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ASSESSMENT OF BAITFISH RESOURCES IN VAVA'U, TONGA
TONGA TUNA LONGLINE PROJECT
FINAL REPORT: FEBRUARY 1994

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ACKNOWLEDGEMENTS

This report presents analyses and a summary of results from baitfish surveys in Vava'u, Tonga during 1992 and 1993, and is based on data collected by Viliami Langi and Siola'a Malimali, under the direction of Dr. Stanley Swerdloff, RDA Project Leader, Tonga and Pita Hurrell, Ministry of Fisheries, Tonga, respectively. The assistance of Sarah Langi is gratefully acknowledged.

Methodological details are included in keeping with the training aspects of the project. Analyses contained in the report were completed using computer spreadsheets and programs written and copied for use on RDA and Ministry of Fisheries computers in Tonga.

1. EXECUTIVE SUMMARY:

A previous report (RDA P-50 92/04) provided recommendations for the establishment of a programme of research and field investigations to assess the baitfish resources of Vava'u, Tonga, and to suggest appropriate levels of sustainable exploitation. The development of an artisanal fishery for baitfish is intended to complement, and provide bait for, a proposed small-scale longline fishery for tuna.

Fishing was carried out from the government research vessel "Albacore" at nine different stations in Vava'u waters. Fishing began in April, 1992, and 93 fishing trips had been completed by the end of 1993. The fishing method involved the deployment of an anchored dinghy fitted with lights to attract baitfish during the hours of darkness. A 80 m circumference purse seine net with 20 mm meshes, set from the research vessel, was used to surround the schooling baitfish.

Although catches varied greatly, the mean catch rate over the survey period of all species combined was 475 kg per night (with a maximum of 2537 kg per night), and returns on fish sales were approximately TS2.00 per kg. A total catch of 16.4 tonnes was landed in 1992, and 27.8 tonnes in 1993. The mean catch rate was higher in 1992 (606 kg per haul) than in 1993 (402 kg per haul), and decreasing catch rates, particularly over 1993, were a cause for concern.

Four species accounted for 85% by weight of the total catch, including the sardine, *Amblygaster sirm* (39%), the scads, *Decapterus macarellus* (27%), and *Decapterus macrosoma* (15%), and the herring, *Herklotsichthys* (4%). The scads were the preferred bait for catching large tuna on longlines, the sardine for catching smaller (<10 kg) tuna around fish aggregating devices (FADs), and the herring was considered too small for use as tuna bait. All species caught were edible, except the herring, which is believed to be ciguatoxic (cause ciguatera fish-poisoning) at times

Growth rates of the four major species were found to be high, suggesting lifespans of between two and three years. The sardine has a lower growth rate, and is therefore likely to be more susceptible to overfishing. In all species, total mortality rates (from both fishing and natural causes) were correspondingly high (greater than 90% per year).

Two species, the sardine, *Amblygaster sirm*, and the scad, *Decapterus macarellus*, matured relatively late in their lifespans and spawned in March/April. Small individuals of these two species were recruited into the fished stock during the early months of the year, and, in the scad, *Decapterus macrosoma*, recruitment occurred over a more extended period beginning in September.

Intensive fishing in a small area showed that local stocks of baitfish are extremely vulnerable to the fishing method. This indicates that a commercial fishing strategy should involve targeting different fishing areas on a rotational basis.

Yield per recruit analyses indicated that baitfish resources are limited, and that the survey vessel alone imposed a fishing mortality of between 29% and 56% (depending on species) of that required to obtain the maximum sustainable yield.

The lack of infrastructure to enforce fisheries regulations in Vava'u means that any controls placed on the fishery would have to be direct and relatively easy to police. For these reasons, input controls on the amount of fishing effort are more appropriate than output controls on the quantity of fish caught (such as catch quotas).

It is assumed that a profit-driven commercial operation would be more efficient than that of the government vessel. A vessel of a similar size, and using similar gear, to the "Albacore" therefore, would make greater catches, and is likely to impose a fishing mortality close to the optimum level. However, the same catch could be taken, and the same level of fishing

mortality imposed, by two or three smaller vessels using smaller gear. Smaller gear may include lift-nets, such as "boki-ami" (Japanese lift nets) or ring-net gear, and the relative efficiency of such gear would have to be determined by trials.

It is recommended that two smaller vessels (using smaller gear to be developed during trials) should be licensed initially to take baitfish commercially. A small licence fee should be imposed to amortize the cost of monitoring catch, fishing effort, and area fished. When compared with the use of a single large vessel, two smaller vessels would;

a) allow the resource to be shared between a larger number of people, and provide greater employment opportunities,

b) allow continuity of a supply of baitfish to the market (in the event of a breakdown of one of the vessels), and,

c) allow authorities to add fishing effort in smaller increments if catch and effort monitoring suggested that fishing effort could be increased.

2. INTRODUCTION

The Kingdom of Tonga lies between latitudes 15°S and 24°S, and longitudes 173°W and 177°W. The country is divided into the three main island groups of Tongatapu and Eua in the south, the Ha'apai group in the centre, and the Vava'u group in the north. The land area of the various islands of the Kingdom of Tonga amounts to a total of 747 km^2. A 200 nautical mile Exclusive Economic Zone (EEZ) encompasses about 700000 km^2 of ocean. Traditionally, seafood has been an important source of protein in Tonga, although in urban centres increasing amounts of imported fish and meat are also consumed. With population growth, there has been an increase in fishing pressure on the stocks of nearshore reefs and lagoons.

A previous report (RDA P-50 92/04) provided recommendations for the establishment of a programme of research and field investigations to assess the baitfish resources of Vava'u, and to suggest appropriate levels of sustainable exploitation. The development of an artisanal fishery for baitfish is intended to complement, and provide bait for, a proposed small-scale longline fishery for tuna; the project is, therefore, one element of the project on tuna fishery development.

Fishing was carried out from the 12 m government research vessel "Albacore" at nine different stations in Vava'u (Figure 2.1) from April 1992 to January 1994. The fishing method involved the deployment of an anchored dinghy fitted with lights to attract baitfish during the hours of darkness. A purse seine net, set from the research vessel, was used to surround the schooling baitfish. The purse seine net had a circumference of 80 m, and a mesh size of 20 mm (stretched point to point). This report presents the analyses of all data collected up to December, 1993, and, based on these, an assessment of the resource.

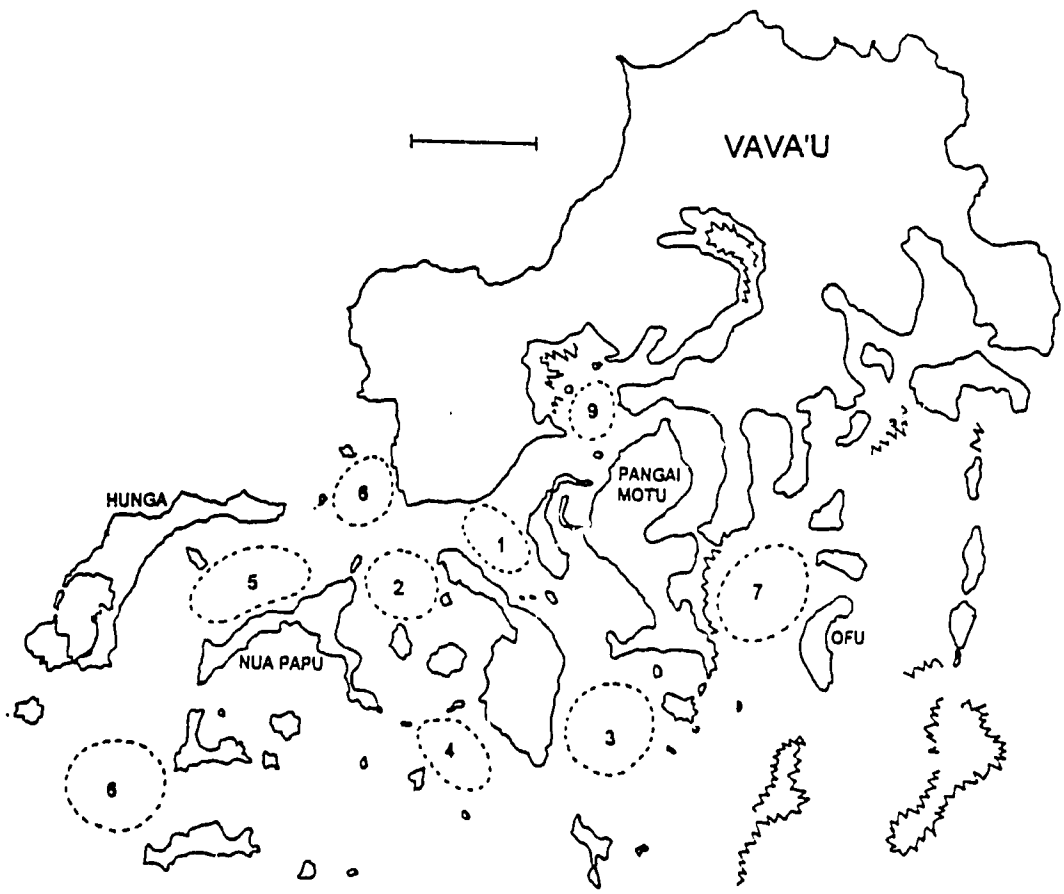

Figure 2.1: Vava'u Islands, Tonga; the nine fishing stations for baitfish are shown as numbers encircled by broken lines. The horizontal scale line indicates one nautical mile.

3. TEMPERATURE and SALINITY

Surface water temperatures and salinities were taken during fishing operations at all stations. Data collected at station 2 constitute the most continuous record, and these are shown in Figure 3.1. Temperatures varied little between stations, and ranged from 23 °C to 28 °C over the year, with a mean of 25.5 °C. Water salinities ranged from 35.8 to 37.4 parts per thousand (ppt), with a mean of 36.3 ppt.

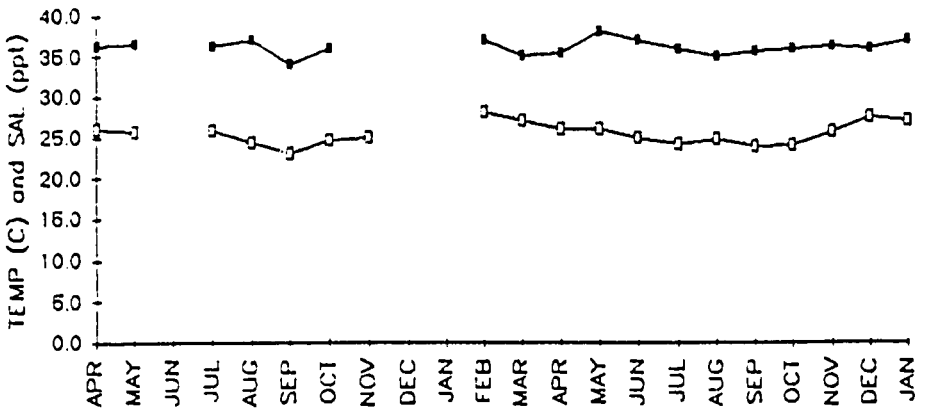

Figure 3.1: Temperature in °C (open squares) and salinity in parts per thousand (solid squares) at station 2 from April 1992 to January 1994, Vava'u Islands, Tonga.

4. CATCH COMPOSITION

The composition of species in the total catch was estimated from a count of individuals of different species in a sample (2 to 10 buckets) taken from each haul of the net. Total catch numbers were estimated from the ratio of the number of buckets in the sample to the number of buckets in the total catch.

Four species accounted for 85% of the total catch by weight over the survey period (Table 4.1). These were the sardine, *Amblygaster sirm*, the scads *Decapterus macarellus* and *Decapterus macrosoma*, and the herring, *Herklotsichthys*; the mean and maximum sizes of these four species are given in Table 4.1. Other species, particularly juvenile jacks (carangids) and surgeonfish (acanthurids), were caught occasionally, and accounted for 15% of the total catch by weight, and 9% by number. A summary of catches during all 93 fishing trips completed in 1992 and 1993 is given in appendix A.

Table 4.1: Catch composition at all stations combined, and mean and maximum sizes of the four major species caught in surveys in the Vava'u Islands, Tonga.

	sardine, *Amblygaster sirm*	herring, *Herklots.* species	scad, *Decapterus macrosoma*	scad, *Decapterus macarellus*
catch % by weight	39	4	15	27
catch % by numbers	36	17	22	16
mean kg per haul	183	20	69	125
mean length (mm)	197	118	175	227
maximum length (mm)	270	160	270	305
mean weight (g)	98	23	60	149
maximum weight (g)	283	60	225	374

The scads were the preferred bait for catching tuna on longlines, and the sardine for catching smaller (<10 kg) tuna around fish aggregating devices (FADs). The herring was considered too small for use as tuna bait. Scads are traditionally caught in small quantities for food by subsistence fishers, and although the sardine is not a traditional Tongan food item, those caught during the surveys were in demand as such. The herring is avoided as it is believed to become affected by ciguatera (fish poisoning).

The catch per haul of all fish species combined, at all stations (one to nine) over the period of the survey is shown in terms of weight and in numbers in Figures 4.1 and 4.2 respectively. The broken lines represent discontinuities in fishing, which were beyond the control of the researchers. A total of 16.4 tonnes was landed in 1992, and 27.8 tonnes in 1993 (all species combined). The mean catch rate was higher in 1992 (606 kg per haul) than in 1993 (402 kg per haul), and over the period of the survey the mean catch rate was 475 kg per haul. Decreasing catch rates (particularly over 1993) were a cause for concern (see Summary and Discussion).

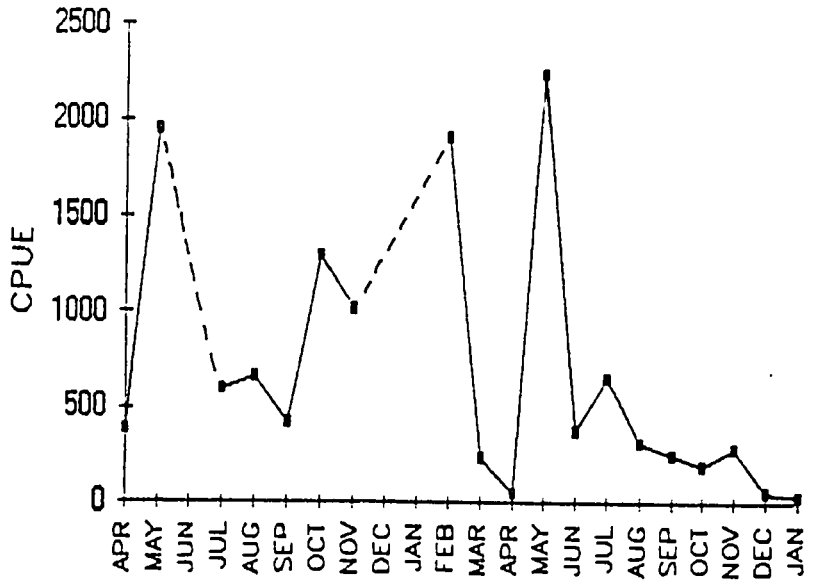

Figure 4.1: Catch (kg) per haul of all fish species, at all stations combined from April 1992 to January 1994, Vava'u Islands, Tonga.

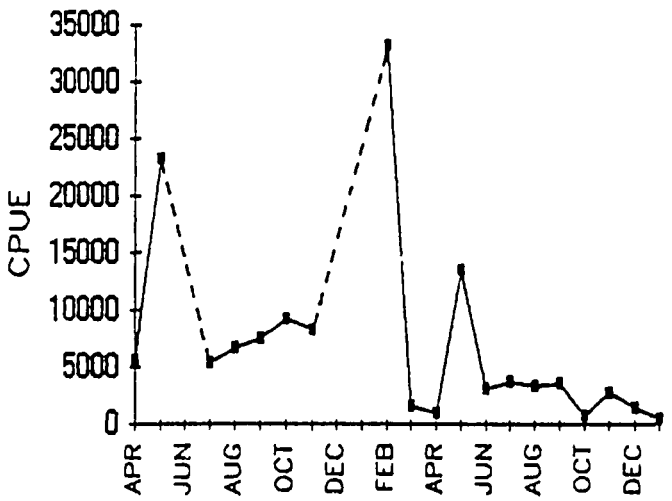

Figure 4.2: Catch (numbers) per haul of all fish species, at all stations combined from April 1992 to January 1994, Vava'u Islands, Tonga.

As most fishing was conducted at station 2, data from this location provided the most continuous record of changes in catch rates over time. Catch numbers per haul by species at station 2 for the period April 1992 to January 1994 are shown in Figure 4.3.

The decrease in numbers of the sardine, *Amblygaster sirm*, the major component species of the catch, was most noticeable, and contributed to the decline in overall catch rates. There was also a fluctuating but decreasing trend in catch rates of the two scads *Decapterus macarellus* and *Decapterus macrosoma*. Conversely, there was a trend of increasing catches of the herring, *Herklotsichthys*, a minor component of the catch (see Discussion and Summary).

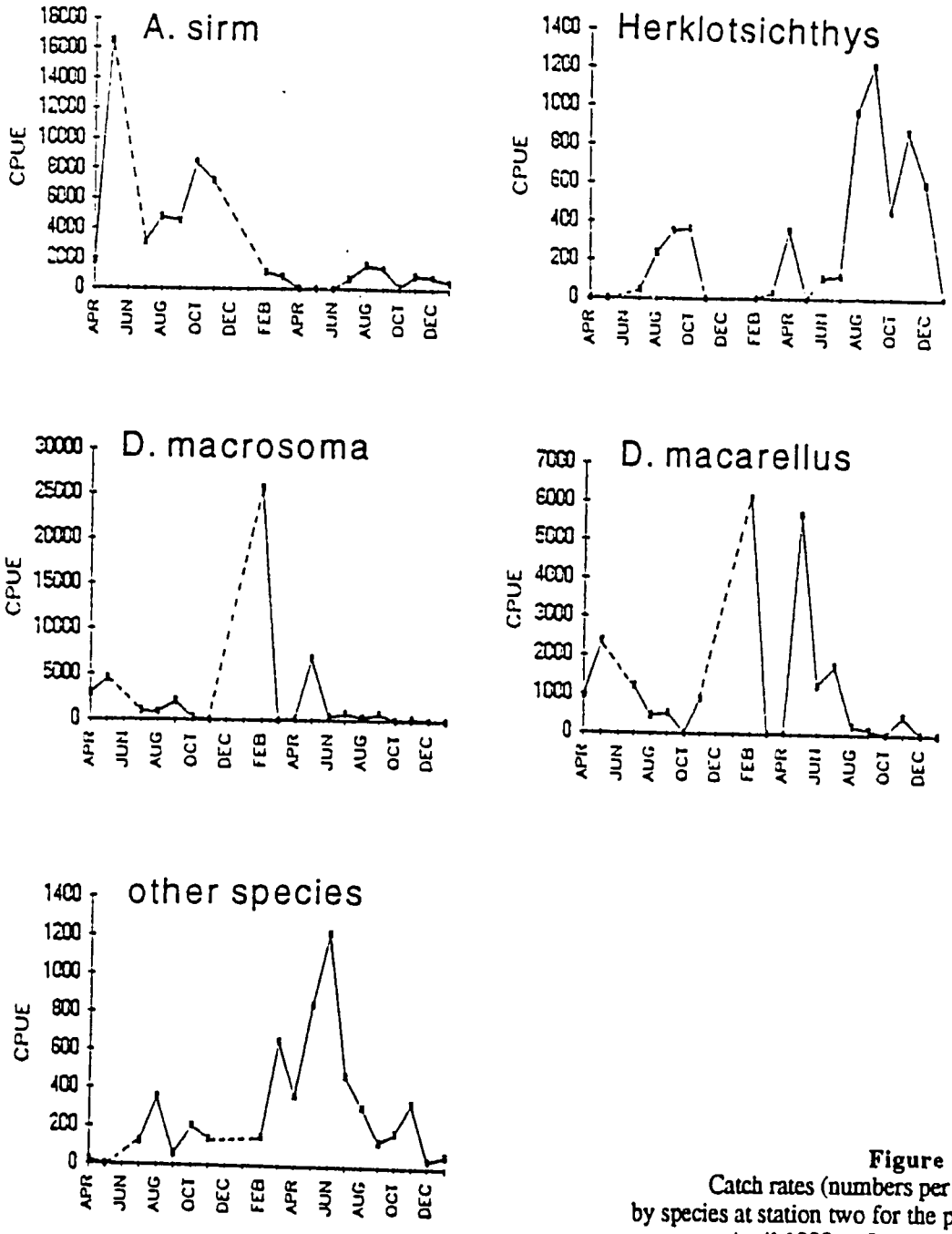

Figure 4.3:
Catch rates (numbers per haul) by species at station two for the period April 1992 to January 1994, Vava'u Islands, Tonga.

5. LENGTH-FREQUENCY DATA

Length-frequency data for each of the four major species are given in Appendices B to E. These data are shown as histograms with growth curves superimposed in the following section (Figure 6.1).

6. GROWTH ESTIMATES

The surveys resulted in a series of length-frequency data over time in which peaks (or modes) may be traced over time. The increases in modal lengths were used to estimate growth by modal progression analysis.

Several models have been used to express growth using simple mathematical equations. The von Bertalanffy growth equation, possibly because of its incorporation into fisheries yield equations, has been most commonly used in studies on marine species. The von Bertalanffy equation, in terms of length, is;

$$L_t = L_\infty(1-\exp[-K(t-t_0)])$$

...where L_t is the length at age t, L_∞ is the theoretical maximum (or asymptotic) length, K is a growth coefficient which is a measure of the rate at which maximum size is reached, and t_0 is the theoretical age at zero length.

The modal length data were analysed using von Bertalanffy plots (King, 1994), and by using the computer program ELEFAN (Gayanilo et al. 1981) which searches for the growth parameters that are the best description of the length-frequency distributions. The program is claimed to be more objective than most methods, although some subjectivity may still be involved in interpreting the results from difficult data. The results of the ELEFAN analyses are shown graphically in Figure 6.1, and the resulting growth parameters are given in Table 6.1.

The relationship between weight (W) and length (L) is of the form of a power curve equation $W = aL^b$. The values of the constants in this relationship were estimated for all species from the collected data (from Hurrell, 1992), and are given in Table 6.1.

Table 6.1: Summary of growth parameters and length-weight relationships for the four major species of baitfish.

	sardine, *Amblygaster sirm*	herring, *Herklots.* species	scad, *Decapterus macrosoma*	scad, *Decapterus macarellus*
K (yr⁻¹)	0.97	1.30	1.21	1.29
L_∞ (mm)	232	147	251	296
W_∞ (g)	169	46	180	341
a (in $W=aL^b$)	0.0000018	0.0000087	0.00000088	0.0000063
b (in $W=aL^b$)	3.37	3.10	3.05	3.13

Growth curves for the four major component species (Figure 6.2) suggest rapid growth rates, and relatively short lifespans of from 2 to 3 years. The sardine, *Amblygaster sirm* has the lowest growth coefficient, a correspondingly greater lifespan, and is likely to be more susceptible to overfishing (see Summary and Discussion).

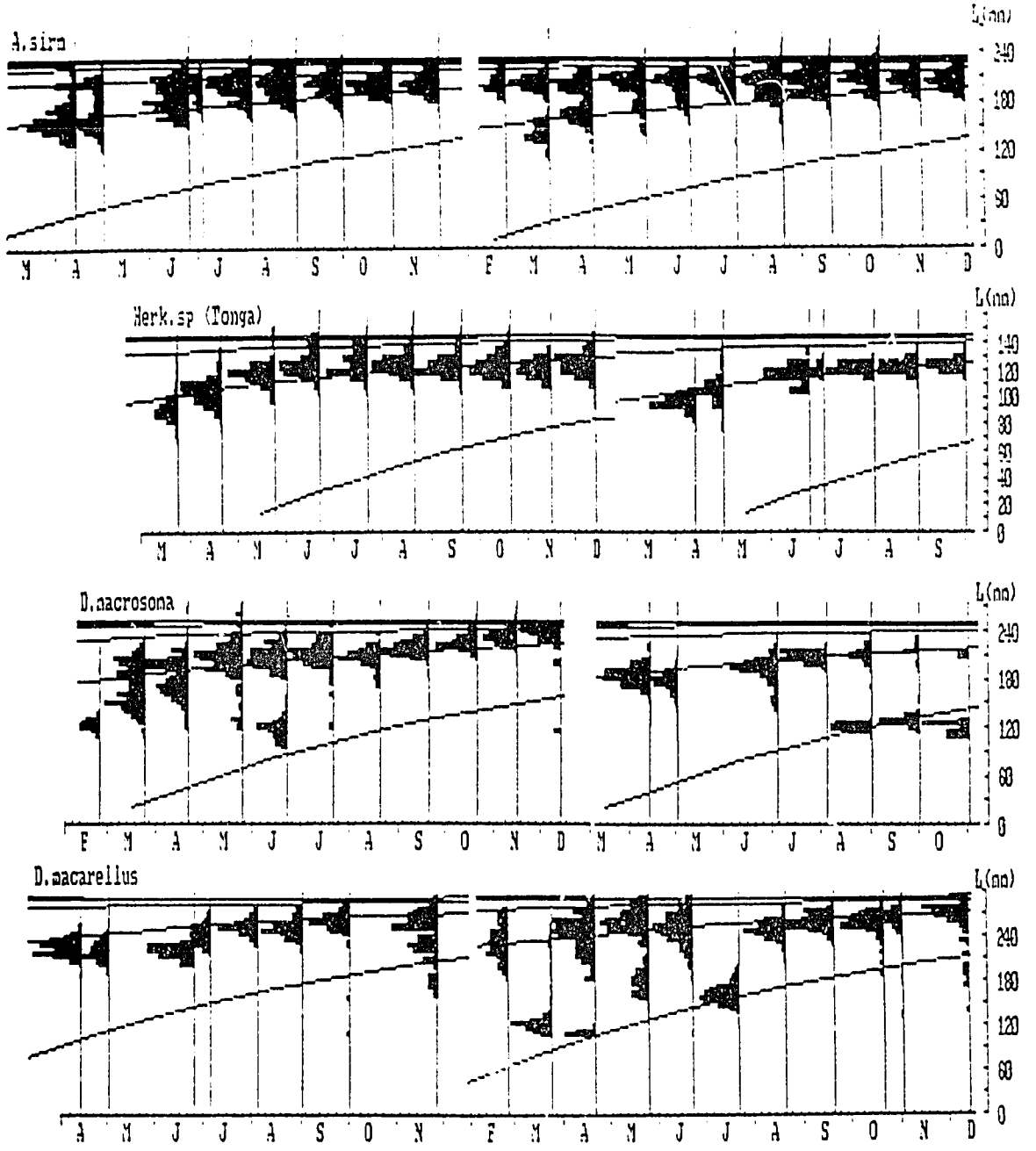

Figure 6.1: Length-frequency data for (from the top) the sardine, *Amblygaster sirm*, the herring, *Herklotsichthys*, and the scads, *Decapterus macarellus*, and *Decapterus macrosoma*, with superimposed growth curves produced by the computer program ELEFAN.

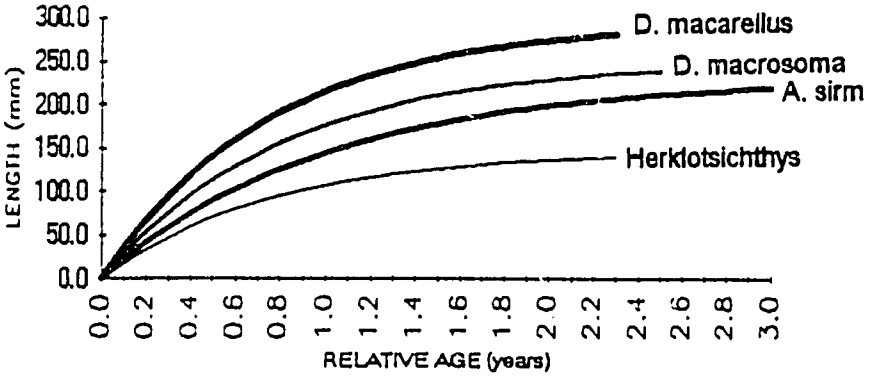

Figure 6.2: Growth curves for the four major species found in surveys in Vava'u, Tonga.

7. MORTALITY ESTIMATES

Length-frequency distributions were converted to age-frequency distributions by means of a length-converted catch-curve. A length-converted catch curve is a plot of ln(F/dt) against t, where F is the number of individuals in each age class, and t is relative age. The value dt is the time taken for the species to grow through a particular length class, and allows for the fact that as growth slows down with increasing size, older length classes contain more age classes than do younger groups. Mortality rates, Z, were estimated from the slope of the regression lines fitted through data which exclude the initial ascending data points; these represent groups of individuals which are either not fully recruited or are too small to be totally vulnerable to the fishing gear. Length-converted catch curves for the four major species are given in Figure 7.1, and instantaneous total mortality rates, estimated from the slope of the regression lines, are given in Table 7.1.

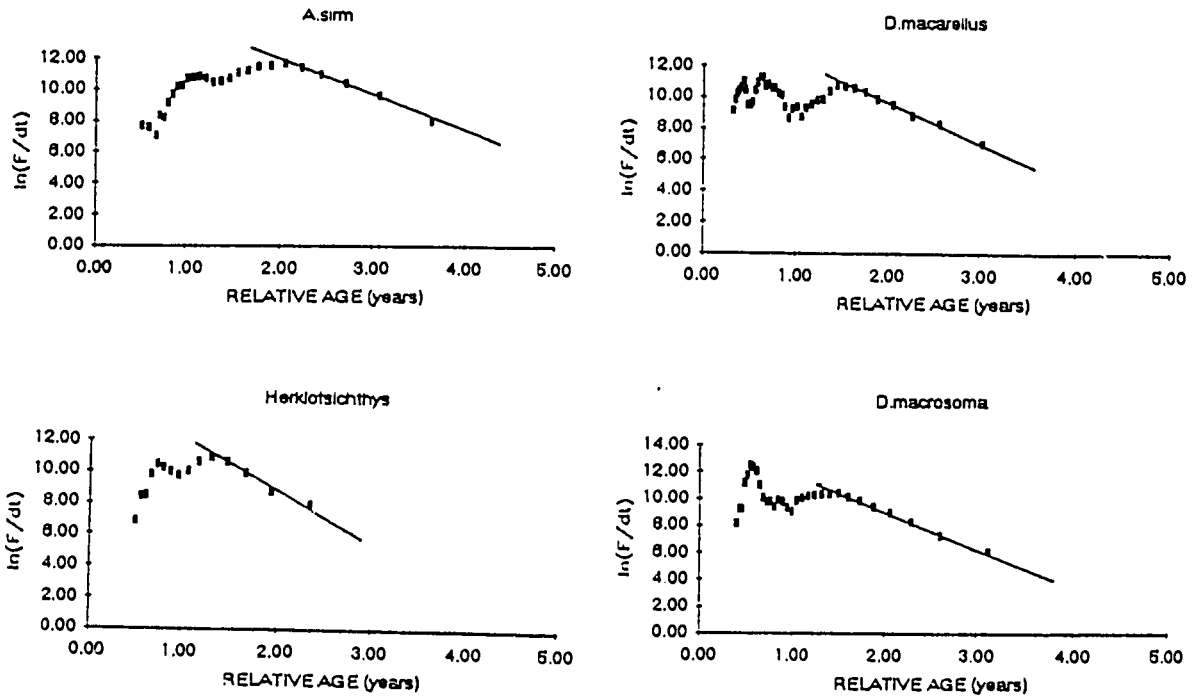

Figure 7.1: Length-converted catch curves for the sardine, *Amblygaster sirm*, the scads, *Decapterus macarellus* and *Decapterus macrosoma*, and the herring, *Herklotsichthys*.

The total mortality rates obtained in the above analyses are high (greater than 90% per year), but not uncommon in small inshore pelagic fish. It should be noted that mortality rates would have been overestimated if larger fish migrate out of the sampling area; this is unlikely to be the case for the sardine and herring, but could be so for the scads.

The natural mortality rate of a species is likely to be related to environmental factors as well as its evolved life-history pattern. Pauly (1980) analysed data from a large number of fish species in an attempt to obtain a general relationship to predict natural mortality, M, from the von

Bertalanffy growth parameters, K (per year) and L_∞ (cm), and mean annual surface temperature, T (°C);

$$\ln[M] = -0.0152 - 0.279 \ln[L_\infty] + 0.6543 \ln[K] + 0.463 \ln[T]$$

Another approximation may be obtained by considering the natural mortality rate required to reduce the numbers of fish in a cohort to close to zero over the period of its lifespan. The oldest individuals in an unexploited stock are often about 95% of their asymptotic length. If mean lifespan (t_{max}) is defined as the time required for a fish to reach 95% of its asymptotic length, L_∞, then;

$$t_{max} = (-1/K) \ln [1-(0.95L_\infty)/L_\infty] \text{ , or, approximately, } t_{max} = 3/K$$

The survival of an unexploited species over its lifespan is $N_t / N_0 = \exp[-M\, t_{max}]$, where N_0 is the initial number of fish in the cohort, and N_t is the number of fish remaining towards the end of the lifespan. If N_t is say 1% of the initial number, N_0, then;

$$1/100 = \exp[-M\, t_{max}], \text{ and,}$$

$$M = -\ln(0.01)/t_{max}, \text{ or, approximately, } M = 1.5\ (K)$$

Table 7.1 presents natural mortality rates based on the latter (more conservative) equations; rates estimated from Pauly's equation were similar for the scads, but approximately 20% higher in the sardine and the herring. Fishing mortality rates, F, were calculated as F=Z-M, and are shown in Table 7.1 with the exploitation rates (F/Z).

Table 7.1: Instantaneous mortality rates (yr^{-1}) with approximate annual percentage equivalents (in brackets) for four major baitfish species in Vava'u, Tonga.

	sardine, *Amblygaster sirm*	herring, *Herklotsichthys* species	scad, *Decapterus macrosoma*	scad, *Decapterus macarellus*
total, Z	2.4 (91%)	3.4 (97%)	2.9 (95%)	2.5 (92%)
natural, M	1.5 (78%)	2.0 (87%)	1.9 (85%)	2.0 (87%)
fishing, F	0.9 (59%)	1.4 (75%)	1.0 (63%)	0.5 (39%)
exploitation rate	38%	41%	35%	20%

8. RECRUITMENT

Recruitment into a vulnerable fish stock often takes place at particular times of the year, and when juveniles have reached a certain age or size. A simple method of examining the timing of recruitment is by plotting the number of small individuals (less than an arbitrarily chosen size) in regular samples taken from the adult stock (Figure 8.1).

Figure 8.1 suggests that small individuals appear in the catches during the early months of the year, except in the case of the scad, *Decapterus macrosoma*, in which recruitment occurs over a more extended period beginning in September (Table 9.1).

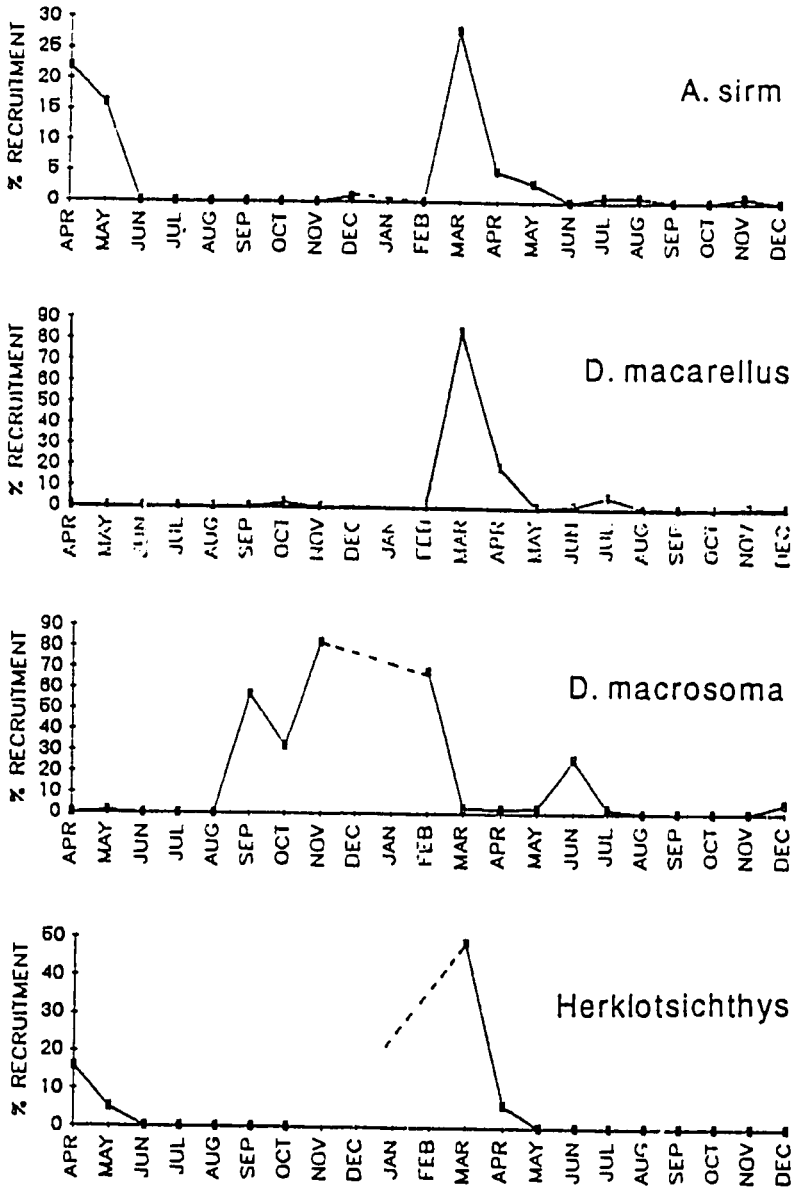

Figure 8.1: Numbers (%) of individuals in the smallest length classes for the sardine, *Amblygaster sirm* (<150 mm), the scads, *Decapterus macarellus* (<150 mm) and *Decapterus macrosoma* (<130 mm), and the herring, *Herklotsichthys* (<95 mm) for the period April 1992 to December 1993.

9. REPRODUCTION

A gonad or gonosomatic index (GI or GSI) was used to follow the reproductive cycle of species over the time. This index, which assumes that gonads increase in size with increasing development, compares the mass of the gonad (GM) with the total mass of the fish (TM);

$$GSI = 100 * (GM/TM)$$

Gonosomatic indices were only available as a conti ;us record for two species, and these are shown in Figure 9.1. Decreases in the indices sug_gest a spawning period in March for the sardine, *Amblygaster sirm*, and possibly in February, for the scad, *Decapterus macarellus* (Table 9.1).

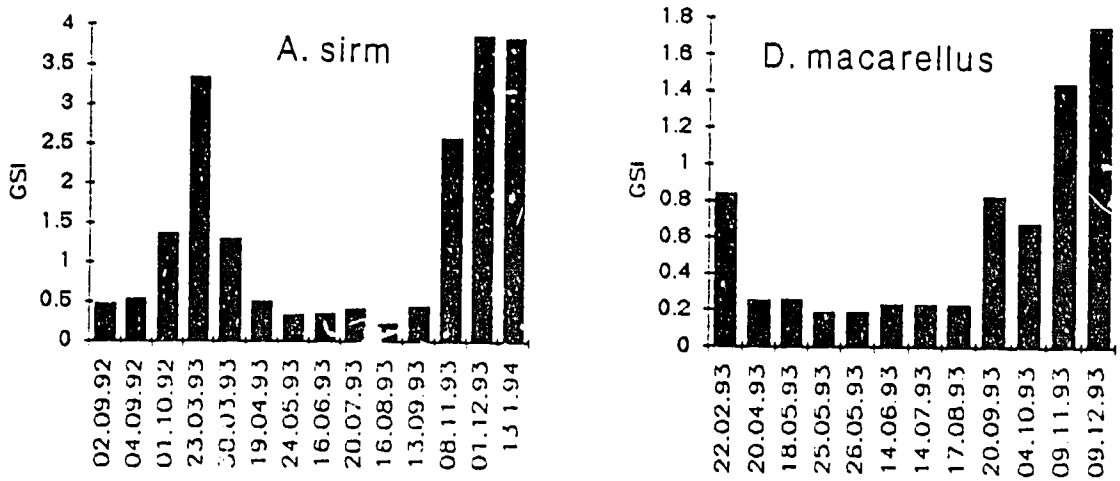

Figure 9.1: Gonosomatic indices for the sardine, *Amblygaster sirm*, and the scad, *Decapterus macarellus*.

The mean length at first reproduction, or mean length at sexual maturity (L_m), was defined as the length at which 50% of all individuals are sexually mature. As not all mature individuals were in reproductive condition at the same time, the data were multiplied by a correction factor to give the number of sexually matu individuals in each size class expressed as a proportion of the *reproductive* population. Figure 9.2 shows logistic curves fitted to the adjusted proportions, in which the mean length at sexual maturity is the length corresponding to a proportion of 0.5 (or 50%) in reproductive condition.

The mean length at first reproduction was 200 mm for the sardine, *Amblygaster sirm*, and 259 mm for the scad, *Decapterus macarellus*. These lengths are approximately 85% of the maximum attainable lengths of each fish, and suggested that the species mature relatively late in their lifespans.

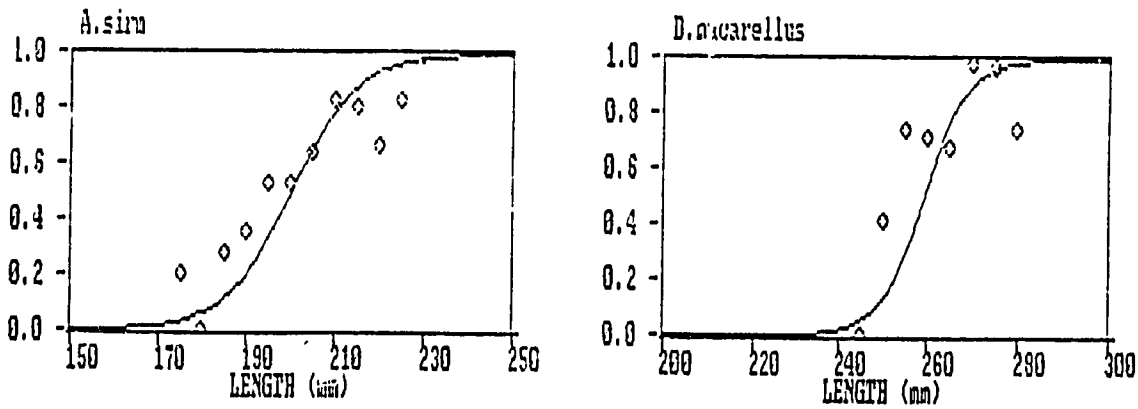

Figure 9.2: Relationships between the number of reproductive individuals (expressed as a proportion of the reproductive population) and length (mm) for the sardine, *Amblygaster sirm*, and the scad, *Decapterus macarellus*.

Table 9.1: Probable spawning and recruitment periods for the four major baitfish species in Vava'u, Tonga.

	sardine, *Amblygaster sirm*	herring, *Herklots.* species	scad, *Decapterus macrosoma*	scad, *Decapterus macarellus*
REPRODUCTION:				
spawning period	March	??	??	Feb.?
mean length (mm) at first reproduction	200	??	??	259
RECRUITMENT:				
recruitment period	Mar-May	Mar-Apr?	Sep-Feb?	Mar-Apr?

10. INTENSIVE FISHING

Intensive fishing over a short period in an isolated area provides two types of information. As long as migration in and out of the area is minimal, a plot of the reduction in CPUE against cumulative catch will provide an estimate of the stock size and, more importantly, the catchability coefficient, q. Intensive fishing was carried out at station five, and this reduced the catch per haul of all four major species dramatically over 7 fishing days (Figure 10.1).

Although the time period of intensive fishing was believed to be sufficiently short to exclude the effects of natural mortality and migration, the area of influence of the fishing lights used to attract baitfish was unknown. For this reason, the data could not be used to estimate stock size. However, the exercise did suggest that local stocks of baitfish are extremely vulnerable to intensive fishing in a small area.

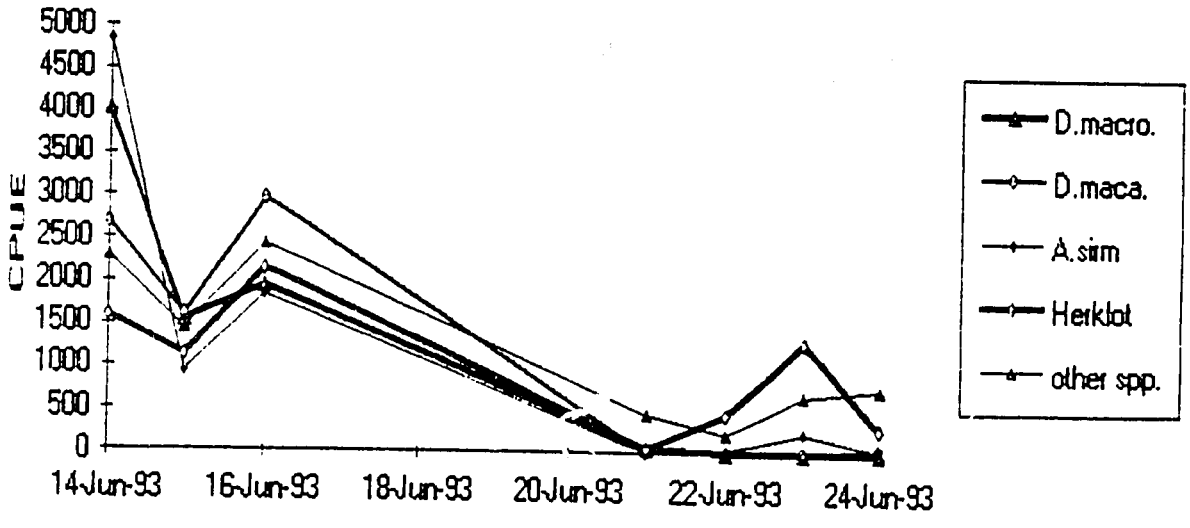

Figure 10.1: Catch per haul over a short time period (7 fishing days) at Station 5 for the sardine, *Amblygaster sirm*, the herring, *Herklotsichthys*, and the scads, *Decapterus macrosoma* and *Decapterus macarellus*.

11. YIELD

As estimates of stock size were unavailable, it was impossible to estimate sustainable catch weight or yield for the stocks. However, the availability of population parameters enabled the calculation of optimum fishing intensity from yield per recruit models.

The classical Beverton and Holt (1957) yield per recruit model considers the dependence of yield upon growth, age at first capture, and fishing mortality. It may be assumed that, after the mean age at first capture (t_c), all fish coming into contact with the fishing gear are subjected to the same fishing mortality. Natural mortality, M, is assumed to be constant after the age at recruitment, t_r, and fishing mortality, F, is constant after the age at first capture, t_c. Weight is predicted by the von Bertalanffy equation (Section 6). The expression for yield per recruit is;

$$Y/R = \{ F.\exp[-M(t_c-t_r)]\}.W_\infty \sum_{n=0}^{3} \{U_n/(Z+nK)\} \{\exp[-nK(t_c-t_0)]\} \{1-\exp[-(Z+nK)(t_{max}-t_c)]\}$$

... where U represents the summation constant in the cubic expansion of the growth equation, and n is the number of summations (U_0= 1, U_1= -3, U_2= 3, and U_3= -1); other symbols are as defined previously. A computer spread sheet program (YPR) based on the above model was written to incorporate data for the four major baitfish species, and yield per recruit curves generated by the program are shown in Figure 11.1.

As mortality rates of the species were high, the yield curves did not reach a maximum (at a fishing mortality of F_{msy}) within a reasonable range of fishing mortality values (Figure 11.1). In such species, the optimum fishing mortality is often taken to be the value at which an increase in one unit of F increases the catch by one tenth (0.1) of the amount caught by the first unit of F (Gulland, 1983); in other terms, the optimum level of F, known as $F_{(0.1)}$, occurs at the point where the slope of the yield curve is 0.1 of the value of the slope at low levels of fishing mortality. Many fisheries managers are basing the total allowable fishing effort on $F_{(0.1)}$, as this is believed to be a more robust and conservative replacement for F_{msy}.

The yield per recruit analyses suggest that baitfish resources are limited, and the survey vessel alone imposed a fishing mortality of between 29% and 56% (depending on species - see Table 11.1) of that required to obtain the maximum sustainable yield.

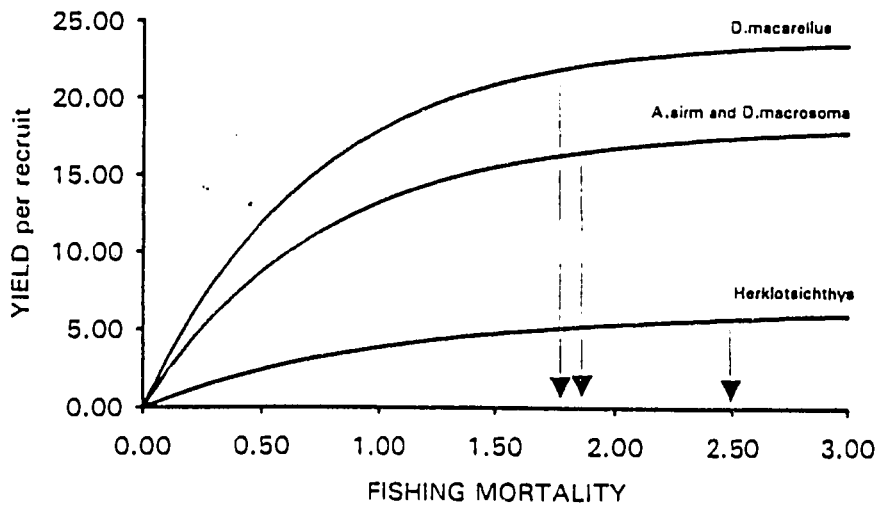

Figure 11.1: Yield per recruit curves for the scad, *Decapterus macarellus* (top curve), the sardine, *Amblygaster sirm*, and the scad, *Decapterus macrosoma* (middle curve), and the herring, *Herklotsichthys* (bottom curve). Vertical arrows show the optimum fishing mortality ($F_{0.1}$) for each species.

Table 11.1: Summary of yield per recruit analyses.

	sardine, *Amblygaster sirm*	herring, *Herklots.* species	scad, *Decapterus macrosoma*	scad, *Decapterus macarellus*
optimum fishing mortality	1.8	2.5	1.8	1.7
present fishing mortality	0.9	1.4	1.0	0.5
% of optimum	50%	56%	56%	29%

One of the simplest ways of considering the size or age at which a resource species should be harvested is by calculating the opposing effects of growth and mortality on a single cohort of fish. After recruitment, the weight of each individual is increasing through growth, and the number of individuals in the cohort is decreasing through mortality. The total weight or biomass of the cohort will therefore increase over time and reach a maximum before decreasing as the growth rate becomes less.

As the strength of recruitment was not known, the relative biomass per 1000 recruits was calculated for each species (Figure 11.2). Biomass reached a maximum at ages between 0.8 and 1.0 years for each species except in the case of the sardine, which reached a maximum at 1.3 years. This suggests that fisheries regulations designed to delay the age of first capture (e.g. using larger mesh nets) would be ineffective in increasing catch weights.

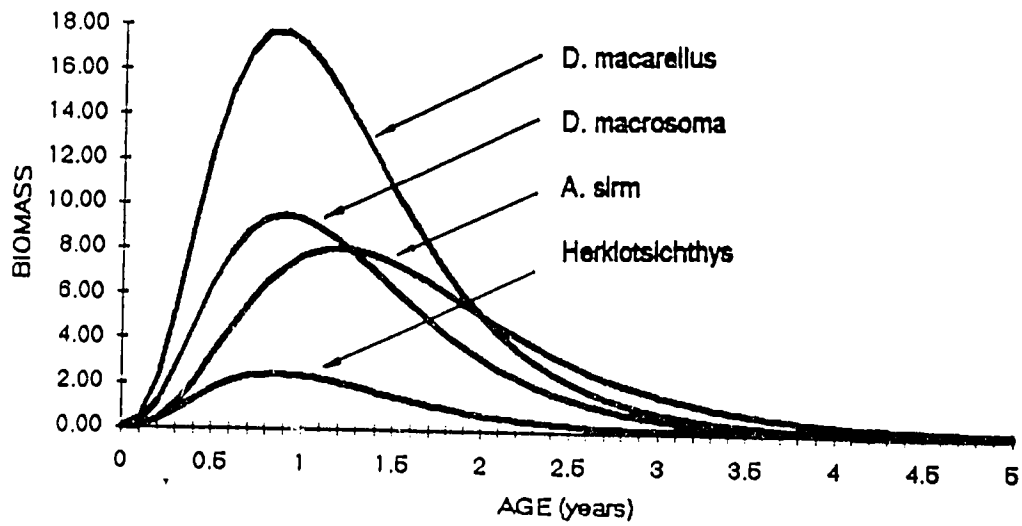

Figure 11.2: Relative biomass curves (stock weight per 1000 recruits) for the scads, *Decapterus macarellus*, and *Decapterus macrosoma*, the sardine, *Amblygaster sirm*, and the herring, *Herklotsichthys*.

12. FINANCIAL ANALYSIS

The economic viability of a commercial operation may be viewed from the possible effects of sustainable catch rates and product price on a vessel's net return. The following is based on financial information collected during the present survey, and extrapolated to a commercial operation. The preliminary estimated costs of fishing using a 12 m purse seine vessel (similar to the survey vessel), a 9 m dip-net vessel, and a 5-7 m dipnet/handline skiff are shown in Table 12.1.

The initial investment includes the fully equipped vessel and fishing gear. Fixed costs, including loan repayments, depreciation, repairs, maintenance, and insurance, are those which

are associated with the vessel, and are incurred whether or not the vessel goes fishing. Depreciation allows for eventual vessel replacement. Running costs are those associated with the fishing operation, and include crew payments, fishing gear replacement, fuel, food, and ice.

Table 12.1: Preliminary estimated costs (TS) of a proposed commercial baitfish operation in Vava'u, Tonga, using either a 12 m purse seine vessel, 9 m dip-net vessel, or a 5-7 m dip-net/handline skiff.

	LARGE VESSEL	SMALL VESSEL	SKIFF
VESSEL LENGTH (m)	12	9	5-7
NUMBER OF CREW	7	4	2
DAYS WORKED PER YEAR	120	120	120
INITIAL INVESTMENT:			
vessel cost	100 000	40 000	6000
fishing gear	20 000	3 000	2000
total investment	120 000	43 000	8000
FIXED COSTS (per year)			
loan repayments (10%)	12 000	4 300	800
depreciation (10%)	12 000	4 300	800
vessel repairs (10%)	12 000	4 300	800
insurance (6%)	7 200	2 580	480
total fixed costs (per year)	43 200	15 480	2880
RUNNING COSTS (per day):			
crew payments	350	200	100
fishing gear repair	25	10	8
fuel	50	20	10
food	30	18	9
ice	25	20	10
total running costs (per day)	480	268	137
total running costs (per year)	57 600	32 160	16 440
TOTAL ANNUAL COSTS	152 400	47 640	19 320

If catch-per-unit effort is in terms of catch per day, the annual returns from a fishing operation will be:

PRICE * CPUE * DAYS FISHED

The cost of fishing is the sum of the daily running costs (RC) and the annual fixed costs (FC), i.e.;

(RC * DAYS FISHED) + FC

At the "break-even" point, where returns to fishermen just balance the total cost of fishing (where no profits are made), the above equations will be equal; i.e.;

PRICE * CPUE * DAYS FISHED = (RC * DAYS FISHED) + FC

This equation can be manipulated to give the market price required to just cover the cost of fishing as a function of catch per unit effort; i.e;

PRICE = [(RC * DAYS FISHED) + FC] / [CPUE * DAYS FISHED]

The break-even curve relating the cost-recovery price to catch per unit effort in a proposed baitfish fishery in Vava'u is shown in Figure 12.1. The area above the curve represents the profit zone, and the area below the curve represents the loss zone. For a given fish price level, the graph may be used to indicate the long-term average catch per unit effort required to cover fishing costs. As fish prices are around T$2 per kg, the graph suggests that a long-term catch per unit effort of 100 kg per night must be maintained to cover costs in the case of the 5-7m vessel, 220 kg per night in the case of the 9m vessel, and 530 kg per night in the case of the 12m vessel.

There are, however, some caveats required when relating catch rates obtained during fishery surveys to those expected in subsequent commercial operations. Commercial catch rates may be initially higher than those obtained during surveys, as fishers can target the areas where densities of the target species have been found to be high. On the other hand, in a fully exploited fishery, catch rates are likely to be about one half of those originally obtained when fishing the virgin stock.

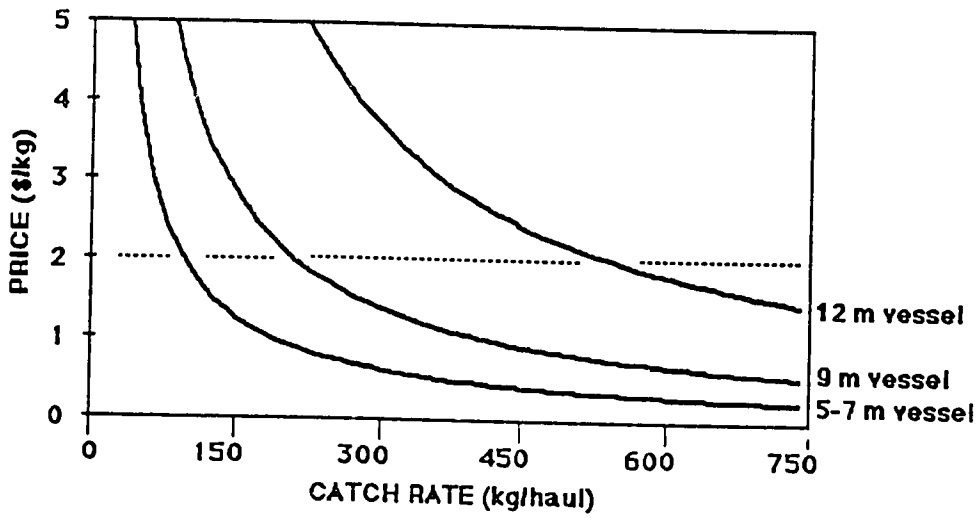

Figure 12.1: Breakeven curves for proposed baitfish operations in Vava'u, Tonga, using a 12 m vessel, a 9m vessel, and a 5-7 m vessel. Curves are based on a static analysis of the vessel's costs without a consideration of the timing of returns.

13. SUMMARY and DISCUSSION

Historically, the main objective of fisheries management has been the conservation of fish stocks. In modern fisheries management this limited aim has been extended to address additional economic, social and environmental objectives such as fishers' welfare, economic efficiency, the allocation of resources, and environmental protection. The broad objectives of fisheries management may, therefore, include the conservation of fisheries resources and their environment, the maximisation of economic returns from the fishery, and payment of fees to the community from profits made by the exploitation of a public resource. Subsuming all these objectives is the need to ensure that fisheries are exploited on an ecologically sustainable basis.

Although maximising profitability may be an appropriate objective in a commercial fishery in which most of the catch is exported, this is not necessarily true in an artisanal fishery which provides food and employment for a local community. In this case, an appropriate objective may be to ensure that as many individuals as possible have an opportunity to share the

resource, and a large number of smaller and less efficient units may be involved in the fishery. The outcome of fisheries research and stock assessment should be to provide advice to fisheries managers in the form of probable biological, economic and environmental outcomes for a range of possible management strategies. This advice should include an assessment of the risks associated with each alternative strategy, and a summary of the particular controls or regulations required to achieve the objectives.

Fishing surveys on baitfish stocks in Vava'u waters, Tonga, produced data which allowed the estimation of the biological parameters summarised in Table 13.1.

Table 13.1: Summary of biological information on the four major baitfish species caught in Vava'u, Tonga.

	sardine, *Amblygaster sirm*	herring, *Herklots.* species	scad, *Decapterus macrosoma*	scad, *Decapterus macarellus*
CONTRIBUTION TO THE CATCH:				
catch % by weight	39	4	15	27
catch % by numbers	36	17	22	16
mean kg per haul	183	20	69	125
REPRODUCTION:				
spawning period	March	??	??	Feb.??
mean length (mm) at first reproduction	200	??	??	259
RECRUITMENT:				
recruitment period	Mar-May	Mar-Apr?	Sep-Feb?	Mar-Apr?
GROWTH/SIZE:				
K (yr^{-1})	0.97	1.30	1.21	1.29
L_∞ (mm)	232	147	251	296
W_∞ (g)	169	46	180	341
mean length (mm)	197	118	175	227
maximum length (mm)	270	160	270	305
mean weight (g)	98	23	60	149
maximum weight (g)	283	60	225	374
WEIGHT to LENGTH (g/mm):				
a (in $W=aL^b$)	0.0000018	0.0000087	0.00000088	0.0000063
b (in $W=aL^b$)	3.37	3.10	3.05	3.13
MORTALITY (yr^{-1}):				
total mortality, Z	2.4	3.4	2.9	2.5
natural mortality, M	1.5	2.0	1.9	2.0
fishing mortality, F	0.9	1.4	1.0	0.5
exploitation rate	38%	41%	35%	20%
YIELD:				
optimum fishing mortality	1.8	2.5	1.8	1.7
present fishing mortality	0.9	1.4	1.0	0.5
% of optimum	50%	56%	56%	29%

Two aspects of the survey produced results which are inherently conflicting. The overall decline in catch rates of scads, and particularly the sardine, *Amblygaster sirm*, may indicate that

these stocks are being overexploited at present. Results from yield per recruit analyses, however, suggest that stocks are being exploited up to 56% of the optimum rate. The two sources of information are independent of each other, the former being based on catch and effort records, and the latter based on growth and mortality estimates from length-frequency data.

Yield per recruit estimates are believed to be based on sound estimates of growth, and on reasonable (and conservative) estimates of mortality. The possibility exists that falling catch rates, and the particularly low catch rates in 1993, were exacerbated by a strong El Nino in early 1993. El Nino is known to have a strong affect on currents, including a reversal of the South Equatorial current in the South Pacific. As the species under study have pelagic larvae, adverse currents are likely to have a drastic effect on the probabilities of larvae reaching and being recruited into local inshore areas. Two of the species, the sardine, *Amblygaster sirm*, and the scad, *Decapterus macarellus* (for which reproductive data were available) have similar spawning periods in March. The herring, *Herklotsichthys*, in which the spawning season is unknown, conversely showed a relative increase in catch rates during the same period.

Yield per recruit analyses suggest that baitfish resources are quite limited, and the survey vessel alone imposed a fishing mortality of between 29% and 56% (depending on species) of that required to obtain the maximum sustainable yield.

It is assumed that a profit-driven commercial operation would be more efficient than that of the government vessel. A vessel of a similar size, and using similar gear, to the "Albacore" therefore, would make greater catches, and is likely to impose a fishing mortality close to the optimum level. However, the same catch could be taken, and same level of fishing mortality imposed, by two or three smaller vessels using smaller gear. Smaller gear may include dip-nets such ring-net gear (as used on similar species in the Philippines) or "bouki-ami" nets, and the relative efficiency of such gear would have to be determined by trials.

The lack of infrastructure to enforce fisheries regulations in Vava'u means that any controls placed on the fishery would have to be direct and relatively easy to police. Output controls such as catch quotas would be expensive to enforce in terms of manpower. It is suggested that input controls on the amount of fishing effort are most appropriate, and the easiest control to enforce is a vessel licensing system - that is, a limited number of vessels be licensed to fish the species commercially.

Two alternative strategies arise from the above; either,

a) a large purse-seine vessel (similar in size to the "Albacore") should be licensed to take baitfish commercially, or,

b) two or more smaller vessels (using smaller fishing gear) should be licensed to take baitfish commercially.

It is suggested that strategy (b) is the better alternative - that is, that two smaller vessels (using smaller gear to be developed during trials) should be licensed initially to take baitfish commercially. A small licence fee should be imposed to amortize the cost of monitoring catch, fishing effort, and area fished. When compared with the use of a single large vessel, two smaller vessels would;

a) allow the resource to be shared between a larger number of people, and provide greater employment opportunities,

b) allow continuity of a supply of baitfish to the market (in the event of a breakdown of one of the vessels), and,

c) allow authorities to add fishing effort in smaller increments if catch and effort monitoring suggested that fishing effort could be increased.

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APPENDIX A: NS = numbers per sample

SURVEYS NH = numbers per haul = NS multiplied by (sample buckets/catch buckets)

DATE	trip no	station no	catch (kg)	buckets sample	buckets catch	D macro NS	D macro NH	D maca NS	D maca NH	A sirm NS	A sirm NH	Hark. NS	Hark. NH	other spp NS	other spp NH	total no. per haul
13-Apr-92	1	1	1473	5	19	25	3568	173	6609	22	840	4	153	8	305	17496
14-Apr-92	2	1	40	3	5	8	13	29	48	130	217	234	390	64	107	775
29-Apr-92	3	2	562	5	38	280	5488	36	706	128	2509	0	0	2	39	8742
30-Apr-92	4	2	205	5	46	14	129	132	1214	117	1076	0	0	1	9	2429
05-May-92	5	2	1950	5	302	74	4470	39	2356	272	16429	0	0	0	0	23254
08-May-92	6	1	457	4	99	14	347	0	0	300	7425	81	2005	32	792	10568
25-Jun-92	7	1	116	2	24	3	36	0	0	129	1548	7	84	38	456	2124
26-Jun-92	8	1	72	2	10	0	0	0	0	85	425	52	260	9	45	730
01-Jul-92	9	2	397	4	71	1	18	8	142	221	39[illegible]	4	71	5	89	4242
02-Jul-92	10	2	553	5	95	57	1083	78	1482	87	[illegible]	0	0	6	114	4332
06-Jul-92	11	2	459	6	65	77	834	20	217	226	[illegible]	5	54	18	195	3748
07-Jul-92	12	2	1500	10	238	101	2404	169	4022	309	[illegible]	4	95	8	190	14066
08-Jul-92	13	2	79	5	12	66	158	79	190	83	199	2	5	8	19	571
04-Aug-92	14	2	1646	7	297	48	2037	31	1315	259	10989	13	552	6	255	15147
05-Aug-92	15	2	30	3	9	3	9	0	0	94	282	14	42	189	567	900
26-Aug-92	16	2	297	5	60	40	480	2	24	251	3012	10	120	19	228	3864
29-Aug-92	17	1	723	5	145	34	986	8	232	193	5597	316	9164	14	406	16365
31-Aug-92	18	1	40	2	8	0	0	0	0	44	176	141	564	150	600	1340
02-Sep-92	19	2	419	4	117	70	2048	18	527	154	4505	12	351	2	59	7488
04-Sep-92	20	1	20	3	8	5	13	31	83	398	1061	102	272	65	173	1603
30-Sep-92	21	3	40	3	11	0	0	1	4	8	29	305	1118	254	931	2083
01-Oct-92	22	2	169	3	33	0	0	0	0	115	1276	62	682	29	319	2277
26-Oct-92	23	2	2418	5	230	11	506	0	0	337	15502	1	46	2	92	16146
18-Nov-92	24	2	365	4	52	0	0	65	845	158	[illegible]	0	0	0	0	2899
19-Nov-92	25	2	256	4	50	0	0	5	63	214	[illegible]	0	0	11	138	2875
23-Nov-92	26	6	1691	4	280	0	0	0	0	121	8470	0	0	1	70	8540
27-Nov-92	27	2	396	4	74	0	0	0	0	130	2405	0	0	0	0	2405
22-Feb-93	28	2	1910	5	255	503	25653	120	6120	22	1122	0	0	3	153	33048
24-Feb-93	29	6	90	2	16	268	2144	0	0	47	376	0	0	14	112	2632
03-Mar-93	30	1	30	1	5	0	0	0	0	34	170	234	1170	24	120	1460
23-Mar-93	31	2	234	2	31	0	0	1	16	52	806	2	31	42	651	1504
24-Mar-93	32	6	15	1	3	4	12	0	0	0	0	0	0	96	288	300
25-Mar-93	33	6	6	1	1	0	0	1	1	0	0	0	0	183	183	184
27-Mar-93	34	3	218	2	42	12	252	117	2457	136	2856	19	399	134	2814	8778
29-Mar-93	35	4	1294	4	219	179	9800	27	1478	89	4873	39	2135	26	1424	19710
31-Mar-93	36	7	55	2	11	9	50	86	473	20	110	275	1513	238	1309	3454
02-Apr-93	37	4	30	1	6	2	12	37	222	54	324	192	1152	2	12	1722
05-Apr-93	38	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Apr-93	39	2	18	1	3	0	0	1	3	3	9	118	354	64	192	558
19-Apr-93	40	1	108	2	18	0	0	0	0	115	1035	51	459	195	1755	3249
20-Apr-93	41	5	583	3	78	13	338	88	2288	1	26	3	78	18	468	3198
22-Apr-93	42	2	72	2	12	55	330	5	30	3	18	59	354	90	540	1272
27-Apr-93	43	6	132	1	17	19	323	24	408	0	0	0	0	1	17	748
28-Apr-93	44	5	454	2	57	98	2793	39	1112	0	0	2	57	3	86	4047
18-May-93	45	5	1789	4	247	7	432	105	6484	0	0	10	618	7	432	7966
19-May-93	46	2	2239	5	303	113	6848	94	5696	0	0	0	0	14	848	13393
25-May-93	47	5	574	3	82	82	2241	24	656	3	82	0	0	3	82	3061
26-May-93	48	4	422	4	97	86	2086	1	24	160	3880	49	1188	14	340	7518
27-May-93	49	6	2126	5	303	93	5636	62	3757	1	61	0	0	5	303	9757
14-Jun-93	50	5	1088	5	216	93	4018	62	2678	112	4838	37	1598	53	2290	15422
15-Jun-93	51	5	298	5	117	56	1644	69	1615	40	936	48	1123	52	1451	6669
16-Jun-93	52	5	1051	5	177	55	1947	84	2974	52	1841	61	2159	69	2443	11363
21-Jun-93	53	5	12	1	2	28	56	2	4	1	2	25	50	226	452	564
22-Jun-93	54	5	36	1	5	0	0	0	0	8	40	92	460	46	230	730
23-Jun-93	55	5	68	3	24	0	0	0	0	31	248	162	1296	84	672	2216

BEST AVAILABLE DOCUMENT

APPENDIX A (continued):

DATE	trip no	stat no	catch (kg)	buckets samp	catch	D macro NS	D macro NH	D maca NS	D maca NH	A sim NS	A sim NH	Hemi NS	Hemi NH	other spp NS	other spp NH	total no D macr
24-Jun-93	56	5	30	1	5	0	0	9	45	8	40	58	290	152	760	1135
25-Jun-93	57	2	379	4	62	29	450	82	1271	0	0	7	109	79	1225	3054
28-Jun-93	58	5	72	2	12	11	66	1	6	2	12	15	90	48	288	462
14-Jul-93	59	2	873	4	120	43	1290	95	2850	0	0	7	210	6	180	4530
20-Jul-93	60	2	431	4	56	10	140	49	686	95	1330	2	28	55	770	2954
21-Jul-93	61	5	90	2	15	1	8	0	0	46	345	201	1508	52	390	2250
23-Jul-93	62	1	2537	5	248	6	298	169	8382	25	1240	58	2877	28	1389	14186
16-Aug-93	63	2	376	5	51	29	296	22	224	197	2009	108	1102	41	418	4049
17-Aug-93	64	1	340	3	58	4	77	4	77	67	1295	278	5375	112	2165	8990
18-Aug-93	65	4	479	4	70	0	0	0	0	186	3255	158	2765	4	70	6090
19-Aug-93	66	8	24	1	3	0	0	0	0	1	3	145	435	13	39	477
20-Aug-93	67	2	245	4	36	37	333	22	198	125	1125	93	837	22	198	2691
23-Aug-93	68	5	216	3	34	0	0	0	0	125	1417	148	1677	5	57	3151
10-Sep-93	69	1	545	5	97	41	795	46	892	121	2347	236	4578	170	3298	11912
13-Sep-93	70	5	216	4	35	0	0	1	9	221	1934	42	368	26	228	2538
14-Sep-93	71	2	557	4	84	77	1617	16	336	148	3108	142	2982	8	168	8211
16-Sep-93	72	1	448	5	74	16	237	0	0	114	1687	656	9709	20	296	11929
17-Sep-93	73	2	168	4	36	70	630	5	45	81	729	48	432	10	90	1926
20-Sep-93	74	6	213	3	42	39	546	49	686	25	350	3	42	6	84	1708
21-Sep-93	75	2	30	1	6	0	0	1	6	28	168	38	228	23	138	540
22-Sep-93	76	4	589	5	104	0	0	0	0	272	5658	17	354	1	21	6032
11-Oct-93	77	5	99	2	17	3	26	2	17	46	391	89	757	41	349	1539
12-Oct-93	78	2	194	2	19	0	0	0	0	10	95	48	456	19	181	732
14-Oct-93	79	6	610	4	92	41	943	35	805	114	2622	26	598	19	437	5405
15-Oct-93	80	6	193	3	46	51	782	20	307	84	1288	2	31	15	230	2637
18-Oct-93	81	9	79	2	11	0	0	0	0	14	77	502	2761	69	380	3218
21-Oct-93	82	1	24	1	4	1	4	0	0	27	108	34	136	101	404	652
08-Nov-93	83	6	104	2	19	0	0	1	10	74	703	197	1872	78	741	3325
09-Nov-93	84	2	103	3	18	0	0	28	168	19	114	44	264	81	486	1032
10-Nov-93	85	2	260	2	26	8	104	12	156	20	260	202	2626	17	221	3367
15-Nov-93	86	5	437	3	61	43	874	0	0	133	2704	0	0	1	20	3599
16-Nov-93	87	2	320	4	52	40	520	41	533	48	624	38	494	34	442	2613
17-Nov-93	88	2	600	5	96	11	211	69	1325	149	2861	40	768	12	230	5395
18-Nov-93	89	1	146	3	39	1	13	0	0	125	1625	95	1235	3	39	2912
19-Nov-93	90	2	126	2	23	9	104	13	150	61	702	18	207	25	288	1449
06-Dec-93	91	2	55	2	13	0	0	0	0	120	780	92	598	6	39	1417
07-Dec-93	92	5	180	3	31	3	31	16	165	132	1364	1	10	8	83	1653
09-Dec-93	93	5	505	5	92	18	331	64	1178	156	2870	16	294	30	552	5226
13-Jan-94	94	2	33	2	5	0	0	0	0	161	403	6	15	26	65	483

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APPENDIX B - Length-frequency data; Decapterus macarellus

L (mm)	13-Apr	1-May	25-Jun	4-Jul	4-Aug	1-Sep	1-Oct	26-Nov	24-Feb	24-Mar	20-Apr	24-May	22-Jun	22-Jul	20-Aug	20-Sep	20-Oct	15-Nov	13-Dec	total
100										1	7		2							10
105										8	11									19
110							1			16	11		1							29
115										26	7									33
120										36	1									37
125										54				1						55
130										30		1		1						32
135										12								2		14
140										6		1		4					1	12
145										1				13						14
150										2				29						31
155										1		2		49						52
160							1			3		11		54						69
165								1				18		48						67
170										1		2		41						44
175								2		3		11		31					2	49
180								2				18		13				1	1	35
185								2	1	1	4	18	2	11				2	1	42
190	1							2	1		2	14		9			1		2	32
195		3							3	2	2	13	1	6				1	2	33
200		3		2				1	5		2	5	4	3					2	27
205	2	11	3					1	5	2	2	1	5				1			33
210	11	15	3					3	4		5	6	4		1					52
215	25	32	7						6	2	7	4	8		1				2	94
220	41	23	2	4				1	11		7	1	6		1		1			98
225	24	22	9	23		1		5	9	3	7	2	12		2			1		120
230	36	19	9	41	1	1	1	6	9	5	6	8	7			1	1		1	152
235	31	18	3	48		2	1	3	10	1	7	11	13		5	2		1	3	159
240	16	10	1	46	2	5		4	9	4	7	7	24		11	4	2	1		153
245	10	7	1	57	4	6	2	1	3	2	13	21	30		16	6	1	9	2	196
250	2	3		37	4	11	5		9	2	15	42	35		21	13	5	10	1	215
255	3		1	39	8	8	6	9	4	2	14	43	37		14	23	12	14	3	240
260		1		23	5	7	11	4	5		14	49	25		9	20	10	30	7	220
265		1		15	3	2	8	6	2		15	45	19		11	16	4	25	5	177
270				10	2	3	7	6	5		5	29	25		2	13	7	26	11	151
275				7	1	2	2	5	1		8	27	14		2	15	5	12	12	113
280				1	1	2	3	4	3		4	17	8		2	4		16	15	80
285				1			2	2			3	19	13			2	1	5	3	51
290								1			3	8	7				2	6	4	31
295								1	1	1	1	11	6					2		23
300											1	5								6
305												1					1			2
sample size	202	168	39	354	31	50	50	72	111	227	191	471	308	313	98	119	54	164	80	3102

APPENDIX C - Length-frequency data; Decapterus macrosoma

L (mm)	13-Apr	1-May	25-Jun	4-Jul	4-Aug	1-Sep	1-Oct	1-Nov	23-Feb	24-Mar	20-Apr	24-May	22-Jun	22-Jul	20-Aug	20-Sep	20-Oct	15-Nov	13-Dec	total
95													4							4
100									3				7							10
105									5				4							9
110		1				1		2	49	1			8							62
115						11	2	2	91	2			11						1	120
120		1				16	6	1	203		2	3	17	1						250
125	1	1				14	16	4	178	4	2	3	8							231
130						1	20	1	138	5	2	6	5							178
135							8		45	8	2	1	3							67
140		2		2			2		13	11	1	1	1							33
145		3		5					4	13	4	2	1							33
150		7		9					1	21	6	1	1							46
155	2	12		10			1		3	10	9		1			1				49
160	3	26		6					5	15	13	3		1						72
165	10	25		6					5	9	15	4								74
170	28	39		4		1			1	4	17	3			2					99
175	29	75		13						9	12			1	2					141
180	45	87		15					3	14	10	7	4		3	1				189
185	44	48		23					5	15	7	9	10	1	2	3				167
190	43	29		47	1	1	1		7	8	12	20	9		2	1				181
195	20	13		57	2		1		6	10	22	12	20	5	4	1				173
200	19	9	1	42	7	3	2		4	14	22	16	23	7	8	4		1	1	183
205	9	2	1	29	14	4	1		1	17	11	23	11	9	16	23	1			172
210	1	1	1	11	12	9	1	1	2	7	4	26	21	9	13	45	5	1		170
215				12	14	6	8			5	9	14	21	10	9	54	13	2		177
220	4			6	1	3	3			3	2	14	9	5	6	42	30	13	1	142
225	1			1		3	1		1	1	1	8	13	3	1	34	18	18	3	107
230				2		1	2		1		1	7	5	4		21	15	26	3	88
235												6	4	3	2	8	5	22	4	54
240									1		1	2	2			5	7	8	5	31
245												3		1				10	2	16
250												2					1	7	1	11
255												1					1	2		4
260												4						1		5
265											1	1						1		3
270												1								1
sample size	259	381	3	301	51	74	75	11	775	206	188	203	223	60	70	243	96	112	21	3352

APPENDIX D- Length-frequency data; Herklotsichthys.sp.

L (mm)	13-Apr	1-May	25-Jun	4-Jul	4-Aug	1-Sep	1-Oct	23-Mar	20-Apr	24-May	22-Jun	22-Jul	20-Aug	20-Sep	20-Oct	15-Nov	13-Dec	total
70								2										2
75								10										10
80	1	2						11	1									15
85	10	1						46	2									59
90	26	1						91	9									127
95	110	10						72	23								1	216
100	72	10						47	36	2	1						1	169
105	18	23	8			2		16	49	2	5	2	2	4		2	1	134
110		16	4			12	1	10	52	6	14	3	9	7	11	24	4	173
115		7	18	2	3	64	19	6	19	13	40	14	32	43	36	59	11	386
120		2	18	8	13	206	112	5	5	20	74	30	53	90	50	77	17	780
125		3	9	3	10	197	161	2	6	11	82	14	88	67	44	70	17	784
130		3		1	1	79	59	4	3	2	41	19	68	48	30	40	20	418
135		2	2			17	13	2	3		24	11	23	15	19	12	7	150
140		1				3	2		1	1	28	12	13	13	9	3	5	91
145						1		1		1	20	2	7	5	4	1	2	44
150										1	2	1	6	3	2			15
155											1		1	1				3
160													1	1				2
sample size	237	81	59	14	27	581	[illegible]67	325	209	59	332	108	303	297	205	288	[illegible]	3578

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APPENDIX E - Length-frequency data; Amblygaster sirm

L (mm)	13 Apr	1 May	25 Jun	4 Jul	4 Aug	1 Sep	1 Oct	1 Nov	1 Dec	24 Feb	24 Mar	20 Apr	24 May	22 Jun	22 Jul	20 Aug	20 Sep	20 Oct	15 Nov	13 Dec	total
90									2												2
95																					0
100									2										1		3
105																					0
110											2								1		3
115									1		6										7
120		1									5	1							1		8
125		11							1		4								2		18
130	5	7									19	2		1	1	2					37
135	7	19	1								29					2					58
140	7	32									21	1	2			2					65
145	14	59									18	4	3			2					100
150	20	70	2	1							14	7	4			2					120
155	15	77	8	3		1					19	12		2		8	2		1		148
160	18	64	16	11	3	3	3				6	11	4	1		2	2				144
165	8	46	11	14	7	11	7				3	16	4	6		8	7				148
170	13	23	18	40	9	27	11		4		2	13	8	13		8	16	1			206
175	9	32	17	49	17	53	21	1	3			7	7	14		29	17	3	1		280
180	6	25	23	70	27	59	29	12	29	1	6	5	7	15	6	44	52	8	8	7	439
185	3	28	13	47	17	86	37	43	40	6	8	5	5	15	7	62	118	19	30	24	613
190	4	26	8	53	34	102	59	55	71	6	20	13	6	15	10	56	122	33	57	47	797
195	3	36	16	88	37	99	53	68	77	14	33	17	15	18	12	61	79	17	62	52	857
200	9	79	16	122	49	126	84	78	92	10	46	17	18	25	16	79	116	29	97	67	1175
205	5	67	11	135	40	129	77	81	86	11	45	20	19	40	20	85	109	49	107	74	1210
210	2	59	19	123	47	116	65	47	61	10	33	10	25	36	22	82	125	39	95	57	1073
215	1	29	11	94	30	97	49	38	58	3	15	5	19	25	15	66	104	42	77	46	824
220	3	11	9	39	23	81	36	21	44	7	8	8	8	21	17	35	82	30	41	26	550
225		11	3	26	3	24	12	7	16		3	1	6	6	5	32	26	12	31	6	230
230		4	5	6	5	15	5	2	9	1	4	1	2	2	2	18	13	6	10	7	117
235			2	3	4	5	4		5				1		1	7	11	8	3		54
240				1		3	1		1				1		2	5	7	5	1		27
245			1		1	1										4	2	2			11
250									1							1	5	1			8
255									1									2			3
260									1		1										2
265											1										1
270																		1			1
ample size	152	816	210	925	353	1038	553	453	605	69	371	176	164	255	136	702	1015	307	626	413	9339