SPC/Fisheries 17/WP.12
16 July 1985
ORIGINAL : FRENCH

SOUTH PACIFIC COMMISSION

SEVENTEENTH REGIONAL TECHNICAL MEETING ON FISHERIES
(Noumea, New Caledonia, 5 - 9 August 1985)

DEEP-BOTTOM FISHES OF THE OUTER REEF SLOPE IN VANUATU

by
F. Brouard
and
R. Grandperrin*

578/85

---

* ORSTOM Centre
B.P. A5
Noumea
New Caledonia

DEEP BOTTOM FISHES OF THE OUTER REEF SLOPE IN VANUATU

Table of Contents

ABSTRACT

This paper deals with the deep demersal fish species caught on the outer reef slopes of Vanuatu. Their physical environment, which is outlined in the first section is comparatively stable at the usual fishing depths. More than 2000 fishing trips, made on small craft, have been taken into account, of which about 700 were analysed in detail. Analysis of catch per unit of effort (C.P.U.E.) fluctuations in relation to depth and to day or night fishing led to classification of species into shallow, intermediate and deep species, with predominantly daytime or night-time activity. A matrix for cluster analysis was established using the catch record data and allowed several different groupings of species to be identified, each being linked to a well-defined set of fishing conditions. Seasonal fluctuations in the C.P.U.E. are not very marked. Analysis of length frequency distributions indicates that, within a given species, large-sized individuals tend to live in deeper waters while smaller specimens prefer shallower waters. Although sexual activity peaks in spring, spawning appears to take place throughout the year. Estimation of growth rates by otolith reading and analysis of modals changes in the length frequency distributions suggest that growth is slow. Calculation of mortality coefficients shows stocks to be virgin. Generally speaking, the very deep species would be more sensitive to fishing pressure than the shallower ones. An attempt is made to estimate the maximum sustainable yield (M.S.Y.) for Vanuatu as a whole and for each island in the Group.

SUMMARY

This document deals with deep snapper caught on the outer-reef slope of the islands of Vanuatu which are located in the tropical zone of the South-West Pacific Ocean (Fig. 1).

1. Bottom fishing for deep snapper is considered to take place over depths ranging from 100 m to 400 m. The area of sea floor extending between these depths was estimated to be 7 360 square km with an average slope of 10 %. General features of hydrological environment show that mean conditions prevailing at fishing depths are fairly stable throughout the year (Fig. 3).

2. More than 2 000 fishings trips carried out on board small boats have been taken into account, of which about 700 were analysed in detail. In addition, experimental longlining was carried out during exploratory fishing surveys. Most of the fish were identified, measured and weighed; otoliths and gonads were taken. Skippers were interviewed so as to obtain detailed information on each fishing trip. Data were captured and processed on a micro-computer. The best measure of fishing effort seems to be the reel hour.

3. The average catch per unit effort (C.P.U.E.) was 3.04 kg/hour (Table 3). Values of C.P.U.E. for other areas from within the region are given in Table 5. A total of 107 species were caught (Table 7). Fish belonging to the *Etelidae* family formed the bulk of the catches although the families *Serranidae* and *Lutjanidae* were well represented (Table 8).

4. The depth range for 84 species is shown in Fig. 8. C.P.U.E.'s calculated for the main species show fluctuations with depth (Fig. 9); some species are caught in shallower water whilst others are caught in deeper water. The index of specific diversity decreases as depth increases. As a result, it is considered that deep resources are more sensitive to fishing pressure than shallower ones. Total catches made at day time and night time were compared (Fig. 10). For the main species, Figs. 11 and 12 show that some are caught more frequently during the day than during the night; however, many are caught both by day and night (Figs. 11 and 12, Table 12). There is a tendency for some species to migrate upwards by 40 m - 80 m during the night, descending again in the daytime (Figs. 10 and 12). Seasonal fluctuations do not seem to

be clear although some general trends are noticeable (Fig. 13). Various factors influencing the catches were considered : skill of the skipper type of bottom, moon phase and type of bait. The average bait : catch ratio is 1 : 13 (Table 13).

5. A matrix for cluster analysis was established using catch record data (Fig. 14). This allowed several different groupings of species to be identified. These indicated that all the species within one grouping were caught at the same depth, time of day and probably on the same type of bottom.

6. An analysis of length-frequency distribution shows that the maximum sizes of fish may vary from one country to another (Table 14). Sizes of fish increase with increasing depth (Fig. 16). Length-weight relationships were calculated for 34 species (Table 15).

7. Reproduction occurs throughout the year but peaks in sexual activity take place during spring and summer (Table 17, Fig. 18). The selective property of lines and hooks is such that the large species like *Etelis carbunculus* and *E. coruscans* enter the fishery before they have reached their sexual maturity. These species are therefore more sensitive to exploitation than the smaller ones like *Pristipomoides* spp. for which a large part of the brood stock is never recruited to the fishery (Table 19).

8. Growth rates were estimated from daily growth rings on otoliths (Figs. 19 to 23). They were also calculated by analysing length-frequency distribution. The second method is derived from Pauly's programme called ELEFAN I (Electronic Length-Frequency Analysis) in which the growth parameters kept amongst many others are the ones which best explain the specific-structure of a set of length-frequency samples. The alteration to Pauly's method is illustrated in Fig. 24 and in Appendices 4 and 5. Fig. 25 shows the growth curve obtained for *Pristipomoides multidens*. Growth was also estimated using an average value of Pauly's "Index of growth performance" calculated for the main species (Table 20). Whatever method is used, it seems that the large species which live in deep water like *Etelis* spp. do not grow as fast as the ones living in shallower water like *Pristipomoides* spp.

9. The parameter of total mortality Z was estimated by two methods. In the first one the natural logarithms of fish numbers were plotted against their age (Fig. 26). The second method was based on Beverton and Holt's relationship (Table 21). The natural mortality parameter M was predicted from Pauly's empirical relationship in which the mean environmental temperature and growth parameter are linked. The data shown in Table 21 leads to the conclusion that the resources are virgin.

10. The lack of a long series of C.P.U.E. data does not allow the calculation of the maximum sustainable yield (M.S.Y.). However, results obtained in Hawaii were applied to Vanuatu where the general environmental conditions are similar (Table 22). The M.S.Y. was estimated to be 1 kg/ha p.a. in the area between isobaths 100 and 400 m and 750 tonnes p.a. for the whole archipelago (Table 23). Additional data from exploratory trawling carried out on virgin stocks in New Caledonia provided an estimated value of 4 kg/ha p.a.

11. The conclusion is that stocks existing in deeper water seem to be more sensitive to fishing pressure than the stocks living in more shallow waters. However, as resources in shallower water are easily exploited there is a need to start thinking about fishery management all along the outer-reef slope. Within the Pacific, only a few countries have undertaken a scientific approach to this matter. Therefore parameters and figures estimated in Vanuatu might well apply to the region, at least until more detailed data become available.

INTRODUCTION

All countries in the tropical Pacific have started to exploit the deep demersal fishes occurring on the outer reef slopes and seamounts, at depths ranging from 100 to 400 metres. In Hawaii the commercial deep bottom fishery is over fifty years old and historical statistics for it are available. It is therefore possible to review changes in the catch per unit of effort (C.P.U.E.) over a long period and from this to estimate the maximum sustainable yield (M.S.Y.) which is the key to fishery management. In other Pacific Islands, commercial fishing for deep bottom species began only very recently, and has usually been carried out without systematic recording of place, depth and volume of catches, which means that planners do not have at their disposal the information base necessary for the establishment of development guidelines.

In Vanuatu, the first exploratory deep bottom fishing trips on record took place in 1976. However, it was not until 1981, when a wellstructured Fisheries Department was set up, that an intensive training and development programme was initiated, leading to the establishment of around twenty fishing associations throughout the Vanuatu Group. While traditional subsistence fishing with handlines rarely reached bottoms below 100m, the use of handreels now allows fishing at much greater depths, where resources are still virgin. These unique conditions were taken advantage of to conduct a detailed study of the daily landings of the Fisheries Department's boats, a study that forms the basis of this document. Concurrently, a simple statistics collection programme was launched in the islands. It presents the enormous advantage of commencing from the very beginning of the fishery.

Fourmanoir (1980) defines deep bottom fishing as starting at a depth of 120m and ending around 400m with the disappearance of marketable species. The target stocks are of considerable economic interest to the island countries, for they can be fished by simple artisanal methods requiring only a modest outlay. Furthermore these deep demersal species appear to be relatively sedentary and present all the year round, and they are, with a few exceptions, not ciguatoxic, hence suitable for export. Nevertheless, because of the absence of a continental shelf, the size of the stocks is limited and the biomass quite small. The individuals are not evenly distributed, but tend to occur in clusters. This pattern of distribution results in very variable catches. Little is known about the biology of the deep bottom species. There are several reasons for this : recent exploitation of the resource, gear selectivity, impracticality of *in situ* tagging and observation, frequent taxonomic confusion and misidentification, etc... The data given in the literature were mostly collected from commercial catches. The economic constraints governing the activity of commercial fishermen result in these data lacking the time and space continuity essential to a systematic research programme. This is true of our own data too, and considerable gaps detract from the seasonal fluctuations and reproduction studies in particular. However we were able to collect a large body of data. Rather than focus on just a few species, we chose to study the fish fauna as a whole since this is more closely tied to the economics of a fishery.

Fishing success can depend on numerous factors : season, weather conditions, time of day, depth, type of bottom fished, type of gear used, bait, etc... not to mention the skipper's skill. A study of the effect of any one of these factors in theory implies that all the others remain constant. This is hardly ever the case, particularly if the fishing fleet is small, as it is in Vanuatu. Consequently, the conclusions we reached indicate general trends rather than clearly circumscribed phenomena. Nevertheless, our contribution to the understanding of deep bottom fishes should help to orient development actions more effectively and to establish guidelines for future research of benefit to the fisheries activities of island countries in the tropical Pacific.

BACKGROUND

1 - Geography

The Vanuatu Island Group (Fig.1) consists of about 80 islands most of which are high islands of volcanic origin. There is no lagoon and coral formations are therefore confined to a narrow coastal strip which makes for easy subsistence fishing. There is no continental shelf, and bottoms drop fairly sharply from the reef fringe to the open sea.

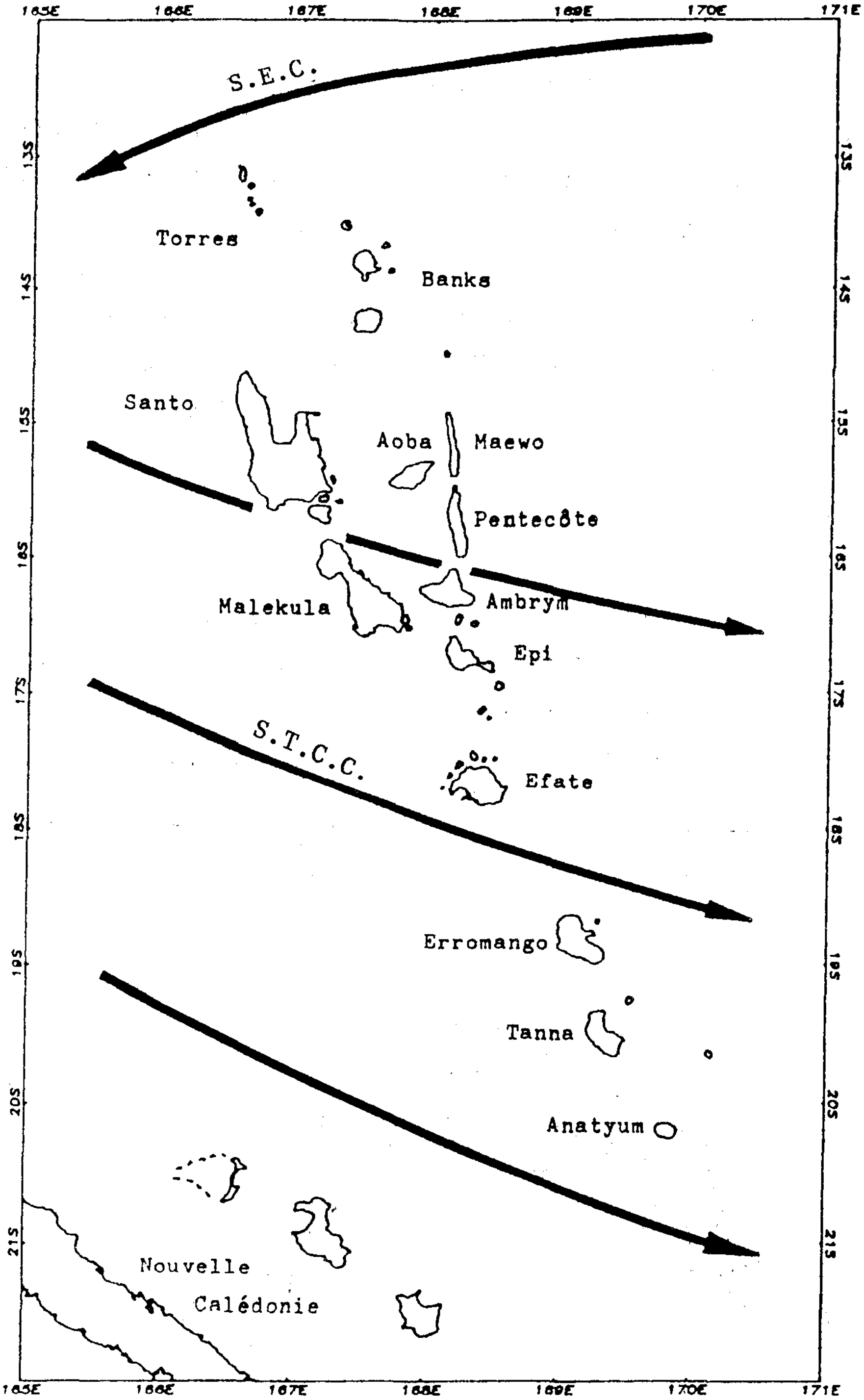


Fig. 1 - Major current patterns in the Vanuatu zone (from Petit and Henin, 1982)

S.E.C. : South equatorial current
S.T.C.C. : South tropical counter current

The area of sea floor where fishing for deep bottom species can take place (100 to 400m) is thus fairly restricted. For the whole of Vanuatu, it can be estimated (by plane geometry calculations) at 7 360 sq.km, which is a little over half the emerged land area (13 480 sq.km). The average slope is 10%, but in fact the slope varies quite considerably from one place to another reaching 40% in the central portion of the west coast of Pentecost and being only 2% on the south coast of Efate (Fig.2). For the whole archipelago, the total length of isobath 100 meters is about 1 400 nautical miles (2 600 km). There are several banks and seamounts at depths of less than 300m. Some of these were recently prospected during an exploratory survey (Grandperrin, 1983).

The capital, Port-Vila, lies on Efate which is the fourth largest island of the Group. Isobath 100m there measures 130 miles (240 km) and the area between isobaths 100 and 400m is 1 300 sq.km for an average slope of 7%. The average width of the fishable area is three miles.

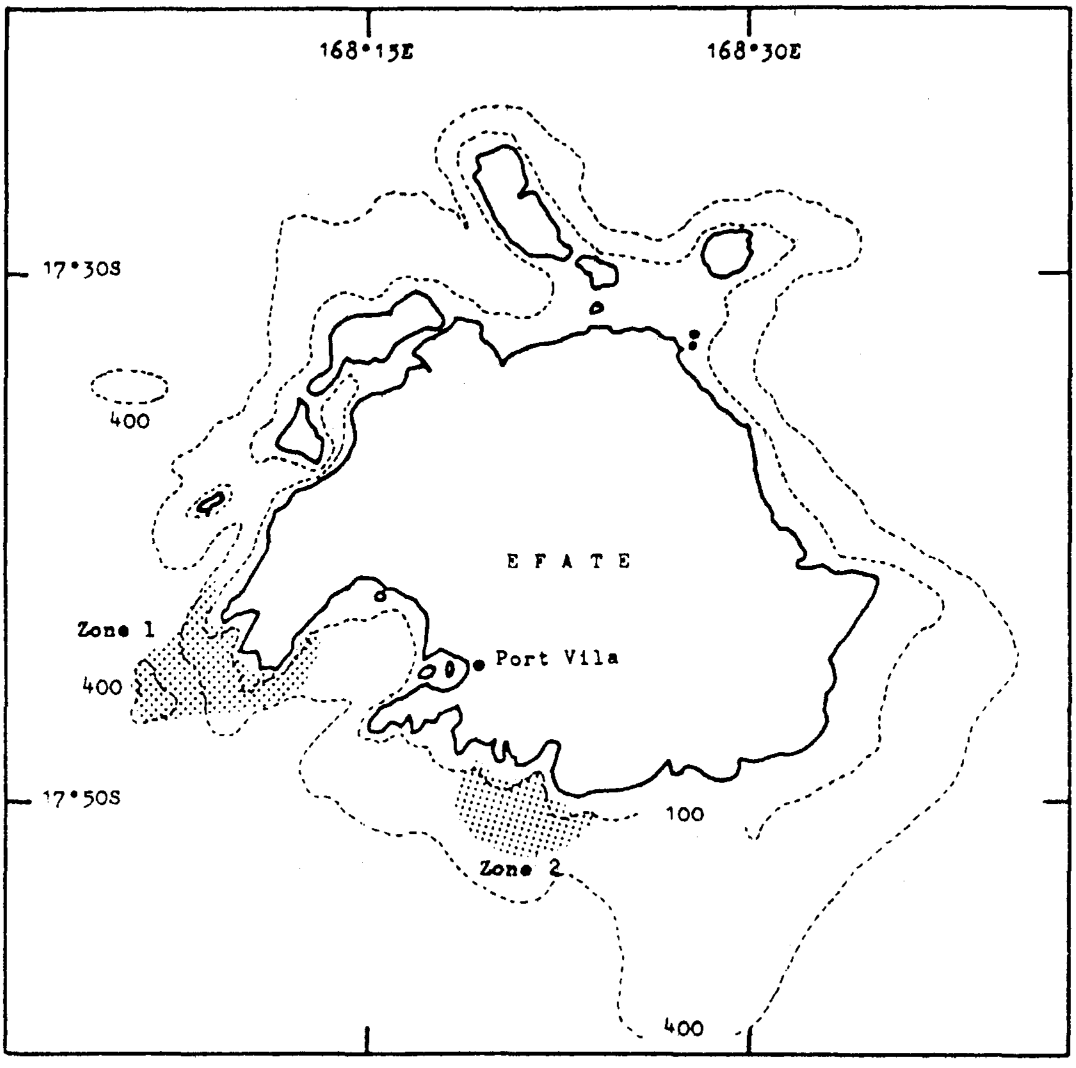


Fig. 2 - Efate : 100 m and 400 m soundings.

2 - Characteristics of the marine environment

Vanuatu lies entirely within the tropical zone. The surface waters, the temperature of which ranges from 24 to 29°C, originate in the Eastern Pacific where they are formed by an upwelling of rich deep waters along the South American continent. Moving westward on the surface, they gradually become warmer and at the same time poorer in nutrients. By the time they reach Vanuatu, they are very typical of tropical waters, with low productivity because of a deep warm isothermal layer blocking all penetration of nutrients from the underlying richer waters. This trend to become gradually poorer is however more or less offset by disturbances resulting from currents, winds and especially the presence of islands.

Hydrological studies suggest the following pattern of major currents in the Vanuatu zone : the northern part of the archipelago, down to 15°S, is affected by a westward flowing current, the South Equatorial Current, whereas between 15° and 20°S, the major current flows east south-east (South Tropical Counter Current) and counteracts surface drift due to the tradewinds (Fig.1). Between these currents, the position of which varies with the years and the seasons (both currents shift noticeably from north to south during the southern hemisphere summer), a convergence phenomenon occurs (1).

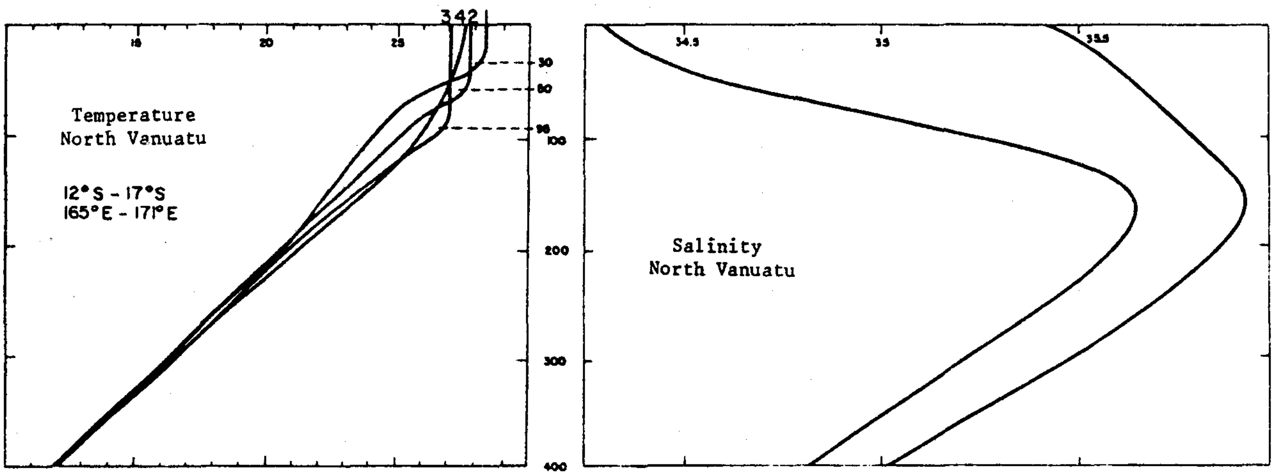
Temperature and salinity features are shown on the diagrams of Figure 3, drawn from Petit and Henin (1982). The vertical thermostructure is characterised by a very slight thermocline, which reflects considerable water stirring by wind. At the end of the southern summer, the thermocline reaches 100m, i.e. the upper limit fo the 100-400m depth range of interest to deep fishing. In the other seasons, the thermocline is between 30 and 100m. Below 100m, seasonal fluctuations are very slight; from 200m downwards they would average only about 1°C. From 100 to 400m, the temperature decreases steadily; it drops from 27°C to 12°C in the northern part of Vanuatu and from 24°C to 14°C in the southern part.

---

(1) This phenomenon is due to the Coriolis force caused by the rotation of the earth . At the level of the Solomon Islands, between the eastward flowing South Equatorial Counter Current and the westward flowing South Equatorial Current, there is on the contrary a divergence, the "Solomon Divergence". An upwelling of the deep richer waters occurs there, causing a certain fertilisation of the zone.

The dissolved oxygen content of the water shows little variation with depth below 100m. On the other hand, it increases as one goes from the north to the south of Vanuatu. It average 3.5 ml/l.

Islands and seamounts considerably disturb the general circulation. Lying roughly north-south, the archipelago can be compared to a grid set perpendicular to the major currents. The "wake effect" of islands may cause considerable turbulence at the tips of the islands and thus produce deep water upwellings reinforced by the effect of strong wind and tide currents. Presence of high-amplitude internal waves has been reported. Island wakes and internal waves could well have localised effects on the environment of deep bottom fish.



a. Vertical distribution of temperature

b. Vertical salinity structures

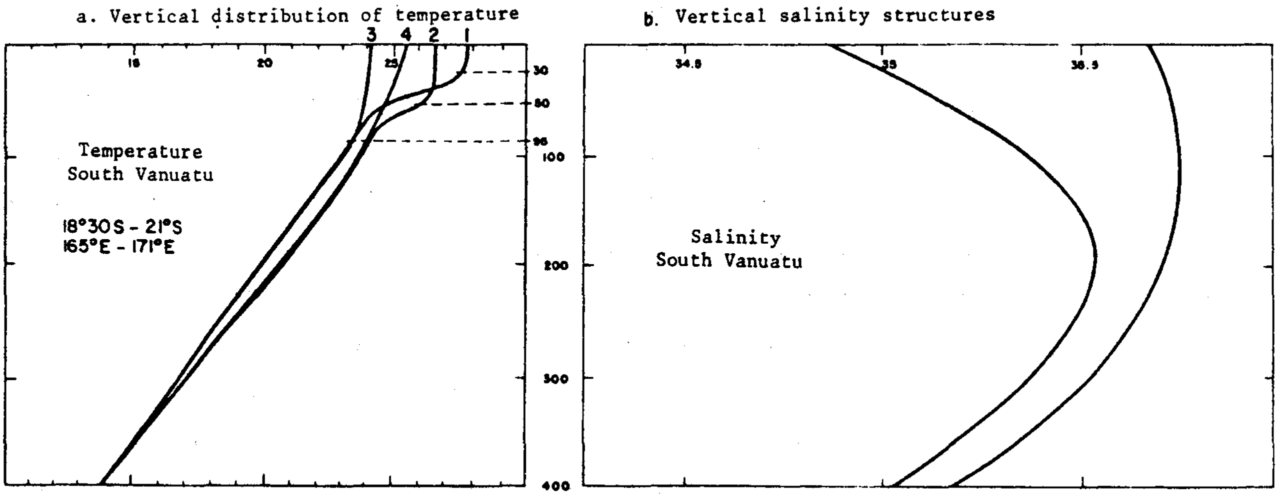


Fig. 3 - Vertical structure of temperatures and salinity in Vanuatu waters (from Petit and Henin, 1982)
1, 2, 3 and 4 : 1st, 2nd, 3rd and 4th quarters.

The quantity of energy available to deep bottom species is proportional to the primary production of the whole column of water. Several series of measurements have been carried out in the Vanuatu waters, particularly one (A) 100 miles west of Efate (Dandonneau *et al*, 1981) and another (B) along longitude 170° East (Rotschi *et al*, 1972). The results are summarised in table 1. The value found being relatively low, it would be unrealistic to expect large yields from deep bottom fishing in Vanuatu.

Table 1 - Phytoplankton and primary production

	Vanuatu (A)	Vanuatu (B)
Chlorophyll (mg/sq.m)	72 (1)	23 (1)
Primary production (mgC/sq.m/h)	37,6 (2)	3,3 (3)

(1) integrated over 0-200 m
(2) integrated over 0-170 m
(3) integrated over 0-100 m

On the whole, the natural environment in which the deep bottom fish live and feed may be said to be very stable.

3 - Artisanal fishing activity

It is difficult to use the term "fishery" to describe the activities involved in the capture of all the different deep fishes eaten in the Vanuatu Group, for the means and methods used are very diverse. The preliminary findings of a large-scale ongoing survey (David, personal communication) are summarised in Table 2. It can be seen that traditional canoes are still widely used, whereas nylon lines have replaced the traditional plant fibre lines. Outboard motors which enable craft to go out further, hence to fish in deeper water, are as yet the only means of mechanised propulsion. They are used on wooden, plywood or aluminium craft varying in length from 3 to 8.50 m. The reels used are either "bicycle" handreels (1) (Fig.4) or wooden handreels (Fig.5). The latter were introduced a few years ago by the Fisheries Department and are likely to become increasingly popular, for they are robust and cheap.

---

(1) The "bicycle reel", as its name indicates, uses the pedal and gear mechanism of an actual bicycle, the pedals being actionned by hand.

Table 2 - Findings of a 1983 survey on the socio-economic aspects of village fishing activity (1), from David (personnal communication)

Population		
Total population of Vanuatu (2)	111 251	inhabitants
	22 621	households
Rural population of Vanuatu	96 207	people
	18 932	households
	781	villages
Rural coastal population	63 797	people
	12 720	households
	496	villages
Fishing activities in the villages		
Fishing population (3)	8 635	households
Yearly total number of fishing trips using boats	196 050	
Yearly total number of fishing trips on foot or diving	320 550	
Yearly average number of fishing trips per boat	50	
Craft used (and owners)		
Boats (520 households)	520	
Outboard motors (500 households)	500	
Canoes (2800 households)	3 400	
Fishing gear (and owners)		
Traditional		
Number of spears (4300 households)	7 250	
Number of pots (130 households)	130	
1950 households use bow and arrow	-	
475 households use poisonous leaves	-	
Modern		
Number of nylon lines (7550 households)	19 400	
Number of spear-guns (2750 households)	3 450	
Number of gill nets (1080 households)	1 370	
Number of cast nets (400 households)	400	
Number of set nets (25 households)	25	
Number of reels (130 households) (4)	130	
Annual catch (5)		
Number of reef fish	3 980 000	
Number of deep water fish	1 430 000	
Number of fresh water fish	2 292 000	
Number of lobsters	669 150	
Number of octopus	331 500	
Number of baskets of shells	202 600	
Number of baskets of freshwater prawns	360	
Annual marketing		
Number of reef fish	1 114 000	
Number of deep water fish	307 333	
Number of freashwater fish	320 000	
Number of lobsters	272 500	
Number of octopus	50 000	
Number of baskets of shells	10 120	

(1) The townships of Port Vila and Luganville are not included.
(2) Including Port Vila and Luganville.
(3) All types of fishing included (on foot, diving or from craft).
(4) Bicycle-type reel or wooden handreel.
(5) The survey workers estimated catches in numbers of fish or numbers of baskets.

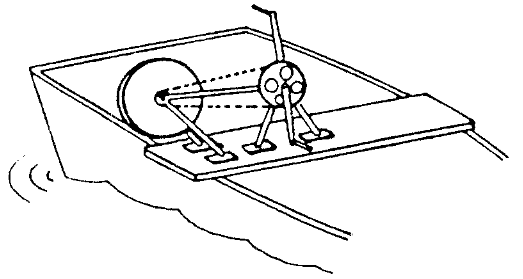


Fig. 4 - "Bicycle-type" handreel

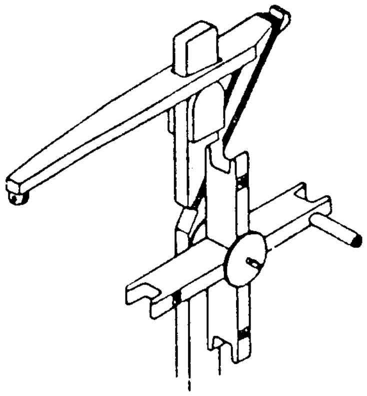


Fig.5 - Wooden handreel

Fishing is carried on both by day and by night, with the boat drifting or anchored. The deep anchoring technique, described by Gulbrandsen (1977) and then by Crossland and Grandperrin (1980) was introduced only recently and is not yet widely used.

Like most Pacific islanders, many Ni-Vanuatu are part-time fishermen. It is therefore difficult to count and classify fishermen, all the more so as there is no recognised occupational category called "commercial fisherman". With Goverment encouragement and assistance, a number of fishing associations have come into being since 1982 (Crossland, 1984a); they can obtain loans on easy terms. Recreational fishermen may take significant quantities of deep bottom fish, but there is no way these can be assessed at present. It would indeed take a very full investigation for the Vanuatu fishery to be sized up more accurately.

Despite the big effort made by the Fisheries Department in recent years to train people in fish processing techniques, the quality of what is marketed still remains only average. The use of ice, cold storage and freezing are only possible in Port Vila and Santo (1). As regards marketing, barter is gradually being replaced by cash sale. In the rural areas, sale of fish takes place on the beaches, from door to door, or in the village store. In the two

---

(1) A recent study on *Pristipomoides flavipinnis* and *P. multidens* (Anonymous, 1984) showed that these fish could be stored for about 10 weeks at -5° C without undergoing any appreciable change. Similar tests are planned for storing on ice.

urban centres, it is handled by the large department stores and the two newly-created fish markets (Crossland, 1984b, 1984c). The tourist industry is an important outlet and should absorb increasing quantities as the supply becomes more regular and the quality improves. The first attempts to export several tonnes of frozen snappers and fillets to Australia and New Caledonia were very successful.

GEAR AND METHODS

1 - Data collection

The data for this study were collected from catches made by the Fisheries Department's boats and by fishing associations in the islands. In addition, an exploratory survey carried out by the research vessel VAUBAN (Grandperrin, 1983) helped to clarify certain aspects of the biology of some species. A total of more than 2000 fishing trips have been taken into account. The constraints of the Fisheries Department's training programme made is necessary on several occasions for boats normally based in Port Vila to be transferred to the islands. This interruption in the records for Efate had unfortunate results, particularly for the interpretation of seasonal variations, and for the reproduction study.

Detailed study of landings by Fisheries Department boats

Fishing was carried out from 8.5m (28 ft) Alia catamarans equipped with four wooden handreels and deep anchoring gear. Mustad tuna circle hooks, n° 6,7,8 (1) were used. Fishing trips were made by day or by night and included trolling, handreel and, occasionally, bottom longline fishing. The landings from 1026 trips, 690 of which included deep bottom catches, were examined in detail. After each trip, the following operations were carried out :

---

(1) The size of a hook is generally calculated on the basis of its width (w) and its length (l). It thus depends on the method of calculation used and the unit of measurement. The hooks used in Vanuatu have the following features : N° 6, w=35mm, l=60mm; n° 7, w=30mm, l=50mm; n° 8, w=25mm, l=40mm.

- Identification of individual fish,
- Measurement of fork length (FL) and weighing (1),
- Determination of sex stage of maturity, and gonad weight (1),
- Collection of otoliths and scales,
- Photographs taken, as required.

In addition, a systematic 10 minute interview of the skipper enabled the information provided by the log book (Appendix 1) to be supplemented or corrected. The data recorded by the South Pacific Commission's Deep Sea Fisheries Development Project in Vanuatu (Fusimalohi and Preston, 1983; Chapman and Preston, in preparation) were also used. However data from Tanna (Fusimalohi, 1979) were not taken into account, since operations there were hampered by many supply problems,nor were data from the Outer Reef Artisanal Fishing Project in Lamap which are very incomplete (Hume, 1975).

Recording of landings in the islands

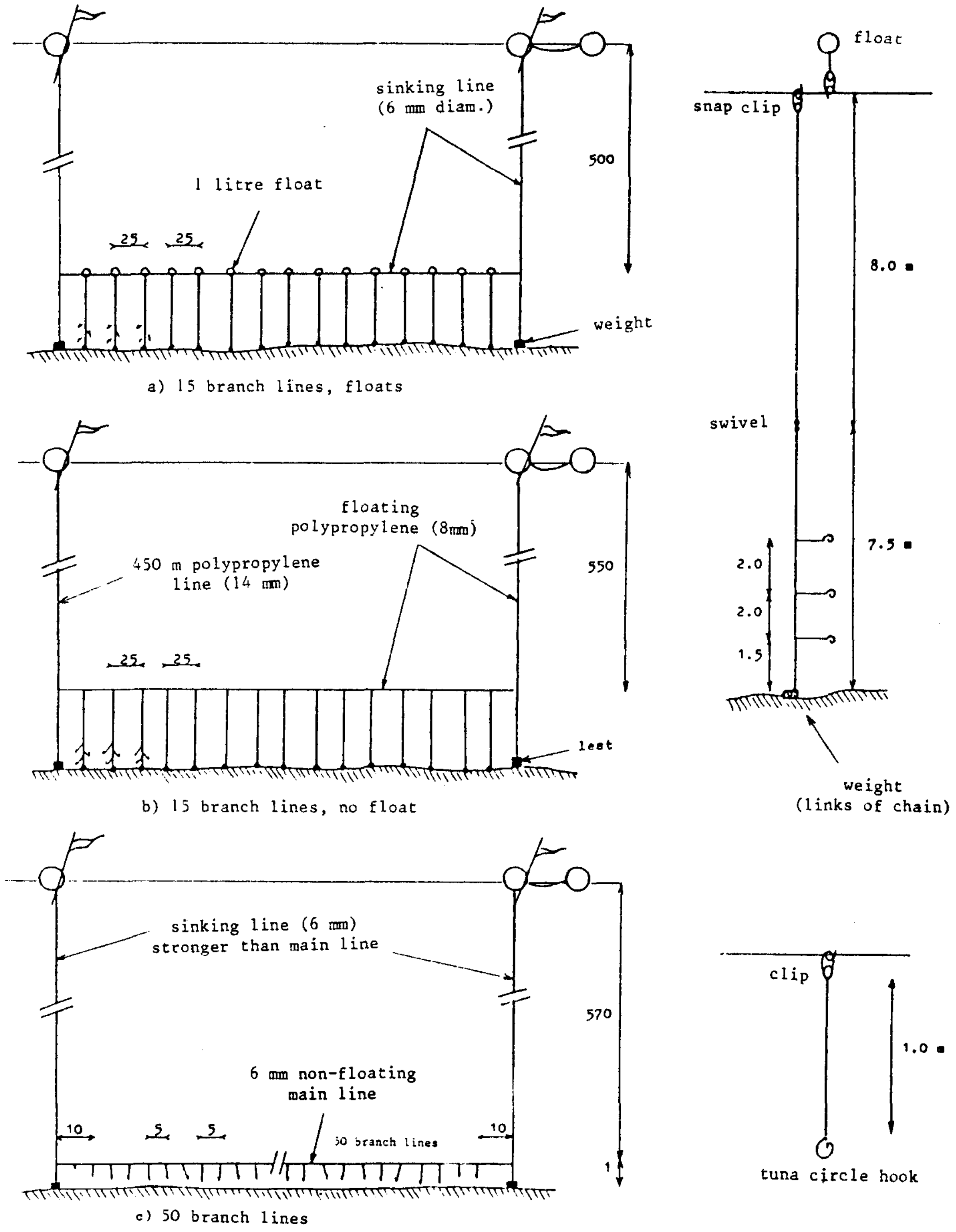
The forms used (Appendix 2) are very simple. They enable fishing effort to be estimated and total catch to be assessed. They also show fishing depth. All fish belonging to the 11 main species are measured. To date, 600 completed forms have been received from 10 different places and 4500 fish have been measured. As the years go by, this programme, which is unique in the Pacific, should bring to light any fluctuations in catch rates and mean sizes, and thus allow the maximum sustainable yield (M.S.Y.) to be defined. For specific studies (seasonal variations, growth), the results of more than 700 other trips made at Santo were also taken into account.

Exploratory Survey

The exploratory survey concentrated on certain coastal zones and seamounts around the more populated islands where fishing activities are significantly developing : Efate and Santo. A total of 861 fish belonging to 63 species were captured with bottom longlines (Fig.6) and both hand and electric reels. In addition to taking measurements (fork length and weight)

---

(1) Since the fish were intended for the market, they were very often gutted at sea which precluded gonad sampling and weighing.



a) 15 branch lines, floats

b) 15 branch lines, no float

c) 50 branch lines

Fig. 6 - Experimental bottom longline used during the exploratory survey of R.V. VAUBAN. Different gear arrangements a,b, c used, (from Fourmanoir, 1980, and Fourmanoir and Chabanne, 1980).

and samples (otoliths and gonads), changes in the C.P.U.E. were carefully monitored in 24 hour cycles, which enabled the preferred depths of certain species and the most usual time of capture to be determined.

2 - Data capture and processing

After coding, the data were transferred to three different forms (cf. Appendix 3) : a "catch and effort" form, a "species" form, and a "biology" form. They were then processed by an HP 85 micro-computer. Appendix 3 gives details of program design and procedures. For the species cluster analysis, the data were processed on an HP 9845 micro-computer.

3 - Unit of fishing effort

Choosing a unit to express fishing effort is always a difficult matter. In a fish stock of constant availability, catches should, in theory, be proportional to the effort expended. In practice however, several factors intervene to disturb this relationship, for example gear interaction and gear saturation.

Eggers *et al,* (1982) studied gear interaction occurring with bottom longlines deployed on the west coast of Canada. They estimated at 48.8 and 4.9 sq.m the respective "capture fields" of one hook for halibut and sablefish, which corresponds to circular areas with a radius of 3.9 and 1.2 m respectively. In the present state of our data, it is not possible to determine the "capture fields" for our deep tropical fishes (1). It seems likely however, looking at figure 6, that there would be less overlapping of capture fields - hence interaction between hooks - with gear arrangements a and b (spacing between hooks : 25 m) than with arrangement c (hook spacing : 5 m). In the case of reel fishing, where several reels and lines are used simultaneously from a single small craft, one may well wonder whether the efficiency of each reel is not diminished through interference with the others, or, in other words, whether the total catch of four reels operating together is not smaller than the catch of a single reel multiplied by four ?

---

(1) Relevant data are currently being collected by recording the position of each catch on the longline.

In practice however, the lines tend to diverge as they go deeper down (the hydrodynamic behaviour of the lines varies, since they are baited and weighted differently), and the spacing of the hooks on the bottom is therefore greater than the spacing of the reels on board. Furthermore, if fishing is good, the baited hooks are rarely all on the bottom at the same time. On the other hand, if the fish are not biting well one can assume that several baited hooks close together exert a stronger attractive force than if they are far apart. As this problem is obviously very complex, we stuck to the generally accepted practice of considering fishing effort per reel, with the total effort thus being the sum of the efforts of the separate reels.

As regards the gear saturation phenomenon, its consequences are slighter with reels than with bottom longlines. With the former, the fisherman brings up his catch as soon as he feels the fish firmly hooked and rebaits the hook before letting the line out again, so that saturation never occurs. With the longline on the other hand, efficiency diminishes with soak time and in proportion to the number of hooks "occupied". To compare the catches of several longline sets, it is therefore necessary to ensure that the lines are immersed for the same length of time.

In conclusion, we could have expressed catch rates in terms of several different units of fishing effort : catch per boat per trip, catch per boat per fisherman, catch per boat per actual fishing hour, catch per fishing hour of one reel (or one longline). In the end we used :

- catch (by number of fish and weight) per reel hour with a three-hook terminal rig;
- catch (by number of fish and weight) per hour of soak time of a 100-hook bottom longline.

FISHING RESULTS

1 - Overall results

This study is based on a total of 644 deep fishing trips using reels and representing more than 2800 fishing hours and nearly 9000 reel hours. In addition there were 46 bottom longline sets, totalling 3801 hooks. Details of the fishing trips made in each zone are given in Tables 3 and 4. Because sampling conditions were not comparable, it is difficult to make comparisons between islands. The data were all grouped and the archipelago considered as a single entity. This grouping is justified by the fact that the main environmental features are not subject to much geographic variation at the depths where the species we are concerned with live. In addition, the aim of our study was to bring out trends for the country as a whole rather than for each island.

The total catch was 10175 fish or 28764 kg. The mean C.P.U.E.s were 1.11 fish or 3.04 kg per reel hour and 10.0 fish or 39.5 kg per hour of longline with 100 hooks. C.P.U.E.s for other Pacific island countries are listed in Table 5.

Not all depths were fished to the same degree. Vertical distribution of the fishing effort is shown in Table 6. Little fishing was carried out in shallow waters, and the effort was concentrated between 80m and 320m for reel fishing and between 280m and 400m for the bottom longlines. We excluded sharks from our calculations of C.P.U.E. at different depths, even though sharks are commonly eaten by some communities. While they figure prominently on the Port Vila and Santo fish markets (Crossland, 1984a), their market value is nevertheless lower than that of the other species. Furthermore, the large sharks that are taken from time to time and affect the C.P.U.E. in an irregular and unpredictable manner, are most often caught in mid-water when the lines are being brought up : they can therefore be regarded as pelagic rather than bottom dwelling species. Vertical distribution of the C.P.U.E. by numbers and weight, shows that the 240 - 320m depth range is the most "productive" (Fig.7).

While these overall results are of great technical and economic interest, they reveal nothing of the biological reality. For this reason they need to be broken down by species.

Table 3 - Summary of reel fishing trips carried out between 9/9/80 and 22/3/84 : effort, catch, and C.P.U.E. (catch per reel/hour).

Zones	Total No of trips (1)	No of trips considered (1)	No of fishing hours (1)	No of reel hours (1)	Catches (1)		C.P.U.E. (1)	
					No	Wt	No	Wt
Banks	6	6	22	88	44	166	0,50	1,89
Santo	44	44	175	393	822	1860	2,09	4,73
Banc Sabine	5	5	6	12	20	47	1,67	3,92
Ambae	30	29	146	422	874	2634	2,07	6,24
Pentecôte	55	54	222	668	837	2513	1,27	3,76
Malekula	56	54	250	876	832	1874	0,95	2,14
Banc Chauliac	4	4	15	60	22	48	0,37	0,80
Ambrym	58	57	216	692	789	2272	1,14	3,28
Paama	19	19	75	302	319	1290	1,06	4,27
Epi	14	14	62	218	433	830	1,99	3,81
Tongoa	19	19	80	240	324	867	1,35	3,61
Emae	4	4	24	72	98	251	1,36	3,49
Efaté	330	304	1466	4739	3904	9267	0,82	1,96
Total (sharks excluded)	644	613	2759	8782	9318	23919	*1,06	*2,72
Total (sharks included)	644	613	2759	8782	9737	26670	*1,11	*3,04

(1) For our calculations, we discarded those trips for which one or several of the following types of data were not available : catch by numbers and weight, number of fishing hours and number of species.

* Calculated from the totals.

Table 4 - Summary of bottom longline sets : effort, catch, and C.P.U.E. (catch per hour/100 hooks, sharks included).

Zones	Dates		No of sets (1)	No of hooks	Catch		C.P.U.E.	
					No	Wt	No	Wt
Paama	10/80		4	730	72	369	9,8	50,5
Santo	4/81	10/83	16	1100	109	601	9,9	54,5
Efate	10/83	3/84	26	1971	201	531	10,2	27,0
Total	-		46	3801	382	1501	10,0	39,5

(1) The 16 longline sets carried out in 1978 around Efate (Rancurel, 1979) have not been taken into account because no data on weight of catches were available.

Table 5 - Deep bottom fishing results in a few other Pacific islands : catch per reel hour in kg.

Iles Cook	HUME, 1976	3,5
Fiji	MEAD, 1980a	9,3
Fiji	ANONYME, 1978	3,0 *
Kiribati	TAUMAIA and GENTLE, 1983	7,2
Kosrae	MEAD and CROSSLAND, 1979	9,6
Niue	FUSIMALOHI, 1978	2,8
"	MEAD, 1979a	7,0
New-Caledonia	FUSIMALOHI and GRANDPERRIN, 1979	
Lifou		7,5
Isle of Pine		7,8
Palau	TAUMAIA and CROSSLAND, 1980a	3,3
Papua/New Guinea	FUSIMALOHI and CROSSLAND, 1980	4,9
Solomon Islands	EGINTON and JAMES, 1979	5,7
American Samoa	MEAD, 1978	4,4
" "	RALSTON, 1978	3,5
Western Samoa	HUME and EGINTON, 1976	4,1
Tonga	MEAD, 1979b	3,6
"	MEAD, 1980b	5,7
Truck	TAUMAIA and CROSSLAND, 1980b	4,1
Tuvalu	EGINTON and MEAD, 1978	2,5
"	TAUMAIA and GENTLE, 1982	6,7
Wallis and Futuna	FUSIMALOHI and GRANDPERRIN, 1980	
Wallis		9,2
Futuna		5,6
Yap	MEAD and CROSSLAND, 1980	6,9
Vanuatu	HUME, 1975	3,5
"	FUSIMALOHI, 1979	3,1
"	FUSIMALOHI and PRESTON, 1983	8,2
"	CHAPMAN and PRESTON (in preparation)	6,7
"	This study	3,0

* about 3.0 kg.

2 - Species recorded

With all fishing techniques using lines and hooks, the prerequisites for the capture of a fish are :

- that it is present in the body of water fished,
- that it is in the feeding phase,
- that it likes the bait used,
- that the hook is adapted to the shape and size of its mouth (hook selectivity).

Table 6 - Vertical distribution of fishing effort.

Depths	Reel-hours	Longline(1) hours
0-40 m	37	-
40-80	54	-
80-120	523	-
120-160	1 252	4
160-200	2 015	4
200-240	1 563	1
240-280	1 479	9
280-320	845	13
320-360	96	13
360-400	12	20
400-440	-	10
440-480	-	3
unknown (2)	906	-
	8 782	77

(1) bottom longline with 50 hooks.

(2) where fishing was carried out at an unknown depth or where the extremes of the range were more than 40 m apart.

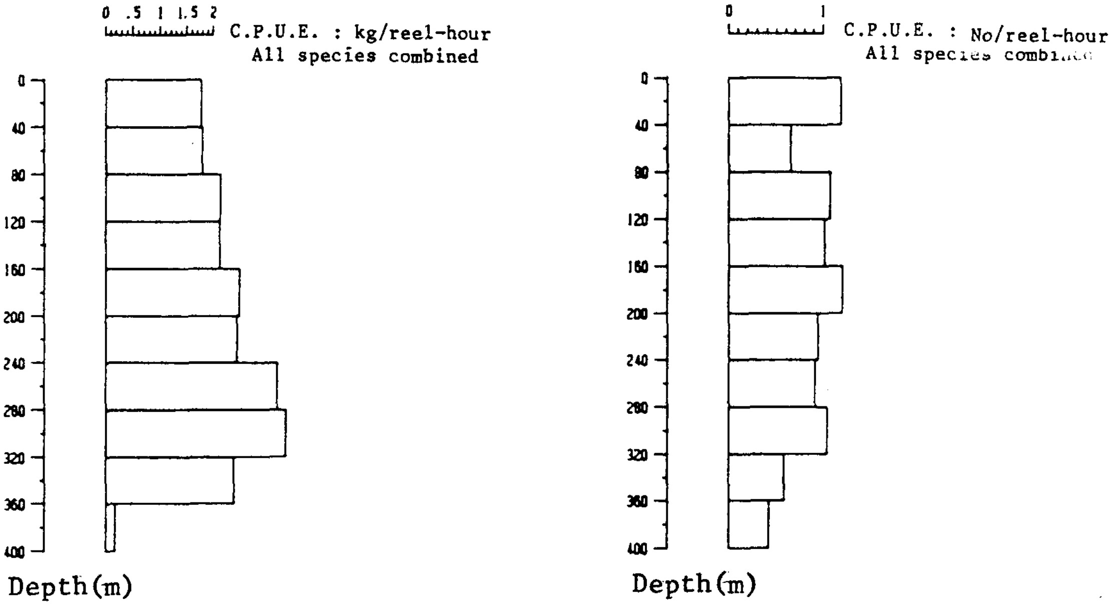


Fig. 7 - Reel fishing : vertical distribution of C.P.U.E. by numbers and weight (sharks not included).

In all that follows, and particularly in the studies of the effect of depth, day/night variations, and seasonal fluctuations, this idea of "catchability" which is all too often overlooked, should constantly be borne in mind.

107 species were recorded. Their scientific and common names are listed in Table 7. The best represented families are Lutjanidae, Etelidae, Serranidae and Lethrinidae. Three species of Lutjanidae could not be identified : *Lutjanus* sp. is very similar to *Lutjanus argentimaculatus; Macolor* sp. differs, in external colouring, from *Macolor niger; Paracaesio* sp. is in-between *P. stonei* and *P. gonzalesi*. The taxonomy of this genus is fairly confused in fact and would need to be clarified. The presence of *Aphareus furcatus* among the Etelidae may seem surprising, since this fish is usually found near the surface and caught by trolling and spear gun, but it can in fact go down to a depth of 150m (Fourmanoir and Laboute, 1976). Only one *Pristipomoides auricilla* was caught. The genus name *Tropidinius* of the two species *T. argyrogrammicus* and *T. zonatus* is nowadays increasingly being replaced in the literature by *Pristipomoides*. We did not follow this trend, since there appear to be notable differences between *Tropidinius* and *Pristipomoides,* both in their general morphology and in the shape of their otholiths. In the Serranidae we did not differentiate *Epinephelus morrhua* from *E. cometae* as some authors do, in particular Masuda *et al,* (1975). In this we followed Randall and Ben-Tuvia (1983), but admittedly variations in colouring and markings were indeed observed in *E. morrhua*. In the Sphyraenidae, the presence of *Sphyraena barracuda* and *S. qenie,* which are usually caught by trolling, is due to a few individuals that bit the hook in shallow waters or near the surface when the lines were being brought up. *Gymnosarda unicolor,* of the Scombridae family, can be taken either by trolling or on deep bottoms.

As regards the sharks, a distinction must be made between the midwater species, that can also be found on the bottom, particularly when feeding, and the strictly bottom-dwelling species. *Alopias superciliosus, Carcharhinus albimarginatus, C. amblyrhinchos, C. falciformis, C. plumbeus, Galeocerdo cuvier, Isurus oxyrhinchus* and *Triaenodon obesus* belong to the former and were caught only occasionally. The other sharks, *Centrophorus scalpratus, Cephaloscyllium* sp., *Heptranchias perlo, Hexanchus vitulus, Loxodon macrorhinus, Mustelus manazo* and *Squalus megalops* are more strictly confined to the sea floor. Their identification was often a problem since they were generally landed already gutted, headed and without fins.

Table 7 - Summary of species captured : scientific and common names

LUTJANIDAE		
Lipocheilus carnolabrum	-	fleshy lipped snapper
Lutjanus argentimaculatus	rouget de palétuvier	mangrove jack
Lutjanus bohar	anglais	red seabass
Lutjanus fulvus	lutjan fauve	-
Lutjanus gibbus	lutjan bossu	paddle-tail seaperch
Lutjanus kasmira	jaunet	blue lined seaperch
Lutjanus malabaricus	perche écarlate	scarlet seaperch
Lutjanus monostigma	-	one-spot seaperch
Lutjanus rufolineatus	jaunet	rufous seaperch
Lutjanus sebae	pouatte	red emperor
Lutjanus timorensis	-	-
Lutjanus sp.	-	-
Macolor niger	perche blanche et noire	black and white seaperch
Macolor sp.	-	-
Paracaesio gonzalesi	fusilier	fusilier
Paracaesio kusakarii	fusilier	fusilier
Paracaesio stonei	fusilier	fusilier
ETELIDAE		
Aphareus furcatus	lantanier noir	-
Aphareus rutilans	lantanier rouge	small-tooth jobfish
Aprion virescens	aprion verdâtre	green jobfish
Etelis carbunculus	vivaneau rouge	short-tailed red snapper
Etelis coruscans	vivaneau la flamme	long-tailed red snapper
Etelis radiosus	vivaneau à forte mâchoire	long-jawed red snapper
Pristipomoides auricilla	vivaneau à taches jaunes	gold-tailed jobfish
Pristipomoides filamentosus	vivaneau blanc	rosy jobfish
Pristipomoides flavipinnis	vivaneau à nageoires jaunes	yellow jobfish
Pristipomoides multidens	poulet	large-scaled jobfish
Pristipomoides sieboldi*	-	-
Pristipomoides typus	-	-
Tropidinius argyrogrammicus	vivaneau à réseau d'argent	large-eyed flower snapper
Tropidinius zonatus	vivaneau rayé	banded flower snapper
SERRANIDAE		
Cephalopholis formosanus	loche de Formose	-
Cephalopholis hemistiktos	loche semi-ponctuée	-
Epinephelus amblycephalus	loche rouge à 6 bandes claires	clearly banded rock cod
Epinephelus areolatus	loche aréolée	yellow-spotted grouper
Epinephelus chlorostigma	loche pintade	brown-spotted grouper
Epinephelus cylindricus	mère loche	rock-cod
Epinephelus dictyophorus	-	-
Epinephelus fasciatus	loche rouge	black-tipped grouper
Epinephelus fuscus	-	-
Epinephelus hoedti	loche bleue	blue grouper
Epinephelus maculatus	grisette	blue-spotted grouper
Epinephelus magniscuttis	loche grosse écaille	large-scaled grouper
Epinephelus microdon	loche crasseuse	-
Epinephelus morrhua	loche à bandes noires	brown-striped grouper
Epinephelus retouti	loche rouge du large	red-banded grouper
Epinephelus septemfasciatus	loche plate grise	seven-banded grouper
Plectropomus leopardus	saumonée	coral trout
Plectropomus melanoleucus	saumonée grosse race	footballer trout
Saloptia powelli	-	-
Variola louti	saumonée hirondelle	lunar-tailed cod
LETHRINIDAE		
Lethrinus amamianus	-	-
Lethrinus chrysostomus	gueule rouge	sweetlip emperor
Lethrinus harak	bossu taché	thumb-print emperor
Lethrinus kallopterus	-	yellow-spotted emperor
Lethrinus mahsena	bossu doré	yellow-tailed emperor
Lethrinus miniatus	bec de cane malabar	yellow-nosed emperor
Lethrinus obsoletus	bossu d'herbe	orange-striped emperor
Lethrinus variegatus	bossu rond	variegated emperor
PENTAPODIDAE		
Gnathodentex mossambicus	brème olive	large-eyed bream
Gymnocranius japonicus	bossu blanc à points noirs	naked headed bream
Gymnocranius lethrinoides	bossu blanc à nageoires roses	-
Gymnocranius rivulatus	bossu blanc grosse race	-
Gymnocranius robinsoni	-	-
LABRIDAE		
Bodianus perditio	perroquet banane	golden-spot wrasse

Table 7 (next) - Summary of species captured : scientific and common names.

CARANGIDAE		
Alectis indicus	carangue à filaments	plumed trevally
Carangoides fulvoguttatus	carangue à taches fauves	gold-spotted trevally
Caranx ignobilis	carangue à grosse tête	giant trevally
Caranx lugubris	carangue noire	black trevally
Caranx melampygus	carangue bleue	bluefin trevally
Seriola rivoliana	carangue amoureuse	deepwater amberjack
EMMELICHTHYIDAE		
Erythrocles schlegeli*	-	bonnetmouth, red sea-haarder
SPHYRAENIDAE		
Sphyraena barracuda	barracouda	barracuda
Sphyraena bleekeri	bécune à chevrons	-
Sphyraena forsteri	bécune foncée	Forster's sea pike
Sphyraena jello	bécune	yellowtail barracuda
Sphyraena qenie	-	dark-finned barracuda
HOLOCENTRIDAE		
Adioryx spinifer	commissaire	squirrel fish
Ostichthys japonicus	-	squirrel fish
PRIACANTHIDAE		
Priacanthus blochii*	-	-
Pristigenys multifasciata*	-	-
BRANCHIOSTEGIDAE		
Branchiostegus wardi	tête de cheval	horse-head
TRIGLIDAE		
Satyrichthys sp.	-	double nose gurnard
GEMPYLIDAE		
Promethichthys prometheus	barracouta	-
Ruvettus pretiosus	ruvet, poisson huile	castor oil fish
Thyrsitoides marleyi	-	Marley's snake mackerel
SCOMBRIDAE		
Gymnosarda unicolor	Thon à dents de chien	dogtooth tuna
POLYMIXIIDAE		
Polymixia berndti	-	-
BRAMIDAE		
Taractichthys steindachneri	brème noire	-
TRIODONTIDAE		
Triodon macropterus	bourse	-
CHIMAERIDAE		
Chimaera monstrosa*	chimère	ghost shark
ECHENEIDAE		
Echeneis naucrates	rémora	suckerfish, remora
REQUINS		
Alopias superciliosus	requin renard à gros yeux	bigeye thresher shark
Carcharhinus albimarginatus	requin à pointes blanches	white-tipped shark
Carcharhinus amblyrhynchos	requin gris de récif	gray reef shark
Carcharhinus falciformis	requin à peau soyeuse	silky shark
Carcharhinus plumbeus	requin à haute dorsale	sandbar shark
Centrophorus scalpratus	squale-chagrin cagaou	smallfin gulper shark
Cephaloscyllium sp.	-	catfish
Galeocerdo cuvier	requin tigre	tiger shark
Heptranchias perlo	requin perlon, à sept branchies	sharpnose sevengill shark
Hexanchus vitulus	requin vache, à six branchies	bigeyed sixgill shark
Isurus oxyrhinchus	taupe bleu, requin maquereau	shortfin mako, mackerel shark
Loxodon macrorhinus	-	plastic nose shark
Mustelus manazo	requin à points blancs	white-spotted shark
Squalus megalops	aiguillat nez court	shortnose spurdog, spiny dogfish
Triaenodon obesus	aileron blanc du lagon	reef white tip shark
APODES		
Congridae	congre	conger eel
RAIES	raie	ray

* Species not listed in Table 8

3 - Relative abundance of species

In Table 8, the species have been listed in decreasing order of numerical abundance. The summary at the bottom of the table indicates the economic importance of the main families. The Etelidae are far ahead of the others, with *Etelis carbunculus, E. coruscans, Pristipomoides multidens* and *P. flavipinnis* the main species. The strong dominance of this family is a characteristic of deep bottom fishing throughout the tropical Pacific (Crossland, 1980). The Serranidae are in second position, mainly because of the capture of a number of *Epinephelus septemfasciatus,* which often weigh as much as 60 or 70 kg each. The two other common species in this family are *E. morrhua* and *E. magniscuttis*. The Lutjanidae were mainly represented by *Lutjanus malabaricus* and *L. argentimaculatus*. As for the Carangidae, only *Seriola rivoliana* is of any importance. The abundance of the *Pentapodidae* seems under-estimated (cf. comments at the bottom of table 8). *Ruvettus pretiosus* stands out in the Gempylidae family.

Sharks represented 11.5% of the total weight of the catches. As we pointed out earlier, it was impossible to identify the smaller species that had been gutted and prepared for sale (by cutting off the fins, etc.) and this resulted in an under-estimation of species such as *Squalus megalops, Mustelus manazo, Centrophorus scalpratus* and *Loxodon macrorhinus*.

Only a few species are unfit for marketing because the risk of ciguatera poisoning through eating their flesh is too great. Worth mentioning are *Lutjanus bohar,* which is systematically thrown away by the fishermen and therefore under-estimated in the catch, and the large specimens of *Lutjanus argentimaculatus* and *L. sebae*.

In this assessment of the overall abundance of the different species, no account was taken of the depths at which they were caught. We shall now focus on this aspect.

4 - Depth distribution

The extent of a species habitat is the depth range within which it lives. However, the mere fact of a species presence does not make it "catcha-

Table 8 - Classification of species (1) ranked in decreasing order by numbers caught.

Species	No of trips	No of fish	Total Wt(kg)
Pristipomoides multidens	316	2 173	4 122,1
Etelis carbunculus	307	1 305	5 305,8
Pristipomoides flavipinnis	241	1 099	1 029,8
Lutjanus malabaricus	127	857	1 599,6
Etelis coruscans	235	791	2 634,2
Tropidinius argyrogrammicus	125	367	110,5
Epinephelus morrhua	131	208	444,8
Seriola rivoliana	115	161	779,4
Squalus megalops	47	153	305,2
Pristipomoides filamentosus	33	144	245,3
Lethrinus miniatus	56	141	465,9
Requins ind.	72	133	856,4
Etelis radiosus	74	123	380,6
Aphareus rutilans	83	121	566,1
Lipocheilus carnolabrum	47	109	251,3
Epinephelus septemfasciatus	66	105	2 703,1
Lutjanus argentimaculatus	49	101	463,7
Lethrinus sp.	41	99	174,7
Epinephelus magniscuttis	71	99	387,1
Gnathodentex mossambicus	35	97	171,0
Tropidinius zonatus	47	96	84,2
Paracaesio sp.	35	77	172,3
Epinephelus chlorostigma	35	76	168,5
Aprion virescens	44	70	297,5
Lutjanus gibbus	15	67	136,9
Lutjanus bohar	18	58	127,0
Epinephelus areolatus	39	55	35,1
Carcharhinus albimarginatus	24	46	452,4
Lutjanus rufolineatus	24	44	16,1
Lethrinus variegatus	17	43	42,8
Paracaesio kusakarii	20	40	100,0
Carcharhinus falciformis	23	36	955,0
Ostichthys japonicus	20	34	35,6
Promethichthys prometheus	6	28	96,0
Caranx lugubris	18	27	69,8
Lutjanus timorensis	3	26	53,0
Hexanchus vitulus	18	25	290,2
Sphyraena forsteri	10	25	33,4
Serranidae ind.	13	23	34,8
Gymnosarda unicolor	18	22	325,6
Gymnocranius lethrinoides	16	21	34,7
Ruvettus pretiosus	14	21	235,2
Lutjanus sp.	12	19	58,3
Lutjanus kasmira	2	19	27,4
Lethrinus harak	6	16	10,5
Epinephelus retouti	12	16	17,4
Lutjanus sebae	14	15	110,0
Epinephelus microdon	11	15	31,9
Mustelus manazo	10	14	33,2
Thyrsitoides marleyi	12	14	90,7
Carcharhinus plumbeus	6	13	153,4
Holocentridae ind.	6	12	12,5
Apodes ind.	10	12	24,0
Gymnocranius japonicus	6	12	15,0
Sphyraena genie	3	11	36,6
Epinephelus cylindricus	2	11	17,0
Branchiostegus wardi	7	10	14,5
Paracaesio stonei	5	10	19,2
Carangidae ind.	9	10	25,9
Sphyraena barracuda	7	9	39,5
Adioryx spinifer	3	8	4,8
Variola louti	7	7	4,1
Aphareus furcatus	6	7	32,0
Loxodon macrorhinus	3	7	11,2
Pristipomoides typus	3	6	9,1
Lethrinus kallopterus	3	6	8,6
Sphyraena bleekeri	5	6	26,1
Epinephelus dictyophorus	2	6	9,4
Lethrinus mahsena	3	6	5,5
Lutjanus monostigma	4	5	4,2
Triodon macropterus	5	5	6,5
Paracaesio gonzalesi	4	5	4,3
Epinephelus hoedti	5	5	27,5
Triaenodon obesus	2	5	22,0
Plectropomus leopardus	5	5	15,7
Lethrinus chrysostomus	3	5	8,5
Macolor sp.	4	5	6,2
Caranx ignobilis	4	5	54,9
Alopias superciliosus	4	5	49,9
Alectis indicus	4	5	13,3
Satyrichthys sp.	5	5	6,7
Taractichthys steindachneri	1	5	17,8
Macolor niger	3	4	13,5
Carcharhinus amblyrhynchos	3	4	73,0
Epinephelus maculatus	4	4	6,4
Sphyraena sp.	3	4	8,0
Cephalopholis hemistiktos	1	4	8,0
Galeocerdo cuvier	1	3	34,0
Centrophorus scalpratus	1	3	3,3
Cephalopholis formosanus	2	3	5,0
Saloptia powelli	3	3	5,0
Gymnocranius robinsoni	3	3	6,0
Lutjanus fulvus	2	3	0,9
Lethrinus amamianus	1	3	4,1
Echeneis naucrates	2	2	2,3
Raies ind.	2	2	65,0
Caranx melampygus	2	2	3,5
congridae ind.	2	2	5,2
Gymnocranius sp.	2	2	2,5
Epinephelus amblycephalus	1	2	1,6
Pentapodidae ind.	1	1	6,0
Plectropomus melanoleucus	1	1	5,0
Pristipomoides auricilla	1	1	1,0
Epinephelus fasciatus	1	1	0,2
Carangoides sp.	1	1	2,2
Polymixia berndti	1	1	0,7
Gempylidae ind.	1	1	1,0
Bodianus perditio	1	1	2,8
Epinephelus fuscus	1	1	1,7
Carangoides fulvoguttatus	1	1	4,5
Heptranchias perlo	1	1	4,8
Isurus oxyrhinchus	1	1	70,0
Lethrinus obsoletus	1	1	2,1
Cephaloscyllium sp.	1	1	4,6
Gymnocranius rivulatus	1	1	3,0
Sphyraena jello	1	1	2,0
Poissons non identifiés	46	398*	526,5
	---	------	--------
Total	644**	10 175	28 763,5

Summary

	Percentage (by numbers)	Percentage (by weight)
ETELIDAE	61,9	51,5
SERRANIDAE	6,4	13,7
REQUINS	4,2	11,5
LUTJANIDAE	14,4	11,0
CARANGIDAE	2,1	3,3
LETHRINIDAE	3,1	2,5
GEMPYLIDAE	0,6	1,5
—	7,3	5,0
	-----	-----
	100,0	100,0

(1) Since this list was drawn up, five other species were caught (cf. Table 7), but as there was only one of each they have not been included here.

* Fish which for some practical reason were not identified when caught. From interviews with the fishermen it would seem that they were a "mixed bag" of *Gymnocranius japonicus, G. lethrinoides, G. robinsoni, Paracaesio kusakarii, Gnathodentex mossambicus* and *Pristipomoides sieboldi*.

** This is not the arithmetic sum of the preceding figures but the total number of fishing trips made.

ble"; it must also be in the feeding phase. Because the following results are all from fisheries data, i.e. based on fish that were actually caught, we have not used the ecological concept of "habitat" but preferred the term "depth range", defined as the fisheries availability range of the species, within which it is both present and actively feeding.

Depth range by species

The depth range of 84 species is shown on Figures 8a and b. Since fishing in shallow waters was carried out only a relatively small number of times, one must be careful not to jump to conclusions as regards the range we recorded for the shallow species that were caught only a few times, such as *Lutjanus fulvus, Macolor niger, Epinephelus fasciatus, Lethrinus kallopterus* and *Adioryx spinifer.* Generally speaking, the same reserve is called for with regard to other uncommon species. Thus *L. argentimaculatus, L. kasmira, L. rufolineatus, L. sebae, Aphareus furcatus, Pristipomoides filamentosus, Cephalopholis formosanus, C. hemistiktos, Epinephelus areolatus, E. cylindricus, E. hoedti, Plectropomus leopardus, Lethrinus chrysostomus, L. obsoletus, Gymnocranius japonicus, Alectis indicus, Caranx lugubris, Bodianus perditio, Carcharhinus albimarginatus, C. falciformis, C. plumbeus, Galeocerdo cuvier* and *Triaenodon obesus* are known to exist in shallow waters and are encountered when diving, whereas in our results they only occurred from 100m and sometimes far deeper. For the deep species, such as *Etelis carbunculus, E. coruscans, Squalus megalops* and *Hexanchus vitulus*, the lower limit of the range remains to be defined by fishing to below 460m. From the economic point of view, the notion of presence-absence is in any case inadequate for guiding the fisherman in his search for the best fishing depths. For this, a study of catch rates in relation to depth is essential.

C.P.U.E. fluctuation with depth

For the 12 main species by weight for which the number of fishing trips at known depth was greater than 50, the vertical distribution of the C.P.U.E. (by weight and numbers of fish) was established for each 40m depth layer (Fig. 9a and b). For 10 further species that were still significant in the catches or that displayed very marked characteristics, the C.P.U.E.s in

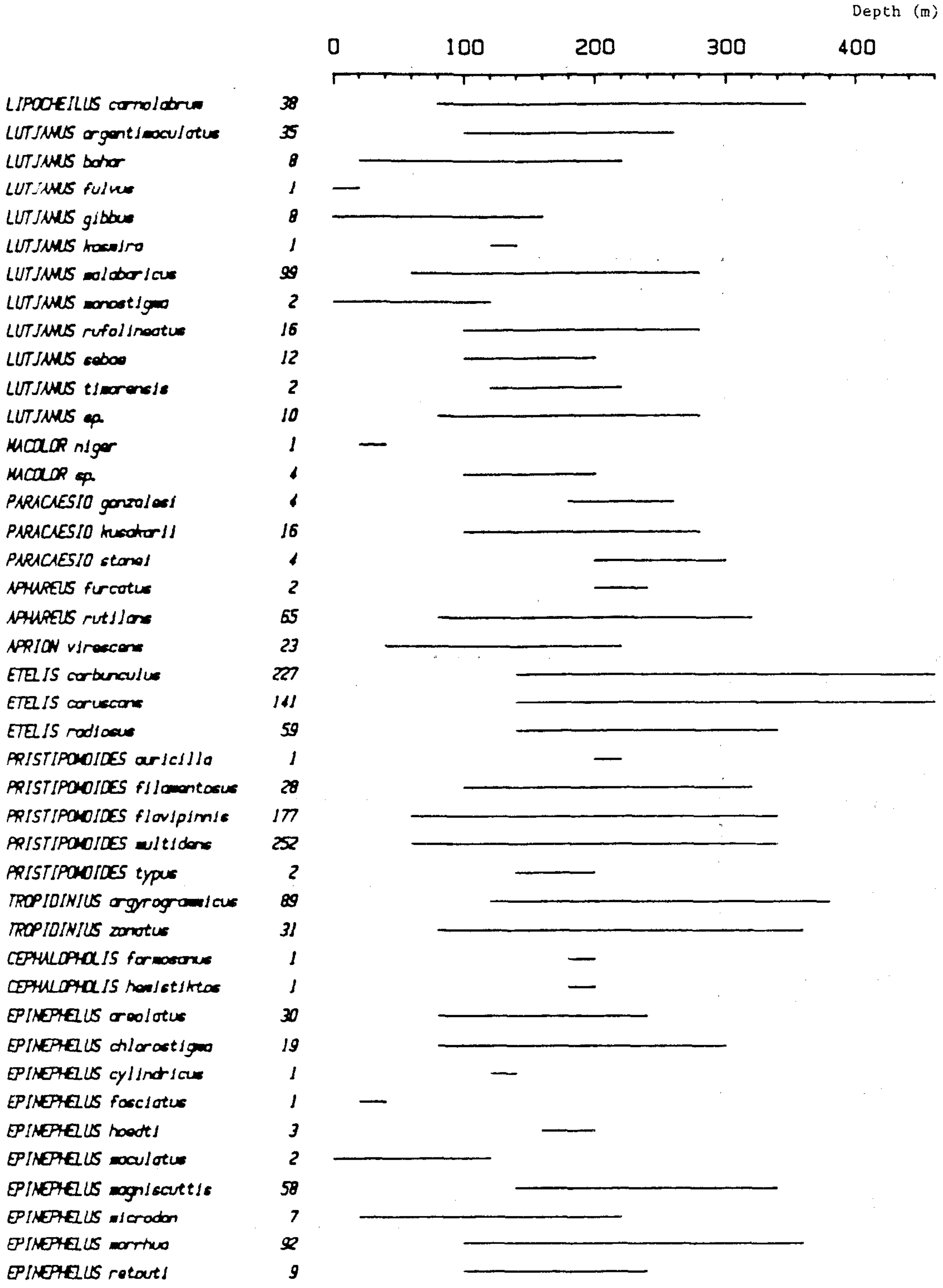


Fig. 8a - Depth range of species (the figures indicate the number of landings in which the species was present).

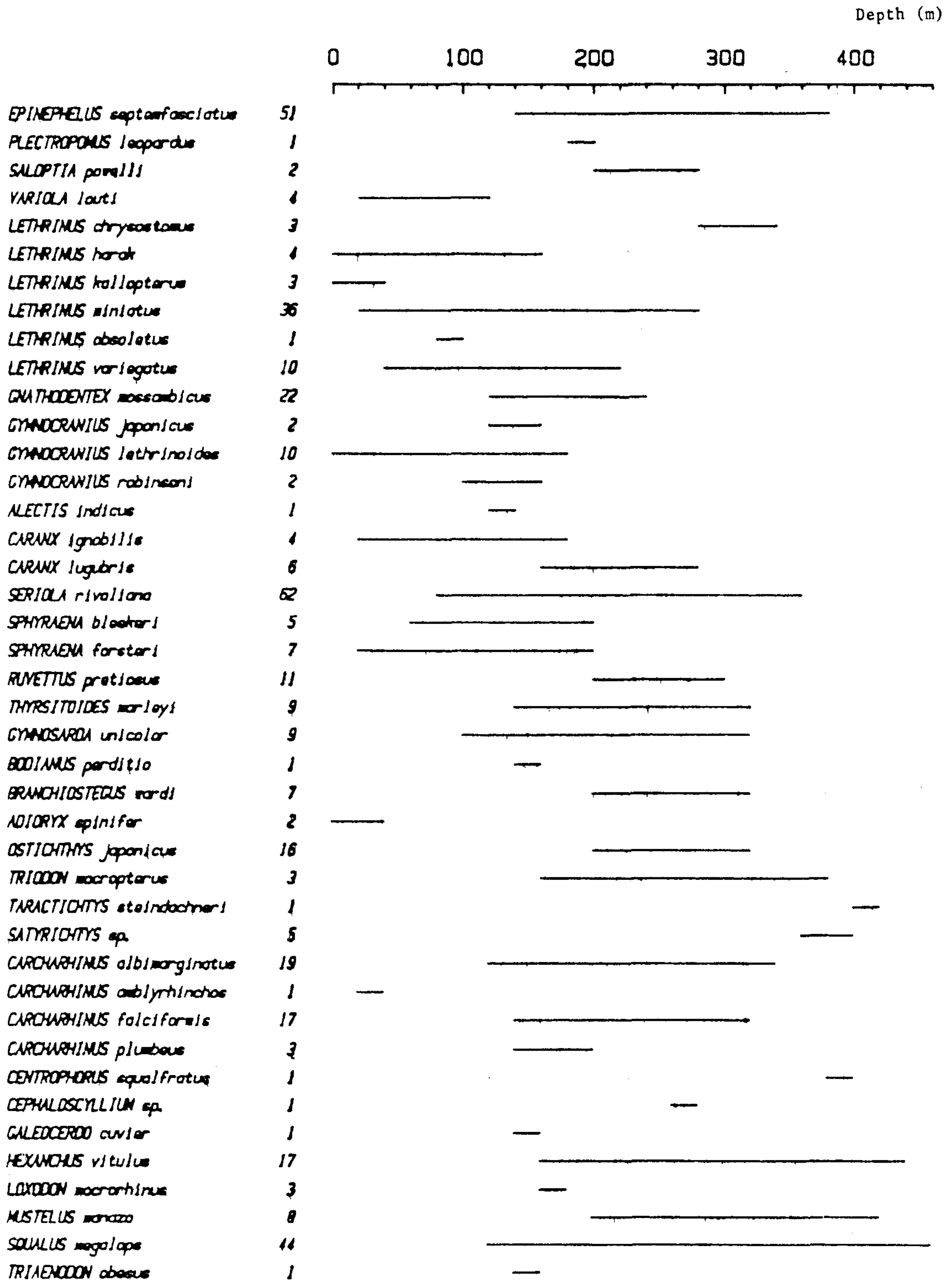


Fig. 8b - Depth range of species (the figures indicate the number of landings in which the species was present).

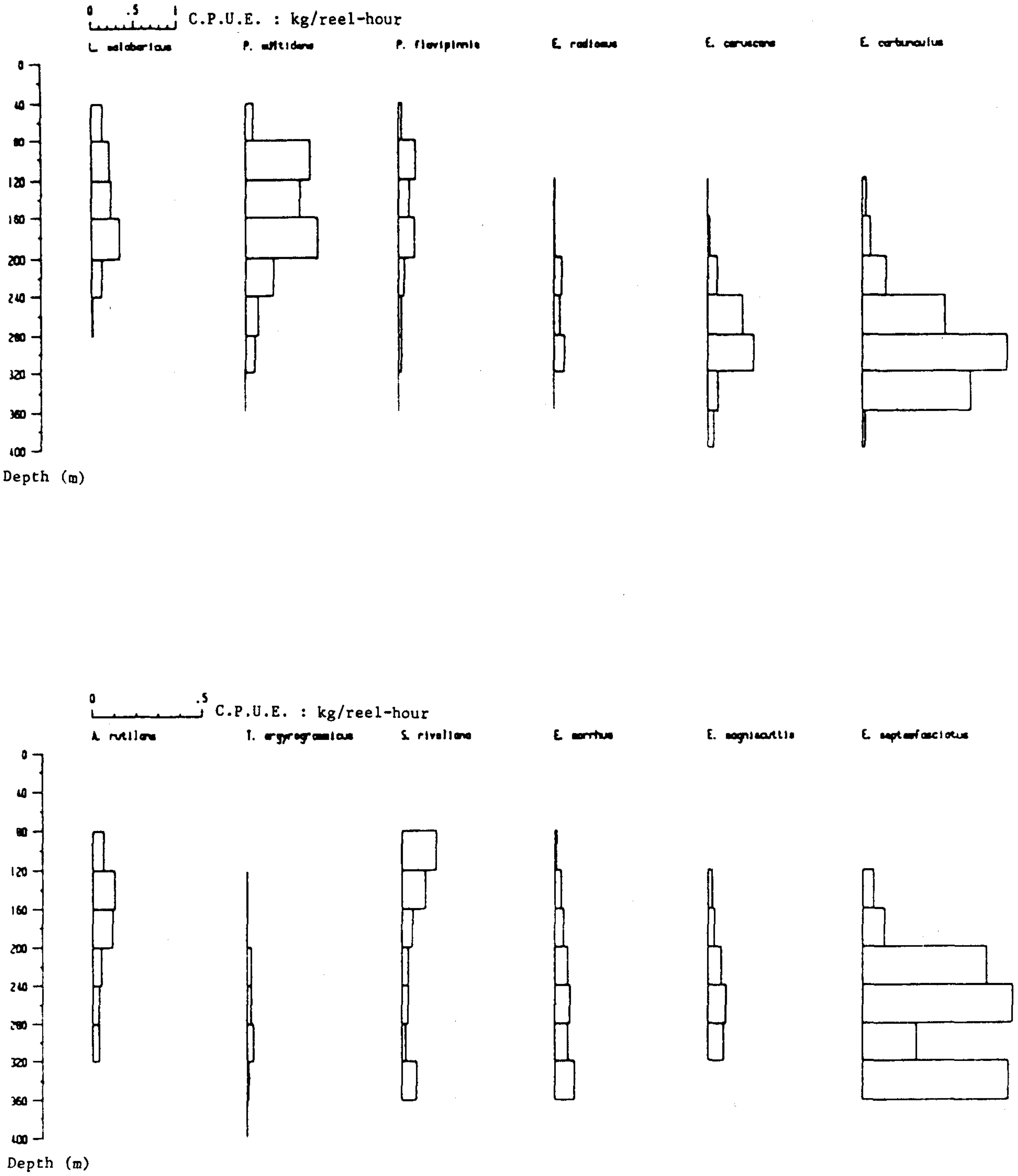


Fig. 9a - Reel fishing : C.P.U.E. (weight) fluctuation with fishing depth.

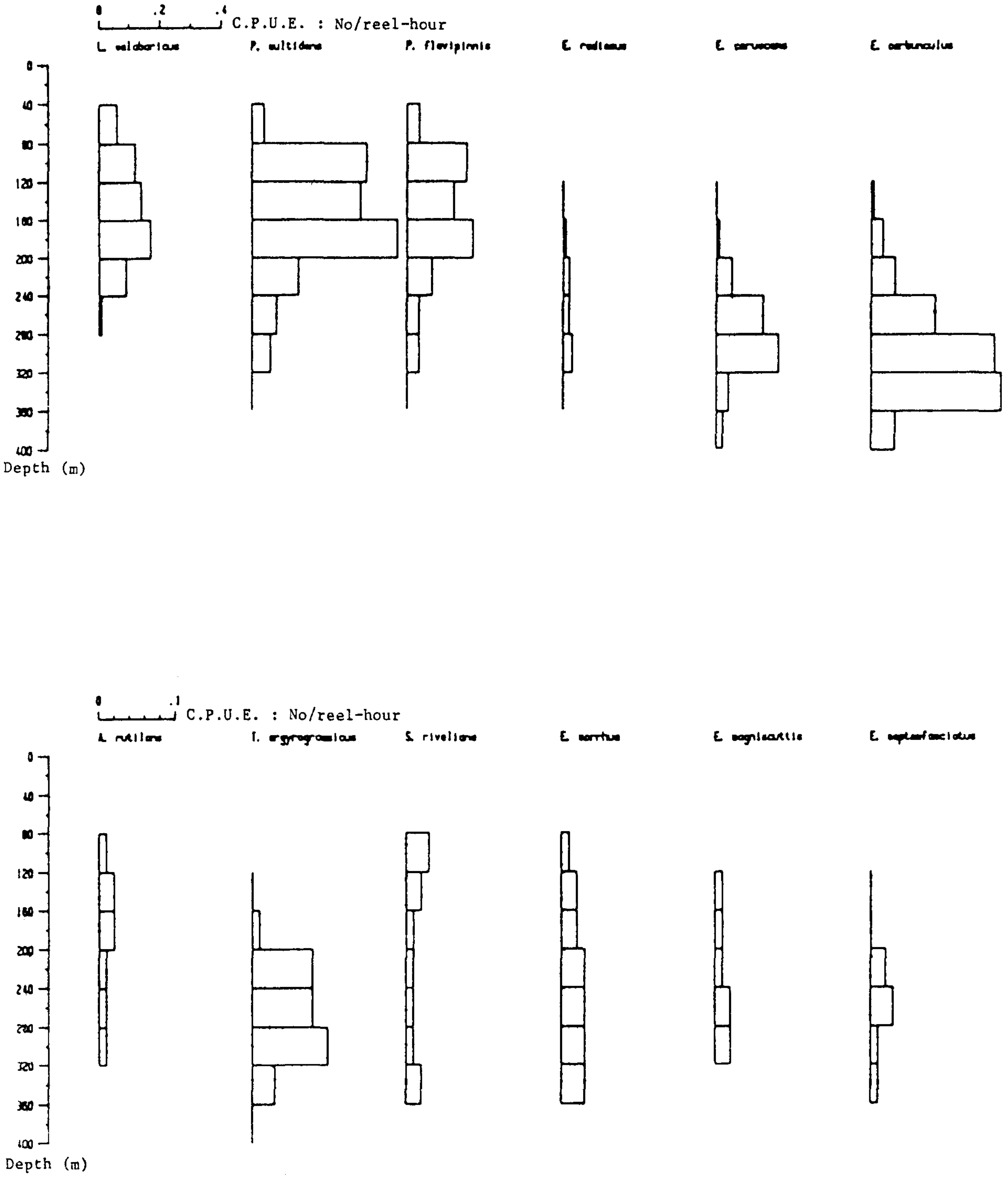


Fig. 9b - Reel fishing : C.P.U.E. (numbers) fluctuation with fishing depth.

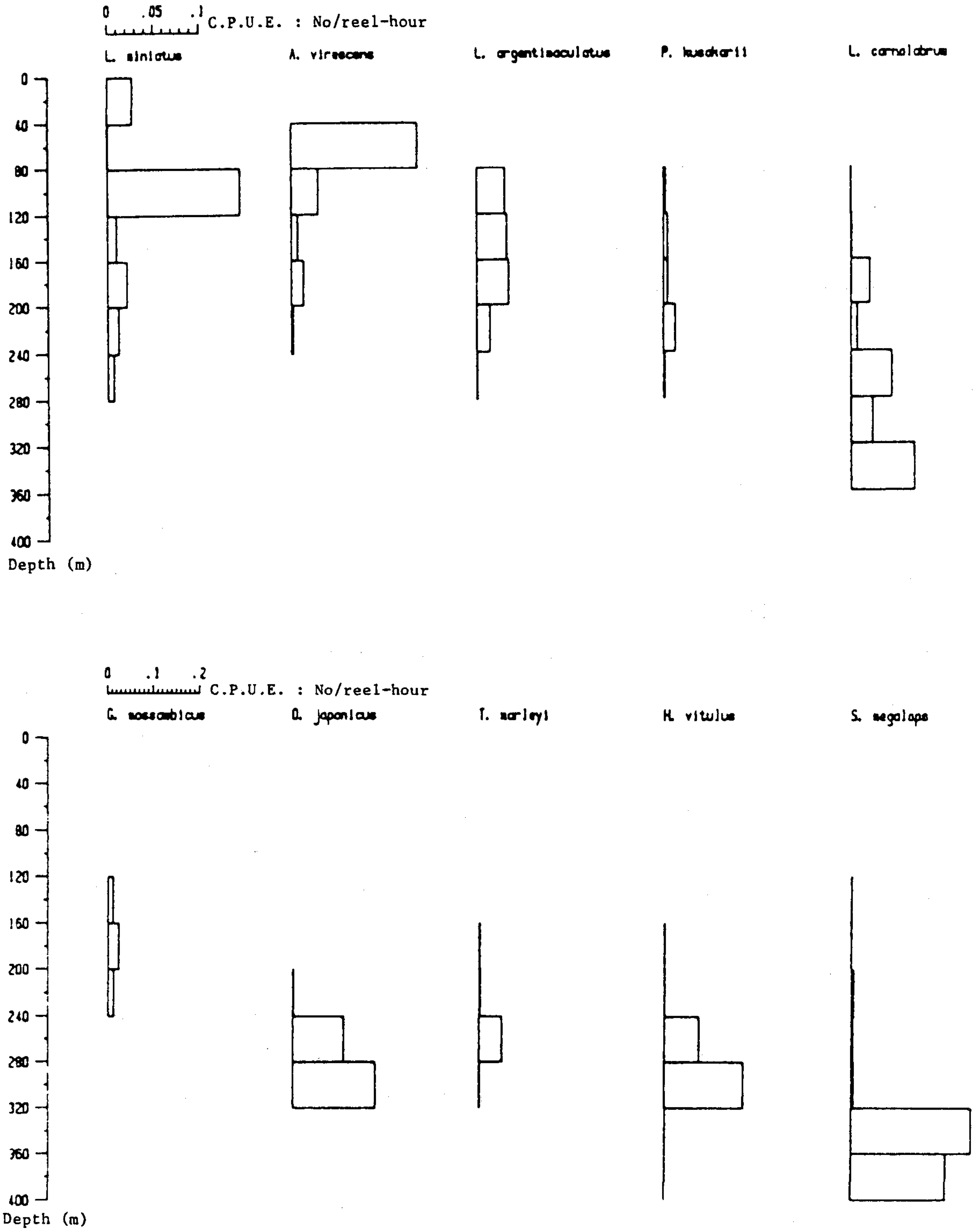


Fig. 9c - Reel fishing : C.P.U.E. (numbers) fluctuation with fishing depth.

numbers of fish were also calculated and are shown in Figure 9c. Using these diagrams, underwater diving observation, and the experience of the fishermen interviewed, we were able to draw up Table 9 which classifies the major species into shallow, intermediate, and deep species according to where their maximum concentration was recorded.

Several authors have provided indications on the vertical distribution of bottom fishes, in particular Masuda *et al,* (1975), Munro (1967), Fourmanoir and Laboute (1976), Fourmanoir (1979, 1980), Ralston (1978), Mead (1979c) and Anonymous (1978, 1980a). Although the data given by these authors tally fairly well on the whole, there are some notable differences between the areas considered. These mainly stem from the fact that the authors are variously concerned either with the maximum range of the species or with the depth range giving the highest catch rates. They may also spring from sampling differences, the reliability of the data increasing with the fishing effort. Generally speaking, the lower limit of the range of the deepest species does not seem at all precisely determined. Nevertheless, real differences between areas do apparently occur. In New Caledonia, Fourmanoir (1979, 1980) found the depth range of *Etelis carbunculus* to be between 230 and 460m, with the best catch rates recorded between 330 and 420m. For *E. coruscans* fishing is best from 290 to 500m. This author furthermore points out that "the temperature which suits large-sized specimens is between 11°C and 14°C. Where there is a very sharp thermocline, as for example in the Mozambique Channel in summer (Europa Island, Comores Islands, Zanzibar), and in the China Sea in spring and summer (Viêtnam, Philippines), the low temperatures that are suitable for *Etelis* (less than 14°C) occur at a depth of only 180m. In New Caledonia, where there is no marked thermocline, fishing for deep snappers must go down below 300m in every season". This statement is in line with our own comments concerning internal waves (cf. page 12) and with other observations (Smith, personal communication) suggesting that the distribution of deep bottom fish could be affected by thermal fronts existing near the bottom. Thus the vertical distribution would to some extent vary with location and also with season.

Table 9 - Classification of species by depth zone of maximum concentration as recorded during deep bottom fishing in Vanuatu.

Shallow species (< 120 m)	Intermediate species (120-240 m)	Deep species (> 240 m)
Adioryx spinifer	Aphareus rutilans	Centrophorus scalpratus
Alectis indicus	Branchiostegus wardi	Cephaloscyllium sp.
Aphareus furcatus	Carcharhinus albimarginatus	Epinephelus septemfasciatus
Aprion virescens	C. falciformis	Etelis carbunculus
Bodianus perditio	C. plumbeus	E. coruscans
Caranx ignobilis	Epinephelus areolatus	E. radiosus
C. lugubris	E. chlorostigma	Hexanchus vitulus
Carcharhinus amblyrhinchos	E. magniscuttis (1)	Lipocheilus carnolabrum
Cephalopholis formosanus	E. morrhua (1)	Loxodon macrorhinus
C. hemistiktos	E. retouti	Mustelus manazo
Epinephelus cylindricus	Gnathodentex mossambicus	Ostichthys japonicus
E. fasciatus	Gymnocranius japonicus	Ruvettus pretiosus
E. hoedti	G. lethrinoides	Satyrichtys sp.
E. maculatus	G. robinsoni	Squalus megalops
E. microdon	Gymnosarda unicolor	Taractichtys steindachneri
Galeocardo cuvier	Lethrinus chrysostomus	Thyrsitoides marleyi
Lethrinus harak	L. miniatus	Triodon macropterus
L. kallopterus	Lutjanus argentimaculatus	Tropidinius argyrogrammicus
L. obsoletus	L. malabaricus	T. zonatus
L. variegatus	L. rufolineatus	
Lutjanus bohar	L. sebae	
L. fulvus	L. timorensis	
L. gibbus	L. sp.	
L. kasmira	Macolor sp.	
L. monostigma	Paracaesio gonzalesi	
Macolor niger	P. kusakarii	
Plectropomus leopardus	P. stonei	
Pristipomoides filamentosus	Promethichthys prometheus	
Sphyraena bleckeri	Pristipomoides auricilla	
Triaenodon obesus	P. flavipinnis	
	P. multidens	
	P. typus	
	Saloptia powelli	
	Seriola rivoliana	
	Sphyraena forsteri	
	Variola louti	

(1) Could possibly be regarded as deep species.

Variation in species diversity with depth

In the tropics, the fish fauna on shallow coral bottoms is characterised by the presence of a very large number of species. This diversity decreases abruptly beyond the outer reef drop-off and we have tried to work out the pattern of decreasing diversity with increasing depth. First of all we calculated, for each depth layer, the mean number of species caught per fishing trip and the mean number of species caught per reel hour (Table 10). As a matter of interest, we have also listed, in Table 10, the mean individual weights of the fish caught. It can be seen that the first two indexes, which reflect the species diversity, decrease as depth increases, more regularly for the former than for the latter. However these indexes do not at all reflect the abundance of each species. This is why we were led to use the specific diversity index (I) derived from Shannon's theory (1948) which takes into account both the number of different species and the abundance of each (1). We calculated it for four depth layers : 0-40m, 40-80m, 120-240m and below 240m. Because of the reduced number of fishing operations in the shallow water layers, we based our calculations for these on the trap fishing results recorded by Munro (1983) on the Carribean reefs, and on line fishing carried out by Loubens (1978) in the large southern passes of the New Caledonian lagoon. The results are shown in Table 10.

The indexes correspond to four different biotopes. The first reflects the extremely high diversity of the reef fauna. The two following biotopes are characterised by a fairly high degree of diversity because the ecological niches here are still varied and numerous. The variability of the environmental parameters and the water movement occurring in these layers are such that a wide variety of organisms can coexist there, all the different biological communities having good self-regulatory mechanisms (Daget, 1979). It is therefore probable that they have reached a state of stable balance at these depths and that their response to fishing pressure will be identical.

---

(1) Specific diversity Index $I = - \sum_{i=i}^{i=n} p_i \log_2 p_i$; p_i being the percentage of individuals belonging to species i, the sum being extended to the n species of the community.

Table 10 - Variation in number of species, average individual weight, and specific diversity index (I) with depth.

Depth (m)	Mean No. of species per trip	Mean No. of species per reel hour	Mean Individual weight	Biotope	I
0- 40	7,0*	0,57*	1,5	Reefs (Munro, 1983)	4,88
40- 80	5,3*	0,39*	2,7	Passes (Loubens, 1978)	3,64
80-120	6,1	0,36	2,0		
120-160	6,7	0,38	2,1	Intermediate outer slope	3,22
160-200	6,4	0,42	2,6		
200-240	5,3	0,44	3,5		
240-280	5,0	0,35	3,2	Lower outer slope	2,47
280-320	4,2	0,34	4,1		
320-360	2,9*	0,21	-		

* Number of fishing trips less than 10, not allowing Index I to be calculated.

The fourth biotope, which features a low specific diversity index, is characterised by great environmental constraints. Only a small number of species can develop there to a significant extent; their recovery capacity (homeostasis) will be lower and they will be more sensitive to fishing pressure. The ecological balance in these deep waters is less stable and overfishing can produce almost irreversible depletion.

5 - Day/night variations

For obvious practical reasons, fishermen were not able to assign an exact time of capture to each of their catches. These were therefore classified only into four broad categories according to whether they resulted from daytime fishing, night-time fishing, daytime fishing extended into the night, night-time fishing extended into the day. In order to bring out day/night variations more clearly, we have considered only the two former and taken the archipelago as a whole. The reel fishing results are summarized in Table 11. It will be noticed that no fishing below 360m was attempted at night. We shall see that this inadequate sampling resulted in a certain imprecision as regards the day/night variations in the distribution of the deepest species. Overall, the daytime C.P.U.E.s are very similar to the night-time C.P.U.E.s (averaging

Table 11 - Fishing efforts, catches and C.P.U.E. by depth layers for daytime and night-time reel fishing (sharks includes).

	Depths Z (m)	No of trips	Effort (No of reel-hrs)	Catches		C.P.U.E.	
				No	Wt	No	Wt
DAY	0 - 40	2	8	10	11,6	1,25	1,45
	40 - 80	2	17	22	36,7	1,29	2,16
	80 - 120	11	125	88	256,0	0,70	2,05
	120 - 160	38	475	426	929,9	0,90	1,96
	160 - 200	43	496	635	1343,1	1,28	2,71
	200 - 240	55	821	636	1702,1	0,77	2,07
	240 - 280	60	753	693	2201,6	0,92	2,92
	280 - 320	68	749	865	3115,8	1,15	4,16
	320 - 360	9	109	101	462,7	0,93	4,24
	360 - 400	1	14	5	3,3	0,36	0,24
	400 - 440	1	12	5	2,0	0,42	0,17
	Unknown Z	125	1156	1643	5312,6	1,42	4,60
	Total D	415	4735	5128*	15377,4*	1,08*	3,25*
NIGHT	0 - 40	4	49	50	100,0	1,02	2,04
	40 - 80	1	26	9	27,1	0,35	1,04
	80 - 120	8	191	148	274,6	0,77	1,44
	120 - 160	15	318	381	1103,3	1,20	3,47
	160 - 200	20	339	553	1151,0	1,63	3,40
	200 - 240	21	461	399	953,5	0,87	2,07
	240 - 280	13	291	222	1389,1	0,76	4,77
	280 - 320	4	71	26	70,7	0,37	1,00
	320 - 360	1	26	8	19,1	0,31	0,73
	Unknown Z	30	476	906	2508,0	1,90	5,27
	Total N	117	2248	2702*	7596,4*	1,20*	3,38*
D + N	Total	532	6983	7830*	22973,8*	1,12* (1)	3,29* (1)

* These are mean values, not totals.

(1) These figures differ slightly from the figures in Table 3 because only fishing trips carried out entirely either by day or by night have been taken into account.

3.25 and 3.38 kg/reel/hour respectively), from which one might be inclined to conclude that fishing gives the same results by day as by night. In actual fact however, the C.P.U.E. variations broken down into 40m depth layers reveal a certain amount of upward migration of the fish in the deep layers during the night (Fig.10). It would therefore be tempting to recommend night fishing, which does not have to be so deep, but in practice the choice depends on the target species. This is why we have tried to determine day and night differences in catchability for the main species.

In the first part of this study, we did not take fishing depths into account at all and, considering only the species represented in significant numbers, we simply compared the night and daytime catches in numbers. However, as the night fishing effort had been less than the daytime effort (2248 reel/hours against 4735), we first had to bring the night fishing effort up to the same level as the daytime effort. We did this by multiplying the night catches by 2.11 which represented the ratio of the efforts. We then determined the night-time (or daytime) trend of each species by expressing the adjusted night catches as a percentage of the sum (D + Na) of the daytime catches (D) and the adjusted night-time catches (Na). In Figure 11, the species are ranked by increasing night-time activity. 95% confidence intervals are also shown. Some species are strongly diurnal e.g. *Lipocheilus carnolabrum, Paracaesio kusakarii, Lutjanus timorensis, Pristipomoides filamentosus* and *Etelis radiosus*. Others are very markedly nocturnal, e.g. *Lutjanus malabaricus, L. argentimaculatus, Promethichthys prometheus, Ruvettus pretiosus* and *Ostichthys japonicus*. In the middle of the diagram, with percentages around 50%, we find species that can be caught either by day or by night, such as *Pristopomoides flavipinnis, P. multidens, Seriola rivoliana, Epinephelus areolatus, E. chlorostigma* and *Lethrinus miniatus*. As pointed out earlier, depths below 300m were hardly ever touched during night fishing, and it is therefore difficult to draw conclusions for the deepest species such as *Etelis coruscans* and *E. carbunculus* which are very abundant in the daytime catches. On the other hand, the two deep bottom sharks *Squalus megalops* and *Hexanchus vitulus*, which were caught mainly at night despite the lesser night fishing effort, certainly have a strong preference for night activity.

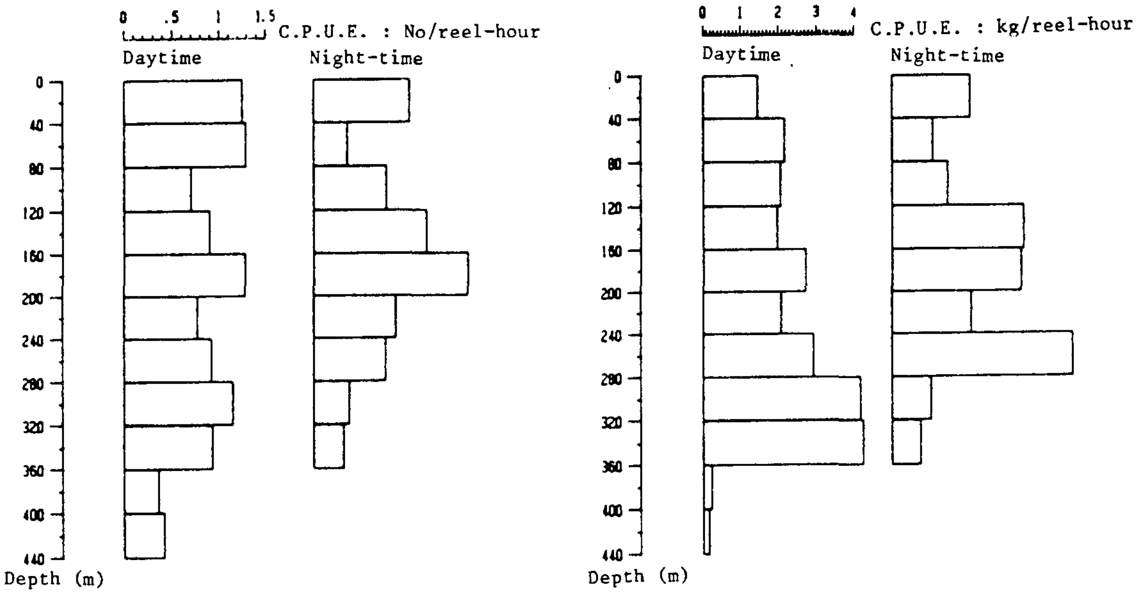


Fig. 10 - C.P.U.E. (by numbers and weight) obtained for different depth intervals during daytime and night-time reel fishing (sharks included).

In the second part of our study, we calculated night/day variations in relation to depth. For the 22 major species previously considered, we calculated the C.P.U.E. by numbers by 40m depth layers (Fig. 12a, b and c). We excluded from our calculations all fishing trips begun in the daytime and continued into the night and vice versa, which explains a number of discrepancies with the diagrams drawn up for the overall vertical distributions (Fig. 9a, b and c). As no night fishing effort went down below 360m, some uncertainty remains with regard to the breakdown of species that are still abundant at a great depth, e.g. *Etelis carbunculus, Tropidinius argyrogrammicus* and *Epinephelus morrhua*. On the whole however, the trends shown on Figure 11 are again observed and three broad categories can therefore be established : species generally catchable in the daytime, species generally catchable at night, species catchable both by day and by night with predominance of diurnal or nocturnal activity in some cases, and no such predominance in others (Table 12).

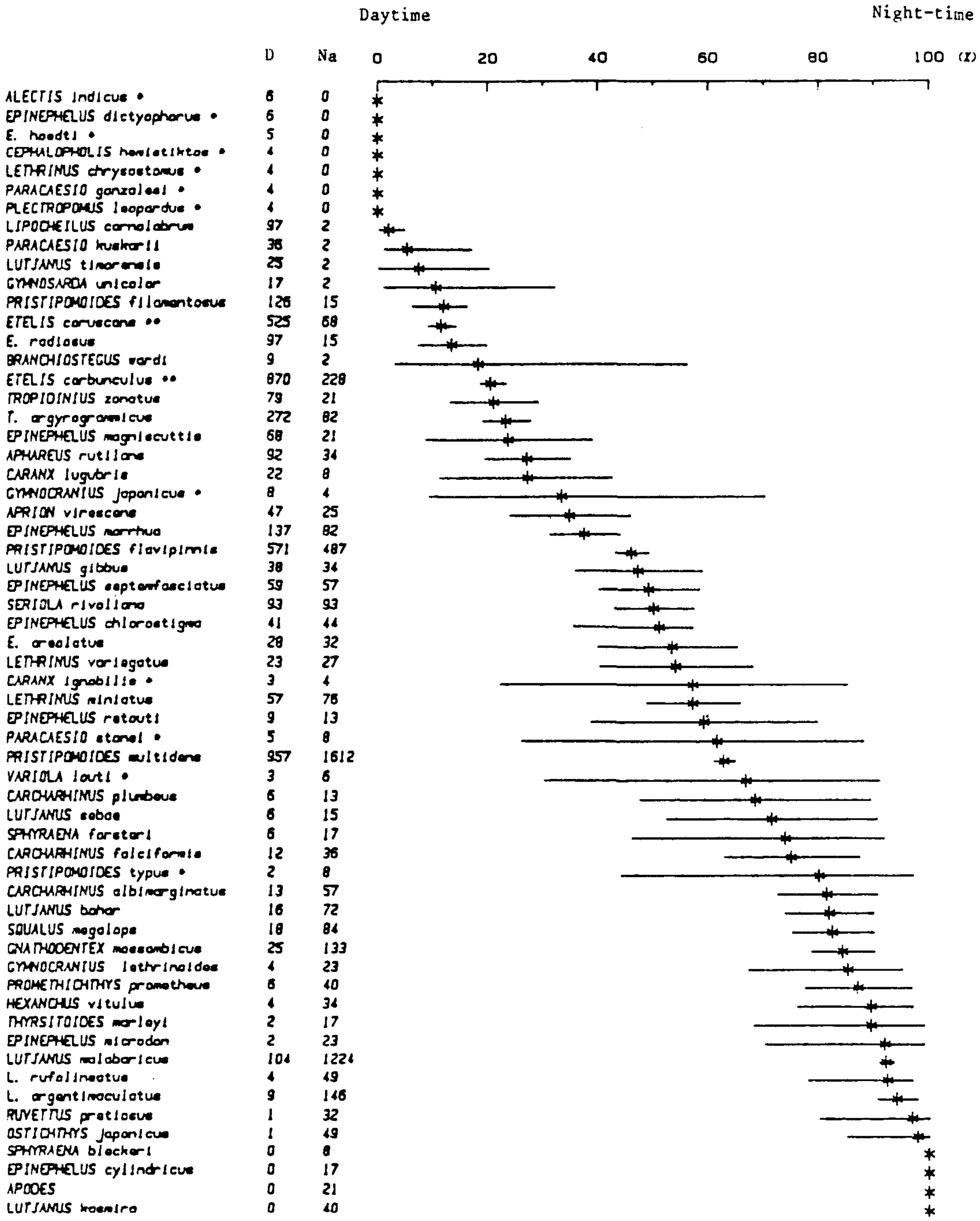


Fig. 11 - Daytime or night-time catchability trends of some species and 95 % confidence intervals.

* Doubtful classification : catches few in number.

** Doubtful classification : depths below 300 m rarely fished at night (cf. Table 11 and text).

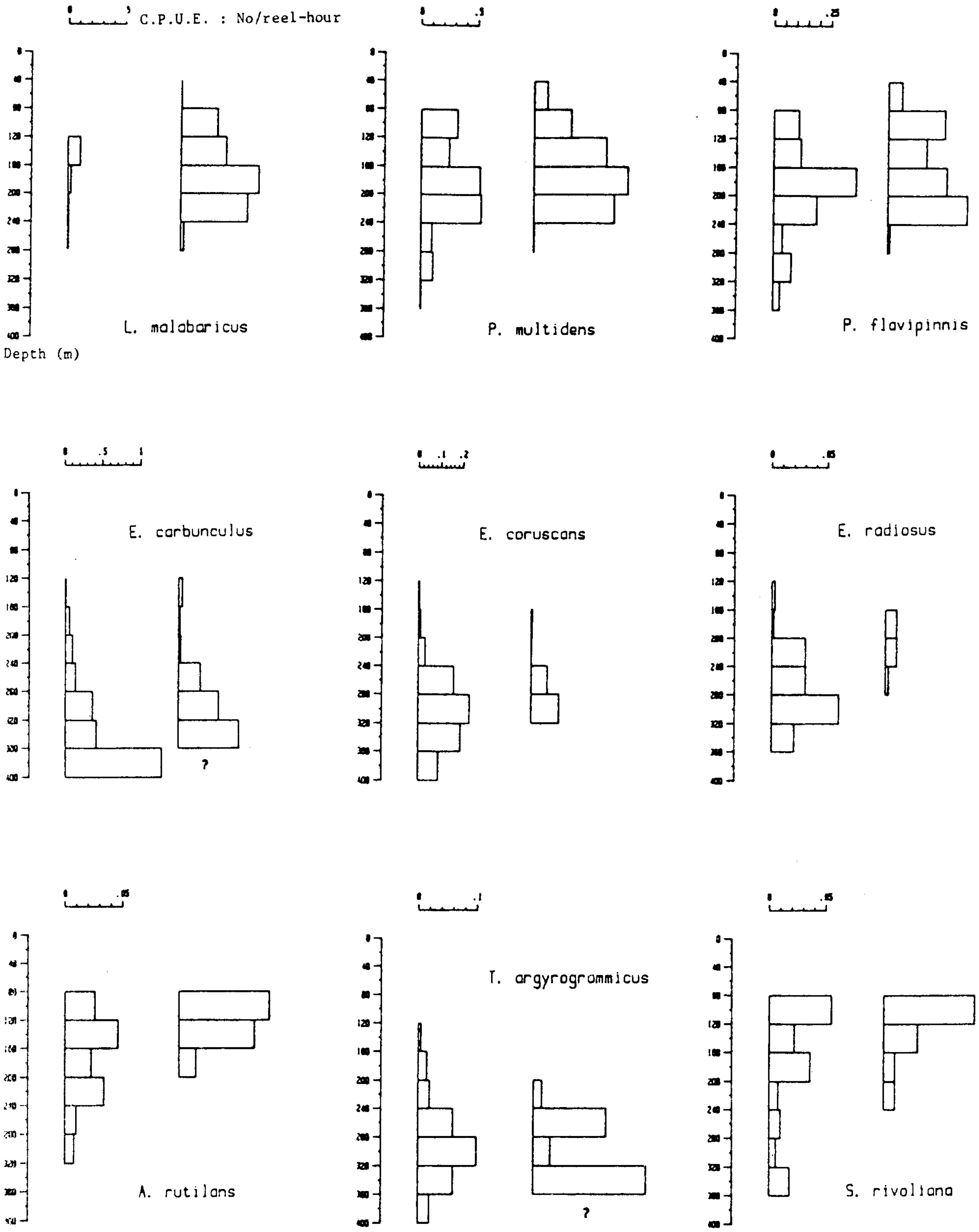


Fig. 12a - Day/night variations of C.P.U.E. in numbers. (left : daytime; right : night-time).

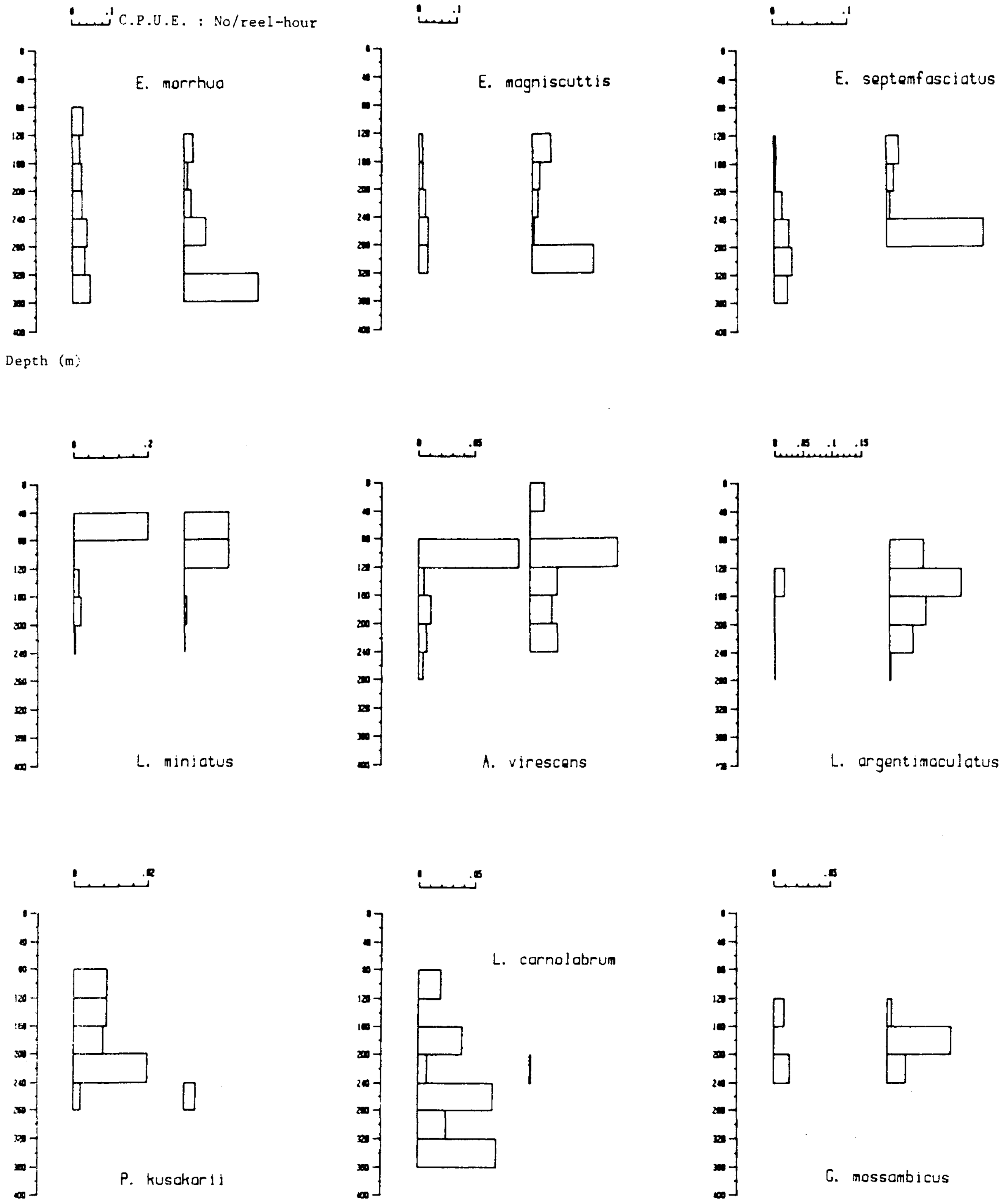


Fig. 12b - Day/night variations of C.P.U.E. in numbers.
(left : daytime; right : night-time).

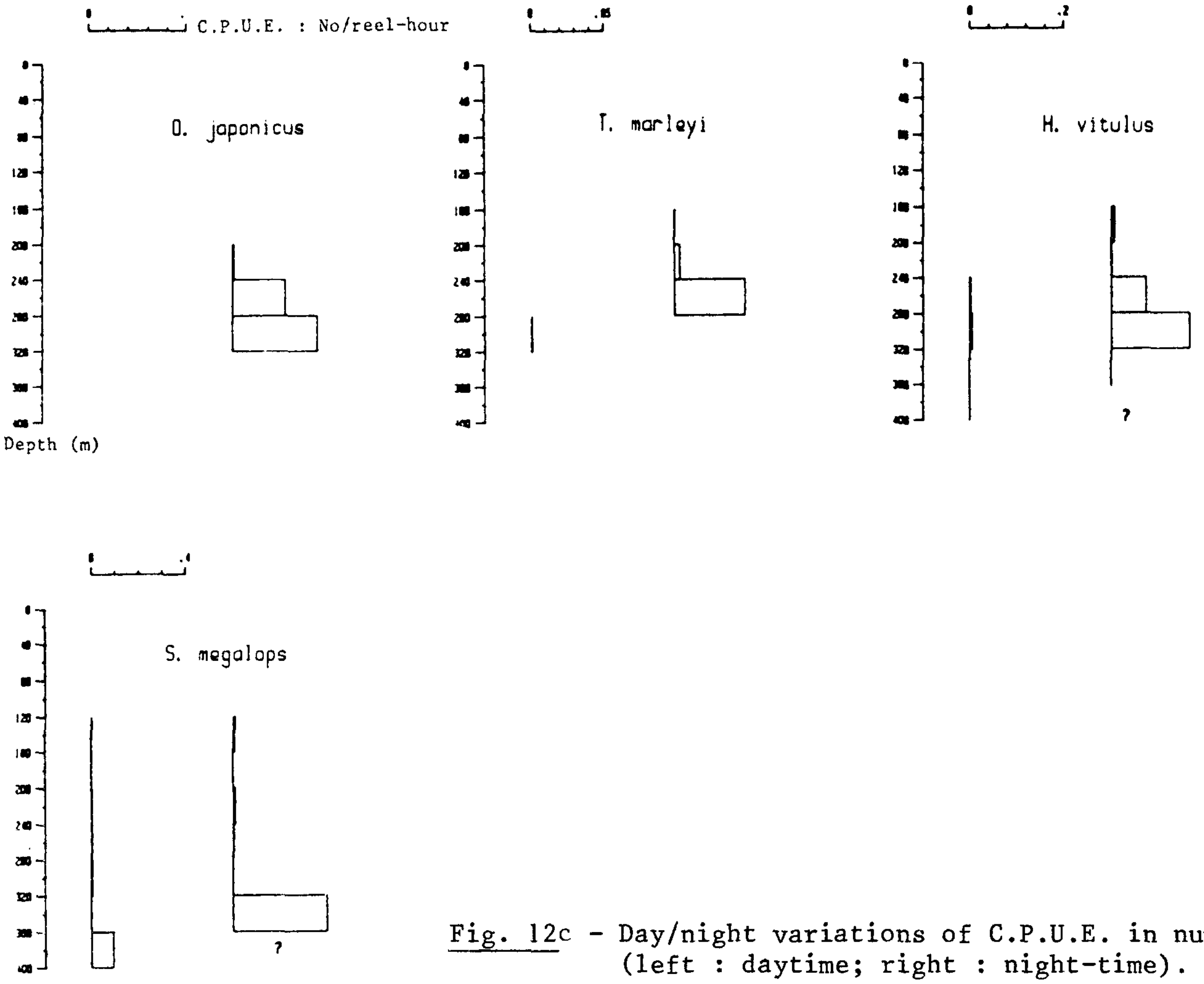


Fig. 12c - Day/night variations of C.P.U.E. in numbers. (left : daytime; right : night-time).

The most notable fact to emerge from this study was a nocturnal upward "migration" of 40 to 80m. This apparent upward movement is particularly marked in species that live at the intermediate depths (80 to 240m) where most of the daytime and night-time fishing effort was applied. Among the species for which this was noted, *Pristipomoides flavipinnis, P. multidens, Aphareus rutilans* and *Seriola rivoliana* figured prominently. This phenomenon is observed in many marine organisms, both demersal and pelagic, and may correspond to actual nocturnal migrations triggered by phototropism or by changes in feeding behaviour. In calculation of C.P.U.E. (sharks included) by depth interval, it produces the day/night differences seen in figure 10.

Table 12 - Best fishing periods for some species

Daytime

Etelis radiosus
Gymnosarda unicolor
Lipocheilus carnolabrum
Lutjanus timorensis
Paracaesio kusakarii
Pristipomoides filamentosus
Tropidinius zonatus

Night-time

Epinephelus cylindricus
E. microdon
Gymnocranius lethrinoides
Hexanchus vitulus
Lutjanus argentimaculatus
L. bohar
L. kasmira
L. malabaricus
L. rufolineatus
Ostichthys japonicus
Promethichthys prometheus
Ruvettus pretiosus
Squalus megalops
Thyrsitoides marleyi

Daytime and night-time

Aphareus rutilans
Aprion virescens
Branchiostegus wardi (N)
Caranx lugubris (D)
Carcharhinus falciformis (N)
C. plumbeus (N)
Epinephelus areolatus
E. chlorostigma
E. magniscuttis (N)
E. morrhua
E. retouti
E. septemfasciatus (N)
Etelis carbunculus (D)
E. coruscans (D)
Gnathodentex mossambicus (N)
Gymnocranius japonicus (D)
Lethrinus harak
L. miniatus (N)
L. variegatus
Lutjanus gibbus
L. sebae (N)
Mustelus manazo (D)
Pristipomoides flavipinnis
P. multidens
Seriola rivoliana
Sphyraena forsteri (N)
Tropidinius argyrogrammicus (N)
Variola louti (N)

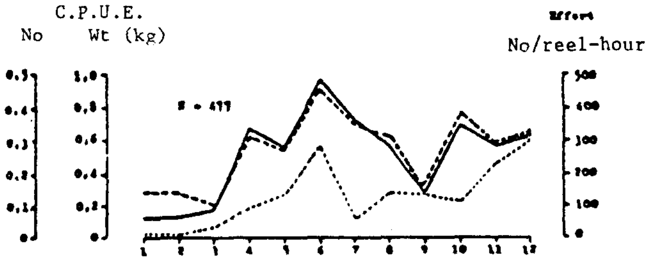
(D) : day-time activity predominant
(N) : night-time activity predominant

6 - Seasonal fluctuations

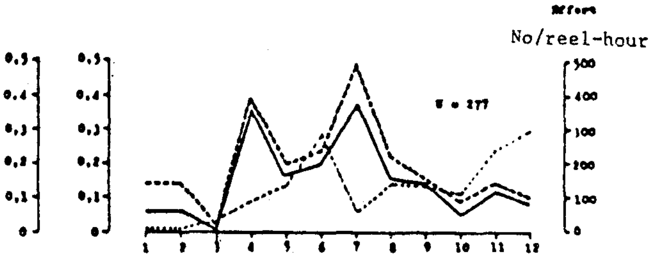
The configuration and nature of the bottom have a determining influence on the geographic distribution of deep bottom fishes, which results in some species being far more abundant than others in any given place. In order to study seasonal fluctuations for any one of these species, it is therefore essential to choose a place where it is abundant and to monitor changes in the C.P.U.E. for this species throughout the year, while endeavouring, as far as possible, to keep the fishing effort constant. As the fishermen we worked with were, for economic reasons, forced to leave certain fishing grounds at certain times of the year when fishing there was no longer profitable, the ideal requirements for a study of this type were not really met. However, by combining three years, month by month, we did nevertheless try to bring out some trends as regards seasonal fluctuations in abundance for five main species : *Etelis carbunculus, E. coruscans, Pristipomoides multidens, P. flavipinnis* and *Lutjanus malabaricus*. It would certainly be desirable for these trends to be confirmed with a larger volume of data. For the *Etelis* ssp., we selected the Toukoutouk - Devil's Point area (zone 1, Fig.2). Since the depth distribution diagrams show the catch rates for these species to be highest between 240 and 360m (Fig. 9a and B), only the results of fishing carried out in this depth range were taken into account. For the *Pristipomoides* spp., we combined zone 1 and the Teouma - Rentabao zone (zone 2, Fig.2), and took into account only the depth range 80 - 200m which gave the highest catch rates (Fig. 9a and b). For *Lutjanus malabaricus,* we used the data provided by the fishing association of Port Olry, in the northeast of Santo.

Mean monthly variations in fishing effort and C.P.U.E. (by numbers and weight) are shown on Figure 13. *Etelis carbunculus* and *E. coruscans* give maximum catch rates between February and June, and minimum rates around the end of the year. In Hawaii, Ralston (1978) found similar fluctuations for *Etelis coruscans, Pristipomoides filamentosus, P. sieboldi* and *Aphareus rutilans,* with however a six-month difference because of the seasons being reversed. For *Pristipomoides flavipinnis* and *P. multidens,* maximums are obtained between April and July. In the case of *Lutjanus malabaricus,* since it is a markedly nocturnal and relatively shallow-water fish (Fig. 9a and b), and since the Port Olry fishermen record neither fishing depths nor fishing times, calculating the C.P.U.E. (catch/line/trip) for this species, on the basis of all the landings, including those from deep daytime fishing trips, might well have produced erroneous results. We therefore plotted two curves : one shows C.P.U.E. fluctuations for the total 672 fishing trips, the other is based only on the 318 fishing trips where this species was present in the catch. Both graphs demonstrate the same fluctuations. Fishing for *Lutjanus malabaricus* gives the highest catch rate in December. Ralston (1978) does not mention this species, but he reports the same trend for *Aprion virescens* and *Seriola dumerili.*

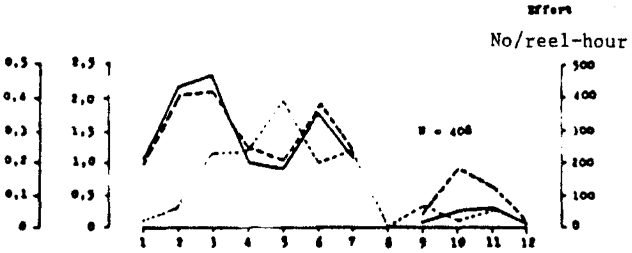
Ralston (1978) views his own conclusions as regards seasonal fluctuations with some scepticism; he feels that they might well be artefacts arising from variations in fishing effort, as Hawaiian fishermen concentrate on



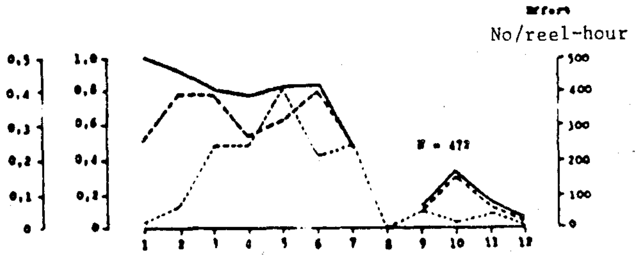
P. multidens



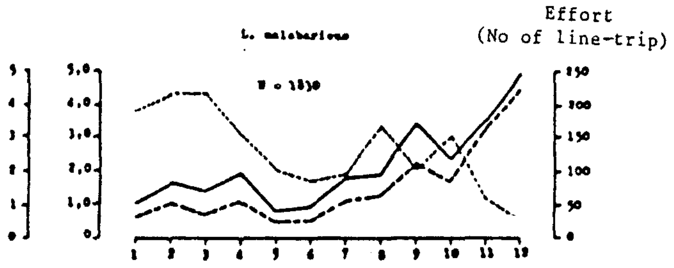
P. flavipinnis



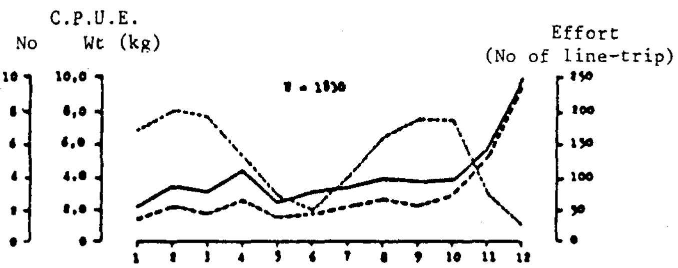
E. carbunculus



E. coruscans



All fishing trips (672 trips)



Trips during which *L. malabaricus* was caught (318 fishing trips)

L. malabaricus

Fig. 13 - Seasonal fluctuations

------- C.P.U.E. (numbers)

——— C.P.U.E. (weight)

.... Fishing effort

a few target species at different times of the year. Obviously this could have been the case in Vanuatu, particularly from November to March, at the height of the pelagic fishing season. But in fact interviews of the fishermen suggest that the reason why fishermen temporarily stop fishing in an area is that catches become poorer. Reduction in fishing effort therefore results from a decline in C.P.U.E. and not from other factors. Although they are not very obvious from our data, especially for the Etelidae, some seasonal fluctuations do seem to occur. What phenomenon brings about these apparent fluctuations remains to be discovered. It is unlikely to be migration of the species. Behavioural changes associated with a biological phase such as reproduction seem a more plausible cause.

7 - Influence of other factors

Catches are not only affected by depth, daytime or night-time fishing, and the seasons, they also depend on factors like the skipper's skill, gear efficiency, weather conditions, strength and direction of tidal currents, type of bottom, bait quality, and, probably, light intensity and moon phase. Their influence is difficult to estimate, as is always the case where there are many simultaneous variations of factors.

Skill of the skipper

In order to determine the effect a skipper's skill might have on the catch rates, we chose six skippers and compared their performance on the same fishing grounds and at the same time of the year. Wilcoxon's rank tests and variance analyses demonstrated differences in respective fishing efforts and total catches. On the other hand there was no difference in the C.P.U.E.s. This means that while some fishermen put in a greater effort than others by staying on the fishing grounds longer, their catch per fishing hour is more or less the same as for the others. Our data would not therefore have any notable bias ascribable to a skipper's individual skill.

Type of bottom

Fishermen know very well that some bottom types are likely to have good concentrations of particular species or species groupings. Mead (1979c) mentions three bottom types common throughout the Pacific but for which there are many variations :

(a) level bottom with a mixture of sand and coral
(b) gradual slope with sand, coral and rock,
(c) sharp drop-off with rock and coral.

In addition there are the muddy bottoms of deep estuarine bays, and the plateaus with rock outcrops where strong currents prevent the deposit of sediment and the parent rock remains bare. According to Mead (1979c), many species of Carangidae are ubiquitous (i.e. live on any type of bottom), as are *Tropidinius argyrogrammicus* and *T. zonatus.* All three bottom types are inhabited by *Aprion virescens,* which however shows a preference for coral, by *Lutjanus kasmira,* which particularly likes type (b), and by *Etelis carbunculus,* which is mainly found on (a) and (b). *Lutjanus gibbus, Lethrinus miniatus,* and all the *Pristipomoides* appear to favour (a) and (b). All the *Epinephelus, Aphareus rutilans, Lutjanus malabaricus, L. sebae* and *Gymnosarda unicolor* show a preference for (b) and (c), as well as *Lutjanus argentimaculatus,* which however seems especially attracted to areas near mangroves and river mouths. Lastly, *Etelis coruscans, Seriola rivoliana* and the *Gempylidae* are more strictly confined to steep type (c) bottoms. According to Fourmanoir (1979), the *Etelis* species most often keep to rocky bottoms at the foot of submarine cliffs. Fourmanoir and Laboute (1976) claim that *Pristipomoides flavipinnis,* a fairly sedentary fish, and *Pristipomoides multidens* prefer fairly gentle slopes to sharp drop-offs. On the other hand, *P. filamentosus,* a very mobile species which sometimes forms schools of several hundred individuals, has been observed by divers on sheer reef drop-offs. *Pristipomoides typus,* of which a few specimens were caught in Vanuatu, is typically taken on the muddy bottoms found in the vicinity of large estuaries. According to Ralston (1978), *Etelis coruscans* is mainly caught near rock outcrops, in the vicinity of pinnacles and sharp drop-offs.

On the basis of our interviews with Ni-Vanuatu fishermen and of the published work of Fourmanoir and Laboute (1976), Fourmanoir (1979, 1980), and Mead (1979c), we have, in the general conclusions to this paper, inserted a summary table showing, among other things, the bottom features preferred by the main species.

Light intensity

Although there is only a small amount of light below the euphotic layer, deep fish species do nevertheless seem sensitive to differences in illumination, whether from the sun (effect of seasons and cloud cover) or from the moon. For example Mead (1979) reports that *Ruvettus pretiosus,* and the *Gempylidae* in general which are all very nocturnal, are commonly caught on moonless nights. This could not be confirmed by the analyses of our own data.

Bait

Fishing success is largely dependent on the type of bait used. Fresh skipjack tuna, *Katsuwonus pelamis,* is regarded as one of the best. Salting the skipjack fillets for a few hours before use increases its hold on the hook by making the flesh firmer. Freezing reduces its effectiveness power, but it still remains an excellent bait. Among the other tunas, *Euthynnus affinis* and *Auxis thazard* give fairly good results, while yellowfin tuna, *Thunnus albacares,* makes poor bait and is rarely used. Useful alternative baits include *Sphyraena barracuda* and *Selar crumenophtalmus,* especially the latter which is very popular in the islands being easy to net close to the shore. Fishermen's opinions vary as to the value of other species (*Sardinella* spp., *Decapterus* spp., etc...). However all fishermen advise against using deep bottom fish as bait, except possibly the Gempylidae. Octopus, cuttlefish and squid are rarely used because they are a valued part of the islanders' traditional diet. Octopus is fished on the reefs by women and children.

Hooks must be rebaited frequently during fishing, so that the attractant smell will spread sufficiently over the bottom. We worked out the amount of bait needed from the results of 528 trips (Table 13). On the average, one kilogramme of bait is enough to catch 13.5 kg of fish; in other words, to bring in a catch of 100 kg of deep bottom fish will require about 7.5 kg of bait. Catches per kg of bait vary a lot however from one fishing trip to another (standard variation above average). This is hardly surprising considering the wide variety of species and conditions and the fact that as much bait is required to catch small fish as big ones. From this point of view, but only in this connections fishermen with bait supply problems could be advised to concentrate on fishing in the deeper layers where the average size of individual fish is greater than in the intermediate layers (Table 10).

Table 13 - Bait consumption

Nb. of fishing trips	528
Catch per kg of bait :	
- weight (kg)	13.47
- numbers	4.78
- standard deviation (kg)	14.09
Bait consumption :	
- per 100 kg	7.42
- per fishing/hour	1.04
- per reel/hour	0.35

Considerable quantities of bait are thus needed, which often limits the development of artisanal fishing (1). Fishing projects launched in the islands come up against this problem daily, all the more so as bait storage facilities are rarely available. This is one of the reasons why fish aggregation devices have been deployed in several islands. They increase and regularise catches of pelagic species while reducing fuel consumption, and are thus an invaluable aid not only for the capture of fish for human consumption, but also for a regular supply of bait.

---

(1) Fusimalohi and Grandperrin (1979) report that some fishermen in the Loyalty Islands (New Caledonia) had to resort to using the Giant African Snail, *Achatina fulica,* as bait. Strangely enough the catches were not nil !.

8 - Groupings of species

For a given place, depth and time of day, an experienced fisherman is able to predict what species he is likely to catch and, among these, which will be the most abundant. It therefore seems logical to distinguish between several different "types of fishing", each focussing on one or more target species, with which a number of other species usually occur. Thus one can speak of *Etelis* fishing, *Pristipomoides multidens* fishing, *Lutjanus malabaricus* fishing, etc..., with the target species determining the fishing strategy. To investigate these groupings or associations of species, we used an ascending hierarchical classification program written in BASIC language for an HP 9845 computer. 450 fishing trips were considered separately, and the C.P.U.E. by numbers were calculated for each of the species that were present in more than five landings. These data led to the establishment of a matrix for cluster analysis using the Chi-squared distance as the dissimilarity criterion (Legendre and Legendre, 1979). Computer processing resulted in the hierarchical classification diagram (dendrogram) shown in Figure 14.

The work of interpreting this diagram and the groupings of species it suggests is the trickiest and most subjective part of the analysis. Interpretation involves determining the basis of association, that is to say, the factors that give rise to the groupings. Within each group, a species (sometimes two) whose space-time distribution and behaviour are best known, is chosen as the reference species and all species that are associated with it are assumed to have similar characteristics. The two most determining factors in the formation of groups are obviously depth and light (day/night). Other factors, such as type of bottom, seasons, moon phase and tidal currents, no doubt also play a part, but their influence is impossible to ascertain. They probably account for some rather odd classifications.

Two main groups Gl and G2 split at point 90 on the diagram. If we consider the depth factor alone, Gl would correspond to species in the upper and intermediate depth strata of the outer reef slope, and G2 species in the lower part of the outer reef slope. Further analysis revealed sub-groups based on the day or night activity of these species.

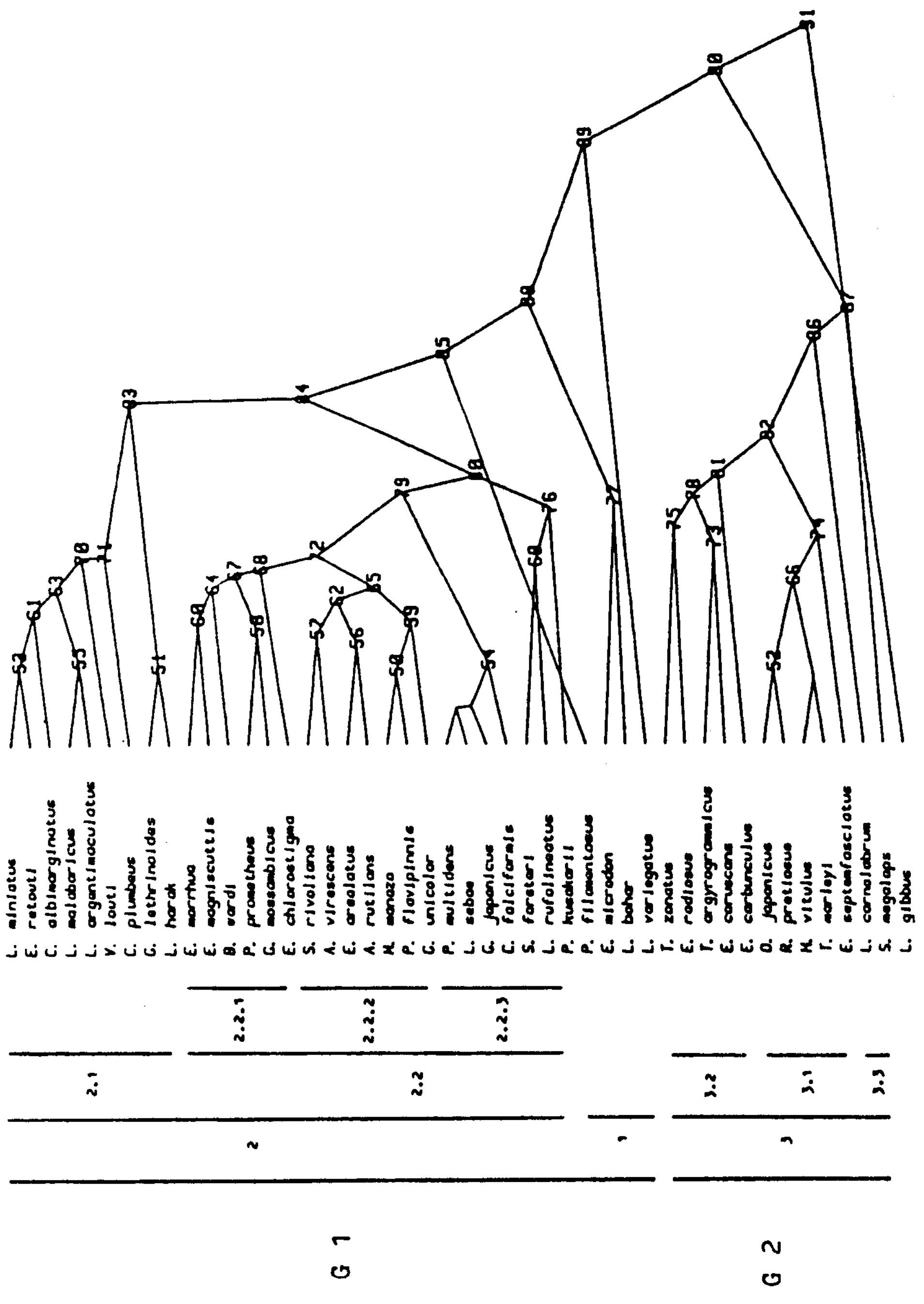


Fig. 14 - Clusters of species : hierarchical classification diagram (dendrogram) for species that were present in more than five landings.

(1) Species of the upper part of the outer reef slope

They are *Pristipomoides filamentosus, Epinephelus microdon, Lutjanus bohar* and *Lethrinus variegatus*. Classification in terms of their most usual period of capture does not appear conclusive since some of the species are strongly diurnal *(P. filamentosus)* and others strongly nocturnal *(E. microdon)*. What brings them together seems to be their tendency to come up into relatively shallow waters.

(2) Species of the intermediate part of the outer reef slope

(2.1.) Species with predominantly nocturnal activity

The reference species are *Lutjanus malabaricus* and *L. argentimaculatus* which are know to be night feeders. Associated with them are some highly nocturnal species *(Carcharhinus albimarginatus)*, some predominantly nocturnal species *(Lethrinus miniatus, Variola louti, Carcharhinus plumbeus)*, and also *Variola louti* which is caught indifferently by day and by night. Although it is strongly nocturnal, *Gymnocranius lethrinoides* appears on the fringe of the cluster. This could be due to other, non-identified, factors. *Lethrinus harak* seems to be incorrectly classified, for it is a very shallow species.

(2.2.) Species with relatively constant day/night activity

(2.2.1.) Species at the lower limit of the range

The reference species are *Epinephelus morrhua* and *E. magniscuttis*. Included in their cluster are *Branchiostegus wardi, Gnathodentex mossambicus* and *Epinephelus chlorostigma*. *Promethichthys prometheus*, which is strongly nocturnal like all the Gempylidae, is not in its proper place here.

(2.2.2.) Species at the upper limit of the range

The reference species is *Pristipomoides flavipinnis*. It is associated with *Seriola rivoliana, Epinephelus areolatus* and *Aphareus rutilans*. Although *Aprion virescens* is regarded as a shallow species, it can be included in this cluster because it has been caught as deep as 200m. On the other hand, *Mustelus manazo* should not be included, as it is a deep-water shark, nor *Gymnosarda unicolor*, which is definitely a daytime species.

(2.2.3.) Species present throughout the intermediate range

The reference species is *Pristipomoides multidens.* Associated with it are *Lutjanus sebae, Gymnocranius japonicus, Carcharhinus falciformis* and *Sphyraena forsteri.* The inclusion here of *Lutjanus rufolineatus,* which is highly nocturnal, and *Paracaesio kusakarii,* which is strongly diurnal, seems questionable.

(3) Species of the lower part of the outer reef slope

(3.1.) Species with predominantly nocturnal activity

The reference species are *Ruvettus pretiosus* and *Ostichthys japonicus.* Included in this cluster are *Hexanchus vitulus, Thyrsitoides marleyi* and, to a lesser extent, *Epinephelus septemfasciatus,* which can also be caught by day.

(3.2.) Species with relatively constant day/night activity

All the species in this cluster belong to the Etelidae family : *Tropidinius argyrogrammicus, T. zonatus, Etelis carbunculus, E. coruscans* and *E. radiosus.* Although they can be caught at night, they do seem to have a strong diurnal preference, with the possible exception of *T. argyrogrammicus.*

(3.3.) Non-classifiable deep species

They are the highly diurnal *Lipocheilus carnolabrum* and the highly nocturnal *Squalus megalops.* The only thing they seem to have in common is that they are both deep-living fish. The type of bottom could possibly be a factor linking them.

Lastly, *Lutjanus gibbus* which lives in very shallow water and is caught both by day and by night seems impossible to classify with any other species.

The cluster diagram brings out certain trends by giving a comprehensive picture of the links existing between species. These links are only valid from a fisheries point of view, for two species are not grouped unless they were caught together. This classification therefore has no ecological value. The fact that a species belongs to a cluster does not exclude the existence of links with species in another cluster, for the sea forms a continuum and there is no rigidity in the groupings. The classification suggested here does not however enable overlappings of clusters to be discerned.

LENGTH STUDIES

1 - Length frequency distributions

The length frequency distributions for 25 species are shown on Figures 15a, b and c. For the six main species - *Etelis coruscans, E. carbunculus, Pristipomoides multidens, P. flavipinnis, Tropidinius argyrogrammicus* and *Lutjanus malabaricus* - males and females have been separated. In the first four species, the females are markedly larger than the males, as regards both maximum lengths and modes. This is fairly common in fish. It may simply be due to differences in response to fishing gear (vulnerability differences) but is more likely a reflection of what actually exists in nature. Length frequency distributions and especially maximum lengths, have been used extensively in the chapters dealing with reproduction, growth and mortality.

Table 14 shows the maximum lengths (L max) recorded for the main species in Vanuatu and in three other Pacific countries : Fiji (Anonymous, 1978), Hawaii (Ralston, 1978; Uchida *et al.*,1982) and New Caledonia (Fourmanoir and Laboute, 1976; Barro, 1980; Loubens, 1980a). Considerable differences can be seen in some cases between these regions. They may be ascribale to differences in respective fishing efforts, for the greater the fishing effort the greater the chance of catching very big specimens. They could also result from differences in fishery development. They may lastly reflect differences in growth potential resulting from more or less favourable environmental factors such as temperature and food availability. It is surprising to note that in Hawaii the maximum size of *Etelis carbunculus* is 62 cm, while in Vanuatu it is 112 cm. In Hawaii, Tahiti and La Réunion, Fourmanoir (1980) ascribed the absence of large individuals to the fact that "deep water handlining has been practised there for a very long time and has led to the disappearance of the big specimens". In New Caledonia, all the maximum lengths

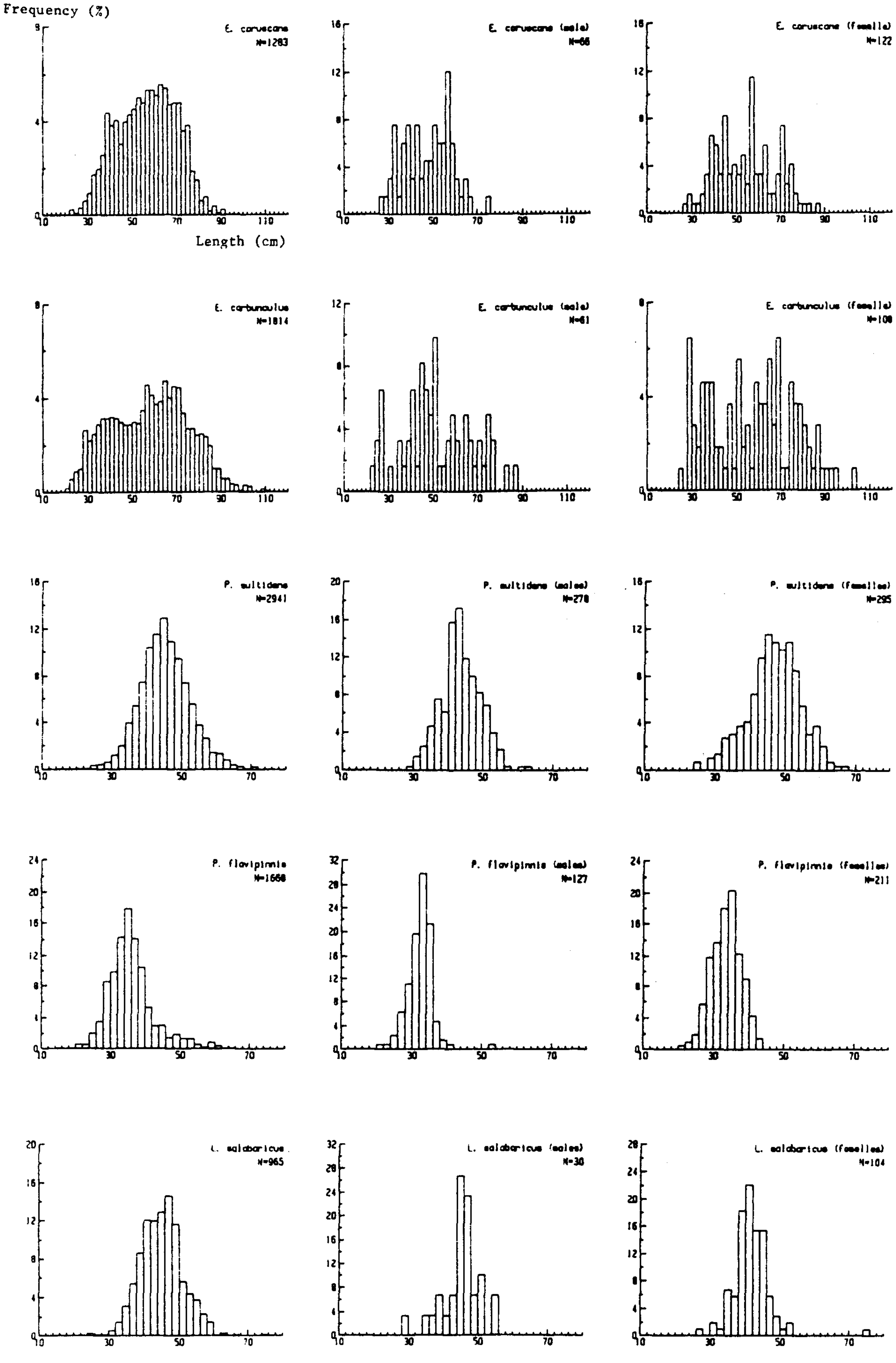


Fig. 15a - Length frequency distribution (forklength in cm).

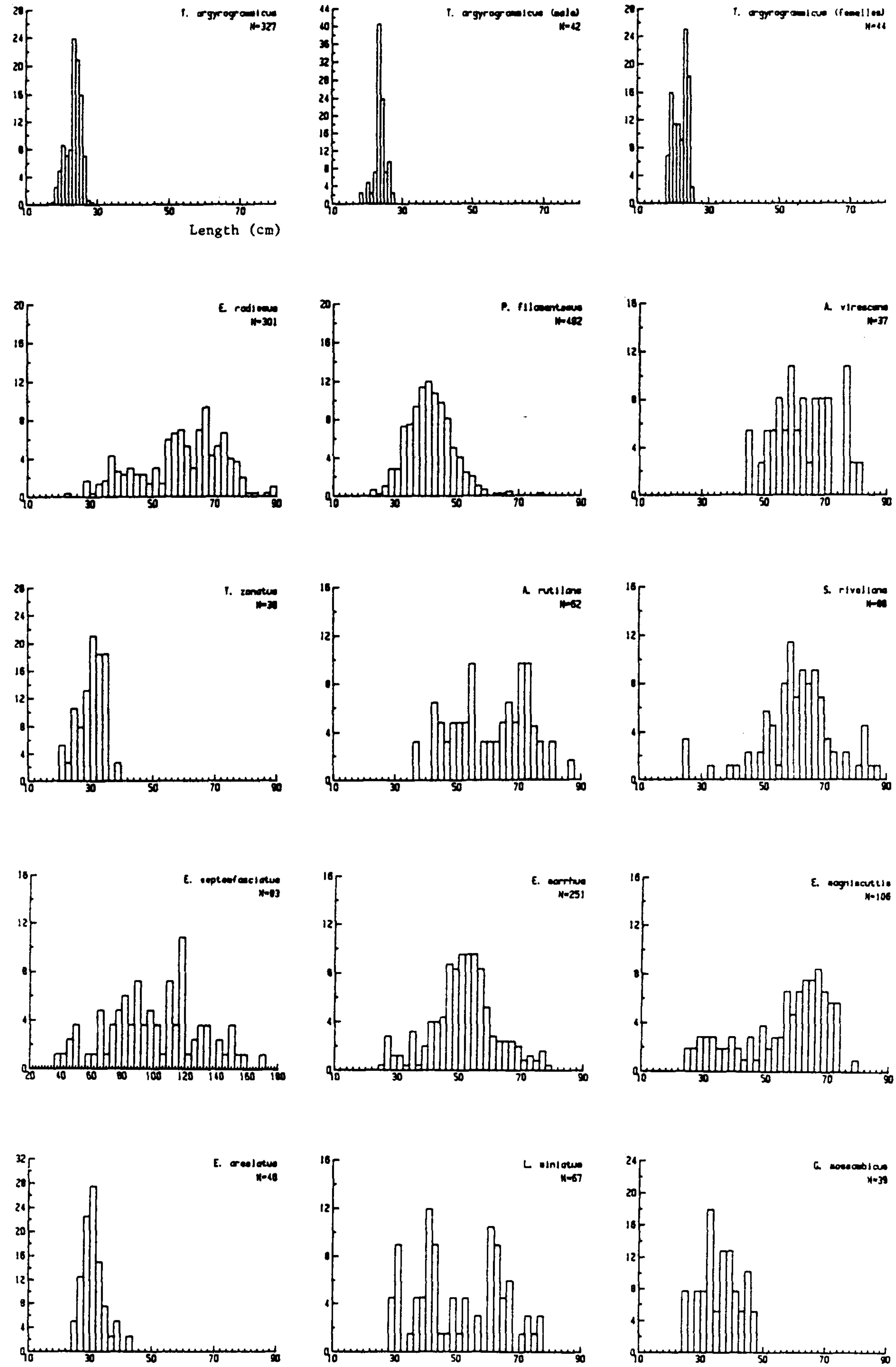


Fig. 15b - Length frequency distributions (forklength in cm).

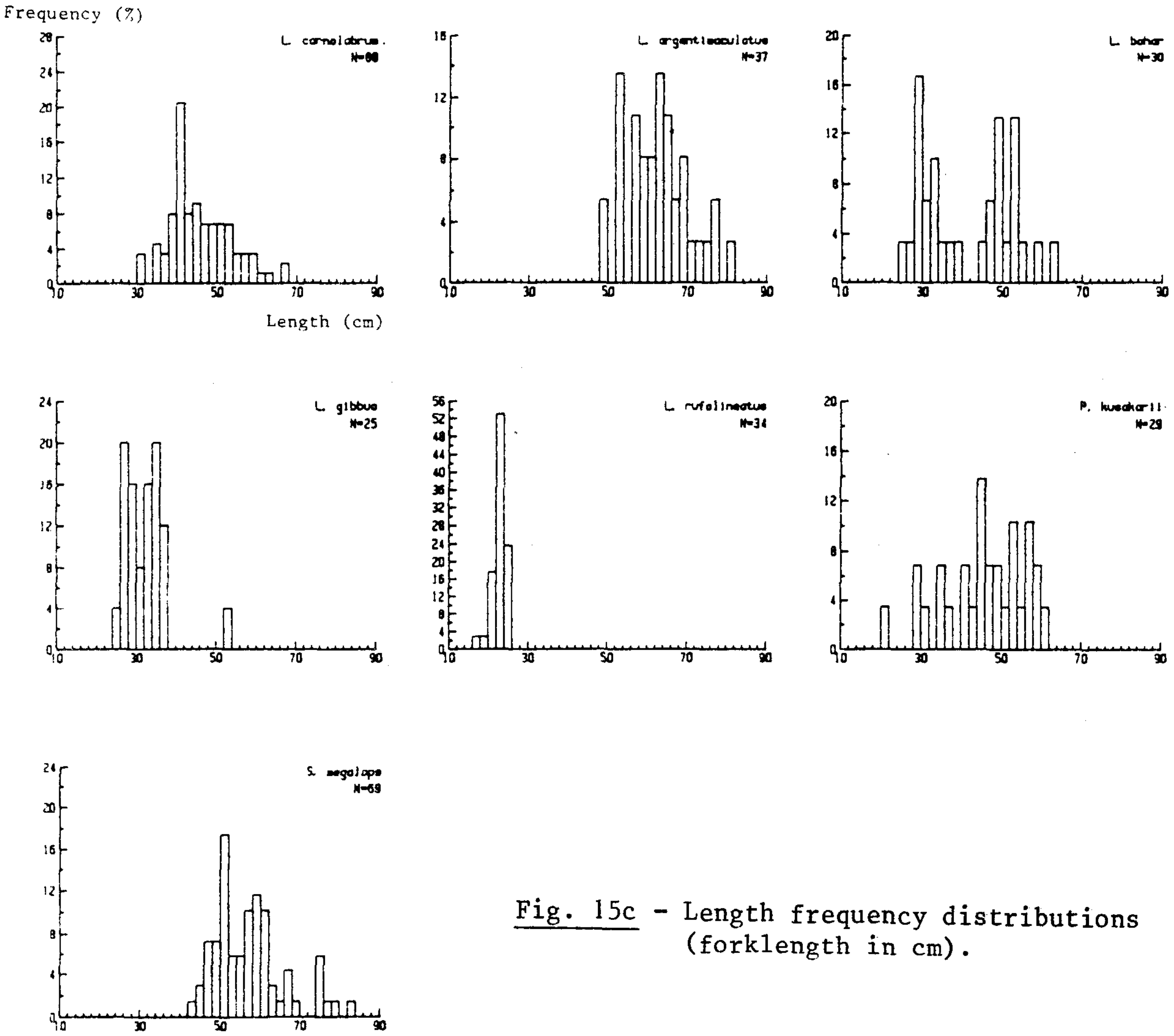


Fig. 15c - Length frequency distributions (forklength in cm).

recorded are lower than in Vanuatu.

In New Caledonia all the specimens, except for *Etelis coruscans,* were caught inside the lagoon and in the passes, at an average depth of 30m and a maximum depth of not more than 80m. Considering that environmental conditions governing growth are roughly the same in these two adjacent areas, one can suggest the hypothesis that some species begin their life cycle inside the lagoon and complete it on the outer reef slope where they reach much larger sizes. This appears to be true, for example, of the mangrove jack, *Lutjanus argentimaculatus*. However, this hypothesis does not account for the small maximum length of *Etelis coruscans,* the largest specimen of which was

Table 14 - Maximum lengths recorded (forklengths)

	Vanuatu	Fiji	Hawaii	New Caledonia (1)
Aphareus rutilans*	88	98	-	-
Aprion virescens*	82	-	80	71
Epinephelus areolatus	44	-	-	33
E. hoedti	71	-	-	62
E. magniscuttis	95	-	-	-
E. microdon	94	-	-	48
E. morrhua	79	-	-	90 (2)
E. septemfasciatus	170	-	-	-
Etelis carbunculus	112	103	63	-
E. coruscans	91	92	88	75 (2)
E. radiosus	89	-	-	-
Gnathodentex mossambicus	48	62	-	-
Gymnocranius lethrinoides	48	-	-	39
Lethrinus miniatus	78	-	-	-
L. variegatus	60	-	-	36
Lipocheilus carnolabrum	68	-	-	-
Lutjanus argentimaculatus	82	-	-	61
L. bohar	64	-	-	58
L. gibbus	52	-	-	37
L. malabaricus	76	68	-	-
L. rufolineatus	35	-	-	-
Paracaesio kusakarii	62	78	-	-
Plectropomus leopardus	69	-	-	64
Pristipomoides filamentosus	76	-	78	-
P. flavipinnis	65	62	-	-
P. multidens	76	-	-	-
Seriola rivoliana	92	98	-	-
Sphyraena bleekeri	101	-	-	70
Squalus megalops (3)	84	-	-	-
Tropidinius argyrogrammicus	29	-	-	-
T. zonatus*	40	-	49	-
Variola louti	45	-	-	44

(1) Fish caught inside the lagoon and in the passes, except for (2)

(2) Fish caught on offshore seamounts

(3) Standard length.

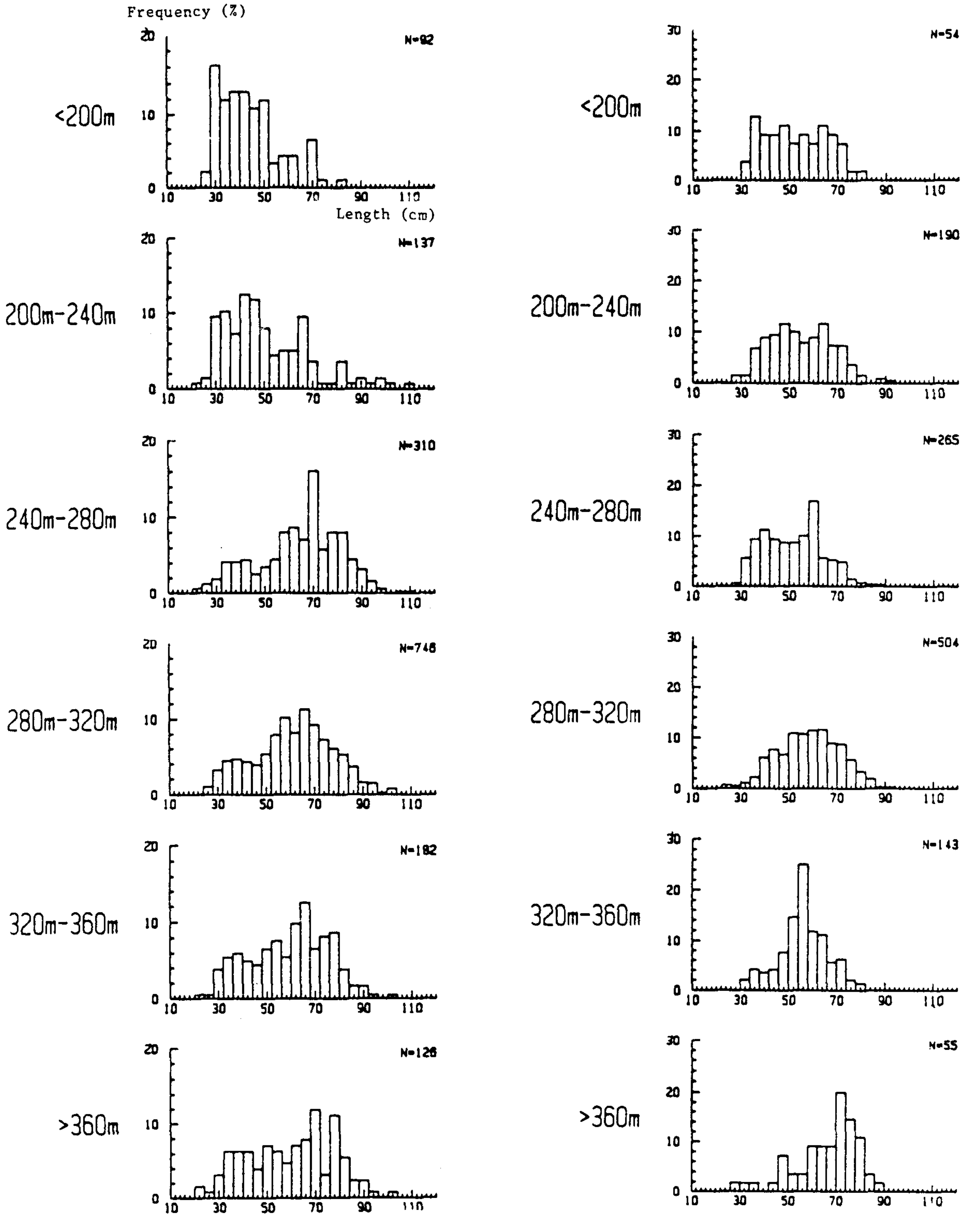
* Druzhinin (1970) reports a maximum length of 110 cm for *Aphareus rutilans,* 102 cm for *Aprion virescens* and 51 cm for *Tropidinius zonatus,* but does not specify the areas where these data were recorded.

found in a sample taken from 23 tonnes of fish caught on the seamounts lying south-east and south-west of New Caledonia, at depths between 250 and 450 m, in an area that is totally unfished (Barro, 1980).

Grant (1978) reports that in Queensland specimens of *Lutjanus malabaricus* reach 15 kg. Using the length-weight key we established for smaller sizes, we obtain a corresponding fork length of 98 cm. In the nearly 1000 individuals of this species that we measured, the longest was only 76 cm, which corresponds to a weight of 6.8 kg. One wonders whether this deviation may not be due to misidentification, since *Lutjanus malabaricus* is often confused by fishermen with *Lutjanus sebae* (Grant, 1978).

2 - Length variation with depth

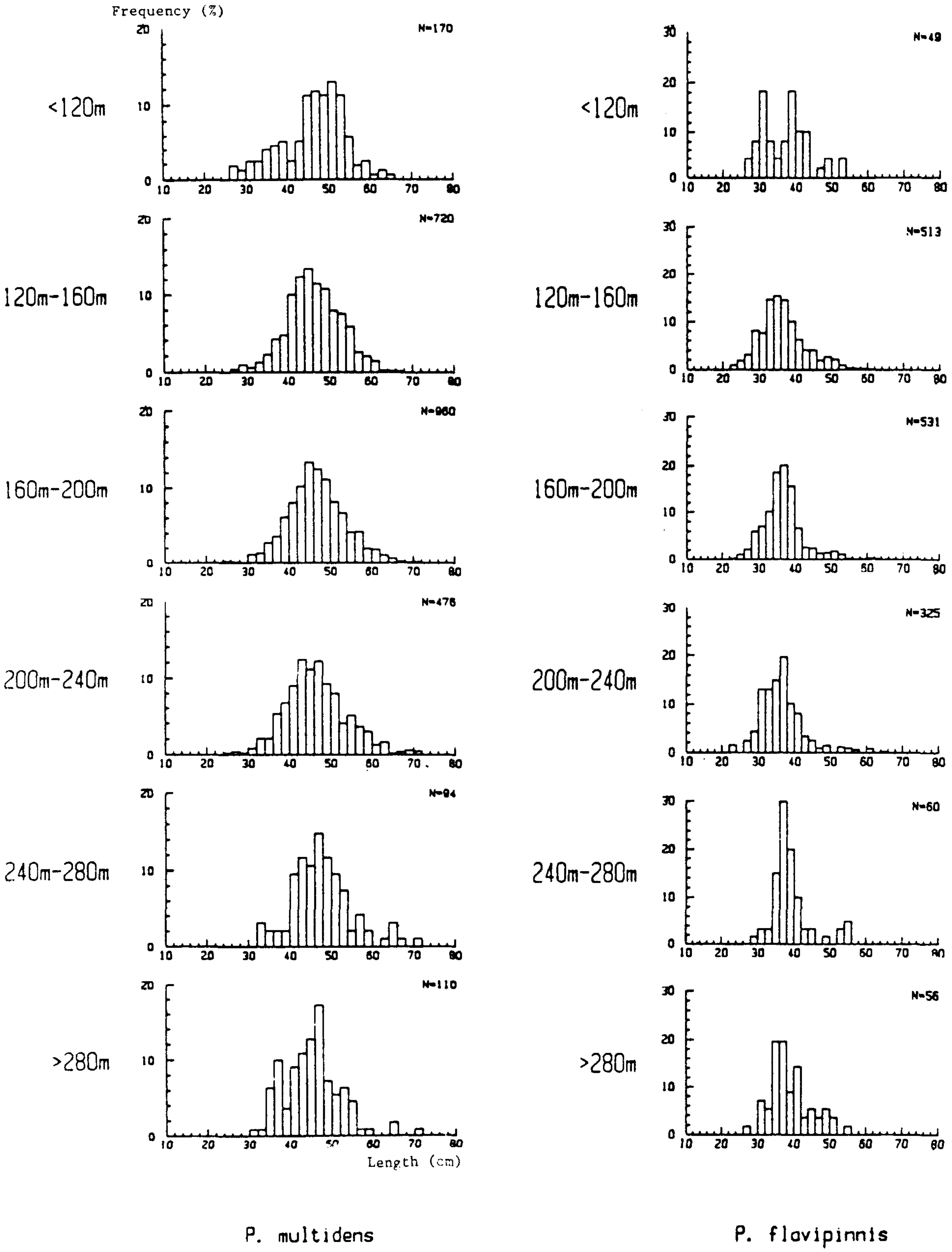
On the basis of his vast experience of fishing throughout the Pacific, Mead (1979c) reports that "in general, greater numbers of smaller fish are found in the upper part of a species depth range and fewer and layer fish in the lower part of the range. The best fishing is usually somewhere in between". For nine species we were able to establish length variations in relation to depth (fig. 16a, b and c). For *Etelis carbunculus* a sudden increase in lengths is observed at 240-280 m. Large specimens are not found in depths of less than 200 m. Small specimens are present throughout the depth range; they are however most abundant in depths of less than 240 m. This trend has already been reported from New Caledonia (Fourmanoir, 1979) and from Fiji (Anonymous, 1980 a). The picture is not quite so clear for *Etelis coruscans,* although below 280m one does notice a decrease in the number of small specimens and a tendency for the modes to shift towards the larger sizes. Roughly the same pattern is observed for *Etelis radiosus, E. magniscuttis* and *Epinephelus morrhua*. This is confirmed by Fourmanoir (1980) for *E. morrhua*. Length frequency distributions for *Pristipomoides multidens, P. flavipinnis* and *Epinephelus septemfasciatus* do not vary at all with depth. Those for *P. filamentosus* show a shift of the mode and the maximum lengths towards the right below 160-240 m. In Hawaii, Ralston (1978) reports a vertical stratification in the sizes of this species, with the smallest individuals being found in the shallowest waters. Lastly, let us mention the same trend, although it has not been demonstrated here, in *Seriola rivoliana* (Fourmanoir, 1980) and *Gnathodentex mossambicus* (Anonymous, 1980a).



E. carbunculus

E. coruscans

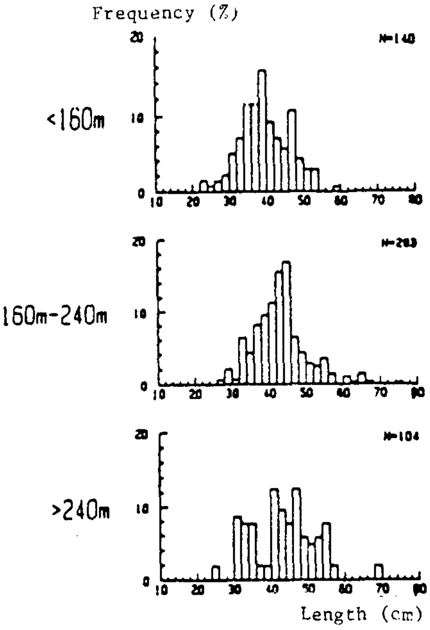
Fig. 16a - Length variations with depth (forklength in cm).



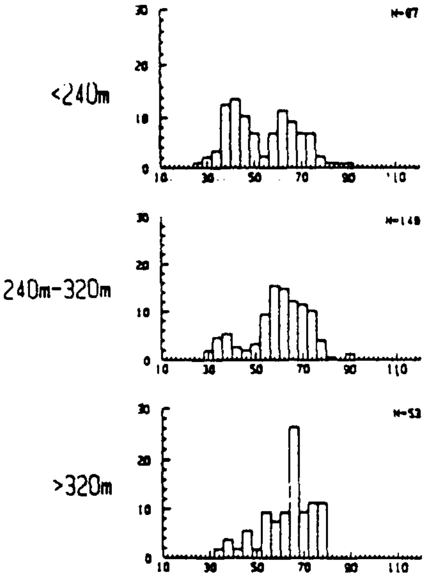
P. multidens

P. flavipinnis

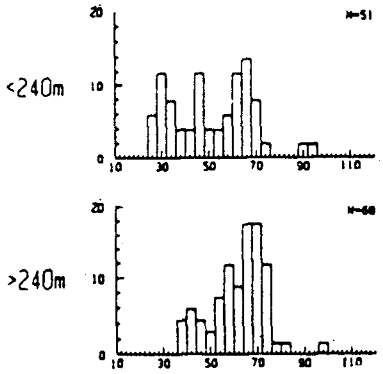
Fig. 16b - Length variations with depth (forklength in cm).



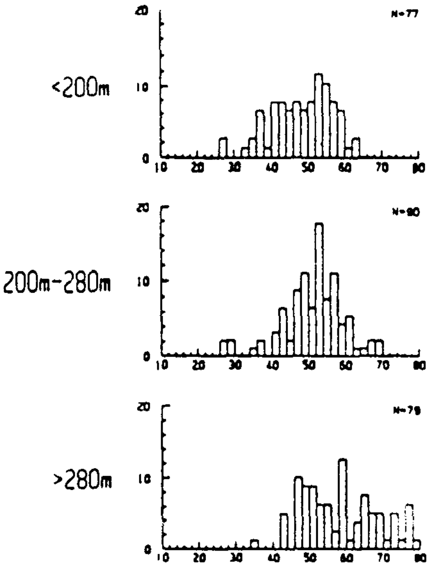
P. filamentosus



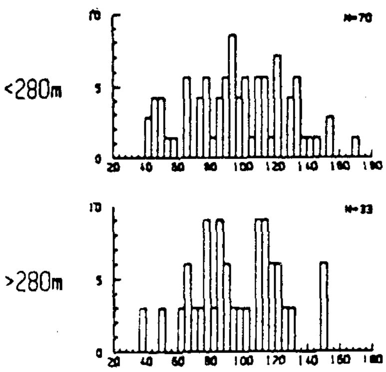
E. radiosus



E. magniscuttis



E. morrhua



E. septemfasciatus

Fig. 16c - Length variations with depth (forklength in cm).

3 - Selectivity of gear

While the selectivity of trawl nets has been amply studied, very little is known about the selectivity of hooks and lines. In practice, a selection curve is drawn up by comparing length frequency distributions in commercial catches with those in representative samples of the fish population in the area. No such data are however available for the outer reef slopes. In Hawaii, Ralston (1982), studying the influence of hook size on the size of three species, was nevertheless able to draw some interesting conclusions about gear selectivity. He shows that the size of the commonly used hooks has little effect on the size of the fish caught. He also claims that the selection curve is a sigmoid curve similar to that for trawl nets. Lastly, he considers that all sizes over 45 cm are well sampled. If we accept this figure for the fishes we are dealing with here, we find that the smallest species such as *Lutjanus rufolineatus, Tropidinius argyrogrammicus* and *T. zonatus* would never reach full recruitement length. Furthermore, the abundance of species such as *Pristipomoides flavipinnis, Lutjanus gibbus* and *Epinephelus areolatus* would be very much under-estimated, since their modal length is under 45 cm. In fact however, while the length factor is very important, the size of the mouth and its ability to swallow large prey should also be taken into account in selectivity studies.

4 - Length-weight relationships

The aim of very precise studies on changes in the length-weight relationship is often to determine fluctuations in the physiological state of the fish in relation to their environment and their activity (food availability, migrations, reproduction). Our own aim in establishing length-weight relationships was primarily to estimate the catch on the basis of fish lengths when it was impossible to weigh the fish. The relationships were also used for the calculation of growth coefficients. They are listed in Table 15 for the main species, with the exception of *Etelis radiosus* and *Pristipomoides filamentosus*. Many authors have established these relationships for deep water species, in particular Barro (1982) for *Etelis carbunculus* and *E. coruscans*; Morize (1984) for *Lethrinus miniatus, Lutjanus gibbus, Epinephelus microdon;* Uchida *et al,* (1982) for *Etelis carbunculus, E. coruscans, Pristipomoides filamentosus, P. sieboldi* and *Tropidinius argyrogrammicus;* Loubens

Table 15 - Length-weight relationships.
$W = aFL^b$ (where FL is the fork length espressed in cm, and W is the weight expressed in g).

	a	b
Aphareus rutilans	0,00336	3,311
Aprion virescens	0,00345	3,330
Caranx lugubris	0,01046	3,087
*Carcharhinus albimarginatus	0,00305	3,243
*C. falciformis	0,04635	2,750
Epinephelus areolatus	0,13556	2,327
E. magniscuttis	0,03916	2,754
E. morrhua	0,06058	2,624
E. septemfasciatus	0,00332	3,348
Etelis carbunculus	0,02161	2,950
E. coruscans	0,04105	2,758
Gnathodentex mossambicus	0,04012	2,824
Gymnocranius japonicus	0,02087	2,928
Gymnosarda unicolor	0,04087	2,800
*Hexanchus vitulus	0,00124	3,474
Lethrinus miniatus	0,03293	2,728
L. variegatus	0,18224	2,284
Lipocheilus carnolabrum	0,14897	2,488
Lutjanus argentimaculatus	0,00540	3,206
L. bohar	0,00003	4,606
L. gibbus	0,00006	4,646
L. malabaricus	0,00853	3,137
*Mustelus manazo	0,00229	3,198
Paracaesio kusakarii	0,01059	3,135
P. stonei	0,19977	2,402
Pristipomoides flavipinnis	0,02991	2,825
P. multidens	0,02003	2,944
P. typus	0,03909	2,733
Seriola rivoliana	0,00636	3,170
Sphyraena barracuda	0,00080	3,487
*Squalus megalops	0,01264	2,879
Thyrsitoides marleyi	0,00015	3,609
Tropidinius argyrogrammicus	0,00976	3,221
T. zonatus	2,50119	1,612

* Standard length not fork length is given here.

(1980b) for *Aprion virescens, Bodianus perditio, Cephalopholis formosanus, Epinephelus areolatus, E. fasciatus, E. hoedti, E. maculatus, E. microdon, Gymnocranius japonicus, G. lethrinoides, G. rivulatus, Lethrinus chrysostomus, L. variegatus, Lutjanus kasmira, Plectropomus leopardus, Sphyraena bleekeri* and *Variola louti;* Anonymous (1978) for *Pristipomoides flavipinnis, Aphareus rutilans, Lutjanus malabaricus, Paracaesio kusakarii, Gnathodentex mossambicus* and *Seriola rivoliana.* It would be fastidious to compare their results with ours since this would involve calculating the pairs of values corresponding to each formula, it being difficult to compare coefficients alone.

REPRODUCTION

The reproduction study was considerably handicapped by the fact that the fish were nearly always gutted at sea before they were landed. Only a few aspects of reproduction could therefore be investigated for the main species. Because of the small number of fish available for study we were not able to determine how the sex ratio changed with size increase and to deduce from this whether or not there exists a tendency to protandrous or, more commonly, protogynous hermaphrodism, the latter being reported by Loubens (1980a) in *Epinephelus areolatus, E. fasciatus, Lethrinus variegatus,* and by Walker (1975) in *Lethrinus chrysostomus.* Neither did we find any cases of synchronous hermaphrodism such as were noted by Thomson and Munro (1974) in a *Cephalopholis* found in Carribean waters. The only significant sex ratio we were able to use was calculated for a series of fishing trials carried out in Santo; for 656 *Pristipomoides multidens,* the male to female ratio was 1.18.

1 - Sexual maturation

The different stages of maturation were generally determined by macroscopic examination, but microscopic observation of a fresh gonad fragment teased apart in water was sometimes necessary. It is always tricky to establish a maturation scale applicable to several species, for the size, shape, colour and vascularisation of the gonads vary considerably from one species to another. We adopted a seven-stage scale. It is summarised in Table 16. Determination of a stage is not always easy and depends on some extent on the observer. In the absence of histological examination, it was occasionally difficult to differentiate stages 4, 5 and 7. The spawning stage (6) was rarely observed, probably because it does not last long (Fontana, 1969; Conand, 1977; Loubens, 1980a).

The available gonads were weighed. The gonosomatic index (GSI) was calculated by dividing the weight of both gonads (expressed in grammes) by the weight of the body (expressed in kilos). For the five main species, (all sizes and all seasons combined) we established a correlation between the maturation stages identified by the observer at the time of sampling and the mean GSI calculated afterwards (Fig.17). The correlation was good, particu-

Table 16 - Sexual maturation scale

Stage	Males	Females
1*	Indetermidate sex.	Indeterminate sex.
2	Gonad poorly developed, long and thin; translucid; whitish to pinkish in colour.	Gonad poorly developed but rather thicker than a mere filament; translucid; slight vascularisation.
3	Flattish testicule; pinkish white colour; does not run after cutting.	Opaque ovary; clear vascularisation ranging from pink to red; oocytes not visible to the naked eye.
4	Thick testicule, white; runs slightly after cutting.	Well developed ovary with strong vascularisation; colouring yellow to dark red; transparent membrane; granulous appearance; oocytes visible to the naked eye.
5	Thick testicule, often with a triangular section; curdled milk appearance; white colouring, runs easily after cutting.	Swollen and granulous ovary with very thin and fragile membranes.
6	Running ripe.	Running ripe.
7	Flaccid testicule, spent and with strong vascularisation.	Spent ovary with strong vascularisation; burgundy red colour; early in this stage some isolated oocytes can still be found after cutting.

* The 0 code usually used for this stage was replace by code 1 to facilitate data computerisation.

larly for the females, and we therefore followed the seasonal changes in gonad maturation by using only the GSI, but nevertheless indicating immininent, observed or recent spawning as evidenced by the appearance of stages 5, 6 and 7 respectively.

Temporal variations in the mean GSI are illustrated for six species in Fig. 18. It will be noticed that the GSI of the males does not fluctuate as widely as that of the females, except perhaps in the case of *Aphareus rutilans*. The general pattern is however roughly the same. For *Pristipomoides multidens*, *P. flavipinnis*, *Aphareus rutilans* and *Lutjanus malabaricus*, the GSI is clearly lowest during the southern hemisphere winter, even though spawning can take

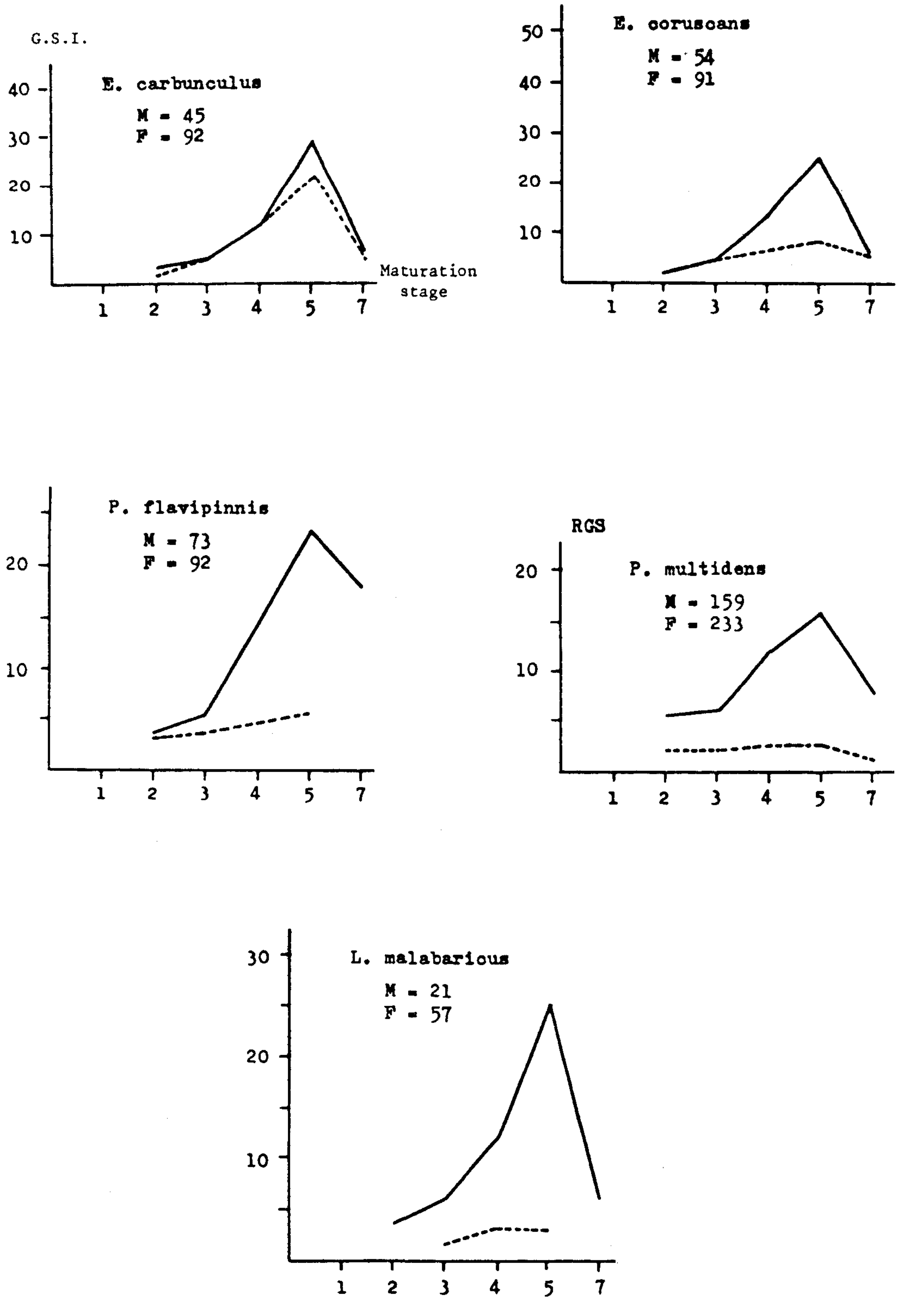


Fig. 17 - Correlation between observed maturation stages and GSI.

——— females ------ males

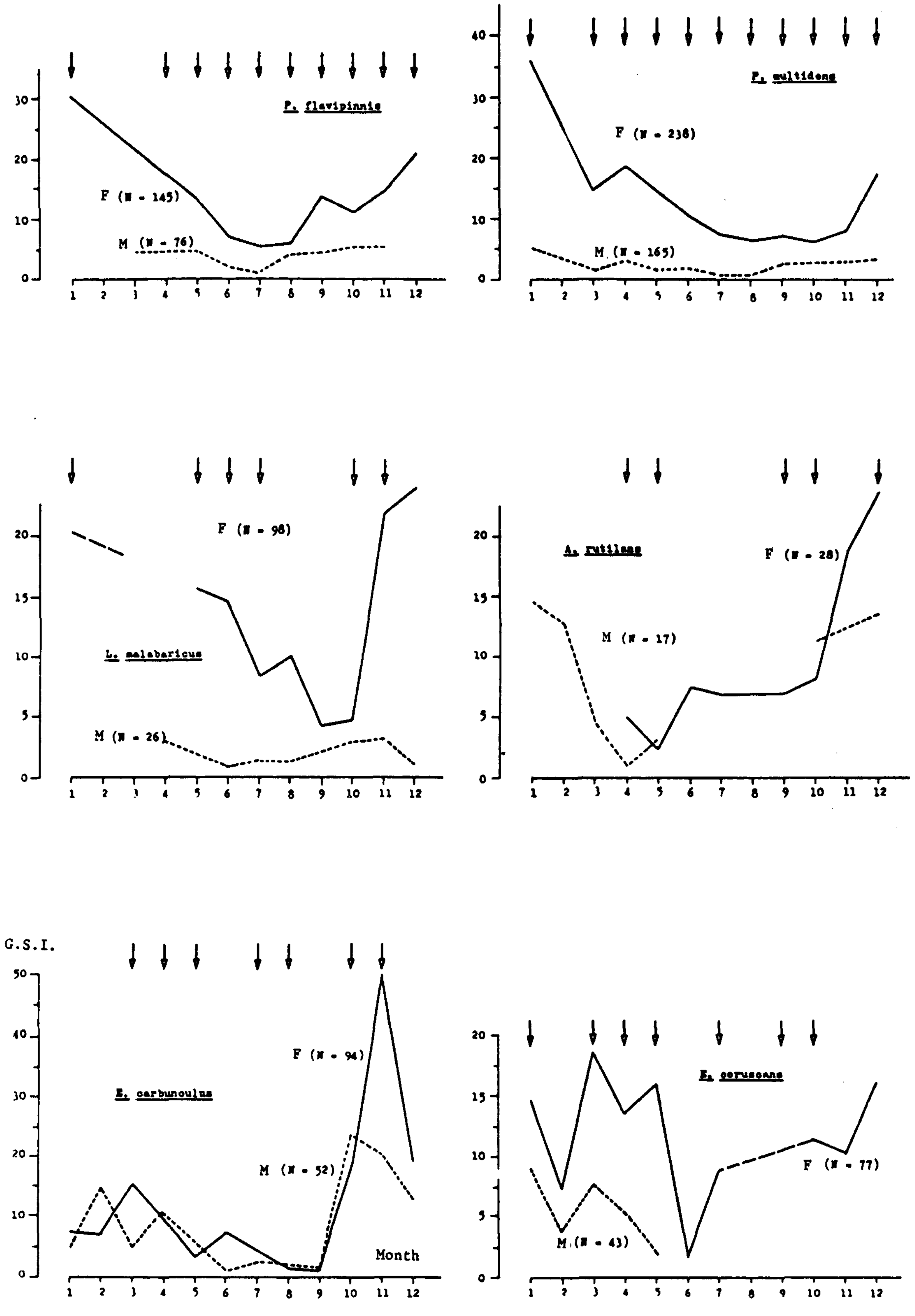


Fig. 18 - Variation of mean GSI in time.

↓ spawning (stages 5, 6 and 7)

F : female; M : male

place throughout the year. Now, the highest concentration of these species occurs at depths above 200 m (Fig. 9a and b) and their range extends upwards to 60-80 m (Fig. 8a). At 200 m, seasonal temperature variations; though slight, can be more than one degree; at 60-80 m they are even more marked. Under these circumstances, a decline in reproduction activity during the winter is compatible with the fact that environmental fluctuations are significant at the depths where these fish dwell. The reduced number of hours of light in winter also probably plays a considerable part in these relatively shallow water strata. The fluctuations of the mean GSI for *Etelis carbunculus* and *Etelis coruscans* are, on the other hand, harder to account for. These species, deeper-dwelling than the previous ones, show maximum abundance between 280 and 320 m (Fig. 9a and b) and do not come up to above 140 m (Fig. 8a). Comparatively speaking, they are therefore less subject to seasonal temperature and light variations. We would therefore venture the hypothesis that the shallower species have their maximum breeding activity in the summer, although they are capable of spawning all the year round, while the deep species do not have such a marked cycle. With a few exceptions, other species in Table 17, seem to show the same trend, although only a few gonads were sampled and examined for each of them and a far larger body of data is needed for this hypothesis to be confirmed. In all species, including the deepest ones, intense sexual activity in the spring (months 10 and 11) seems to be very common (Fig. 18 and Table 17).

Information about the spawning period is seldom found in the literature. In New Caledonia, Fourmanoir and Laboute (1976) suggest October to January as the spawning period for *Aprion virescens,* and April for *Pristipomoides flavipinnis*. During survey carried out in November-December, Barro (1980) found the females of deep bottom species to be at an advanced stage of maturation. According to Barro (1982), breeding of *Etelis carbunculus* and *E. coruscans* occurs in the summer, peaking in January.

2 - Size at sexual maturity

The sexual maturity size is generally defined as the length L m at which 50% of the individuals of a species are mature. Since our samples were too small for L m to be estimated, we confined ourselves to determining the smallest recorded sizes associated with sexual maturity, on the basis of the

Table 17 - Occasional spawning observations (O) and high GSI (+) (the number of gonads examined is shown in brackets next to each species).

Species		Months											
		1	2	3	4	5	6	7	8	9	10	11	12
Lipocheilus carnolabrum	(7)		0										
Lutjanus argentimaculatus	(19)										0+	0+	
Aprion virescens	(17)	0+									0+		
Tropidinius zonatus	(7)										0+		
Epinephelus magniscuttis	(12)	0										+	
Lethrinus miniatus	(7)										+		
L. variegatus	(8)										+		
Gymnocranius japonicus	(7)										0		
Gnathodentex mossambicus	(12)										0+		
Caranx lugubris	(5)										0		
Paracaesio kusakarii	(11)	0			0+						+		+
Epinephelus septemfasciatus	(8)				+						+		
Pristipomoides filamentosus	(46)	0+			+								
Etelis radiosus	(38)	0	0		0+		+				0+	0	
Seriola rivoliana	(18)	0				0+	0+				+		0+
Tropidinius argyrogrammicus	(82)		0		0+	0				0+	+	0+	
Epinephelus morrhua	(36)			0	+	+	0+	+	0+	+	+		
E. areolatus	(9)					0	0+				0		0+
Thyrsitoides marleyi	(3)							0+					

occurence of a high GSI and maturation stages 5, 6 and 7 (Table 18). In addition, we used the relationship established by Beverton and Holt (1959) which links the maximum length L max to the size at maturity L m i.e. L m = k L max. These authors equated L max. with $L\infty$. Now, while L m is a measurable biological parameter, this is not the case for $L\infty$ which is a mathematical parameter, often quite different from L max. It therefore seems preferable to use the mean maximum size, $\bar{L}$ max, defined as "the last size significantly present in annual catches" (Fontana, 1979). For $\bar{L}$ max, we arbitrarily chose the size beyond which the sum of the fish numbers not taken into account is equal to 1% of the total fish numbers.

If we consider a representative sample of a population, we most certainly find $\bar{L}$ max to be influenced by L max. Indeed, the greater the maximum length is, the higher the mean maximum length will be. Now, we have seen that L max can vary from one area to another (Table 14). The maximum lengths found by Loubens (1980a) in New Caledonia were very much smaller than ours. Using

Table 18 - Minimum sexual maturity sizes recorded

	Minimum sizes with a raised GSI (1)	Minimum sizes associated with stages 5, 6 and 7 (2)
Epinephelus morrhua	44	41
Etelis carbunculus	28	30
E. coruscans	38	33
E. radiosus	-	31
Lutjanus malabaricus	38	38
Pristipomoides flavipinnis	28	27
P. multidens	32	33
Tropidinius argyrogrammicus	21	19

(1) Minimum sizes for which the GSI was above the mean GSI calculated for maturation stage 5.

(2) Minimum sizes where maturation stages 5, 6 and 7 were first noted.

his data, this author worked out a coefficient k = 0.71. If we had applied this to our maximum lengths, which are much greater than his, we would have obtained sexual maturity sizes for Vanuatu fish far greater than they are in reality. We therefore preferred to use as the coefficient k the average of the values obtained for 34 tropical fish species on the West Coast of Africa (Anonymous, 1977), i.e. k = 0.576.

The sexual maturity sizes L m thus calculated for 26 species are listed in Table 19, without any sex distinction. If 45 cm is accepted as the full recruitment length, it is obvious that, for several species, the fishery captures individuals that have not yet reached sexual maturity. These species will therefore be sensitive to fishing pressure, for the fishery operates on their whole potential brood stock. The species concerned are *Aphareus rutilans, Epinephelus septemfasciatus, Etelis carbunculus, E. coruscans, Seriola rivoliana, Squalus megalops,* and, to a lesser degree, *Aprion virescens, Epinephelus morrhua* and *Lutjanus argentimaculatus*. The smaller species are not recruited into the fishery until they are well above their sexual maturity size and the fishery will therefore only affect a fraction of their brood stock.

Table 19 - Sexual maturity sizes L m worked out from mean maximum lengths $\bar{L}$ max.
(L m = 0.576 $\bar{L}$ max.)

	N(1)	L max(2)	$\bar{L}$ max	L m
Aphareus rutilans	67	88	84	48
Aprion virescens	40	82	78	44(4)
Epinephelus areolatus	45	44	39	22(5)
E. magniscuttis	110	95	71	40
E. morrhua	260	79	76	44
E. septemfasciatus	93	170	145	83
Etelis carbunculus	2068	112	94	54
E. coruscans	1845	91	82	47
E. radiosus	330	89	70	40
Gnathodentex mossambicus	46	48	45	25
Lethrinus miniatus	68	78	74	42
L. variegatus	27	60	53	30(5)
Lipocheilus carnolabrum	91	68	62	35
Lutjanus argentimaculatus	37	82	77	44
L. bohar	30	64	63	36
L. gibbus	25	52	38	21
L. malabaricus	976	76	60	35
L. rufolineatus	51	35	28	16
Paracaesio kusakarii	42	62	58	33
Pristipomoides filamentosus	503	76	60	35
P. flavipinnis	1772	65	58	33
P. multidens	3101	76	64	37
Seriola rivoliana	88	92	86	49
Squalus megalops (3)	97	84	82	47
Tropidinius argyrogrammicus	391	29	25	14
T. zonatus	38	40	35	20

(1) Number of fish in sample

(2) Maximum length recorded

(3) This is the standard length

(4) The Lm value recorded by Talbot (1960) for *Aprion virescens* in South Africa was 46 cm

(5) Lm values observed by Loubens (1980a) in the New Caledonian lagoon were : *Epinephelus areolatus* 19
Lethrinus variegatus 21

GROWTH AND MORTALITY

Stock assessment, and, consequently, stock management, necessarily requires an understanding of the growth and mortality of the fish species making up the stock. This chapter gives the results obtained for the main Lutjanidae (1) of the outer reef slope.

1 - Growth

Growth is usually expressed by von Bertalanffy's equation (1938) in which :

$$L = L_\infty (1 - e^{-k\,(t-t_o)})$$

L : length at age t

L_∞: asymptotic length

k : growth rate

t_o: age at length 0.

The biological data from which growth parameters can be estimated may be obtained by three methods : reading of periodic marks on hard structures, analysis of length frequency distributions, tagging and recapture. Because of the great depths at which the species studies live, tagging is not feasible with the techniques normally used. Furthermore, in small tropical fisheries like the Vanuatu one, the other two methods come up against two major difficulties, one associated with the uniformity of the environmental conditions, the other with problems of sampling large numbers of fish in a relatively short period of time. Nevertheless, we did succeed in determining the growth parameters of *Etelis carbunculus, E. coruscans, Pristipomoides flavipinnis* and *P. multidens* by counting the daily growth rings on their otoliths. For *P. multidens,* the most abundant species, length frequency distributions were analysed by the method developed by Pauly and David (1981), adjusted to our requirements. Lastly the results were checked by the "auximetric method" (Pauly, 1980a).

---

(1) In this chapter, we have, for convenience, considered the Lutjanidae and the Etelidae as a single family, as do many authors who then classify the latter in the subfamily Etelinae.

Age determination by otolith reading

The technique of reading the daily growth rings on otoliths first suggested by Pannella (1971, 1974) and subsequently adopted by many authors working on tropical fishes (Le Guen, 1976; Ralston, 1976; Brothers *et al,* 1976; Taubert and Cable, 1977; Pannella, 1980; Brothers, 1980; Gjøsaeter and Beck, 1980; Ralston and Miyamoto, 1981,1983; Tanaka *et al,* 1981; Mujiya and Muramatsu, 1982; Uchida *et al,* 1982; Victor, 1982; Brothers *et al,* 1983; Gobert, 1983), was used by us to estimate the age and growth of *Etelis carbunculus, E. coruscans, Pristipomoides multidens* and *P. flavipinnis.*

Described in detail by Brouard *et al,* (1983), the technique may be summarised as follows. The sagittal otoliths are removed through the inner side of the skull, under the gill cover, which does not damage fish intended for the market. After being washed in water, they are kept dry, without any special precautions, in small paper envelopes. Preparation comprises three stages : embedding in resin; cutting into thin section (100 microns) with a diamond saw; application to the sections, for about 30 seconds, of a 10% solution of hydrochloric acid to increase contrast between light and dark lines. A compound microscope is used to read the otholiths. A camera connected to a television screen facilitates reading, as long as the rings are wider than the definition of the television image.

Two quite distinct types of zones can be distinguished. The first type is characterised by regular rings believed to be laid down daily and the width of which diminishes gradually from the nucleus the edge of the otolith (Fig. 19 and 20). Superimposed on this general tendency are alternate increases and decreases of ring thickness (Fig. 21) which may relate to lunar cycles (Pannella, 1980). The second type are dark discontinuity zones (Fig. 21 and 22) on either side of which the slant of the growth rings is different. These dark zones may correspond to spawning periods, but could also result from other forms of biological stress. The delicate task of determining the various causes which may lead to the formation of such discontinuity zones will be undertaken at a later date.

Fig. 19 - Thin cross-section of an otolith of *Etelis carbunculus* observed in the central area. The nucleus (N) and, towards the left, the beginning of the sulcus can be seen. The daily growth rings (J) are clear and wide.

Fig .20 - Thin cross-section of an otolith of *Etelis carbunculus* (same section as in Fig. 19 and same magnification) observed around the thousandth ring. Rings are much narrower than in the vicinity of the nucleus.

Fig. 21 - Thin cross-section of an otolith of *Pristipomoides flavipinnis*. The discontinuity zones (D) can be clearly seen, as can an area (Z) within which the width of daily growth rings decreases and increases alternately.

Fig. 22 - Thin cross-section of an otolith of *Etelis coruscans*. Discontinuity zones (D) can be seen separating the series of daily growth rings. They may relate to spawning periods or other forms of stress.

Counting of the growth rings and plotting of the results led to the growth curves shown on Figure 23. The observations were fitted to von Bertalanffy's model by means of the function minimisation method, developed by Nelder and Mead (1965). Two problems make the plotted curves inaccurate for lengths that are close to $L\infty$. One is that it becomes very difficult to count the last rings on old fish, the other is that since the rings are laid down episodically (Ralston and Miyamoto, 1983), the number of uncounted days increases with increasing age. For large old fish, age under-estimation is therefore much more significant than for small young specimens.

Analysis of length frequency distributions

Among the available methods of estimating growth parameters from length frequency data, we chose the one developed by Pauly (Pauly and David, 1981; Pauly *et al*, 1980; Pauly, 1982) with some substantial alterations however (Appendix 4). This method, based on a computer program written in BASIC language and called ELEFAN (short for Electronic Length Frequency Analysis), makes use of a concept called ESP (Explained Sum of Peaks) which is calculated as follows. Given a set of length frequency distributions each corresponding to an instant T, this set is projected forward in time, as many times as the apparent longevity of the species requires. An attempt is then made to increase the contrast between the "peaks" and the "troughs". This is achieved by smoothing the curve corresponding to the length frequency distributions and then dividing the observed frequency values by the new "smoothed" (running average) frequencies. Thus, where the observed frequencies are lower than the running average frequencies, the resulting values are less than 1, and where the observed frequencies are higher than the running average frequencies, the resulting values are greater than 1. By substracting 1 from these values one obtains troughs that are represented by negative values and peaks by positive values.

A pair of parameters $L\infty$, k is then chosen and the corresponding von Bertalanffy curve plotted. This curve runs through a number of positive peaks and negative troughs. The algebraic sum of the peak values and the trough values is called the explained sum of peaks, ESP. Through iteration of the parameters $L\infty$, k, one obtains a whole series of curves and corresponding ESP.

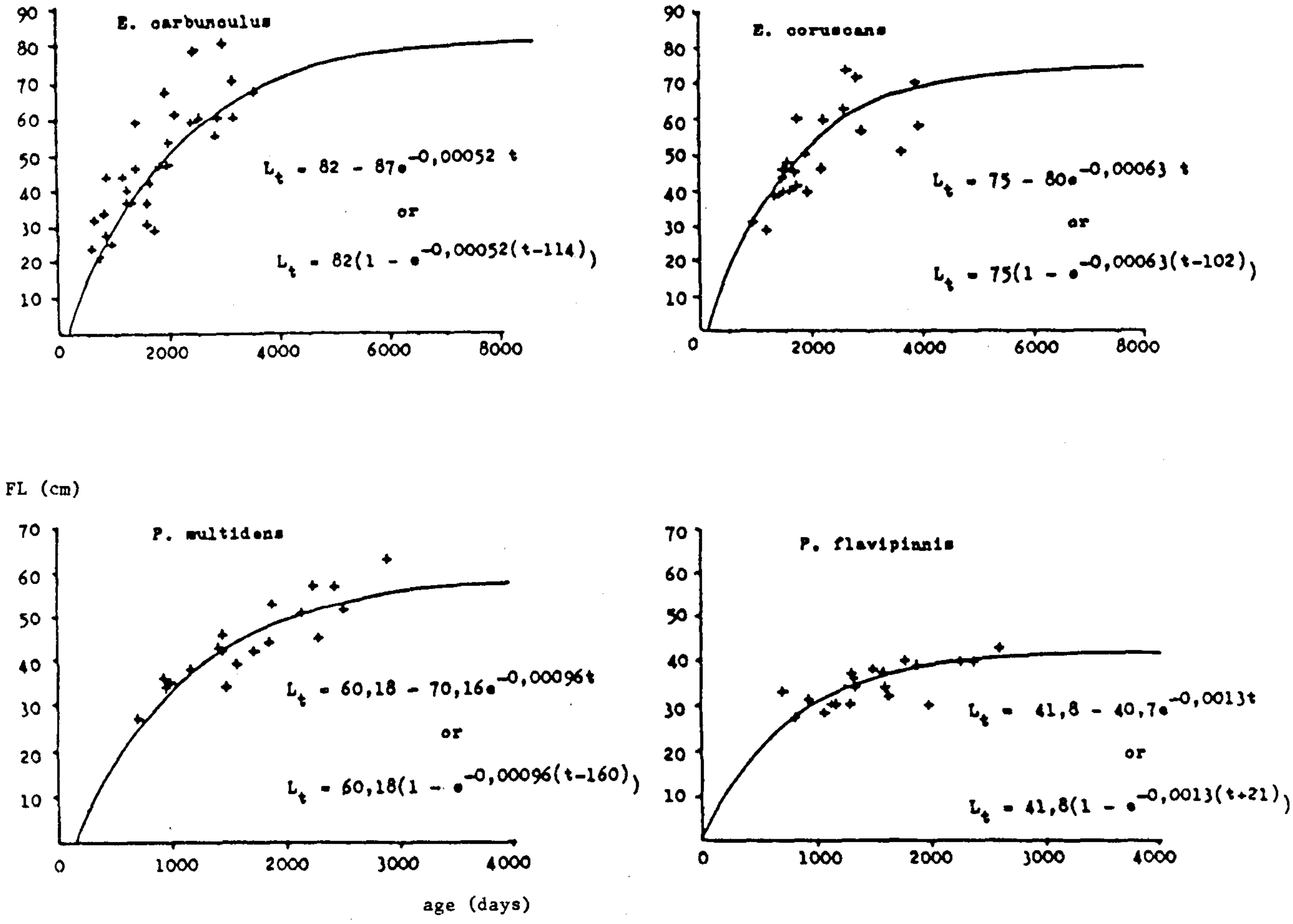


Fig. 23 - Growth curves plotted on the basis of otolith readings, with two forms of the von Bertalanffy growth equation (length is in cm and age in days).

According to Pauly and David (1981), the best L ∞, k pair will be the one for which the curve runs through the maximum number of length frequency peaks and the minimum number of troughs. (1).

This method has three shortcomings :

(a) Since it does not set any limits to the search for the optimum solution, it sometimes, after tedious calculations by successive iterations, leads to L ∞, k values that are completely unrealistic.

---

(1) These are the restructured length frequency samples (cf. Appendices 4 and 5).

(b) It only gives a single maximum ESP, i.e. only one pair of L_∞ and k values, whereas a whole series of local maximums exists, each one of which is, in theory, of as much interest as the others.

(c) The maximum ESP criterion has no biological significance. It rests on a number of implicit and arbitrary hypotheses on the validity of the modes, that may very well not correspond at all to reality. They imply, in particular, that supernumerary modes, as well as absence of modes are unlikely. They also lead to the assertion that between two L_∞, k pairs, one of which suggests that an apparent mode is in fact a combination of two modes and the other that there is only one mode, the former must systematically be chosen.

In order to correct these shortcomings, a few changes have been made to the ELEFAN I program (Appendix 4). One modification consists of calculating the ESP only between certain limits of L_∞ and k. Another is to introduce a three-dimensional space defined by the axes of the k values, the L_∞ values and the ESP values. The set of ESP values can be expressed as height marks on a surface which are graphically represented by projection on to the plane defined by the L_∞ and k axes, with the crests (maximum ESP values) appearing as dark areas and the troughs (minimum ESP values) as light areas (Fig. 24). This gives a synthetic view of all possible L_∞, k pairs, the most plausible ones being associated with the crests. Data from sources other than the length frequency samples will assist at this stage in selecting the best L_∞, k pair. The choice is necessarily subjective to some extent, but experience helps to reduce the margin of error.

Figure 24 shows the surface of the ESP values traced from four length frequency distributions for *Pristipomoides multidens* obtained in 1984. Two main crest lines are apparent. In this particular case, it would seem that the pair of parameters $L_\infty = 65$, $k = 0.28$ defined by the maximum ESP is the one that best explains growth. In Figure 25, the corresponding growth curve was traced for four successive cohorts. The same calculations were also made on several length frequency distributions of *Etelis coruscans*. The image given by the representation of the ESP values was so unclear that it was impossible to choose a pair of parameters. This failure may be ascribable to the fact that this species, which is much deeper-dwelling than *Pristipomoides multidens* is not subject to the seasonal variations that give rise to spawning peaks.

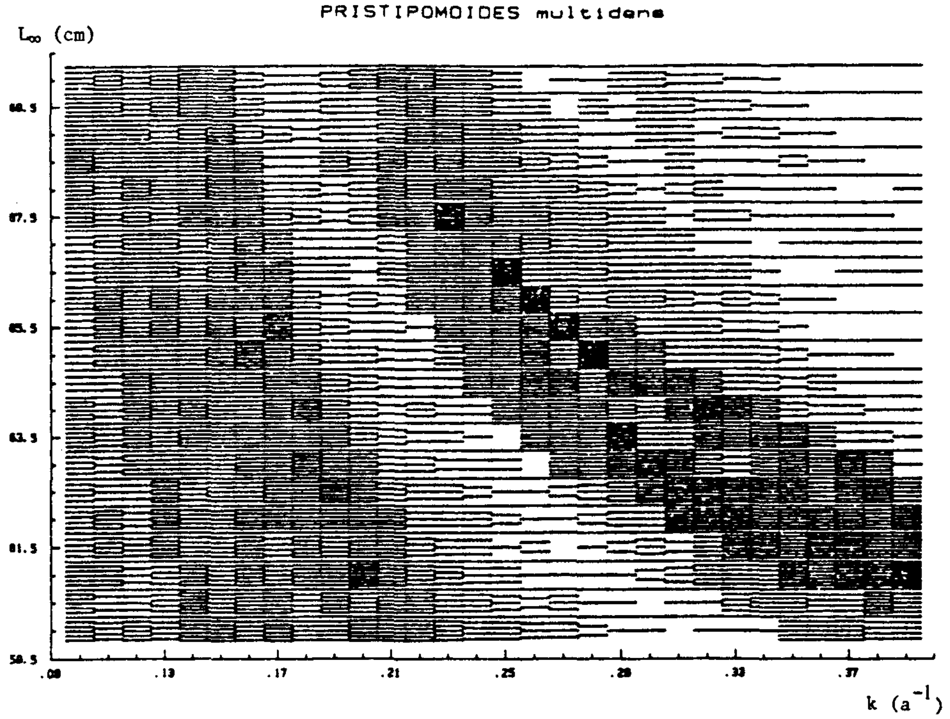


Fig. 24 - Surface of the ESP values (*Pristipomoides multidens*)

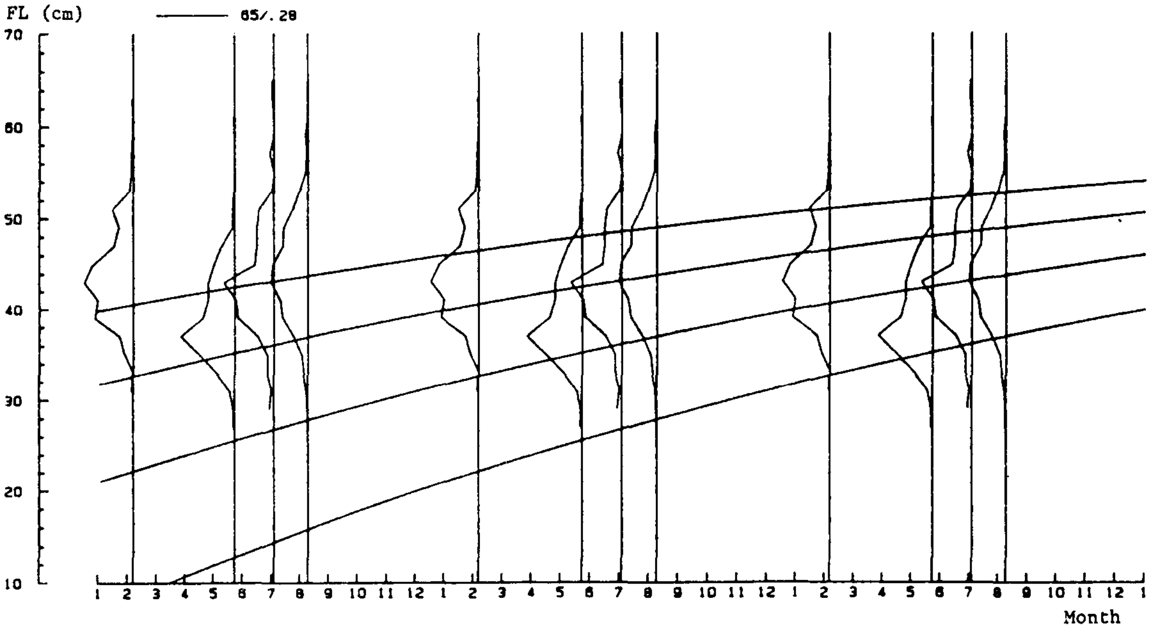


Fig. 25 - Growth curves of *Pristipomoides multidens* (N = 1029)

Determination of growth rate by auximetry (1)

Pauly (1980a) defines an index of growth performance (P) as follows :

$P = \log_{10} (k\, W_\infty)$

where k is the growth coefficient for one year and

W_∞ is the weight expressed in g.

He shows that this index is relatively constant for species that are taxonomically and ecologically similar. In Table 20, we have listed some W_∞ and k values found in the literature for the Lutjanidae. P can be seen to be roughly equal to 3, which allows the above equation to be converted into $k = 10^3/W_\infty$. On the basis of this P value, we calculated the growth coefficient k for the main Lutjanidae found in Vanuatu. In order to do so, we assumed that L_∞ is equal to $\bar{L}$ max as defined in the chapter on reproduction. We then converted L_∞ into W_∞ using the previously established length-weight relationships. Table 21 summarises the results obtained. The growth coefficients obtained by this method have the advantage of being applicable to large-sized specimens, whereas the growth values resulting from otolith readings are believed to be reliable only for young fish. The former were therefore used to determine natural mortality and total mortality.

Whatever method is used, the growth rates of the main Lutjanidae occurring on the outer reef slope in Vanuatu seem to be low. They appear lower for the deep species like *Etelis carbunculus* and *E. coruscans* than for the shallower ones like *Pristipomoides flavipinnis* and *P. multidens*. As the productivity of a fish stock depends on the growth rate of the individuals composing it (as well as on their fecundity), that of the deep Lutjanidae is likely to be rather low, unless their slow growth is offset by

---

(1) Pauly (1980a) uses what he calls an "auximetric grid" (from the Greek "auxein" meaning "growth" and "metron" meaning "measure"). The title of this section if therefore a pleonasm, since it says the same thing twice. However we chose it because it is short and simple, in preference to the more accurate but longer title "Determination of growth rate by Pauly's method (1980a) using an auximetric grid".

Table 20 - Von Bertalanffy parameters and the growth performance index P calculated for some species of Lutjanidae.

Species	k(1/a)	L∞(cm)	W∞(g)	$P=\log_{10}(k.W_\infty)$	References
Aprion virescens	0,31	65,6	4680	3,16	LOUBENS, 1980 b
Etelis carbunculus	0,36	63,9	4500	3,21	UCHIDA *et al*,1982
"	0,19*	82	9500	3,26	BROUARD *et al*,1983
Etelis coruscans	0,23*	75	6100	3,15	BROUARD *et al*,1983
Lutjanus bohar	0,11	52	4200	2,66	LOUBENS, 1980 b
L. campechanus	0,17	94,1	12300	3,32	NELSON & MANOOCH,1982
L. malabaricus (1)	0,064	-	13600	2,94	DRUZHININ, 1970
Ocyurus chrysurus	0,25	60	3600	2,95	THOMPSON & MUNRO,1983
Pristipomoides filamentosus	0,15	78	6500	2,99	RALSTON & MIYAMOTO,1983
"	0,31	97,1	13900	3,63	UCHIDA *et al*, 1982
P. flavipinnis	0,42*	42	1100	2,66	BROUARD *et al*, 1983
P. multidens	0,35*	61	3600	3,10	BROUARD *et al*, 1983
"	0,28*	65		3,08	This study

(1) The high W∞ value suggests that *Lutjanus malabaricus* may have been confused with *Lutjanus sebae* (Grant, 1978).

* Vanuatu

a high reproduction rate. In the present state of the fishery, *Etelis carbunculus* and *E. coruscans* over 60 cm in length represent respectively 44% and 48% of the catch by numbers, and 79% and 69% of the catch by weight. As the development of deep bottom fishing is currently being strongly encouraged in some parts of Vanuatu, these large specimens are likely to disappear quite rapidly. In the medium term, catch rates for the lower part of the outer reef slope are bound to decline.

Table 21 - Von Bertalanffy parameters, total mortality index (Z) and natural mortality index (M) for six major species of the outer reef slope in Vanuatu.

			Mean growth (cm/year)							
	$k(a^{-1})$	L_∞(cm)	$30<L<40$	$40<L<50$	$\bar{L}$(cm)	Lc(cm)	T(°C)	$Z_1(a^{-1})$	$Z_2(a^{-1})$	$M(a^{-1})$
E. carbunculus	0,07	94	4,2	3,42	57	28	15	0,07	0,089	0,149
E. coruscans	0,128	82	5,99	4,71	55	30	16	0,107	0,136	0,237
L. malabaricus	0,310	60	7,65	4,47	44	32	23	0,447	0,401	0,545
P. flavipinnis	0,356	58	8,06	4,39	35	27	23	0,648	1,006	0,602
P. filamentosus	0,295	60	7,28	4,26	41	31	23	0,467	0,587	0,527
P. multidens	0,244	64	7,01	4,53	44	34	22	0,375	0,460	0,448

$k = 1000/W$

$W = a\bar{L}m^b$ (a, b are obtained by means of the length/weight relationship; $\bar{L}m$ = mean maximum length as defined in the chapter on reproduction).

$Lc = (L_{100} + L_o)/2$ (cf. "Mortality" section)

T(°C) : mean temperature of the water where maximum concentrations of the species are found, in degrees Celsius.

Z_1 : total mortality calculated by regression of the Log of the number of individuals as a function of time (Fig. 26).

Z_2 : $k\,(L_\infty - \bar{L})/(\bar{L} - Lc)$

M : natural mortality expressed by the equation
$\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log k + 0.4634 \log T$.

Pauly (1980c) distinguishes between overfishing that affects a stock's biomass increase through growth of its individuals, and overfishing that affects recruitment, i.e. the brood stock. We calculated that in the case of *Etelis carbunculus* and *E. coruscans,* individuals would have to the allowed to reach a length of 60 cm, i.e. the age of 10 years, for catches not to drop below 70% of what they are at present. A regulation prohibiting the taking of individuals below this size would be hard to enforce and overfishing of the first type, i.e. affecting the biomass increase of the stock through growth thus seems inevitable. Furthermore, we saw that, for some species, the size at maturity was often greater than the full recruitment size (gear selectivity); there is therefore, in theory, a risk of the brood stock dying out altogether. The intermediate parts of the outer reef are more productive than the very deep strata, in particular because they get more light. Since the growth rate of the shallower species, such as *Pristipomoides flavipinnis* and *P. multidens,* is, furthermore, higher than that of the deeper species, overfishing affecting biomass increase of the stock is likely to cause a less rapid decline than for the deep species. As regards overfishing affecting recruitment through reduction of the parent stock, it seems unlikely in the shallower species since these are already mature and reproducing by the time they reach the full recruitment size. *Pristipomoides* resources would therefore be less sensitive to fishing pressure than *Etelis* resources. However, the very fact that they are in shallower water makes them easier to exploit, so that they too will need careful management to prevent depletion.

2 - Mortality

Total mortality Z is equal to the sum of natural mortality M and mortality through fishing. Where there is no fishing activity at all, Z = M.

Total mortality

It was estimated by two methods. The first uses the equation :

$$N = N_o \, e^{-z_1 \, (t - t_o)}$$ where

N = number of individuals at time t

N_o = number of individuals at time t_o

Z_1 = total mortality coefficient

The regression of Log N in relation to t allows determination of Z_1 which is the slope of the line. The regression lines for the main deep Lutjanidae are shown on Figure 26. The second method applies the relationship developed by Beverton and Holt (1956) :

$$Z_2 = k(L_\infty - \bar{L}) \;/\; (\bar{L} - L_c) \text{ where}$$

k = growth parameter
L_∞ = asymptotic length
$\bar{L}$ = mean length
L_c = mean length at first capture,

on the basis of the equation $L_c = (L_{100} + L_0) / 2$ where L_{100}, determined from the annual length frequency distributions, is the size after which the frequencies no longer increase in a regular manner, and L_0 is the first size class observed. The results appear in Table 21.

Natural mortality

To estimate natural mortality we used the following empirical formula developed by Pauly (1980b) :

$$\log M = -\ 0.0066 - 0.279 \log L_\infty + 0.6543 \log k + 0.4634 \log T$$

L_∞ = asymptotic length (cm)
k = growth rate (year^{-1})
T = mean temperature of the environment (°C)

The results are listed in Table 21. It can be seen that, apart from the values obtained for *Pristipomoides flavipinnis,* the two procedures for estimating Z give roughly the same results. Secondly it will be noticed that the natural mortality values are of the same order of magnitude than the total mortality values, which means that mortality through fishing is close to zero. This finding was predictable. Since commercial exploitation of deep bottom fishes started only recently in Vanuatu, the stocks are still practically virgin and the effect of fishing not yet perceptible. For the *Etelis* species, M is markedly higher than Z. This apparently absurd result does have an explanation : Z was estimated for individuals over 60 cm, in length, and is therefore strictly speaking only valid above this size. The fish concerned have few predators and are subject to very little stress since they live at great depths. On the

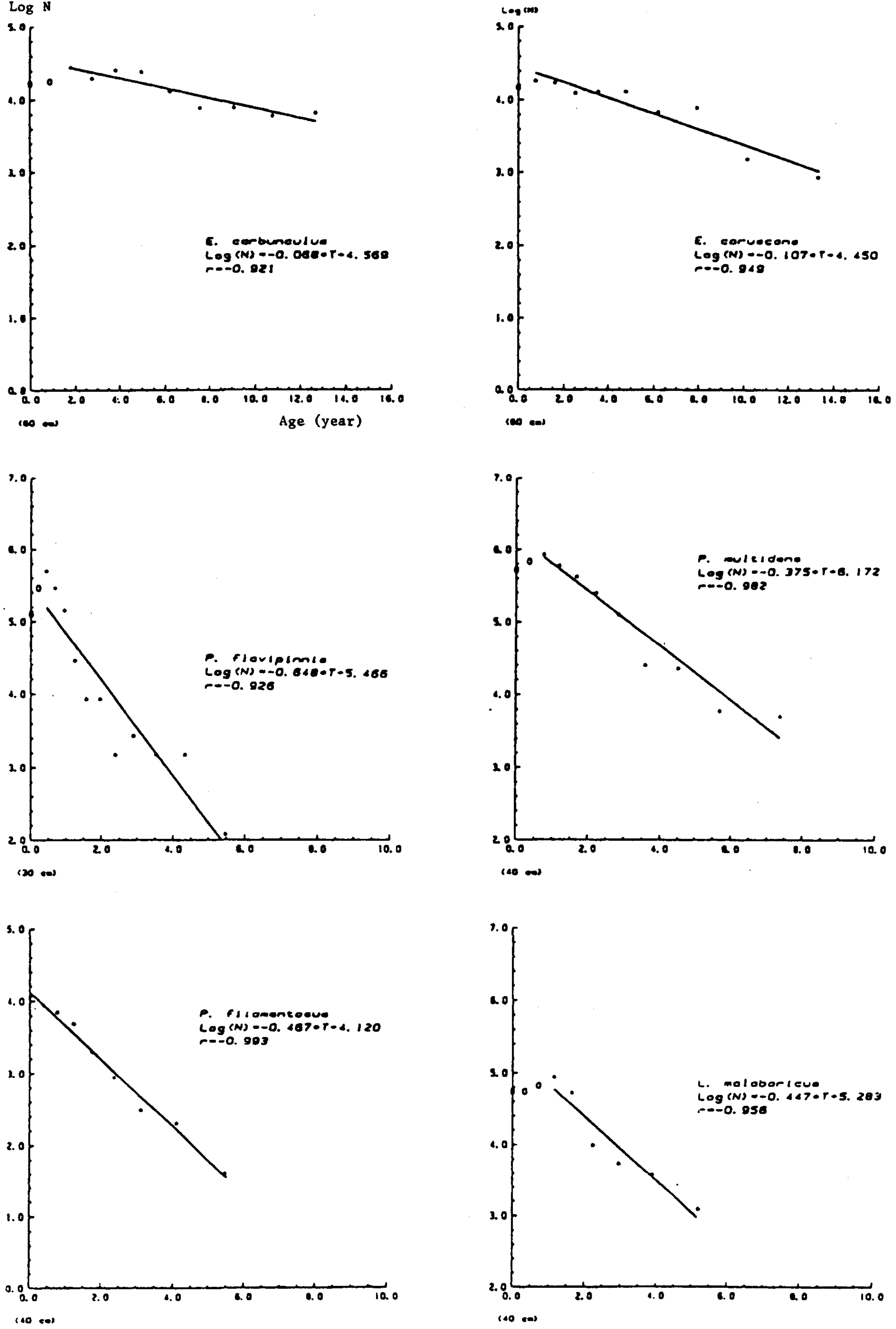


Fig. 26 - Total mortality Z_1 estimated for a few species (Z_1 is the value of the slope of the line).

other hand, fish under 60 cm in length live in shallower waters (Fig. 16a), i.e. in a more aggressive environment where their predators are fairly numerous. Their mortality would naturally be higher than that of the large specimens. In other words, the differences observed between Z and M in the *Etelis* species are probably not due to an erroneous estimation of parameters. They more likely reflect a change of habitat in the course of the life cycle.

The mortality values calculated for the deep demersal fish stocks of Vanuatu are of considerable interest. They confirm the validity of Pauly's formula for estimating natural mortality, and give an exact indication of the state of the stocks at the very beginning of their exploitation. Population dynamics studies are often hampered by difficulties encountered in the estimation of baseline parameters. The work done in Vanuatu on virgin stocks will facilitate management and make it possible to use theoretical models to monitor any changes.

PRODUCTION

Not enough catch and effort data were gathered in Vanuatu for any form of modelling to be undertaken as yet. Even the approximation proposed by Gulland (1971) for virgin or under-fished stocks (M.S.Y. = 0.5 M x Bm, where M is the natural mortality and Bm the virgin biomass), or the more complicated formula developed by Caddy and Csirke (1983), cannot be applied to the Vanuatu fishery. This is because estimation of Bm, usually accomplished by trawling, acoustic techniques or tagging, is at present impossible on the outer reef slope. On the other hand, the method described by Eggers *et al,* (1982), based on estimation of the capture field of traps or hooks, could be used there, provided a very large number of longline sets is made. However, as has been suggested (Welcomme and Gulland, 1980; Anonymous, 1980b) potential production can be roughly assessed by comparison with areas that have similar environmental characteristics and for which precise production figures are known. The Hawaiian Islands have been used as the reference. We shall, firstly, discuss the similarities between the two regions and then attempt an estimation of the productivity of the deep bottom fishery in Vanuatu on the basis of the results given for Hawaii by Ralston and Polovina (1982).

1 - Similarities between Hawaii and Vanuatu

Most of the islands in the Vanuatu Group lie between 15°S and 18°S, while the Hawaiian Islands extend from 19°N to 22°N. The latter are thus slightly further from the equator, but both groups belong to the tropical zone since, in the Pacific, the thermal equator coincides with the geographic equator. The two archipelagoes are structurally very similar, having no lagoon and a very steep outer reef slope. Their deep demersal fauna is also very similar. In Hawaii, at depths between 80 and 240 m, the main species caught by the commercial fishery are *Pristipomoides filamentosus, Epinephelus quernus, Seriola dumerili* and *Tropidinius zonatus*. Between 200 and 350 m the dominant species are *Aphareus rutilans, Pontinus macrocephalus, Etelis coruscans, E. carbunculus* and *Pristipomoides sieboldi*. With the exception of *Pontinus macrocephalus* of the Scorpaenidae family, all these species, or closely related ones, are found in Vanuatu. *Pristipomoides filamentosus,* which is the most important single species in catches in Hawaii, seems to be less abundant in Vanuatu where it is replaced by *P. multidens* and *P. flavipinnis*. Our data, as well as those published by Uchida *et al,* (1979,1982) show the C.P.U.E. to be of the same order of magnitude in both areas. There do not therefore seem to be any marked differences in abundance.

The physico-chemical characteristics and primary production values for these two regions are shown in Table 22. In Hawaii, measurements were taken 12 miles off the west coast of the island of Hawaii (Bienfang and Szyper, 1981). In Vanuatu, as we saw in the first chapter (Background) one series of measurements (A) was carried out 100 miles west of Efate, another (B) along longitude 170°E. In all three cases, measurements were taken far enough offshore for the "island wake effect" not to be strongly felt. If it does exist, it is probably similar in both island groups. The physico-chemical parameters are similar in both regions. The primary production estimates seem contradictory for Vanuatu. On the basis of these data alone, it is not possible to assert that one region is richer than the other. However, research by Dandonneau (1982) suggests that primary production may be greater in Vanuatu than in Hawaii. If the trophic chains leading to the deep demersal fish species are the same in both island groups, one would expect the potential primary production to be similar, possibly slightly greater in Vanuatu than in Hawaii.

Table 22 - Hawaii - Vanuatu comparison : physico-chemical parameters at 200 m and primary production.

	Hawaii	Vanuatu (A)	Vanuatu (B)
Temperature (°C)	17	18	20
Salinity (°/oo)	34,5	35,5	35,4
Dissolved oxygen (ml/l)	4	3,9	4
Chlorophyll (mg/m^2)	24,5 (1)	72 (2)	23 (2)
Primary production (mgC/m^2/h)	8,79 (3)	37,6 (4)	3,3 (5)

(1) Integrated over 0-260 m

(2) Integrated over 0-200 m

(3) Integrated over 0-120 m

(4) Integrated over 0-170 m

(5) Integrated over 0-100 m

2 - Assessment of potential fishery production in Vanuatu

In Hawaii, maximum fishing effort is applied in the vicinity of isobath 100 fathoms (185 m). In their calculation of the maximum sustainable yield (M.S.Y.), Ralston and Polovina (1982) therefore related catches to the length of this isobath. They estimated the M.S.Y. of two areas. One comprises the islands of Maui, Lanai, Kohoolawe and Molodai (MLKM) which account for 56% of the total catch for the archipelago. The length of isobath 100 fathoms is 390 miles in this area. The M.S.Y. was found to be 106 tonnes per year, i.e. 272 kg per mile of isobath 100 fathoms and per year. The other area is around Oahu. It accounts for 12% of the total catch for Hawaii. The length of isobath 100 fathoms is 150 miles here. The annual M.S.Y. is 15.7 tonnes or 105 kg per mile of isobath 100 fathoms and per year. We have assumed - and feel justified in doing so on the basis of the charts - that the topography of the sea bottoms in Vanuatu is roughly the same as in Hawaii and that the length of isobath 100 meters does not differ significantly from that of isobath 100 fathoms. By applying the figures obtained in Hawaii to the Vanuatu archipelago as a whole, where the total length of isobath 100 m is 1,400 miles (2,600 km), we calculated, as a tentative estimate, that the maximum sustainable yield (M.S.Y.) would be between 147.0 and 380.8 tonnes/year. Around Efate, where the length of isobath 100 m is 130 miles (240 km), the M.S.Y. would be between 13.7 and 34.4 tonnes/year.

These values may seem low. If they were applied strictly by planners, they might hamper the development of the fishery. On the other hand, if they were disregarded those who initiated overly ambitious development could commit errors that would have grave consequences for investors. We shall therefore try to refine these figures as much as we can. The maximum sustainable yields calculated in Hawaii are under-estimated because commercial catches are not comprehensively recorded and because recreational fishing, which is very popular in Hawaii, is not taken into account at all. Under the circumstances, we felt that the M.S.Y. could in fact be multiplied by a factor close to two, in which case it would be between 300 and 700 tonnes/year for Vanuatu as a whole. As the area between 100 and 400 m was determined planimetrically to be 7,360 km^2, the M.S.Y. would therefore be around 1 kg/ha/year. Taking a mean C.P.U.E. of 3 kg/reel-hour which was the value obtained from our fishing records, and on the basis of boats of the same type as those used by the Fisheries Department operating at a similar rate (150 deep fishing trips per year; four or five fishing hours per trip using three reels) we worked out how many boats would represent a sustainable exploitation for each island (Table 23). About 120 boats could operate in the whole of Vanuatu where the overall M.S.Y. would be in the vicinity of 740 tonnes/year, and 16 could operate in Efate for a M.S.Y. of around 100 tonnes/year.

In New Caledonia, Barro (1980) collected interesting data from trawling carried out on unfished seamounts south-east and south-west of the mainland. Out of the 43 hauls made, we discarded all the deep hauls (500-600 m) and took into account only the 18 shallower ones (220-320 m). Catches of *Etelis carbunculus* and *E. coruscans* totalled 25,695 kg (Appendix 6). Considering the shape and size of the gear used, we estimated its effective capture width at 50 m, which gave us 811 ha for the total surface area trawled. As *Etelis coruscans* made up 90% of the *Etelis* catches, we used the natural mortality coefficient M = 0.237 (Table 21). With these parameters, application of the estimation formula M.S.Y. = 0.5 M x Bm gives a maximum sustainable yield of 3.7 kg/ha/year for the *Etelis* species. We did not calculate what percentage of the total catch in Vanuatu between 220 and 320 m was made up of *Etelis* species, but 80-90% by weight is a reasonable estimate. Thus the M.S.Y. based on Barro's data (1980) and applied to Vanuatu would be nearly 4 kg/ha/year between 220 and 320 m, i.e. four times greater than what we calculated from the résults obtained in Hawaii. In other words it would total 3,000 tonnes/year

Table 23 - M.S.Y. per island area, and number of Alia-type boats that would give the M.S.Y.

Area	Length of isobath 100 m (miles)	Surface area between isobaths 100 and 400m (ha)	M.S.Y. (tonnes p.a)	Number of boats *
Torres	64	20 596	21	3
Banks	136	45 826	46	8
Santo + Malo	235	142 970	143	24
Malekula	165	101 344	101	17
Maewo	70	33 468	33	5
Ambae	52	11 843	12	2
Pentecôte	75	25 000	25	4
Ambrym	68	26 650	27	4
Paama-Lopevi-Epi	101	76 512	77	13
Sheperd	86	45 354	45	7
Efate	126	95 330	95	16
Erromango	75	53 658	54	9
Tanna	65	42 438	42	7
Anatyum	40	14 816	15	2
Total Vanuatu	1 358	735 805	736	121

* Alia-type catamaran; 3 reels; 4 to 5 hours deep-bottom fishing per trip; 150 deep fishing trips per year; mean C.P.U.E. 3 kg/reel-hour.

and allow nearly 500 boats to operate. We decided, however, that it would be unwise to include these figures in Table 23, for the productivity of the New Caledonian seamounts may be quite different from that of the Vanuatu outer reef slope.

Although these values are only rough estimates, they should nevertheless assist development planners in choosing their objectives. The bottom fish resources of the outer reef slope are, as it turns out, rather limited, which means that the fishery must be managed with great care. The simple statistics collection and fish measuring programme started in the Vanuatu islands will assist in this, since it will enable changes in the C.P.U.E. and the mean fish sizes, hence in the state of the stocks, to be closely monitored over the coming years.

CONCLUSIONS

The aim of all fisheries research is to provide the information needed for sound management that allows fishermen to make a good living while preserving the resource that forms their livelihood. Although the artisanal deep bottom fishery in Vanuatu has been properly structured for only a short time, recent research has clarified several aspects of the biology of the main deep demersal species and led to the estimation of parameters that will prove essential for future modelling (Table 24).The environment of deep species is so stable on the whole, both in time and in space, that no sharply contrasted phenomena occur there in a given region. However, vertical temperature structures may vary slightly between regions, giving rise to differences in the vertical distribution of species. In addition, scientists are beginning to suspect that internal waves and thermal fronts play an important part, possibly enhanced by the wake effect.

Analysis of the overall catch results, all species and all trips included, shows an extreme variability in the C.P.U.E. This is because the fishing conditions were very variable, such factors as place, depth, bottom type, weather, time of day or night, fluctuating widely from one trip to another. Catch results must therefore be broken down into the component species and consideration must also be given to depth and time of capture. This approach enables species to be classified into shallow, intermediate and deep groups, catchable by day in some cases, by night in others, or indifferently by day and by night. A nocturnal upward migration of some 40 to 80 m appears to be fairly general. Analysis of seasonal variations requires even more care, since the latter cannot be demonstrated unless the location and depth remain constant. The matrix of clusters of species, established from species frequency in catches without taking into account the different environmental conditions of each fishing trip, since the cluster criterion is purely mathematical, fits fairly well with the above-mentionel classifications. It defines several different "catch types" each of which is characterised by a target species with which others are associated and which a fisherman will catch together in the same place, at the same depth and at the same time of the day-night cycle. These links between species are valid only from fisheries point of view. They have no ecological value, since no two species will be associated unless they have actually been caught together and species with different feeding behaviours will not be linked, even if they have the same ecological requirements and in fact live close together in the environment.

The length frequency study shows that maximum lengths may vary considerably between Pacific regions. In some cases, these variations result from real differences in fishery development and fishing effort. In others, they reflect the fact that the catches were not made at the same depths; thus in many species the large specimens tend to desert the shallow waters which are, on the other hand, preferred by the smaller ones. This stratification according to depth could explain why the maximum sizes of fish caught in the lagoons do not seem to reach those of fish caught outside the reef.

The specific diversity index decreases markedly as depth increases. In the deepest strata, environmental conditions, though stable, are rather harsh and only a small number of species is well equipped to thrive there. The recovery capacity (homeostasis) of deep water stocks is probably reduced, so that the effect of heavy fishing pressure is likely to be rapid and strong and the results of overfishing hard to reverse. This hypothesis is confirmed by our reproduction, growth and mortality studies.

The reproduction study shows a general tendency toward more intense sexual activity in the spring, although spawning is spread over the whole year for many species. This spread seems to involve mainly the deeper species, i.e. species that live in an environment where seasonal fluctuations are slight. The size at maturity of the "small species" such as *Pristipomoides filamentosus, P. multidens* and especially *P. flavipinnis* is well under the full recruitment size which is linked to hook selectivity. The adults of these species thus have ample time to breed before entering the fishery. The situation is different for the "large species" such as *Etelus carbunculus* and *E. coruscans,* for which the size at sexual maturity is larger than the recruitment size. They would be more sensitive to strong fishing pressure, since the fishery affects the whole of their brood stock.

The growth rates of the main commercial species are fairly low. They seem comparatively higher however for the shallow and intermediate species (*Pristipomoides* spp.) than for the deep species (*Etelis* spp.).

Table 24 - Summary of characteristics of some species.

	Etelis carbunculus	Etelis coruscans	Etelis radiosus	Pristipomoides filamentosus	Pristipomoides flavipinnis	Pristipomoides multidens	Lutjanus malabaricus	Lutjanus argentimaculatus	Lutjanus rufolineatus	Aphareus rutilans	Aprion virescens	Lipocheilus carnolabrum	Paracaesio kusakarii	Tropidinius argyrogrammicus
Depth range (m)	120 460*	120 460*	120 340	60 320	60 340	60 340	60 200	(40) 260	100 280	80 320	(40) 220	80 360	100 280	120 380
Maximum concentration (m)	280 360	240 320	200 320	100 180	80 200	80 200	100 200	80 100	80 200	120 200	40 80	160 360	120 240	200 320
Temp. range of max. concentration	(°c) 18 14	19 16	21 16	25 22	26 21	26 21	25 21	26 25	26 21	24 21	27 26	22 14	24 19	21 16
Bottom types prefered	rocks steep slopes	rocks foot of cliffs	rocks steep slopes	rocks steep slopes	"coral" on gentle slopes	"coral" on gentle slopes	rocks, steep to very steep slopes	steep slopes near estuaries	"coral" on gentle slopes	rocks, steep to very steep slopes	"coral" on sandy bottom	rocks, steep slopes, foot of sliffs	sand, "coral" gentle slope	any bottom except mud
Day and/or night	$\underline{J}$ + N	$\underline{J}$ + N	J	J	J + N	J + N	N	N	N	J + N	J + N	J	J	J + $\underline{N}$
L modal (cm)	64	64	67	41	35	45	47	63	24	72	59	40	45	24
L max. (cm)	112	91	89	76	65	76	76	82	35	88	82	68	62	29
$\bar{L}$ max. (cm)	94	81	70	57	50	61	55	77	28	84	78	62	58	25
L at sex. mat. (cm)	54	47	40	35	33	37	35	44	16	48	44	35	33	14
$P_{(g)} = aL^b$ a	0,02161	0,04105			0,02991	0,02003	0,00853	0,00540		0,00336	0,00345	0,14897	0,01059	0,00976
b	2,950	2,758			2,825	2,944	3,137	3,206		3,311	3,330	2,488	3,135	3,221
P max. (kg)	24,0	10,4			4,0	6,9	6,8	7,4		9,2	8,1	5,4	4,4	0,5
k (a^{-1})	0,07	0,128		0,295	0,356	0,244	0,310							
L∞ (cm)	94	82		58	60	64	60							
Z1 (a^{-1})	0,07	0,107		0,467	0,648	0,375	0,447							
M (a^{-1})	0,159	0,237		0,602	0,527	0,448	0,545							
L at 1 year	6	10		15	18	14	16							
L at 2 years	12	19		26	31	25	28							
L at 5 years	28	39		45	50	45	47							
L at 10 years	47	59		55	58	58	57							
L at 20 years	71	76		58	60	64	60							

Table 24 (next) - Summary of characteristics of some species

	Tropidinius zonatus	Epinephelus magniscuttis	Epinephelus morrhua	Epinephelus septemfasciatus	Gnathodentex mossambicus	Gymnocranius lethrinoides	Lethrinus miniatus	Ostichthys japonicus	Ruvettus pretiosus	Thyrsitoides marleyi	Seriola rivoliana	Hexanchus vitulus	Squalus megalops
Depth range (m)	80 360	120 340	100 360	140 380	120 240	20 180	20 280	200 320	200 300	140 320	80 360	160 440	120 460*
Maximum concentration (m)	220 260	200 320	200 360	200 280	160 240	80 100	80 120	240 320	200 280	200 280	80 160	240 320	320 400
Temp. range of max. concentration (°c)	20 18	21 16	21 14	21 18	22 19	26 25	26 24	19 16	21 18	21 18	26 22	19 16	16 13
Bottom types prefered	any bottom except mud	rocks, steep to very steep slopes	rocks, steep to very steep slopes	rocks, steep to very steep slopes	"coral" on gentle slopes	sand "coral" flat bottom	"coral" on gentle slopes	rocks steep slopes	rocks steep slopes	rocks steep slopes	rocks steep slopes	sand "coral" flat bottom	mud, sand, boulders, gentle slopes
Day and /or night	J	J + N	J + N	J + N	J + N	N	J + N	N	N	N	J + N	N	N
L modal (cm)	31	67	53	118	33		42				58		51
L max. (cm)	40	95	79	170	48	48	78	37	150	160	92	129	84
$\bar{L}$ max. (cm)	35	71	74	145	45		74				86		82
L at sex. mat. (cm)	20	40	44	83	25		42				49		47
$P_{(g)} = aL^b$ a	2,50119	0,03916	0,06058	0,00332	0,04012		0,03293			0,00015	0,00636	0,00124	0,001264
$P_{(g)} = aL^b$ b	1,612	2,754	2,624	3,348	2,824		2,728			3,609	3,170	3,474	2,879
P. max. (kg)	1,0	11,0	5,8	97,4	2,3		4,8			13,5	10,7	26,6	4,4

There is every reason to believe therefore that the depth stratification of species of the outer reef slopes corresponds to a stratification in their vulnerability to intensive fishing. The calculated mortality coefficients show that stocks in Vanuatu are virgin stocks. Because of this privileged situation, very large-sized, therefore very old, *Etelis* are frequently captured. If fishing pressure were to be increased very significantly, it is likely that these large specimens would rapidly disappear, as seems to have been the case in other Pacific countries where the commercial deep bottom fishery has been operating for half a century. The fact that the very deep resources are rather difficult to reach affords them some protection which the more accessible, shallow and intermediate resources do not have, and it is therefore obvious that the whole of the outer reef slope will require sound fishery management in the near future. The parameters estimated for Vanuatu and shown in this document are not definitive. Accurate estimation of the M.S.Y. necessarily implies analysis of statistical series showing fluctuations over a long period of time. As no such series are available in Vanuatu, the results of regions where they do exist were used to suggest tentative M.S.Y. values that will need to be adjusted in due course. In the mean time they will assist local planners in making appropriate decisions, and they should also be useful for all Pacific countries where geomorphological and hydroclimatic conditions are comparable to those in Vanuatu and where the deep bottom fishery is now being developed.

ACKNOWLEDGEMENTS

The authors wish to thank the Fisheries Department, and in particular its successive Directors Mr. Crossland and Mr. Kaltonga for their close cooperation and helpfulness, as well as all the fishermen without whom this study would not have been possible. Our deep gratitude also goes to Mr. Campillo, the ORSTOM Representative in Vanuatu, whose trust and understanding encouraged us at all times. We are also much endebted to the ORSTOM staff and notably Mr. Koulon, our local assistant, whose patience and efficiency were praiseworthy indeed.

REFERENCES

The documents marked with an asterisk* are also available in French

ANONYME - 1977 - Inventaire critique des données utilisées pour l'étude de la reproduction. *In Rapport du groupe de travail sur la reproduction des espèces exploitées du Golfe de Guinée.* Dakar, nov. 1977, ORSTOM-ISRA : 8-20.

ANONYME - 1978 - Deepwater snapper survey, *In Fiji Fisheries Division, 1978 Annual Report*, Suva, Fiji : 74-92.

ANONYME - 1980a -*Annual report 1980*, Fisheries Division, Ministry of Agriculture and Fisheries, Fiji, 99 p.

ANONYME - 1980b - Quelques problèmes scientifiques sur les pêcheries multispécifiques. Rapport de la conférence d'experts sur l'aménagement des pêcheries multispécifiques. Rome, 20-23 septembre 1977. *FAO Doc. Tech. Pêches*, 181, 46 p.

ANONYME - 1984 - *Interim report on frozen storage trials of Pristipomoides species from Vanuatu.* Tropical Development and Research Institute, 16 p.

BARRO, M. - 1980 - *Rapport de mission à bord du chalutier japonais "KAIMON MARU" (du 26 novembre au 10 décembre 1980).* Centre ORSTOM de Nouméa, Nouvelle-Calédonie, 21 p.

BARRO, M. - 1982 - *Données préliminaires sur la biologie d'Etelis carbunculus et d'Etelis coruscans en Nouvelle-Calédonie.* Centre ORSTOM de Nouméa, Nouvelle-Calédonie, 2 p.

BERTALANFFY, L. (Von) - 1938 - A quantitative theory of organic growth. *Hum. Biol.*, 10 : 181-213.

BEVERTON, R.J.H. et S.J. HOLT - 1956 - A review of methods of estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. *Rapp. P. - v. Reun. Cons. Perm. Int. Explor. Mer*, 140(1) : 67-83.

BEVERTON, R.J.H. et S.J. HOLT - 1959 - A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. *In* G.E.W. WOLSTENHOLME et M. O'CONNOR (ed.). *Ciba Foundation colloquia on ageing*, Churchill, London, 5 : 142-180

BIENFANG, P.K. et J.P. SZYPER - 1981 - Phytoplankton dynamics in the subtropical Pacific off Hawaii. *Deep Sea Research*, 28(9) : 981-1000.

BROTHERS, E.B. -1980 - Age and growth studies on tropical fishes. *In* S.B. SAILA and P.M. ROEDEL (Ed.). *Stock assessment for tropical small-scale fisheries.* Proceedings of an international workshop held September 19-21, 1979 at the University of Rhode Island, Kingston, R.I. International Center for Marine Resource Development, Univ. of Rhode Island, Kingston : 119-136.

BROTHERS, E.B., C.P. MATHEW et R. LASKER - 1976 - Daily growth increments in otoliths from larval and adult fishes. *Fish. Bull. (U.S.)*, 74(1) : 1-8.

BROTHERS,E.B., D.M.B. WILLIAMS et P.F. SALE - 1983 - Length of larval life in twelve families of fishes at "One Tree Lagoon", Great Barrier Reef, Australia. *Mar.Biol.* 76 : 319-324.

BROUARD, F., R. GRANDPERRIN, M. KULBICKI et J. RIVATON - 1983 - Notes sur les lectures de stries journalières observées sur les otolithes de poissons démersaux profonds à Vanuatu. *Mission ORSTOM de Port-Vila, Notes et documents d'Océanographie* 8, 9 p. (also available as "Note on observations of daily rings on otoliths of deepwater snappers, *ICLARM Translations* 3, 8 p., 1984).

CADDY, F. et J. CSIRKE - 1983 - Approximations to sustainable yield for exploited and unexploited stocks. *Océanogr. trop.* 18(1) : 3-5.

CHAPMAN, L. et G. PRESTON - (en préparation) - *Deep Sea Fisheries Development Project. Report of 3rd visit to Vanuatu.* South Pacific Commission, Noumea, New Caledonia.

CONNAND, C. - 1977 - Contribution à l'étude du cycle sexuel et de la fécondité de la sardinelle ronde, *Sardinella aurita* : pêche sardinière dakaroise en 1975 et premier semestre 1976. *Cah. ORSTOM, sér. Océanogr.*, 15(4) : 301-312.

* **CROSSLAND, J. - 1980 - Fishes of the outer reef slopes, *The South Pacific Commission Fisheries Newsletter,* 21 : 26-35.**

CROSSLAND, J. - 1984a - *The Vanuatu village fisheries development programme.* Fisheries Department, Ministry of Agriculture, Forestry and Fisheries, Government of Vanuatu, 32 p.

CROSSLAND, J. - 1984b - *Port-Vila Fisheries Ltd : the establishment and operation of a government owned fish market company.* Fisheries Department, Ministry of Agriculture, Forestry and Fisheries, Government of Vanuatu, 23 p.

CROSSLAND, J. - 1984c - Fish marketing in Vanuatu. *FAO Infofish, Marketing Digest*, 6/84 : 22-24.

CROSSLAND, J. et R. GRANDPERRIN -1980 - The development of deep bottom fishing in the tropical Pacific,*South Pacific Commission Occasional publication*, 17, 13 p.

DAGET, J. -1979 - Echantillonnage et information, diversité spécifique *In* MASSON (éd.) *Les modèles mathématiques en écologie* : 9-28.

DANDONNEAU, Y. -1982 - Time and space variations of surface chlorophyll in the Pacific Ocean : first results. *ORSTOM Nouméa, Océanographie, Rec. Trav. 9*, n° 246, 19 p.

DANDONNEAU, Y., H. CARDINAL, J.L. CREMOUX, J.M. GUILLERM, P.MOLL, J.P. REBERT et P. WAIGNA - 1981 - Rapport de la campagne Hydrothon 5 à bord du N.O. Coriolis, 2-12 juin 1981 - *ORSTOM Nouméa, Océanographie, Rapports scientifiques et techniques*, 23, 38 p.

DRUZHININ, A.D.- 1970 - The range and biology of snappers (Family *Lutjanidae*). *J. ichthyology*, 10 : 717-736.

EGGERS, D.M., N.A. RICKARD, D.G. CHAPMAN et R.R. WHITNEY - 1982 - A methodology for estimating area fished for baited hooks and traps along a ground line. *Can. J. Fish. Aquat. Sci.*, 39 : 448-453.

EGINTON, R. et R.H. JAMES - 1979 - *Report on the South Pacific Commission Outer Reef Artisanal Fisheries Project in Solomon Islands (5 April 1977 - 31 January 1978)*, South Pacific Commission, Noumea, New Caledonia, 11 p.

EGINTON, R. et P. MEAD - 1978 - *Report on the South Pacific Commission Outer Reef Fisheries Project in Funafuti, Tuvalu (21 September 1976 - 28 March 1977)*, South Pacific Commission, Noumea, New Caledonia, 19 p.

FONTANA, A. - 1969 - Etude de la maturité sexuelle des sardinelles *Sardinella eba* (Val.) et *Sardinella aurita* (Val.) de la région de Pointe-Noire. *Cah. ORSTOM, sér. Océanogr.*, 7(2) : 101-114.

FONTANA, A. - 1979 - *Etude du stock démersal côtier congolais.* Thèse Univ. Paris VI/Museum, 300 p.

FOURMANOIR, P. - 1979 - *Pêche des Etelis en Nouvelle-Calédonie avec mise au point sur les deux espèces à détermination controversée.* Commission du Pacifique Sud, Nouméa, Nouvelle-Calédonie, SPC/Fisheries 11/WP 13, 8 p.

* FOURMANOIR, P. - 1980 - Deep bottom fishing in New Caledonia. *The South Pacific Commission Fisheries Newsletter,* 20 : 15-20.

FOURMANOIR, P. et J. CHABANNE - 1980 - Pêche à la palangre profonde en Polynésie Française. *ORSTOM Tahiti, Notes et Doc. Océanogr.*, 80/26, 19 p.

FOURMANOIR, P. et P. LABOUTE - 1976 - *Poissons de Nouvelle-Calédonie et des Nouvelles Hébrides.* Ed., Les éditions du Pacifique, 376 p.

* FUSIMALOHI, T. - 1978 -*Report on the South Pacific Commission Deep Sea Fisheries Development Project in Niue (3 July - 31 August 1978)*, South Pacific Commission, Noumea, New Caledonia, 7 p.

* FUSIMALOHI, T. - 1979 - *Report on the Deep Sea Fisheries Development Project in Tanna, New Hebrides, (11 September - 8 December 1978 and 12 February - 16 March 1979).* South Pacific Commission, Noumea, New Caledonia, 11 pp.

FUSIMALOHI, T. et J. CROSSLAND - 1980 - *Report on the South Pacific Commission Deep Sea Fisheries Development Project in West New Britain, Papua New Guinea (5 September - 14 December 1979)*, South Pacific Commission, Noumea, New Caledonia, 14 p.

* FUSIMALOHI, T. and R. GRANDPERRIN - 1979 - *Report on the South Pacific Commission Deep Sea Fisheries Development Project in New Caledonia (9 April - 3 September 1979)*. South Pacific Commission, Noumea, New Caledonia, 28 pp.

* FUSIMALOHI, T. and R. GRANDPERRIN - 1980 - *Report on the South Pacific Commission Deep Sea Development Project in Wallis and Futuna (13 February - 2 July 1980)*, South Pacific Commission, Noumea, New Caledonia, 25 pp.

FUSIMALOHI, T. et G. PRESTON - 1983 - *Deep Sea Fisheries Development Project. Report of 2nd visit to Vanuatu, 12 August 1980 - 14 June 1981*. South Pacific Commission Noumea, New Caledonia, 41 p.

GJØSAETER, J. et I.M. BECK - 1980 - *Age determination of fish species from Mozambique using daily rings in otoliths*, FI : Moz./77/001, Mimeo, FAO, Rome, 10 p.

GOBERT, B. - 1983 - Observations préliminaires sur la microstructure des otolithes de *Sardinella maderensis* des côtes congolaises. *Doc. Sci. Centre ORSTOM de Pointe-Noire*, NS 60, 10 p.

GRANDPERRIN, R. - 1983 - Prospection de certaines zônes côtières et de quelques monts sous-marins à Vanuatu. *Mission ORSTOM de Port-Vila, Notes et documents d'océanographie*, 9, 40 p.

GRANT, E.M. - 1978 - *Guide to Fishes*. The Department of Harbours and Marine, Brisbane, Queensland, 768 p.

GULBRANDSEN, G. - 1977 - *Outer reef fishery in Western Samoa*. Working paper 9, South Pacific Commission Ninth Regional Technical Meeting on Fisheries (Noumea, New Caledonia, 24-28 January 1977), 15 p.

GULLAND, J.A. - 1971 - The fish resources of the ocean. West Byfleet, Surrey, Fishing News (Books) Ltd., for FAO, 255 p. Rev. ed. of *FAO Fish Tech. Pap.*, 97, 425 p.

* HUME, H. - 1975 - *Report on the South Pacific Commission Outer Reef Fisheries Project in the New Hebrides, (1 August - 28 February 1975)*, South Pacific Commission, Noumea, New Caledonia, 13 pp.

HUME, H. - 1976 - *Report on the South Pacific Commission Outer Reef Fisheries Project in the Cook Islands (1 December 1975 - 31 May 1976)*. South Pacific Commission, Noumea, New Caledonia, 21 p.

HUME, H. et R. EGINTON - 1976 - *Report on the South Pacific Commission Outer Reef Fisheries Project in Western Samoa (1 April - 31 October 1975)*, South Pacific Commission, Noumea, New Caledonia, 19 p.

LEGENDRE, L. et P. LEGENDRE - 1979 - *Ecologie numérique. 2. La structure des données écologiques*. Ed. MASSON, Paris et les Presses de l'Université du Québec, Collection d'Ecologie 12, 254 p.

LE GUEN, J.C. - 1976 - Utilisation des otolithes pour la lecture de l'âge des Sciaenidés intertropicaux ; marques saisonnières et journalières. *Cah. ORSTOM, sér. Océanogr.*, 14(4) : 331-338.

LOUBENS, G. - 1978 - La pêche dans le lagon néo-calédonien. *Centre ORSTOM de Nouméa, Océanographie, Rapp. Sci. et Techn.* n° 1, 52 p.

LOUBENS, G. - 1980a - Biologie de quelques espèces de poissons du lagon néo-calédonien. II Sexualité et reproduction. *Cahiers de l'Indo-Pacifique*, 2(1) :41-72.

LOUBENS, G.- 1980b - Biologie de quelques espèces de poissons du lagon néo-calédonien. III Croissance. *Cahiers de l'Indo-Pacifique*, 2(2) : 101-153.

MASUDA, H., C. ARAGA et T. YOSHINO - 1975 - *Coastal fish of Southern Japan*. Ed., Faculty of Marine Science and Technology, Tokai University, 379 p.

MEAD, P. - 1978 - *Report on the South Pacific Commission Deep Sea Fisheries Development Project in American Samoa (28 March - 2 July 1978)*, South Pacific Commission, Noumea, New Caledonia, 13 p.

MEAD, P. - 1979a - *Report on the second visit of the South Pacific Commission Deep Sea Fisheries Development Project to Niue* (24 August - 26 October 1979), South Pacific Commission, Noumea, New Caledonia, 27 p.

MEAD, P. - 1979b - *Report on the South Pacific Commission Deep Sea Fisheries Development Project in the Kingdom of Tonga (3 June - 20 September 1978)*, South Pacific Commission, Noumea, New Caledonia, 12 p.

* MEAD, P. - 1979c - Common bottom fishes caught by SPC fishing projets. *South Pacific Commission Fisheries Newsletter*, 18 : 1-4.

MEAD, P. - 1980a - *Report on the visit of the South Pacific Commission Deep Sea Fisheries Development Project to Fiji (8 November - 13 December 1979 and 13 March - 1 September 1980)*, 21 p.

MEAD, P. -1980b - *Report on the second visit of the South Pacific Commission Deep Sea Fisheries Development Project to the Kingdom of Tonga (15 June - 25 August 1979)*, South Pacific Commission, Noumea, New Caledonia, 18 p.

MEAD, P. et J. CROSSLAND - 1979 - *Report on the South Pacific Commission Deep Sea Fisheries Development Project in Kosrae, Trust Territory of the Pacific Islands* (17 April - 27 May 1979), South Pacific Commission, Noumea, New Caledonia, 12 p.

MEAD, P. et J. CROSSLAND - 1980 - *Report on the South Pacific Commission Deep Sea Fisheries Development Project in Yap district, Trust Territory of the Pacific Islands*, (25 September 1978 - 29 March 1979), South Pacific Commission, Noumea, New Caledonia, 29 p.

MORIZE, E. - 1984 - Contribution à l'étude d'une pêcherie artisanale et de la dynamique des populations des principales espèces de poissons exploitées. *In* L'atoll de Tikehau, premiers résultats. *ORSTOM Tahiti, Notes et Doc. Océanogr.*, 22 : 14-35.

MUGIYA, Y. etJ. MURAMATSU - 1982 - Time marking methods for scanning electron microscopy in goldfish otoliths. *Bull. Jap. Soc. Fish.*, 48(9) : 1225-1232.

MUNRO, I.S.R. - 1967 - *The fishes of New Guinea*, Victor, C.N. Blight, Government Printer, Sydney, Australia, 651 p.

MUNRO, J.L. - 1983 - The composition and magnitude of trap catches in Jamaican waters. *In* J.L. MUNRO (ed.) *Caribbean Coral Reef Fishery Resources*, ICLARM Studies and Reviews 7 : 33-49.

NELDER, J.R. et R. MEAD - 1965 - A simplex method for function minimization. *Computer Journal*, 7 : 308-313.

NELSON, R.S. et C.S. MANOOCH III - 1982 - Growth and mortality of red snappers in the West-central Atlantic Ocean and Northern Gulf of Mexico. *Transactions of the American Fisheries Society*, 111 : 465-475.

PANNELLA, G. - 1971 - Fish otoliths : daily growth layers and periodical patterns. *Science* (Wash.), 173(4002) : 1124-1127.

PANNELLA, G. - 1974 - Otolith growth patterns : an aid in age determination in temperate and tropical fishes. *In* T.B. BAGENAL (ed.). *The ageing of fish.* UNWIN Brothers Ltd., Old Woking, Surrey, England : 28-39.

PANNELLA, G. - 1980 - Growth patterns in fish sagittae. *In* D.C. RHOADS and R.A. LUTZ (ed.). *Skeletal growth of aquatic organisms : biological records of environmental change.* (Topics in geobiology series, vol. 1). Plenum Publ., New York : 519-556.

PAULY, D. - 1980a - A new methodology for rapidly acquiring basic information on tropical fish stocks : growth, mortality and stock recruitment relationships. *In* SAILA, S.B. et REEDEL, P.M. (ed.). *Proceedings of the international workshop on stock assessment for tropical small scale fisheries.* Int. Cent. Mar. Res. Div., Univ. Rhode Island, Sept. 1979, Kingston : 154-172.

PAULY, D. - 1980b - On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *J. Cons. int. Explor. Mer*, 39(2) : 175-192.

* PAULY, D. - 1980c - A selection of simple methods for the assessment of tropical fish stocks. *FAO Fish. Circ.* N° 729 FIRM/C 729, 54 pp.

PAULY, D. - 1982 - *Studying single - species dynamics in a tropical multispecies context.* *In* Theory and management of tropical fisheries, Ed., D. PAULY et G.I. MURPHY, ICLARM Conference Proceedings 9, 360 p.

PAULY, D. et N. DAVID - 1981 - ELEFAN I a BASIC program for the objective extractions of growth parameters from length-frequency data. *Meeresforsch.*, 28(4) : 205-211.

PAULY, D., N. DAVID et J. INGLES - 1980 - ELEFAN I : User's instruction and program listings (rev. 2). Memeo. pag. var.

* PETIT, M. and C. HENIN - 1982 - Aerial radiometry and tuna survey. Final report, Vanuatu. *Mission ORSTOM de Port-Vila, Notes et documents d'Océanographie,* 3, 98 pp.

RALSTON, S. - 1976 - Age determination of a tropical reef butterflyfish utilizing daily growth rings in otoliths. *Fish. Bull. (U.S.)*, 74(4) : 990-994.

RALSTON, S. - 1978 - *A description of the bottomfish fisheries of Hawaii, American Samoa, Guam and the Northern Marianas.* A report submitted to the Western Pacific Regional Fisheries Management Council, Honolulu, Hawaii. (first draft), 102 p.

RALSTON, S. - 1982 - Influence of hook size in the Hawaian deep-sea handline fishery. *Can. J. Fish. Aquat. Sci.*, 39 : 1297-1302.

RALSTON, S. et G.T. MIYAMOTO - 1981 - Estimation of the age of a tropical reef fish using the density of daily growth increments, *In* E.D. GOMEZ, C.E. BIRKELAND, R.W. BUDDEMEIER, R.E. JOHANNES, J.A. MARSH, Jr and R.T. TSUDA (Ed.). *The reef and man.* Proceedings of the fourth international coral reef symposium, vol. 1. Marine Sciences Center, University of the Philippines, Quezon City : 83-88.

RALSTON, S. et G.T. MIYAMOTO - 1983 - Analyzing the width of daily otolith increments to age the Hawaiian snapper, *Pristipomoides filamentosus. Fishery Bulletin*, 81(3) : 523-535.

RALSTON, S. et J.J. POLOVINA - 1982 - A multispecies analysis of the commercial deep-sea handline fishery in Hawaii. *Fish. Bull.*, 80(3) : 435-438.

* RANCUREL, P. - 1979 - Report on a deep water fisheries survey in the New Hebrides. *South Pacific Commission Fisheries Newsletter,* 18 : 11-13.

RANDALL, J.E. et A. BEN-TUVIA - 1983 - A review of the groupers (*Pisces : Serranidae : Epinephelidae*) of the Red Sea, with description of a new species of *Cephalopholis. Bull. Marine Science*, 33(2) : 373-426.

ROTSCHI, H., P. HISARD et F. JARRIGE - 1972 - Les eaux du Pacifique occidental à 170°E entre 20°S et 4°N. Coupes et cartes dressées par les océanographes du Centre ORSTOM de Nouméa. *Travaux et documents de l'ORSTOM*, 19, 113 p.

SHANNON, C.E. - 1948 - A mathematical theory of communication. *Bull. Syst. tech. J.*, 27 : 379-423.

TALBOT, F.H. - 1960 - Notes on the biology of the *Lutjanidae* (*Pisces*) of the East African Coast, with special reference to *Lutjanus bohar* (Forskal).*Annals S. African. Mus.*, 46 : 549-573.

TANAKA, K., Y. MUGIYA et J. YAMADA - 1981 - Effects of photoperiod and feeding on daily growth patterns in otoliths of juvenile *Tilapia nilotica. Fish. Bull. (U.S.)*, 79(3) : 459-465.

TAUMAIA, P. et J. CROSSLAND - 1980a - *Report on the South Pacific Commission Deep Sea Fisheries Development Project in Koror, Palau, Trust Territory of the Pacific Islands (1 Novembre 1979 - 31 January 1980)*, South Pacific Commission, Noumea, New Caledonia, 18 p.

TAUMAIA, P. et J. CROSSLAND - 1980b - *Report on the South Pacific Commission Deep Sea Fisheries Development Project in Truk (1 February - 31 March 1980)*, South Pacific Commission, New Caledonia, 15 p.

TAUMAIA, P. et M. GENTLE - 1982 - *Report on the Deep Sea Fisheries Development Project in Funafuti, Tuvalu (18 November 1980 - 15 February 1981)*, South Pacific Commission, Noumea, New Caledonia, 29 p.

TAUMAIA, P. et M. GENTLE - 1983 - *Deep Sea Fisheries Development Project : report of visit to Kiribati (23 April - 18 November 1980)*, South Pacific Commission, Noumea, New Caledonia, 27 p.

THOMSON, R. et J.L. MUNRO - 1983 - The biology, ecology and bionomics of the snappers, *Lutjanidae*. *In* J.L. MUNRO (ed.). *Caribbean coral reef fishery resources*. ICLARM Studies and reviews 7, ICLARM Manila, Philippines : 94-109.

TAUBERT, B.0 et D.W. CABLE - 1977 - Daily rings in otoliths of three species of *Lepomis* and *Tilapia mossambica*. *J. Fish. Res. Board Can.*, 34 : 332-340.

UCHIDA, R.N., B.M. ITO et J.H. UCHIYAMA - 1979 - *Surveys of bottom fish resource in the North Western Hawaiian Islands.* South Pacific Commission, Noumea, New Caledonia, SPC/Fisheries 11/WP 4, 17 p.

UCHIDA, R.N., D. TAGAMI et J.H. UCHIYAMA - 1982 - *Results of bottom fish research in the northwestern Hawaiian Islands.* South Pacific Commission 14th Regional Technical Meeting on Fisheries, Background Paper 2, 14 p.

VICTOR, B.C. - 1982 - Daily otolith increments and recruitment in two coral-reef wrasses, *Thalassoma bifasciatum* and *Halichoeres bivittatus. Marine Biology*, 71 : 203-208.

WALKER, M. - 1975 - *Aspects of the biology of Emperor fishes, Family Lethrinidae in North Queensland Barrier Reef waters.* Ph. D. Thesis, James Cook University, Townsville, Australia, 241 p.

WELCOMME, R.L. et J.A. GULLAND - 1980 - *Methods for assessing the resources available to small-scale fisheries.* FAO, IPFC/80/SYM/SP/7, 10 p.

LOCATION		Trip number:		Departure time:		Fishing area		Boat:		Fuel:	
				Return time:				Skipper:		Amount:	

DATE	TIME	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24
ENGINE HOURS																																																	
METHODS	Trolling																																																
Bottom fishing	Handreel																																																
	Handline																																																
FISHING DEPTH (m)																																																	
CATCH RATE	Numbers																																																
	Weight (kg)																																																

WEATHER		CREW (Names):	BAIT		FISHING EFFORT	
WIND			Type	Wt (kg)	No. of trolling lines	
SEA					No. of handreels	
CURRENT		No. of trainees:			No. of handlines	

BOTTOM CATCHES (including sharks)

Species	No.	Wt (kg)
TOTALS		

TROLL CATCHES

Species	No.	Wt (kg)
TOTALS		

CATCHES OTHER METHODS

TOTALS		

REMARKS:

TOTAL CATCH PER TRIP	No.	Wt (kg)

Appendix 1 - Sample sheet from log book used on Fisheries Department boats.

Appendix 2 - Form used in connection with village fishing project.

VILLAGE FISHING PROJECT
BIOLOGICAL FORM

Project location

Boat name

Time out

Departure date

Time in

Return date

Fishing depth (m)

Fishing zone (see chart)

Number of reels fishing

Bottom fishing total catch (kg)
(do not include the sharks)

Troll fishing total catch (kg)

Fish name	Fish measurement (fork length in cm)
Etelis coruscans	
E. carbunculus	
E. radiosus	
Pristipomoides multidens	
P. flavipinnis	
P. filamentosus	
Epinephelus morrhus	
E. magniscuttis	
E. septemfasciatus	
Lutjanus malabaricus	
Aphareus rutilans	

Remarks :

Appendix 3 - Data entry and processing

A Hewlett-Packard 85 micro-computer was used with a plotter and a printer. The major drawbacks of the equipment were its small working memory (about 30 K bytes) and cassette tape storage resulting in a comparatively low speed of access to the data and the risk of losing data through wearing out of the tapes.

INPUT

The data were sorted out into three main sets, the fishing trip number being the link between them :

- "CATCH and EFFORT" data concerning the actual fishing carried out and its overall results (coding form, Fig. 27),
- "SPECIES" data combining information on the numbers and weights of the different species caught (coding form, Fig. 28),
- "BIOLOGY" data, i.e. individual lengths and weights, sex, gonad maturation and weights, etc... (coding form, Fig. 29).

Figure 30 is a block diagram indicating the data entry sequence. The three sub-programs ACQPRI, ACQESP and ACQB00 respectively allow input of the "CATCH and EFFORT" data, the "SPECIES" data, and the "BIOLOGY" data. In the first two, the data are entered in the order of fishing trip numbers in the files PRIXX and ESPXX (XX being the file number). In the third, they are classified by species in the BXXXYY files (XXX being the species code and YY the file number for species XXX). The three sub-programs EDICOR, REPDAT and LISDAT respectively correct, replicate and edit the data. Lastly, the PROCOD sub-program enables the code and name of new species recorded to be entered in file CODESP. Options for correcting and editing are included in this sub-program.

PROCESSING

The diagram in Figure 31 shows the processing program design. It comprises two types of sub-programs : "direct access" programs and "indirect access" programs. The former (left on the figure) have direct access to the main files. The other seeks out the data in several different files which are derived from the main files and whose purpose is to speed up processing.

ARTISANAL FISHERY : CATCH AND EFFORT

Trip number 1 ☐☐☐☐

Date of trip 2 ☐☐ 3 ☐☐ 4 ☐☐

Time out 5 ☐☐ 6 ☐☐ Time in 7 ☐ 8 ☐☐ 9 ☐☐

No. hours of rest 10 ☐☐ 11 ☐☐

Fishing area 12 ☐☐ Location 13 ☐☐

Latitude (S) 14 ☐☐☐ ☐☐ Longitude (E) 15 ☐☐☐☐☐☐

Boat 16 ☐☐ Type 17 ☐ Fuel 18 ☐☐☐ Crew 19 ☐

Bottom fishing 20 ☐

Minimum depth 21 ☐☐☐ Maximum depth 22 ☐☐☐

Gear 23 ☐ No. of lines 24 ☐ No. hooks/line 25 ☐☐☐

No. fishing hours 26 ☐☐ 27 ☐☐ Day/Night 28 ☐

Bait type 29 ☐☐ Weight (0.1 kg) 30 ☐☐☐

Total catch 31 ☐☐☐☐☐ (0.1 kg)

No. fish 32 ☐☐☐ No. species 33 ☐☐

Trolling 34 ☐

Trolling depth 35 ☐☐

No. lines 36 ☐☐ No. hours 37 ☐☐ 38 ☐☐ Lure type 39 ☐☐

Total catch 40 ☐☐☐☐☐ (0.1 kg)

No. fish 41 ☐☐☐ No. species 42 ☐☐

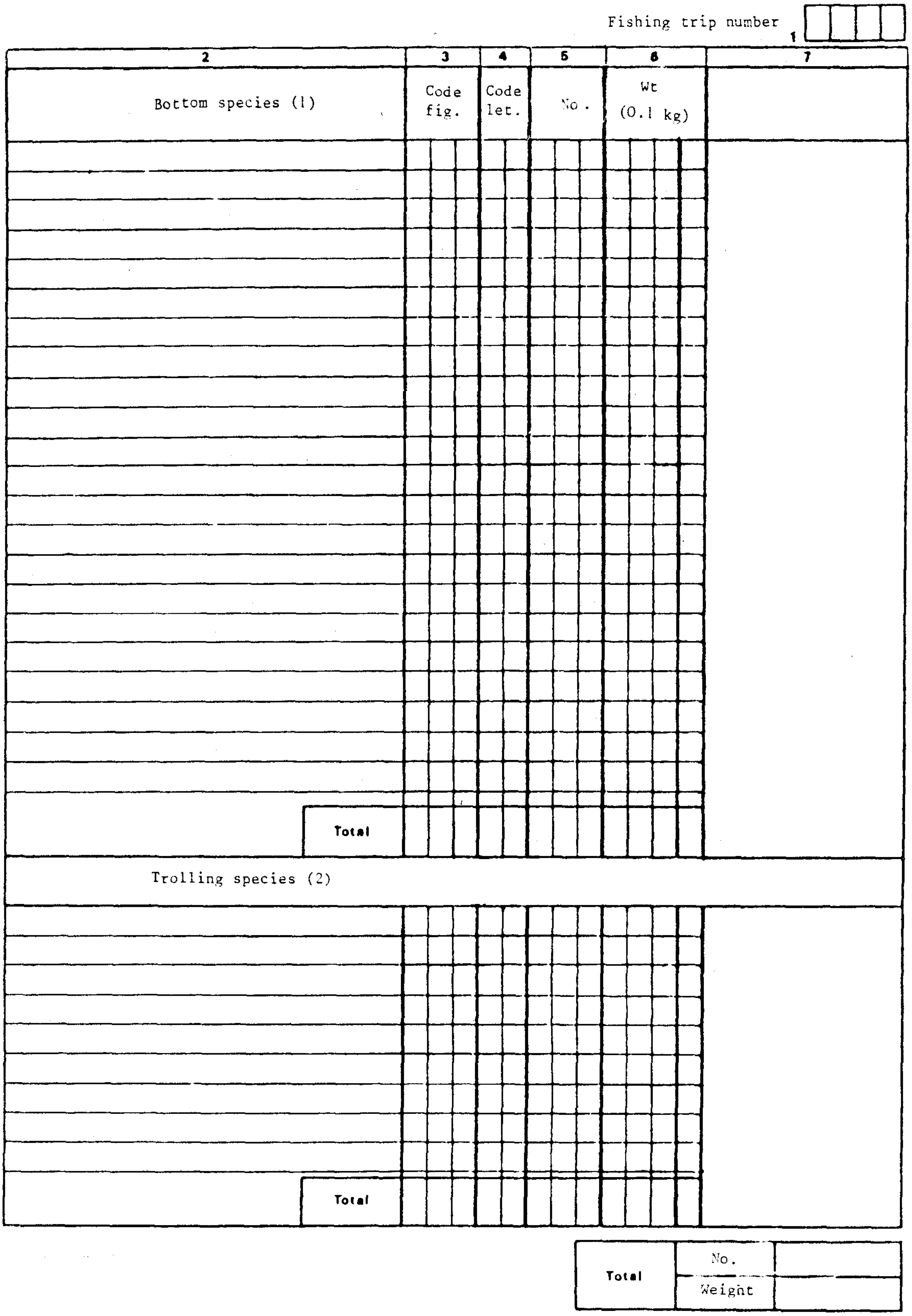
Conditions out at sea

Wind 43 ☐ Sea 44 ☐ Current (0.1 knots) 6 ☐☐

Skipper 46 ☐☐ Moon 47 ☐☐

Fig. 27 - "CATCH and EFFORT" data coding form

ARTISANAL FISHERY : SPECIES



Fishing trip number 1 ☐☐☐☐

2	3	4	5	6	7
Bottom species (1)	Code fig.	Code let.	No.	Wt (0.1 kg)	
Total					
Trolling species (2)					
Total					

Total	No.	
	Weight	

Fig. 28 - "SPECIES" data coding form.

FISH BIOLOGY

Gear :

Species :

Species codes 2 ☐☐

1								3	4	5	6	7	8	
Trip number	Date	Zone	Loc.	Depth (m)	G	D N	b	FL (cm)	Wt(0.1 kg)	Gonads			C	
										S	Wt(g)	M		

Loc : location; G : gear; D : day; N : night; b : bait
S : sex; M : maturation stage; C : body condition

Fig. 29 - "BIOLOGY" data coding form.

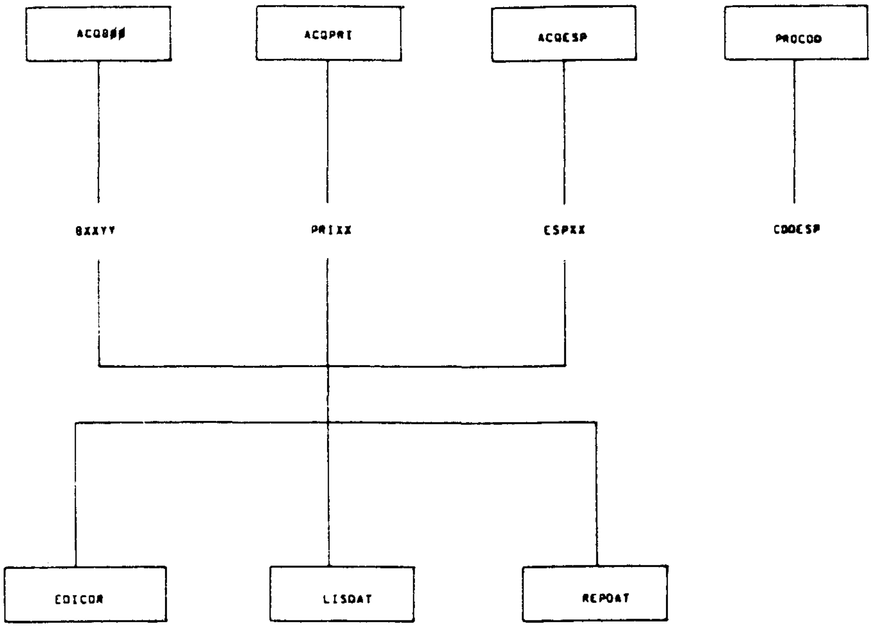


Fig. 30 - Data entry program design.

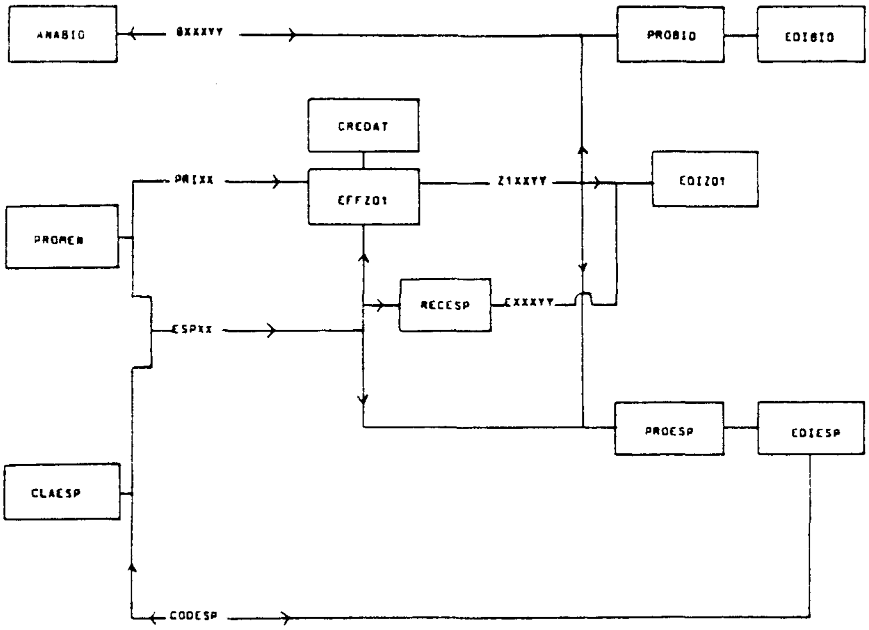


Fig. 31 - Data processing program design.

1. Direct access programs

ANABIO uses only data on the BXXXYY files. It gives information on length-weight relationships, GSI, maturity, length frequencies.

PROMEN was designed to provide the Fisheries Department, rapidly and on a monthly basis, with catch and effort data for bottom fishing and trolling, all species combined, and by species.

CLAESP allows relative abundance of species to be obtained and species to be classified in decreasing order of abundance (number of individuals caught).

2. Indirect access programs

With the type of computer used, processing of the data in the main PRIXX files is cumbersome. To speed up processing, simplified files were derived from the former, with the data slightly modified (for instance, data on sharks were discarded) and reorganised area by area. These data are entered into the new files ZIXXYY (XX : area code; YY : file number for area XX) with the EFFZ01 and CREDAT programs. Similarly, the RECESP program allows extraction from the main ESPXX files (catches by weight and numbers for all species) of the data concerning any one of the species. These data are stored in files EXXXYY (XXX : species code; YY : file number for species XXX).

Three processing programs use these simplified files :

PROBIO uses the "BIOLOGY" data and the "CATCH and EFFORT" data. For a given species, it allows determination of fluctuations in time of length frequencies, the gonad index and sexual maturity, and of length variations with depth. The associated EDIBIO program edits the results.

EDIZO 1 provides all catch and effort data for a given area. Results by species are obtained by introducing files EXXXYY.

PROESP establishes presence-absence lists for the different species by depth classes for given areas. It is used with EDIESP which edits the results.

Appendix 4 - A program for the analysis of length frequency distributions, based on the ELEFAN I program designed by Pauly and David (1981).

a) Data entry

```
 10 ! PROGRAMME P1/SAI
 20 ! SAISIE DES DONNEES POUR TR
    AITEMENT ELEFAN I
 30 !
 40 !
 50 OPTION BASE 0
 60 DIM N$[39]
 70 CLEAR
 80 DISP "SAISIE DES DONNEES POU
    R ANALON" @ DISP
 90 DISP "Nom du fichier ";@ INP
    UT F$
100 CLEAR
110 DISP "Nom de l'espece ";@ IN
    PUT N$
120 DISP "Nbre d'echantillons ";
    @ INPUT N1
130 DISP "Taille d'un intervalle
    ";@ INPUT A3
140 DISP "Taille minimale ";@ IN
    PUT A1
150 DISP "Taille maximale ";@ IN
    PUT A2
160 N2=(A2-A1)/A3
170 DISP "Le fichier est-il cree
    : O/N";@ INPUT R0$
180 IF R0$="O" THEN 220
190 IF R0$#"N" THEN 170
200 N=100+40*N1*N2
210 CREATE F$,1,N
220 ASSIGN# 1 TO F$
230 PRINT# 1 ; N$,N1,N2,A3,A1,A2
240 FOR S1=0 TO N1-1
250 CLEAR @ L,F=0 @ I=1
260 DISP "Mois et jour de l'echa
    ntillon";S1+1 @ INPUT M,D
270 CLEAR @ DISP "Echantillon";S
    1+1 @ DISP "Mois";M
280 IF I=2 THEN DISP "Donnees pr
    ecedentes:";L-A3;F
290 ON I GOSUB 370,390
300 IF F#9999 THEN PRINT# 1 ; S1
    ,L,F,M,D @ L=L+A3 @ GOTO 270
310 NEXT S1
320 S1=9999
330 PRINT# 1 ; S1,L,F,M,D
340 ASSIGN# 1 TO *
350 CLEAR @ DISP "FIN DE SAISIE
    DES DONNEES."
360 END
370 DISP @ DISP "Longueur, frequ
    ence ";@ INPUT L,F
380 I=2 @ RETURN
390 DISP @ DISP "Longueur ";L
400 DISP "Frequence (9999 si
    'FIN') ";@ INPUT F
410 RETURN
```

b) Data processing

```
 10 REM ELEFAN I VERSION 2
 20 ! MODIFICATIONS ORSTOM VANUA
    TU DU 01/08/84
 30 ! PROGRAMME P2/ANA
 40 !
 50 OPTION BASE 0
 60 CLEAR
 70 DISP "      ... ELEFAN I VERS
    2 ..." @ DISP
 80 U2=0
 90 COM T0(12) ,SHORT S(30,30)
100 COM F1(12,60),F0(60),L1(48),
    L2(48),N$[39]
110 BEEP @ DISP "Nom du fichier"
    ;
120 INPUT F$
130 BEEP @ DISP "Installez la K7
    ; puis faire CONT" @ PAUSE
140 ASSIGN# 1 TO F$
150 BEEP @ CLEAR @ DISP TAB(6);"
    ... INITIALISATION ... "
160 FOR I=0 TO 11
170 T0(I)=0
180 FOR J=0 TO 60 @ F1(I,J)=0 @
    NEXT J
190 NEXT I
200 BEEP @ CLEAR @ DISP "IMPRESS
    ION DES DONNEES: O/N";@ INPU
    T S$
210 IF S$#"O" AND S$#"N" THEN 20
    0
220 READ# 1 , N$,N1,N2,A3,A1,A2
230 IF S$="N" THEN 310
240 PRINT @ PRINT "ESPECE: ";N$
    @ PRINT
250 PRINT F$ @ PRINT "======"
260 PRINT "NB ECHANT.";N1
270 PRINT "NB INTERV.";N2
280 PRINT "TAILLE INTERVALLE";A3
290 PRINT "LONG. MIN.";A1
300 PRINT "LONG. MAX.";A2
310 READ# 1 ; S1,L,F,M,D
320 FOR I=0 TO N1-1
330 IF S$="N" THEN 360
340 PRINT @ PRINT "ECHANTILLON";
    S1+1 @ PRINT D;"/";M
350 PRINT @ PRINT "LONGUEUR ";TA
    B(15);"FREQUENCE" @ PRINT
360 L1(I)=L
370 T0(I)=M+(D-1)/31
380 IF S1>I THEN 470
390 J=(L-L1(I))/A3+1
400 F1(I,J)=F
410 L3=L
420 IF S$="N" THEN 440
430 PRINT L;TAB(15);F
440 READ# 1 ; S1,L,F,M,D
450 IF S1>=9999 THEN 470
460 GOTO 380
470 L2(I)=L3
480 J1=1
490 J2=(L2(I)-L1(I))/A3+1
500 R=0
510 FOR J=J1 TO J2
520 K1=J-1
530 K2=J-2
540 W1=J+1
550 W2=J+2
560 F0(J)=0
570 IF K2<0 THEN K2=0
580 IF W1>J2 THEN W1,W2=0 @ GOTO
     600
590 IF W2>J2 THEN W2=0
600 M2=F1(I,J)+F1(I,K1)+F1(I,K2)
    +F1(I,W1)+F1(I,W2)
610 M2=M2/5
620 IF M2#0 THEN F0(J)=F1(I,J)/M
    2 @ R=R+F0(J)
630 NEXT J
640 R=R/J2
650 IF R=0 THEN 690
660 FOR J=J1 TO J2
670 F1(I,J)=F0(J)/R-1
680 NEXT J
690 FOR J=J1 TO J2
700 IF F1(I,J)<0 THEN GOTO 850
710 K1=J-1
720 K2=J-2
730 W1=J+1
740 W2=J+2
750 IF W1>J2 THEN W1,W2=0 @ GOTO
     770
760 IF W2>J2 THEN W2=0
770 IF K2<0 THEN K2=0
780 M2=0
790 F1(I,0)=-1
800 IF F1(I,K1)<=-1 THEN M2=M2+1
810 IF F1(I,K2)<=-1 THEN M2=M2+1
820 IF F1(I,W1)<=-1 THEN M2=M2+1
830 IF F1(I,W2)<=-1 THEN M2=M2+1
840 F1(I,J)=F1(I,J)*EXP(-M2)
850 NEXT J
860 M2=0
870 M3=0
880 FOR J=J1 TO J2
890 IF F1(I,J)>0 THEN M2=M2+F1(I
    ,J) @ GOTO 910
900 M3=M3+F1(I,J)
910 NEXT J
920 R=1
930 IF M3<>0 THEN R=M2/M3
940 FOR J=J1 TO J2
950 IF F1(I,J)<0 AND F1(I,J)<>-1
     THEN F1(I,J)=F1(I,J)*(-R)
960 NEXT J
970 REM END OF DEEMPHASIZE
980 REM COMPUTE ASP
990 J=J1
1000 IF J>J2 THEN GOTO 1100
1010 IF F1(I,J)<=0 THEN J=J+1 @
     GOTO 1000
```

```
1020 U1=F1(I,J)
1030 J3=J+1
1040 IF J3>J2 THEN U2=U2+U1 @ GO
     TO 1100
1050 IF F1(I,J3)>U1 THEN U1=F1(I
     ,J3) @ J3=J3+1 @ GOTO 1040
1060 IF F1(I,J3)>0 THEN J3=J3+1
     @ GOTO 1040
1070 U2=U2+U1
1080 J=J3+1
1090 GOTO 1000
1100 FOR J=1 TO J2
1110 IF F1(I,J)=-1 THEN F1(I,J)=
     0
1120 NEXT J
1130 NEXT I
1140 CLEAR
1150 ASSIGN# 1 TO *
1160 BEEP @ DISP "IMPRESSION DE
     L'ECHANTILLON RE- STRUCTURE
     : O/N ";@ INPUT S$
1170 IF S$#"O" AND S$#"N" THEN 1
     160
1180 IF S$="N" THEN 1280
1190 PRINT @ PRINT "ECHANTILLON
     RESTRUCTURE "
1200 PRINT "--------------------
     ------"
1210 FOR I=0 TO N1-1 @ PRINT @ P
     RINT "ECHANTILLON";I+1 @ PR
     INT
1220 PRINT "LONGUEUR";TAB(15);"F
     REQUENCE" @ PRINT
1230 FOR J=1 TO (L2(I)-L1(I))/A3
     +1
1240 PRINT L1(I)+(J-1)*A3;TAB(15
     );F1(I,J)
1250 NEXT J
1260 NEXT I
1270 PRINT @ PRINT "ASP=";U2
1280 CLEAR @ FOR I=0 TO 9 @ BEEP
      @ NEXT I
1290 DISP "    <<< SURFACE DES ES
     P >>>   " @ DISP
1300 DISP "Longevite ";@ INPUT T
     9
1310 DISP "Linf minimum, Linf ma
     ximum ";@ INPUT Z0,Z9
1320 DISP "Pas de Linf ";@ INPUT
      Z1
1330 DISP "K minimum, K maximum
     ";@ INPUT K0,K9
1340 DISP "Pas de K ";@ INPUT K1
1350 DISP "Echantillon de depart
      ";@ INPUT C0@ C0=C0-1
1360 IF C0>N1-1 THEN BEEP @ GOTO
      1350
1370 DISP "Longueur initiale ";@
      INPUT L0
1380 DISP "Increment de longueur
      initiale ";@ INPUT P1
1390 IF P1=0 THEN P1=A3
1400 I9=(Z9-Z0)/Z1 @ J9=(K9-K0)/
     K1
1410 Z=Z0-Z1
1420 FOR I=0 TO I9
1430 Z=Z+Z1 @ K=K0-K1
1440 FOR J=0 TO J9
1450 K=K+K1
1460 S0,R=0 @ P=L0
1470 CLEAR @ DISP USING "K,2D,A,
     2D,A" ; "CALCULS DE S(",I,"
     ,",J,")"
1480 T=FNB2(P) @ S(I,J),R1=0 @ C
     1=C0
1490 C2=C1 @ GOSUB 1880
```

```
1500 C2=(C1+1) MOD N1
1510 T1=(T0(C2)-T0(C1)) MOD 12
1520 IF T1=0 THEN T1=12
1530 T1=T1/12 @ T=T+T1
1540 IF T>T9 THEN 1590
1550 GOSUB 1880
1560 IF R1=1 THEN 1590
1570 C1=C2
1580 GOTO 1500
1590 T=FNB2(P) @ R1=0 @ C1=C0
1600 C2=(C1-1) MOD N1
1610 T1=(T0(C1)-T0(C2)) MOD 12
1620 IF T1=0 THEN T1=12
1630 T1=T1/12 @ T=T-T1
1640 IF T<0 THEN 1690
1650 GOSUB 1880
1660 IF R1=1 THEN 1690
1670 C1=C2
1680 GOTO 1600
1690 IF S(I,J)>S0 THEN S0=S(I,J)
      @ P2=P
1700 P=P+P1 @ IF P<L0+A3 THEN 14
     80
1710 S(I,J)=S0
1720 NEXT J
1730 NEXT I
1740 CLEAR @ DISP "Enregistremen
     t: O/N ";@ INPUT R0$
1750 IF R0$="N" THEN 2020
1760 IF R0$#"O" THEN 1740
1770 DISP "Nom du fichier";@ INP
     UT F$
1780 DISP "Le fichier est-il cre
     e: O/N ";@ INPUT R0$
1790 IF R0$="O" THEN 1810
1800 IF R0$#"N" THEN 1780 ELSE N
     =120+(I9+1)*(J9+1)*8 @ CREA
     TE F$,1,N
1810 ASSIGN# 1 TO F$
1820 PRINT# 1 ; N$,C0+1,L0,Z0,Z9
     ,Z1,K0,K9,K1
1830 FOR I=0 TO I9 @ FOR J=0 TO
     J9 @ PRINT# 1 ; S(I,J) @ NE
     XT J @ NEXT I
1840 ASSIGN# 1 TO *
1850 CLEAR @ DISP "ENREGISTREMEN
     T TERMINE"
1860 STOP
1870 !
1880 !
1890 L=FNB1(T)
1900 IF (L<A2)*(L>A1)=0 THEN R1=
     1 @ RETURN
1910 C=(A3+L-L1(C2))\A3
1920 IF C<1 THEN RETURN
1930 S(I,J)=S(I,J)+F1(C2,C)
1940 RETURN
1950 DEF FNB1(X)
1960 X=EXP(-(K*X))
1970 FNB1=Z*(1-X)
1980 FN END
1990 DEF FNB2(X)
2000 FNB2=LOG(Z/(Z-X))/K
2010 FN END
2020 END
```

c) Representation of the ESP surfaces

```
 10 ! ORSTOM VANUATU
 20 ! PROGRAMME P3/ESP
 30 ! EDITION SURFACE DES ESP
 40 !
 50 !
 60 PLOTTER IS 705
 70 DEG
 80 OPTION BASE 0
 90 DIM N$[40]
100 COM S(30,30)
110 CLEAR @ DISP "     SORTIE DES
      SURFACES ESP " @ DISP
120 DISP "Nom du fichier ";@ INP
    UT F$
130 CLEAR @ DISP "Installez la K
    7 adequat; puis   faire CONT
    ." @ PAUSE
140 CLEAR @ ASSIGN# 1 TO F$
150 READ# 1 ; N$,E0,L,L0,L9,L1,K
    0,K9,K1
160 I9=(L9-L0)/L1
170 J9=(K9-K0)/K1
180 FOR I=0 TO I9
190 FOR J=0 TO J9
200 READ# 1 ; S(I,J)
210 IF I=0 AND J=0 THEN M0,M9=S(
    0,0) @ GOTO 240
220 IF S(I,J)>M9 THEN M9=S(I,J)
230 IF S(I,J)<M0 THEN M0=S(I,J)
240 NEXT J
250 NEXT I
260 !
270 !
280 !
290 LIMIT 10,250,10,180
300 LOCATE 10,10+70*J9/I9,20,90
310 SCALE K0-K1,K9+K1,L0-L1,L9+L
    1
320 FXD 2,1 @ PEN 1
330 CSIZE 1.8,.6
340 LAXES -K1,L1,K0-K1,L0-L1,4,4
350 CSIZE 1.8,.6,15
360 MOVE K0-K1,L9+L1*1.5 @ LORG
    4 @ LABEL "Linf (cm)"
370 MOVE K9+K1,L0-2*L1 @ LORG 9
    @ LABEL "k (1/a)"
380 LORG 6 @ MOVE K9+2*K1,L0+(L9
    -L0)/2 @ LDIR 90
390 LABEL USING "19A,2Z" ; "Echa
    ntillon init.:",E0
400 LABEL USING "16A,3D.D" ; "Lo
    ngueur init.:",L
410 LABEL USING "8A,2D.4D,4X,8A,
    2D.4D" ; "ESPmin: ",M0,"ESPm
    ax: ",M9
420 LDIR 0
430 CSIZE 2.5,.9,15 @ LORG 4 @ M
    OVE K0+(K9-K0)/2,L9+3*L1
440 LABEL "SURFACE DES ESP" @ LA
    BEL N$
450 SCALE 0,J9+2,0,I9+2
460 PEN 2
470 FOR I=0 TO I9
480 FOR J=0 TO J9
490 C=(S(I,J)-M0)/(M9-M0)
500 C=IP(C*10)+1
510 GOSUB 550
520 NEXT J
530 NEXT I
540 STOP
550 !
560 MOVE J+.5,I+.5
570 K=0
580 IMOVE 0,1/C @ K=K+1/C
590 IF K>1 THEN RETURN ELSE IDRA
    W 1,0
600 IMOVE 0,1/C @ K=K+1/C
610 IF K>1 THEN RETURN ELSE IDRA
    W -1,0
620 GOTO 580
```

d) Representation of the growth curves

```
10 ! PROGRAMME P4/CRB
20 ! REPRESENTATION DES COURBES
    DE CROISSANCE
30 !
40 !
50 OPTION BASE 1
60 INTEGER C1
70 COM T(12,50),M(12),L1(12),L2
   (12),N$[40]
80 S0=INF
90 CLEAR @ DISP "Nom du fichier
    ";@ INPUT F$
100 DISP "Faire CONT si pret." @
     PAUSE
110 CLEAR @ DISP "LECTURE DU FIC
    HIER"
120 ASSIGN# 1 TO F$
130 READ# 1 ; N$,N1,N2,A3,A1,A2
140 READ# 1 ; S1,L,F,M,D
150 IF S1=9999 THEN 210
160 IF S0#S1 THEN I=S1+1 @ S0=S1
     @ L1(I)=L
170 L2(I)=L
180 T(I,1+(L-L1(I))\A3)=F
190 M(I)=M+(D-1)/31
200 GOTO 140
210 CLEAR @ DISP "CALCULS"
220 T9=0
230 FOR I=1 TO N1
240 T0=0 @ J1=1 @ J2=1+(L2(I)-L1
    (I))\A3
250 FOR J=J1 TO J2 @ T0=T0+T(I,J
    ) @ NEXT J
260 FOR J=J1 TO J2
270 T(I,J)=T(I,J)*100/T0
280 IF T(I,J)>T9 THEN T9=T(I,J)
290 NEXT J
300 NEXT I
310 GOSUB 740
320 CLEAR @ DISP "Histogramme (1
    ) ou courbe (2) ";@ INPUT C8
330 DISP "Echelle maximum des fr
    equences ;" @ INPUT C7
340 C=0 @ F9=C7*.95/T9
350 FOR I=1 TO N1
360 IF N1=1 THEN P=C+1+M(I)/12 E
    LSE P=M(I)+C
370 J2=1+(L2(I)-L1(I))\A3
380 IF C8=1 THEN 400
390 MOVE P,L1 @ DRAW P,L2
400 FOR J=J1 TO J2
410 F=F9*T(I,J) @ L=A3*(J-1)+L1(
    I)
420 IF J=J1 THEN MOVE P-F,L+A3/2
430 IF C8=1 THEN CLIP P-F,P,L,L+
    A3 @ FRAME ELSE DRAW P-F,L+A
    3/2
440 NEXT J
450 NEXT I
460 IF N1#1 THEN 490
470 C=C+1
480 IF C>=C0-1 THEN 510 ELSE 350
490 C=C+12
500 IF C+1<=C0*12 THEN 350
510 !
520 !
530 !
540 CLEAR @ DISP " PARAMETRES DE
     VAN BERTALANFFY" @ DISP
550 DISP "Entrez Linf,K ";@ INPU
    T Z,K
560 DISP "Longueur et echantillo
    n de       depart ";@ INPUT X
    0,D0
570 DISP "Temps minimal (en anne
    e) ";@ INPUT S0
580 DISP "Type de ligne ";@ INPU
    T V0
590 CLIP C1,C2,L1,L2
600 IF N1=1 THEN S9=S0+C2 ELSE S
    9=1+(S0+C0)*12
610 S2=(M(D0)-1)/12 @ S1=FNB2(X0
    )
620 S2=FP(S1)-S2
630 LINETYPE V0,3
640 IF N1=1 THEN GOSUB 1080 ELSE
     GOSUB 1150
650 CLEAR @ DISP "Legende parame
    tres: O/N ";@ INPUT R0$
660 IF R0$="O" THEN 680
670 IF R0$="N" THEN 540 ELSE BEE
    P @ GOTO 650
680 DISP "Longueur de l'echantil
    lon ";@ INPUT E0
690 DISP "Position ";@ INPUT E1,
    E2
700 UNCLIP
710 T$=VAL$(Z)&"/"&VAL$(K)
720 MOVE E1,E2 @ IDRAW E0,0 @ IM
    OVE E0*.2,0 @ LORG 2 @ CSIZE
     2,1,.15 @ LABEL T$
730 GOTO 540
740 !
750 !
760 !
770 CLEAR @ DISP "S'assurer que
    le PLOTTER est surON; puis f
    aire CONT." @ PAUSE
780 PLOTTER IS 705
790 DEG
800 CLEAR @ DISP "Lmin=";A1;"Lma
    x=";A2
810 DISP "Echelle des longueurs
    (min,max) ";@ INPUT L1,L2
820 DISP "Grad. 1aire, frequence
     des grad.2aires ";@ INPUT L
    3,L4
830 DISP "Longevite ";@ INPUT C0
840 DISP "Etiquette annuelle (1)
     ou men-  suelle (2) ";@ INP
    UT C9
```

```
850 IF C9=2 AND N1=1 THEN BEEP @
     GOTO 840
860 CLEAR
870 IF N1=1 THEN C2=C0 @ C1=0 EL
    SE C2=1+C0*12 @ C1=-1
880 LIMIT 0,250,0,180
890 LOCATE 10,130,30,90
900 CSIZE 2,1
910 SCALE 0,C2,L1,L2
920 LAXES 0,L3,0,0,0,L4
930 MOVE 0,L2*1.02 @ LORG 4 @ CS
    IZE 2,1,15 @ LABEL "Longueur
     (cm)"
940 SCALE C1,C2,L1,L2
950 XAXIS L1,1,1,C2
960 LORG 6 @ CSIZE 2,1
970 FOR I=1 TO C2
980 MOVE I,L1-(L2-L1)*.01
990 ON C9 GOSUB 1040,1070
1000 NEXT I
1010 MOVE C2,L1-(L2-L1)*.05 @ LO
     RG 9 @ CSIZE 2,1,15
1020 IF N1=1 THEN LABEL "Temps (
     annee)" ELSE LABEL "Temps (
     mois)"
1030 RETURN
1040 IF N1=1 THEN LABEL I @ RETU
     RN
1050 IF (I-1)\12=(I-1)/12 THEN L
     ABEL (I-1)/12
1060 RETURN
1070 LABEL 1+(I-1) MOD 12 @ RETU
     RN
1080 !
1090 MOVE 0,FNB1(S0)
1100 FOR S=S0 TO S9 STEP  1
1110 DRAW S-S0,FNB1(S+S2)
1120 NEXT S
1130 PENUP
1140 RETURN
1150 !
1160 S0=S0*12
1170 MOVE 1,FNB3(S0)
1180 FOR S=S0 TO S9 STEP .2
1190 DRAW S-S0+1,FNB3(S)
1200 NEXT S
1210 PENUP
1220 RETURN
1230 !
1240 DEF FNB1(X)
1250 X=EXP(-(K*X))
1260 FNB1=Z*(1-X)
1270 FN END
1280 DEF FNB2(X)
1290 FNB2=LOG(Z/(Z-X))/K
1300 FN END
1310 DEF FNB3(X)
1320 M=X MOD 12/12
1330 A=X\12
1340 X1=A+M+S2
1350 FNB3=FNB1(X1)
1360 FN END
```

Appendix 5 - Restructuration of samples (*Pristipomoides multidens*)

```
SPECIES : PRISTIPOMOIDES MULTIDENS

PRI84
======
NUMBER SAMPLE 4
NUMBER INTERVAL 22
SIZE INTERVAL 2
MIN. LENGTH 20
MAX. LENGTH 64

SAMPLE 1

 7/2
LENGTH             FREQUENCY                 RESTRUCTURED SAMPLE

 30                   1                     -5.42633533524E-2
 32                   0                      0
 34                   5                     -9.48518274371E-2
 36                   8                     -8.52581831079E-2
 38                   22                     .30056955021
 40                   20                    -8.45062022676E-3
 42                   25                     .32103305711
 44                   23                     .25393296533
 46                   11                    -.101781566915
 48                   8                     -8.90534739962E-2
 50                   12                     .73177442781
 52                   2                     -.176028775607
 54                   1                     -.20647013117
 56                   1                      3.06769295017E-2
 58                   0                      0
 60                   0                      0
 62                   1                      7.15536004381E-2
 AMPLE

 24/5

LENGTH             FREQUENCY                 RESTRUCTURED SAMPLE

 26                   1                      1.42806521723E-2
 28                   1                     -.18748460116
 30                   3                     -.152088438014
 32                   10                    -3.21981723059E-2
 34                   19                     .34646732439
 36                   29                      80112896971
 38                   17                     .01042199835
 40                   14                    -2.65929141317E-2
 42                   14                     22835615559
 44                   11                     29369424897
 46                   7                      .13803585003
 48                   1                     -.214836187955
 50                   1                     -.114547036374
 52                   0                      0
 54                   0                      0
 56                   0                      0
 58                   0                      0
 60                   1                      8.29259360873E-2
```

SAMPLE 3

4/7

LENGTH	FREQUENCY	RESTRUCTURED SAMPLE
28	2	6.76125417851E-2
30	1	-8.88260014246E-2
32	3	-2.77912670052E-2
34	3	-9.49486080124E-2
36	7	-5.04901351778E-2
38	15	.08841417565
40	16	.07433518632
42	21	.41006493204
44	8	-6.92647922425E-2
46	7	-6.34609169906E-2
48	7	.0859120741
50	6	.104980031582
52	1	-.127666286964
54	0	0
56	2	.099533596543
58	0	0
60	0	0
62	1	6.22034303155E-2
64	1	6.22034303155E-2

SAMPLE 4

10/8

LENGTH	FREQUENCY	RESTRUCTURED SAMPLE
24	1	- 240952979459
26	3	3.69231560426E-2
28	4	-.1860567283
30	7	-.139336514548
32	14	-.672389196489
34	19	-.237438649914
36	41	.02070292554
38	70	.24637100466
40	77	.097516851
42	102	.35880737894
44	96	.29138489285
46	68	.00301599196
48	66	.23510642707
50	41	.0950259541
52	23	-8.39960923436E-2
54	8	-.372058143991
56	4	-.394255843806
58	9	1.1528930211
60	1	-.506284860059
62	1	-.417840899858
64	1	.112862305511

ASP= 5.05351776587

Appendix 6 - Trawling on sea-mounts in New Caledonia : haul conditions and catches by weight of *Etelis carbunculus* and *E. coruscans*, from Barro (1980).

Haul number	Depth range (m)	Distance covered (m)	Catch by weight of *Etelis* (kg)
5	258-264	6 480	20
7	240-288	10 000	10
8	286-293	4 630	0
9	232-250	6 110	0
10	268-270	8 330	0
11	312-318	10 560	0
18	254-300	12 040	5 200
19	230-320	10 740	300
20	220-280	9 260	140
24	244-320	9 260	1 500
25	230-250	15 740	2 400
26	230-284	14 450	13 500
27	250-280	11 300	60
28	236-264	7 040	45
35	230-282	12 960	2 400
36	240-300	11 670	120
41	254-280	930	0
42	234-310	740	0
		162 240	25 695