8. RATIONAL STOCK MANAGEMENT

8.1 Introduction

The intensified exploitation of fishery resources has created a need for their rational management, even where small-scale activities are concerned.

In countries such as Japan and China, where the bêche-de-mer industry started long ago, management is exercised by the cooperatives on the basis of regulated fishing seasons and grounds, and bans on fishing specimens below a certain size.

In the countries of the tropical Pacific, holothurian fishing did not start until the eighteenth century and activity fluctuated greatly (cf. Chapter 3). Very little official control was exercised over this sector. Referring to the nineteenth century, however, scientists Saville-Kent (1903) and Koningsberger (1904) raised the problem of overfishing, but thought that legislation was unnecessary or would be too difficult to enforce, reasoning that the species gathered occurred in very varied sizes and that the fishing grounds were recolonised by individuals migrating upwards from deeper waters. It should be borne in mind that only easily accessible animals in shallow water are harvested and that in coral environments many individuals remain hidden. Also, weather conditions often restrict the fishing seasons. Clark (1921), on the other hand, recommended government involvement to set up a research body for these fisheries.

In the more recent past, the fisheries divisions of the international organisations, FAO and SPC, as well as the countries and territories of the South Pacific and their research laboratories have turned their attention to the management of this resource (Sachithananthan, 1972; Conand, 1979; Gentle, 1979; Harriot, 1985; Shelley, 1985).

The management of a fishery generally consists of designing production models which combine the population dynamics of the species exploited, the fishing activity itself and the economic aspects at each stage, from harvest to consumption. In some cases, particularly in the countries of the tropical Pacific, social factors may also have an important part to play.

The mathematical models belong to either of two main groups (Laurec and Le Guen, 1981). The comprehensive models, whose approach is synoptic, describe how catches and yields fluctuate in relation to the fishing effort and determine maximum production. With fisheries that fluctuate so widely, however, it would appear difficult to assess effort and catch per unit effort consistently and accurately. The analytical models seek to identify and integrate the elementary factors affecting stocks: recruitment, growth, natural mortality and mortality due to fishing.

Knowledge presently available on holothurians is insufficient to develop models for their rational management. This chapter, which reports progress on research into populations and fisheries, outlines the main difficulties to be resolved to carry out sampling and appraises the prospects for management, concludes the present survey.

8.2 Sampling holothurian fisheries

In developed countries, fisheries administrations generally have available regularly-compiled statistics, although these may not always be totally accurate for small artisanal fisheries. In the tropical Pacific, however, such information is non-existent or almost so due to the small size of countries and the proliferation of small-scale activities. Statistics should be assembled both on the intensity of fishing activity and on its spatial distribution. For holothurian fisheries, these could also extend to processing and the final product.

8.2.1 Harvest statistics

What little information is available on catch and fishing effort values was given in Chapter 5. Most of these data come from one-off evaluations by scientists for the purpose of assessing resources.

With the kind cooperation of a trader who buys sea cucumber from fishermen for processing, a survey made it possible to monitor his first year of activities in New Caledonia. From small boats, divers also gathered reef fish, trochus, etc. Monthly fishing logs (Table 38) totalled daily catches per boat as well as the effort involved, in terms of the number of divers and their diving times. Information relating to the geographical location of the fishery and the circumstances of the dive, weather conditions in particular, which would have been useful, could not be gathered on a regular basis. The results are given in Table 39. A distinct increase in the fishing effort emerges, as witnessed by both an expansion in the flotilla and an increase in the number of days devoted to fishing. Since the survey established that each boat carried two or three divers, each of whom spent four to five hours diving, a boat's fishing effort was between 8 and 15 hours per day. CPUE was computed using an average value of 12 hours. The species fished changed after a number of months; *H. scabra* succeeded *H. scabra* var. *versicolor* because of prevailing market prices and the fact it was easier to gather. Whereas catch data for the latter related to eviscerated weights, they usually corresponded to total, fresh weights for the former. CPUE values, expressed in terms of fresh weight (cf. Figure 45) therefore varied from 83 to 230 kg per diver per hour for *H. scabra;* for *H. scabra* var. *versicolor* they were lower, ranging from 47 to 77 kg.

No such summary of statistics could be carried out with the other traders, possibly because of the competition which swiftly sprang up in this sector. It would however be desirable to start collecting these data on a regular basis. They would provide the required information to monitor developments in the region's fisheries.

8.2.2 Bêche-de-mer production statistics

Statistical information about the processed product is easier to come by. Sampling should apply to each of the different species, which are sometimes already graded. Length, or preferably weight distributions should be calculated. These may then be used, by applying the calculated (cf. Chapter 6) fresh/processed weight ratio, to obtain the weight frequency distribution for the specimens harvested. Some difficulty may arise in trying to determine sampling methods. The product is sampled in a warehouse where the bêche-de-mer is stored prior to packaging and shipping.

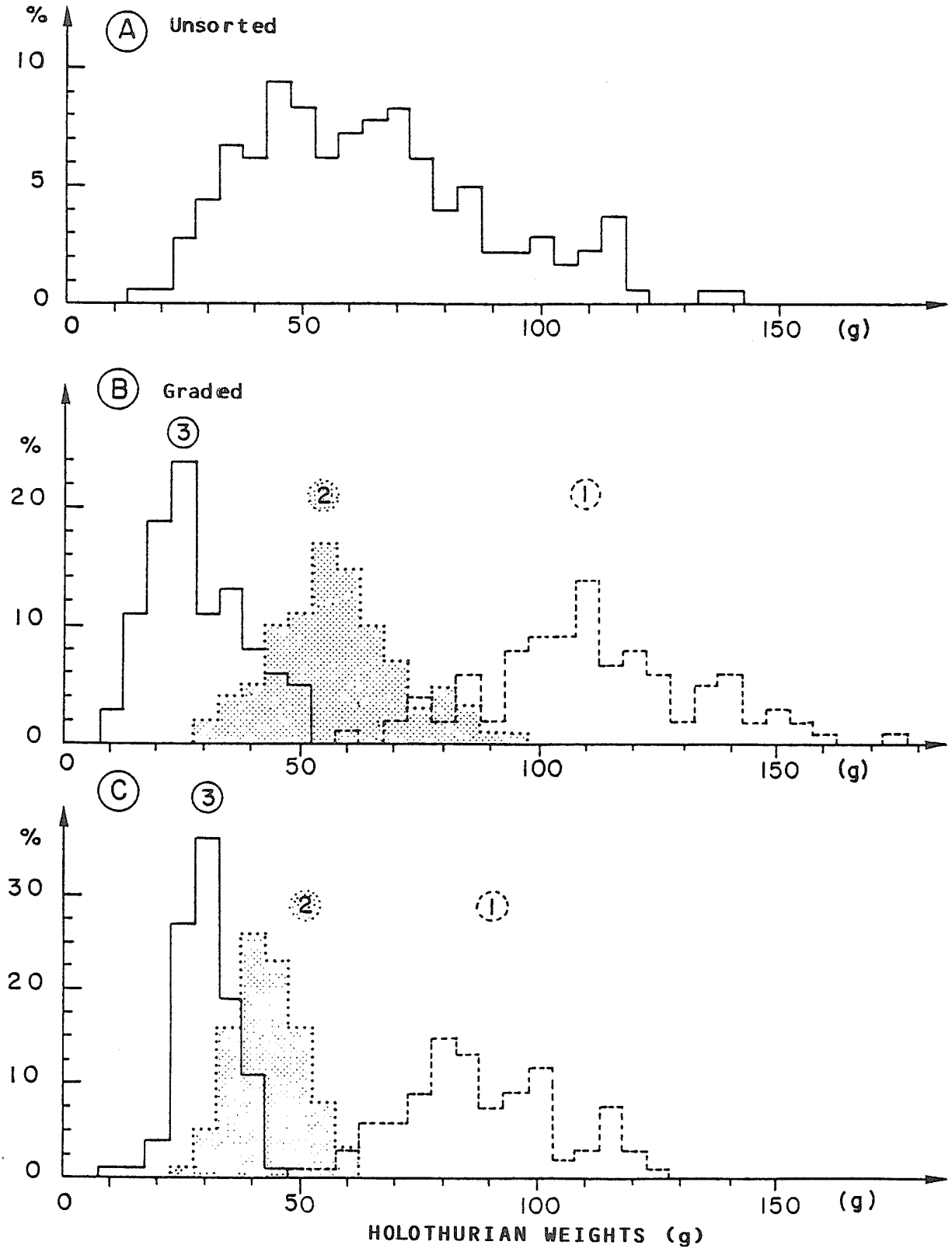

Figure 50: Sampling results of bêche-de-mer *Holothuria scabra* in New Caledonia.

As shipments are irregular, stocks build up between each one; consequently, it is not easy to determine the times at which sampling should be carried out. The time lag of several weeks which occurs during the drying period also needs to be taken into consideration, if these results are to be read together with those from the sampling of the harvest.

Measurements should ideally be taken just before shipment, but this requirement has proved practically impossible to meet and sampling was done on a monthly basis. During the early months of the activity, storage techniques also varied. Initial sorting into three grades, often carried out after drying, made it necessary to stratify the sampling process.

Figure 50 shows some examples of dry weight distributions for *H. scabra*, firstly without sorting, from which direct calculations can be made of the weights of holothurians fished (A) and also the size category (B and C). In these cases (B and C), 100 specimens of each category were weighed and had to be related to their relative proportion in order to obtain the distribution by weight group for that catch. It was shown that groups slightly overlap and that modes may vary slightly from one trip to another. There were also differences between exporters.

These difficulties demonstrate that close cooperation is needed between the operator, the fisheries administration and scientists if an attempt is to be made to standardise methods.

8.2.3 Bêche-de-mer export statistics

As the production of tropical Pacific bêche-de-mer is export oriented, trade statistics are another way of monitoring the activity. Country statistics are normally compiled from these figures as are the FAO's world statistics. Their advantage is to yield annual values, which can be used to follow long-term developments (cf. Chapter 3). Were they more detailed, they could be used to assess the demographic structure of the harvest. In New Caledonia, for example, monthly tonnages by species and by size group were recorded. Analysis of these statistics, for species *H. scabra* especially, showed that grades varied slightly from exporter to exporter, ranging from the six categories described in Chapter 6 (Table 40) to only three. Using the results of dry product sampling, it was possible to group the data into three categories: large (1) corresponding to categories A and B on the market, medium (2) or categories C and D, and small

categories E and F. Table 40 presents total exports and exports per trader, in 1983 and 1984, for the various grades of *H. scabra*. The distribution pattern is very close to that obtained by sampling processed but unsorted products (Figure 50A). The second category, bêche-de-mer weighing from 30 to 65 g, accounts for over half of all exports. Making allowances for weight reduction during processing, this group includes individuals whose fresh weight must have been between 600 and 1,500 g. The care taken in processing and sorting into grades and the way such grades are defined are, however, so many factors contributing to the inaccuracy of these first estimates.

Simultaneous preparation of fishing, processing and trade statistics, using a standardised grading system, should nevertheless remove the barriers to establishing the demographic structure of the harvest.

8.3 Survey of commercial holothurian stocks

8.3.1 Assessment of abundance of stocks

Coral ecosystems, which predominate in shallow tropical waters, cover a total of approximately 600,000 km^2, of which around 13 per cent is located in the South Pacific (Smith, 1978). Many species are fished, most of which only account for a small percentage of the total catch. Most scientific research relates to fish and, up to the present time, very few surveys of commercial holothurian stocks have been carried out (cf. Chapter 5). Recent research conducted in Australia (Harriot, 1985) identified the main features of species distribution on the Great Barrier Reef. In New Caledonia, Conand and Chardy (1985) revealed three main species groupings, as determined by the lagoon biotopes. The densities and biomasses of commercially important species were also worked out. Stock assessment in relation to the surface area of the various biotopes has not however yet been possible for more than a few reefs, using remote-sensing data. This technique should make it possible to undertake thematic mapping of shallow coral areas to a sufficient degree of accuracy, with the assistance of appropriate sampling of holothurian species, to appraise the order of magnitude of resources. The results obtained in New Caledonia therefore relate to a continental-type high island of the western Pacific region, where the most highly diversified fauna is concentrated. A survey of holothurian stocks in atolls should therefore be carried out to give fuller scope to the results on the distribution and abundance of the main species in their principal coral habitats.

8.3.2 Study of population parameters

Available information about the biology of commercial holothurians has been given in detail for each species (cf. Chapter 4). Recent research in Australia, Papua New Guinea, Fiji and New Caledonia has led to an understanding of some parameters, but others have as yet barely been touched upon.

The main references to publications relating to holothurian population parameters in the tropical Pacific are given in Table 41.

Table 38 : Sample catch record card used in New Caledonia.

CONFIDENTIAL

HOLOTHURIAN CATCH RECORD CARD

ORSTOM BP A5 NOUMEA

DATA	NUMBER OF DIVERS	DIVING TIME	NAME OF BOAT	WEIGHT OF SPECIES (x if gutted)					OBSERVATIONS	
				TEATFISH	SANDFISH 1	SANDFISH 3	OTHER	TOTAL	PLACE	PREVAILING WEATER CONDITIONS

Table 39: Results of sampling of the holothurian fishery in New Caledonia over one year.
Species exploited: 1: *H. scabra* - 2: *H. scabra* var. *versicolor*
*: eviscerated weight

MONTH	NUMBER OF BOATS	NUMBER OF DAYS FISHING		SPECIES	TOTAL CATCH (kg)	CATCH per day (kg)	C.P.U.E. kg/diver /hr
		Total	m per boat				
1	2	12	6	2	5 440*	454*	38* = 63
2	2	12	6	2	4 070*	339*	28* = 47
3	2	14	7	2	7 020*	500*	42* = 70
4	3	11	4	2	4 090*	408*	34* = 57
5	4	15	4	2 + 1	8 345*	556*	46* = 77
6	3	26	9	2 + 1	12 900*	496*	41* = 68
7	2	18	9	2	6 715*	373*	31* = 52
8	3	12	4	1	15 333	1 277	106
9	2	8	4	1	15 900	1 988	165
10	2	5	3	1	13 883	2 776	230
11	4	26	6	1	38 842	1 494	124
12	6	52	9	1	52 145	1 002	83

Table 40: Exports of *Holothoria scabra* by grade and by trader.

GRADE (%)	A	B	C	D	E	F
	1		2		3	
YEAR EXPORTER	140 to 65 g		65 to 30 g		30 to 10 g	
1983	28.7		42.9		28.4	
1984	27.9		56.7		15.4	
Exp. 1	6.4	17.6	37.8	21.0	13.3	4.0
Exp. 2	28.3		34.3	24.6	7.4	5.4
Exp. 3	4.9	24.7	26.9	26.5	16.6	
Exp. 4	57.0		43.0		-	

Table 41: Parameters of holothurian populations exploited in the tropical Pacific. *: this report

SPECIES	BIOMETRICS	GROWTH	REPRODUCTION				
			Annual cycle	First maturity	Fecundity	Recruitment	Mortality
H. scabra	Harriot, 1980 Shelley, 1981 Conand*	Shelley, 1985	Krishaswamy & Krishnan, 1967 Harriot, 1980 Shelley, 1981 Conand*	Conand*			
H. scabra var. *versicolor*	Conand*		Conand*	Conand*	Conand*		
H. nobilis	Conand, 1981		Conand, 1981	Conand, 1981	Conand*		
H. fuscogilva	Gentle, 1979 Conand, 1981		Conand, 1981	Conand, 1981	Conand*	Gentle, 1979	
A. echinites	Shelley, 1981 Conand, 1982	Shelley, 1985 Conand, 1983	Shelley, 1981 Conand, 1982	Conand, 1982	Conand*		
A. miliaris	Conand*						
T. ananas	Conand, 1981		Conand, 1981	Conand, 1981	Conand*		

The biometry and annual reproductive cycles are fairly well known for the principal species, except *A. miliaris*. The relevant research was carried out by means of monthly sampling at stations where the populations were fairly dense. These species do not usually show any asexual reproduction or hermaphrodism. Their sex-ratio does not differ from 1:1 in the populations surveyed and the same biometric relationships can be applied to males as to females. Apart from *H. scabra*, whose reproductive cycle includes two spawning seasons, the second being shorter, the other species have a single reproductive season which varies in length and takes place during the warm season, except in the case of *H. nobilis*. Absolute fecundity, which is variable according to species, is very high, sometimes reaching several million ovocytes. The size at first sexual maturity has not often been determined; it would however appear that small-sized species reach this stage relatively early.

Little is yet known about growth for most species, because the variability in weight and length measurements make it difficult to follow the evolution of modal values in the frequency distributions of these parameters. Shelley (1985) was, however, able to estimate average monthly growth, in terms of both length and weight, for *A. echinites* and *H. scabra*. Knowing the average density of these species, he computed annual production and potential bêche-de-mer production, the values for which amounted respectively to 497 kg/ha/yr and 15 kg/ha/yr for *A. echinites*. The values for *H. scabra* are very similar: 487 kg/ha/yr and 24 kg/ha/yr. These calculations are based on populations with assumed zero recruitment, mortality and migration.

The few observations made on juveniles only usually concern isolated specimens and recruitment remains an unknown factor for most species.

Not much knowledge is available about natural mortality. Isolated cases of predation on adults have been reported (Bakus, 1973). The most common predators are thought to be fish, gastropods and starfish. During research in New Caledonia, observations of predation only related to species of family Stichopodidae: *T ananas* and *S. variegatus* often had very marked scarring on the body wall, *S. horrens* was photographed while being eaten at night by *Tora perdix* and *Bohadschia argus* by *Charonia tritonis* (Laboute, personal communication).

No investigation has yet been made of the impact of the many potential symbiotic or parasitic species on the biology of the host holothurian.

The need therefore remains to continue research on various aspects of the biology, especially growth, recruitment and mortality, before considering rational management, because available data are either inadequate or insufficiently accurate to envisage the use of mathematical models.

8.4 Economic and social aspects

8.4.1 Economic aspects

The history of the trade (cf. Chapter 3) and the market survey (cf. Chapter 7) showed that holothurian fishing operations varied greatly in intensity and distribution. The world market is a complex one. There are many intermediate stages between fisherman and consumer: processing, transport and storage, export, import to the world market, packaging, wholesale and then retail market. The market is ultimately dependent on the

demand from Chinese communities. If demand increases, there is a corresponding surge in fishing, processing and trading. The decline which is often observed after a period of prosperity may be due to a number of reasons: overfishing reducing stocks and therefore the profitability of the operation, drop in demand due to a fall in the standard of processing or a drop in prices on the Hong Kong and Singapore markets. The general economic context plays a prominent part in the way these fisheries fluctuate. In recent years, a relevant example is the opening up of the Chinese market, which increased demand for bêche-de-mer in Hong Kong and made it easier to start up a fishery in New Caledonia. This new demand, however, only concerns low quality products and has therefore led to a drop in the average value of imports and exports to and from Hong Kong.

The pricing structure has to take into account fishing, processing and transport costs. These are fairly high for the countries of the tropical Pacific, despite the fact that trade has been facilitated in recent years.

It would appear that the present price structure allows for a reasonable profit to be taken at each of the various stages. There can be no doubt that the profits accruing to Pacific islands (fishing, processing, export) could be increased, if the following suggestions from Singapore wholesalers were acted upon:

- species should be harvested as determined by specific market requirements;

- processing should be in line with importers' requirements, in particular where smoking is concerned;

- processed products should be sorted into commercial grades before export;

- supply should be regular in terms of both quantity and quality;

- packing should be more appropriate for lengthy transport. Bêche-de-mer shipped in wooden crates or cardboard boxes lined with plastic would be more effectively sheltered from risks of damage than they are in the jute sacks currently used.

To prepare economic models for these fisheries, comparable to the production models, statistics are required on the value of the harvest (or of the processed product in the case of holothurians) and on production costs. On the basis of the value of the fishing effort, curves for total value, gross economic return in terms of gross value of the production per unit of cost, gross economic gain and net total economic profit can be drawn (Troadec, 1982). This index shows a maximum representing the management objective. As for stocks, however, these models cannot be produced until a statistics collection system has been set up.

8.4.2 Social aspects

The way the three closely-interested sectors of harvesting, processing and trade are organised has a social impact. In the Pacific islands, the participation of fishermen in modern economic life is a factor to be considered alongside their employment and the raising of their income. Employment and income enhancement for traders processing this product are also important factors.

The countries concerned traditionally have a wide variety of social organisations and ways of sharing reef resources. These traditions are, however, tending to die out near urban areas (Munroe, 1985). Competition may then break out between different communities for access to the fishing grounds.

The organisation of holothurian fishing varies from country to country. Only rarely does a fisherman work alone with just the assistance of his family, because although the capital outlay for equipment is limited to a small boat and a dryer, processing requires more labour. Fishermen therefore form either groups at the village level or cooperatives. These cooperatives may then federate to organise marketing (Sachithananthan, 1972).

Fisheries administrations also often play an important role, as in Fiji for example, by organising training courses on bêche-de-mer processing, assisting in the setting up of cooperatives or dealing with marketing.

Elsewhere, in New Caledonia for example, the fishermen form groups around the traders, who handle processing and marketing.

However this activity is organised, the fishing and processing of holothurians are rarely sole activities; the fishermen diversify their catch and the traders their commodities under the influence of local and general economic circumstances.

8.5 Regulating the industry

This can be done by setting a limit on total effort by means of quotas or bans on fishing at particular times or in particular areas, or by changing the distribution of effort over the age groups of the resource by setting size limits on individual animals or on the processed product.

Little official control is exercised over holothurian fisheries in countries of the South Pacific. The low returns obtained on small-sized products usually spontaneously restricts fishing to large specimens, which are in fact more widely available.

In Australia however, the Queensland Fisheries Department, pending the results of their resource assessment, took interim control measures in 1976 (Curtis, 1980). These restrictions ban all fishing except pilot operations, for which licenses are issued.

In some Indian Ocean countries, the sizes of export products are regulated. This applies to species *H. scabra* in Madagascar, Sri Lanka and India. In India, for example, the export of specimens under 75 mm in length (approximately 16 g) is prohibited, which even prompted an exporters'

association to petition for this minimum size to be reduced to 50 mm (INFOFISH, 1985). The regulations do not generally appear to be based on scientific results and vary from country to country for the various species.

In countries where this activity is an ancient one, such as China and Japan, the rules vary from region to region. In Japan, for example, they are applied by the cooperatives to areas and times when fishing is closed (Suguri, in Mottet, 1976). In China, the fishing activity exercised by the people's communes is regulated by restrictions on seasons and the size (or weight) of the processed product.[6]

In the countries of the tropical Pacific, each of the possible methods of regulation, if based on scientific results, could have advantages and disadvantages, but it would be necessary to be able to check that the rules are actually complied with. Annual quotas can, for example, be checked through the custom statistics, but their distribution between fishermen and traders can be hard to determine. The seasonal fishing ban can hinder exports, since the buyers on the Hong Kong and Singapore markets have always insisted that supplies should be regular. A longer closed season can be considered where yields drop drastically. It is difficult to enforce closures of fishing zones and their boundaries must respect local customs, when these non-mobile resources are exploited under a system of traditional reef ownership. Limiting fishable sizes tends to favour recruitment. When applied to catches, such restrictions are hard to verify but when applied to the processed product, they are realistic and can be checked through exports. The limits should be set on the basis of scientific results relating to size at first sexual maturity. The values presented in Table 42, for example, are obtained by multiplying L_{50} and W_{50}, the length and weight at first sexual maturity, by the factor for shrinkage due to processing. These values could be used as a basis for setting legal size limits, not forgetting that they are minima and that better knowledge about growth remains essential so as to be able to leave individuals undisturbed for one or more breeding seasons before harvesting them.

Table 42: Length and weight values for processed bêche-de-mer, corresponding to L50 and W50, parameters relating to holothurians at first sexual maturity.
%: parameter measured in dry rather than fresh condition (cf. table 30).

SPECIES	LENGTH (mm) W_{50}	%	Processed	WEIGHT (g) P_{50}	%	Processed
H. scabra	160	38	60	184	5	10
H. scabra var *versicolor*	220	38	85	490	6	30
H. nobilis	260	51	130	800	9	70
H. fuscogilva	320	44	140	1175	8	95
T. ananas	300	38	115	1230	5	60
A. echinites	120	47	55	90	11	10

6. Gratitude is due to the scientific department of the French Embassy in China, who supplied this information.

8.6 Stock improvement methods and aquaculture

Bearing in mind their long-standing taste for holothurians, it is not surprising that it should have been the Japanese who first attempted to increase the natural stocks. Mitsukuri (1912) was an early proponent of the construction of artificial reefs in coastal zones to improve the recruitment of juveniles and make the summer dormancy period easier for adults of *S. japonicus*. Choe (1963) reported that this practice was already traditionally widespread in the nineteenth century, with young individuals being transplantated to increase stocks or adults to favour spawning. Many projects were also implemented by the prefectures in areas where this activity was carried on, but only rarely were the results evaluated. Larva rearing produced much research, from Inaba (1937) and Imai *et al.* (1950) to more recent investigations attributable to Ishida (1979) and Anon. (1983). Other references are quoted by Mottet (1976). The aquaculture of *S. japonicus* has also been the subject of research in China, with the following articles describing these experiments: Anonymous (1976, 1977), Shuxu and Gonchao (1981), Shui Xi-Lin *et al.* (1984, 1985). Some Russian investigations, particularly those by Mokretsova (1978) and Levin (1982), confirmed that these techniques were likely to develop in the future. It would however be premature, in view of the knowledge presently available on these species, to consider applying these techniques to the species of the tropical Pacific. Even if the techniques were mastered, there would be no guarantee of economic viability.

8.7 Conclusion

The main characteristics of these small artisanal fisheries have been described in this chapter; the methods for sampling catches and populations have been defined. At present, the lack of statistical catch data and the absence of more thorough knowledge about the biology of the species concerned restrict the scope for developing mathematical models for the purpose of planning rational stock utilisation. Figure 51 summarises the main factors involved in achieving rational management of these fisheries in the future.

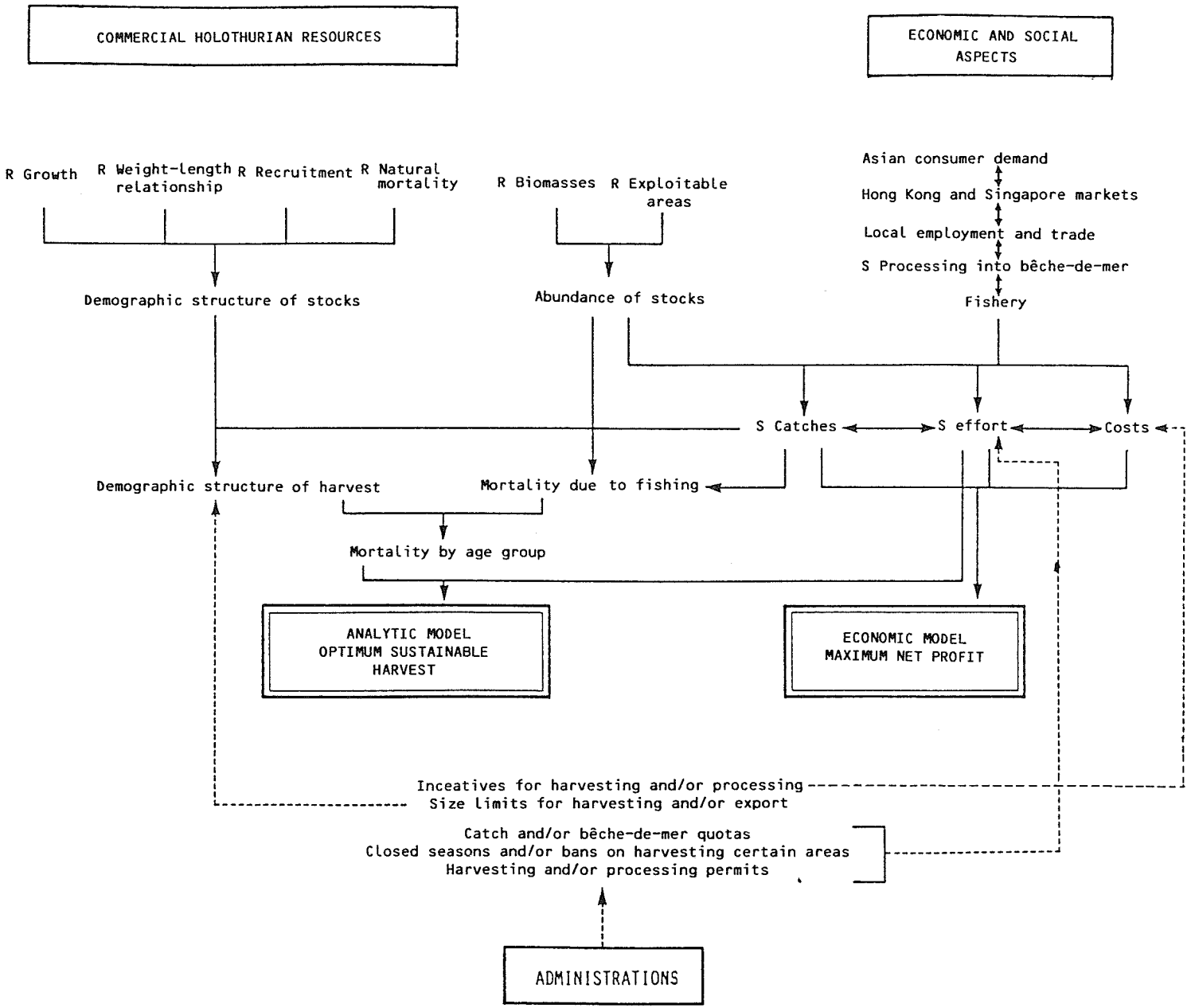

Figure 51 : Factors affecting the rational management of holoturian fisheries in the tropical Pacific.
S : sampling R : research