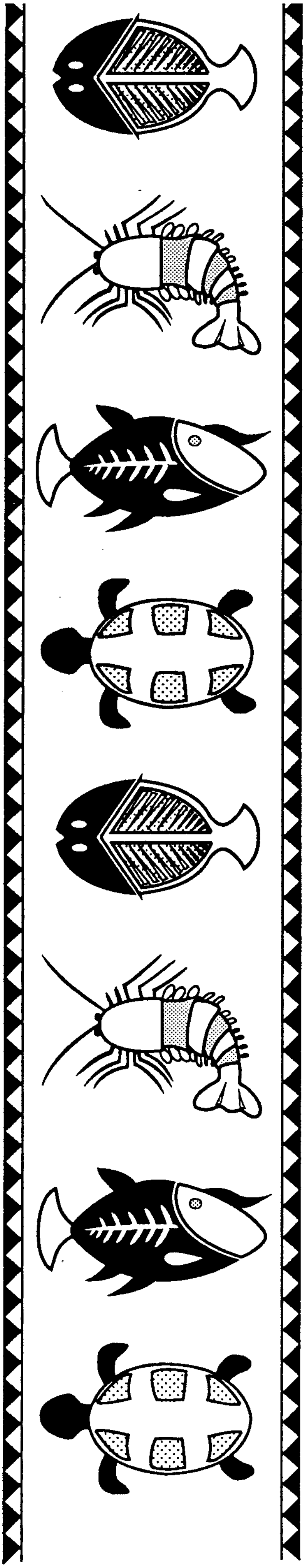

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# PAPERS ON FISHERIES SCIENCE FROM THE PACIFIC ISLANDS

## Volume 1

South Pacific Commission
Noumea, New Caledonia

SOUTH PACIFIC COMMISSION

# PAPERS ON FISHERIES SCIENCE FROM THE PACIFIC ISLANDS
**Volume 1**

**edited by**

**P. Dalzell**
**Inshore Fisheries Scientist**

**Inshore Fisheries Research Project**
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## FOREWORD

All but one of the contributions in this first volume of 'Papers on Fisheries Science from the Pacific Islands' were presented at the South Pacific Commission's Inshore Fisheries Research Workshop held in March 1988, at SPC headquarters in Noumea. Altogether a total of 157 papers was presented at this workshop, as keynote addresses, background papers or information papers. The volume of technical and scientific literature prepared by Pacific Island fisheries scientists and fisheries officers was ample testament to the need for greater dissemination within the South Pacific region of literature dealing with different aspects of inshore or coastal fisheries science. In this context, fisheries science is taken to encompass not only biology, ecology and stock assessment, but also disciplines such as economics and sociology.

The issue of Volume 1 marks the establishment of a forum for Pacific Island fisheries scientists working on inshore or coastal fisheries in the South Pacific region. Six papers were selected from those presented at the 1988 workshop. It is hoped that these reflect the broad aim of this new SPC series, which is to offer a vehicle for technical literature on coastal fisheries of the region. The seventh paper in this volume was initially submitted to the *SPC Fisheries Newsletter*, which in the past published papers on technical aspects of fisheries in the South Pacific. However, the establishment of a new series dedicated to fisheries science in the region will permit the *Newsletter* to concentrate on its main function of public information dissemination, rather than serving as a platform for technical papers.

The continuation of this series is naturally dependent on contributions from its target audience, fisheries scientists and fisheries officers in the South Pacific. In many countries of the South Pacific, publication of fisheries technical reports and papers is difficult because infrastructure, editorial skills and/or funds for printing and related costs are lacking. The establishment of this series is intended to alleviate these problems.

Ideally, manuscripts for publication should be submitted with the text on a computer disk file. The Commission can deal with most word-processing software. Where camera-ready final drawings of graphs are not included in the manucript, the raw data should also be sent, so that figures can be generated with the appropriate software or drawn by hand by a graphic artist at the Commission.

Papers will be reviewed by SPC Fisheries Programme staff and, if necessary, external reviewers before being accepted for publication. If changes or corrections are needed we will do our best to assist authors in finalising their contributions. We are aware that in some cases authors may have little publishing experience and that English may be their second language. We are sensitive to these difficulties and hope that this will not deter workers in the region from writing up the large amount of valuable fisheries data presently hidden away in offices and laboratories. Even if only a small amount of this information is ultimately published, it will help others to avoid costly repetition of work that has already been done or mistakes that have already been made.

The Commission's official working languages are English and French. An abstract in French is presented at the beginning of each paper.

**Acknowledgement**

Funds for publication of this paper were generously made available by the United Kingdom Government through the British Development Division in the Pacific as part of its contribution to the work of the SPC Inshore Fisheries Research Project.

*P.D. Dalzell*
*Inshore Fisheries Scientist*
*Inshore Fisheries Research Project*
*South Pacific Commission*

CONTENTS

# A REPORT ON THE MARKET SURVEY OF REEF AND LAGOON FISH CATCHES IN WESTERN SAMOA

by
Nancy Helm,
Peace Corps Marine Biologist, Fisheries Division, Western Samoa

## Abstract

*Statistics on the inshore fisheries production from Western Samoa have, in the past, been unreliable. Previous estimates of total landings range from 109 to 932 tonnes per annum. An initial programme of statistical data collection at Apia Fish Market recorded sales of 247 tonnes and 175 tonnes in 1986 and 1987 respectively. Landings in both years were dominated by surgeonfishes (Acanthuridae), parrotfishes (Scaridae) and emperors (Lethrinidae). The big-eye scad,* Selar crumenophthalmus, *formed an important component of the catch in 1986 but only made a minor contribution to landings in 1987. The factors that may influence variation in landed volume of the catch are discussed and the methods employed to collect these data are evaluated with respect to continued collection of landing statistics in Western Samoa.*

## Résumé

*Les statistiques dont on disposait sur la production de la pêche côtière au Samoa-Occidental étaient peu fiables; les évaluations du volume total débarqué allant de 109 à 332 tonnes par an. Un premier programme de collecte de données statistiques a donc été réalisé sur le marché aux poissons d'Apia, où le volume des ventes s'est établi à 247 tonnes en 1986 et à 175 tonnes en 1987. Pendant ces deux années, les chirurgiens (Acanthuridae), les perroquets (Scaridae), les bossus et becs de cane (Lethrinidae) dominaient les prises. Le maquereau à gros yeux,* Selar crumenophthalmus, *constituait, lui, une part importante des prises en 1986, mais n'était que faiblement représenté dans les quantités débarquées en 1987. Dans le document ici résumé, on examine les différents facteurs susceptibles d'avoir une incidence sur les variations du volume des prises et on évalue les méthodes utilisées pour recueillir ces données dans le cadre d'un programme permanent de collecte de statistiques sur les quantités débarquées au Samoa-Occidental.*

## Introduction

The market survey of reef and lagoon fish catch is a Fisheries Division programme in which sales of inshore fish and invertebrates at the Apia Fish Market are monitored on a regular basis. For the purpose of this programme, 'inshore' is defined as the area from the outer edge of the fringing reef which is accessible to non-motorised fishing craft. In Western Samoa this area is heavily fished by thousands of individuals using a wide variety of non-mechanised fishing methods. Traditionally this has been a strictly subsistence fishery. The urbanisation of the Apia area and the development of a central fish market have brought about changes in the fishery over the past twenty years. The sale of reef and lagoon fish in the Apia Fish Market has become an increasingly important source of income for village fishermen. Inshore fishing is still a source of food for villagers but it can also be a source of cash when there is an excess of fish or when there is a need for cash income.

Obtaining accurate catch data, or even an estimate of catch size, for a fishery as diverse as this can be an extremely difficult problem. A Department of Statistics survey in 1978 estimated Western Samoa's inshore fish catch to be about 666 t (DOS, 1979). Other recent estimates have ranged from 40 per cent greater than this figure, or 932 t (Johannes, 1982) to 109 t reported by the 1983 Fisheries Annual Report (DAFF, 1983).

In January 1986 the research section of the Fisheries Division began a programme of regular data collection from the inshore fishery. Due to the limited resources, only one component of the fishery, the Apia Fish Market, was studied. A programme was designed to collect data on the total sales of inshore fish and shellfish at the market on two days per week. The primary goal was to estimate the total catch from the inshore fishery more accurately and on a continuing basis. It was also planned to obtain information on catch composition, fishing methods and economics of the fishery.

## Methods

In order to discuss the methods used in this programme it is necessary to describe the Apia Fish Market and its operation. The market, located in central Apia near the produce market, was built in 1981 under a Japanese Government aid programme. It consists of a total of 996 m² of floor space encompassing both an open sales area and a closed area for office space, cold storage and sales. The 496 m² of open sales area, which are tiled, contain sales counters and four fresh-water sinks. These sales counters are available to the general public for sales of fish. All sellers pay WS$1.00 per day tray-rental fee which is collected by the lessee of the market and retained by him. Spaces cannot be reserved from day to day. The 400 m² of enclosed area are used by the lessee for fish processing, storage, and sales to the public. The enclosed section of the fish market takes in fish from Western Samoa's fleet of small, motorised vessels and processes fish both for export and for sales to the general public. In the open sales area fish are sold from the motorised fleet and from the inshore fishery. Inshore fish are sold only in the open section of the market.

Fish are sold at the Apia Fish Market by individual fishermen or members of their families and occasionally by one or two people representing a small group of fishermen. All prices are set by the sellers, though occasional bargaining does take place. Small fish are sold on strings, while larger ones are sold individually. Fish are brought to the market every day of the week beginning at about 6.00 a.m. During the week fish are brought in throughout the day until mid-afternoon. On Saturdays most activity ceases shortly after noon, while on Sundays sales start very early and last until about 8.00 a.m. Sunday sales provide fresh fish for the important Sunday noon meal. Tuna and bottom fish from the motorised fleet are also sold in the Apia Fish Market in a similar manner. There is no requirement for sellers to report their sales. This survey is therefore the only source of information on sales from the public section of the fish market.

Typically an individual seller brings 5–30 kg of fish to the market at one time. This is usually the catch of one fisherman or a small group employing a single fishing method. Two to ten species of fish and one or more species of invertebrates are generally represented in the catch. Often the catch consists entirely of fish on strings but larger fish, sold individually, are not uncommon.

Data collection took place at the fish market one or two days per week from 6.00 a.m. to 4.00 p.m. The day of sampling changed each week in order to represent all days equally, since the volume of sales was usually greater toward the end of the week. Each person selling fish was treated as a single survey unit. An attempt was made to interview each seller and to weigh a sample of his or her fish. This formed the basis for estimating total sales for each sampling day, from which the total monthly and annual sales were calculated.

Ideally, each seller was interviewed soon after arriving at the market. The person conducting the survey approached the seller and asked permission to weigh some of the fish, using a hand-held spring balance. If there were strings of fish, he chose one string which appeared representative of the catch as a whole, weighed it, asked the price of the string, and recorded the kind of fish on the string and the number of each kind. The same procedure was repeated for any individual fish and for each kind of shellfish. Prices of shellfish were not recorded. The data collector recorded the total number of strings, fish, crabs, lobster, clams and octopus belonging to the seller. Fishing method and the village near which the fish were caught were also recorded.

As in any programme of data collection, certain assumptions were made about the sampling universe and sample data. A statement of these assumptions and discussion of their justification is presented here.

*The strings sampled were representative, in weight and composition, of each person's total catch.*

Catches usually include fish of more than one species and a range of sizes. For ease of handling, sellers make up strings of fish which can all be sold for the same price. In most cases this results in strings which are about the same weight and have a similar mix of fish species.

*The sampling days each month formed a representative sample of the month as a whole.*

Sampling days were changed each week but no sampling was done on Saturdays and Sundays. Because of the high level of activity on weekend mornings it was felt that accurate sampling would not be possible and that attempts to interview sellers would interfere with their work. Observations of the market at weekends and estimates of total sales volume indicated that the increased level of activity was offset by the shorter working day. The catch composition also appeared to be similar, although shellfish might have been under-represented by sampling only on weekdays.

*Accurate information was obtained by interviewing the persons selling fish.*

The fish sellers are generally the fishermen themselves or members of their families who, no doubt, know the correct answers to the questions asked. Some early resistance to the interviews was encountered but that largely disappeared as the sellers became accustomed to the survey. Sellers sometimes attempted to joke or give obviously false answers, but experienced data collectors could quickly pick this up and find ways to obtain accurate answers.

Data collected in the fish market were analysed on a monthly basis and annual summaries were also produced. The following information was obtained from this analysis:

- An estimate of the total weight of fish and shellfish sold in the market;
- An estimate of the total value of fish sales and the average cost/kg of fish;

- The approximate composition of the catch by major taxon;
- The relative importance of the major fishing methods;
- The relative importance of various outlying areas in supplying fish to the Apia Fish Market.

The following formulae were used the in analysis of the market data:

Total daily fish catch =
$\Sigma$*[((wt. of string) x (no. of strings)) + ((wt. of fish) x (no. of fish))]*

Total daily shellfish catch =
$\Sigma$*[((wt. of crabs) x (no. of crabs)) + ((wt. of lobster) x (no. of lobster)) + ((wt. of clams) x (no. of clams)) + ((wt. of octopus) x (no. of octopus))]*

Total monthly catch =
*(Mean of total daily catch for all sampling days) x (no. of days in the month)*

Average price per kg (fish only) =
*(price of all sampled fish and strings)/wt. of all sampled fish and strings)*

The composition of the shellfish catch was computed as the percentage of the total shellfish weight made up by each of the four major groupings of shellfish.

For example:

$$\% \text{ crabs} = \frac{\Sigma[(wt.\ of\ crabs) \times (no.\ of\ crabs)]}{\Sigma[wt.\ of\ all\ shellfish]} \times 100$$

## Total catch

Fish catch composition was based on 15 major taxa – – either genus or family — and was initially computed as a percentage of the total number of fish. Percentage by number of fish was used because individual weights could not be obtained for fish sold on strings. Total number of each taxon was calculated by multiplying the number of fish of that taxon on a sampled string by the total number of strings for that seller. For each taxon, a monthly total was obtained by adding the values from all sellers for the entire month.

An additional calculation was used to estimate the fish catch composition by weight. This was based on the observation that most of the fish sold in the market tended to be of a typical size for each species. Using a chart of standard length/weight relationships for various types of fish (based on data for fishes of Fiji, L. Zann, University of the South Pacific, Suva, pers. comm.) an average weight for each major taxon was estimated. The total number of fish of each taxon was multiplied by the estimated average weight to obtain a total weight for each taxon. From this the catch composition by weight was calculated.

The result of calculating the fish catch composition by this method can be considered as only a rough estimate. Its validity was then tested by comparing the total weight obtained by this method with the weight obtained by summing daily totals. These numbers were generally found to be within ten per cent of each other.

The total catch (both fish and shellfish) was also broken down according to the location of fishing and fishing method. To simplify data analysis, the various fishing methods were grouped into four generalised methods: net, spear, hook and line, and trap (including both fixed and movable traps). The fishing locations were grouped together into eight regions (see Figure 1). For each of these a percentage of the total catch based on weight was calculated.

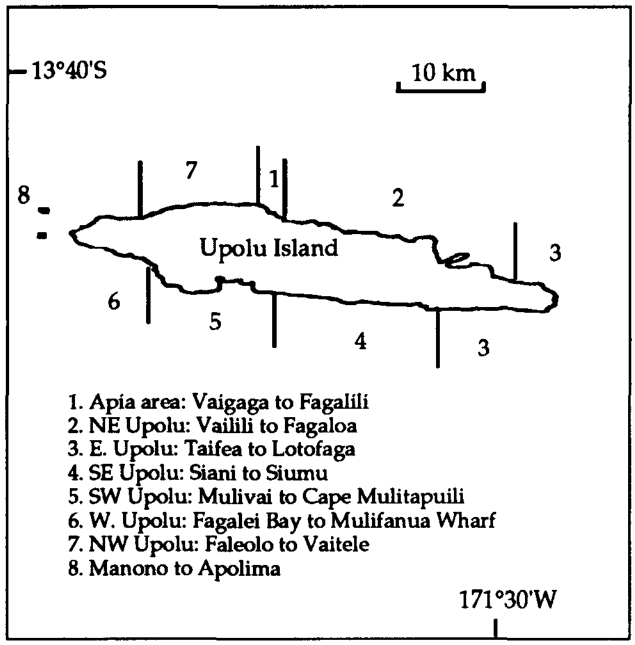


**Figure 1. Areas defined for purposes of the survey**

## Results

The data obtained from the market survey were summarised as monthly and annual reports. Table 1 shows the summary reports for all 1986 and the first eleven months of 1987. Although it is unwise to make general conclusions about Western Samoa's entire inshore fishery from this small data collection effort, some of the results are worth noting. The most obvious differences between the two years were the drop in volume and increase in price. Even after estimating a 12-month total for 1987, the volume of fish sales was 55,000 kg less than in 1986 and the shellfish sales were lower by 10,000 kg. The average price of fish in 1987, however, was nearly 25 per cent greater than in 1986.

Another obvious difference was the lack of atule (*Selar crumenophthalmus*) catch in 1987. In 1986 **atule** made up a large portion of the catch during the period March to June. At that time the appearance of **atule** was reported to be a regular seasonal event, but the catch never materialised in 1987.

**Table 1: Reef and lagoon catch (market sales)**

| Summary | 1986 Total | 1987 (Jan–Nov) |
|---|---|---|
| Total fish catch | 246472 | 175307 |
| Estimated 12-month total (1987) | | 191256 |
| Average price/kg (WS$) | 3.72 | 4.63 |
| Total shell catch | 37076 | 24597 |
| Estimated 12-month total (1987) | | 26832 |
| **Catch by region** | % wt. | % wt. |
| Apia area | 15 | 16.0 |
| NE Upolu | 14 | 8.0 |
| E Upolu | 3 | 0.3 |
| SE Upolu | 1 | 0.2 |
| SW Upolu | 3 | 3.0 |
| W Upolu | 7 | 2.0 |
| NW Upolu | 22 | 20.0 |
| Manono & Apolima | 35 | 50.0 |
| **Catch by fishing method** | % wt. | % wt. |
| Net | 24 | 40 |
| Spear | 48 | 31 |
| Trap | 12 | 16 |
| Hook and line | 16 | 13 |
| **Shellfish catch composition** | % wt. | % wt. |
| Crabs | 26 | 39 |
| Lobsters | 29 | 34 |
| Clams (*Tridacna*) | 27 | 7 |
| Octopus | 18 | 19 |

| **Fish catch composition** | % no. (1986) | % wt. (1986) | % no. (1987) | % wt. (1987) |
|---|---|---|---|---|
| *Naso* spp. | 4.2 | 6.5 | 2.9 | 6.5 |
| Other Acanthuridae | 27.0 | 11.0 | 39.0 | 15.0 |
| *Selar crumenophthalmus* | 19.0 | 5.1 | 1.1 | 0.3 |
| Other Carangidae | 5.6 | 8.1 | 2.3 | 2.6 |
| Scaridae | 7.3 | 11.0 | 10.0 | 17.0 |
| Mullidae | 5.6 | 7.3 | 7.8 | 8.8 |
| Mugilidae | 3.7 | 11.0 | 3.5 | 9.9 |
| Gerridae | 2.0 | 0.8 | 0.8 | 0.2 |
| Holocentridae | 4.4 | 1.1 | 8.6 | 3.4 |
| Serranidae | 2.2 | 2.8 | 4.5 | 6.3 |
| Muraenidae | 1.3 | 3.4 | 1.4 | 2.4 |
| Lutjanidae | 1.6 | 21.0 | 1.3 | 1.8 |
| Siganidae | 1.6 | 1.0 | 2.9 | 1.1 |
| Labridae | 0.6 | 0.8 | 0.6 | 0.8 |
| Lethrinidae | 7.7 | 24.0 | 5.5 | 15.0 |
| Others | 4.2 | 4.4 | 7.1 | 7.9 |

Figures 2 shows the average fish price and total volume of fish sales on a monthly basis for 1986 and 1987. Here the trend of decreasing volume and increasing price is clearly evident. The free market structure of the fish market allows fluctuations in supply and demand to control the price. Demand for reef and lagoon fish is consistently high in the fish market since these favoured species are not otherwise available to most of the Apia area population. The strength of demand and the willingness of customers to pay premium prices for these fish is evident in the large price increase between December 1986 and February 1987. This price increase is not coupled with a correspondingly large drop in total volume and observations indicate that it was the result of a cooperative effort by sellers to raise prices.

It is not at all clear, from the data in Figure 2, whether or not the decrease in volume at the fish market is part of a long-term trend. The extremely high volume seen in March to June 1986 is due, at least in part, to the large catch of **atule** at this time. The same period in 1987 saw almost no **atule** catch. Further, the low volume of fish landed in May and June of 1987 is probably related to activities surrounding the celebration of Western Samoa's 25th Anniversary of Independence. These activities apparently took precedence over fishing, leading to substantial decrease in effort. With the exception of the month of September, some recovery in total volume seems evident at the end of 1987. The September value seems improbably low and may indicate problems in data collection.

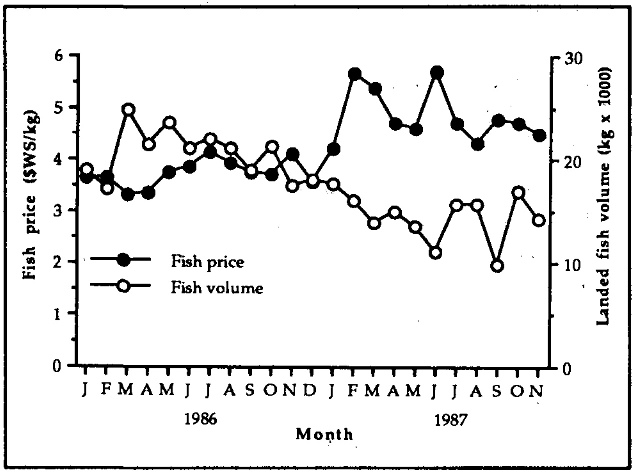


**Figure 2. Monthly landed volume of fish at Apia fish market and corresponding average monthly unit price**

It is, however, equally possible that there may be a steady decline in catch rates for Western Samoa's nearshore waters due to overfishing. Fishing pressure in easily accessible areas is very high and Samoans are noted for their utilisation of almost any marine organism of any size. Although no length-frequency data have been collected, casual observation at the Apia Fish Market shows that the average size of all species is quite small. In addition, the high price of fish, relative ease of entry into the fishery, and lack of sources of income for villagers make it unlikely that rural fishermen are decreasing their fishing effort.

Aside from the previously mentioned drop in the **atule** catch, the fish composition by taxa is fairly consistent between 1986 and 1987. Surgeonfishes (Acanthuridae), parrotfishes (Scaridae) and mullets (Mugilidae) make up over 50 per cent of the total market sales. The present analysis does not show catch by taxon for each fishing method, but this would be a useful addition to the programme. It could, for example, provide confirmation of the observation that a significant fraction of the mullet catch is taken by nets and stationary traps (weirs) during the September to November spawning period.

The shellfish catch composition shows a large drop in the catch of tridacnid clams. Despite the fact that composition is based on weight and includes the shell weight of clams, *Tridacna* spp. represented only 7 per cent of the shellfish sold in the market in 1987 (down from 27 per cent in 1986). Although this does not necessarily indicate a decrease in the total catch, it is consistent with other observations of declining stocks of giant clams.

The breakdown of catch by region shows that, for both 1986 and 1987, more than 75 per cent of the fish sold in the market came from the north side of Upolu and Manono and Apolima. This is to be expected, given the larger lagoon area, greater population and easier access to Apia. The percentage catch from Manono and Apolima is especially high and may indicate an essentially commercial exploitation of Manono Island's large lagoon.

## Discussion

Based on this initial data collection exercise, some recommendations can be made for refinement of the market survey. In any survey the information obtained is only as good as the raw data that are collected. The design of the data sheet was the result of a series of compromises between obtaining the necessary information and producing an unwieldy questionnaire that would be burdensome to the fish sellers. Some thought might be given to expanding the information collected by interviewing only a random sample of fish sellers every day. Total volume of sales could be estimated from tray rental receipts, provided that the clerks at the market indicated the type of fish ('inshore' or 'offshore') on each receipt.

When this survey was initiated it was hoped that the catch data from the Apia Fish Market could be used to estimate the total catch by Western Samoa's inshore fishery. It is now recognised that this is not possible without some complementary data collected directly from the villages. There is no reason to assume that market sales represent a fixed subset, in either composition or volume, of the total inshore catch. This survey does provide a picture of one segment of the fishery, undoubtedly the largest single segment, and some indication of the fishery as a whole. It also provides some valuable economic information, such as the financial contribution of the fish sales in Apia to rural income, which may merit further study.

Expansion of the inshore catch assessment programme to include data collection in rural areas would require a substantial increase of both money and personnel. The assessment of any traditional coral reef fishery is a difficult problem. Western Samoa's inshore fishery, with its large number of landing points, fish species, and fishing methods, is especially complex. If collection of catch data in villages were considered worthwhile, it could be simplified by focusing on a relatively small, well defined area such as Manono Island and its surrounding lagoon.

Information from this survey and from other sources suggests that Western Samoa's inshore resources are being fished near, or perhaps above, their maximum sustainable yield. If this is the case, at least as much attention should be given to ways of decreasing pressure on the resource as to continued data collection. The information obtained from this survey should be used to determine future inshore data collection needs and the level of priority of data collection for the inshore fishery.

## Acknowledgements

Valuable advice on the design of the survey was provided by Russel Freeman of Western Samoa's Department of Statistics. He also allowed access to Department of Statistics computers, for which we are very grateful. Most of the data collection was performed by Faafouina Fuli, Etuati Ropeti and Patrick Tafunai. Lui A.J. Bell of the Western Samoa Fisheries Division provided encouragement, advice and technical support without which this project would not have taken place. We are also grateful to Mike McCoy, Western Samoa's Fisheries Adviser, for countless valuable comments and suggestions.

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# A COST-BENEFIT ANALYSIS OF FISH AGGREGATION DEVICES (FADS) IN THE ARTISANAL TUNA FISHERY IN RAROTONGA, COOK ISLANDS

by Neil Sims, Senior Fisheries Research Officer, Ministry of Marine Resources, Rarotonga, Cook Islands


### Abstract

***A year-long creel-census of the artisanal offshore fishery of Rarotonga was conducted, in an effort to investigate the cost-benefit of FADs. An average coverage of 18.8 per cent was effected. Species and size compositions of catches were recorded, and volume and value of landings were estimated for each reef sector and FAD fished, and for each fishing method employed. Trolling on FADs was NZ$0.91/line-hour more productive than trolling elsewhere, resulting in increased landings worth $10 400. Mid-water fishing landings from FADs were worth $26 500.***

### Résumé

***Un relevé des prises réalisées par les pêcheurs pratiquant la pêche pélagique artisanale a été entrepris sur un an à Rarotonga; ce projet avait pour objectif d'évaluer la rentabilité des dispositifs de concentration du poisson (DCP). Le taux moyen de couverture a été de 18,8 pour cent. On a ainsi pu recueillir des données relatives à la composition par espèce et par taille et évaluer le volume et la valeur des quantités débarquées pour chaque secteur du récif, chaque DCP exploité et pour chaque méthode de pêche utilisée. Au terme de ces travaux, il est apparu que la rentabilité de la pêche à la traîne à proximité de DCP était de 0,91 dollars néo-zélandais par ligne et par heure supérieure à celle des ligneurs opérant en eau libre, ce qui correspond à une augmentation de 10 400 dollars au débarquement. La valeur des prises réalisées à proximité de DCP immergés à mi-profondeur était de 26 500 dollars.***


## Introduction

Fish aggregation devices have been deployed off Rarotonga since 1980 (see Table 1 and Figure 1). Since their deployment, there has been a marked increase in catches by the local trolling fishery, which mainly targets surface tunas and other pelagic fishes. These catch increases have been accompanied by reported increases in the cost-effectiveness and number of boats participating in the fishery. Similar benefits have been widely noted, and FADs represent an integral part of any strategy for enhancement of tropical surface fisheries.

**Table 1: FAD history during survey period**

| FAD no. | 1 | 4 | 5 | Average |
|---|---|---|---|---|
| Deployed | Early 1986 | 24/10/86 | 24/10/86 | - |
| Lost | 1/1/87 | 1/1/87 | Still in place | - |
| Days in place | 124 | 68 | 311 | 168 |
| % year in place | 34 | 19 | 85 | 46 |

Fishing trials by SPC Masterfishermen and local Fisheries Officers, and the enthusiasm of local fishermen, have proved the success of the FAD programme in Rarotonga. An analysis of the FAD programme in Hawaii from 1980 to 1982 provided catch estimates from 26 FADs. These estimates were evidently based on fishermen's reports, and although 'about 900,000 pounds of fish were reportedly caught at the buoys,...the actual amount...probably exceeded 2.5 million pounds', (Anon, 1982). A cost-benefit ratio of 1:3 was estimated for the FADs deployed, but benefits were considered as all catches taken at FADs, rather than real improvements in catch rates provided by FADs.

Buckley (1986) had used test-fishing data to demonstrate the enhancement value of FADs in American Samoa. A comprehensive study of the 'bonitier' fishery in Tahiti (Depoutot, 1987) was, however, less conclusive, with better fishing (CPUE expressed in terms of number of fish per day) around flotsam and baitfish schools than FADs. Catches were analysed for species and size-class proportions, but no economic evidence was provided relating FADs to the fishery.

FAD programmes are still, then, often viewed as short-term development initiatives, possibily providing better catches, but sometimes simply disappearing down the outer-reef slope. Consequently, FAD programmes encounter some difficulty in attracting long-term financial support for the considerable capital costs involved. Administrators of national and external funding sources might be more easily persuaded to release funds by definitive evidence of real economic benefits of FADs. This work attempts to provide a 'bottom line' by estimating the value of FADs to an actual fishery.

A survey programme of the Rarotongan artisanal tuna fishery was initiated in August, 1986. The primary aim was to determine the cost-effectiveness of FADs, examining both effort and landings of fishermen working the FADs, and thereby to identify the economic benefits FADs bring to the fishery.

## Methods

The survey consisted of a year-long creel-census of fishermen working out of the three small-boat harbours of Rarotonga (Figure 1). Sampling was done every second day, at alternate sides of the island (Avarua and Avatiu harbours on the north coast; and Ngatangiia harbour in the east). Each harbour was thus surveyed every fourth day.

Fishermen were interviewed upon return from trips, and information obtained on location (reef zones or FAD fished), effort and catch (length and species), for each fishing method employed. Individual lengths were the easiest measure to obtain on the wharf or beach, and approximate weights were obtained from the lengths, by rough estimation.

The commercial values of fish were the average beach prices during the survey year. By-catch prices were estimated according to the average value, on the basis of the proportional species composition of the by-catch for each fishing method.

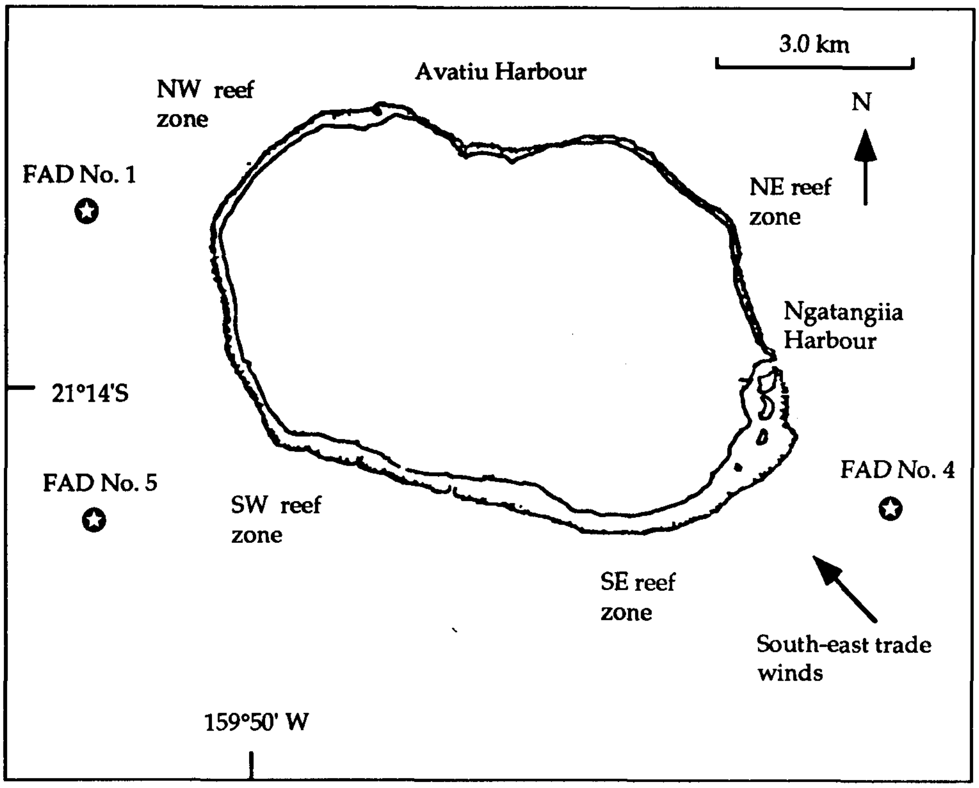


**Figure 1. Map of Rarotonga showing FAD locations, reef zones and harbours**

## Results

### *Coverage*

Data were collected over 137.5 survey days, with 400 trips recorded. Survey activities were cancelled for over a month after Cyclone Sally hit Rarotonga (when little fishing took place), and on 45 other days either surveys were not done, or the data were discarded as insufficient or too inaccurate. Average coverage was thus 18.8 per cent, giving a conversion-factor for full-year estimates of 5.32.

### *Effort by harbour*

No-fishing days were highest at Ngatangiia in the east (facing the trade winds), where no trips occurred on 40 per cent of the survey days. On the north coast, there were only seven per cent of days when no fishing was done, as weather conditions were usually less inclement in the north, and boats working out of the northern harbours are both larger and more numerous. The average number of trips on fishing days and maximum number of trips on any one day were about three times higher in the north than at Ngatangiia (Table 2).

**Table 2: Fishing effort by harbour during survey period**

| | Ngatangiia | North coast | Total |
|---|---|---|---|
| Days covered | 65.5 | 72 | 137.5 |
| % days covered | 17.9 | 19.7 | 18.8 |
| Trips surveyed | 105 | 295 | 400 |
| Trips per year | 587 | 1,485 | 2,072 |
| Average trips/day | 1.6 | 4.1 | 2.9 |
| Max. no. trips for one day | 5 | 13 | — |

### *Trolling catch and effort*

Trolling data show that the south-eastern zone produced far better catch rates (2.6 kg/line hr) than other reef zones (average CPUE for all reef zones was 1.5 kg/line-hour). FADs proved the next most productive fishing area, with an average catch rate of 1.8 kg/line-hour (Table 3A). The greatest effort, however, was expended in the north-western zone and at FAD No.1 (25.4 per cent and 25.1 per cent of total line-hours), as these zones were closest to the northern harbours and in the lee of the trade-winds. Fad No. 1 was only in place for 124 days out of the entire year. Overall, FADs attracted 43.2 per cent of effort, while the average period for which each FAD was operable was only 46 per cent of the survey year.

**Table 3: Catch and fishing effort during survey period**

A. Trolling

| | Reef zone NW | NE | SE | SW | Total Reef | FAD No. 1 | 4 | 5 | Total FADS | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Visits | 830 | 436 | 431 | 452 | 2149 | 580 | 118 | 388 | 1086 | 3235 |
| Line hrs | 6703 | 3398 | 2681 | 2335 | 15117 | 6629 | 740 | 4043 | 11412 | 26529 |
| % effort | 25.30 | 12.80 | 10.10 | 8.80 | 57.00 | 25.00 | 2.80 | 15.20 | 43.00 | 100.00 |
| CPUE (kg/l/hr | 1.30 | 0.90 | 2.60 | 1.50 | 1.50 | 1.60 | 1.90 | 1.90 | 1.70 | — |
| | | | | | Reef | | | | FADS | |
| $PUE (NZ$/l/hr | | | | | 7.24 | | | | 8.15 | |

Trolling differential: FADs vs Reef NZ$ 0.91/line hour

B: Mid-water fishing

| | VLL | Palu-ahi |
|---|---|---|
| Visits | 106 | 176 |
| Line hours | 569 | 1218 |
| CPUE (kg/line hr) | 4.3 | 2.7 |
| $PUE | NZ$21.2 | NZ$13.2 |

## *Trolling catch composition and value*

Although trolling around FADs produced a significantly higher number of fish than trolling in reef zones, the greater size of fish caught off the reef meant that FADs produced only 46.3 per cent of total trolling landings by weight (Table 4A). The average weight of yellowfin tuna from the FADs was only 7.2 kg while those caught in reef zones averaged 9.5 kg. Further, a significant proportion of the catch from reef zones was wahoo (16.5% by number; 35.7% by weight), with an average weight of 23.6 kg.

The higher value of yellowfin and wahoo also increased the returns from trolling in reef zones, whereas FADs produced a greater proportion of less valuable skipjack. Only 45.9 per cent of the value of trolling landings came from FADs. Even though the fish caught by trolling around FADs were smaller and of less valuable species, the higher CPUE resulted in an average return of NZ$0.91/line-hour more than that achieved by trolling in reef zones.

## *Mid-water fishing*

All of the mid-water catches were taken on FAD No. 1, until its loss on 1 January in Cyclone Sally. A total of 1,787 line-hours was spent mid-water fishing, of which 68 per cent were by the palu-ahi or dropstone method, and the remainder vertical long-lining (VLL). Most boats which undertook VLL usually dropped palu-ahi lines between VLL sets.

Vertical longlining proved far more productive, with catch rates of 4.3 kg/line-hour and return rates of $21.20/line-hour respectively. Most VLLs were rigged with between 8 and 15 hooks. As palu-ahi lines consisted of single hooks, the catch rate per hook-hour was markedly greater for palu-ahi.

## *Total landings*

Total landings of 47.6 t of fish, worth an estimated NZ$ 226,000, consisted of 42.1 t from trolling, and 5.5 t from mid-water fishing. This production figure from mid-water fishing, along with the 19.7 t from trolling on FADs, gives a total volume of catches from FADs of 25.2 t (53 per cent of all landings), worth NZ$ 119,600 (Tables 4A (iii) and (iv), and 4 B).

**Table 4: Landings and value by sector and species**

A. TROLLING

| | Reef zones NW | NE | SE | SW | Total reef | FADs 1 | 4 | 5 | Total FADs |
|---|---|---|---|---|---|---|---|---|---|
| **Total no. of fish** | | | | | | | | | |
| YF | 202 | 149 | 532 | 160 | 1043 | 569 | 133 | 798 | 1500 |
| SJ | 53 | 16 | 144 | 335 | 548 | 1266 | 0 | 628 | 1894 |
| WH | 202 | 69 | 489 | 21 | 340 | 0 | 0 | 5 | 5 |
| ETC | 69 | 11 | 27 | 21 | 128 | 27 | 37 | 5 | 69 |
| Total (yr) | 526 | 245 | 751 | 537 | 2059 | 1862 | 170 | 1436 | 3468 |
| | | | | | **Av. reef** | | | | **Av. FADS** |
| ***Average weight (kg)*** | | | | | | | | | |
| YF | 12.7 | 9.8 | 8.1 | 9.4 | 9.5 | 8.7 | 6.9 | 6.2 | 7.2 |
| SJ | 4.9 | 3.6 | 6.0 | 3.7 | 4.4 | 4.2 | 0.0 | 4.1 | 4.1 |
| WH | 24.1 | 22.2 | 24.0 | 22.7 | 23.6 | 0.0 | 0.0 | 13.6 | 13.6 |
| ETC | 16.8 | 10.9 | 22.7 | 13.0 | 17.7 | 12.9 | 12.5 | 15.9 | 15.9 |
| | | | | | **Total reef** | | | | **Total FADs** |
| **Total catch (kg)** | | | | | | | | | |
| YF | 2565 | 1460 | 4309 | 1504 | 9838 | 4950 | 917 | 4947 | 10815 |
| SJ | 259 | 57 | 864 | 1239 | 2420 | 5317 | 0 | 2575 | 7892 |
| WH | 4868 | 1531 | 1152 | 476 | 8028 | 0 | 0 | 68 | 68 |
| ETC | 1159 | 119 | 612 | 273 | 2165 | 348 | 462 | 79 | 890 |
| Total zones | 8852 | 3169 | 6938 | 3493 | 22453 | 10615 | 1380 | 7669 | 19666 |
| | **Total troll catch** | | | | | **42119 kg** | | | |

**Catch value NZ$**

(Fish prices/kg: YF & WH $5.00; SJ & ETC $4.00)

| Fish spp. | Total landed value Reef | FADs | Total |
|---|---|---|---|
| YF | 49194 | 54078 | 103272 |
| SJ | 19651 | 34724 | 54375 |
| WH | 40143 | 340 | 40483 |
| Others | 9526 | 3917 | 13433 |
| Total | 109515 | 93060 | 202575 |

B. MID-WATER FISHING

| | Spp. | VLL | Palu-ahi | Total |
|---|---|---|---|---|
| Total no. fish | YF | 128 | 175 | 303 |
| | ETC | 11 | 42 | 53 |
| Average weight (kg) | YF | 16.8 | 15.9 | |
| | ETC | 22.7 | 9.0 | |
| Total catch (kg) | YF | 2150 | 2782 | 4933 |
| | ETC | 250 | 378 | 628 |
| **Total (kg)** | | | | **5561** |
| Catch value (NZ$) (Fish prices/kg: YF $5.00; ETC $3.00) | | | | 26548 |
| **TOTAL LANDED VALUE (TROLLING AND MID-WATER FISHING)** | | | | **NZ$ 229 123** |

Note: YF = Yellowfin
SJ = Skipjack
WH = Wahoo
ETC = Others

## Discussion

In the absence of FADs, trolling effort will largely be directed elsewhere (although somewhat decreased), and so the figure given above for value of FAD landings does not represent the real benefit of FADs. Without considering variables such as the influence of FADs on fish behaviour or fishing patterns, a rough estimation of the real value of the FADs can be obtained by using the difference between FAD and non-FAD trolling in economic returns per unit of effort.

With trolling returns $ 0.91/line-hour more productive than reef trolling, and 11,412 hours of FAD trolling throughout the year, the presence of FADs resulted in an additional $ 10,400 worth of fish being landed from trolling. With the further assumption that mid-water fishing activities did not cause a decrease in trolling effort (as mid-water fishing was usually conducted throughout the day, while most FAD trolling occurs at dawn/dusk), the total mid-water fishing returns of $ 26,500 may be added to give a total benefit from the FADs of $ 37,000.

If three FADs had been in place year-round, a 117 per cent increase in these benefits could have been expected (with assumed null net influences of seasonal fish and fishing distribution patterns), with estimated returns of $ 80,500.

The cost of materials for a single FAD is about NZ$ 4,000. With increased fishing returns of $ 12,500 per FAD, returns of 312 per cent on expenditure can be realised.

There are, of course, other minor costs for construction and deployment of FADs, but similarly, there are tangible and intangible benefits from a continuing FAD programme which reach far beyond actual value of fish landed. These benefits, which include increased employment opportunities, development of supporting industries, improved nutrition and import substitution, make the returns from FADs of even greater significance to small Pacific Island countries.

## Conclusions

Trolling around FADs produces higher returns, in terms of catch rate and dollars per unit of effort, than trolling in reef areas. FADs also enhance the development of highly productive mid-water fishing activities.

For the survey period, landings from trolling on FADs were only slightly less than those from other areas despite the fact that the three FADs were each only in place, on average, for less than half the survey period. With mid-water fishing landings included, FADs contributed the largest proportion of the volume and value of total landings, and had the potential to realise an overall increase in landed fish value of $ 80,500.

On a cost-benefit basis (material costs and landed value benefit), FADs could provide returns of 312%, along with a range of flow-on benefits for developing

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# GROWTH AND MORTALITY RATES AND STATE OF EXPLOITATION OF SPINY LOBSTERS IN TONGA

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## Abstract

*An analysis was made of length frequency data for the spiny lobsters,* Panulirus penicillatus *and* P. longipes, *caught on coral reefs in Tonga. The length data were used to estimate both growth and mortality parameters for populations caught around the main island, Tongatapu, and the Ha'apai islands in the centre of the Tonga archipelago. Growth parameters were computed by the interactive ELEFAN computer method and were consonant with those of other tropical spiny lobsters. The results suggested that mortality rate for males is somewhat higher than for females and is much greater in Tongatapu than in Ha'apai. Yield-per-recruit analysis showed that the Tongatapu fishery is being subjected to growth overfishing and that harvests could be substantially increased by raising the size at first capture. The implications for management and the recommended size increases for the legal minimum harvestable size of lobsters in Tonga are discussed.*

## Résumé

*On a procédé à une analyse des données de fréquences de tailles relative aux langoustes,* Panulirus penicillatus *et* P. longipes, *capturées sur les récifs coralliens de Tonga. Les données de tailles ont servi à l'évaluation des paramètres de croissance et de mortalité des populations évoluant au large de l'île principale de Tongatapu et des Iles de Ha'apai situées au centre de l'archipel des Tonga. Par la suite, les paramètres de croissance ont été calculés à partir d'une méthode informatique interactive appelée ELEFAN et on a pu ainsi constater qu'ils correspondaient aux données relatives à d'autres espèces de langoustes tropicales. Les résultats obtenus semblent indiquer que les taux de mortalité des mâles sont légèrement supérieurs à ceux des femelles et beaucoup plus élevés à Tongatapu qu'à Ha'apai. L'analyse du rendement par recrue indique que les stocks de Tongatapu font l'objet d'une exploitation des spécimens en pleine croissance alors que les récoltes pourraient augmenter sensiblement si l'on ciblait davantage les individus de plus grande taille. On examine par ailleurs dans le document résumé ici l'incidence de cette situation sur la gestion de la ressource ainsi que la question du seuil de croissance en deçà duquel la pêche de la langouste de Tonga devrait être interdite.*


## Introduction

Despite their relatively great economic importance there are few reliable estimates of growth and mortality rates for tropical Indo-Pacific spiny lobsters. The only really detailed work has been accomplished in Western Australia (*P. cygnus*), in Hawaii (*P. marginatus*) and in the Caribbean Sea (*P. argus*). Estimates of growth parameters and mortality rates are summarised in Table 1, which also gives the calculated values of the growth performance indices, Ø and Ø' (Munro and Pauly, 1983; Pauly and Munro, 1984). It is well established that the largest spiny lobsters are usually males, presumably a result of superior growth rates. This is reflected in the growth performance indices.

The material upon which this analysis is based consists of separate sets of length frequency samples of male and female *Panulirus penicillatus* and *P. longipes*, measured at Tongatapu and Ha'apai between February 1984 and January 1985. Data collections were organised by Dr L. Zann of the Institute of Marine Resources of the University of the South Pacific. Zann (1984) gives details of the research project in Tonga, of the fishery and of the reproductive characteristics and behaviour of the lobsters.

## Data collection and analysis

Samples were collected from February 1984 to January 1985 from lobsters landed in Tongatapu and at two islands in the Ha'apai group. Information on sample sizes is summarised in Table 2. The largest samples were of male *P. penicillatus* at Tongatapu (N = 3364 in 12 monthly samples ranging in size between 93 and 637 individual measurements). Measurements are of carapace length (L), along the mid-dorsal line from between the horns to the rear margin of the carapace.

**Table 1: Growth and mortality parameters and growth performance indices for species of spiny lobsters**

| Source | Species/ location | Sex | CL | $W_\infty$ | K | M | a | b | Ø' | Ø |
|---|---|---|---|---|---|---|---|---|---|---|
| Ebert & Ford | *P.penicillatus* | M | 146.5 | 2133 | 0.211 | 0.284 | 0.002 | 2.773 | 3.66 | 1.54 |
| 1986 | (Enewetak) | F | 96.5 | 580 | 0.580 | 0.244 | 0.002 | 2.773 | 3.73 | 1.61 |
| Zann (1984) | *P.penicillatus* | M | | | | | 0.237 | 1.727 | | |
| | (Tonga) | F | | | | | 0.006 | 2.571 | | |
| Phillips et al. | *P.cygnus* | M & | 113.5 | | 0.495 | 0.226 | 0.003 | 2.744 | 3.80 | |
| (1980) | (W. Aust) | F | | | | | | | | |
| Munro | *P.argus* | M | 190.0 | 4700 | 0.215 | 0.400 | 0.003 | 2.738 | 3.89 | 1.78 |
| (1974) | (Caribbean) | F | 190.0 | 4700 | 0.215 | 0.600 | 0.003 | 2.738 | 3.89 | 1.78 |
| Uchida & | *P.marginatus* | M | 127.7 | | 0.270 | | | | 3.64 | |
| Tagami | (Oahu, | F | 106.0 | | 0.386 | | | | 3.64 | |
| (1984) | Hawaii) | | | | | | | | | |
| | (Necker Is) | M | 124.6 | | 0.263 | | | | 3.61 | |

Note: CL = asymptotic carapace length; $W_\infty$ = asymptotic weight, K = coefficient of growth, M = coefficient of natural mortality; a = constant in length (mm)/weight (g) relationship; b = exponent in l/w relationship; ø' and ø = growth performance indices in terms of length and weight.

The size frequency data were analysed using the 'Kiel version' (December 1986 update) of the ELEFAN I and

II programs (Brey and Pauly, 1986). After experimentation, the size frequency data were compiled into 0.5 cm groups for analysis. One-centimetre size classes were too coarse and caused detail to be lost.

**Table 2: Sample sizes and distributions for male and female *Panulirus penicillatus* and *P. longipes* sampled at Tongatapu and Ha'apai between February 1984 and January 1985**

| | *P. penicillatus* | | | | *P. longipes* | | | |
|---|---|---|---|---|---|---|---|---|
| | Tongatapu | | Ha'apai | | Tongatapu | | Ha'apai | |
| | Male | Female | Male | Female | Male | Female | Male | Female |
| Feb | 93 | 87 | 1314 | 755 | 132 | 181 | 22 | 46 |
| Mar | 261 | 228 | 70 | 52 | 47 | 48 | 0 | 0 |
| Apr | 146 | 180 | 534 | 516 | 55 | 69 | 33 | 41 |
| May | 330 | 253 | 474 | 363 | 25 | 35 | 72 | 67 |
| Jun | 117 | 81 | 380 | 332 | 16 | 10 | 86 | 64 |
| Jul | 254 | 76 | 75 | 64 | 180 | 85 | 14 | 11 |
| Aug | 344 | 86 | 0 | 0 | 191 | 129 | 0 | 0 |
| Sep | 510 | 207 | 316 | 225 | 101 | 80 | 26 | 30 |
| Oct | 496 | 150 | 0 | 0 | 167 | 126 | 0 | 0 |
| Nov | 637 | 230 | 112 | 139 | 285 | 291 | 21 | 15 |
| Dec | 158 | 36 | 91 | 87 | 72 | 50 | 26 | 15 |
| Jan | 318 | 113 | 0 | 0 | 132 | 118 | 0 | 0 |
| Total | 3364 | 1727 | 3366 | 2533 | 1403 | 1222 | 300 | 289 |

The protocol adapted for the analysis is as follows:

(i) The monthly size frequency distributions for each sex, species and area are converted to percentage frequencies, weighted by the square root of the sample size and, where there are gaps in the sampling, also weighted with respect to the time interval which the sample 'represented'. The weighted samples are then summed to give the best representation of the annual average size frequency distribution of the catches. These are all routines which are available within the structure of the ELEFAN programs.

(ii) The annual average size frequency distributions by sex, species and area are then used to obtain a first estimate of the asymptotic size ($L_\infty$) and of the ratio of the coefficients of mortality to growth (Z/K) from a Wetherall plot (embodied in the ELEFAN 2B program) (Wetherall, 1986; Wetherall et al,1987).

(iii) The monthly size frequency distributions for each sex and species are then restructured using the ELEFAN 1A program, to highlight the peaks and troughs (Brey and Pauly, 1986) and the results are inspected to identify the most likely 'starting point', normally a highly conspicuous peak through which it can reasonably be assumed that the growth curve must pass. Using ELEFAN 1B, a narrow search is then performed using as fixed values the initial estimates of $L_\infty$ and of the starting point. This results in a first estimate of the growth coefficient, K.

(iv) The ELEFAN 2A program is then run, using the first estimates of K and $L_\infty$. This yields a first estimate of Z, the total mortality coefficient and, if an estimate of the natural mortality rate is available, first estimates of the probabilities of capture of the smallest size classes (within the selection curve) can be calculated.

(v) The observed frequencies of the smallest size groups in the monthly samples are/can then be corrected by dividing the observed frequencies by the probabilities of retention of successive size classes.

(vi) The corrected data are then restructured (ELEFAN 1A), the most conspicuous peak identified (the starting point or SP) and a 'response surface' generated for that starting point and a range of values of K and $L_\infty$ which bracket the first estimates. This will result in one or more combinations of the K and $L_\infty$ which give the largest ratios of the 'estimated sum of peaks' to the 'available sum of peaks' ($E_{max}/A$).

(vii) The 'starting point' is then allowed to vary for the current estimates of K and $L_\infty$ to see if the $E_{max}/A$ ratio can be improved and, thereafter, a final response surface generated for a narrow range of values of K and $L_\infty$, yielding final estimates of the growth parameters.

(viii) A growth curve is then calculated and superimposed on the restructured length frequency data to verify the fit.

(ix) Once the growth parameters are available the mortality rate is estimated, using the ELEFAN 2A program to generate length-converted catch curves for each sex, species and area. The option in which the samples are converted to percentage frequencies, weighted by the square roots of the sample size and, if there are gaps in the data, weighted in respect of the interval between samples, has been routinely chosen. Trials showed that provided the sampling has been adequate, the results are remarkably insensitive to the weighting mode used.

(x) The ELEFAN 2A program also generates estimates of the mean size of first capture ($L_c$) and sizes at which they are fully selected (L') together with the probabilities of retention of successive size classes.

It is emphasised that it is not possible simply to run the ELEFAN 1B program and blindly accept the answers which are generated. The program does nothing more than fit the best von Bertalanffy growth curve to a set of length frequency data. If the sampling program has been inadequate or selective, the result might be erroneous. As a general case the program should not be used if no modal progression is apparent to the eye. Clearly more weight can be ascribed to growth curves which are based on large samples and which pass through all or most 'peaks' and avoid most 'troughs'. Mortality analyses were done separately for the island groups, as the fisheries are known to differ in their rate of exploitation, the fishery being more intensive at Tongatapu, the site of the Tongan capital city of Nuku'alofa.

## Results

The parameter estimates are summarised in Table 3. As in any other form of analysis, the estimates are only as good as the samples and as a general rule are improved by large sample sizes. The monthly size frequency distributions, fitted growth curves and length-converted catch curves are shown in Figures 1 to 8.

**Table 3: Summary of estimates of growth and mortality rates for *Panulirus penicillatus* and *Panulirus longipes* in Tongatapu and Ha'apai, Tonga**

| Growth parameters (all areas) | *Panulirus penicillatus* Male | *Panulirus penicillatus* Female | *Panulirus longipes* Male | *Panulirus longipes* Female |
|---|---|---|---|---|
| Asymptotic carapace length($CL_\infty$) | 179.00 | 128.00 | 133.00 | 118.00 |
| Asymptotic weight($W_\infty$)g | 3718.00 | 1467.00 | 1884.00 | 1356.00 |
| Growth coefficient (K) | 0.27 | 0.32 | 0.31 | 0.42 |
| Ø' | 3.94 | 3.72 | 3.74 | 3.77 |
| Ø | 1.82 | 1.63 | 1.69 | 1.72 |
| Mortality and recruitment | | | | |
| M | 0.284* | 0.244* | (0.23**) | (0.23**) |
| M/K | 1.05 | 0.76 | (0.73) | (0.55) |
| Tongatapu | | | | |
| Z | 1.66 | 1.33 | 1.19 | 1.41 |
| $L_c$ | 77.00 | 62.00 | 41.00 | 42.00 |
| L' | (82.50) | 72.50 | 47.50 | 47.50 |
| F | 1.38 | 1.09 | 0.96 | 1.18 |
| E | 0.83 | 0.82 | 0.81 | 0.84 |
| Ha'apai | | | | |
| Z | 0.75 | 0.88 | 0.61 | (0.89) |
| $L_c$ | 70.00 | 67.00 | 52.00 | (49.00) |
| L' | 82.50 | 77.50 | 57.50 | (52.50) |
| F | 0.47 | 0.64 | 0.38 | (0.66) |
| E | 0.62 | 0.72 | 0.62 | (0.74) |

* from Ebert & Ford (1986)
** from Phillips et al. (1980) for *Panulirus cygnus*

Note: Values in brackets are approximations and should not be regarded as definitive. Lengths in mm, weights in g.

## Growth parameters

### *Panulirus penicillatus*

*Males:*

The Wetherall plot produced first estimates of $L_\infty$= 178 mm (Z/K = 2.195) at Ha'apai but gave a non-significant regression for the data from Tonga. Analysis of the Tongatapu data yielded estimates of $L_\infty$ = 179 mm and K = 0.27 (SP = 57.5 mm November, $E_{max}/A$ = 233). This is a relatively low E/A value but the curve does fit the major peaks (Fig. 1). It is possible that there is some seasonality in the growth curve, with diminished growth in the cooler months (June–September), but the data are not sufficiently good to substantiate this.

Data for Ha'apai gave low E/A ratios for combinations of $L_\infty$ and K, bracketing the values of K and $L_\infty$ found for Tongatapu. $E_{max}/A$ was only 133 for K = 0.28 and $L_\infty$ = 179 mm. These values are close to the estimates for Tongatapu.

*Females:*

The analysis produced estimates of K = 0.32, $L_\infty$ = 128 mm (SP = 48 mm in September, $E_{max}/A$ = 326). The progression of recruits from 37.5 mm in May through to the following January is particularly clear (Fig. 2).

No modal progression could be seen in the data for Ha'apai and the E/A ratio was close to zero for the combination of K and $L_\infty$ found for Tongatapu.

### *Panulirus longipes*

*Males:*

The standard analytical protocol produced estimates of K = 0.31, $L_\infty$ = 133 mm (SP 42.5 mm in September, $E_{max}/A$ = 569) for samples taken in Tongatapu. The relatively high value of $E_{max}/A$ gives much credence to the estimate. Figure 3 shows the fit of the calculated growth curve. The sample from Ha'apai was too small (N = 300) to warrant analysis.

*Females:*

Estimates of K = 0.42 and $L_\infty$ = 118 mm (SP = 40 mm in August, $E_{max}/A$ = 434) were produced by the usual routine. Figure 4 shows a moderately good fit of the calculated growth curve to the monthly peaks, but with some conspicuous peaks missed around 62.5 mm in September to November. The sample from Ha'apai was too small (N = 289) for analysis.

## Mortality and recruitment parameters

Parameters estimated for *P. penicillatus* and *P. longipes* at Tongatapu and Ha'apai are summarised in Table 3.

It must be borne in mind that the size frequencies that have been recorded are a combination of the results of selective action by the spear-fishermen and may also be influenced by decisions concerning which size groups will be offered in the market place at Nuku'alofa in Tongatapu or which would be purchased by the fish dealers in Ha'apai. The selective action of the fishermen would be manifested by selective spearing of the largest lobsters, but the perception of what is large would be expected to change towards smaller sizes in a heavily exploited fishery. It is also possible that behavioural traits, such as movement of larger lobsters into deeper water, could affect the catchability of different size groups. Finally, a number of different year-classes are represented in the catches and any marked deviations away from a steady rate of recruitment would be manifested as departures of the right-hand arm of the catch curves from linearity.

The real test of the validity of the length-converted catch curve is the degree of scatter of the points on the right hand limb. Points in the larger size classes which are based on less than five specimens are ignored (Brey and Pauly, 1986).

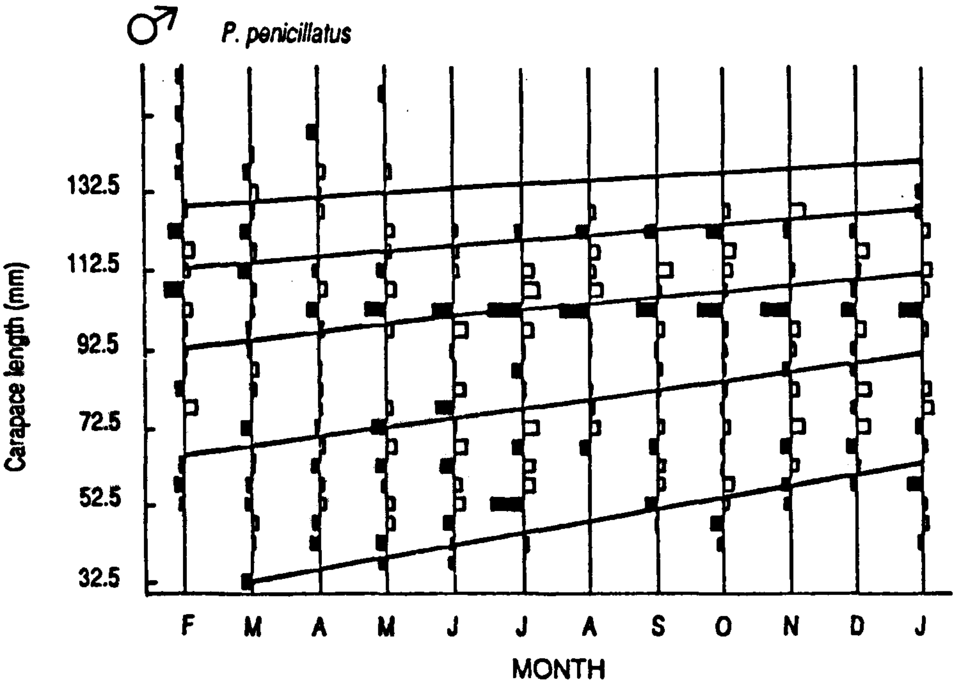


**Figure 1. Restrictured size frequency distributions and fitted von Bertalanffy growth curves for male *Panulirus penicillatus* at Tongatapu. $L_\infty$ = 179 mm, K = 0.27, SP = 57.5 mm in November, $E_{max}/A$ = 233**

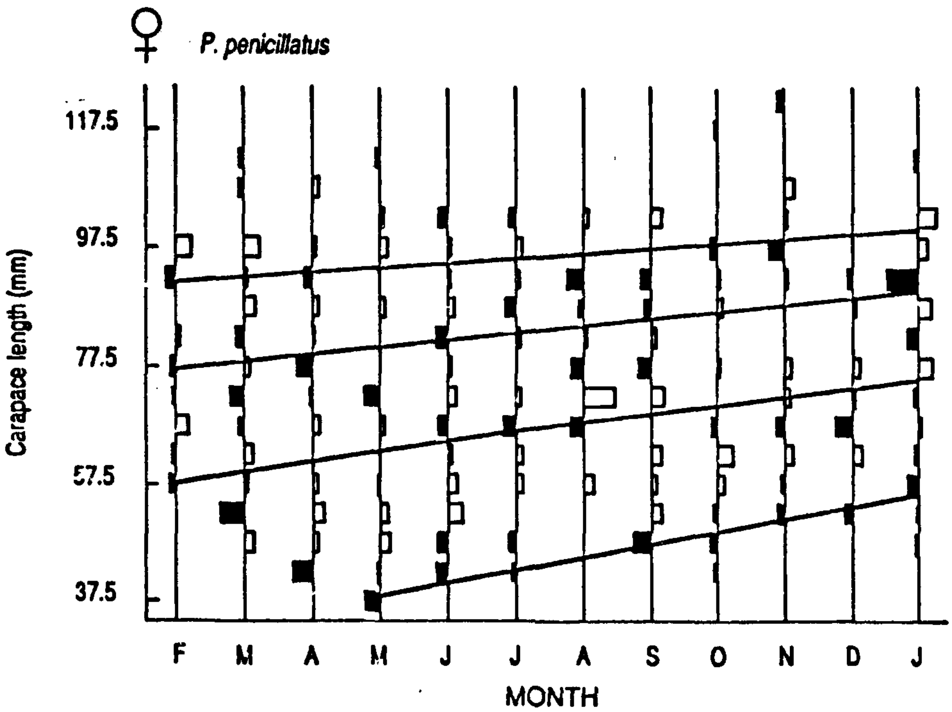


**Figure 2. Restructured size frequency distribution and fitted von Bertalanffy growth curves for female *Panulirus penicillatus* at Tongatapu. $L_\infty$ = 128 mm, K = 0.32, SP = 48 mm in September, $E_{max}/A$ = 326**

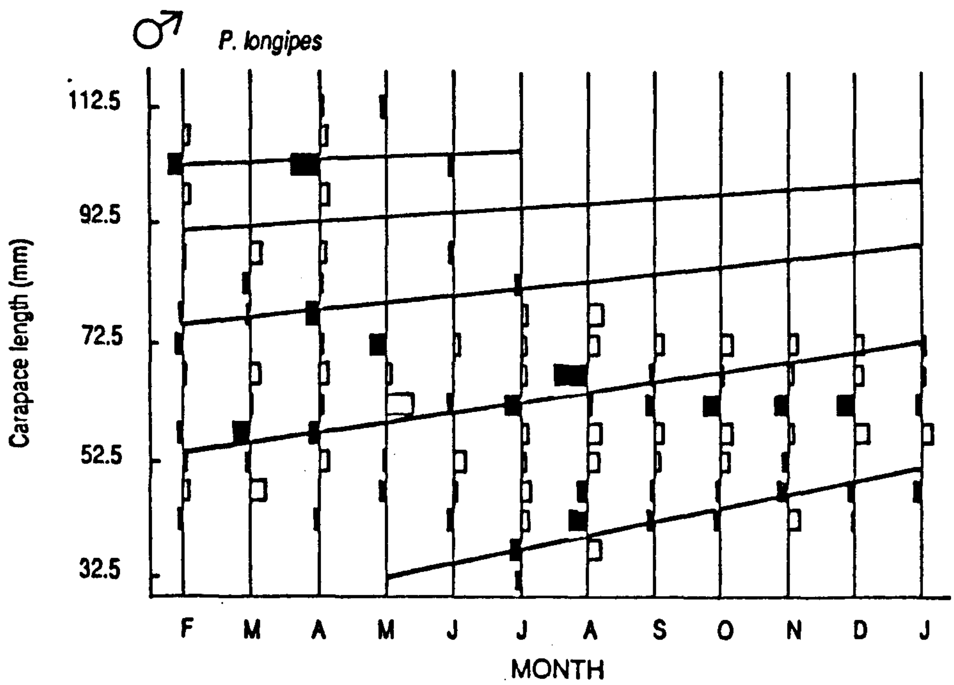


**Figure 3. Restructured size frequency distributions and fitted von Bertalanffy growth curves for male *Panulirus longipes* at Tongatapu. $L_{\infty}$ = 133 mm, K = 0.31, SP = 42.5 mm in September, $E_{max}/A$ - 569**

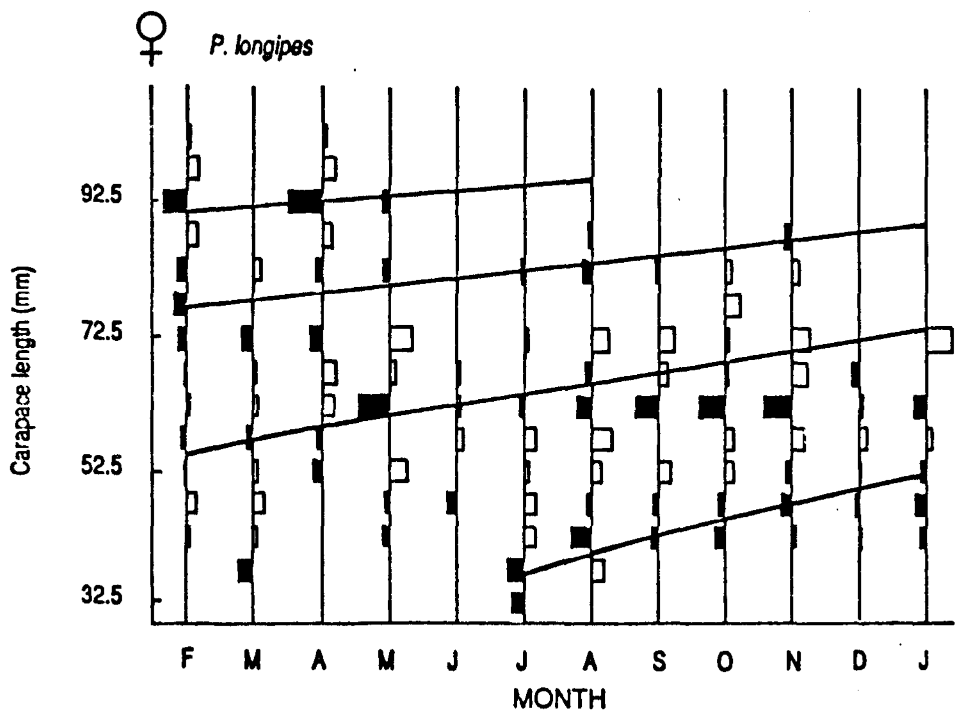


**Figure 4. Restructured size frequency districutions and fitted von Bertalanffy growth curves for female *Panulirus longipes* at Tongatapu. $L_{\infty}$ = 118 mm, K = 0.42, SP = 40 mm in August, $E_{max}/A$ = 434**

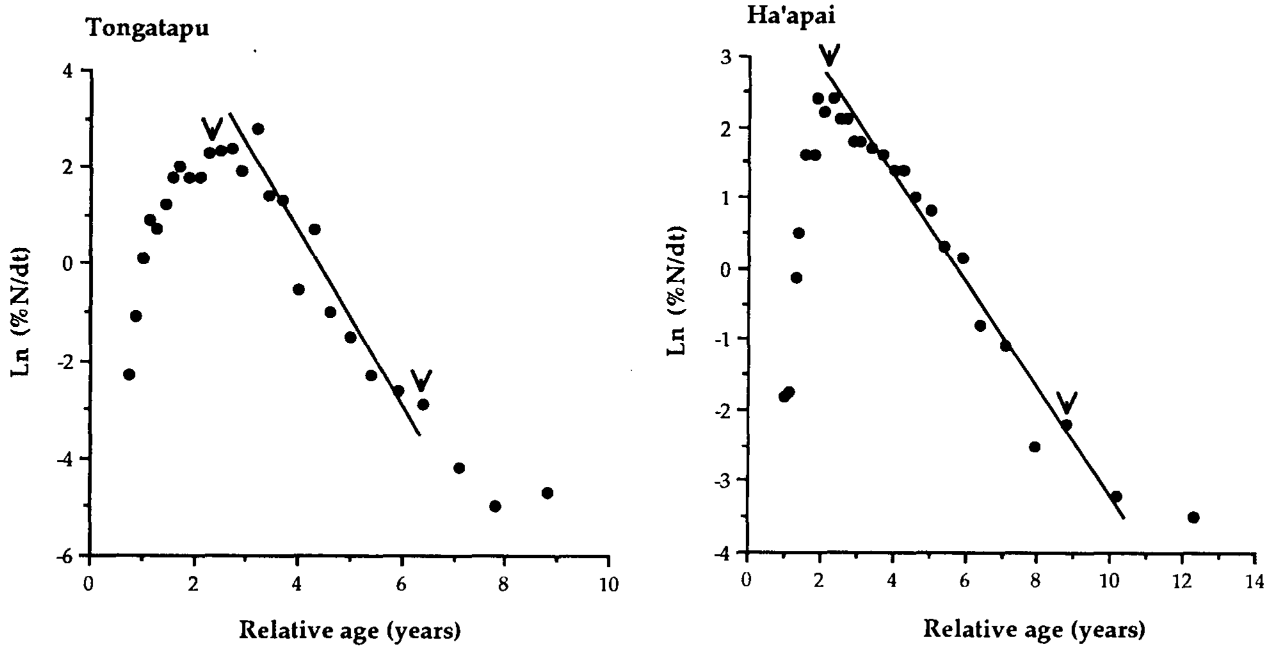


**Figure 5. Length-converted catch curves for estimation of total mortality rate (Z) of male *Panulirus penicillatus* at Tongatapu and Ha'apai. The portion of the curve delineated by arrows was used in the calculation of total mortality.**

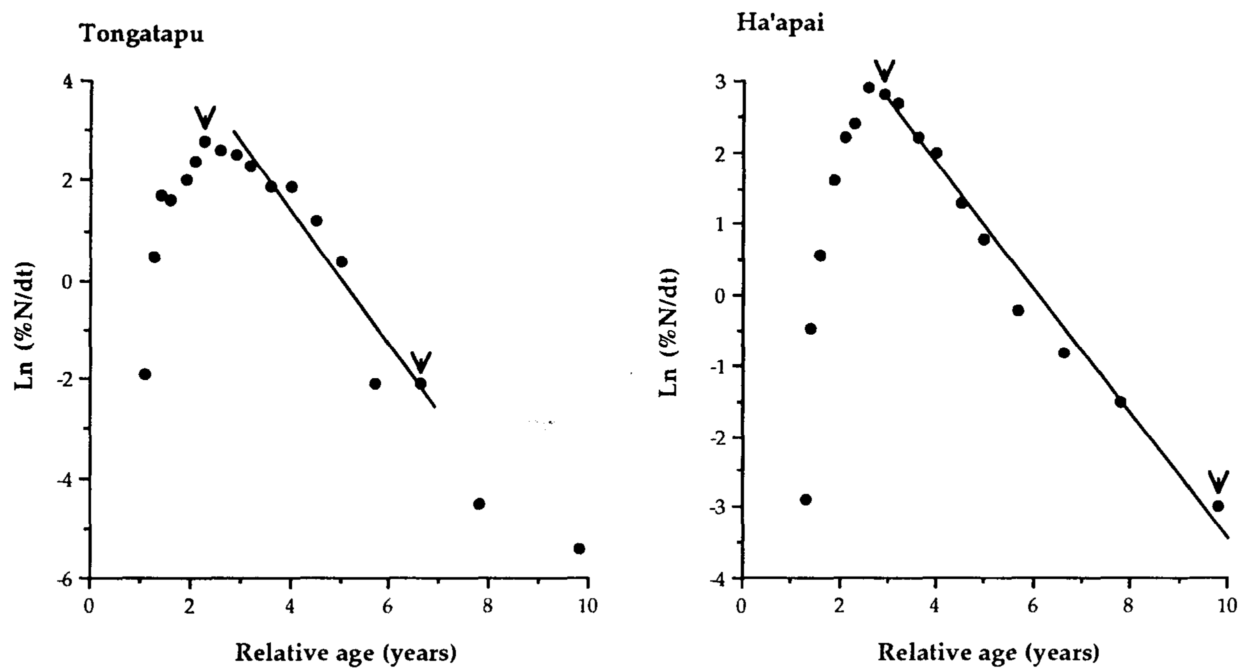


**Figure 6. Length-converted catch curves for estimation of total mortality rate (Z) of female *Panulirus penicillatus* at Tongatapu and Ha'apai. The portion of the curve delineated by arrows was used in the calculation of total mortality.**

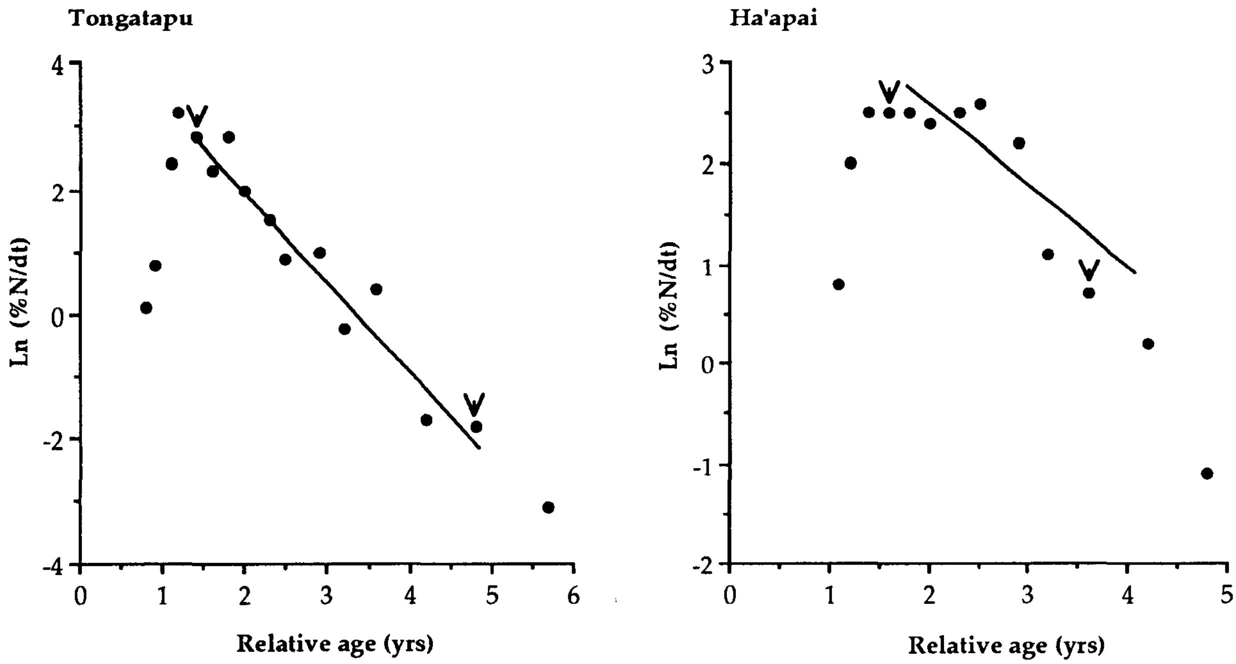


**Figure 7. Length-converted catch curves for estimation of total mortality rate (Z) of male *Panulirus longipes* at Tongatapu and Ha'apai. The portion of the curve delineated by arrows was used in the calculation of total mortality.**

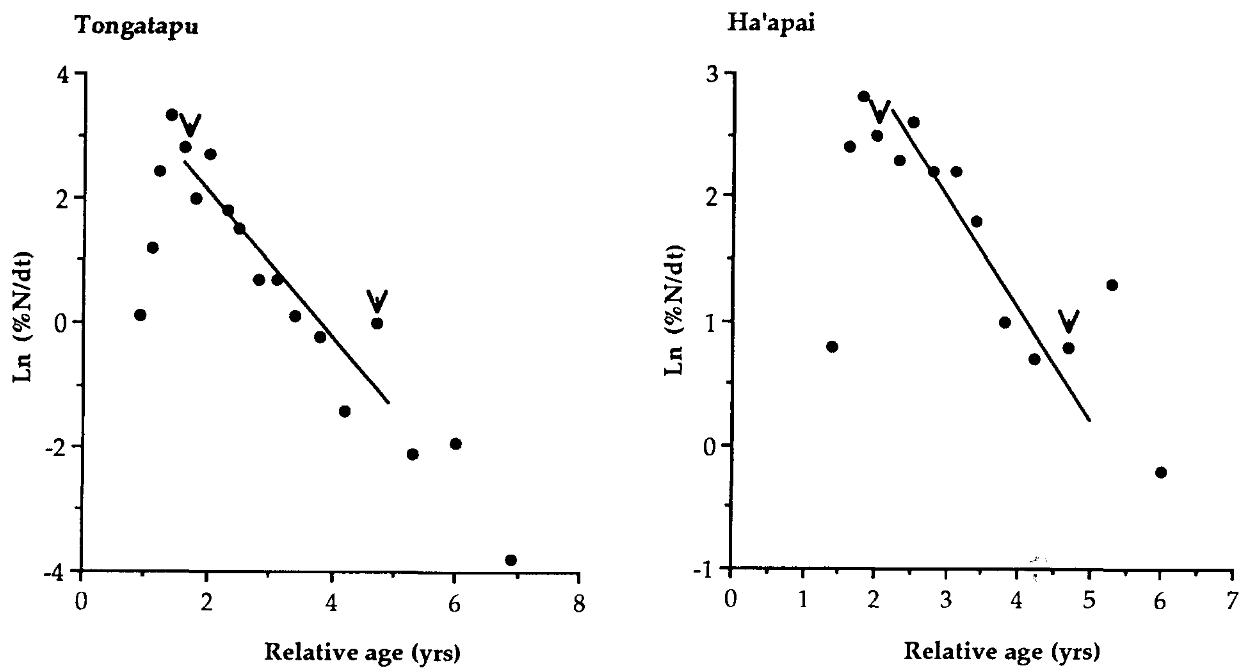


**Figure 8. Length-converted catch curves for estimation of total mortality rate (Z) of female *Panulirus longipes* at Tongatapu and Ha'apai. The portion of the curve delineated by arrows was used in the calculation of total mortality.**

### *Panulirus penicillatus*

Figures 5 and 6 show length-converted catch curves for males and females at Tongatapu and Ha'apai. The results suggest that the mortality rate for males is somewhat higher than for females and is much greater in Tongatapu than in Ha'apai.

*Males:*
For male *P. penicillatus* at Tongatapu the left-hand limb of the catch curve (Fig. 5) ascends to a plateau at 82.5–92.5 mm L whereas for Ha'apai the curve descends linearly from 82.5 mm. As it could be expected that the length at full recruitment (L') would be larger at Ha'apai (because the lobsters are actually selected by divers), it is reasonable to believe that L' = 82.5 mm CL at Tongatapu, and that any peaks at larger sizes are artefacts resulting from the sampling or from variation in recruitment. A regression based on the size range 87.5–147.5 mm gives an estimate of Z = 1.66 for male *P. penicillatus* at Tongatapu. A similar regression for the Ha'apai male stock based on the range between 82.5–167.5 mm gives Z = 0.75.

At Tongatapu males are recruited at a mean size, $L_c$, of 77 mm whereas at Ha'apai the estimate is $L_c$ = 70. The estimates of $L_c$ are rather sensitive to the frequencies in the successive length groups and to the estimated natural mortality rate and therefore should be regarded as generalisations.

*Females:*
As was the case with male *P. penicillatus*, the catch curve is more sharply peaked for the Ha'apai stocks (Fig. 6), suggesting full recruitment at L' = 77.5 mm, whereas the Tongatapu stocks had a L' = 72.5 mm.

A regression covering the range 72.5–112.5 mm L for the Tongatapu stock yields estimates of Z = 1.33 and $L_c$ = 62 mm, while for the Ha'apai stock over the range 77.5–122.5 mm, estimates were Z = 0.88 and $L_c$ = 67 mm.

### *Panulirus longipes*

Large samples of this species were available for Tongatapu (Table 1) but for the Ha'apai Islands the recorded catches were very low. The reasons for this difference are not known.

*Males:*
From the length-converted catch curve for this species at Tongatapu (Fig. 7), it appears that the males are fully recruited to the fishery at L' = 47.5 mm. A length-converted catch curve regressed over the length range 52.5–102.5 mm yields an estimate of Z = 1.19 and $L_c$ = 41 mm.

For the small sample from Ha'apai, the males appear to be fully recruited by L' = 57.5 mm and a regression of the catch curve regressed over the range 62.5–102.5 mm yields an estimate of Z = 0.61 and $L_c$ = 52 mm.

*Females:*
The length-converted catch curve for Tongatapu indicates full recruitment, L', at 47.5 mm (Fig. 8) and a regression over the range 52.5–102.5 mm yields estimates of Z = 1.41 and $L_c$ = 42 mm.

The small sample from Ha'apai gives a length-converted catch curve which is almost horizontal between CL of 42.5–67.5 mm, and then declines sharply. The samples are strongly biased towards the situation in May and June when almost half of the total sample was measured. Using entirely unweighted samples to remove any bias towards these months had no appreciable effect. A regression over the range 57.5–92.5 mm CL yields preliminary estimates of Z = 0.89 and $L_c$ = 49 mm.

## Yield per recruit and rate of exploitation

Figures 9 and 10 show yield-per-recruit curves and computations for the two species based on the population and fishery parameters which are summarised in Table 3.

For each species the curves selected for illustration include one curve representing the current size at first capture at Tongatapu, one curve showing the maximum yield per recruit which could be attained at current levels of fishing effort, but with a change in the size at first capture, and several other representative curves.

### *Panulirus penicillatus*

*Males:*
Figure 9 shows that the Tongatapu fishery is being subjected to growth overfishing and the harvest could be substantially increased by raising the size at first capture to 127.5 mm CL. Larger or similar harvests could be taken by half the current fishing effort. Any increase in effort at Ha'apai will result in decreased landings.

*Females:*
As is the case for males, the fishery would benefit from a substantial increase in the size at first capture and a decrease in the fishing effort (Fig. 9). The optimum $L_c$ is around 95 mm CL. Harvests off Ha'apai will decrease if effort is increased.

### *Panulirus longipes*

*Males:*
Harvests could be doubled by increasing $L_c$ to 100 mm CL. A halving of fishing effort would have no appreciable effect on yield/recruit when $L_c$ = 100 mm and would increase harvests substantially at the current Lc = 41 mm (Fig. 10). The Ha'apai fishery is fully exploited at current levels of F and Lc.

*Females:*
The situation is the same as for males. Figure 10 shows that the optimum $L_c$ = 95 mm.

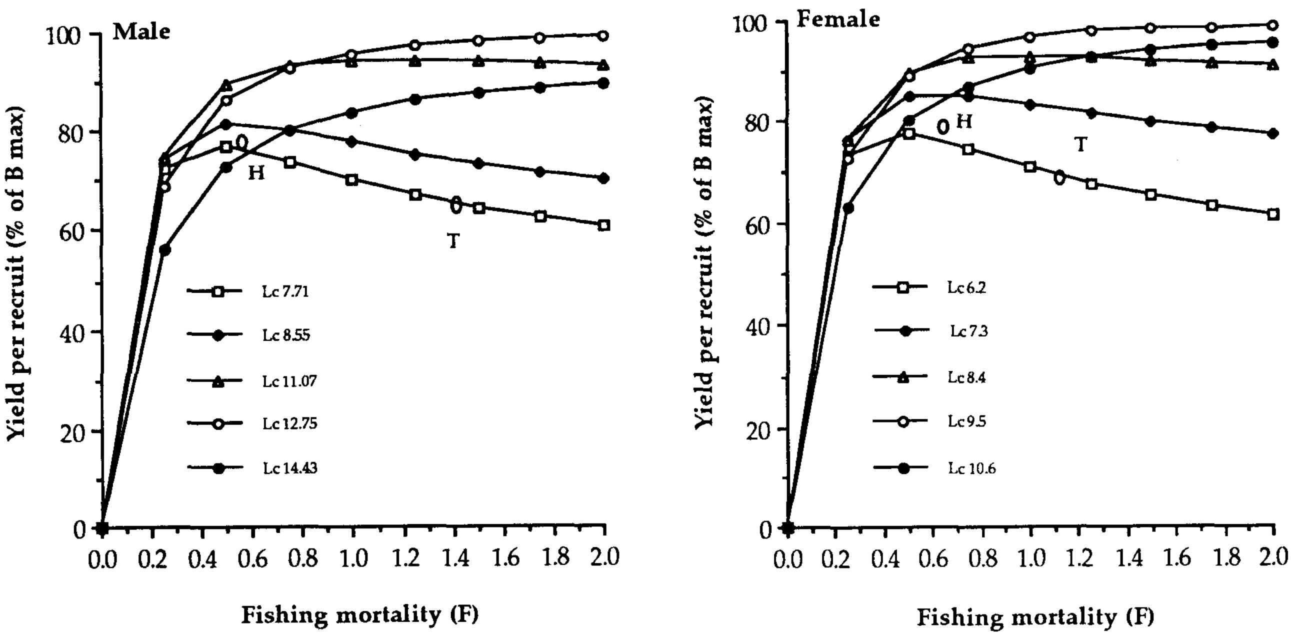


**Figure 9. Yield per recruit of male and female *Panulirus penicillatus*, relative to fishing mortality, F, expressed as percentage of maximum biomass of a cohort, for five sizes at first capture. T and H indicate points representative of the status of the Tongatapu and Ha'apai fisheries in 1985/86.**

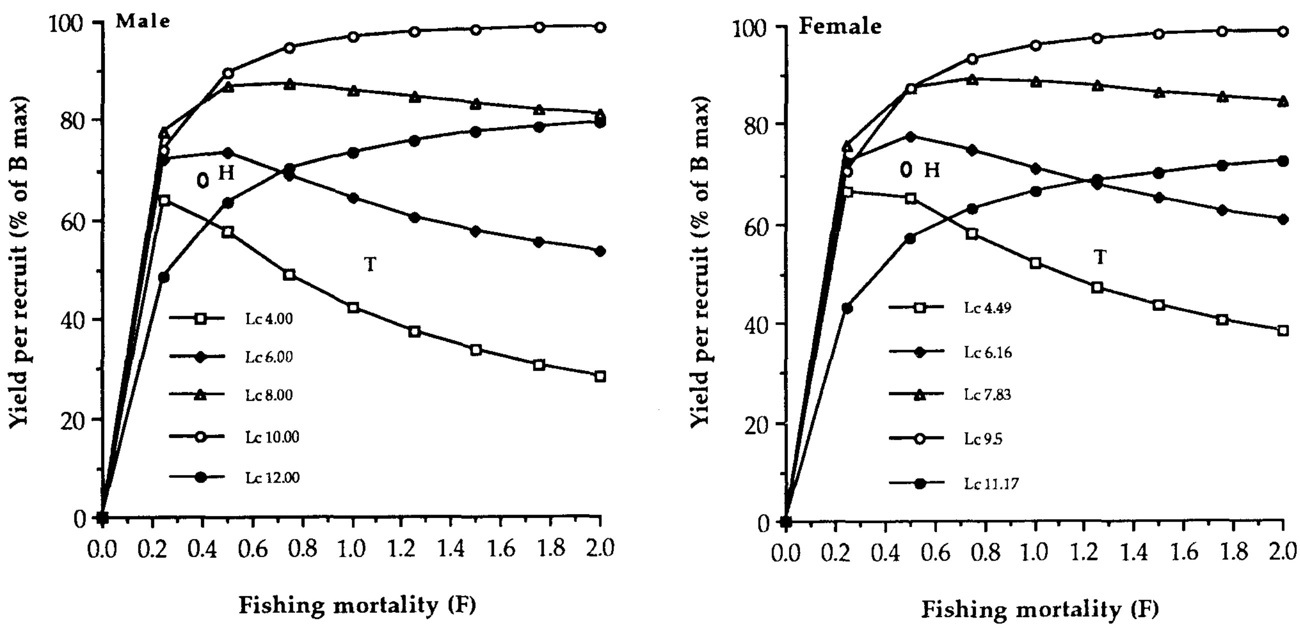


**Figure 10. Yield per recruit of male and female *Panulirus longipes*, relative to fishing mortality, F, expressed as percentage of maximum biomass of a cohort, for five sizes at first capture. T and H indicate points representative of the status of the Tongatapu and Ha'apai fisheries in 1985/86.**

## Management options

The optimum values of $L_c$ are 127.5 mm and 95 mm respectively for male and female *P. penicillatus* and 100 mm and 95 mm for male and female *P. longipes*. These are substantially greater than the current $L_c$s for all species. Imposition of a minimum size regulation combined with mandatory possession of a standard gauge, as suggested by Zann (1984), is an obvious solution. If marketing requirements dictate smaller $L_c$s it must be recognised that this will be at the price of lower landings.

It is suggested that minimum size regulations be phased in over three years, with the immediate imposition of a 75 mm size limit, increased to 85 mm in the second year and to 95 mm in the third year.

Measures to reduce fishing effort need to be considered within the framework of the entire nearshore fisheries situation. It is obvious that increases in fishing effort will result in no increases, or even in decreases, in harvests.

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# THE STATUS OF THE KIRIBATI LIVE-BAIT FISHERY

by James Ianelli, Tuna and Billfish Assessment Programme, South Pacific Commission

## Abstract

*Catch statistics from commercial baitfishing and survey fishing, primarily in Tarawa lagoon, Kiribati, were used in combination with artisanal fishing data to look at the potential interaction between commercial baitfishing operations and the local fisheries. Analyses were performed on the data to look at the impact commercial baitfishing may have on the local communities, the lagoon ecosystem and the wild baitfish stocks of the Tarawa lagoon. Three clupeid species,* **Herklotsichthys quadrimaculatus, Spratelloides delicatulus** *and* **Amblygaster sirm,** *dominated the catch of the baitfishery. The herring* **H. quadrimaculatus** *or* **tarabuti** *is also targeted by artisanal fishermen in Kiribati but the catches of the baitfishery do not appear to affect this local fishery adversely. Catch rates in the baitfishery did not show trends indicative of overfishing but there appeared to be an inverse relationship between the abundance of* **tarabuti** *and that of the sardine,* **A. sirm.** *The relationship between the abundance of baitfish stocks and rainfall was also examined and it was concluded that rainfall may influence baitfishing success, particularly in the case of the sprat,* **S. delicatulus.**

## Résumé

*Les statistiques sur les prises réalisées par les flottilles commerciales pratiquant la pêche à l'appât et par les bateaux de recherche, en particulier dans le lagon de Tarawa (Kiribati), ont été utilisées en parallèle avec les données relatives à la pêche artisanale en vue de déterminer les interactions potentielles entre les opérations de pêche à l'appât commerciales et les activités de pêcherie locales. On a procédé à une analyse de ces données dans le but d'évaluer l'incidence de la pêche commerciale à l'appât sur les communautés locales, l'écosystème du lagon et les stocks de poissons-appâts naturels du lagon de Tarawa. Dans les prises réalisées par les flottilles commerciales pratiquant la pêche à l'appât, trois espèces de clupéides étaient prédominantes :* **Herklotsichthys quadrimaculatus, Spratelloides delicatulus** *et* **Amblygaster sirm.** *Les petits pêcheurs de Kiribati ciblent également le hareng* **H. quadrimaculatus,** *également appelé tarabuti, mais le volume des prises effectuées par les flottilles commerciales pratiquant la pêche à l'appât ne semble pas avoir d'incidence néfaste sur la pêche artisanale. Les taux de prises de la flottille commerciale ne font état d'aucune tendance à la surexploitation des stocks; toutefois, il semble y avoir une relation inverse entre l'abondance de tarabuti et celle des sardines* **A. sirm.** *On a également procédé à une étude du rapport entre l'abondance des stocks de poissons-appâts et les précipitations et on a pu en tirer la conclusion que les pluies peuvent influencer les résultats de la pêche à l'appât, notamment dans le cas du sprat,* **S. delicatulus.**

## Introduction

Kiribati's largest natural resource is the tuna found within the waters of its 200-mile exclusive economic zone. The people of Kiribati have a well-deserved reputation of being very knowledgeable about the sea and fishing in general. These two points combined have led to the development of local commercial-scale pole-and-line tuna fishing. The bait required to operate these vessels is caught within the lagoons of Kiribati and supplemented by an extensive milkfish rearing venture. The success of these vessels currently depends on the productivity of natural baitfishes. Consequently, there is concern about the levels of commercial fishing that can be maintained. Traditional use of certain baitfish species (for example, as a component of artisanal catches) is also an important consideration for managing this resource.

In response to a request by the Government of Kiribati to study the impact of commercial baitfishing within its lagoons, the SPC Tuna and Billfish Assessment Programme assigned a scientist to help address this problem, with the following terms of reference:

- Compile baitfishing data logged by both the Te Mautari pole-and-line vessels and by past baitfish surveys into a common format for analysis;
- Design appropriate monitoring methods necessary to assess the condition of the baitfish stocks;
- Perform analyses for gauging the impact of the commercial baitfishing operations on the lagoon ecosystem, the local fishing communities, and the future of the pole-and-line tuna industry within Kiribati.

## Methods

### *Artisanal and survey data*

A small-scale survey conducted for 14 months in 1976 and 1977 in Tarawa obtained detailed species composition from 182 sets of a 50-metre beach seine in shallow water (Cross, 1978). Although species important to commercial baitfishing operations were common, the catch data were not of the scale to be compared with commercial baitfishing operations. Frame surveys of artisanal fishing activities indicate that bait species are caught only in shallow water with cast nets (Mees and Yeeting, in press).

### *Pole-and-line data*

Commercial-scale data collection on baitfishing began in 1977, when a Japanese survey was undertaken

(JICA, 1978). These data were extracted and incorporated into a database format. South Pacific Commission vessels surveyed two of the baiting grounds during their visits in 1978 and 1979 (Kleiber and Kearney, 1983). The data from these surveys have also been incorporated into the database. The Food and Agriculture Organization of the United Nations conducted fishing trials with the Kiribati vessel *Nei Manganibuka*, donated by the Japanese Government, from 1979 to 1980 (FAO, 1983). Only gross summaries for this period were available, as detailed data had been destroyed by fire.

With the establishment of a national fishing company, Te Mautari Limited (TML), commercial-scale data again became available in 1982. Summary records had been compiled for the Kiribati Fisheries Division in the past (McCarthy, 1985). However, extraction of all baitfishing data from TML's daily logs had not been performed. In all, 4,108 baiting operations were transcribed from the JICA reports and from the TML daily logbooks. These were then keypunched and incorporated, along with the SPC data, into a DBASE II file. Altogether, 85 per cent of the data obtained had at least rough estimates of dominant species composition of the catch.

Using monthly tuna catch data by TML vessels, catches of bait are compared with the tuna catch per unit of bait to see if fishing conditions influenced the apparent catchability of bait. Units of bait used throughout this report are in buckets, the average weight of which is approximately 2–2.5 kg (Iwao Shindo, Te Mautari Ltd., pers. comm.). As one vessel of the TML fleet was reported to have two-thirds of the fishing power of the other vessels, it was standardised for baitfishing days accordingly.

### *Rainfall data*

Rainfall data recorded in Betio, Tarawa were kindly tabulated by the Kiribati Meteorological Service on a monthly basis from 1976 to November 1986. These data were used in the analysis in an attempt to help explain changes in baitfishing catch-rate patterns.

**Table 1: Vessel specifications for the national fishing fleet of Kiribati**

| Vessel name | Fishing started | Bait well size (m3) | Brine capacity (tonnes) | No. of crew |
|---|---|---|---|---|
| *Nei Arintetonga* | February 1982 | 24.12 | 33.22 | 26 |
| *Nei Manganibuka* | February 1982 | 24.42 | 22.84 | 26 |
| *Nei Kaneati* | March 1983 | 23.72 | 25.62 | 26 |
| *Te Tiaroa* | March 1983 | 9.09 | 0.00 | 19 |

## Results

### The baitfishery

### *The national fleet*

As the majority of data obtained are from the pole-and-line fleet, characteristics of the fleet operating in 1986 are presented here. The commercial baitfishery of Kiribati had grown from a single experimental pole-and-line vessel, which began commercial fishing operations for TML prior to 1982, to a fleet of four vessels by March 1983. Three vessels were of similar size, while one was smaller and had no freezing capability (Table 1).

### *The baitfishing areas*

Four lagoons in Kiribati are suitable for regular baitfishing activities, with others being too shallow, without a suitable entrance, too distant, or too dangerous to conduct normal baitfishing methods (Fig. 1).

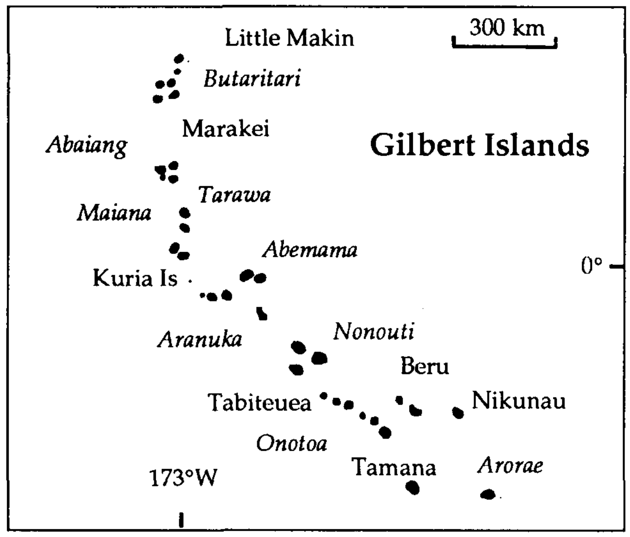


**Figure 1. The Gilbert Islands of the Republic of Kiribati. Atolls where baitfish data were collected are shown in italics.**

Tarawa was the home port for the fleet; Tarawa lagoon consequently had the most intensive fishing pressure (Table 2). Baiting locations within lagoons were often recorded, using adjacent village or island names. However, this information was not consistently provided.

**Table 2: Distribution of baitfishing effort on boat-days by method between the different baitfishing grounds of Kiribati, 1977–1986**

| Area | All gears | Bouki-ami | Beach seine | Lift-net | Aquaculture | Unknown |
|---|---|---|---|---|---|---|
| Tarawa | 2348 | 2009 | 79 | 3 | 257 | 0 |
| North Tarawa | 511 | 496 | 10 | 5 | 0 | 0 |
| Abemama | 464 | 410 | 49 | 0 | 0 | 5 |
| Butaritari | 460 | 423 | 37 | 0 | 0 | 0 |
| Abaiang | 328 | 276 | 26 | 24 | 0 | 2 |
| Nonouti | 9 | 9 | 0 | 0 | 0 | 0 |
| Maiana | 6 | 5 | 1 | 0 | 0 | 0 |
| Onotoa | 1 | 1 | 0 | 0 | 0 | 0 |
| All areas | 4,127 | 3,629 | 202 | 32 | 257 | 7 |

Tarawa lagoon is divided into two regions, North Tarawa (a rural district), and South Tarawa, which is the site of the national government headquarters.

These two sections of Tarawa lagoon have separate local councils and ideally the catches between them should have been kept separate. This was not always possible. Hence, the data in Table 2 show two areas for Tarawa ('North Tarawa' and 'Tarawa') but the area 'Tarawa' contains some data from fishing in North Tarawa.

## Baitfish species

Table 3 gives a summary of common bait species in Kiribati with the local names, Linnean names and common English names.

**Table 3: Names of common natural bait species found in Kiribati**

| English name | Gilbertese name | Scientific name |
|---|---|---|
| Gold spot herring | **Tarabuti** | *Herklotsichthys quadrimaculatus* |
| Blue sprat | **Auan** | *Spratelloides delicatulus* |
| Sardine | **Tiatiin** | *Amblygaster sirm* |
| Hardy heads | **Rerekoti** | Atherinidae |
| Jack mackerel | **Ikarikiriki** | *Selar crumenopthalmus* |
| Cardinal fish | **Ika kirati** | Apogonidae |
| Fusiliers | | Caesiodidae |

## Impact on local fisheries

Part of this study concerned the investigation on the possible detrimental effects of commercial baitfishing to the lagoon ecosystem and, in particular, on the artisanal and subsistence fishermen. The author interviewed several persons familiar with this problem, as well as the fishing masters of the local pole-and-line vessels. The main concern voiced by the outer island councils was that the commerical baitfishing activities:

— Targeted on the **tarabuti**, *Herklotsichthys quadrimaculatus*, and thus depleted local stocks available to artisanal fishermen. **Tarabuti** is a favoured food fish;

— Caught considerable quantitites of several juvenile reef species that would otherwise grow into large, highly valued food-fish;

— Depleted the source of food for larger predatory species, thereby indirectly reducing the abundance of the larger species.

In response to these questions, it became apparent that there were two kinds of fishing that the island councils objected to—the use of beach seines to catch **tarabuti** and the use of coral-head lift-nets. There was also some opposition to the use of bouki-ami; however, it is understood that the **tarabuti** are not strongly attracted to the night lights and bouki-ami catches were more frequently made up of other species less important for consumption. Table 4 lists the reported dominant species compositions for the three gear types.

The beach seine operations were carried out in shallow areas and, at times, were reported to deplete visibly schools of fish that might otherwise be readily available to local fishermen with their cast nets. The fishing masters of TML who were interviewed confirmed that this occurred. Use of beach seine gear in sensitive areas was subsequently discontinued.

**Table 4: Percentage of catch by dominant species for the different gear types used**

| Species | Bouki-ami | Beach seine | Coral lift-net |
|---|---|---|---|
| *Herklotsichthys quadrimaculatus* | 17.7 | 93.8 | 0 |
| *Spratelloides delicatulus* | 40.5 | 2.1.0 | 0 |
| *Amblygaster sirm* | 27.8 | 0 | 0 |
| Atherinidae | 5.3 | 3.9 | 0 |
| Apogonidae | 0.8 | 0 | 11.0 |
| Others | 8.0 | 0.2 | 89.0 |
| Fishing days | 3629 | 202 | 32 |

The claim that juvenile reef species were caught in appreciable numbers, particularly by the coral-head lift-nets, cannot be substantiated without more detailed records of species compositions of the catches. Gillett (1984), in his development of his technique in Tuvalu, found that the majority of the catch was made up of adult fusiliers and cardinal fish, with few or no juvenile reef species being caught. If juveniles were caught using this method, to arrive at the conclusion that it was detrimental to the abundance of adults would require a considerable amount of data, as well as a detailed knowledge of survival rates and recruitment patterns for each species. Clearly, a study of the species composition and recovery rates of previously fished coral-heads should be made. Given the high fecundity of many important reef species and their low survival rates at the early life stages, incidental catches of juvenile species would probably not adversely affect recruitment of adults at the levels of fishing intensity of the Kiribati fleet.

The problem of assessing the interaction between the reef fish food chains and commercial baitfishing operations requires a much more intensive study and broader database than was possible within the context of this report. Extensive analyses of predatory fish stomach contents over a wide range of different prey species densities and compositions are necessary to address this question, as well as reliable indices of abundance and population responses of the predatory species. In general, as Lewis (1983) suggests, the large fluctuations observed in the abundance of prey-type species and the relative stability in the abundance of predators indicate that the predators, for the most part, are not food-limited and can adapt to different food sources. It is possible that this concept applies to the situation in Kiribati. However, the available data do not provide conclusive evidence.

## The condition of natural baitfish stocks

Catch rate patterns of commercial fishing vessels were examined in order to assess the condition of baitfish stocks. For relatively short-lived species, with catch and effort data spanning several years and catch rates declining after a period of high effort, production models can be used to estimate equilibrium stock size and sustainable yield. Some preliminary investigations were made using a surplus production approach, but due to the short time period covered by these data and the lack of a clear drop in catch-per-unit-effort at the highest levels of effort, this type of analysis was rejected.

Catch rates by species were analysed in order to gain insight into the effect fishing may have on shifting baitfish species composition. A clear shift in composition between the sardine and tarabuti was observed, along with an apparent 'pulse' in abundance of the sardine. This observation was analysed with a model presented below. In view of the assumption about catch rate indices of abundance, a discussion of the problems associated with this is also presented below.

## Problems with using baitfish CPUE data as an index of abundance

Wetherall (1977) outlines problems with using catch per unit of effort (CPUE) data from the Hawaiian baitfishery which are also applicable to the situation in Kiribati. First of all, the data do not include information on how many sets of the net were performed, as catches were recorded on a nightly basis. During periods when baitfish were very abundant, the boats sometimes loaded up to their full capacity in one set of the bouki-ami and then either discarded or stored the remainder. At the other end of the spectrum, if bait was known to be particularly scarce during a period, the vessels either ordered milkfish from the aquaculture unit or opted not to fish at all. In the early years of TML's operation, much more beach seining was carried out and switching of methods occurred when bait catches by one gear type were particularly low. Another factor which could affect baiting performance occurred during periods when fish were biting very poorly. There are two possible problems with data collected during these periods:

- Little effort was expended to maximise bait catches, as the prospect for reward was poor; and
- It is possible that the vessels under-reported bait catches so that the poor tuna catch did not reflect on the ability or performance of the crew.

These factors have the overall effect of condensing data toward the mean catch rate and make periods of extremely good and poor conditions less obvious. The degree to which they bias results is not possible to ascertain. In view of these problems, caution must be exercised when interpreting results from analyses using CPUE data. In the future, catch data should be recorded by set rather than by night's fishing. Also, records should be kept of bait that is discarded, transferred to other vessels, or held in pens.

## Catch rate trends

### *General patterns*

In order to observe patterns in the catch rates of natural baitfish, using the available catch information, the data were selected by gear type and area over time. Bouki-ami fishing is the major gear type and as it is likely to give the most consistent results in terms of effort expended during a typical night's baitfishing, it is used exclusively in this analysis. By area, fishing effort in Tarawa lagoon was the highest and had the fewest gaps over time. For comparison, all other areas are treated together as well as individually.

Bouki-ami catch rates for TML vessels within Tarawa lagoon averaged 39 buckets of natural bait per night. The catch rate over time was highly variable. However, no upward or downward trend was apparent. In order to look at the level of exploitation, it is useful to plot catch rates versus fishing effort. If the effort measures are valid and catch rates unbiased, when fishing intensity was high enough a decrease in catch rates would appear, the pattern of which would depend on the underlying biological responses of the fish to fishing and other factors that potentially influence fish abundance. Such a decrease in catch rates would indicate that management of fishing effort might be necessary and provisions for reducing effort would need to be formulated. For the combined data there was no marked decline in catch rates at high levels of effort (Fig. 2).

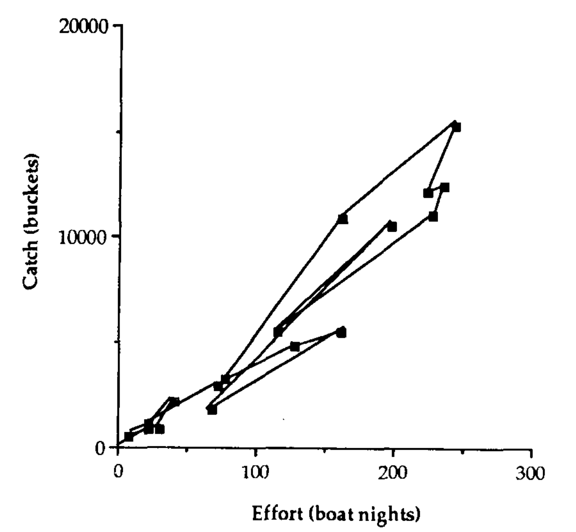


**Figure 2. Quarterly catch versus fishing effort for the baitfishery of the Gilbert Islands, Kiribati**

### *Species-specific catch rates by area*

Dominant species were recorded in 87 per cent of the total catch by bouki-ami nets. Due to the fact that non-technical people (i.e. fishermen) recorded this information, the level of accuracy of percentage species composition may be highly variable. The number of species that dominate the catch in Kiribati is relatively small and only general catch patterns were sought. For these reasons, the data compiled should reveal species composition changes with enough reliability to identify major trends. The categories of species have been separated into the **tarabuti**, *Herklotsichthys quadrimaculatus*; the blue sprat, *Spratelloides delicatulus*; the sardine, *Amblygaster sirm*; with all other species in 'others'. This naming convention was the most frequently used aboard the TML vessels.

Bouki-ami catches show a definite succession pattern for different species for each area (Figs. 3–6). For a long period (1978–81) no data were available; consequently, I used only the most recent data. It is worth noting that the change in species composition occurred over a wide geographic area, indicating that recruitment may be independent of local lagoon-specific stock sizes. The greatest change in relative abundance appears to be between the **tarabuti** and the sardine (Fig. 7). For Tarawa, where the most data were recorded, the change between the sardine and **tarabuti** catch rates over time suggest several possible explanations.

Accepting the assumption that catch rates reflect the abundance of the two species, an explanation of the shift in species composition may be one or a combination of the following:

— The two species coincidentally had opposing relative recruitment strengths by chance alone;

— The two species compete for similar resources, which affects the success of each species;

— The sardine, being more susceptible to night lighting, has been selectively depleted in favour of the **tarabuti**.

Rejecting the assumption that catch rates reflect abundance, two explanations for the catch pattern observed might be as follows:

— The catchability (e.g. night-light attractability) of one or other of the species changes;

— The vessels targeted on one species in favour of the other; in other words the fishermen were able to identify good and poor areas for a specific baitfish type.

It is difficult to say with absolute certainty that one single factor contributed to the observed shift in species composition; a few possibilities can , however, be considered very unlikely. For example, it is unlikely that 'targeting' on one species more than the other occurred, given the limited number of suitable baitfishing grounds. Concentration of baitfishing effort in areas where catches had been good might influence the dominant species composition. However, given the similar pattern of change in different lagoons, it is unlikely that species-specific 'targeting' occurred. A shift in catchability of a species, while entirely possible, is difficult to demonstrate in practice. This problem is one of the major pitfalls of using catch per unit of effort as an index of abundance and should be kept in mind when considering analyses using this type of information.

It is the opinion of the author that the change in catch rates does reflect a shift in abundance and that one or a combination of the first three explanations suggested above adequately provides reasons for the shift. The effect fishing has on the shift in species composition is addressed in the next section.

## The decline in apparent abundance of the sardine, *Amblygaster sirm*

In this section the assumption is made that abundance is related to catch rate by species, and an attempt is made to assess the impact fishing may have on the apparent decline in abundance of the sardine in particular.

### *Modelling for pulsed recruitments of* A.sirm

Data on catch rates of the sardine within Tarawa lagoon were analysed. Conand (1984) reported on the biology of this species on the basis of observations in New Caledonia and found a strong annual recruitment pattern. In Kiribati, if one assumes catch rates indicative of abundance, there also exist pulses of sardine abundance, at roughly 10- to 11-month intervals. A great deal of variability is apparent in the strengths of the recruitment at each time. A difference equation that describes recruitment explicitly is:

$$B_t+_1 = B_tS - E_{tq}B_t+R_t$$

Where:

$B_t$ is the biomass (in buckets) at time t;

S is the survival rate, i.e. the proportion of fish surviving for one month;

$E_t$ is the effort in standard boat-days;

q is the catchability coefficient; and

$R_t$ is the recruitment at time t.

Simply stated, the amount of bait expected next month, $B_t + 1$, is equal to the amount of bait in the month $B_t$, times the fraction that will survive, S, minus the amount taken by fishing, $E_{tq}$, plus any new fish entering the fishery by recruitment, $R_t$. A nonlinear gradient search algorithm (Vaessen, 1984), minimising the sum of squared deviations between observed monthly catch and that predicted by the model for the level of effort, was used to estimate the initial biomass, the survival rate, the catchability coefficient, and four recruitment sizes.

With seven parameters being estimated, the sums of squares surface did not converge well and a trough developed between values of q and the initial biomass

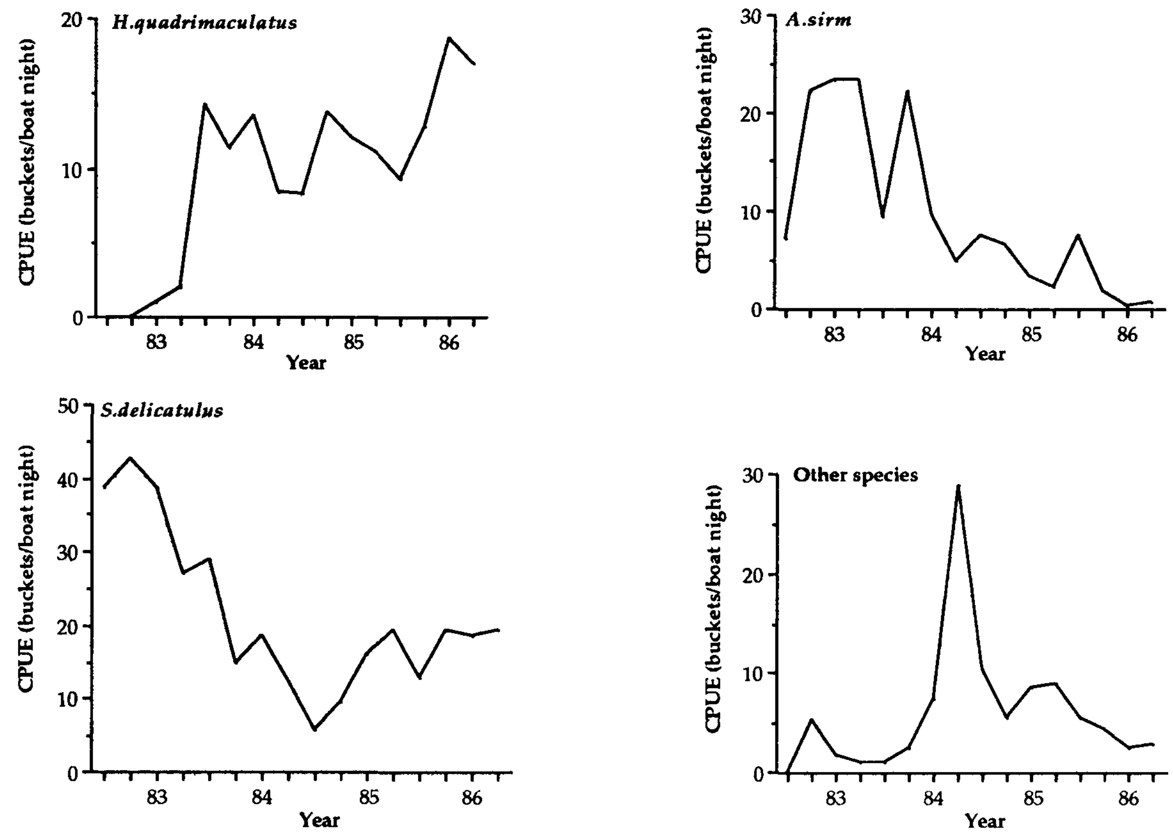


**Figure 3. Individual catch rate trends for the four dominant species categories in the Tarawa Lagoon**

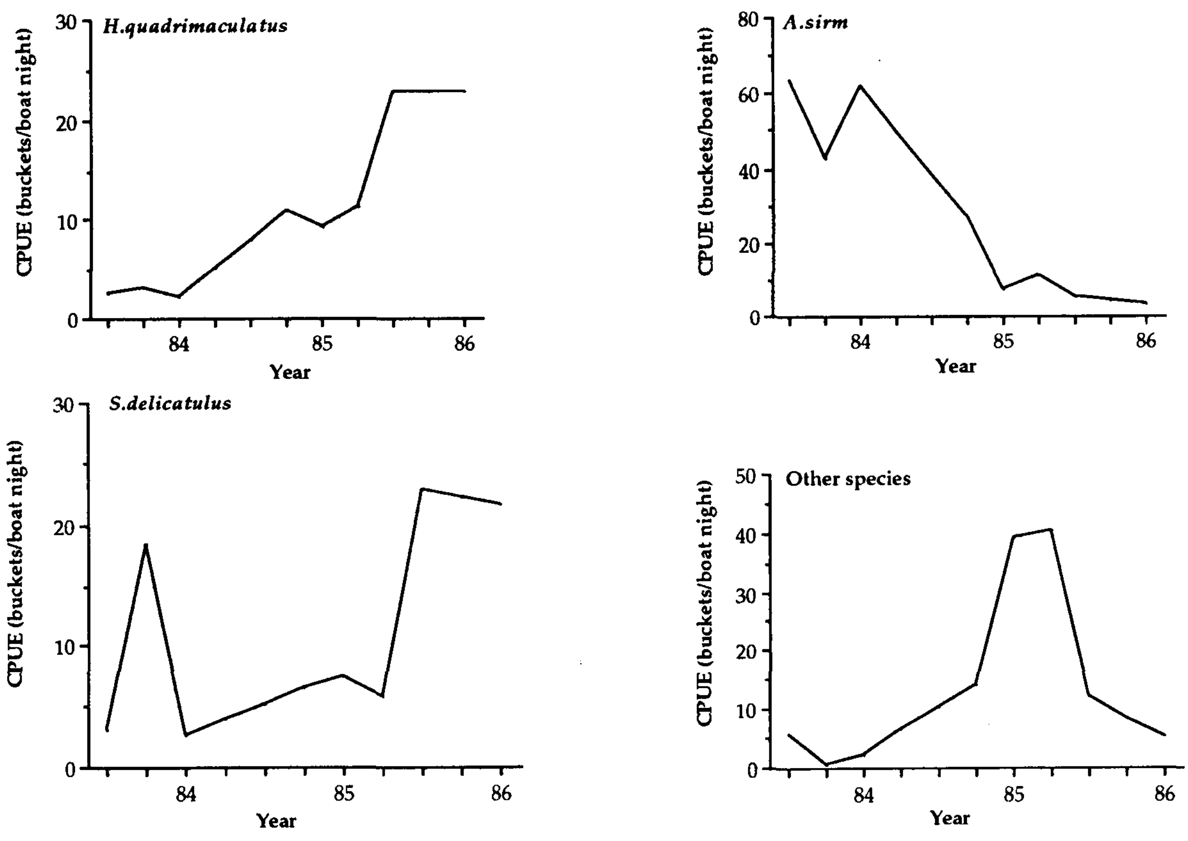


**Figure 4. Individual catch rate trends for the four dominant species categories in the Abemama Lagoon**

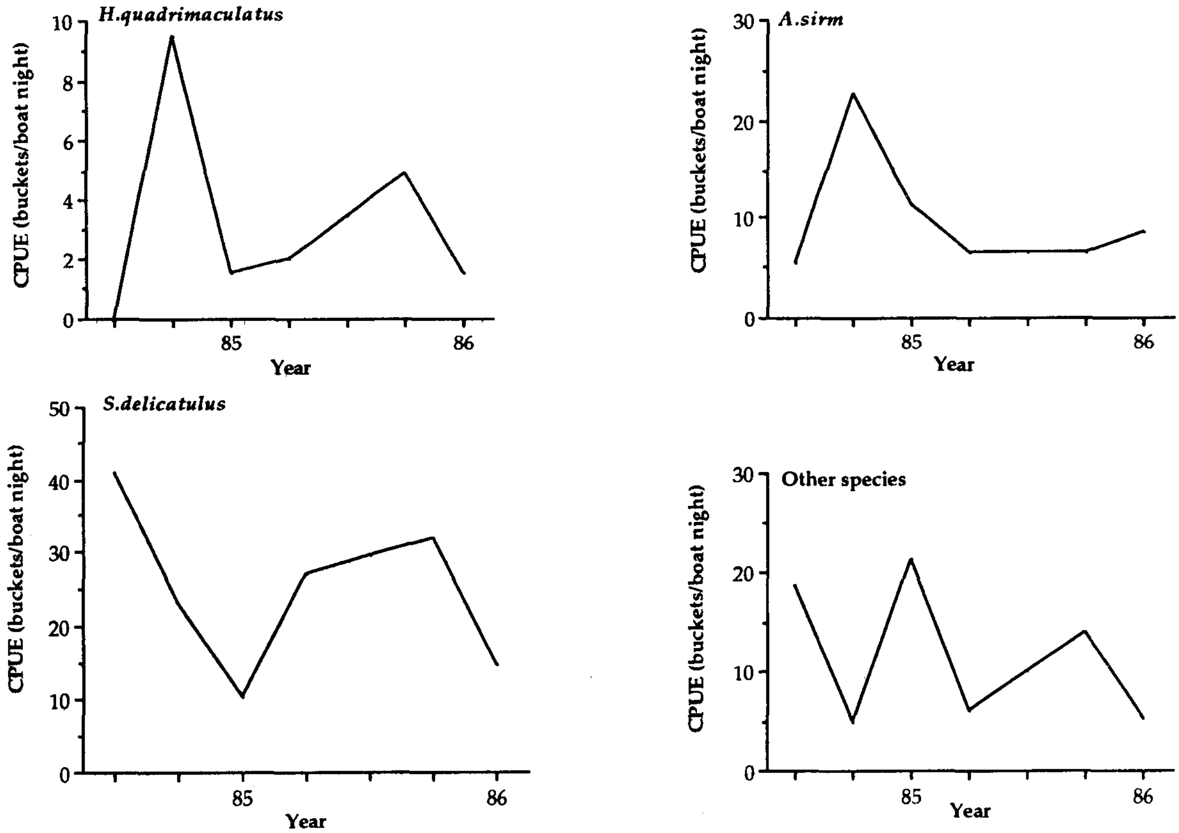


**Figure 5. Individual catch rate trends for the four dominant species categories in the Butaritari Lagoon**

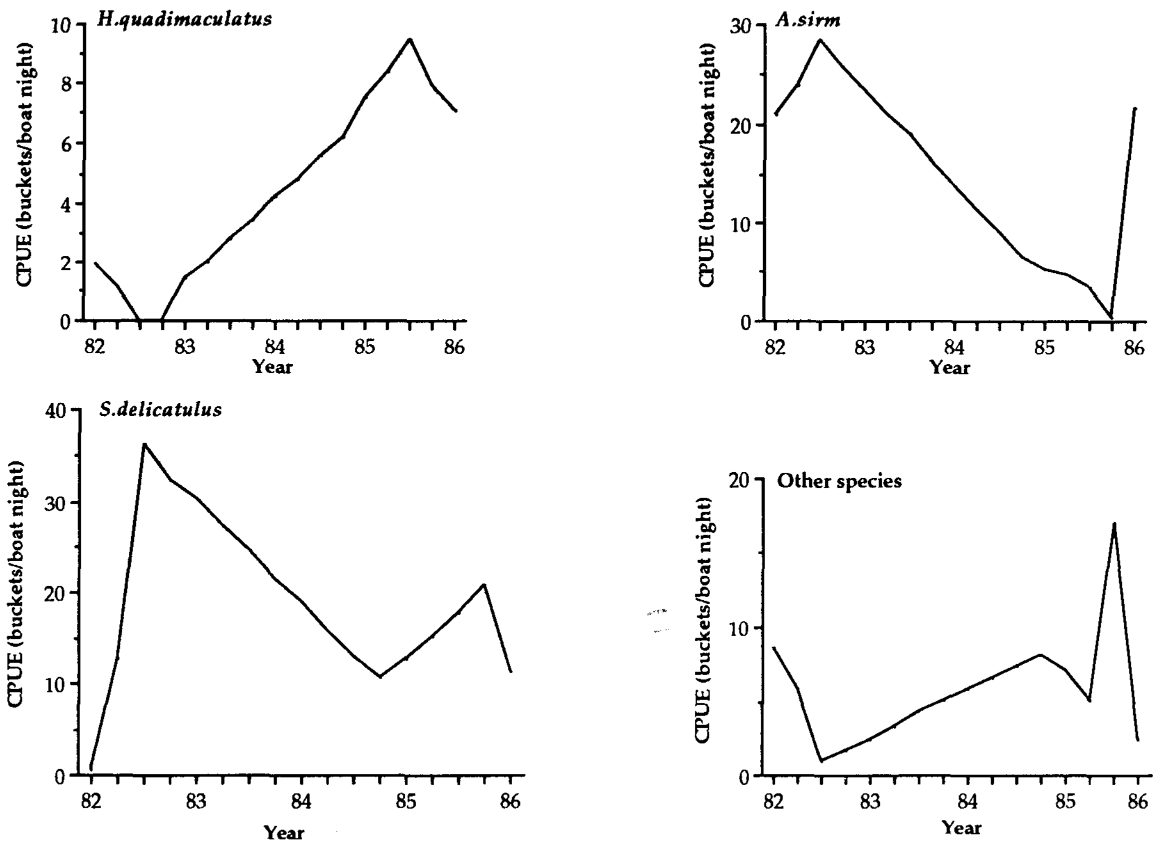


**Figure 6. Individual catch rate trends for the four dominant species categories in the Abaiang Lagoon**

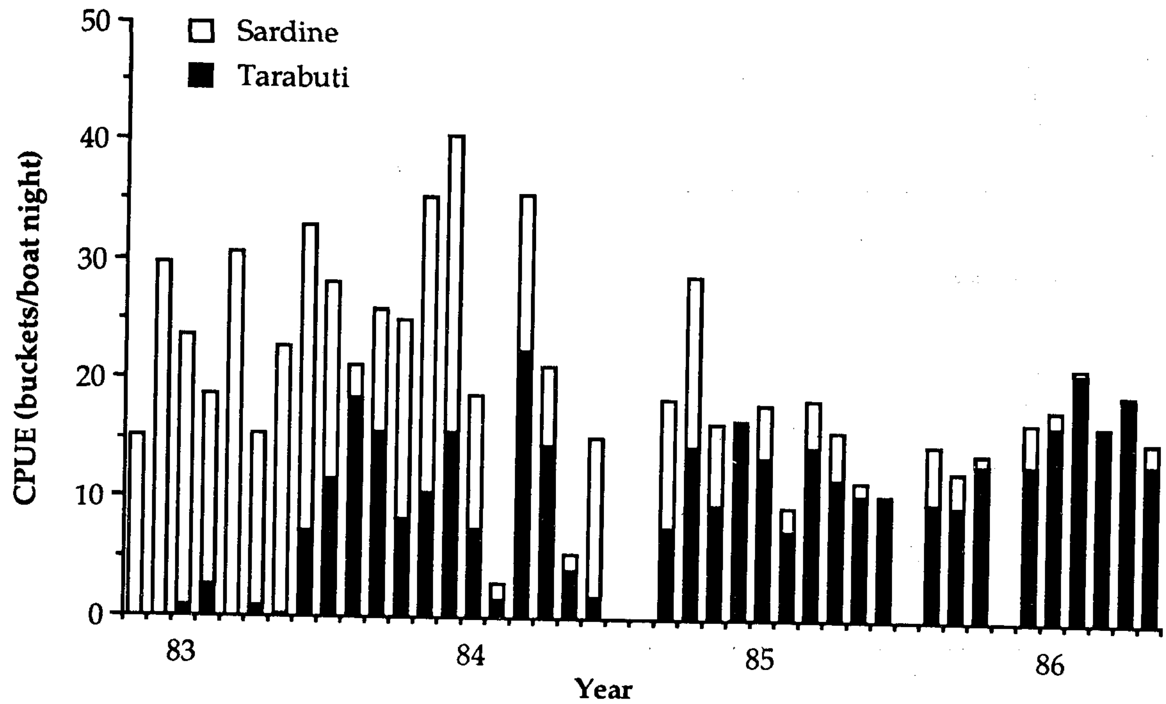


**Figure 7. Changes in catch rate over time between tarabuti (black bars) and sardine (clear bars)**

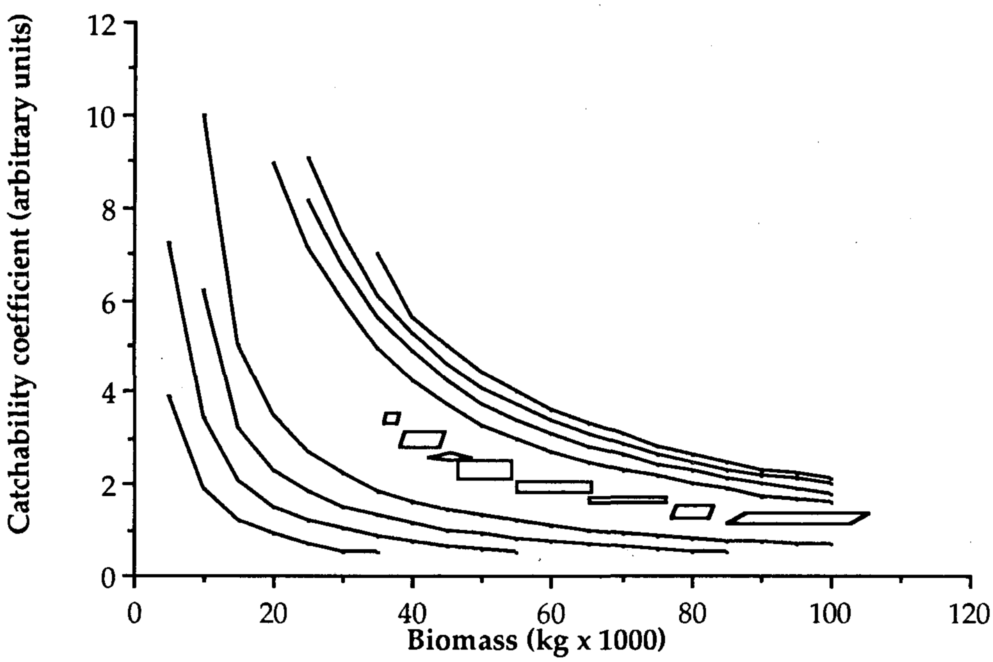


**Figure 8. Plot of contours of the sums of squares surface, showing how estimates of catchability are confounded with initial biomass estimates**

(Fig. 8). In view of this, q was fixed at an empirical value for bouki-ami gear derived by Muller (1977) to 0.012. One further modification performed was to apply weights to the deviations (between catch and predicted catch) proportional to the amount of effort spent during each month. The weighting of the sums of squares by effort made use of the amount of information that went into each data point used in the model. A plot of the observed sardine catch rates, raised catch rates predicted by the model, and the magnitude of effort for each month (proportional to the weights used) is given in Figure 9. The results estimate an initial biomass of 18,500 buckets, a survival rate of 88.1 per cent per month and the average exploitation rate of 4 per cent per month. This suggests that fishing pressure is relatively light on this stock.

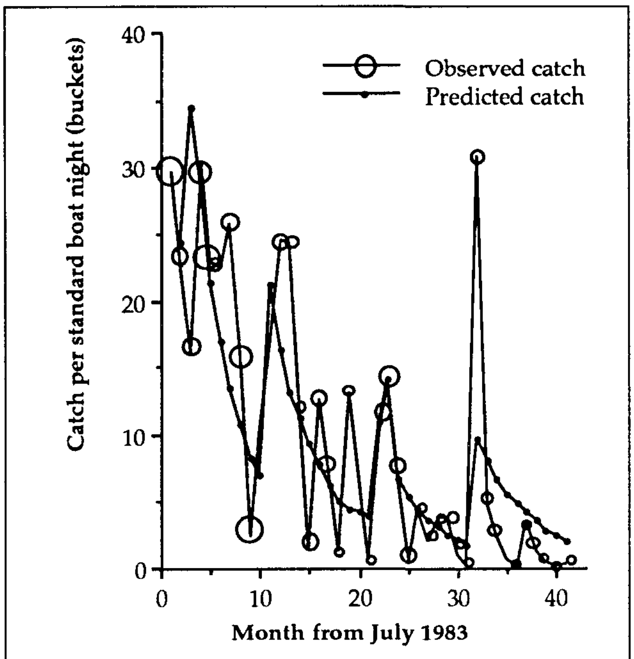


**Figure 9. Observed sardine catch (open circles) and the weighted fit of a pulse recruitment model (closed circles)**

In order to compare the value for survival rate, it was transformed to mortality rate and checked with an independent estimate of mortality. The instantaneous natural mortality rate, M, came to 0.0823 on a monthly basis. This compares with an M of 0.0851 from Pauly's (1980) multiple regression model using Conand's (1984) estimates of K=2.633, $L_\infty$=18.03 cm for *A.sirm* from New Caledonia and an annual average water temperature of 27° C.

In summary, this analysis points out that recruitment rates are variable, and that harvest rates do not appear to be the major cause of the shifts in species composition observed.

## Influence of rainfall

Environmental conditions are often considered to be important factors influencing fishing conditions (Raja, 1972; Ellway and Kearney, 1981; Dalzell and Wankowski, 1980). For Kiribati, rainfall effect was examined using regression analyses in several different ways. Overall, the catch rates for bouki-ami fishing in Tarawa show a general increase during periods of high rainfall (Fig. 10).

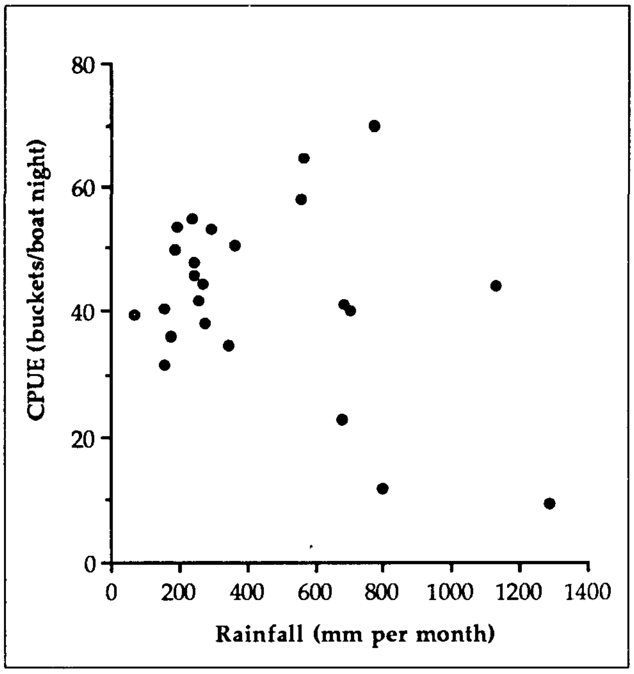


**Figure 10. Average catch per day of baitfish from Tarawa lagoon versus total monthly rainfall**

When broken down by species, catch rates for the sprats and sardines had positive correlation coefficients, whereas coefficients for the **tarabuti** and the 'others' category were negative (Table 5). The lack of strong correlation between the longer-lived species, i.e. the **tarabuti** and sardine, and the amount of rainfall may be attributed to a lag period. The recruitment of a closely related species in the Indian Ocean was shown to be affected by the amount of rainfall during the spawning period (Raja 1972). The sprat, because it is considered to spawn over extended periods and not live beyond four months of age (Lewis et al., 1983a), may show a more direct relationship between apparent abundance and the amount of rain. While the amount of rainfall appears to influence baitfishing success, rainfall levels may only play a small role in describing mechanisms that drive recruitment processes.

**Table 5: Correlation coefficients between rainfall and catch rates for Tarawa by species composition. Critical coefficient for alpha = .05 is 0.288 with 45 degrees of freedom.**

| Species | Correlation coefficient |
|---|---|
| Tarabuti | -0.1425 |
| Sprats | 0.5622 |
| Sardines | 0.2069 |
| Others | -0.3132 |

## The influence of tuna catch rates on baitfishing and vice versa

The success of tuna fishing influences the efficiency of baitfish operations (Ellway and Kearney, 1981; Kearney, 1977). That is, for periods where tuna are biting well, the crew make extra effort to maximise the bait catch and thereby ensure that the tuna catch will be within the range of the bonus payment system. For periods when the conditions are particularly poor for tuna fishing, it does not pay for the crew to expend extra energy on maximising bait catch when there is little or no hope of catching enough to earn a bonus payment. The tuna fishing conditions (based on the conversion of a unit of bait to a unit of tuna), are highly variable on a month-to-month basis, with periods of apparently poor and good conditions (Fig. 11). Correlation analyses between tuna-bait conversion rates and baiting effort, overall bait catch per unit of effort, and catch rates by species revealed no significant relationships. While this does not show any relationship, the fact that it has no influence on baitfish catch rates cannot be ruled out. Argue et al. (1987) performed an in-depth analysis on several aspects of baitfish effectiveness and concluded that very little of the total variability of tuna fishing effectiveness could be explained by independent variables similar to the ones presented in this report.

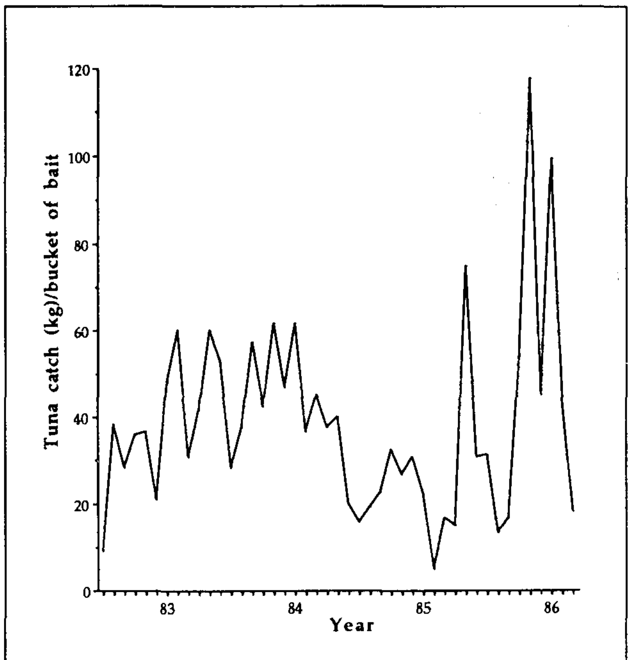


**Figure 11. Average monthly tuna catch per bucket of bait for the TML pole-and-line vessels**

## Discussion and conclusions

### *The impact of baitfishing on the coastal fisheries*

At the time of this study the Fisheries Division of Kiribati was collecting survey data from artisanal and subsistence fishermen useful for future stock assessment purposes. These data show that a large percentage of local catches is made up of species that are not taken by baitfishing gear and do not forage on bait species. For species that do overlap, either directly or indirectly, with baitfishing activities, the current practices do not appear to aggravate the conditions for either group of fishermen. In some outer islands where baitfishing occurs, surveys of artisanal fishing activities have been limited. To assess properly the magnitude of interaction between local fisheries and the commercial baitfishing operations, more data are needed both on the incidental species caught by the commercial baitfishing operations and on the local fishing practices.

Lewis (1983) reviewed the impact of commercial baitfishing on coastal fisheries from a regional perspective. He points out that the natural fluctuations in abundance of bait species generally do not coincide with changes in abundance of predatory species often sought as food. When a particular species of food for predatory fish becomes less available, the predators seek other food items. Measuring the impact of commercial baitfishing on the lagoon ecosystems of Kiribati requires identification of all factors that affect the ecosystem. Environmental fluctuations, competition among species, and the life history patterns of individual organisms within the ecosystem all interact to an unknown degree. Clear explanations of observations with fishing pressure added are difficult, if not impossible, without considering the other components. Estimates for the sardine indicate that catches by commercial vessels contributed only a small portion of the total mortality of the population and were probably not the major cause of fluctuations in abundance of baitfish.

### *The condition of baitfish stocks*

Conand (1984), Dalzell and Wankowski (1980), and Lewis et al. (1983a), noted considerable variability of species composition by area over time. In Kiribati, future occurrences of fluctuating species composition seem likely. The sardines of Kiribati have become less predominant in the bouki-ami catches in recent years, while the catch of the **tarabuti** has increased. These two species have similar life-spans (Conand, 1984; Lewis et al., 1983a), and may have overlapping habitats which put them in competition over space and time. The hypotheses presented above may describe the apparent replacement of one species by the other and further analytical methods may shed light on the relationship. It is possible that the **tarabuti** had met with conditions favourable to recruitment through the early life stages while the sardine met with successively poorer recruitment conditions.

Relationships of apparent abundance and the amount of rainfall showed a positive correlation for the short-lived species, *Spratelloides delicatulus*. It is possible that, as hypothesised by Raja (1972), the rainfall boosts the productivity of the water and improves the survival rate through the early life stages of clupeoid fishes. The response to this productivity change would be most obvious in sprat abundance because sprats spawn over long periods and live for less than four months. The sardine and **tarabuti**, on the other hand, are considered to spawn for only short periods and live beyond one year.

Overall, the condition of natural baitfish stocks did not appear to be above sustainable levels, but increases in baitfishing effort should proceed cautiously given the variability of catch rates. Stone and Kristjonsson (1980) reported that potential for the pole-and-line fishery in Kiribati was enough to support eight vessels. Only one species predominant in the bait catches is short-lived; its recruitment success appears to be relatively resilient to harvest and/or environmental pressures. The failure of the other baitfish groups, for whatever reasons, may severely limit the viability of large increases in baitfish captures.

The variability of baitfish populations in atoll island groups has been well documented (cf. Kleiber and Kearney, 1983; Johannes, 1981; Hida and Uchiyama, 1977). The careful planning of an alternative baitfish supply considered adequate to meet the needs of the pole-and-line fishery was therefore necessary.

Based on the observations and analyses presented in this paper, the following recommendations were made:

— Improve the quality and quantity of milkfish to enhance baitfish supply during periods of low natural bait catches;

— Restrict beach seining activities by commercial pole-and-line vessels in areas where local fishing communities regularly rely on catching **tarabuti**;

— Encourage accurate collection of baitfishing details, particularly with regard to the number of sets during a given night, species composition of the catch, and the number of standard buckets loaded.

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# AN ASSESSMENT OF CORAL EXPLOITATION IN FIJI

by F. Viala, Fisheries Division, Ministry of Primary Industries, Suva, Fiji


## *Abstract*

***Between 12 and 17 ship container-loads of coral per year were exported from Fiji between 1985 and 1987 for ornamental purposes. Collection of coral is conducted entirely by local fishermen within their own traditional fishing areas. Over 40 different species of coral are harvested by fishermen, with 10 species comprising just over 70 per cent of the total production by number of pieces. The staghorn corals (**Acropora **spp) make the largest contribution by a single taxon and comprise just under 50 per cent of harvests. Collection of coral is confined at present to the eastern coast of Viti Levu and the coast of Ovalau. There are no regulations governing the harvesting of corals in Fiji, but if coral harvesting expands beyond present levels it may be necessary to introduce them.***

## *Résumé*

***Entre 1985 et 1987, Fidji a exporté annuellement l'équivalent de 12 à 17 chargements de conteneurs de corail ornemental. Le ramassage du corail est réalisé entièrement par les petits pêcheurs de la région qui utilisent leurs propres zones de pêche traditionnelles. Ils récoltent plus de 40 espèces différentes de corail, dont 10 constituent un peu plus de 70 pour cent de la production totale en quantité de pièces. Les acroporae (**Acropora **spp.) constituent la variété la plus fréquente, avec quelques 50 pour cent des récoltes. A présent la collecte de corail se limite à la côte orientale de l'Ile de Vitu Levu et aux côtes de Ovalau. Il n'existe à ce jour aucune réglementation régissant la collecte de corail à Fidji. Toutefois, de telles mesures s'avèreront nécessaires dans le cas d'une intensification de l'exploitation des coraux.***


## Introduction

The exploitation of hermatypic (reef-building corals) in Fiji has existed for quite some time in coastal villages, for construction of sea-walls and fabrication of ornaments by small-time curio vendors. Also, records from the Lands Department (Fiji Government) dating back to 1965 show the utilisation of coral boulders (family Poritidae) in the construction of drains and soakage pits for septic tanks, as required by Suva City Council regulations.

The first commercial exploitation of hermatypic corals for export began in 1985 and the first shipment was made in February the same year. This paper reviews the present exploitation practices and current yields of corals in Fiji, and discusses the level of exploitation with respect to other factors.

## Collection sites and methods

Present collection activity is confined to areas in Bau waters, on the East coast of Viti Levu, and recently, another site on Ovalau Island (see Figure 1). Collection is performed entirely by local fishermen, within their traditional fishing rights, and coral is sold by the piece to the exporting company. Collectors use snorkelling gear and a steel bar approximately 2.5 cm in diameter and 75 cms in length, sharpened to a chisel point at one end, to extract corals from the substrate. Each specimen is passed over to the boatman, who lays it on the boat floor. Much caution is exercised to avoid damage to the specimen.

## Packing

On reaching shore, collectors lay out the corals on a bamboo rack or plastic sheeting on the ground to dry for 1–2 days. They are then selected by species, measured, recorded and placed on a packing table to be wrapped in old newspaper. The packages are then stacked in wooden crates specifically constructed for the export of corals. Measurements of these crates are 50.8x50.8x73.7 cm or a volume of 0.19 sq m. A total of 120 crates is shipped in a standard 6 m container.

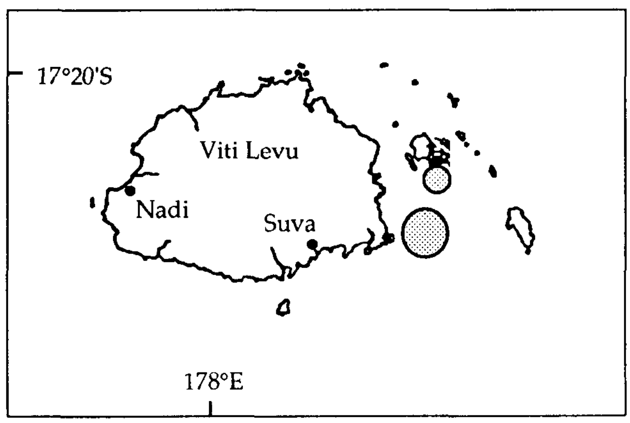


**Figure 1. Coral collection areas in Fiji. Areas of collection are indicated by shading.**

## Exports

### *Grades and prices*

The grading unit used is the diameter of the coral in inches and there is no difference in price for different species. Prices paid to collectors are as follows:

| Grades | Price to collectors |
|---|---|
| 5–10 ins | 15 cents/piece |
| 10–20 ins | 20 cents/piece |
| 20 ins and over | 40 cents/piece |

Table 1 provides an example of typical composition by size of an export consignment.

**Table 1: Typical size composition of coral harvested (from shipment made on 31 May 1985)**

| Size (inches) | Quantity | Percentage |
|---|---|---|
| 5 - 7 | 1900 | 28.6 |
| 7 - 10 | 2784 | 41.9 |
| 10 - 15 | 1715 | 25.8 |
| 20 and over | 211 | 3.1 |

## Export volume

The number of container-loads shipped since exports began is noted in Table 2.

**Table 2: Shipments made by numbers of containers**

| Year | Jan | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| 1986 | 1 | 1 | 1 | 1 | 1 | - | 2 | - | 2 | 1 | 1 | 2 |
| 1987 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 |

## Exploited taxa

According to the returns submitted by the exporters, 56 species (or species groups) of corals are exploited from 11 Scleractinia families and 3 non-Scleractinia families, as follows:

### *Scleractinia families*

| | | |
|---|---|---|
| Acroporiidae | Merulinidae | Poritidae |
| Fungiidae | Mussidae | Faviidae |
| Agariciidae | Dendrophylliidae | Oculinidae |
| Pocilloporidae | | Pectiniidae |

### *Non-Scleractinia families*

| | | |
|---|---|---|
| Milleporidae | Stylasteridae | Tubiporidae |

Table 3 lists exports of the various taxa by numbers for the years 1985–1988. The branching coral families (e.g. Acroporiidae, Pocilloporidae and Merulinidae) are the most exploited, whereas exports of the massive types are almost negligible. The free-living varieties (Fungidae) are little exploited.

## Management guidelines

There is currently no legislation restricting the harvesting of corals. A cautious attitude towards exploitation has been adopted in view of the Fisheries Division's lack of local data on the resource. The introduction of a quota system will be investigated if exploitation shows sign of increasing. Zoning of harvesting areas has been recommended, with some, preferably most, reef areas being protected from commercial collection.

Recommendations based on surveys carried out by the Fisheries Division have been put forward to the collectors. Collectors have been advised to move operations to fringing reefs and inner lagoon reefs, rather than inshore reefs, as the latter are affected by freshwater run-off and turbidity, and likely to be slow to regenerate.

The following guidelines have been suggested for the exploitation of ornamental corals:

— Export permits to be required, and full listing of species exported to be supplied;

— Management requirements for particular areas to be determined by consultation between the collector and the Fisheries Division;

— Traditional custodians of marine resources to be involved to the maximum extent practicable in the harvest of corals;

— Use of SCUBA gear for collection to be prohibited.

**Table 3: Number of coral pieces exported, by taxa, from Fiji, 1985—1988**

| Coral export summary (no. of pieces) | | No. | % | Rank |
|---|---|---|---|---|
| *Acropora arcuata* | Small branch | 17054 | 11.1 | 2 |
| *Acropora echinata* | Pinetree | 2519 | 1.6 | 17 |
| *Acropora humilis* | Finger | 8334 | 5.4 | 8 |
| *Acropora nobilis* | Staghorn | 8462 | 5.5 | 7 |
| *Acropora palifera* | Catspaw | 5040 | 3.3 | 11 |
| *Acropora prostrata* | Table | 17182 | 11.2 | 1 |
| *Acropora subglabra* | Tree | 10886 | 7.1 | 5 |
| *Acropora vaughani* | Table | 2711 | 1.8 | 16 |
| *Agaricia tenuflora* | Mushroom? | 342 | 0.2 | 32 |
| *Dendrophylla micranthus* | Octopus | 244 | 0.2 | 32 |
| *Echinopora lamellosa* | Lettuce/rose | 518 | 0.3 | 26 |
| *Euphyllia divisa* | Divided brain | 87 | 0.1 | 37 |
| *Fungia concinne* | Mushroom | 3641 | 2.4 | 14 |
| *Galaxea fascicularis* | Tooth | 350 | 0.2 | 32 |
| *Gonastrea* spp. | Brain | 3456 | 2.2 | 15 |
| *Herpolitha* spp. | Slipper | 2337 | 1.5 | 19 |
| *Leptoria phrygia* | Closed brain | 5734 | 3.7 | 10 |
| *Leptoseris fragilis* | Glass | 29 | 0.02 | 46 |
| *Lobophylla corymbosa* | Open brain | 1408 | 0.9 | 20 |
| *Mendusa korei* | Korei | 383 | 0.2 | 32 |
| *Mendusa lakeri* | Lakeri | 258 | 0.2 | 32 |
| *Merulina ampliata* | Merulina | 13676 | 8.9 | 3 |
| *Merulina* spp. | Star | 203 | 0.1 | 37 |
| *Millepora dichotoma* | Fire | 687 | 0.4 | 25 |
| *Millepora* spp. | Fire | 5148 | 3.3 | 11 |
| *Montipora striata* | Montipora | 512 | 0.3 | 26 |
| *Montipora* spp. | Bermuda | 94 | 0.1 | 37 |
| *Pacheseris rugosa* | Rugosa | 402 | 0.3 | 26 |
| *Pavonia frondifera* | Lettuce | 1275 | 0.8 | 22 |
| *Pavonia lata* | Cactus | 950 | 0.6 | 23 |
| *Petcinia lactuca* | Lettuce | 504 | 0.3 | 26 |
| *Petcinia* spp. | Cluster | 11243 | 7.3 | 4 |
| *Pocellopora damicornis* | | 2406 | 1.6 | 17 |
| *Pocellopora eyoduxi* | Cauiflower | 1443 | 0.9 | 20 |
| *Pocellopora verrucosa* | | 48 | 0.03 | 45 |
| *Porites* spp. | Porites | 134 | 0.1 | 37 |
| *Sandlothia* spp. | Cup | 685 | 0.4 | 25 |
| *Seriatopora hystrix* | Birds nest | 9986 | 6.5 | 6 |
| *Stylaster* spp. | | 68 | 0.04 | 42 |
| *Stylophora pistillata* | Elkhorn | 7356 | 4.8 | 9 |
| *Stylophora* spp. | Black elkhorn | 416 | 0.3 | 26 |
| *Tubipora musica* | Pipe organ | 4091 | 2.7 | 13 |
| *Turbinaria mollis* | Rose/Cup | 214 | 0.1 | 37 |
| *Turbinaria* spp. | Frond | 501 | 0.3 | 26 |
| *Zoopilus echinatus* | Big cup | 16 | 0.01 | 47 |
| Fan coral | Fan coral | 55 | 0.04 | 42 |
| Miscellaneous/Specials | | 966 | 0.6 | 23 |

## Discussion

### *Status of stocks*

Attempts have been made in most countries to regulate ornamental coral harvests, in recognition of the increasing pressures to which coral reefs are subjected in many areas, and the complexity of the reef ecosystem of which they are an integral part.

Nevertheless, coral reefs are a renewable resource which Fiji possesses in abundance and which, provided appropriate management measures are enforced, has considerable harvest potential. More information is needed on the distribution and abundance of commercial species in Fiji and rates of regeneration.

### *Status of trade*

Only one company is involved at present in the export trade, and the utilisation of *Porites* spp for local construction and by small-time curio vendors is limited.

## Conclusion

Corals are fundamental to the reef ecosystem. The effects of harvesting, even on a small-scale commercial level, are not fully understood. Certainly more research work has to be done. It is the firm belief of the Fisheries Division that the Fiji situation should continue to be monitored closely. A great deal can be learned from the experiences of other countries in the region regarding the biology and exploitation of this sensitive resource.

# PRELIMINARY STUDY OF THE BIOLOGY OF MULLETS (PISCES: MUGILIDAE) FROM NUKU'ALOFA, TONGA

by S.A. Langi, T.F. Latu and S. Tulua, Fisheries Division, Ministry of Agriculture, Forestry and Fisheries, Nulu'alofa, Tonga.


## Abstract

*Populations of mullets around the coast of Tongatapu were sampled over six months between June and November 1987. A nominal total of five species of mullet was identified from larvae and adult specimens. However, both* Valamulgil engeli *and* Liza macrolepis *were rare and discrepancies were noted between the published descriptions of* Liza subviridis *and the collected specimens. Almost 75 per cent of commercial landings of mullets were* Mugil cephalus, *with most of the balance made up from* Liza *spp. Some seasonality in the production of mullet was evident from the data, with a peak in landings during July. Mullet landings during the lunar month were greatest during the period of the first quarter before the full moon. Peaks in spawning activity of mullets appeared to be greatest over the period of the new moon. Both* M. cephalus *and* Liza *spp. exhibit sexual size dimorphism, with females growing larger than males. Length-weight equations for* M. cephalus *and* Liza *sp. are presented.*

### Résumé

*De juin à novembre 1987, on a procédé à un échantillonnage des populations de mulets évoluant à proximité des côtes de Tongatapu. En un premier temps, on a pu déterminer un total de 5 espèces de mulets à partir des larves et des adultes capturés. Toutefois, les spécimens de* Valamulgil engeli *et* Liza macrolepis *pêchés étaient peu nombreux et on a pu constater certaines disparités entre les descriptions publiées de* Liza subviridis *et les caractéristiques des spécimens capturés. Près de 75 pour cent des quantités de mulets débarquées par les flottilles commerciales appartenaient à la famille des* Mugil cephalus, *les prises restantes étant essentiellement constituées de* Liza *spp. Les données ainsi recueillies ont permis de mettre en évidence le caractère saisonnier du volume des prises de mulets, lesquelles atteignent des quantités maximales au mois de juillet. Par ailleurs, pendant le cycle lunaire, on constate une augmentation des quantités débarquées pendant le premier quartier précédant la pleine lune. Quant au comportement reproductif des mulets, il semble s'intensifier pendant la nouvelle lune. Tant les* M. cephalus *que les* Liza *spp. se caractérisent par un dimorphisme sexuel qui se manifeste par leur taille, les femelles adultes étant plus grosses que les mâles. On trouvera également dans le document résumé ici les équations longueur-poids pour les* M. cephalus *et les* Liza *spp.*


## Introduction

Mullet is one of the most highly esteemed fish in the diet of Tongan people. In 1983 it was estimated that 110 t of mullet were caught in the waters of Tonga (Uwate et al., 1983). Anecdotal information from fishermen suggests that both the size of the mullet catch and the mean size of mullet captured have declined in recent years. One partial solution to this problem may be the development of mullet aquaculture in Tonga. A proposal for a mullet farm in the northern islands of Vava'u was evaluated by the Tongan Government (PIDP, 1983), but was rejected because of low projected profitability. Interest in mullet culture in Tonga remains, however, and it might be feasible if the technology employed were kept simple and fry caught locally (Hepher, 1987).

In order for mullet culture to be developed in Tonga, certain facts have to be established concerning the identity of the mullet species present and their biology. From the aquaculture perspective it is important, for the collection of fry, to establish the timing and location of spawning. In June 1987 the first stages of a biological programme on mullet research were begun around the island of Tongatapu. This paper presents the initial results of this work based on the first six months of sampling.

## Materials and methods

The mullet data collection programme was divided into two parts. The first part was a series of contact interviews with experienced local fishermen to ask them about their knowledge of mullet life-history. Johannes (1981) has shown that Pacific Island fishermen may be a valuable source of observations on the biology of a variety of species. In this instance interviews were carried out with a veteran mullet fisherman and with a younger fisherman who learned his trade from his father.

The identification of mullet species was made from FAO identification sheets for the West Indian Ocean (Fischer and Bianci, 1984), from data on pyloric caeca from Oren (1981) and from photographs in Masuda et al. (1984). Specimens of mullet fry were sent to the Tokyo University Marine Research Centre for identification.

Fishing for adult mullets is seasonal and is prosecuted mainly with gill nets and fish corrals. Fishing for juvenile mullets with cast nets occurs throughout the year. Sampling of landings of six fishermen on Tongatapu was carried out between June and November 1987 at the locations indicated in Figure 1. Three of the fishermen used gill nets, whilst the remainder employed fish corrals. All locations were visited on average once a week, and information on mullets captured included species, fork length (mm), total body weight (g) and gonad weight (g).

Gonads were also staged macroscopically following the eight stages proposed by Munro (1983) for Caribbean reef fishes. These were as follows:

| | |
|---|---|
| Stage 0 : immature | Stage IV : active ripe |
| Stage I : inactive | Stage V : ripe or gravid |
| Stage II : maturing | Stage VI : spawning |
| Stage III : active | Stage VII : spent |

A gonad index was calculated from:

GSI = (gon.wt/tot.body wt.) x 100.

## Results

### *Interviews with fishermen*

According to the fishermen, adult mullet are usually scattered randomly around the lagoon in Tongatapu. In April, however, they gather at the lagoon entrance, ready to leave for a spawning run. During this period fishermen place gill nets at the mouth of the lagoon, usually making up to four sets in the intertidal periods. Mullet schools are spotted and surrounded with the net while they are feeding on the sea bed and stirring up clouds of sediment. When the mullet leave the lagoon they migrate in two main directions, around the western and eastern tips of the island (Fig. 1), to the spawning grounds on the exposed coasts of east and south-east Tongatapu. As the mullet migrate round the western tip of Tongatapu they are caught in fish corrals.

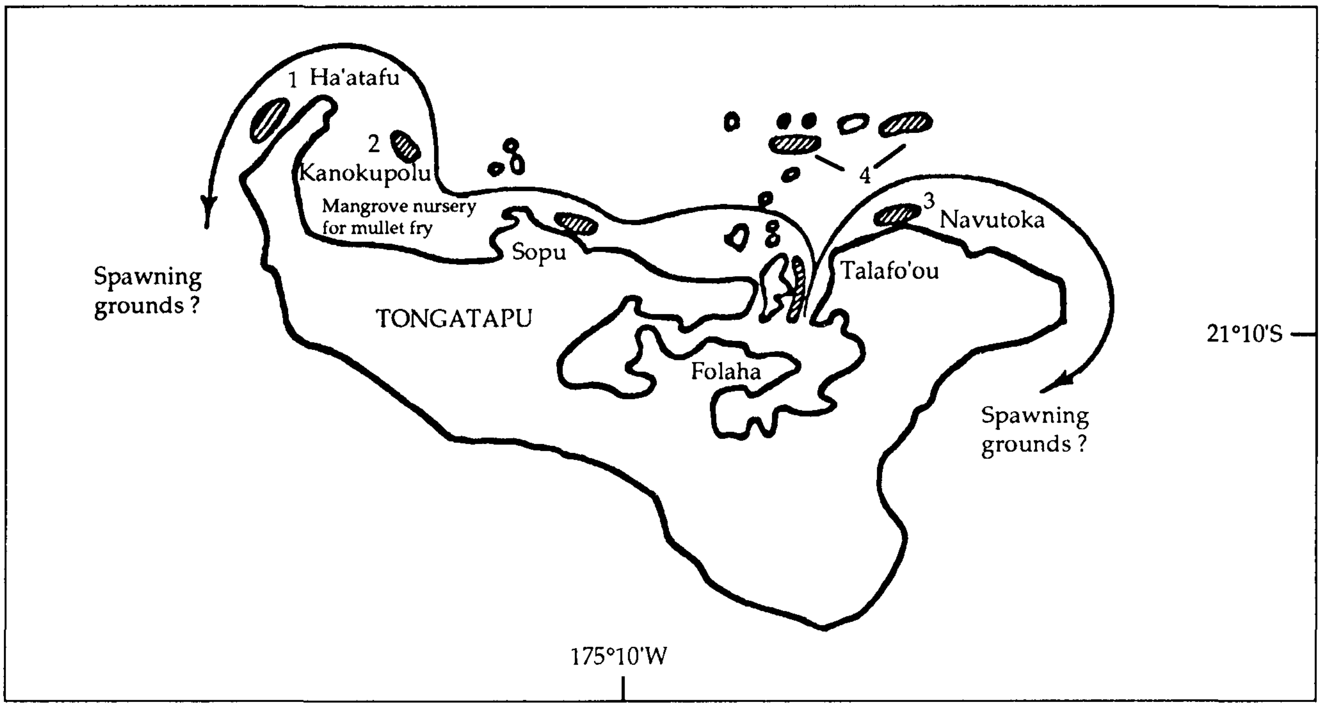


**Figure 1. Sketch map of Tongatapu showing the areas where mullet were sampled from fish corrals and the route of the annual spawning migration (based on information from fishermen)**

According to the fishermen there are five times in the lunar month when mullet spawn:

- no moon,
- new moon,
- 7 days before full moon,
- 4 days before full moon (peak),
- full moon.

The fishermen believe that mullet spawn where the sea is rough because the wave action 'massages' them into spawning. They distinguish three species of mullet:

- **Ngalau**, which has a big gonad and a big body,
- **Kanahe**, which has a small gonad and big body,
- **Unomoa**, which has a small gonad and a smaller body.

According to the fishermen, **Ngalau** spawn from May until August, and **Kanahe** from September to March. Mullet fry one to two inches in length start appearing in September in schools as they return to the lagoon, sheltering periodically in the mangroves of the northern coast.

## Species identification

A nominal total of five species of mullet was identified from the adult and larval specimens. The larvae were identified as *Valamulgil seheli* and *V. engeli*, whilst the adults were *Mugil cephalus*, *V. seheli*, *Liza subviridis*, and

*L. macrolepis*. No adults of *V. engeli* were seen in the catches landed by the fishermen in this survey. Further, identification of *L. macrolepis* was based on only a single specimen, while some problems were encountered with the positive identification of *L. subviridis* due to discrepancies between published descriptions of this species. For the remainder of this paper distinction is therefore made only between *M. cephalus*, *V. seheli* and *Liza* sp.

## Species composition and abundance

The composition of the catch in numbers at each location and by gear type is shown in Figure 2. Almost 75 per cent of the mullet catch was *M. cephalus*, with most of the remainder made up of *Liza* sp. *V. seheli* contributed very little to the total catch. Nearly 70 per cent of the mullet catch was taken by the fish corral at Ha'atafu at the western edge of Tongatapu, with most of the remainder more or less evenly distributed between catches from Navutoka, Talafo'ou and Folaha. The lack of productivity in areas other than Ha'atafu was ascribed to problems with outboard engines (Folaha), lack of expertise with gill nets (Kanukopulu), non-productive location (Navutoka) or simply low fishing effort (Sopu and Talafo'ou) Both *M. cephalus* and *V. seheli* were caught by nets and fish corrals, while *Liza* sp. was taken only by the fish corrals.

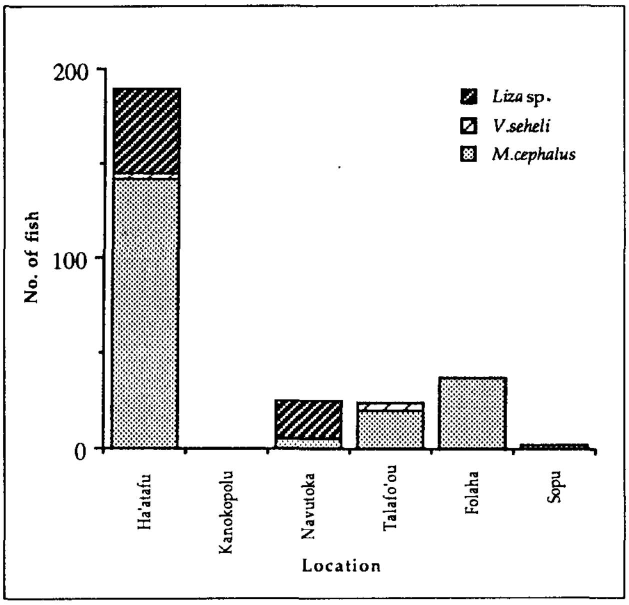


**Figure 2. Number of different mullet species captured at different locations on Tongatapu**

The monthly species composition of the catch is shown in Figure 3. Limited as the data are, they suggest a peak in overall mullet abundance during July, with a steady decline in landings between August and September. No mullets were recorded in the landings at the six fishing sites on Tongatapu during October and November. The pattern of mullet landings is generally a reflection of the abundance of *M. cephalus*, which was absent from landings after August. The true index of abundance in this instance is not known since the data represent landed volume rather than the catch per unit of effort (CPUE).

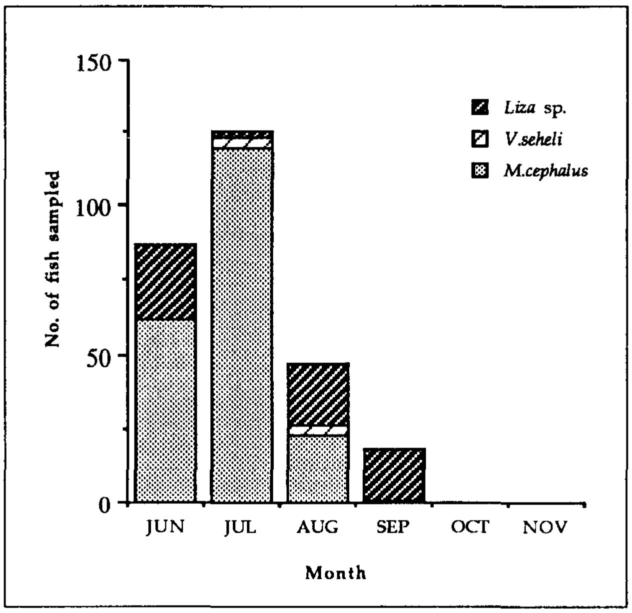


**Figure 3. Monthly species composition of mullet catch from Tongatapu**

The catch of mullets versus moon phase is shown in Figure 4. All data on landings were aggregated into the four lunar quadrants: new moon (NM), first quarter (FQ), full moon (FM) and last quarter (LQ). Cumulative landings of mullets were greatest during the first quarter before the full moon; they declined appreciably in the full moon period. Again it should be emphasised that these data refer only to landed volume and not to CPUE. As with the other data on mullet abundance, the pattern for the lunar month reflects that of *M. cephalus*.

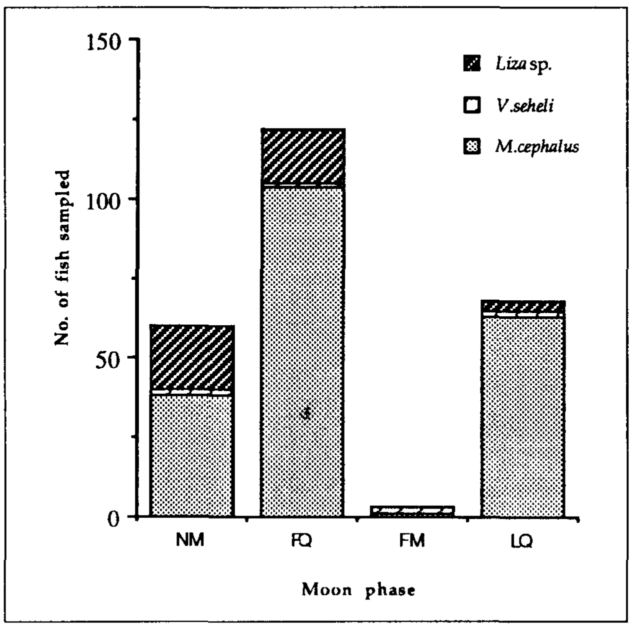


**Figure 4. Cumulative catch of mullets by species versus moon phase for the period of catch sampling on Tongatapu**

## Reproduction and spawning

The sex ratio (females to males) of *M. cephalus* was 1.6: 1 and for *Liza* sp. 1.85 : 1. The percentage of fishes in a spawning condition (Stage VI) between June and November is shown in Figure 5. Spawning *M. cephalus* were present in the catches between June and August with a peak in July. Spawning specimens of Liza sp. were present during August and September, with a sharp peak during August. Specimens of *V. seheli* were not observed in a spawning condition over this period but pre-spawning and spent fishes were taken in the samples.

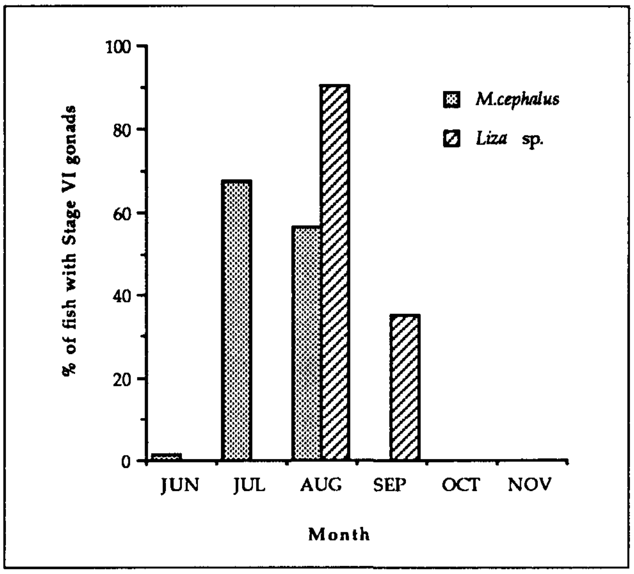


**Figure 5. Percentage of mullet species captured each month around Tongatapu with ripe (Stage VI) gonads**

The average monthly gonad index is plotted for the three species of mullet in Figure 6. However, the data refer only to records made between June and August due to problems with weighing scales during September.

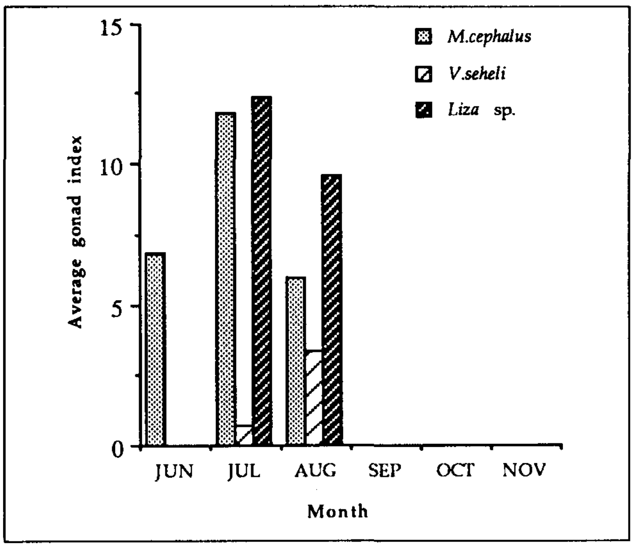


**Figure 6. Average monthly gonad index for mullet species captured around Tongatapu**

The limited data show, however, that the period between June and September is one when all three species of mullet are reproductively active and that the third quarter of the year (the winter months) is a period of spawning activity. This is further substantiated by the plot of average gonad stage versus month (Fig. 7).

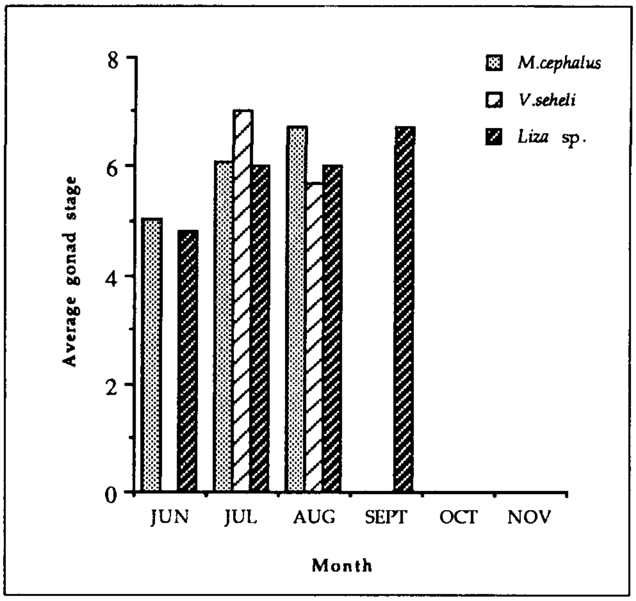


**Figure 7. Average gonad maturation stage for mullet species captured around Tongatapu**

The gonad indices of the three mullet species were aggregated into the four lunar quadrants described above (Fig. 8). Reproductive activity would appear to be greatest between the last quarter and the first quarter. For the commonest species, *M. cephalus*, there is a clear peak in reproductive activity during the new moon. This analysis must be treated with caution, however, since few specimens of all species were taken during the full moon period.

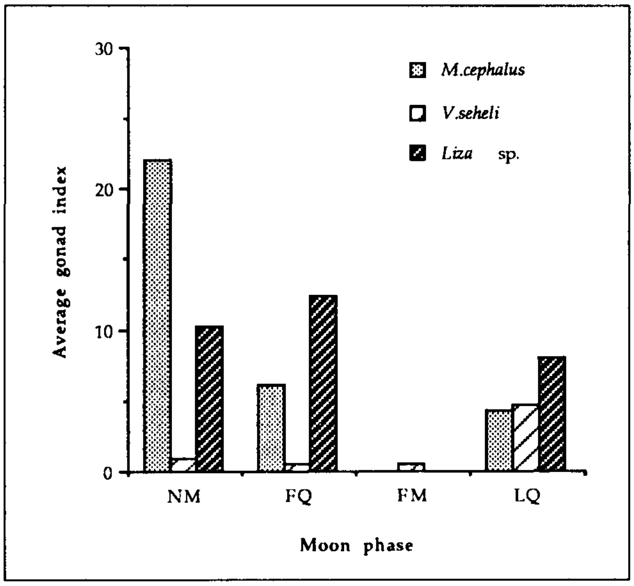


**Figure 8. Average gonad index of mullet species captured around Tongatapu versus moon phase**

## Length frequencies and length-weight equations

The length frequency distributions of *M. cephalus* and *Liza* sp are shown in Figures 9 and 10. Based on these limited data there appears to be sexual dimorphism (SSD) between males and females of these two species, with the female growing to larger sizes in both instances. It is not known whether this pattern of macrogynous SSD is found in all the mullet species in Tonga.

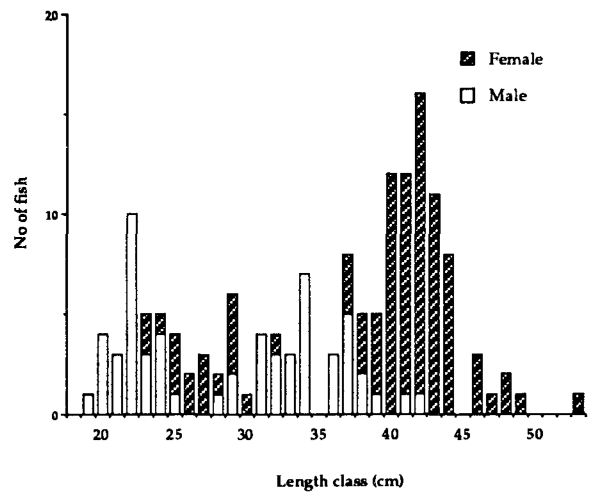


**Figure 9. Length frequency distributions of male and female *M. cephalus***

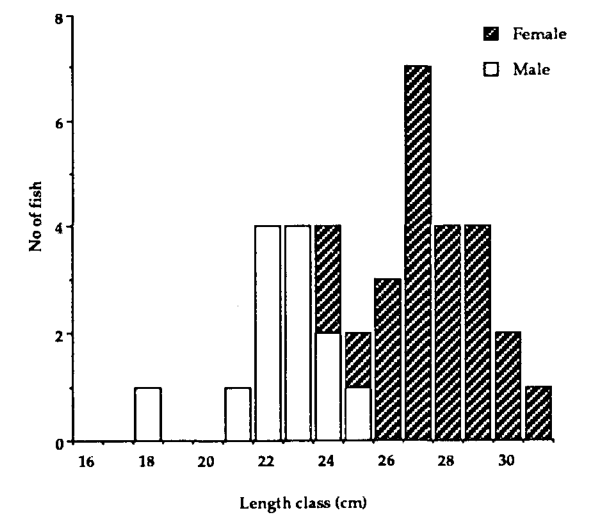


**Figure 10. Length frequency distributions of male and female *Liza* sp.**

The relationships between length and weight for male and female *M. cephalus* and *Liza* sp. are given in Table 1. The data for *M. cephalus* cover fish in the size ranges 19 to 41 cm for males and 23 to 52 cm for females. The size ranges of *Liza* sp. were 18 to 25 cm for males, and 23.5 to 31 cm for females.

**Table 1: Length-weight constants for mullet species from Tongan waters**

| Species | Sex | a | b | N | $r^2$ |
|---|---|---|---|---|---|
| *Liza* sp. | M | $1.7 \times 10^2$ | 2.89 | 8 | 0.99 |
| *Liza* sp. | F | $1.3 \times 10^2$ | 3.02 | 8 | 0.99 |
| *M. cephalus* | M | $6.7 \times 10^2$ | 2.54 | 10 | 0.99 |
| *M. cephalus* | F | $4.0 \times 10^2$ | 2.69 | 8 | 0.99 |

## Discussion

The results of this short study are based on a limited amount of data but indicate the direction that future investigations on the biology of Tongan mullets might usefuly take. Problems associated with the identification of species should be resolved by increasing observations both on landed catches and on the juveniles. Attempts to catch mullets independently of commercial fishermen were unsuccessful, despite the pressing need to have an accurate estimate of CPUE for relative abundance. Emphasis might be given to recording catches from only one or two of the most consistent fishermen, rather than spreading sampling effort to unproductive parts of the coast.

The anecdotal information recorded from the fishermen is generally in line with the data reported here from the sampling survey. It would be useful to have the fishermen actually identify the three species of mullet for which there are local names, as these might correspond to *M. cephalus*, *Liza* sp. and *V. seheli*. The other two species, *L. macrolepis* and *V. engeli*, may be naturally uncommon and thus not encountered frequently by the fishermen.

Judging from the present data, mullet fishing in Tonga appears to be based mainly on *M. cephalus*, since this forms almost 74 per cent of the catch. There is some indication of seasonality of abundance of *M. cephalus* (Fig. 3), but this is in terms of numbers, not of CPUE. Further, the data only cover a six-month period; a better picture of seasonal abundance will only emerge after the collection of data over a number of years. Initially, however, an effort should be made to collect catch data over a full 12-month period.

Similarly, the greatest volumes of mullet were landed over the period of the lunar first quarter. Without any estimates of fishing effort, however, it is difficult to say whether this reflects increased CPUE of mullet in this lunar quadrant.

The sample data suggest that mullets in Tongan waters are reproductively active between July and September, with spawning commencing in the third quarter of the year, during the cooler months. However, many marine tropical fish species have twin spawning peaks and concomitant twin recruitment periods (Longhurst and Pauly, 1987). Mullet species in Tonga may thus also have a second spawning peak later in the year. That this might be the case is partially suggested by the accounts of the fishermen, who indicate that spawning of some mullet species extends from September to March. Clearly the true pattern of spawning activity will only be elucidated with further sampling.

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# ESTIMATION OF EXPLOITATION RATES IN A MULTI-SPECIES EMPEROR (Pisces: Lethrinidae) FISHERY IN FIJI BASED ON LENGTH-FREQUENCY DATA

by
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## *Abstract*

***Preliminary estimates of the von Bertalanffy growth curve parameters of Fijian lethrinid fishes were estimated from length-frequency data. An estimate of the asymptotic size, $L_\infty$, was determined from these data, whilst estimations of the growth constant, K, were based on the growth parameters of lethrinids from elsewhere in the Indo-Pacific region. The length frequencies were converted by the von Bertalanffy growth curve to length-converted catch curves from which were derived the total mortality rates. The probable under-representation of larger fish in the catches due to gear selectivity leads to positively biased estimates of apparent total mortality and exploitation ratios which, however, are rather low. The results suggest that Fijian lethrinids are below the point of optimal exploitation.***

## *Résumé*

***On a procédé à des évaluations préliminaires des paramètres de la courbe de croissance de type von Bertalanffy des léthrinidés fr Fidji à partir des données de fréquences de tailles. Une estimation de la taille asymptotique $L_\infty$ a également été calculée à partir des données ainsi recueillies, la constante de croissante K étant pour sa part calculée à partir des paramètres de croissance des léthrinidés d'autres zones de la région Indopacifique. Les fréquences des tailles des prises ont été converties en fréquences d'âges à partir de la courbe de croissance établie selon le modèle de von Bertalanffy et on en a déduit les coefficients de mortalité totale. Les poissons de plus grande taille sont probablement sous-représentés dans ces statistiques du fait de la sélectivité des engins de pêche; il en résulte des évaluations très relatives de la mortalité totale apparente et des taux d'exploitation qui sont toutefois relativement peu élevés. Les résultats obtenus semblent indiquer que les stocks de léthrinidés de Fidji sont encore en deçà du niveau d'exploitation optimale.***

## Introduction

Fishes of the family Lethrinidae (emperors) form an important part of the marine fish production from Fijian waters. Lethrinids are the single most important family of fishes captured by artisanal fishermen. Due to their high value and the strong demand for these fishes, landings of lethrinids have increased over the period 1982 to 1987 by about 100 per cent (Table 1). Between eight and nine thousand tonnes of lethrinids are landed annually with a value of two million Fijian dollars. A total of twelve species contribute to the catch but three species, *L. nebulosus*, *L. mahsena* and *L. harak*, comprise about 80 per cent of the total landings of these fishes (Table 1).

**Table 1: Summary of data on artisanal landings (t) of lethrinid species in Fiji between 1982 and 1987**

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|
| Total lethrinid landings | 429.1 | 451.6 | 677.7 | 842.5 | 885.6 | 796.8 |
| Lethrinid landings sold through markets | 160.4 | 148.7 | 108.7 | 138.3 | 150.0 | 158.5 |
| Lethrinid landings sold through other outlets | 268.6 | 302.9 | 568.9 | 703.7 | 735.6 | 638.3 |
| Landings of *L.harak* | 66.5 | 72.6 | 141.4 | 273.4 | 303.0 | 223.0 |
| Landings of *L.mahsena* | 196.0 | 123.3 | 140.9 | 203.2 | 171.0 | 155.2 |
| Landings of *L.nebulosus* | 112.3 | 142.3 | 164.9 | 171.0 | 246.1 | 236.2 |
| Total fish landings in Fiji | 3921.3 | 2916.5 | 4276.7 | 4834.1 | 4336.1 | 4710.2 |
| Lethrinids as % of total fish landings | 14.7 | 11.5 | 15.9 | 17.4 | 20.4 | 16.9 |

(Source: Fisheries Division records)

A number of studies on the biology of lethrinids have been made throughout the Indo-West Pacific region. Those studies that include estimates of parameters necessary for stock assessment are given in Table 2. Estimates of age, growth and mortality rates have not been made for Fijian lethrinid stocks. A large amount of length-frequency data was collected from Fijian lethrinid landings by Fisheries Division personnel during 1984. From these data, it was possible to make some preliminary estimates of population parameters, based on comparative studies. These showed that at present, Fijian lethrinid stocks may still be approaching the point of optimal exploitation. The methods used are described in detail in order to demonstrate to other workers in the South Pacific region the usefulness of such an approach where data are limited.

## Methods

The standard lengths to the nearest centimetre of the six commonest lethrinid species landed into markets of the Western, Central and Northern Divisions of Fiji were measured weekly. The data were pooled on a Divisional basis and summed over the sampling period to give annual length-frequency distributions

(Table 3). These six species account for nearly 90 per cent of all lethrinids sampled at the various landing sites.

**Table 2: Age, growth and mortality parameters for lethrinid stocks from the Indian and Pacific Oceans**

| Species | Location | $L_\infty$ | K | Ø' | $M^a$ | Source |
|---|---|---|---|---|---|---|
| *L. chrysostomus* | New Caledonia | 47.3 | 0.27 | 2.781 | 0.66 | 6 |
| *L. chrysostomus* | Norfolk Island | 47.3 | 0.27 | 2.781 | 0.30 | 7 |
| *L. enigmaticus* | Seychelles | 55.0 | 0.13 | 2.594 | 0.40 | 8 |
| *G. japonicus* | New Caledonia | 35.1 | 0.24 | 2.470 | 0.67 | 2 |
| *G. japonicus* | New Caledonia | 39.5 | 0.22 | 2.536 | 0.61 | 2 |
| *L. lentjan* | India | 64.0 | 0.27 | 3.043 | 0.61 | 9 |
| *L. lentjan* | New Caledonia | 29.2 | 0.33 | 2.449 | 0.87 | 6 |
| *G. lethrinoides* | New Caledonia | 37.0 | 0.28 | 2.583 | 0.73 | 2 |
| *L. mahsena* | Gulf of Aden | 58.9 | 0.32 | 3.045 | 0.70 | 2 |
| *L. mahsena* | New Caledonia | 32.7 | 0.29 | 2.492 | 0.78 | 6 |
| *L. mashenoides* | Gulf of Aden | 42.6 | 0.48 | 2.939 | 1.00 | 2 |
| *L. miniatus* | Gulf of Aden | 58.9 | 0.23 | 2.902 | 0.57 | 2 |
| *L. miniatus* | Gulf of Aden | 106.5 | 0.06 | 2.839 | 0.20 | 2 |
| *L. nebulosus* | Gulf of Aden | 87.0 | 0.09 | 2.833 | 0.27 | 1 |
| *L. nebulosus* | Gulf of Aden | 84.0 | 0.11 | 2.890 | 0.32 | 2 |
| *L. nebulosus* | Gt. Barrier Reef | 48.0 | 0.39 | 2.954 | 0.85 | 4 |
| *L. nebulosus* | Kuwait | 62.7 | 0.19 | 2.873 | 0.47 | 5 |
| *L. nebulosus* | New Caledonia | 52.6 | 0.22 | 2.788 | 0.57 | 6 |
| *L. nebulosus* | NW Australia | 56.5 | 0.11 | 2.569 | 0.37 | 3 |
| *L. nematacanthus* | New Caledonia | 15.0 | 0.87 | 2.292 | 1.98 | 6 |
| *G. rivlatus* | New Caledonia | 46.4 | 0.23 | 2.696 | 0.60 | 2 |
| *L. variegatus* | New Caledonia | 30.3 | 0.43 | 2.595 | 1.03 | 6 |

1. Edwards et al. (1985)
2. Aldonov & Druzhinin (1979)
3. Kuo & Lee (1986)
4. McPherson et al. (1985)
5. Baddar (1987)
6. Loubens (1980)
7. Walker (1979)
8. Lebeau & Cueff (1975)
9. Toor (1964)

$M^a$ estimated from Pauly's (1980) formulation.

**Table 3: Summary of the data sets of six species of lethrinids used to estimate exploitation rates**

| | Numbers of fish | | | |
|---|---|---|---|---|
| Species | Central | Western | Northern | Total |
| *L. harak* | 2950 | 2538 | 255 | 5743 |
| *L. mahsena* | 4503 | 1760 | 309 | 6572 |
| *L. nebulosus* | 1971 | 2036 | 191 | 4198 |
| *L. ramak* | 1027 | 770 | 152 | 1949 |
| *L. semicinctus* | 1286 | 280 | - | 1566 |
| *L. xanthochilus* | 893 | 278 | 243 | 1414 |

It was assumed, on the basis of Table 2, that Fijian lethrinids grow in accordance with the von Bertalanffy growth function. The growth function takes for length the form:

$$Lt = L_\infty = [1\text{-exp.-}k(t-t_0)]$$

where $L_\infty$ is the asymptotic size, K a growth constant, Lt is the length at time t and $t_0$ is the origin of the curve. The asymptotic length, $L_\infty$ was estimated in this instance by the method of Weatherall (1986), modified and incorporated into the computer programme ELEFAN II by Pauly (1986). In the original method, a plot is made of the mean lengths (Lm) of a series of partially overlapping sub-samples against the respective cutoff lengths (L'). For the total length distribution of a given species, the sequential cutoff lengths are the lower limit of each class interval and their respective mean sizes. Pauly (1986) suggested a modification where (Lm-L') is plotted on L'. This gives a descending line with an intercept on the abscissa equivalent to $L_\infty$.

No studies have been made of age and growth of Fijian lethrinids other than a few observations on the otoliths of *L. harak* (Dalzell, unpub. data). Data from studies elsewhere (Table 2) show conclusively that lethrinids are slow-growing, long-lived fish and that even small specimens such as *L. variegatus* (max. length = 30 cm) can live well beyond ten years of age. The smallest species in the genus, *L.nematacanthus*, lives to about 6—7years of age. In such circumstances, estimation of growth parameters from length-frequency data is at best difficult. Modal progression analysis or the use of curve-fitting routines such as ELEFAN I (Pauly and David, 1981) that fit von Bertalanffy functions to sequential samples is unlikely to work where growth rates are slow. Further, Edwards et al. (1985) have suggested that isolation of 'year classes' from length data of *L. nebulosus* is not particularly reliable.

An alternative method for estimating the growth of Fijian lethrinids is by the empirical technique of Pauly and Munro (1984). Pauly and Munro showed that VBGF growth parameters could be compared directly through the use of Ø' where:

$$Ø' = \log_{10} K + 2 \log_{10} L_\infty$$

For a given taxon of fish, the distribution of Ø' values should correspond to a normal curve. From the values in Table 2, a frequency distribution of Ø' values was constructed (Fig. 1) which indeed suggests a normal curve, albeit with some positive kurtosis. From the values in Table 2, a mean of Ø' = 2.726 was computed from which an empirical estimate of K for each Fijian lethrinid species was derived. An exception was *L. nebulosus*, for which, since there were six studies, a mean figure of Ø' = 2.818 was used.

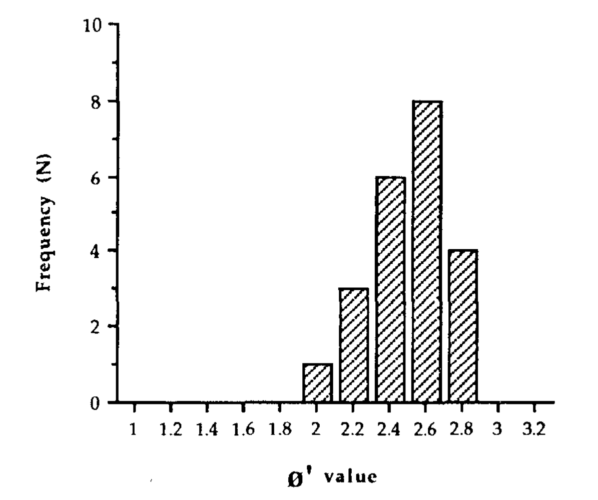


**Figure 1. Frequency distribution of Ø' values for Indo-Pacific lethrinid stocks**

Where growth parameters are known, the total mortality rate (Z) can be estimated from a length-converted catch curve (Gulland, 1983; Pauly, 1984). Length-frequencies can be converted to age frequency by the use of the VBGF and the descending limb of the catch curve takes the form:

$$\log_e N / \Delta t = a + bt$$

where N is number of fish in a given length class, $\Delta$ t is the time taken to grow through that length class and t is relative age in years. The slope of the line (b) is equivalent to the total annual mortality rate.

Similarly, growth parameters and mean environmental temperature may be used in conjunction with the empirical equation of Pauly (1980) who showed that an estimate of the natural mortality rate (M) could be determined from:

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

## Results and discussion

Examples of the estimation of $L_\infty$ from length-frequency data by Weatherall's method are shown in Figure 2. Sample size can affect the estimation of $L_\infty$ and related parameters from length-based methods as shown by Weatherall et al. (1987). The best length data sets for Fijian lethrinids come from the Central Division, where all but one set of length data are composed of over 1000 fish. Half of the Western Division data sets comprised similar relatively large samples, while all of the Northern Division length data number between 100 and 300 fish. Less reliance can be placed on the results of growth and mortality estimates from these smaller samples. They are included here, however, primarily as an example of the methodology and to cover as many of Fiji's lethrinid stocks as possible. The estimated growth parameters for Fijian lethrinid stocks are given in Table 4.

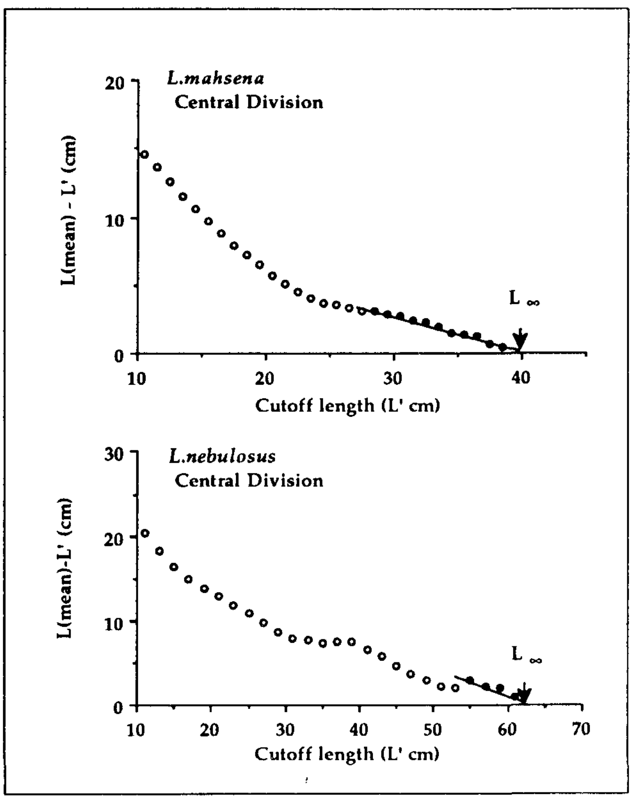


**Figure 2. Examples of the modified regression plot for Fijian lethrinids. Regression line is fitted to black dots.**

**Table 4: Growth and mortality estimates for Fijian lethrinid stocks**

| Species | Location | $L_\infty$ | K | Z | M | F | E |
|---|---|---|---|---|---|---|---|
| *L. harak* | C.D. | 33.0 | 0.49 | 1.60 | 1.07 | 0.53 | 0.33 |
| *L. mahsena* | C.D. | 41.3 | 0.31 | 1.03 | 0.75 | 0.28 | 0.27 |
| *L. nebulosus* | C.D. | 64.6 | 0.16 | 0.53 | 0.43 | 0.10 | 0.20 |
| *L. ornatus* | C.D. | 32.7 | 0.49 | 2.35 | 1.09 | 1.27 | 0.54 |
| *L. semisinctus* | C.D. | 30.0 | 0.59 | 2.69 | 1.25 | 1.44 | 0.54 |
| *L. xanthochila* | C.D. | 62.2 | 0.14 | 0.35 | 0.39 | 0.0 | 0.0 |
| *L. harak* | W.D. | 34.2 | 0.45 | 2.03 | 1.01 | 1.02 | 0.50 |
| *L. mahsena* | W.D. | 41.4 | 0.31 | 0.90 | 0.75 | 0.15 | 0.16 |
| *L. nebulosus* | W.D. | 62.3 | 0.17 | 0.51 | 0.45 | 0.06 | 0.12 |
| *L. ornatus* | W.D. | 33.1 | 0.48 | 1.74 | 1.07 | 0.67 | 0.39 |
| *L. semisinctus* | W.D. | 26.4 | 0.76 | 1.93 | 1.53 | 0.40 | 0.21 |
| *L. xanthochila* | W.D. | 64.0 | 0.17 | 0.73 | 0.45 | 0.28 | 0.39 |
| *L. harak* | N.D. | 33.9 | 0.46 | 1.52 | 1.03 | 0.50 | 0.33 |
| *L. kallopterus* | N.D. | 51.7 | 0.20 | na | 0.53 | na | na |
| *L. mahsena* | N.D. | 42.8 | 0.29 | 0.65 | 0.71 | 0.0 | 0.0 |
| *L. nebulosus* | N.D. | 50.2 | 0.21 | na | 0.55 | na | na |
| *L. ornatus* | N.D. | 30.9 | 0.55 | 2.34 | 1.19 | 1.16 | 0.49 |
| *L. xanthochila* | N.D. | 53.9 | 0.18 | na | 0.49 | na | na |

The estimates of $L_\infty$ and K for *L.nebulosus* lie within one standard deviation of the means of those stocks in Table 2. Similarly, the estimates of $L_\infty$ and K for Fijian *L.mahsena* stocks lie between those for populations in New Caledonia and the Gulf of Aden. Age observations on *L.harak* from Fiji by counts of presumed annulus formations in the otoliths (Fig. 3) suggest that this fish achieves a length of about 25 cm at nine years of age. Counts of presumed annuli in otoliths of *L.semicinctus* from Papua New Guinea (Dalzell, unpub. data) suggest that this species also achieves a length of 25 cm between nine and ten years of age.


**Figure 3. Scatter of age from presumed annulus markings of the otoliths versus length for *L. harak*, Fiji**

The various length-converted catch curves for the different stocks of lethrinids in Fiji are shown in Figures 4 to 6. In most instances, it was possible to fit a straight line to the descending limb of the catch curves. Exceptions were data for *L. xanthochila*, *L. nebulosus* and *L. kallopterus* from the Northern Division, probably due to the low sample sizes as discussed above. In some instances, the estimates of Z were lower than the empirically computed M values, suggesting a very low value of Z. For the remainder, an estimate of

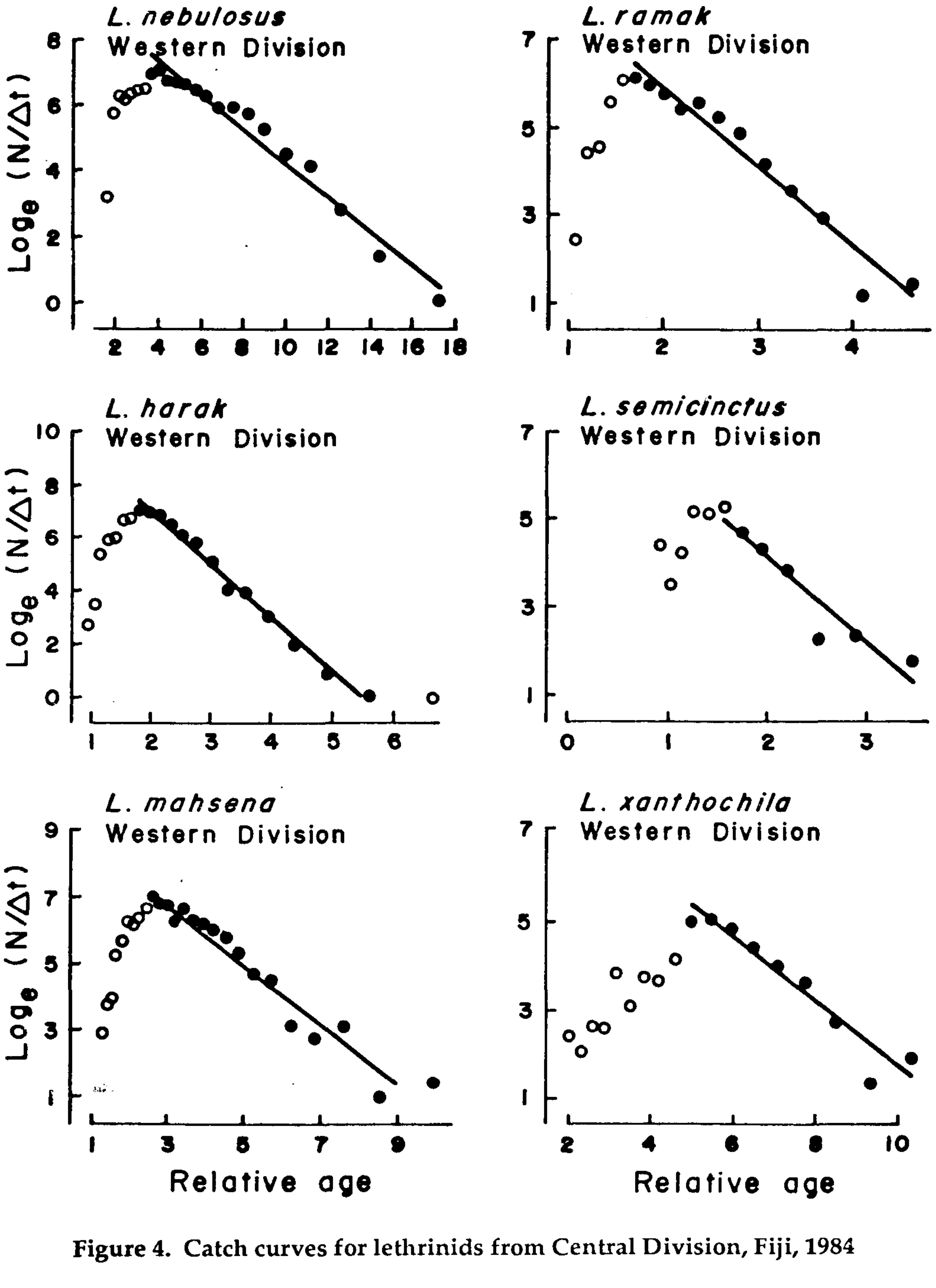


**Figure 4. Catch curves for lethrinids from Central Division, Fiji, 1984**

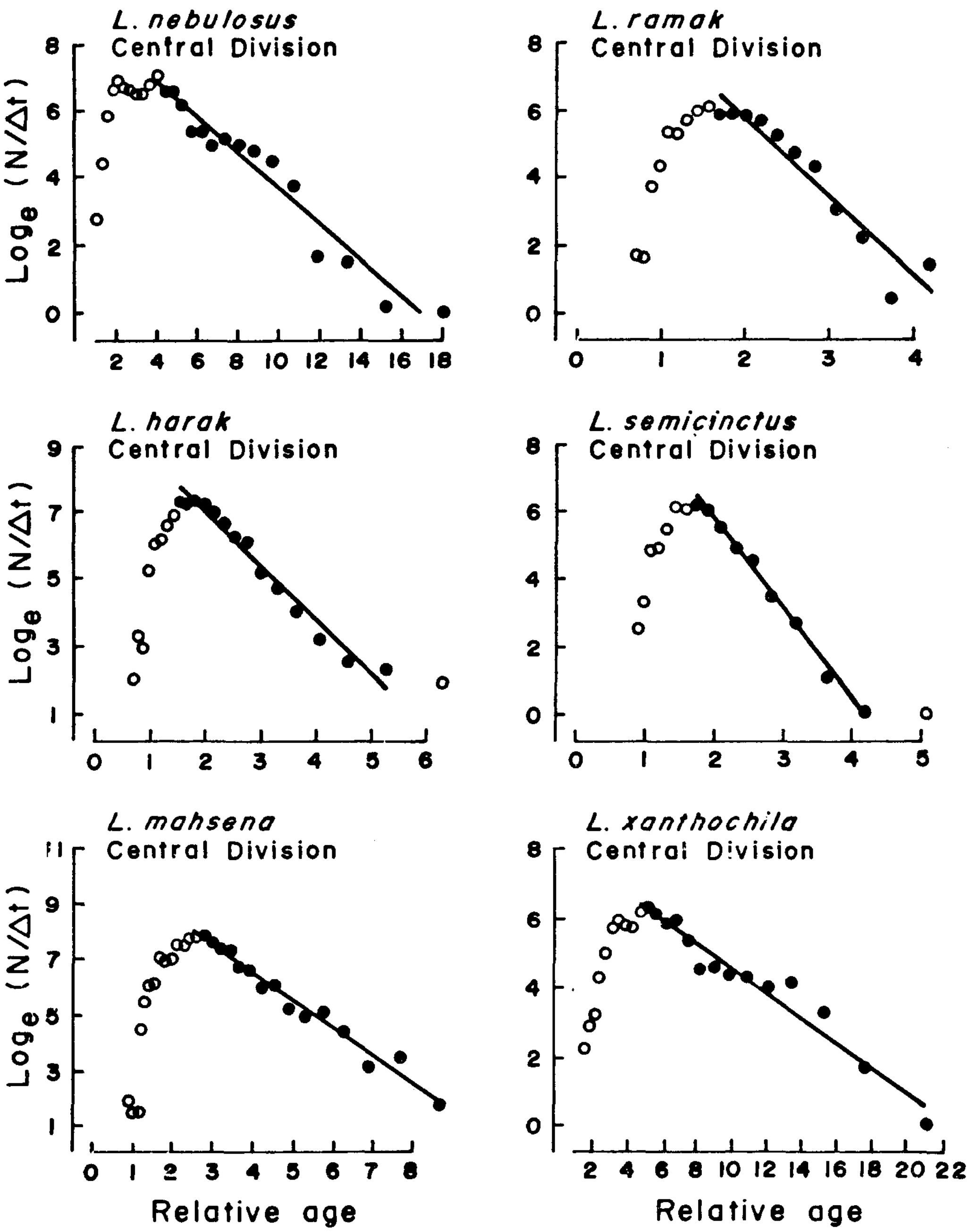


**Figure 5. Catch curve for lethrinids from Western Division, Fiji, 1984**

fishing mortality (F) or the difference between Z and M could be calculated (Table 4). This in turn permitted estimation of the exploitation ratio (E) where:

$$E = \frac{F}{F+M} = \frac{F}{Z}$$

The values of E for Fijian lethrinids ranged from 0.16 to 0.54 (Table 4), with an average value of 0.34 and of 0.30 if the cases are included where 'Z' < 'M' (i.e., as E=0).

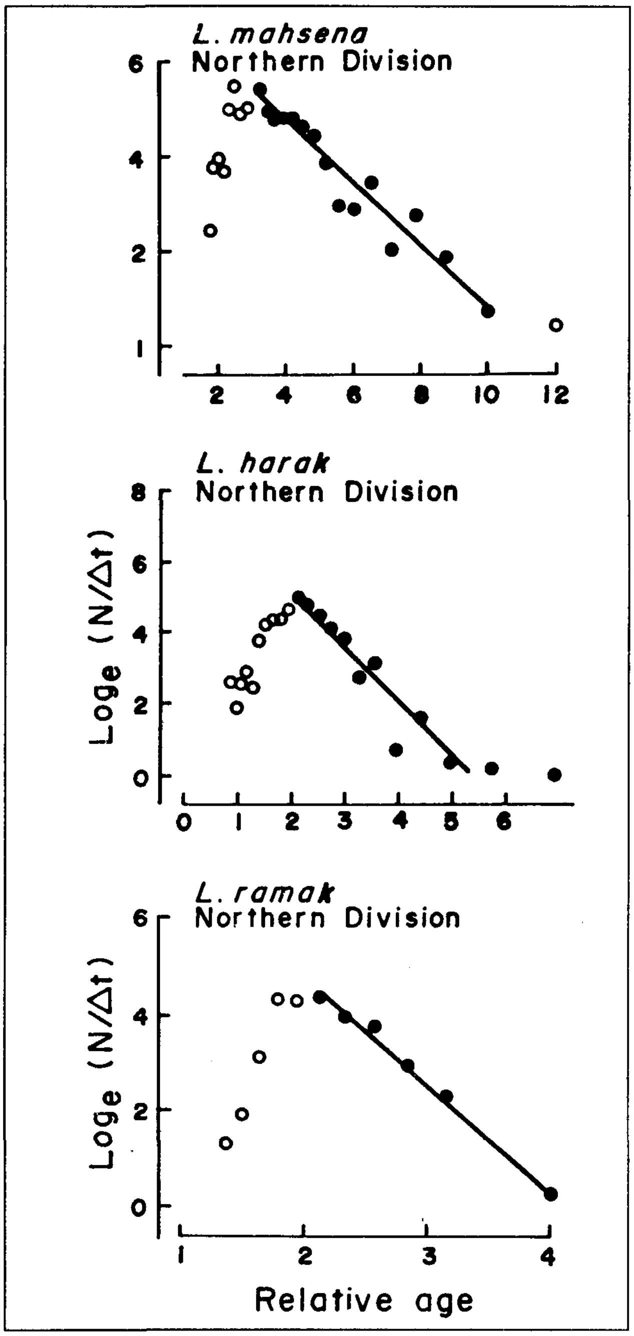


**Figure 6. Catch curves for lethrinids from Northern Division, Fiji, 1984**

Gulland (1971) has suggested that a fish stock is optimally exploited when the fishing mortality is equal to the natural mortality rate or:

$$F_{opt} = M, \text{ or } E_{opt} = 0.5$$

More recently, Pauly (1984), based on Beddington and Cooke (1983), proposed a more conservative definition of optimal fishing mortality or:

$$F_{opt} = 0.4\,M, \text{ or } E_{opt} = 0.3$$

The results from these analyses would suggest that the majority of Fijian lethrinid stocks are at or approaching the point of optimal exploitation. However, whilst the growth parameter estimates are probably reasonable, the length distributions may not be representative of the sampled populations. The estimates of growth parameters in Table 2 are based on annual marks of scales, otoliths and vertebrae, and, in some cases, have been cross-checked and validated. Further, limited observations on otoliths of Fijian and Papua New Guinea lethrinids support these growth estimates. Thus, the empirical estimates of the growth parameter K are, in this instance, probably realistic.

The fishing gears used to capture lethrinids in Fiji are gill nets, seine nets and hand lines. All these gears are selective, not only against smaller fish, but, especially in the case of gill nets, against larger fish also. If larger fish are under-represented in the catch, this will lead to upwardly biased estimates of Z and, in turn, of F and E. In this context, the inclusion of values of E = 0 where 'Z' < 'M' also introduces a positive bias in the estimation of the mean exploitation ratio. The mean exploitation ratio computed from the present data suggests that, according to the formulation of Pauly (1984), Fijian lethrinids are optimally exploited at present. Given the biases described above, this is likely to be an upper limit of the true range of values for these species.

The foregoing analyses are not intended as a substitute for a detailed investigation of the status of exploited lethrinid stocks in Fiji. The skeletal structures of lethrinids appear to be suitable for ageing specimens using procedures developed in cooler temperate waters. Length-converted catch curves, where selection effects are accounted for, would improve on the present estimates of total mortalities and exploitation ratios. However, the results do illustrate that it is possible with limited information to make preliminary conclusions about the status of exploited fish stocks. This study should, therefore, form a benchmark against which the results of more detailed and accurate sampling programmes can be compared.

Pauly (1979) discussed the problems of managing multispecies-multigear fisheries in tropical waters. Setting optimum mesh sizes is particularly difficult where a large range of different-sized fishes are caught in a fishery. The Fijian lethrinids are no exception and this can be demonstrated by comparing the length distributions of *L.nebulosus* and *L.harak* (Fig. 7). These species were chosen to be representative of 'large' and 'small' lethrinids. Large lethrinids include *L.xanthochila* and *L.kallopterus*, while the small category includes *L.ornatus*, *L.semicinctus*, *L.variegatus* and *L.mahsena*. The modal size classes of *L.harak* and *L.nebulosus* landed by the fishery are distinctly different, as are the length ranges captured. Similarly, *L.nebulosus* has a maximum life span of about 20 years, while the life expectancy of *L.harak* is about half this. Setting mesh size regulations or minimum permissible sizes to control the fishery must take account of these factors.

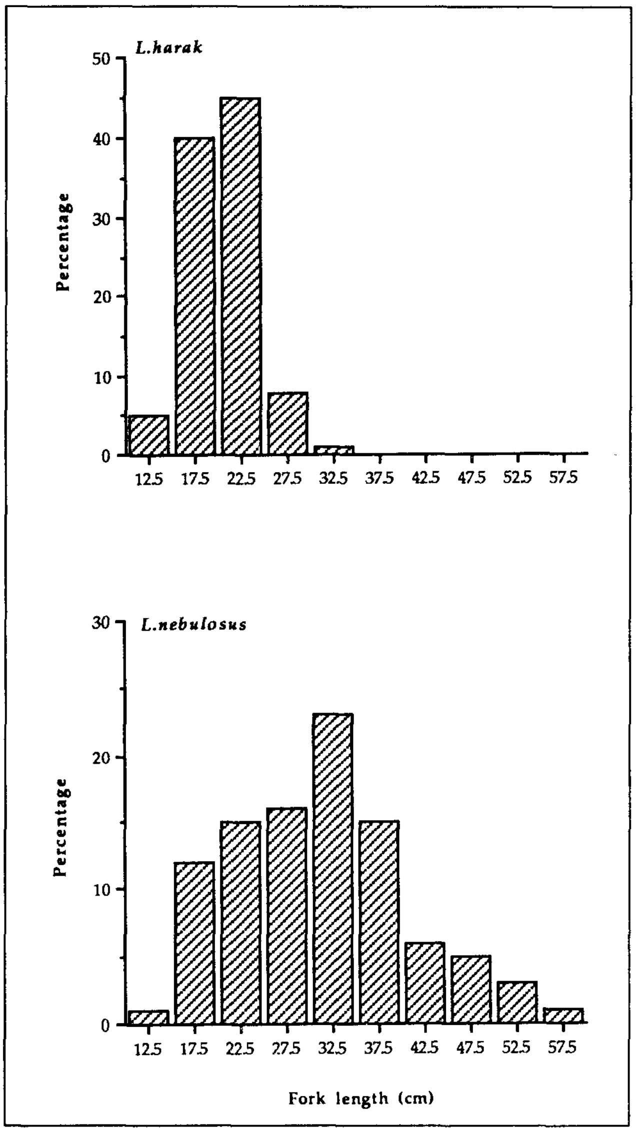


**Figure 7. Size frequencies of *L. harak* and *L. nebulosus* from Central Division landings, Fiji, 1984**

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