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The status of statistical reporting from artisanal fisheries in Vanuatu

by

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INTRODUCTION

In common with other Pacific Island countries, the Government of Vanuatu has pursued a policy of developing small scale artisanal fisheries to improve the supply of fresh fish and to provide income earning opportunities at the village level. This policy has led to the development of an artisanal fishing industry that was initially based on the exploitation of deep slope fishes but is presently diversifying into catching large pelagic fishes and shallow water reef fish. Vanuatu also has a button and ornamental shell industry based chiefly on the harvests of the top shell (*Trochus niloticus*) that has grown from two processing plants in 1990 to eight in 1992. Finally, the islands of Vanuatu have large numbers of coconut crabs, which are harvested mainly for hotels and restaurants that serve the important tourism industry in Vanuatu.

These various fishing and harvesting activities generate large volumes of catch and fishing effort data, particularly on fin-fish production. This information, however, is not being processed in a timely manner and is not available for fisheries officers concerned with managing and developing coastal fisheries in Vanuatu. The collection of data, although in some cases well established and maintained, is not being critically reviewed in the light of changes in coastal fishing. Further, there is a need to improve the reporting of information on harvests of trochus and coconut crabs which at present is poorly understood but thought to be excessive.

The problems being faced by the Vanuatu Fisheries Department are common in the Pacific. The Resource Assessment Branch (RAB) is small and has relied on technical assistance for a number of years from the French overseas scientific organisation ORSTOM[1]. One ORSTOM staff member was attached to the Fisheries Department to provide information for the management of deep slope fisheries. Technical assistance for other resource management studies eg trochus, green snail, etc.was provided by the attachment of volunteers from the French organisation VSNA[2]. The ORSTOM technical position attached to fisheries is likely to be moved to another department in the future. The present staffing of the RAB is one biologist. Further, one technical staff member that worked in the RAB and who was responsible for the maintenance of computers and database management has left for employment elsewhere.

The Fisheries Department has submitted a plan for an expansion of the RAB but this is yet to be approved by the Vanuatu Government. The expansion of the RAB will include two new biological positions and technical staff, one of whom will be in charge of computers and database maintenance. The Department will also seek external funding for a research advisor to direct research activities and improve the level of skills within the RAB. In the interim, the Fisheries Department requested that South Pacific Commission Fisheries Programme review the present collection of fisheries statistical data and suggest ways in which the flow of information for extension and management can be improved. The request to the SPC also specified provision of the terms of reference for the research advisor.

Fisheries research and statistical data collection has been previously reviewed in Vanuatu by Wright (1989) and Dalzell (1990) (attached here as Appendix 3). This review concentrates principally on the various fisheries statistical data collection programmes in Vanuatu discusses how these can be improved. In order to demonstrate the value of the present fisheries data collection, some analyses are also made of one of the data currently generated from the fisheries

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1. ORSTOM = Institut Francais de Recherche Scientifique pour le developement en Cooperation

2. VSNA = Volontaire du Service National Actif

extension centres in Vanuatu. Finally, the terms of reference are given for a Fisheries Research Adviser to be appointed to develop more effective fisheries data collection and dissemination in the Department's Resource Assessment Branch.

FISHERIES DATA COLLECTION

Information on fish catches in Vanuatu comes from three sources. The oldest of these is the catch record system established by ORSTOM, principally for monitoring the dynamics of the deep slope fishery. Deep slope fisheries resources in Vanuatu began to be seriously exploited after 1982 when the Village Fisheries Development Project (VFDP) was established. The VFDP provided assistance to ni-Vanuatu villagers who wished to fish on deep slope fish stocks, but lacked the available capital for a vessel and gear, and the expertise to catch, preserve and market deep slope fishes. Coincident with the development and extension of deep slope fishing was a catch data recording system designed to monitor the progress of the fishery.

From 1982 to early 1987, village fishing projects were obliged to keep a daily record of each fishing trip in order to qualify for purchasing duty free fuel. The data collected on these form as specified total catch, duration of fishing trip, fish sales and expenses incurred for the particular trip. Over 11,000 fishing trips were recorded in this manner between 1982 and 1987. Trip record forms were also available from ORSTOM and a reward of 50 vatu was provided for completed daily trip forms as an incentive for the fishermen. This programme started in mid 1983 and recorded information on location of fishing area, fishing depth in metres, catch by gear type, duration of fishing trip and measurement of all fish belonging to the eleven major species in the catch. A total of 2391 trip records were compiled on this form and a total of 30,616 individual fish were measured.

In 1987 the trip record forms of the Fisheries Department and ORSTOM were merged to avoid conflict of information and misreporting. The new form permitted the fishermen to but duty free fuel and ORSTOM maintained the incentive payment of 50 vatu. As in the past the new form was produced in Bislama (Appendix 1) and consists of a series of questions designed to solicit information on catch, fishing effort, income and expenditures. Collection of data throughout this form has been maintained from 1987 to the present.

No direct record was made of the species composition on the merged form or on its predecessors. Instead, the lengths of the eleven common species could be used to compute weights from length-weight relationships, and thus express these as a percentage of the total reported weight. The numbers of fish in the catch are not recorded. The numbers of the eleven commonest fish in the catch can be obtained from the length observations but these can not be expressed as percent composition in the same manner as weight.

Although the ORSTOM-VFDP form has served a useful role in monitoring the deep slope fishery and estimating MSY, it was not designed to provide the type of information for fisheries extension and development officers. This problem was addressed in 1989 and 1990 by the introduction of a new data collection system operated by fisheries extension centres and the two main fish markets in Vanuatu (Natai in Port Vila and Santofish in Luganville). This system, the goods received note (GRN) is essentially a receipt for fish purchased from fishermen Appendix 1). The data collected from the GRNs falls in to two categories, that collected from fisheries extension centres and that from the two fish markets

The receipt used at fisheries extension centres records details of the trip length (in hours) and composition of the catch. The catch composition is given in numbers, weight and value and contains 13 bottom fish species, 4 large pelagic species, 3 coastal small pelagic species and mixed reef fish. Fishermen reporting their catch to extension centres and the fish markets are then eligible for duty free fuel. Some fishermen do not wish to sell through the government institutions but do want the duty free fuel. They can become eligible for the cheap fuel by filling in GRNs themselves when they return from fishing trips.

The GRN from Natai and Santofish is simpler and contains no record of fishing effort or catch composition (Appendix 1). Catch composition is, however, usually recorded, based on the price listing used at these markets. Hence all eteline snappers are listed as 'poulet fish', groupers as lôche, lutjanine nappers 'snappers' or 'sea perch' etc. Reef fish are usually grouped as mixed reef fish or in some instances parrotfish are distinguished as 'blue fish'.

A fourth data source that is implicit in the records of catches from the Santo are the catch records made by the Fisheries Training Centre (FTC) in Santo (Appendix 1). The training centre was established to support Vanuatu's developing small scale fishing industry by providing villagers wanting to become fishermen with the necessary skills to maintain and run a small scale fishing operation. The training courses include many hours spent fishing which generates a substantial fish catch. This is sold to Santofish and accounts for up to half the annual volume of fish processed through this market.

The data collected by the FTC is similar to the information on the ORSTOM form and records in detail the catch, fishing effort and catch composition, and the value of the catch. However, most of the fishing data is concerned with catches from the south coast of Santo. In the future, catches from the FTC will likely contain greater volumes of pelagic fish caught around FADs deployed off the south Santo coast. Besides the training imparted to the fishermen, the reason for targeting on large pelagics is to generate income for the FTC as Government funds will not be sufficient.

The ORSTOM data and the GRN data from the extension centres and the two fish markets are entered into computer files using DBASE 4. Three databases have been constructed to file and summarise the data. Data entry is now a familiar routine in the Department and presents no problems to the staff. Unfortunately, DBase programmes require that report sub-programmes be written to summarise the data in a given manner and print it out. The report programmes for the three databases are incomplete and only one (for the extension centre GRN data) is working well enough to produce useful summaries (see further below).

Little use is made of the data collected on fin-fish production in Vanuatu to produce reports and management advice. The last document on deep slope fish production produced by Department was the paper in 1989 resulting from the USAID-NMFS workshop on tropical deep slope fisheries in Hawaii (Carlot & Cillauren 1990). Previous reports on the deep slope fisheries resources in Vanuatu include Brouard & Grandperrin (1983), Schaan et al (1987) and Carlot & Nguyen (1989). All of these papers are concerned with aspects of stock assessment of the deep slope resources based on historical data and do not reflect the present nature of the fishery that is based around the extension centres and the Natai fishmarkets.

Subsistence fisheries production can be estimated from the smallholder agricultural survey, conducted in 1990 (Anon 1991). According to the survey about 70 % of the population fish in any one week, with an average of three fish meals per week. Assuming an average portion size of 150 g and using a 1990 population estimate of 146,400, then the total subsistence fisheries production is estimated at 2,295 t. A further 353 t of shellfish can be added to this based on similar data for the 30 % of the population consuming shellfish in any one week, with an average of three meals a week and a portion size of 50 g.

Little information is available on the recent harvests of trochus and other similar molluscs. Prior to the expansion of the button and ornamental shell industry since 1990, the annual harvest of trochus and other shells amounted to less than 100 t/yr. The button factories are not permitted to export whole shells and the only information that is available are the records of the exports of button blanks from the Vanutau Customs Office. There is presently no information being collected from the on the levels of harvesting and on the size frequencies of the shells collected from the different islands.

Most coconut crab is sent to the main island of Efate for the tourist industry, however, there is again little to no information on the volume of production. Since all crab shipments are made by air it might be possible to determine these through checking the Van Air freight records. Concern at the levels of harvest have caused a moratorium on sales of coconut crabs during the breeding season.

ANALYSIS OF EXTENSION CENTRES AND NATAI FISH MARKET DATA.

Extension Centres

For the purposes of this report, the data from the six extension centres (Lakatoro, Lamen Bay, Lolowai, Pentecost, Sola and Tongoa), collected between 1990 and 1991, was summarised from the GRN database. This represents over 1000 fishing trips generating a catch of about 32 tonnes worth 5,230,833 vatu. Most of the landings at the six extension centres are thought to be fish caught on the deep reef slope since high value large pelagic fishes such as mahi-mahi and yellowfin tuna are usually marketed privately.

The extension centres are shown ranked by the total landings over the two year period in Figure 1. The greatest volume of fish. 11.3 t, was landed at Lamen Bay and the least at Lolowai. Lamen Bay and Lolowai had the respective maximum and minimum values of the catch (Figure 2), as might be expected, however, the ranking order by value of the other four extension centres was not the same as for volume of landings. This is due to a combination of the various prices paid for different fishes and the spoilage and disposal of fishes that were not sold.

The catch per unit effort (CPUE) for fishes landed into the extension centres can be expressed as kg per trip or as kg per trip-hour. The average cpue expressed per trip and trip-hour for fishermen landing into the six extension centres is shown in ranked order in Figures 3 and 4. The ranked order of average cpue on a per trip basis is quite different from the ranked order of the cpue expressed per trip hour. The greatest volume of fish per trip is landed at Lamen Bay, but the greatest hourly catch rates are experienced by fishermen landing at Lolowai.

It is difficult to comment on these data without making corroborating observations in the field. The main criticism of both expressions of fishing effort is that they are too crude and do not take into account numbers of fishing gears or the types of gears used. Trip length is likely to vary between the different locations and will be a factor of distance from the fishing grounds, Type of fishing (ie trolling or bottomfishing) and possibly social factors such as the need for cash to meet eduction fees or other responsibilities.

The cpue values for each extension centre were averaged over the months of the calendar year then smoothed with a running average of three (Figure 5). There is a clear peak in the average CPUE between February and April, followed by a smaller less obvious peak between July to September. The periods between these two peaks in cpue are 5 and 7 months, which may reflect biological and behaviourial responses of the fish to climate driven seasonal environmental changes leading to increased catchability in March and August. The seasonal variation in the monthly frequency of fishing trips for 1990 and 1991 was also very similar to the variation in CPUE (Figure 6) and may reflect the greater incentive for the fishermen to go fishing during periods of increased catch rates.

The average weights of the fishes landed at the six extension centres are shown in Figure 6. The average weight of fish landed at all centres except Pentecost ranged from 1.5 to 2.7 kg. The average weight of fish landed at Pentecost was 9.9 kg and was considerable larger than the range of values for the other extension centres. The fish landings at Pentecost are from fishing grounds that have only been exploited relatively recently and thus the larger individuals that are normally removed form the population through persistent fishing are still being captured at Pentecost. It would be interesting to analyse this data further when species composition data can be extracted from the GRN database.

The fishing effort for landings at the GRN can be expressed as number of trips or total trip hours. Trip hours are not always reported by the fishermen, although trip hours is probably a better expression of fishing effort than simply trips. However, the average trip length could be computed from the GRN data and then multiplied by total number of trips to obtain fishing effort. The total catch between 1990 and 1991 for each of the six extension centres is shown plotted against the corresponding total effort in Figure 7 and the CPUE versus effort in Figure 8. The data suggest that CPUE declines with effort and that relationship between catch and fishing effort might be explained by a simple surplus production model.

This analysis is not taken any further here since the catch and fishing effort are expressed as simple totals and not as functions of the area fished. Further, the catch data refer to a multispecies complex and not to a single species. Conventional production models describe changes in catch in response to changes in fishing effort at one location over time. These data refer to six different locations fished over the same time period. Such an approach has been used by other workers (Munro & Williams 1985; Lock 1986) in the absence of long time series of data on catches.

Natai Fish Market

The composition of landings to the Natai fish market in Vila between January and September 1991 is shown in Figure 9. The dominant feature of the catch is poulet fish or eteline snappers, which account for about half of all landings. The eleven other species that are recorded in the catch such as amberjack and bream, comprise about 13 per cent of landings.

The 'other species' category of fish are mainly shallow water reef fishes which have been increasingly targeted for commercial catches and now account for about 34 % of fish sold through the Natai market in Port Vila. However, little is known about the true composition of these reef fish catches, with most emphasis being given to recording details of the bottomfish and large pelagics at both the fish markets and the extension centres. From observations at the Natai facility, parrotfish, goatfish and small emperors were dominated the reef fish catches. Normally a mixed reef fish catch is so recorded, without any separation into component groups. Occasionally parrotfish are recorded as bluefish due to the preponderance of blue species in this family.

Concluding remarks on the GRN and Natai data

The analyses of the GRN and Natai data presented here are not meant to be accepted as definitive studies. They are presented to show what is possible with the data presently available. These results could be greatly improved by a more detailed summary of information from the databases and, especially in the case of the GRN data base, looking at catches of individual species and species groups.

Greater definition needs to be given to the areas fished by fishermen landing into each extension centre. This information is reported on the GRN forms but was not retrievable for this study. The scatters of points in Figures 7 and 8 suggests that production models based on spatial variation in fishing effort may be a useful approach to managing deep slope fishery resources in Vanuatu

The recommended types of output that should be routinely produced from the various fisheries databases are summarised in Appendix 2. The majority of these data summaries can then be written up as an annual report on the fishing industry in Vanuatu. Attached with this report as Appendix 3 is the earlier review of fisheries research in Vanuatu by Dalzell (1990), which contains detailed synopses of the various fisheries in Vanuatu and some suggested methods about how information from these fisheries might be analysed.

PUBLICATIONS AND REPORTS

There is an increasing volume of data being collected in Vanuatu on fisheries production. Information is not only generated through records of landings but ancillary activities such as the recent smallholder agricultural survey (Anon 1991) produce substantial amounts of information on fish consumption and fishing activity for finfish and other marine resources such as trochus. However, apart from the smallholder survey, none of the information on fisheries production in Vanuatu is being regularly condensed and summarised into reports, with the result that valuable information on the status of coastal fishing in Vanuatu is not being used for development and management.

Several consultancy reports have been produced on the operations of the VFDP deep slope fishery (Anon 1987, Shepherd 1988, Anon 1992) as well as a number of internal annual reports on the activities of the extension centres. These reports are characteristically individual reports, not for the public domain, and do not present catch data in the form required by the extension service. What is required is a regular report on the catch data, probably in the form of an annual report on fisheries production that includes other data on shellfish etc.

FISHERIES STATISTICS AND THE FISHERIES RESEARCH ADVISER

Fisheries statistics

It should be emphasised here that the databases for fisheries production account for about 37 per cent of landed volume of fish in Vanuatu (Anon 1992). The majority of commercial fisheries production in Vanuatu is either marketed privately to restaurants, hotels and stores, or enters the subsistence economy at the village level. Some species of fish such as mahi-mahi (*Coryphaena hippurus*) big yellowfin, wahoo, coconut crabs and lobsters are rarely seen in the public markets and are mostly marketed privately to hotels and restaurants for the tourist trade.

Thus the databases do not reflect the fisheries sector as a whole in Vanuatu and information from other sources will be required to give a complete picture of fisheries production.

Part of the problem relating to fisheries statistics and fisheries monitoring in Vanuatu is the limited scientific personnel available for such work. The RAB presently has one fisheries biologist who has been working mainly on trochus resources. The collection of information from the deep slope fishery was the responsibility of and ORSTOM scientist and ORSTOM has paid for the salary of one technical staff member to assist the ORSTOM scientist.

Whilst the association with ORSTOM has been beneficial, there is a negative aspect in that the RAB has not developed its own in-house capability for research and monitoring of deep slope and other fin-fish resources in Vanuatu. The new staff structure of the RAB includes two additional biologists positions and two technical officers. One biologist in the RAB should be devoted to monitoring of the village based coastal fisheries and is here provisionally designated as the Fisheries Analyst and Statistical Officer (FASO).

The duties of the FASO would be to oversee the collection of fisheries statistical information from the extension centres and the two Natai facilities. This would not simply mean ensuring the data was entered into the computer but checking and validating the information at the extension centres, improving the databases where possible based on field observations and looking at collecting information on fish landings that do not pass through the government establishments.

The main output of the FASO would be summaries of the catch and effort data summaries in report form and to supply information required by other branches of the Fisheries Department or indeed other government departments. However, the FASO should not simply be concerned with the compilation of fisheries production data, but as a biologist analyse the information and describe the nature of the fisheries and any significant observations and results.

For example, the increase in the volume of shallow water reef fish landed at government fisheries centres is an important development in the exploitation of Vanuatu's coastal fisheries resources. This switch to shallow reef fish was initiated by the Fisheries Department to relieve fishing pressure on the deep slope fisheries resources. These have not been as productive as was first thought and the profitability of village based fishermen fishing on deep slope resources is marginal.

If shallow reef fish stocks are going to be increasingly targeted in Vanuatu by commercial fishermen, then attempts will have to be made to estimate sustainable yields. The possibilities of using a production model based on spatial effort variation might also be applicable for shallow reef fisheries as has been indicated by workers elsewhere.

Research Adviser

The Research Adviser would coordinate all fisheries research related activities within Vanuatu on fin-fish, trochus and other molluscs, coconut crabs and subsistence fisheries. This very important, as not all fisheries research in Vanuatu has been carried out by biologists of the RAB (eg coconut crab research, trochus research) but this should still be initially reported to the Research Adviser so that progress can be reviewed and management information made available ahead of formal publication of results. The Research Adviser would liaise with regional organisations such as FFA and the SPC Fisheries Programme to undertake training of RAB staff and to conduct work that might be beyond the scope of the limited number of staff in the

RAB.

The type of work to be carried out by the FASO will require a person with experience of tropical multispecies artisanal fisheries. It is likely that the FASO will be a recent graduate from a biology or fisheries degree and will not have much field and analytical experience. The same is true of the other officers in the RAB, with the exception of the senior biologist. However, given that most fisheries research functions have, until recently, been conducted by ORSTOM, there is a need for a Research Adviser to oversee and direct fisheries research in the RAB whilst the scientific and technical staff gain direct work experience.

The Research Adviser should be a fisheries scientist with considerable experience with tropical fisheries and familiar with the conditions that prevail in developing economies such as Vanuatu. The Adviser should have a strong back ground in population biology and fisheries management, and have proven abilities to collect, collate, summarise and draft reports and papers on exploited fisheries resources. Ideally, the Research Adviser would have experience of the Pacific region or the Indo-Pacific region, and be familiar with the types of fish and marine resources exploited there.

By working with the Research Adviser, the RAB staff would receive in-house training in a variety of statistical and analytical skills. The Research Adviser would implement the types of data summary and analytical routines outlined in this report and then assist staff in carrying out these tasks. The Research Adviser would set priorities for research and monitoring based on the Government policy. The RAB would then be responsible for providing an annual report on the status of fisheries production in Vanuatu, for drafting technical reports on specific fisheries and for supplying information for management and development of Vanuatu's fisheries resources.

Ultimately the need for a Research Adviser should diminish as the RAB biologists gain experience in the collection, interpretation and reporting of fisheries data. The duties of the Research Adviser would then be assumed by the Senior Biologist. The initial period where a Research Adviser is attached to the RAB should be for three years to allow sufficient time for progress to be made in the collection of data from Vanuatu's fisheries and to permit sufficient time for developing job related skills. The future of the Research Adviser could then be reviewed following this three year period

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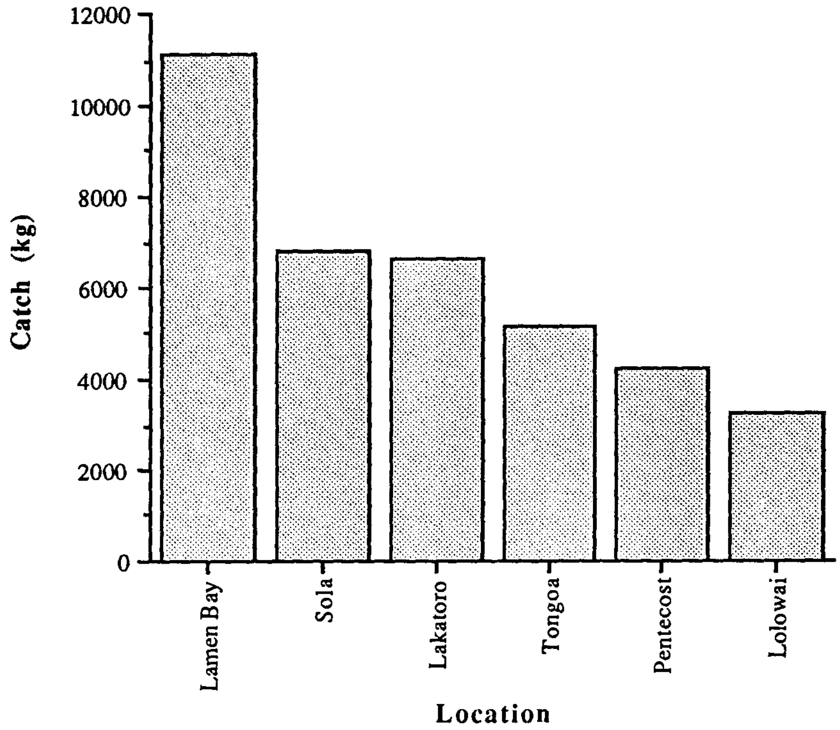

Figure 1. Landings of fish at six extension centers in Vanuatu between 1990 and 1991

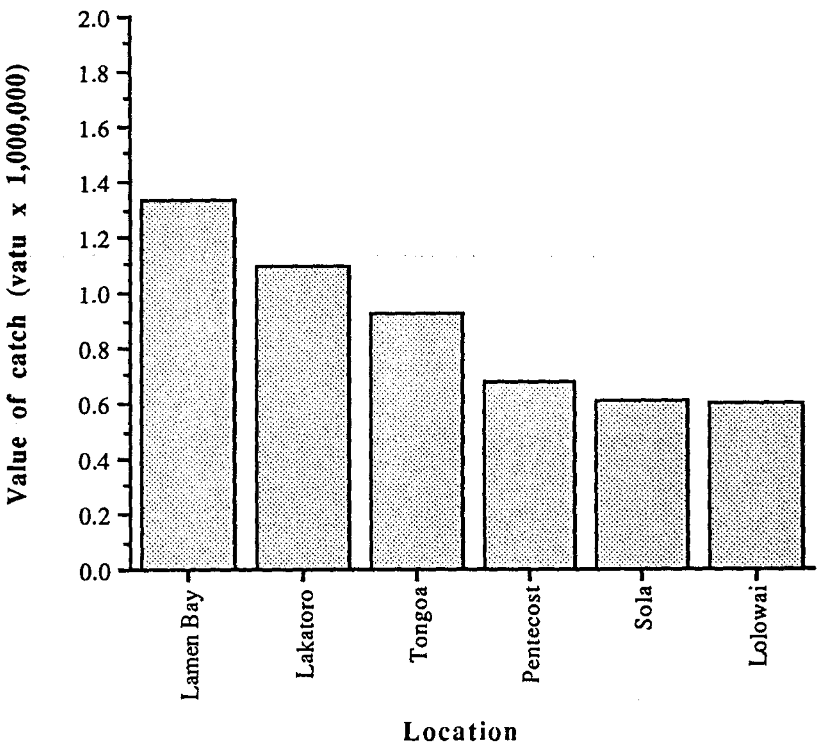

Figure 2. Value of fish landings at six extension centres in Vanuatu between 1990 and 1991

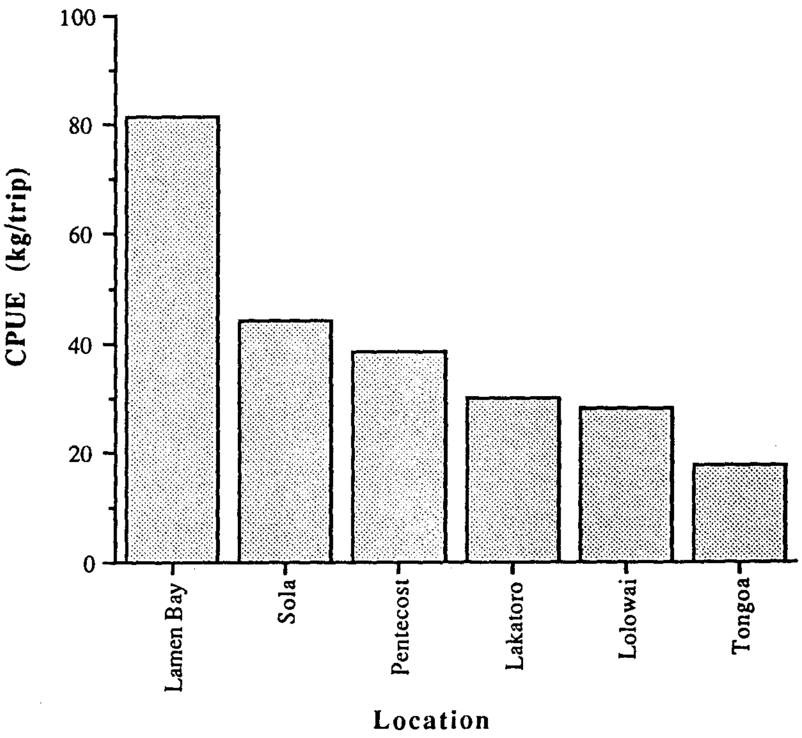

Figure 3. Average CPUE in kg/trip for six extension centres in Vanuatu between 1990 and 1991

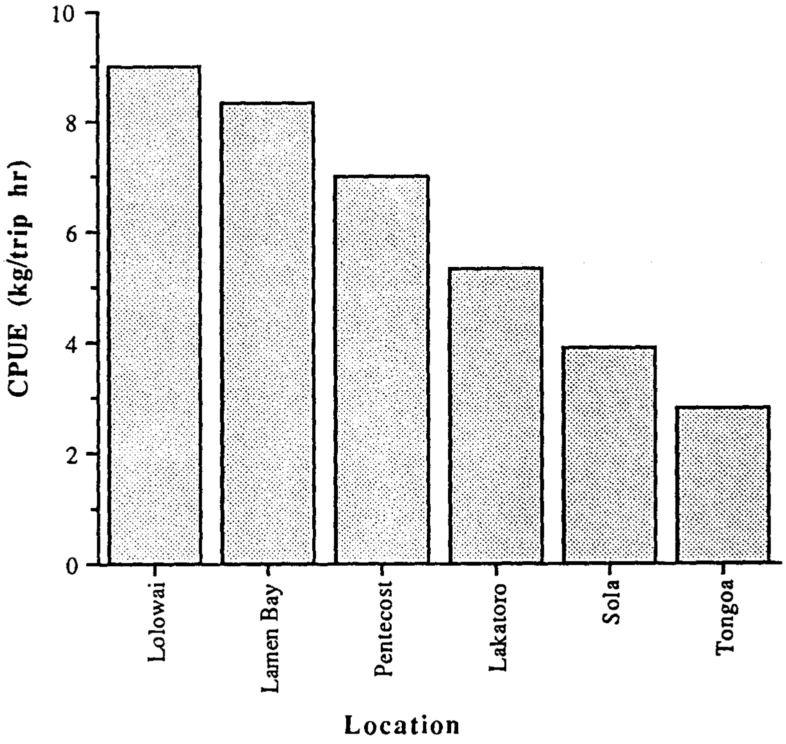

Figure 4. Average CPUE in kg/trip-hr for six extension centres in Vanuatu between 1990 and1991

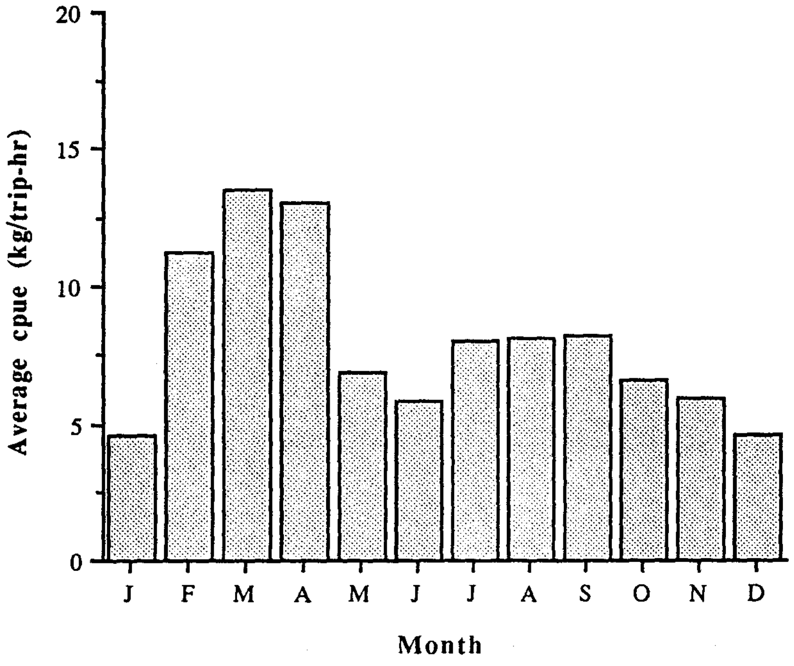

Figure 5. Average monthly CPUE from all six extension centres in Vanuatu between 1990 and 1991

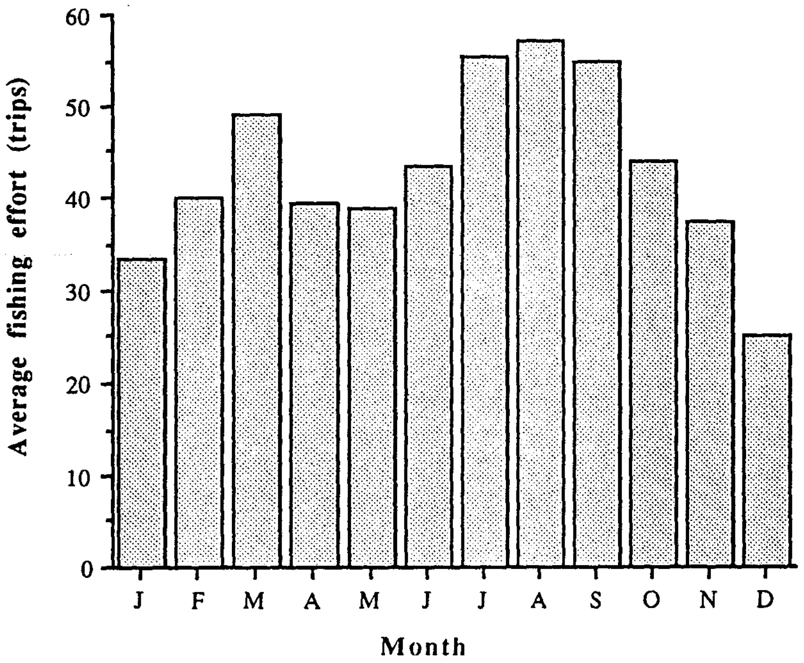

Figure 6. Average total monthly fishing effort in trips for six extension centres in Vanuatu between 1990 and 1991

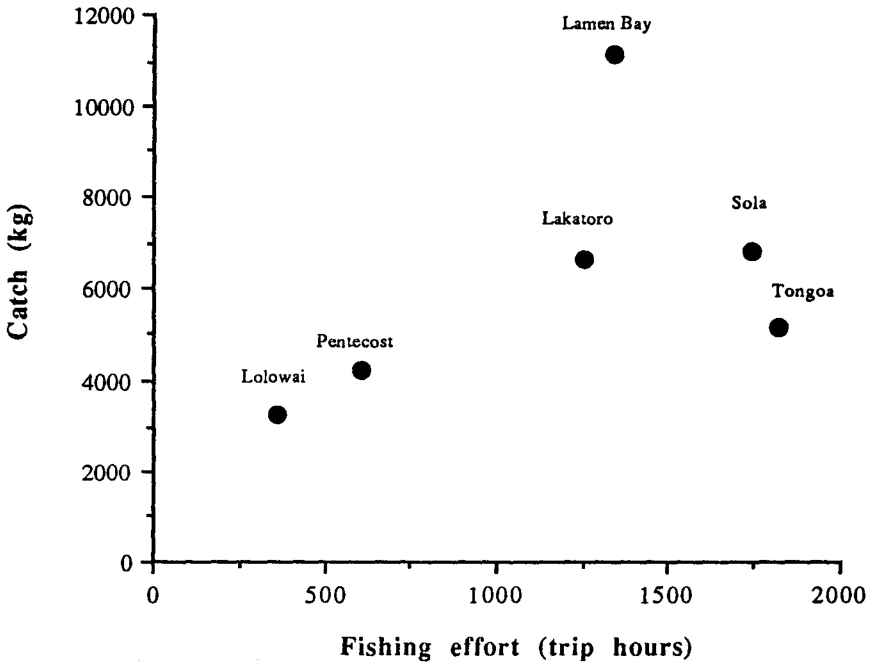

Figure 7. Catch versus fishing effort for six extension centres in Vanuatu between 1990 and 1991

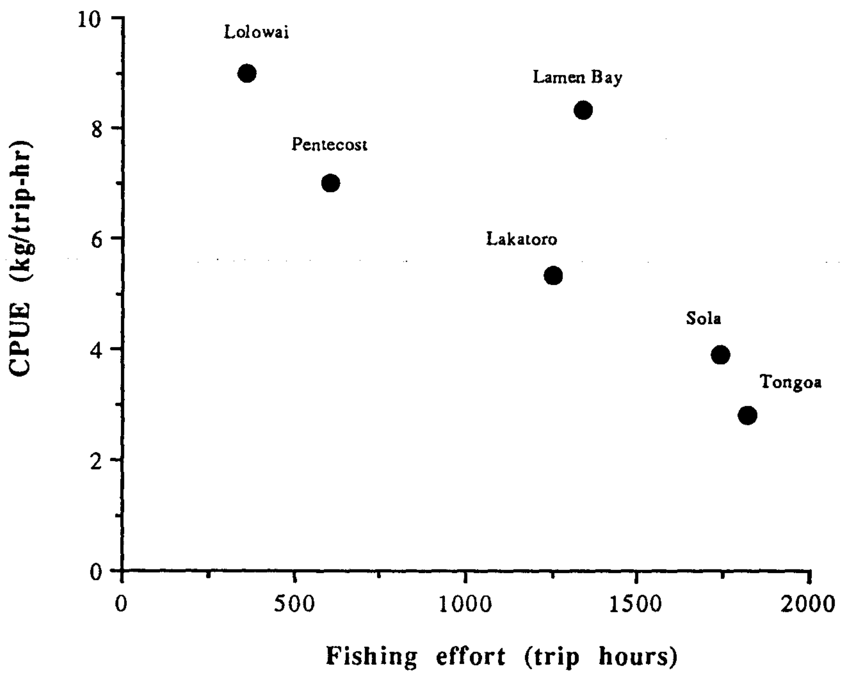

Figure 8. CPUE vs effort for six extension centres in Vanuatu between 1990 and 1991

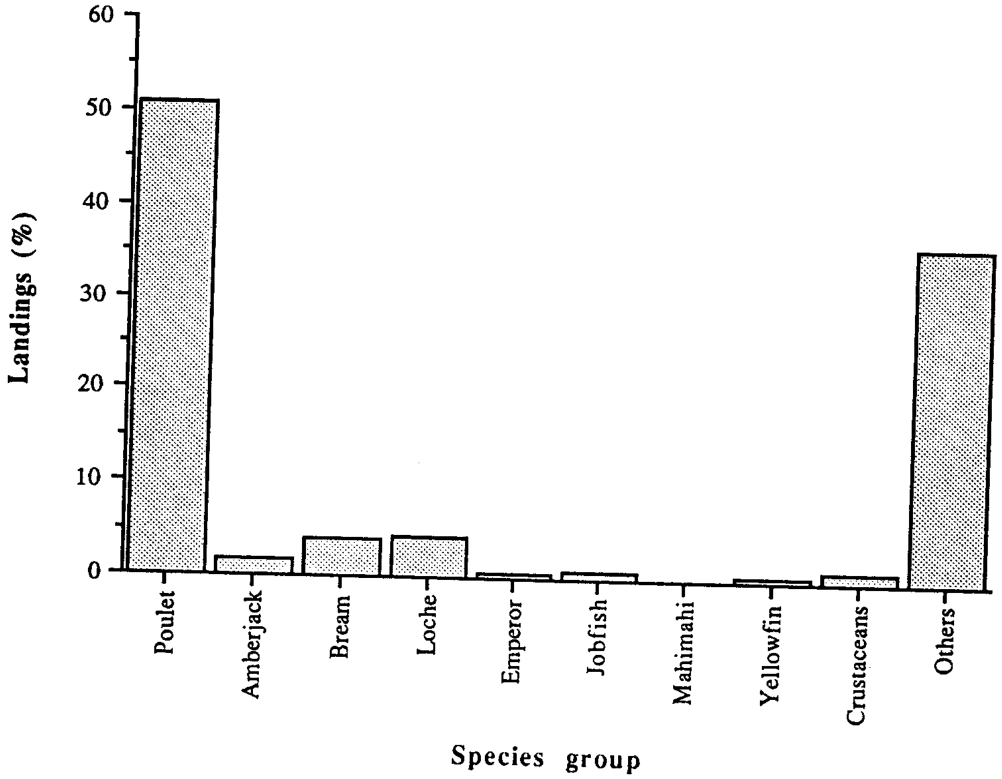

Figure 9. The composition of fish landings at Natai fish market, Port Vila, between January and September 1991

APPENDIX 1. examples of the forms used to collect fisheries data in Vanuatu.

No. 1 = ORSTOM-VFDP form, No. 2 = Extension Centre Goods Received Note, No. 3 = Natai Good Received Note, No. 4 = Fisheries Training Centre fishing record

VILEJ FISING PROJEK

REKOT BLONG FISING LONG WAN TRIP

DP - 1

Nem blong kampani : FATWAO

Nem blong bot : FATWAO	Hamas man i stap long bot : 3
Deit yu ko aot : 25 - 02 - 92	Taem yu ko aot : 6 - Am
Deit yu kam bak : 25 - 02 - 92	Taem yu kam bak : 11 - Am
Fising eria : South and north	Fising depth :
Hamas line yu usum long dip solwota : 2 (two)	Hamas line yu usum long trolling :
Hamas kilo fis yu kasem long dip solwota : 39.5 kg	Hamas kilo fis yu kasem long trolling : kg
Taem yu start bottom fising : 6 Am	Taem yu start troll :
Taem yu stop bottom fising : 11 Am	Taem yu stop troll :
Wanem kaen beit yu usum : local beit	Hamas kilo beit yu usum : — kg

INCOME

Hamas mane yu kasem long fis sales : 7,900 VT	Nara income : — VT

HAMAS MANE YU USUM

Benzene/oel : 20 litres	Repair mo maintenance : —
Samting blong fising : —	Freight : 2000 VT
Pay : —	Ol nara expense : —

Nem blong fis	Mesament blong fis (length long cm)
Etelis coruscans	
Etelis carbunculus	
Etelis radiosus	
Pristipomoides multidens	
Pristipomoides filamentosus	
Pristipomoides flavipinnis	
Epinephelus magniscuttis	
Epinephelus morrhua	
Epinephelus septemfasciatus	
Lutjanus malabaricus	
Aphareus rutilans	

REMARKS

REPUBLIC OF VANUATU

FISHERIES EXTENSION SERVICE
FISHERIES DEPARTMENT
GOODS RECEIVED NOTE

GRN 5603

Extension Centre Lugo Village S.W. Bay Malekula Date 24-06-92.

Fishing Project Mamboncu Naki Procode Mambonc Naki

Fishing Area Dixon S.W. Bay Trip Length 10 Hours

PIECES	SPECIES		KILOS	PRICE	VALUE
	E. carbunculus	(Red Short Tail)			
	E. coruscans	(Red Long Tail)			
	E. radiosus	(Silver Jaw)			
	P. multidens	(Large Scaled Jobfish)			
	P. flavipinnis	(Yellow Jobfish)			
	P. filamentosus	(White Poulet)	12	200	2400
	L. malabaricus	(Red Snapper)			
	A. rutilans	(Green Jobfish)			
	S. rivoliana	(Amberjack)			
	E. magniscuttis	(Spotted Loche)			
	E. morrhua	(Brn. Striped Loche)			
	E. septemfasciatus	(7 Banded Loche)			
	G. unicolor	(Dog Tooth Tuna)			
	T. albacares	(Yellow Fin Tuna)			
	K. pelamis	(Skipjack)			
	T. alalunga	(Albacore)			
	C. hippurus	(Mahi-mahi)			
	M. seheli	(Mullet)			
	S. crumenophtalmus	(Mangreau)			
	Clupea sp.	(Sardine)			
	Mixed Reef Fish				
	Other Species		1.5.	150	225
		TOTAL	13.5.		2625

Received from Fisheries Extension Service 2625 VT.

Signed [signature]

"NATAI"

PORT VILA FISHERIES LIMITED
P.O. Box 883, Port Vila — Telephone : 23344
P.O. Box 211 — Luganville, Santo — Telephone : 36841

GOOD RECEIVED NOTE № 13619

Date : 22/9/92

Received from : Lakatoro Malekula

AWB No :

Bag No's :

CODE
Grade A - First Grade
B - Second Grade
C - Third Grade
IKE - Killed
HIG - Headed & Gutted
H/G - Head Off
G&G - Gilled & Gutted
WH - Whole
L - Live
D - Dead
F - Frozen

Description of Goods	Code	Kgs	Price	AMOUNT Vts
POULET		80.6	310	24.986
SNAPPER		4.5	280	1.260
LOCHE		18.9	220	4.158
REEF FISH		23.2	255	5.916
AMBER JACK		2.4	200	480
SNAPPER REJECTED		16.6		—
POULET		8.6		—

Total Kgs 129.6 Sub Total

Goods Received Signed : [signature] Freight Ded

Approved Payment Signed : [signature] Other Ded

Till Cash .... Cheque No. 0525409 Total Payable 36.800

RECORD OF TRAINING TRIP NO.________

NAME OF BOAT________________ INSTRUCTOR______________________

TRAINEES 1.____

2.____

3.____

4.____

DATE OUT________ DATE IN________ TIME OUT________ TIME IN______

NO. HOURS OUT______ DAY/NIGHT FISHING______ FISHING AREA________

BAIT____________ FUEL USED__________________________________

TOTAL WHT. LANDED__________KG.

SPECIES	NOS.	KG.	VT/KG
1. Etelis coruscans			
2. " carbunculus			
3. " radiosus			
4. Pristipomoides multidens			
5. " filamentosus			
6. " flavipinnus			
7. Epinephelus magniscuttus			
8. " morrhua			
9. " septemfasciatus			
10. Lutjanus malabaricus			
11. Aphareus rutilans			
12.			
13.			
14.			
15.			
16.			

TOTAL REVENUE__________ VT.

MONEY FROM SANTO FISH__________ PAID TO TREASURY___________

% TO INSTRUCTOR_________ % TO TRAINEES__________

SEA ALLOWANCE TO INSTRUCTOR __________ GOVT. TO INSTRUCTOR________

COMMENTS.

APPENDIX 2. Suggested criteria for report programmes for fisheries databases

Extension centres GRN database

1. Monthly catch by weight and numbers, and value in Vatu by extension centre

2. Monthly fishing effort in trips and trip hours by extension centre

3. Monthly average trip hours by extension centre

4 Fishing effort from (ave trip hours x no trips) by extension centre

5. CPUE in No/trip-hr and Wt/trip-hr by extension centre

6. Same as the above but with individual species or species groups.

7. Same as the above but using records from individual fishermen or fishing groups

8. Species composition by month in numbers and %, and weight and %, for each extension centre with an annual summary

9. Species composition by month in numbers and %, and weight and %, for individual fishermen or fishing groups

9. All the above to printed as tables for years specified

Natai GRN database

1. Monthly landings by species in weight and %, and annual summary

2. Monthly value of landings by species groups

3 Monthly summary of landings by species by source of supply

4. All the above to be printed as tables for years specified

ORSTOM fishermen catch sampling form

1. Monthly summary of catch returns by month by different islands/fishing ground

2. Monthly summary of catch, effort and CPUE for island/fishing ground for bottom fishing and troll fishing

3. Species composition by month for bottom fishing and troll fishing by island/fishing ground

4. Monthly summary of CPUE for different species from bottom /fishing and troll fishing by month

5. Monthly income from fishing by fishing ground/island

6. All the above to be printed as tables for years specified

FTC training vessel catch database

1. Monthly landings by species in weight and numbers and annual totals

2. Monthly landings by species in percentage weight and numbers and annual means.

3. Monthly total CPUE by gear type for total catch

4. Monthly total CPUE by gear and species

APPENDIX 3

A review of fisheries research activity in the Republic of Vanuatu

by

P. Dalzell
Inshore Fisheries Scientist
Inshore Fisheries Research Programme
1990

South Pacific Commission
Noumea, New Caledonia

Executive summary

1. A review is made of the fisheries research activities in Vanuatu and the present status of knowledge on the exploitation of marine resources.

2. Changes in the infrastructure of the deep slope fishery necessitate changes in the sampling programme that place more emphasis on the collection of fishery and biological data from central landing areas and less reliance on the fishermen themselves supplying the information.

3. Attempts should be made to estimate the fraction of the deep slope catch that is disposed of privately so that a more accurate total production estimate can be determined for management purposes. A survey of the volume of fish and other marine organisms disposed of through stores and restaurants in Port Vila is recommended.

4. Attempts should be made to determine the total commercial harvest of trochus and other molluscs in Vanuatu. This will require that all shell factories are obliged to provide information on the amounts of shell shipped to them. Sampling of shipments from different locations will be required beyond the normal categorising of shells into 0.5 cm size classes.

5. Efforts should be made to determine what information is available about some of the other marine resources such as beche-de-mer, coconut crabs and lobster. As these animals are either exported or transported into Port Vila by air, records of shipments should be available to determine production.

6. It is recommended that a person in the Fisheries Department be specifically assigned to the collection of fisheries statistics, particularly on those resources not presently covered by established sampling programmes. this position might be created and then funded from external sources or by organising existing people in the Department.

7. A management unit should be established within the Fisheries Department that recommends and enforces legislation. The unit would comprise representatives of different branches in the Department and would oversee and review the progress of research and monitoring programmes

8. Various stock assessment methods are suggested by which the status of the deep slope stocks and other resources can be determined. In general, more effort directed towards summarising, analysing and writing up research data is recommended. Help from the SPC Inshore Fisheries Research Programme should be solicited for reports on those resources not covered under the present Fisheries Department/ORSTOM agreement.

Introduction

The Republic of Vanuatu is a Y-shaped archipelago in the western South Pacific, extending 875 km on a north-south axis between 13 and 21°S. The archipelago is composed of about 80 islands with a total land area of 14,800 km^2. The islands of Vanuatu are, for the most part, bordered by narrow fringing reefs and beyond the reef slope the shelf descends steeply into deep water. There is an estimated 7358 km^2 of shelf around the various islands (Brouard & Grandperrin 1985) in depths between 100 and 400 m. The exclusive economic zone of Vanuatu extending to 200 nmi from the shore, encloses an area of 848,000 km^2 of ocean. Vanuatu lies completely within the tropics and has an average air temperature of 25_0C and sea temperature 26.3°C.

The total population of Vanuatu was estimated in 1984 to be 127,800 people of which 70 % live on the coast. Most of the people of Vanuatu are Melanesian (known as ni-Vanuatu) and comprise 92 % of the population. Certain areas of Vanuatu such as Erromanga suffered severe depopulation in the 19th century due mainly to the introduction of disease from the European colonists. However, in common with many other nations of the South Pacific the Republic of Vanuatu presently has a very high population growth rate (estimated to be 3.7 %/yr in the early 1980s [Connell 1984]) with a population doubling time in one generation or 25 years.

There are two major urban centers, the capital of Port Vila on the island of Efate, and the town of Luganville on the island of Espiritu Santo. The economy of Vanuatu is poorly developed with little manufacturing industry. The main sources of revenue are primary industry and tourism. Copra, cocoa, coffee and beef are the principal exports of Vanuatu. Albacore (Thunnus alalunga) and yellowfin tunas (*Thunnus albacares*), captured by commercial longliners were also transhipped from Vanuatu until 1986 when operations of the South Pacific Fishing Company [SPFC] were transferred elsewhere. The main commercial fishing activity at present is a small scale artisanal fishery for deep reef slope snappers and groupers that has recorded landings of about 50 tonnes annually.

Other commercial exploitation of marine organisms include the harvesting of trochus (*Trochus niloticus*) and other shells for mother of pearl production, coconut crab (*Burgus latro*) for the local restaurant trade, and beche-de-mer for export to Asia. Exact figures for the production of these resources are not available. The subsistence harvest of fish and marine organisms in Vanuatu has been estimated to be about 2403 tones of which 42.5% consists of fin fish, 33.5% molluscs, 20.5% lobster, 3.0% octopus and 0.5% prawns (David & Cillauren 1989). Imports of fisheries products to Vanuatu, principally tinned mackerels and sardines (93%), amount to about 800 t/yr.

Local production of fish and other marine organisms are likely to continue as an important source of animal protein for the ni-Vanuatu population. Further, fisheries are likely to continue as a source of income in a country with limited natural resources and development opportunities. It is therefore important that accurate assessments are made of the fisheries sector and in this regard, monitoring programmes that determine the status of the fish stocks with respect to exploitation. This report, prepared at the request of the Government of the Republic of Vanuatu, presents a review of the research and monitoring methods employed by the Fisheries Department of and suggests means for improving the statistical data base to manage the exploitation of fish and other organisms. The terms of reference for this review were as follows:

1. Review of data collection system.

2. Review Fisheries Department computer software usage.

3. Preparation and dissemination of information for fisheries managers

4. Identification of the need for external funding of research activities.

5. Provide a report with recommendations on the above.

This follows a previous report of fisheries research activity in Vanuatu made by Forum Fisheries Agency (FFA 1988) which examined the resource base, research needs and infrastructure of the Fisheries Department. It is not the intention of this report to duplicate that work but rather to complement it by focusing on the mechanics of data collection, and the types of analytical approaches that can be made to monitor stocks and thereby provide general statistical information for the Fisheries Department and other government agencies.

Fisheries Research in Vanuatu

Within the present Fisheries Department there are positions for two research officers and two economists who would be expected to undertake research and data gathering functions. In addition the French scientific organisation ORSTOM[2] provides the Department with a marine biologist and geographer under an arrangement established in 1979 with the Vanuatu Government. The ORSTOM staff also includes a technician and the occasional French volunteer, or VSNA[3], who spend just over a year in Vanuatu. This arrangement is unique in the South Pacific and means that much of the research effort in Vanuatu's fisheries is accomplished with little cost to the Government. Due to the integral role of ORSTOM's staff in the Fisheries Department, the comments and suggestions about research activities will be addressed collectively to both organisations.

Assessment and monitoring of fish stocks

A great deal has been written on the collection and analysis of data to assess the status of exploited fish populations and interested readers are directed to the books of Beverton & Holt (1957), Ricker (1975), Gulland (1983) and Pauly (1984) for reviews of the theory and methods, and an entry to the literature. Briefly, collection of data to assess fisheries can be divided into three types:

1. Short term intensive survey data; either using trial fishing, hydroacoustics or a combination of methods to obtain an estimate of the standing stock biomass of the population and then estimation of the potential yield as a function of the biological characteristics of the principal species

2. Long term collection of information on actual fishing activities; eg catch volume (either weight or numbers) and fishing effort, collected over time and often stratified by depth, species, time of day, geographic location, gear, etc. Common analyses made with this type of data include examination of variations in catch per unit effort (CPUE) with changes in fishing effort, when sufficient time series are available, and the estimation of maximum or optimum sustainable yield (MSY) and optimum fishing effort. Changes in CPUE of the catch and catch components can also be monitored over time as can the catch composition. This type of approach is often applied to tropical fisheries where diversity of species and gears makes recording further detailed biological data rather difficult

3. Long term collection of detailed biometric data; biological observations on all or some

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[2]. Institut Francais de Recherche Scientifique pour le Development en Cooperation

[3]. Volontaire Service National Actif

of the species in the fishery to determine the effects of fishing on the population(s). Estimates of the age and growth rate of component stocks are usually determined from reading time markers on skeletal hard parts, from tagging, from length frequency data, or a combination thereof. Estimates are made of mortality rates from fishing and natural causes and these parameters, along with growth data, are used to estimate yield as a function of the interaction of fishing gears with the biology and ecology of the species involved. Other allied studies include food and feeding studies, reproductive biology and the factors governing recruitment to the fishable stock. In the developing countries of the tropical zone, the problems due to the lack of resources to carry out such work can be compounded by such difficulties as reliable ageing of fish, and the sheer number of species, and their recognition.

Many fisheries research and monitoring programmes are a combination of the above approaches, particularly in countries with developed economies and large fishing industries. In the South Pacific the lack of financial and human resources common to most of the countries and territories militates against the implementation of long term routine data gathering programmes. However, fishing of marine resources targeted for commercial exploitation should not proceed without some form of monitoring to record at least the production or some index of it. This is not only to assess the scale of harvesting but to provide accurate data so that planners and extension services are able to judge the efficacy of extension and development projects.

The following sections review the fisheries resources of Vanuatu; what data is needed and why; what should be collected in future and what type of analytical approaches might be taken to assess the status of the various populations.

Bottom fish

Comprehensive accounts and analyses of the fishery for deep reef-slope snappers and groupers (plus other species) are given in Brouard & Grandperrin (1985), Schaan *et al* (1987), Carlot & Nguyen (1988) and Carlot & Cillauren (1988). This fishery began after resource surveys carried out between 1974 to 1981 by the South Pacific Commission's Deep Sea Fisheries Development Project (DSFDP) demonstrated the existence of deep slope resources in Vanuatu. The fishing method used was an adaptation of deep-water bottom handlining using a reel assembly developed in Western Samoa (Gulbrandsen 1975). These were mounted on either 8 m catamarans or 5 m dories, both powered by 25 hp outboard engines. Similar fisheries have also been established in Tonga and Fiji, but with diesel rather than petrol-driven craft.

Initial research efforts on Vanuatu's deep slope stocks by Brouard & Grandperrin (1985) looked at data collected from Fisheries Department fishing vessels, vessels operated from village fishing associations, and from the cruises of an ORSTOM research vessel. These studies provided detailed accounts of the characteristics of the fishery, influences on CPUE and seasonal variation, catch composition, species associations with depth and biological studies on the principal species such as age, growth rate, sexual maturity and spawning season. Brouard & Grandperrin also compared yield with the Hawaiian deep slope fishery and made empirical estimates of the potential yield of the Vanuatu fishery based on a number of comparative approaches. Initially these authors suggested that the MSY for the deep slope fishery may lie between 150 and 380 t/yr, but then citing the Hawaiian fishery, where there is a large unrecorded recreational catch, proposed that the Vanuatu fishery might yield between 300 to 700 tonnes annually.

Under the VFDP a total of 25 village based fishing projects were originally planned to increase the supply of high quality fresh fish to the rural populace in Vanuatu under the Village Fisheries Development Project (VFDP) and this initiative commenced in 1981. Due to the offer of significant subsidies to encourage the development of the bottom fishery applications to establish fishing projects quickly exceeded the planned 25 enterprises. By 1988 a total of 180 fishing projects were registered under the VFDP, although not all of these were directly involved in fishing but concentrated on marketing instead. When the VFDP was conceived the data requirements for monitoring the fishery were also included in the project infrastructure. For example duty free gasoline was offered to fishermen by the government to actively promote fishing. However, to obtain the fuel the fishermen were required to fill in a catch form supplied by ORSTOM. The fishermen were also asked to measure the lengths of eleven common species in the catch and an additional reward of VT 50 was offered by ORSTOM for each form on which the length data was correctly completed.

In theory therefore, the data forms should permit the estimation of the total catch for each year on a national and a regional basis, since the area of fishing is included on the form. Provision for an index of fishing effort, in terms of trip length and number of fishing lines, is given on the forms so that fishing effort in terms of line hours (= No. of lines fishing x fishing time) can be computed. However, trip length and number of lines are not filled in consistently and the most convenient measure of fishing effort has thus been the number of fishing trips made throughout the year. No direct record is made of the species composition. Instead, the lengths of the eleven common species can be used to compute weights from the length/weight relationships, and thus express these as a percentage of the total reported weight. The numbers of fish in the catch are not recorded, thus, whilst the numbers of the eleven commonest species can be obtained from the length observations these cannot be expressed as percent composition in the same manner as weights.

A major criticism of the present catch reporting system from the deep slope fishery is the reliability of the data. The system of recording data from the fishermen was established when the initial target for the deep slope fishery was only 25 projects and these could be visited regularly by a limited number of people to encourage the correct completion of the data forms. The presentation of the catch forms for duty free gasoline is not necessarily a guarantee that the reported data will be reliable, or indeed not faked. This also applies to the completion of length frequency data on the catch forms for the VT 50 reward from ORSTOM. A further perceived source of error is the 'leakage' of some of the catches through non-government establishments such as restaurants, hotels and stores. Fishermen may dispose of their catch as they wish, but can still obtain duty free gasoline on presentation of a completed catch form.

Non-recording of catch and effort will lead to a downwardly biased estimate of annual total production and possibly to a biased estimate of CPUE. Inclusion of false data that cannot be identified or quantified makes analysis and the conclusions therefrom unreliable. In the case of the Vanuatu bottom fishery, reliable data are required both for monitoring the performance of the fishery and to assess the effectiveness of the Extension Programme in developing a fishing industry. The VFDP has now ended and the Extension Programme has taken over the management and development of the bottom fishery. The Extension Service is now the agency requiring the results of research monitoring programmes.

Since the inception of the bottom fishery there have been a number of changes that are relevant to the structuring of a data gathering programme. When the project was initiated a marketing operation was also established in Port Vila known as the Natai Fish Market. This received fish from all over Vanuatu and from fishing projects on Efate. Fish were transported to Vila by air using commercially produced large cooler boxes. Later, in 1983 a second marketing operation (Santofish) was started at Luganville so that fish from the largest of the countries deep slope fishing grounds off the east coast of Santo, was no longer sent to Vila. During the late 1980s there was a contraction of the internal airlines in Vanuatu which severely limited the volume of air cargo that could be carried from the outer islands to Vila. Production on Efate has increasingly bypassed the Natai Fish Market and gone to the restaurant trade because of the demand and concomitant higher prices being offered.

It is not possible to state authoritatively how much bottom fish bypasses the two urban fish markets and goes directly to the private sector. However, on Efate it is thought to be in the range of 90 to 95% of landings, are sold privately whilst only 20% of catches around Santo are disposed of in this manner. The fish production from around Santo comes from the east and south coasts and presently comprises about two thirds of the national accountable catch. The Santo fishing ground is the most important in Vanuatu and can be readily monitored by recording catches as they are landed at the Santofish facility. This is indeed being done by the Santofish staff for those fishermen who bring their fish without completed forms. It would be reasonable, therefore, to station an enumerator or data gatherer at Santofish full-time to be responsible for the collection of catch and length frequency data.

A similar arrangement can be made for the Natai fish market although at present the small volume of bottom fish passing through this establishment is rather small (0.5t during Jan 1990). To keep the Natai operation viable it is planned to have two larger commercial fishing vessels operating around the different islands and seamounts and landing once or twice a week to the fishmarket. It is likely that the larger fishing boats will use bottom longlines rather than handreels to capture fish, or possibly a combination of the two gears. If this plan goes ahead, then there will be a need to monitor both catches and size frequency distributions from these operations. However, landed catches from the commercial vessels will comprise a mixture of fishes caught at different depths and locations, and on different gears. It may be necessary therefore to have an observer working on the fishing vessel recording the details of catches and collecting size frequency data. This is to be encouraged, since the fishing operations of the commercial vessels may provide the most reliable estimates of stock abundance from catch data.

Another recent source of reliable data, at least on catches, catch composition and fishing effort, comes from five fisheries extension centers that have been established on Tongoa, Malekula, Sola, Lolowai and Lakatoro. These centers buy fish from the village project fishermen and issue a receipt known as a Goods Received Note (GRN). Included on the GRN are the total catch in weight and numbers, effort in trip length, and catch composition of the important species. It will therefore be possible to monitor changes in CPUE and catch composition at a further five islands and associated fishing grounds and check these data against the ordinary catch return forms submitted by the fishermen. Neither of the two Natai fish markets uses the same GRN as the extension centers, but instead issue a simpler version that records details of total catch volume and composition by weight. Records of the composition of the total monthly landings at the Natai market in Vila are, however, kept independently by the manager. If it will not cause any major problems then it is recommended that both the Natai plants also adopt the GRN as a receipt. This will act as another method of passive data gathering in the event of no active data collection by enumerators.

What are the outputs that can be expected from the analyses of data from the deep slope fishery, given that it has been collected without interruption from 1982 onwards, albeit with some questions about reliability? Catch and effort data can be broken down on the basis of eleven fishing areas or expressed for the country as a whole. An initial analysis of the data collected from the VFDP between 1982 to 1986 looked at catch rates, catch composition and length frequencies of the dominant species at the different fishing grounds in the archipelago (Schaan *et al* 1987). These authors concluded that the deep slope stocks in Vanuatu were not fully exploited based on the yield estimates given by Brouard & Grandperrin (1985). Interestingly, however, the monthly CPUE at both Tanna and Santo fishing ground showed steady declines with sustained fishing over this five year period and may indicate a long term depletion of the stocks.

An analysis of the VFDP data from the period between 1983 to 1988 by Carlot & Nguyen (1989) also looked at trends in CPUE with fishing effort and time and made some preliminary analyses with the length frequency data to ascertain the effect of exploitation on some of the dominant species. The trends in catch rate with changes in fishing effort (expressed as number of trips) showed that over the lifetime of the fishery (between 1982 to 1988) the average CPUE had declined from 40 kg/trip to 29 kg/trip and that the lowest CPUEs occurred at the highest levels of fishing effort. Some declines in annual CPUE at individual fishing grounds were particularly pronounced, such as at Paama and Ambae islands. At Paama the average CPUE had declined from 69.3 kg/trip to 22.6 kg/trip between 1982 to 1988, whilst at Ambae from 1984 to 1988 the CPUE declined from 30.1 kg/trip to 17.7 kg/trip.

The measure of this decline as a true reflection of stock abundance, however is dependant on the trip length remaining relatively constant over the years and the composition of the fishing units being relatively constant, i.e. number of crew, number of reels, depths fished etc. Some of this information is available in theory from the data forms and some exploratory analyses of these factors should be performed to see how much variation is inherent within a trip. From the point of view of the VFDP the results for all of Vanuatu and from most of the individual locations should promote cause for concern, given that 160 trips/year with an estimated 35 kg/trip was projected to generate pure profit from the fishery. Further, it is likely that a catch of 35 kg/trip will about break even, given that the cost of one fishing trip at present prices for fuel, ice, gear and food is about US$ 50 (Frank Kalmarri, NAFTA/ARAITA Association, Efate, *pers comm)*. This does not take into account the depreciation of the boat and engine or the opportunity costs of capital and labour. Further, Shepherd (1988) has shown that many of the VFDP fishing projects have negative internal rates of return on the original investment to go fishing.

Estimates of life history parameters such as age, growth and mortality rates have been made for only a few species captured in the bottom fishery. Notes on methods used to estimate life history and production parameters for exploited and deep slope stocks and other resources are contained in Appendix I. Brouard & Grandperrin (1985) presented estimates of growth and mortality parameters for six species of snapper (*Etelis carbunculus, E.coruscans, Lutjanus malabaricus, Pristipomoides filamentosus, P.flavipinnis, P.multidens*). The estimates of mortality rates pertain to the initial years of the fishery in the early 1980s and, as might be expected, total mortality rates were about equal to natural mortalities, or as expressed by Brouard & Grandperrin (1985), the catches were from virgin stocks.

More recently, Carlot and Nguyen (1989) examined length frequency data for the snappers, *Etelis carbunculus, E.coruscans E.radiosus* and *L.malabaricus* from the deep slope fishery. The total mortality rates were computed for data covering the years 1983 to 1988 and suggested that the total mortality rates were higher than natural mortality rates, and that sustained fishing on the deep slope stocks was having a demonstrable effect on the different fish populations. Carlot & Nguyen (1989) also showed that for the three eteline species there is evidence of a decline in the largest size classes in the population over the seven years of fishing, as indeed was predicted by Brouard & Granperrin (1985). Estimates of the virgin biomass of deep slope species at Paama and Ambae Islands by Carlot & Cillauren (1989) have been used to predict MSY on a regional and national basis. However, deep slope stocks that are fished regularly, such as those along the east coast of Santo, should be monitored for changes in CPUE, species composition, mortality rates and biomass. Such changes and parameter estimation can be determined from the present sampling programme for deep slope stocks.

Trochus and other shellfish

Trochus (*Trochus niloticus*), or top shell, and other shellfish that yield substantial quantities of mother of pearl are in demand by the fashion and the furniture industries in Asia and Europe. MacClancy (1981) mentions that French settlers were harvesting trochus for the shells in Vanuatu at the beginning of the 20th century, but no records of production volume are available from this time. However, Dunbar (1981) states that trochus exports in 1921 were approximately 60 tonnes. It is likely that harvesting of trochus commenced in Vanuatu during the 19th century with the rise of the beche-de-mer industry in these islands and the rest of the South Pacific (Ward 1972).

Available published records on the annual accountable export of trochus from Vanuatu extend from 1950 to 1958 (Devambez 1959) and 1969 to 1985 (Bour et al 1985; Kenneth 1989). Between 1950 to 1958, trochus exports production ranged from 26 tonnes to 126 tonnes, with a mean 89.0 tonnes, and from 2 to 271 tonnes, with a mean of 74 tonnes between 1969 to 1985. The term accountable export is used here because consignments of trochus may possibly be exported without declaration to customs and thus remain unrecorded. Further, according to Devambez (1959) foreign ships were implicated in poaching shells from reefs in Vanuatu. Figures for more recent production (after 1985) do indeed exist but are either unavailable from shell processors or are supplied to Fisheries Division/ORSTOM in confidence and cannot be detailed here. The important point is that trochus harvesting in Vanuatu for other than subsistence purposes has a long history, and that this is a mature fishery, not a recent development like the bottom fishery. As such, the populations of trochus on the reefs of Vanuatu have been influenced by long-term sustained exploitation as well as by natural phenomena.

Initial observations on the densities of trochus in Vanuatu are reported by Devambez (1959 1961) for surveys carried out on different island reefs in 1959 and 1961. The 1959 survey was carried out by Devambez in response to the then New Hebrides Government's concern over declining densities on the reefs after a decade when 800 tonnes of trochus was exported overseas. During this period the lower size limit for harvesting was 5.0 cm, in contrast to the 9.0 cm limit in force at present. Densities of trochus were indeed low and the average CPUE was 7 trochus/diver hour. Very few juvenile trochus were observed in the 1959 survey and the bulk of the survey catch lay between 8.2 to 12.7 cm or 2.5 to 5 yrs old. Based on the results of this survey the trochus fishery was closed until the 1961 when a second survey was carried out to assess the effects of the moratorium on harvesting. The 1961 survey found greatly increased numbers of juveniles on the same reefs plus much greater stock densities than during 1959, with a mean CPUE of 24.1 trochus/diver hour. Further, although the overall mean length of the catch did not increase markedly (10.0 cm in 1959 vs 10.4 cm in 1961) the bulk of the 1961 survey catch lay between 11.2 to 14.2 cm or 4 to 7 yrs old. These reports are of relevance in a contemporary sense since they document the speed at which exploited reefs might recover if trochus populations are left unfished.

Apart from trochus a variety of other shells are harvested in Vanuatu, including the green snail (*Turbo mamoratus*), black lip pearl shell (*Pinctada margaritifera*) and big eye (*Turbo* sp). Also collected for the ornamental shell trade are cowries (*Cypraea* spp), helmet shells (*Cassis cornuta*), triton shells (*Charonia tritonis*) and large spined sea urchins (*Heterocentrotus* spp). At present there are three shell companies and four shell factories in Vanuatu, one in Luganville and three in Port Vila. Initially trochus shell was simply collected from the various islands, and sent overseas via Port Vila and Luganville. Regulations pertaining to this harvest formerly included export quotas of 75 t on trochus and 20 t for green snail. The present minimum sizes permissible for collection are 9.0 cm basal diameter for trochus and 15.0 cm for green snail. This regulation is still in force but the export quotas are no longer applicable because of the in country processing of shells, mainly to button blanks. There is, therefore no upper limit on the harvest of shellfish and the only limiting factor is the processing capacity of the four factories.

Although trochus are harvested throughout Vanuatu the collection of data on harvests and size frequencies of captured animals should not present a problem. All commercial harvests are sent either to Luganville or Vila by a network of buyers distributed throughout the islands. At the largest of the three shell processing concerns, Melanesian Shell Products (MSP), records are kept of the weight and origin of each consignment of shells. The shells are sent unsorted and are repacked in the factory into 50 kg loads according to 0.5 cm size class from 9.0 cm basal diameter upwards. This procedure is followed at both the MSP Vila and Luganville factories. It is not known wether these procedures are followed at the other two factories in Vila, (Hong Shell Products [HSP] and Vanuatu Coral Shell Processing Factory [VCSPF]) but presumably it follows some similar pattern, i.e. consignments of shells from different locations and grading into different size classes. In the case of the MSP operation the average numbers of shells of each size class in a representative sample of the 50 kg bags should be counted so that total production in weight can be converted to numbers of individuals of a certain size.

Given the centralisation of processing in the two urban centers then, in theory, it should be possible to maintain a very accurate data collection and monitoring programme on this fishery. This relies, however, on the goodwill of the factory managers, since the present fisheries legislation does not compel them to cooperate with fisheries officers in the collection of statistics. The manager of MSP has been very forthcoming with information on harvests and these are supplied in confidence to ORSTOM. The same is not true of HSP where there has been a little or no cooperation with the Fisheries Department. The scale of this operation and the size of the harvests put through the HSP factory are unknown. The VCSFP operation has only just commenced so it is not possible to comment on the level of cooperation with Fisheries Department. Another problem is the reputed export of whole pearl shell that is not accounted for by Customs but leaves the country unrecorded. Naturally this is a sensitive issue and it is not the purpose of this report to make comments on this other than to raise it as a possible source of error when computing total annual production.

Assuming that greater degrees of accuracy can be achieved in determining levels of harvests, what are the research priorities with the trochus fisheries?. Total accountable harvests of trochus alone between 1969 to 1985 amounted to 1254 tonnes. Unverified anecdotal data suggests that harvests of trochus in the early 1970s were much larger than reported in official statistics. More recent figures are unknown because of the confidentiality of the MSP data or simply non-reporting by other concerns. However, other anecdotal information suggests that large-sized animals, > 13.0 cm basal diameter, have become very scarce and that localised overfishing of individual islands, eg Erromanga, is already occurring.

Research priorities should thus be directed towards estimating the biomass of trochus and other shellfish at the various islands and the levels of harvests therefrom. As with the bottomfish the size frequency distributions of trochus can be converted to catch curves, since the growth of trochus has been determined for this species in Vila. A caveat here is that growth of trochus may vary throughout the archipelago, particularly in a north-south direction. Further there is evidence of density dependent effects on the growth of trochus (Smith 1987) so that harvesting might affect the size at age distribution. Further tagging and growth estimates can be made at locations north and south of Vila to look at this problem, however, and in the mean time the available growth rates can be used to compute mortality rates of the different populations.

Unlike the bottom fishery, estimates of fishing (or harvesting) effort are unknown and probably under present circumstances it is not practical to try to obtain them. Cohort analysis (see Appendix 3) can, however, also be performed on the Vanuatu trochus data in the same manner as was carried out stocks of this species in New Caledonia. Trochus in Vanuatu have a single spawning peak during the austral summer between October to February so the respective size and fishery contribution by each successive year class can determined.

Proposed field studies of trochus populations and tagging of different stocks are dealt with elsewhere in a report by the FAO/UNDP consultant Mr Warwick Nash. It should be pointed out, however, that biomass estimates from VPA can also be compared with those from surveys and also from tag and recapture studies. The objectives of these studies should be to determine quotas for individual areas and to, possibly, selectively set size limits on minimum and maximum sizes for capture. It should be mentioned here that the Vanuatu Fisheries Department is experimenting with hatching and rearing trochus, with the possibility of restocking depleted reefs. This operation is described in greater detail by Mr Nash in his report, however, this facility is still in the experimental stage and even if stocking is successful this will only be a partial solution for areas where depletion of trochus has been extensive.

Similar exercises can also be made for the other shellfish, such as green snail and big eye, where catch figures and size frequency data are available. For these species growth parameter estimates for stocks in Vanuatu are not available, but might also be computed from tagging studies. Alternatively, empirical estimates of growth parameters can be generated for Vanuatu stocks based on age and growth studies on the same or similar species elsewhere. Similarly, empirical methods exist to compute total and natural mortality rates based on knowledge of growth parameters and maximum age in the population. Initial use of these methods is encouraged to get a 'feel' for the population dynamics of the stocks involved. The work of Villanoy *et al* (1988) on giant clams in the Philippines is relevant in this context since it shows what kind of population statistics can be generated from the size frequencies of commercially harvested shellfish and application of a comparative empirical methods.

Beche-de-mer

Latham (1929) reported that beche-de-mer was one of the principal exports of Vanuatu at the beginning of the 20th century. As with trochus, harvesting of this marine resource has a history of more or less continuous exploitation for at least 150 years. Exports of beche-de-mer were officially terminated in Vanuatu after 1988 due to the consistently poor product being exported overseas by inexperienced processors. Following the SPC beche-de-mer processors course in 1989, eight harvester processors were licensed by the Fisheries Department to export overseas. Little is known about contemporary levels of exploitation or the areas where harvesting occurs. The Vanuatu Customs Department is supposed to record all shipments of beche-de-mer going overseas, thus at least a figure for total production should be available for the whole country. There have been indications, however, that some shipments of beche-de-mer leave Vanuatu without being recorded.

Chambers (1989) recorded a total of 18 species of beche-de-mer from the reefs and seagrass beds of Vanuatu and found that in most locations the densities of these animals were generally low. No information is available on the species composition of the beche-de-mer harvests although anecdotal data suggests targeting on the teatfish, *Holothuria nobilis*. From anecdotal sources it appears that the beche-de-mer harvester/processors travel to different areas of the country and work an area of reef until the stocks of animals are reduced to uneconomic levels. It is likely that they keep records of the harvests at different locations and possibly the amounts of different size grades of beche-de-mer. Although the potential of such data is limited it can be useful to document changes in size of animal with sustained exploitation as was demonstrated by Ito (1984). There are no estimates of age and growth of beche-de-mer in Vanuatu although some data exists for beche-de-mer species from Papua New Guinea (Shelley 1981) and New Caledonia (Conand 1986).

The morphology and behaviour of soft-bodied beche-de-mer makes the use of usual measures of body size such as length or mass a problem. Tags can be inserted into the calcareous integument of the animal but there is a high rate of shedding. Beche-de-mer also have a propensity to lose weight after tagging. Modal progression analysis was used by Conand (1988) in connection with two species, *Thelenota ananas (max size = 60cm)* and *Stichopus chloronotus* (max size = 30 cm) to estimate age and growth. The maximum recorded ages of *S. chloronotus and T. ananas* were four and ten years respectively. It should be pointed out here that to achieve unequivocal measurements of length, Conand (1988) anaesthetised each sample of beche-de-mer before making measurements. At present such detailed studies are beyond the capabilities of the Fisheries Department and ORSTOM and research priorities should be given to collecting basic data from the harvester/processors to look at the scale of exploitation on a regional and national level.

Coconut crabs

The coconut crab, *Birugus latro.* is a large land crab related to the smaller hermit crabs. It has a unique flavour and is much in demand by restaurants in Vila for the growing tourist trade. These crabs are harvested on the outer islands then airfreighted to Efate. Crabs are also caught on Efate and can occasionally be seen sold in street markets.

In common with the trochus and bottom fish, coconut crabs have been the focus of research work in Vanuatu, due to their economic importance at the village level (Fletcher 1988). Studies have been made on the density and dynamics of wild populations of coconut crabs, the age and growth, and the spawning and recruitment of this species. Coconut crabs have along life span and may live for as much as 50 yrs. More importantly, the size at which the crabs may be legally harvested for commercial purposes (9.0 cm carapace length, 600 g weight) is equivalent to an age of between 12 to 15 yrs. Not surprisingly the areas of Vanuatu where coconut crabs have been harvested have experienced rapid declines in wild populations and elimination of large individuals. More disturbing is that recruitment of coconut crabs appears to occur at a very low level, and areas where coconut crab have been harvested do not appear to recover, even after several years.

As with the most other fisheries resources in Vanuatu, the scale and geographic patterns of coconut crab exploitation are poorly known. Again, anecdotal information suggests that the major harvesting grounds are found on Santo and the Banks and Torres Islands. The same sources report airshipments of up to 800 kg a week coming from the Banks and Torres Islands destined for the Vila restaurant trade. Given that this is the prime market for the coconut crabs a survey of the volume of this animal handled by the restaurants and hotels may give a first index of the production on a national basis. Another source of information is the records of airshipments from various islands in Vanuatu on commercial airlines. Regular checks of the airwaybills of lading from the air carriers might permit estimation of regional levels of coconut crab production. If these records are still available for previous years then time series of harvests might be established.

The recommendations made by Fletcher (1988) include the need to make regular censuses of the coconut crab densities in different areas of Vanuatu to assess the state of the stocks and the effectiveness of any conservation measures. Unlike the other resources discussed in this report the surveys for coconut crabs are carried out on land and the methodologies for obtaining and index of abundance have been established. At the same time the size frequencies of the sampled populations can be collected. Sampling at one site need not take all year but can be made intensively over a short time period. As growth and recruitment effects are likely to be small between years then apart from natural catastrophes the changes in crab density should be a reflection of removals through harvesting.

The implementation of some form of monitoring programme can build on the initial work reported by Fletcher (1988). The scale of exploitation reported by Fletcher (1988) and from anecdotal sources suggests that some form of government intervention is imperative to preserve the species and the potential of coconut crab as a cash crop for villagers. Intervention on a rational basis can only be made if information on the scale of exploitation and the dynamics of the 'fishery' are available.

Other resources

Other marine and freshwater invertebrates caught and harvested in Vanuatu include lobsters (*Panulirus* spp.), mangrove crab (*Sycilla serata)*, land crabs (*Cardisoma* sp.), cockles (*Anadira* sp.), giant clams (*Tridacna* spp. and *Hippopus* sp.) and giant freshwater prawns (*Macrobrachium* spp.). As will be now apparent the size of the resource for each of these different organisms is unknown as are the levels of exploitation. Anecdotal sources suggest that lobsters are increasingly important as a source of cash revenue for villagers and increasing amounts are sent by air to Vila. If so, then a data gathering exercise combining hotel and restaurant surveys with examination of airwaybills might yield some preliminary figures on the level of exploitation and highlight the regions of the country where fishing pressure is greatest.

Zann & Ayling (1988) surveyed the giant clam resources of Vanuatu during 1987 and reported that four species were present in the archipelago, *Tridacna maxima*, *T.squamosa*, *T.crocea* and *Hippopus hippopus*. They concluded that whilst *T.squamosa* and *T.crocea* were naturally uncommon, stocks of *H.hippopus* populations around inhabited islands are overfished. Stocks of *T.maxima* appear to be common and plentiful throughout Vanuatu. Clams such as H.hippopus are vulnerable to subsistence harvesting, particularly where population densities are high . Zann & Ayling record that giant clams are an esteemed food item for ni-Vanuatu who consume an average of 19.1 kg of shellfish/capita/yr. Given that the giant clams are important in the subsistence sector further information on these resources is likely to be included in any studies of subsistence exploitation.

The same is true of the cockles, crabs and freshwater prawns which are all taken for subsistence purposes. Cockles and, particularly, land crabs , however, are a feature of the markets on Saturday mornings in Vila and some estimates of the weekly volume that is sold through this outlet, the major produce market in the country, could be made to assess the commercial importance of these resources. Other items sold at the market which could also be targeted for data collection are sales of reef fish, coconut crabs and ornamental shells.

Fisheries Research Infrastructure and Data Requirements

Fisheries research activities currently being pursued by the Fisheries Department/ORSTOM are bottom fish stock assessment, trochus mariculture and some statistical data gathering from wild populations, and aspects of the subsistence fisheries. In this review, suggestions are made as to how the data can be analysed to obtain results pertinent to management. Further, other data gathering exercises are proposed to increase knowledge of these and other resources. In some cases it is possible that the information already has been collected passively as receipts, airwaybills and harvests records of private individuals. What is required is for some one to actively pursue these surreptitious data sources, collate them, tabulate them or produce them as figures and then issue them in some form of statistical bulletin.

Part of the terms of reference for this review were to advise on information useful for fisheries managers. Apart from the reports published by ORSTOM and the occasional unpublished manuscript from the Fisheries Department there is no compendium of data on the fisheries and aquatic resources of Vanuatu. This means that the effectiveness of extension, development and management initiatives cannot be judged in the context of prior conditions in the various fisheries. Besides a lack of knowledge on the scale and distribution of production for most resources there is little readily available information on the nominal fishing effort in terms of numbers of fishing boats and fishing gear in each location. Records are kept of the sale and lease of the Hartley 5 m fishing boats, but are there records to examine the decommissioning of these vessels through attrition? Further, the Fisheries Department has built and sold reels to fishermen to fit to canoes. Again what is the scale of this nominal effort? Such observations on the fleet dynamics are just as important as those on the catches and biology of the target species (Hilborn 1985).

Nominal fishing effort for the subsistence fishery was been determined during the Agricultural Census for 1983 by David (1988). The information on fishermen densities and distribution of gears and boats could be summarized within the statistical bulletin to make it more readily available. Given that the fisheries sector represents an important revenue source of income to ni-Vanuatu villagers and revenue to the Government, then economic statistics on the fisheries sector should also be included in any statistical data summary. In concert with this are the annual records of amounts of imported canned and frozen fish and fish products, and exports of marine produce from Vanuatu. It is possible that the kind of survey/data gathering exercises discussed here cannot be undertaken each year due to financial and personnel constraints. However, it would be most useful from a research and extension viewpoint to obtain an accurate contemporary portrait of fishing activities in Vanuatu, against which future work in both fields can be compared by a similar exercise in the future.

Some of the other suggestions here will also require additional data collection effort on the part of the Fisheries Department/ORSTOM. Some of this might also be handled with the existing personnel, but the range of resources and the work involved would require at least one or more further persons. Presently ORSTOM pursues specific research goals and should continue to do so. What is required, however, is a general fisheries statistician/researcher to collate information that is presently available and to conduct data gathering exercises such as track down surreptitious data sources and conduct surveys. Such an individual might fall outside the general scope of research activities of ORSTOM and be recruited directly into the Fisheries Department. There is certainly a need within the Fisheries Department to strengthen the capabilities for such data collection, summarization and analysis to serve the needs of other branches of the Fisheries Department such as the Extension Service and, at times, other government departments. The latter is important for government planning and investment since only with reliable information on the state of stocks can resources be allocated or legislation drafted for management.

Management options for Vanuatu's fisheries

The present fisheries legislation in Vanuatu is rather limited and covers only the licensing of foreign vessels, though allowing for some size regulations and permits enforcement. The Department, therefore, has little to enforce and probably needs more powers to set regulations, open and close fishing grounds and to issue licenses and quotas. Presently, other government departments can issue licenses for processing of marine products such as trochus without reference to the Fisheries Department. This may be due to the desire to promote commercial ventures within Vanuatu but they should not run counter to the information generated from research and monitoring activities of the Fisheries Department.

The most effective management measure that can taken by the Fisheries Department to conserve stocks is the limitation of fishing effort. This might be done by licensing fishermen and harvesters of different stocks, closing and opening fishing grounds, limiting the marketing outlets for different products (i.e. licensing the processors) and setting selective quotas for different areas. At present regulations dealing with inshore fisheries production pertain to size regulations based on the mean size at which various organisms become sexually mature. Whether, however, it is a conservation measure to fish only the breeding stocks is a moot point given that the stock recruitment relationships for these animals are unknown. Thus, whilst it is not recommended that these size regulations are abandoned, their efficacy in maintaining stocks should be reviewed from time to time and other possible strategies discussed, such as upper and lower size limits.

Ultimately, however, the conservation of stocks will rely heavily on the restriction of harvesting, either by limited entry into the fishery or by quota systems, and where appropriate setting size limits for the target species. Clearly this cannot apply to the subsistence fisheries in Vanuatu but can be integrated into management for those stocks that are harvested as part of the cash economy such as trochus etc. In terms of both subsistence and other resources it may be possible to use the traditional powers of the traditional elders to regulate harvests, as has been done in Malekula with respect to beche-de-mer harvesting (N Crysler, Fisheries Division, Luganville, *pers comm*).

Conclusions and Recommendations

Despite the resource limitations of the Vanuatu Fisheries Department and ORSTOM, a large volume of fisheries data is generated each year, both intentionally from sampling and monitoring routines, and from the commercial records of other marine organisms. In the past, attention has been focused primarily on the deep slope fishery but will be expanded to other organisms such as trochus and other molluscs. It is recommended here that data on production might also be collected for other species, particularly if information already exists in the form of purchase receipts, waybills etc. It was suggested that a position might be created within the Fisheries Department to facilitate this, but recognising obvious constraints there may be ways to undertake this work with the current staff complement. In any event more emphasis needs to be given to the collection of production data and the exploration of how this might be accomplished and what data sources are available.

Management of the fisheries resources of Vanuatu will stem in part from the results of research efforts carried out by the Fisheries Department/ORSTOM. These results and recommendations, however, will effect the work of other branches in the Fisheries Department such as the Extension, Training and Inspection services. There is a need, therefore, to regularly assess the requirements of these sister agencies with respect to the information generated from research and monitoring programmes. A possible approach might be the development of management unit in the Fisheries Department composed of representatives from the various branches that has effective powers to recommend and enforce legislation. This might also have the dual function of guiding future research from a management orientation and from the information needs of the different departmental branches and other Government agencies.

The analytical approaches suggested in this report emphasise the need to conduct more stock assessment orientated work on the exploited marine resources in Vanuatu. Further, it is only by regularly summarising and analysing collected information that the efficacy of a sampling/monitoring programme can be assessed. For example sampling of the deep slope fishery in Vanuatu has been carried out since 1982, yet little emphasis has been placed on the species composition of the landed catches with respect to time. However, temporal changes in species composition are an important indicator of the response of a stock(s) to continues exploitation and now greater emphasis will be placed on the collection of this type of information. Essentially, a sampling programme has to be responsive both to external changes that impact on the fishery (e.g. contraction of air services on the deep slope fishery) and to the changes dictated by the results generated from sampling.

Finally, the results of various data analyses should be properly documented so that a permanent record is kept of the various work that has been undertaken. there is provision for this with the deep slope fisheries through the Notes & Documents series of ORSTOM Vanuatu, but this may not extend to the documentation of the other resources. Summaries of research data should be compiled into data volumes where possible, and results of sampling/monitoring programmes written up as technical reports. Since this work is expected to be management orientated, there should be a clear summary of any proposals or advice. If there are no resources available to publish such reports then help might be sought from the SPC Inshore Fisheries Research Project which has a commitment to helping fisheries departments in the region produce technical documentation.

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APPENDIX 1

Notes on methods to estimate life history parameters of exploited fish stocks in Vanautu

Age and growth

Age and growth parameters for fish and shellfish in Vanuatu have been estimated from periodic marks on the otoliths or ear stones, from length frequency data and by mark and recapture experiments. Growth of all species was described using the von Bertalanffy growth function (VBGF) which takes the form for length of:

$$L_t = L_{\infty}[1 - e^{-K(t-to)}]$$

where L_{∞} is the asymptotic length, K a growth constant, L_t length at time t and t_o is the curve origin. For growth in weight the curve takes the form:

$$W_t = W_{\infty}[1 - e^{-K(t-to)}]3$$

where W_{∞} is the asymptotic weight and W_t is weight at time t.

Brouard & Grandperrin (1985) used counts of daily growth increments of the sagittal otoliths (see Campana and Nielsen [1985] for a review of the methodology) to age *Etelis carbunculus, E. coruscans, L. malabaricus, Pristompomoides flavipinnis, P. multidens* and *P. filamentosus* from Vanuatu and to estimate parameters of the VBGF. Length frequency data for *P. multidens* was also analysed with the computer programme ELEFAN 1 (Pauly 1987) to obtain estimates of L_{∞} and K. Mark and recapture, or tagging, was employed by Bour and Grandperrin (1985) to estimate VBGF growth constants for trochus on reefs adjacent to Efate.

Ageing of long-lived deep slope fishes through the use of daily growth increments will probably yield more unequivocal results than length analysis (but see Morales-Nin [1988] and should probably be extended to the other species such as *Etelis radiosus, Aphareus* spp. and *Epinephelus* spp. The ORSTOM facility in Port Vila does not have the resources to carry out the ageing studies on the these bottom fishes. This might be accomplished in the ORSTOM facility in Noumea or perhaps by contracting out the work to another agency such as the National Marine Fisheries Service Honolulu which has a regular sampling programme to age deep-slope fishes from the Hawaiian fishery.

Where age and growth estimation is difficult or not practicable then the empirical method of Munro and Pauly (1983) and Pauly and Munro (1984) can be used to generate growth parameters. These authors showed that the VBGF growth parameters can be directly compared by estimating $\emptyset$ or $\emptyset$' from:

$$\emptyset = Log_{10}K + Log_{10}W_{\infty}$$

and

$$\emptyset' = Log10_K + 2Log_{10}L_{\infty}$$

If either $\emptyset$ or $\emptyset$' is computed from reported values of a given species or closely related congeners then this can be used to estimate a value of K, given that the asymptotic size can be determined or approximated from size frequency data. Carlot and Nguyen (1989) used ' to estimate an empirical value of K for *E. coruscans* in Vanuatu based on O' values for other eteline species.

Mortality rates

Mortality rates here refer to instantaneous rather than annual extinction rates. The ratio of population numbers at the beginning of a year (N_o) to those survivors at the end of a year (N_1) or N_1/N_o) is termed the survivial rate (S). The fraction of the population that died during the year is the annual mortality rate (A) hence: S = 1-A. The survival rate is also equivalent to the natural logarithm of the total mortality rate (Z) with the sign changed hence: $S = e^{-Z} = N_1/N_o = 1 - A$. if for example a fish stock had a total mortality rate = 0.3/yr then $e^{-0.3} = 0.74 = S$. Therefore in one year 74% of the stock would survive whilst 26% of the stock would die over the same period.

A simple method of computing total mortality rate, Z, of a stock is the mean length formulation of Beverton and Holt (1957) which takes the form:

$$Z = K(L_{\infty} - L')/(L' - L_c)$$

where K and L_{∞} are growth parameters, L_c is the length at full recruitment and L' is the mean length of al fish > L_c Another method of computing the total mortality rate of a fish stock is from a length converted catch curve. Length frequency data are converted to age frequency data and the descending limb of the resulting curve takes the form:

$$Loge(Ni/dt = a + bt$$

where t is the age of the fish, dt is the time taken to grow through one age class (i) and Ni is the number of fish in length class (i). A regression of $Log_e(Ni/dt)$ versus t for the descending limb of the catch curve gives the intercept (a) and the slope of the line (b) which is also the total mortality rate (Z).

From the mortality data estimated for the deep-slope species an initial indication of the status of these stocks can be gained from the ratio of fishing mortality rate (F) to the total mortality rate (Z). The total mortality rate comprises both the deaths through fishing and those from natural causes or:

$$Z = F + M$$

The ratio fishing mortality to the total mortality is known as the exploitation rate (E) where:

$$E = F/Z$$

or:

$$E = F/F + M$$

Gulland (1971) suggested that in a stock that is optimally exploited, fishing mortality should be about equal to the natural mortality rate, or F_{opt} = M and E_{opt} = 0.5. Recently Pauly (1984), based on Beddington and Cook (1983), proposed a more conservative definition of optimum fishing mortality where F_{opt} = 0.4M and E_{opt} = 0.3. For the deep-slope species in Vanuatu Carlot and Nguyen (1989) computed an average global estimate of E = 0.26, based on mortality estimates for *E. carbunculus, E. coruscans, E. radiosus and L. malabaricus*. There was also evidence to suggest that the mean lengths and 95 percentile length for the three *Etelis* spp. declined between 1983 to 1988. There was, however, no evidence from the data however, to suggest that the same reduction in size occurred with *L. malabaricus.*

The analyses presented by Carlot and Nguyen (1989) on deep-slope species in Vanuatu referred to exploitation on a national rather than regional basis and for length data aggregated over all years for all catches. The results suggested that the bottom fish stocks are only moderately exploited, however, this analysis was by necessity rather crude and might be improved by looking at mortality rates on an annual basis for each fishing ground. The would also permit the estimation of mortality rates at different levels of fishing effort (f) and so possibly lead to direct estimates of the natural mortality rates (M) from:

$$Z = M + qf$$

This is a simple linear equation with a Y axis intercept at zero fishing effort equivalent to the natural mortality rate, M. The slope of the line, q, is the catchability coefficient which relates fishing effort to fishing mortality, since qf = F.

At present natural mortality rates are computed empirically from the relationship of natural mortality with growth and environmental temperature. Pauly (1980) has shown that the following equation provides a reasonable empirical estimate of the natural mortality rate, M:

$$\text{Log}_{10}M = -0.0066 - 0.279\text{Log}_{10}L_{\infty} + 0.6543\text{Log}_{10}K + 0.4643\text{Log}_{10}T$$

where Loo and K are growth constants and T is mean environmental temperature. Another empirical approach to estimating natural mortality rates for deep-slope snappers and groupers is that of Ralston (1987) where:

$$M = -0.0066 + 2.52K$$

All that is required in this instance to predict M is an estimate of the von Bertalanffy growth function. Finally, a predictive equation for estimating total mortalities from the maximum observed age in a stock was given by Hoenig (1983) where:

$$\text{Log}_eZ = a + b\text{Log}_e(t_{max})$$

This equation might be used as an alternative to catch curves and mean length equation to estimate Z and in cases where virgin stocks are being fished the estimate of total mortality should be equivalent to the natural mortality rate.

Biomass and production.

Such parameter estimates are not an end in themselves. The purpose of these exercises is to determine the effects of fishing on the stocks and to suggest levels of fishing effort and catches beyond which the stocks will decline. If the virgin biomass or that part of it amenable to exploitation is know, then the MSY can be estimated as that fraction of the biomass that can be removed annually in the form of surplus production. One method of estimating virgin biomass in an exploited stock is to look at the rate at which fishing depletes the population and from this compute an estimate of the virgin biomass (B..). Carlot and Cillauren (1989) used the depletion method of Allen (1966) for the deep-slope fisheries around the islands of Paama and Ambae and the results extended to the rest of Vanuatu. Carlot and Cillauren estimated that the MSY of the Vanuatu bottom fish stocks lay in the range of 113 to 190 t/yr from existing fishing grounds.

In terms of monitoring the stock, however, it is useful to look at the changes in biomass from year to year, particularly if the stock is being steadily depleted through excessive fishing. One simple method to compute annual biomass (B) in an exploited stock is to first compute the fishing mortality rate (F) and divide this into the catch (C) since:

$$C = FB$$

therefore:

$$B = C/F$$

Total mortality rates can be computer from the catch curves or mean length equations and the natural mortality rates approximated from one of the empirical methods suggested above.

Some doubts have been expressed, however, concerning catch curves for the estimation of mortality rates if recruitment is highly variable (D. Somerton, National Marine Fisheries Service, Hawaii, *pers comm.*) This problem was noticed with the dropline fisheries in Hawaii where it was thought that an estimate of total catch and an index of mortality rate could be used to monitor the dynamics of the fishery. This approach did not consider the recruitment problem nor the dynamics of the fishery, which in certain circumstances is very size selective for particular species; or that fishermen's behaviour can strongly influence the size composition of different species. The recruitment question might be examined through virtual population analysis (see below), whilst the latter source of bias may not be a problem in the Vanuatu fishery since the market for fresh fish is much less sophisticated than in Hawaii and, as such, fishermen are targeting for general volume rather than specific size or species.

An approach that might be taken to overcome some of the problems associated with catch curves is the use of length-based virtual population analysis (also known as cohort analysis). This uses the information on catch and population size structure in conjunction with information on age and growth to determine the populations of each year class that has generated an annual catch. The mathematics of the various methods are complicated and will not be dealt with here, however, the various methods are readily available as prepackaged software for microcomputers and indeed are amongst the software in the Fisheries Department in Vial. Such analyses can be run for individual fishing grounds, and the biomass of different populations might be assessed. A complimentary analysis of this type would be useful to compare with estimates of biomass from catch divided by fishing mortality and also with the virgin biomass estimates from the depletion studies.

A further approach to generating indices of stock exploitation is to estimate the total annual mortality rate for a given stock and to look at the relationship of this versus the annual catch. This approach was first suggested by Csirke and Caddy (1983) and obviates the necessity to establish the annual fishing effort or and index of it. Instead, the annual catch of a stock is plotted against annual total mortality rate, or an index of it, computed from either catch curves or other methods. If the natural mortality rate is constant over all size classes beyond complete recruitment to the fishery then variations in Z must be a function of the fishing effort which generates the catch. A plot of catch (C) on Z should conform to a parabola of the form:

$$C = a + bZ + cZ^2)$$

The model generates estimates of the MSY, F_{opt}, Z_{opt}, M, the net specific increase in population biomass (r_m) and virgin biomass (B_{∞}). Estimates of virgin biomass would be of particular interest to compare with estimates of the same from application of depletion studies. The estimation of the model parameters can be readily accomplished using a personal computer spreadsheet programme or the programmes for Hewlett Packard calculators published by Paul (1984) and Vakily *et al* (1986).

The Csirke and Caddy model is a modification of an earlier surplus production approach by Schaefer (1954, 1957), who showed that Cpue declines as fishing effort increases, the rate of increase of catch declines and the relationship between the two can be described a parabolic function. A later modification of the model by Fox (1970) suggested that an asymetrical curve may give a better fit to catch and effort data. The original Schaefer model was conceived for single species stocks by variations of the model have also been used for multispecies stocks (Brown *et al* 1974; Gulland 1979; Marten and Polovina 1982; Ralston and Polovina 1982; Munro 1983; Dalzell 1984; Munro and Williams 1985). The rationale behind this has been that a multispecies assemblage showed variation in fishing pressure in a manner similar to a single species stock.

The Schaefer model takes the form:

$$C = af - bf^2$$

where C is catch, f is fishing effort and a and b are constants of the equation. The model is fitted by plotting C/f or Cpue against effort which yields the Y axis intercept (a) and the slope of the line (b). This in turn yields the MSY and optimal fishing effort (f...) from:

$$MSY = a^2/4b$$

and:

$$f_{opt} = a/2b$$

The Fox model takes the form:

$$C = fe^{a}.e^{-bf}$$

and is fitted by plotting Loge C/f against corresponding fishing effort. This again yields the curve constants and the MSY and f.. from:

$$MSY = e^{a-1}/b$$

and:

$$f_{opt} = 1/b$$

The catch and fishing effort data from the Vanuatu deep-slope stocks constfained in the report of Carlot and Nguyen (1989) were used here as an example of the fitting of the Schaefer and Fox models. With the Schaefer curve the MSY was 82.7 tonnes with an optimal fishing effort of 4,100 trips. Fitting the same data with the Fox models gave a predicted MSY of 103.2 tonnes at f_{opt} = 6,900 trips. This example underscores the need to for a comparative approach in the estimation of sustainable yields from fisheries in Vanuatu. First the figures pertain only to those grounds being currently fished in Vanuatu rather than in the country as a whole. Second, the index of fishing effort is trip number rather than the more accurate product of fishing time and the number of gears. Last, the fishery is still very recent and with changes in fishing effort from year to year is unlikely to have moved into equilibrium with respect to surplus production. Estimates of MSY for the Vanuatu deep slope fisheries range from between 100 to 800 t/yr depending on the authors and methods used (Brouard & Grandperrin 1985; Carlot & Nguyen 1989; Carlot & Cillauren 1989). The figures estimated here are consonant with the lower end of this range but are clearly only part of a suite of possible estimates.

The approaches outlined above refer mainly to monitoring deep- slope stocks since they fit in with the infrastructure of the existing data collection procedures. However, they can be adapted for most of the other aquatic resources exploited in Vanuatu. For the deep-slope fishes, most of the methods outlined simply require some manipulation of the past and present data to generate various required indices of growth and exploitation. Further studies are to be encouraged in conjunction with a laboratory elsewhere to obtain additional estimates of age and growth for the main target species of the deep-slope fisheries. Other methods exist to determine the biomass of the fished and unfished stocks such as tagging, hydro-acoustics and visual surveys, but are inappropriate in the context of deep slope fisheries in Vanuatu. Visual surveys are likely to be important, however, for exploited shallow water invertebrates such as trochus and beche-de-mer. No one method is likely to provide wholly satisfactory results and a better approach, as suggested by Gulland 1988, is to use a variety of techniques for parameter estimation, estimate the confidence limits of these estimates and to compare the results.