthly sampling or tagging, evisceration occurs more frequently with *H. scabra* (Table 9). Ecologically speaking, (cf. Chapter 5.2.7.2), they are characteristic of different environments. They are both absent from the barrier reef, the slopes and the outer lagoon, while remaining abundant in biotopes under terrigenous influence. *H. scabra* was gathered in sixteen locations, usually on inner reef flats, and *H. scabra* var. *versicolor* at twenty stations in the inner lagoon or in bays. Only in three places were they found together and in all such cases one or other was greatly predominant. Both burrow into the muddy or sand-and-mud sediment; this behaviour was described by Yamanouchi (1956). The maximum density for *H. scabra*, 6,000 individuals per hectare, was recorded on a beach, to seaward of a mangrove swamp, and high densities were recorded on inner reef flats

Table 8: Distribution of phenotypes of *H.* scabra var. *versicolor* in New Caledonia

n: number of animals %: percentage

STATION	HOW COLLECTED	PHENOTYPE					
		Black		Blotchy		Beige	
		n	%	n	%	n	%
1. Seagrass	Tagging	58	34	50	30	61	36
2. Outer slope	Sampling	67	26	85	33	105	40
2. Outer slope	Tagging	265	36	147	20	313	43
	TOTAL	390	34	282	24	479	42

Table 9: Evisceration by *H. scabra* and *H. scabra* var *versicolor*.

n: number collected; e: number eviscerating; %e: evisceration rate
* evisceration sometimes occurring one hour after tagging

SPECIES	TAGGING			SAMPLING		
	n	e	% e	n	e	% e
H. scabra	254	37	14.6*	365	25	6.9
H. scabra var *versicolor*	453	5	1.1	273	3	1.1

Table 10: Biometric relationships for *Holothuria scabra* and *H. scabra* var *versicolor* in New Caledonia

df: degree of freedom; r: correlation coefficient;
c: confidence interval of slope (s = 0.05)

X	Y	*Holothuria scabra*				*H. scabra* var *versicolor*			
		dl	r	Equation	c	dl	r	Equation	c
TL	TW	323	0.78	Log Y = 2.28 Log X - 6.35	2.13-2.44	268	0.76	Log Y = 2.26 Log X - 5.97	2.09-2.44
TL	DW	322	0.74	Log Y = 2.29 Log X - 6.65	2.12-2.46	270	0.63	Log Y = 2.44 Log X - 7.42	2.22-2.67
TL	GW	322	0.73	Log Y = 2.23 Log X - 6.67	2.07-2.40	270	0.64	Log Y = 2.29 Log X - 6.83	2.09-2.51
TW	DW	322	0.95	Y = 0.80 X - 7.10	0.78-0.83	268	0.84	Y = 0.68 X - 13.47	0.63-0.73
TW	GW	322	0.93	Y = 0.57 X - 4.69	0.55-0.59	268	0.75	Y = 0.44 X + 86.56	0.41-0.48
DW	GW	321	0.97	Y = 0.71 X - 0.36	0.69-0.72	270	0.93	Y = 0.66 X + 95.24	0.63-0.69

of fringing or islet reefs; the average density was 683 per hectare. Densities of *H. scabra* var. *versicolor* were generally lower, with an average of 82 per hectare. The higher densities, 450 individuals and upwards, were found in the deeper lagoon biotopes.

As well as publications on the reproductive cycle and the biochemical constituents of *H. scabra* by Krishnans and Krisnaswamy (1967, 1968, 1970, 1971), the biology of a number of populations has been studied in Moreton Bay, Australia (Harriot, 1980) in Papua New Guinea (Shelley, 1981) and in New Caledonia (Conand, unpublished).

4.2.1.2 Morphometric parameters and biometric relationships

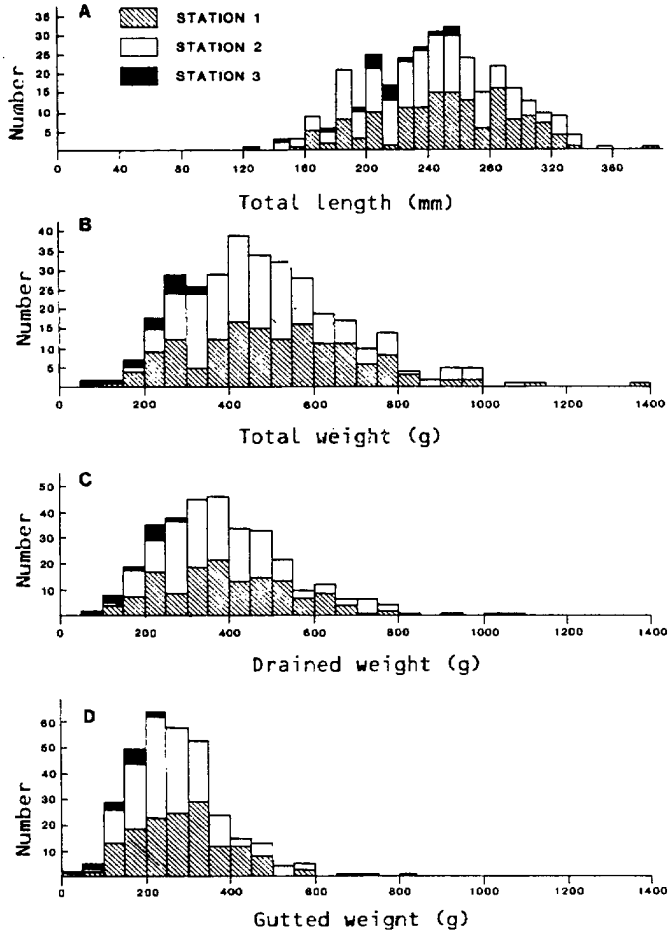
The three studies on *H. scabra* by Harriot (1980), Shelley (1981) and Conand (unpublished) were based on monthly sampling of some twenty specimens, gathered by diving at low tide. In New Caledonia, they were taken mainly from two stations (Figure 8A) on an inner islet reef flat. The frequency distributions of total lengths (TL) were fairly similar; individuals measured from 16 to 32 centimetres, with the general average being 24 cm. In Papua New Guinea, the results obtained by Shelley from the population of an inner fringing flat south-east of Port Moresby were fairly comparable; most individuals measured between 16 and 32 cm, with a mean length of 25 cm.

Three indices were used to express fresh weight: total weight (TW), drained weight after making an incision down the inside of the back to drain the coelomic liquid (DW) and gutted weight (GW) or body wall weight. In most cases, individuals surveyed in New Caledonia (Figures 8B, C, D) weighed in at between 150 and 1,000 g, with a mean weight of 480 g; their drained weight varied from 150 to 850 g, the mean drained weight being 350 g, while the gutted weight range of 50 to 600 g gave an average of 270 g. The comparison of these figures with Shelley's shows that the weights were slightly greater at the PNG survey station, the mean values being TW: 590 g, DW: 480 g and GW: 340 g. For Moreton Bay (Harriot, 1980), the mean total weight was 440 g, not dissimilar to the average weight obtained for New Caledonia.

Most of the samples of *H. scabra* var. *versicolor* were gathered from a site in the inner lagoon, at the foot of an outer reef slope close to a lagoon islet, at a depth of between 15 and 20 m. The frequency distributions of the parameters measured (Figures 9A, B, C, D) were as follows:

TL between 24 and 48 cm	- mean:	35 cm;
TW between 600 and 2,500 g	- mean:	1,450 g ;
DW between 400 and 1,800 g	- mean:	970 g ;
GW between 300 and 1,300 g	- mean:	730 g .

This variety is therefore larger and heavier than *H. scabra*. The biometric relationships for both varieties are given in Table 10.



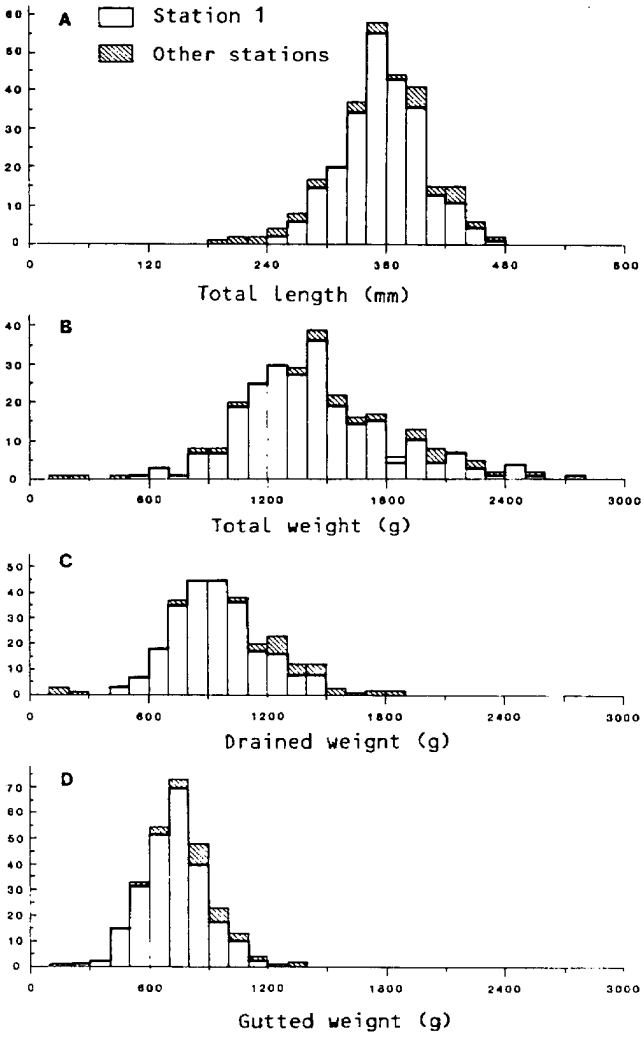


Figure 8:

Distributions of measured characters of H. scabra, New Caledonia.

Figure 9 :

Distributions of measured characters of H. scabra var. versicolor.

4.2.1.3 Reproduction

Sexual cycle

Information on the sexual cycle of these two varieties was obtained by analysing the monthly samples. It relates to the sex-ratio, the anatomy of the genital organs and their stages of development and the evolution of the gonad index. According to the authors, this index is related either to the total weight or the drained weight, which is considered less variable (Conand, 1981). Hence the following calculation: GI = G x 100/TW and GI2 = G x 100/DW, where G is the fresh weight of the gonads.

A synopsis of the results can be made from the three studies. The sexes are separate and the sex-ratio is not significantly different from 1:1. The genital organs, ovaries and testes, consist of a tuft of tubules whose development shows cyclical variations. From the macroscopic examination of their colour, shape and consistency and the histological examination of their gametes can be defined a five-stage scale of maturity for each sex. The characteristics, broadly comparable for all species of the holothurian family, will be described using *H. nobilis* as an example (cf. Chapter 4.2.2). At maturity, the female gonads are heavier than the male ones, producing a higher gonad index (Table 11). A comparison of the two varieties showed that *H. scabra* var. *versicolor* has heavier gonads, but as the drained weight is greater, the mean GI2 is relatively lower.

The progression of the monthly percentages for each stage of maturity for male and female *H. scabra* var. *versicolor* shows a single annual cycle, confirmed by the GI2 variations (Figures 10A, B). Maturation occurs between June and September during the cold water season and as the water begins to warm up. The GI2's increase and the percentage of mature individuals is at its highest in October-November. It declines from December to February while the percentage of individuals in the post-spawning stage rises; the gradual fall in GI2 continues in April/May. In 1978, the cycle was less marked than in 1979, possibly due to the varied origins of the first samples or because of irregular variations in temperature, which did not reach a monthly maximum until March. This cycle shows that the resting period was brief and that spawning continued throughout the warm water season. Reproducing animals were photographed during the day in February 1980 (Laboute, personal communication).

The cycle of *H. scabra* in New Caledonia is more complex. Mature individuals have been found at most times of year and variations seem to occur from year to year. From observations of the progress from stage to stage of maturity (Figure 11A) and the variations in GI2 (Figure 11B), it would appear that, after the main reproduction season during the warm water period, (December-January), there is a second breeding period at the end of the cool months. The existence of a secondary reproduction season has also been shown in other areas where the species has been studied, for example in India (Krishnaswamy and Krishnan, 1967), in Australia (Harriot, 1980), and in Papua New Guinea (Shelley, 1981). Figure 12 illustrates the variations in GI1; it emerges that the main peak clearly occurs during the warm water season, whereas the timing of the secondary peak is more variable. In New Caledonia, it comes from a small fraction of the population. Comparison of three locations shows that GI1 maximums are lower in Papua New Guinea; they are comparable to those of the Mannar Gulf in

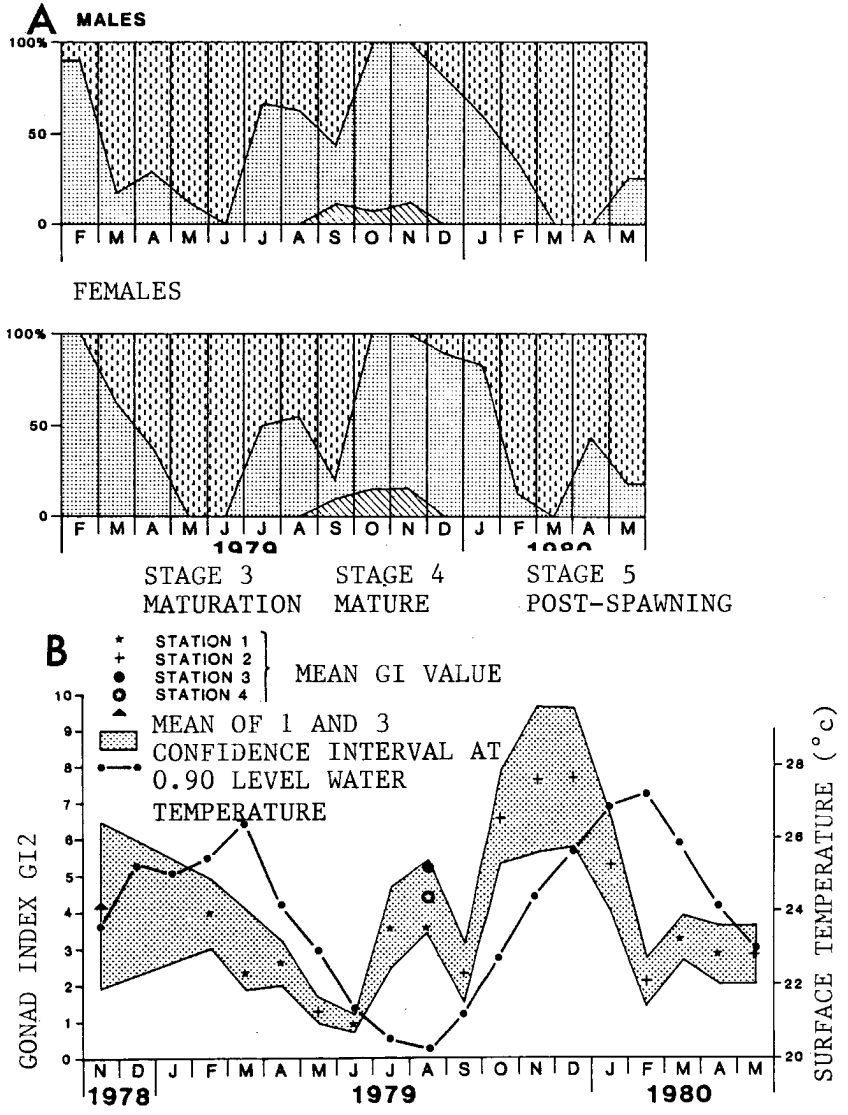


Figure 10: Sexual cycle of H. scabra, New Caledonia.
A: monthly percentages of stages of maturity.
B: monthly variations in GI2.

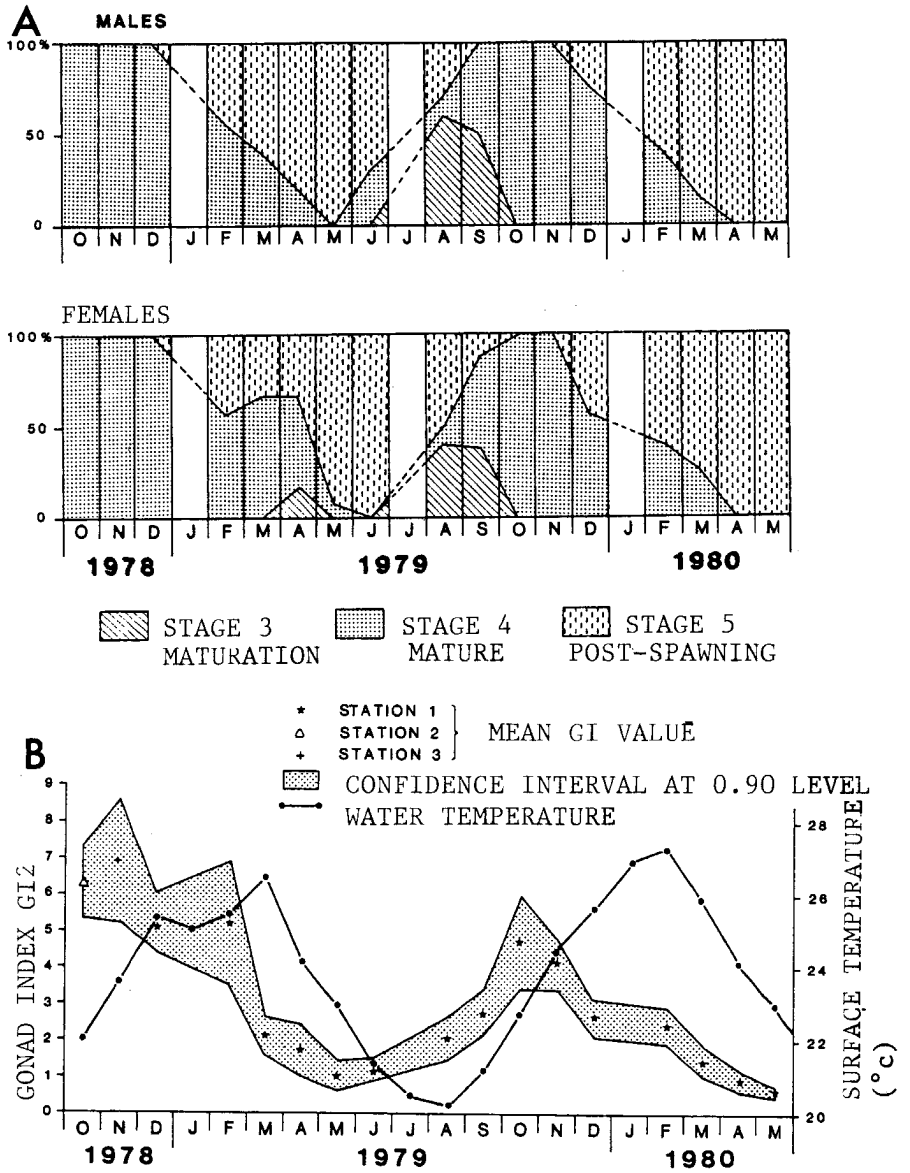


Figure 11: Sexual cycle of H. scabra var. versicolor.
A: monthly percentages of stages of maturity.
B: monthly variations in GI2.

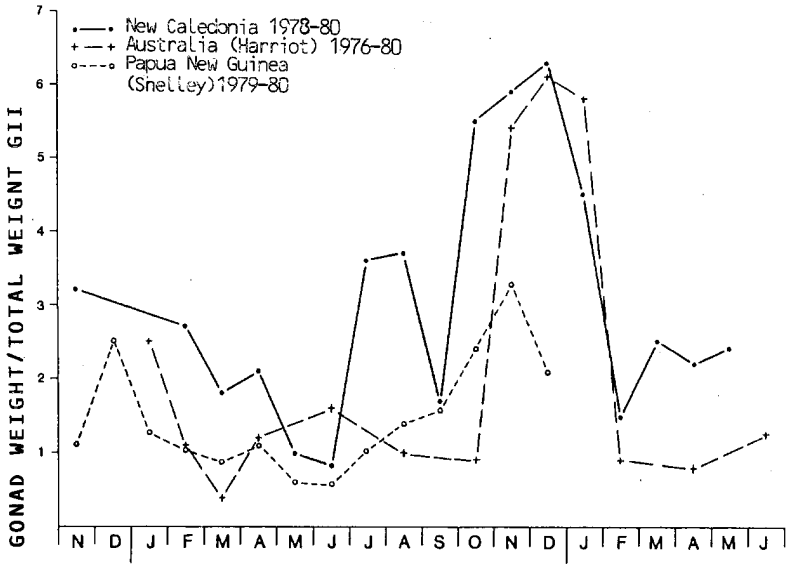


Figure 12: Monthly variations in GI 1 with *H. scabra* in various localities

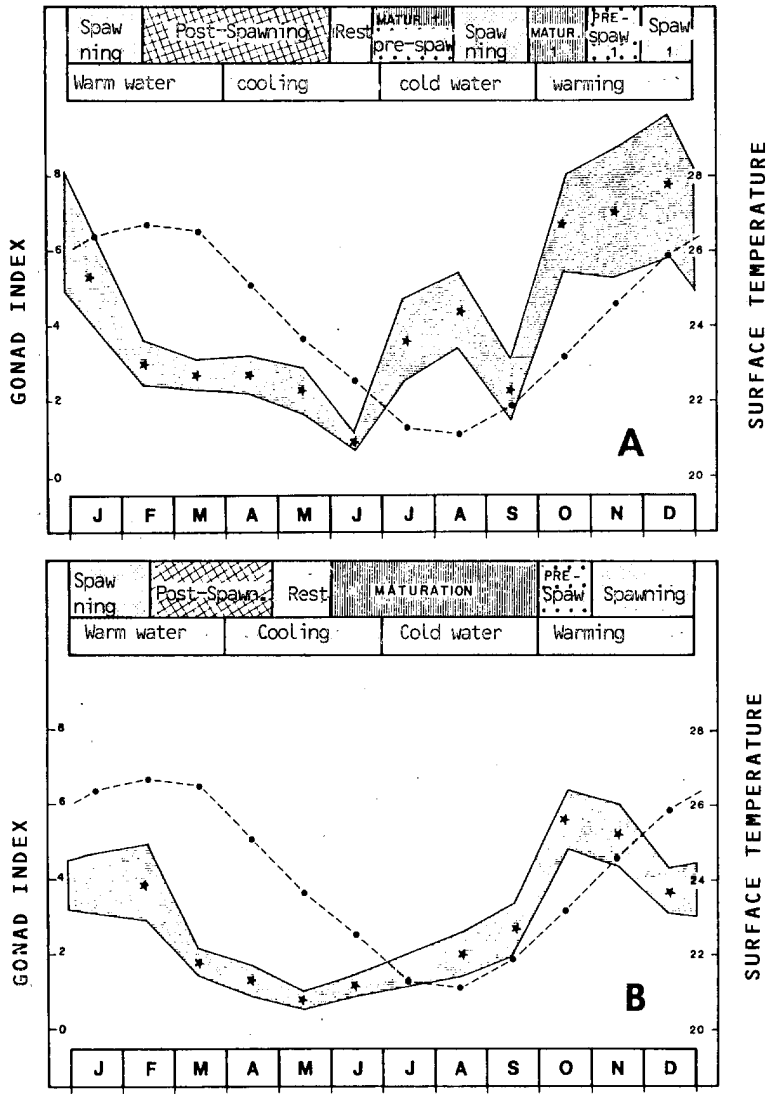


Figure 13: Reproduction of *H. scabra* (A) and *H. scabra* var. *versicolor* (B)

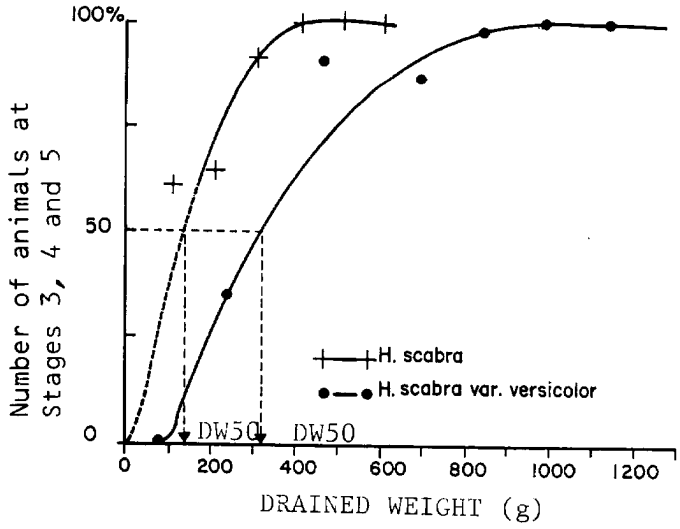


Figure 14: *H. scabra* and *H. scabra* var. *versicolor*; first sexual maturity

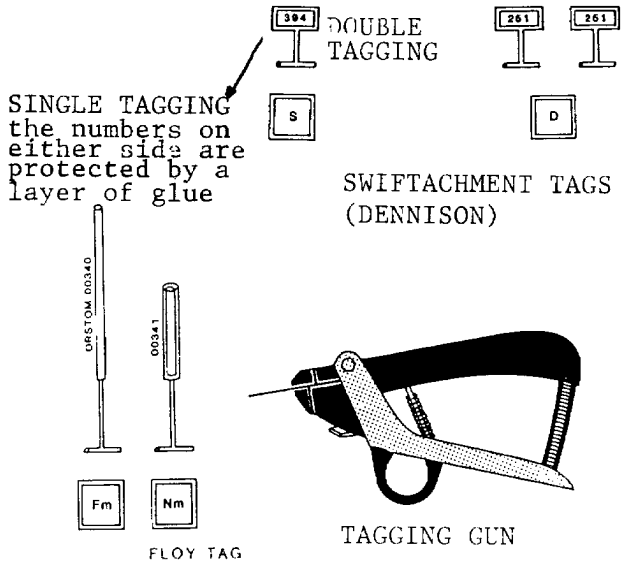


Figure 15 : Tagging method.

Table 11: Characteristics of mature gonads (stage 4) of *H. scabra* and *H. scabra* var. *versicolor* (after Shelley, 1981 and Conand, in press).
( ): number of animals in sample.

SPECIES/PLACE		SEX	G (g)	Length (mm)	TUBULES Diameter ($mm.10^{-1}$)	GONAD INDEX GI 1	GI 2
H. scabra	PNG	M	13,6 (17)	62,9 (17)	14 (17)		
H. scabra	NC	M	23,8 (74)	81,7 (72)	10,3 (69)	4,35 (74)	5,43 (73)
H. scabra	PNG	F	19,9 (21)	75,2 (19)	15 (21)		
H. scabra	NC	F	31,2 (65)	80,5 (62)	13,2 (61)	5,85 (65)	7,21 (65)
H. scabra var. *versicolor*	NC	M	45,9 (72)	136,7 (72)	12,9 (70)	-	4,01 (72)
		F	69,7 (53)	125,6 (53)	18,6 (49)	-	5,84 (53)

Table 12: Tagging and tag returns
N°: operation no. n: number of specimens tagged
d: number of days since tagging
%r: percentage of tagged specimens recovered

Holothuria scabra					*H. scabra var. versicolor*				
N°	n	J	% r	Place	N°	n	J	% r	Place
1	100	5	13	PNG	1	43	90	7	NC
		14	10				190	5	Reef flat
		117	10	PNG			267	7	
2	52	76	11	(Shelley)			356	5	
							664	0	
					2	31	77	13	NC
							166	29	Reef flat
1	56	90	32	NC			476	3	
		190	4		3	65	89	28	NC
		267	9				399	0	Reef flat
		356	5						
2	32	100	15	NC					
		177	19						
		266	3		4	117	78	16	NC
3	50	77	10	NC			245	3	Out slope
		166	12				410	4	
		476	2				505	4	
4	106	89	64	NC	5	81	167	1	NC
		399	2				332	1	Out slope

India. Figures for New Caledonia and Australia are broadly comparable. Spawning was observed by Shelley (1981) in December; all individuals showed the characteristic behaviour already described for other species such as *Bohaschia marmorata* by Mortensen (1937): the animal raises its front section upright, the genital papilla is dilated and protuberant and gametes are released, while the front portion sways slowly backwards and forwards; spawning varies in duration and probably recurs several times in a season. Figures 13A and B summarise results obtained in New Caledonia on the reproductive cycles of *H. scabra* and *H. scabra* var. versicolor in relation to the sea water seasons, which are characterised by surface water temperatures.

Fecundity

Fecundity is one population parameter with potential influence on recruitment. Research in this area is difficult to carry out because prior knowledge of the reproductive cycle is needed in order to be able to define a sampling system during the pre-spwaning stage, when the oocytes are ripe and GI values at their maximum level. The various authors have also observed a very high degree of variability between individual samples at this stage. Lastly, the relationship established between a size parameter (length or weight) and the weight of mature gonads is variable, depending on the species and the comparison method used. For *H. scabra,* for example, there is no significant correlation between weight and gonad weight (Shelley, 1981; Harriot, 1980), but there is such a correlation for the species *H. atra* and *H. edulis* (Harriot, 1980). In such a case, sampling for the purposes of a fecundity study has to cover each of the various size groups.

The fecundity of *H. scabra* in New Caledonia was determined by methods usually used for fish (Conand, 1977). Absolute individual fecundity is defined as the number of oocytes of the principal mode in the pre-spawning stage. Oocyte diameter distribution in the ovaries is variable. Whereas it is generally difficult to clearly distinguish between modes at stage 3 of maturity, these do reveal themselves individually at stage 4, making it possible to count the oocytes of the last batch. These are considered to be equivalent to the oocytes spawned in one reproduction season, because individual gonads, observed after partial spawning, still contain oocytes from this batch. Ovaries at the post-spawning stage often contain oocytes from a smaller-diameter batch, thought to be reabsorbed; sometimes oocytes from the principal mode also remain, but these small numbers will be ignored.

Samples of a mature ovary, weighing approximately 1 g, were taken from the median part of a tubule, drained, weighed (w) and placed in a gilson fixative which helps disintegrate the ovarian stroma and harden the oocytes. Before counting them, a volumetric sub-sample was prepared: after rinsing to remove fragments of ovary wall and separation of oocyte clusters with a pair of tweezers, they were placed in solution in a graduated tube. Homogenous suspension was then obtained using a cyclo-vibrator; a sub-sample was taken using a manostatic pipette. A second dilution is generally necessary before counting in a Dollfus tank. If n is the number of oxocytes counted in sample w, GW being the weight of the ovary, absolute individual fecundity is:

$$Af = n \times G/w$$

Relative fecundity is the ratio of the absolute fecundity of a specimen to the weight of the ovaries, i.e. Rfg = Af/G = n/w, expressed in terms of number of oocytes per gram of ovary, or to its gutted weight, i.e. Rfe = Af/G, expressed in terms of number of oocytes per gram of gutted weight.

The preliminary results obtained for five *H. scabra* showed an absolute fecundity ranging from 9 to 12 x 10^6 oocytes, the average Rfg being equal to 133 x 10^3 and Rfe 31 x 10^3 oocytes. For *H. scabra* var. *versicolor*, on the basis of twelve specimens, Af varies from 2 to 18 x 10^6, relative fecundities being lower, with Rfg equal to 93 x 10^3 and Rfe 11 x 10^3 oocytes.

For *H. scabra*, these values can be considered maxima, since the ovaries were chosen from the best developed specimens, but these preliminary results should be further refined by research on the evolution of relative fecundity in relation to size and an appraisal of the importance of the second surge of reproductive activity.

For *H. scabra*, the diameter of oocytes in the last batch, after fixing in formalin, varied between 150 and 230 microns, with a mode at 190 microns or thereabouts; the gilson caused the diameter to shrink by 20 to 25 per cent. This shrinkage, due to the histological fixatives, explains the lower figures recorded by Harriot (1980) for this species, from 80 to 125 microns, with a mean of 111 microns for mature ovocytes.

With *H. scabra* var. *versicolor*, mature oxocytes measured from 170 to 245 microns, with the mode falling at around 210 microns.

First sexual maturity

The size of individuals at first sexual maturity can be determined graphically, on the curve representing the percentage of individuals in the process of maturation, mature or in the post-spawning stage, by length or weight intervals. The drained weight has been used for this purpose. The number of immature individuals drops as weight increases. The point on the curve where 50 per cent of individuals are considered mature is taken as the index of first maturity. Progression from 0 to 100 per cent takes longer for some species than others.

Despite the low number of immature individuals observed, the drained weight at first maturity can be calculated as approximately 140 g for *H. scabra* and 320 g for *H. scabra* var. *versicolor* (Figure 14). The biometric relationships make it possible to calculate corresponding length and total weight, i.e. TL_{50} = 16 cm, TW_{50} =184 g for *H. scabra* and TL_{50} =22 cm, TW_{50} = 490 g for *H. scabra* var. *versicolor*.

4.2.1.4 Growth

Various standard organism growth study methods were used to try and determine the growth of holothurians, but each was difficult to apply. The results obtained are therefore restricted to a few species and generally to a limited phase of their life cycle.

With regard to tropical holothurians of commercial importance, the first publications were those by Shelley (1981, 1985) and Conand (1983) on the basis of tagging experiments, progression of the modal size of frequency distributions and monitoring of individuals in aquaria.

Tagging

Various methods have been tried, both in the aquarium and at sea, to try and distinguish individuals in a group or assign an individual number to specimens of sea cucumber. The techniques used have included gluing tags to the body wall, scratching, using colouring agents, burning, and attaching tags with wire. Most of these tags were rejected or caused necrosis to some degree. With the temperate species, *Parastichopus parvimensis*, Muscat (1983) succeeded in tagging, giving an interesting insight into the migratory habits. These tags, which remained in place for two to three years, did not seem to affect movements or mortality rates. Tags of the type used in the clothing industry, to which was stuck a small label, were attached using a pistol. This technique was also used to apply tags consisting of coloured plastic strips or Floy Tags (Figure 15). Various tagging operations have been carried out on *H. scabra* in Papua New Guinea and on *H. scabra* var. *versicolor* in New Caledonia; the results with regard to tag recovery rates are shown in Table 12. These were generally fairly high for the first three months after tagging but fell away rapidly thereafter. It is difficult to determine the main causes for this drop: migration, natural mortality or mortality due to tagging or to loss of tags. In addition, because of inaccuracies in measurements of total weight in the field (weighing problems and the state of contraction in which individuals are found), such data is not easy to interprete (Conand, in press).

Farming

Trials carried out with juvenile *H. scabra* in large aquaria were inconclusive for Shelley (1981) with regard to growth. Although the farming conditions closely resembled the natural environment, mortality was high and the juveniles probably failed to gain weight.

A transplantation experiment was carried out in the Andaman Islands of India (CMFRI Newsletter, 1978); 500 juveniles, measuring from 6.5 to 16 cm, were released in a 15,000 m^2 pond in January. By July, the recorded lengths were between 19 and 29 cm, a growth of more than 10 cm in seven months. No further information on this experiment could be secured.

Progression of modal sizes

For holothurians, it is difficult to determine weight or length intervals and monitor how these factors develop over time, because of the variability in units of measurement, the unpredictability of recruitment and the scarcity of juveniles. The growth trends of *Stichopus japonicus* (Choe, 1963), *Stichopus chloronotus* (Franklin, 1980) and *Actinopyga echinites* (Shelley, 1981) have nevertheless been determined in this way. Fish (1967), noticing the absence of any substantial change in mode with *Cucumaria elongata*, inferred that its growth was slow and subsequently proved his theory using weight distributions recorded at various stations over several consecutive years. Shelley (1985) kept track of the length distributions of some *H. scabra* specimens in one quadrat for fourteen months. There was no very obvious progression of modal values in the early months but clear