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ASSESSEMENT OF BAITFISH RESOURCES IN VAVA'U, TONGA

Pacific Islands Marine Resource Project
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1.0 EXECUTIVE SUMMARY

This report presents analyses and a summary of results from baitfish surveys in Vava'u, Tonga during 1992, and is based on data collected by Viliami Langi, RDA, Tonga, and Siola'a Malimali, Ministry of Fisheries, Tonga, under the direction of Dr. Stanley Swerdloff, RDA Project Leader, Tonga. Additional information on financial aspects is contained in a student report submitted by Pita Hurrell, a Tongan fisheries student whose project work has been supported by RDA.

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The report includes methodological details in the interests of providing instruction to local fisheries staff; the interim results contained in this report, however, are subject to revision after a more complete data set is available. Analyses contained in this report were produced by computer spreadsheets and programs written and copied for use on RDA and Ministry of Fisheries computers in Tonga.
Fishing surveys using the government research vessel began in April, 1992, and 23 fishing trips were completed in the nine month period up to January, 1993. Length frequency and catch and effort data have been collected over this period, and reproductive studies began more recently due to delays in obtaining equipment.

Although catches varied greatly, the mean catch rate over the nine month period was 570 kg per night (with a maximum of over 2 tons per night), and returns on sales were approximately T$2.00 per kg. Four species accounted for 97% of the total catch, including the spotted sardine, *Amblygaster sirm,* the scads, *Decapterus macrosoma* and a herring, *Herklotsichthys* sp. Initial analyses suggest that length frequency data will yield reliable results. Growth rates of the scads and the herring are high, suggesting lifespans of less than three years. The spotted sardine has a lower growth rate, and is therefore likely to be more susceptible to overfishing. Small individuals appear to be recruited into the vulnerable stock at different times of the year for each of the four main species. This has particular implications in the development of a fishery. For each of the component species, catch rates are likely to be high after recruitment, and decrease over succeeding months; in the case of multi-species stocks, decreasing catch rates in one species may be compensated for by increasing catch rates in other species.

Progress in three research areas is disappointing; these areas are;

a) The collection of catch-per-unit-effort data over a 28 day period to determine the lunar vulnerability of component species,

b) Running depletion experiments in "isolated" areas in an attempt to estimate stock sizes, and

c) Fishing over a wider geographic area to determine the distribution of the component species.

At present, crew members have little incentive to go fishing at the period of the full moon (when catch rates are believed to be low), and to commit themselves to the considerable physical effort involved in fishing over a sustained period; a depletion experiment is likely to require fishing over at least 10 consecutive working days (excluding the weekend which is sacrosanct under local custom).

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2.0 INTRODUCTION

A previous report (RDA P-50 92/04) provided recommendations for the establishment of a program of research and field investigations to assess the baitfish resources of Vava'u, Tonga, and ultimately 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 in the vicinity of Nieafu, Vava'u. An anchored dinghy fitted with lights was used to attract baitfish during the hours of darkness, and a purse seine net set from the research vessel used to surround and catch the schooling baitfish.

3.0 CATCH COMPOSITION

The composition of species in the total catch was estimated from a count of individuals of different species in a sample of 2 to 10 buckets taken from each catch. 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 (Table 1).

Four species accounted for approximately 97% of the total catch by numbers over the seven month period from April to October, 1992. The most common species in the catch was the spotted sardine, *Amblygaster sirm*, (68.9%), followed by the scads, *Decapterus Macarellus*, (8.0%), and the herring, *Herklotsichthys* sp. (6.7%).

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Table 1: Estimated catch composition by numbers of the scads, *Decapterus macrosoma* and *Decapterus macarellus*, the spotted sardine, *Amblygaster sirm*, and the herring, *Herklotsichthys sp.* Catches of minor component species are grouped as "others".

	D.macro	*D.macar*	*A.sirm*	*Herkl*	*others*	TOTAL
3/4/92(week 14.7) - buckets in sample = 5; buckets in catch = 191	9588	6609	840	153	306	17496
14/4/92 (week 14.9) - buckets in sample; buckets in catch = 5	13	48	217	390	107	775
29/4/92 (week 17.0) - buckets in sample = 5; buckets in catch = 98	5488	706	2509	0	39	8742
30/4/92 (week 17.1) - buckets in sample = 5; buckets in catch = 46	129	1214	1076	0	9	2429
5/5/92 (week 17.9) - buckets in sample = 5; buckets in catch = 302	4470	2356	16249	0	0	23254
8/5/92 (week 18.3) - buckets in sample = 4; buckets in catch = 99	347	0	7425	2005	792	10568
25/6/92 (week 25.1) - buckets in sample = 2; buckets in catch = 24	36	0	1548	84	456	2124
26/6/92 (week 25.3) - buckets in sample = 2; buckets in catch = 10	0	0	425	260	45	730
1/7/92 (week 26.0) - buckets in sample = 4; buckets in catch = 71	18	142	3923	71	89	4242
2/7/92 (week 26.1) - buckets in sample = 5; buckets in catch = 95	1083	1482	1653	0	114	4332
6/7/92 (week 26.7) - buckets in sample = 6; buckets in catch = 65	834	217	2448	54	195	3748
7/7/92 (week 26.9) - buckets in sample = 10; buckets in catch = 238	2404	4022	7354	95	190	14066
8/7/92 (week 27.0) - buckets in sample = 5; buckets in catch = 12	158	190	199	5	19	571
4/8/92 (week 30.9) - buckets in sample = 7; buckets in catch = 297	2037	1315	10989	552	255	15147
5/8/92 (week 31.0) - buckets in sample = 3; buckets in catch = 9	9	0	282	42	567	900
26/8/92 (week 34.0) - buckets in sample = 5; buckets in catch = 60	480	24	3012	120	228	3864
29/8/92 (week 34.4) - buckets in sample = 5; buckets in catch = 145	986	232	5597	9164	406	16385
31/8/92 (week 34.7) - buckets in sample = 2; buckets in catch = 8	0	0	176	564	600	1340
2/9/92 (week 35.0) - buckets in sample = 4; buckets in catch = 117	2048	527	4505	351	59	7488
4/9/92 (week 35.3) - buckets in sample = 3; buckets in catch = 8	13	83	1061	272	173	1603
30/9/92 (week 39.0) - buckets in sample = 3; buckets in catch = 11	0	4	29	1118	931	2083
1/10/92 (week 39.1) - buckets in sample = 3; buckets in catch = 33	0	0	1276	682	319	2277
26/10/92 (week 42.7) - buckets in sample = 5; buckets in catch = 1380	3036	0	93012	276	552	96876
TOTAL(%)	13.8	8.0	68.9	6.7	2.6	100

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4.0 LENGTH FREQUENCY DATA

The length frequency appear to be of high quality, and the sample sizes are adequate; an example set of length frequency data for the sardine, *Amblygaster sirm*, is show in Table 2.

Table 2: Length frequency data (%) by date for the sardine, *Amblygaster sirm*

LENGTH (mm)	13 Apr	29 Apr	25 Jun	4 Jul	4 Aug	31 Aug	30 Sep	26 Oct
<125		0.2	1.9	0.1				
125		1.3						
130	3.3	0.9						
135	4.6	2.3	0.5					
140	4.6	3.9						
145	9.2	7.2						
150	13.2	8.6	0.9	0.1				
155	9.9	9.4	3.7	0.3		0.1		
160	11.8	7.8	7.5	1.2	0.8	0.3		
165	5.3	5.6	5.1	1.5	2.0	1.0		
170	8.6	2.8	8.4	4.3	2.5	2.8		
175	5.9	3.9	7.9	5.3	4.8	5.0		0.3
180	3.9	3.1	10.7	7.6	7.6	5.6	3.2	2.7
185	2.0	3.4	6.1	5.1	4.8	8.2	8.1	9.8
190	2.6	3.2	3.7	5.7	9.6	9.7	8.1	13.4
195	2.0	4.4	7.5	9.5	10.5	9.4	17.7	13.9
200	5.9	9.7	7.5	13.2	13.9	12.0	18.5	16.3
205	3.3	8.2	5.1	14.6	11.3	12.3	17.7	17.8
210	1.3	7.2	8.9	13.3	13.3	12.0	5.6	11.9
215	0.7	3.5	5.1	10.2	8.5	9.2	8.1	8.6
220	2.0	1.3	4.2	4.2	6.5	7.7	4.8	4.7
225		1.3	1.4	2.8	0.8	2.3	4.0	0.6
230		0.5	2.3	0.6	1.4	1.4	3.2	
235			0.9	0.3	1.1	0.5		
240				0.1		0.3	0.8	
245	0.5	0.5			0.3	0.1		
>245	0.1							

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5.0 INITIAL GROWTH ESTIMATES

The surveys have produced a series of length frequency data over time for each species (as the example in Table 2). Peaks (or modes) may be traces over time,and the increase in length used to estimate growth by modal progression analysis. It is recommended that a von Bertalanffy plot be used to estimate growth for all four major species, and the methodology is given below.

The von Bertalanffy growth equation may be manipulated to give;

$$\ln[1-L_t/L_\infty] = -Kt_0 + Kt$$

This equation is of a linear form and suggests that the left-hand side of the equation may be plotted against age, t. In this plot, K (the growth coefficient) is estimated by the slope of the line.

The method requires that the relative ages of the modal groups are known, and that an estimate L_∞ (the maximum or asymptotic length) is available. Several techniques are available for estimating L_∞ (including a Wetherall plot), but the simple expedient of approximating L_∞ as the mean of the 10 largest individuals found in samples obtained over the entire year would suffice. An example is given using length frequency data from the sardine, *Amblygaster sirm*, in which L_∞ = 249.3 mm. The relative ages of the modal groups are estimated as the number of weeks after a "birth-date" (which may be based on a spawning peak when reproductive studies are complete); at present the "week of the year" was used as relative age, in which case t_0 in the growth equation cannot be estimated.

A von Bertalanffy plot of $\ln[1-L_t/L_\infty]$ against the age, t, is shown in Figure 1. The straight line has a slope of 0.020, and therefore the growth coefficient K = 0.02 wk^{-1} or approximately 1.04 yr^{-1}. Similar analyses were carried out for the four major species, and the results are summarized in Table 3 and Figure 2.

Figure 2 shows that three of the major component species grow at a fast rate and have possible lifespans of less than 3 years. The sardine, *Amblygaster sirm* has a growth coefficient of approximately one half of the others, a correspondingly greater lifespan, and is likely to be more susceptible to overfishing.

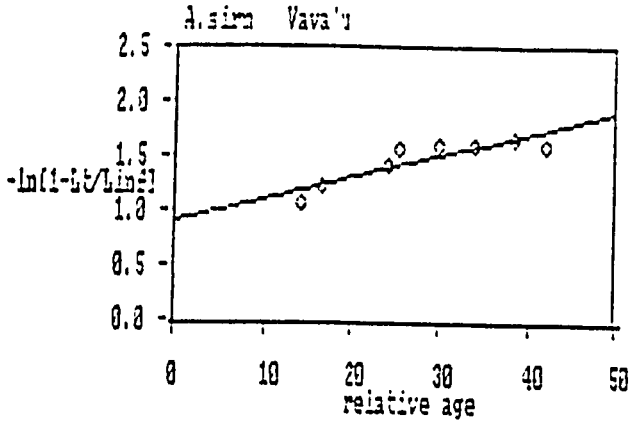

Figure 1: A von Bertalanffy plot for the sardine, *Amblygaster sirm*.

Table 3: Maximum length (mean of 10 largest individuals), and provisional estimates of the growth coefficient, K, for the four major species found in surveys in Vava'u, Tonga

SPECIES		L_{max} (mm)	K (wk^{-1})
spotted sardine	*Amblygaster sirm*	249.3	0.020 ± 0.009
scad	*Decapterus macrosoma*	231.7	0.045 ± 0.022
scad	*Decapterus macarellus*	285.5	0.042 ± 0.036
spotted herring	*Herklotsichthys sp.*	141.5	0.038 ± 0.020

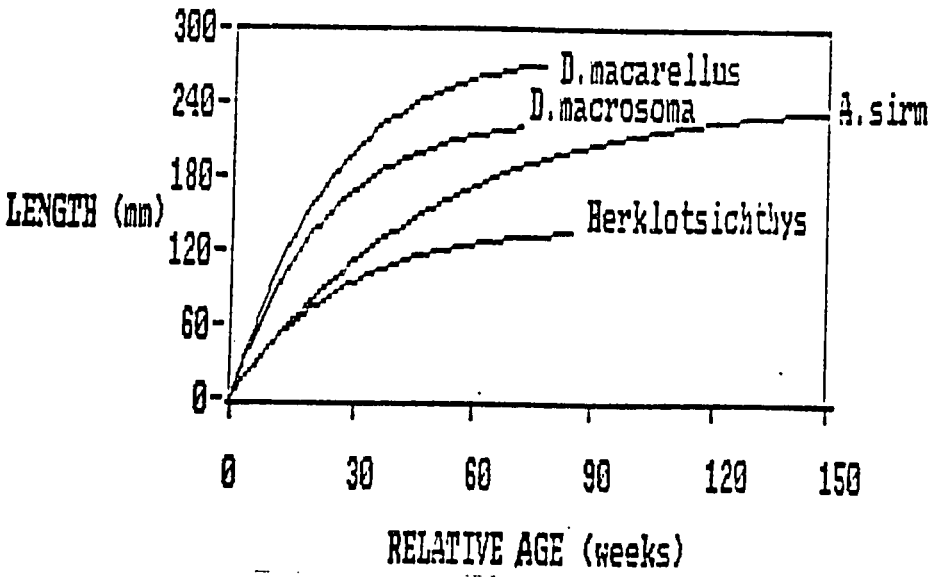

Figure 2: Provisional growth curves for the four major species found in surveys in Vava'u, Tonga

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6.0 INITIAL MORTALITY ESTIMATES

As long as growth data are available for the species, a length frequency distribution can be converted to an age-frequency distribution by means of a length-converted catch-curve. Length frequency data for the scad, *Decapterus macrosoma* (Figure 3) are analyzed as an instruction example.

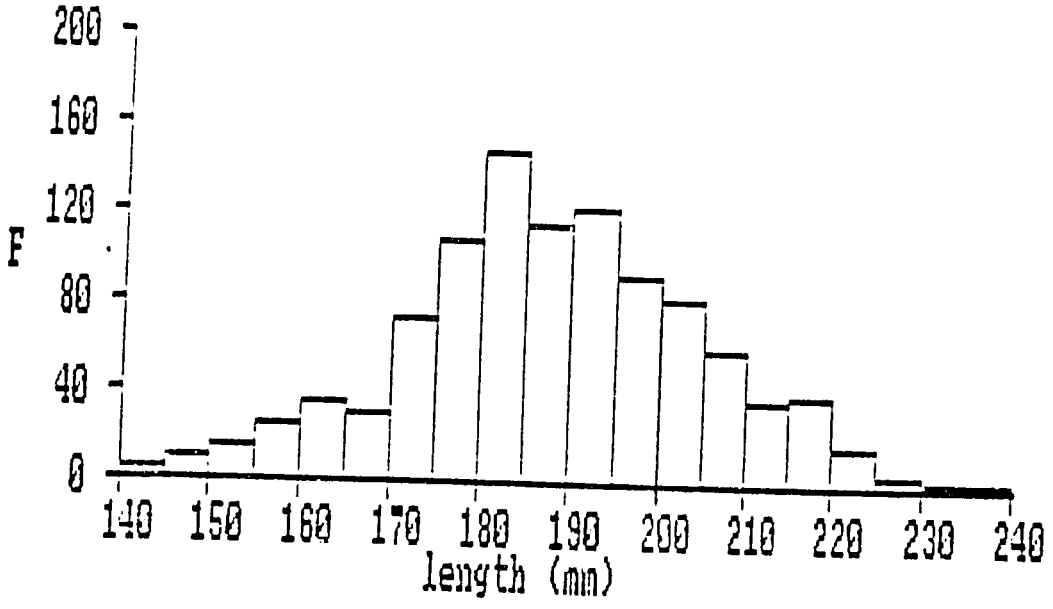

Figure 3: Length frequency distribution for the scad, *Decapterus macrosoma* collected in Vava'u

A length-converted catch curve is a plot of 1n(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.

Table 4 shows a method of using the length frequency data for the scad, *Decapterus macrosoma*, (from Figure 3) to construct a length-converted catch curve. Column 4 lists the frequency (F) by length-class (L_1-L_2). In column 5, the relative age, t, is calculated using the inverse of the von Bertalanffy equation, with t_0 set at zero as only relative age is required, and with K = 2.34 yr^{-1}, and L_∞ = 231.7 mm for the scad, *Decapterus macrosoma*. That is;

$$t = (-1/K)\ 1n\ [1-L_1/L_\infty]$$

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The value dt, the time taken for the species to grow through a particular length class, is estimated as the age at L_2 ($t_{(L2)}$) minus the age at L_1 ($t_{(L1)}$). Mean ages, used as the independent (X) values in the length-converted catch-curve, are approximated as the ages at the midpoint of each length-class, $(L_1 + L_2)/2$. This is also calculated using the inverse of the von Bertalanffy equation.

$$t_{(L1+L2)/2} = (-1/K)\ 1n[1-((L_1+L_2)/2)/L_\infty]$$

Finally the natural logarithms of the frequency divided by the change in age, 1n [F/dt] are used as the dependent (Y) values in the length-converted catch-curve (Figure 4).

Table 4: The use of length frequency data for the scad, *Decapterus macrosoma* to construct a length-converted catch-curve. Growth parameters used are K - 2.34 yr^{-1}, and L_∞ = 231.7

L_1 (cm)	L_2 (cm)	L (cm)	F	AGE (yr)	AGE CHANGE (dt)	MEAN AGE	ln(F/dt)
140	145	142.5	6	0.396	0.024	0.408	5.52
145	150	147.5	9	0.420	0.025	0.433	5.87
150	155	152.5	16	0.445	0.027	0.459	6.38
155	160	157.5	25	0.472	0.029	0.487	6.77
160	165	162.5	35	0.501	0.031	0.516	7.03
165	170	167.5	29	0.532	0.033	0.548	6.77
170	175	172.5	72	0.565	0.036	0.583	7.60
175	180	177.5	107	0.602	0.039	0.621	7.91
180	185	182.5	147	0.641	0.043	0.662	8.13
185	190	187.5	115	0.684	0.048	0.708	7.77
190	195	192.5	122	0.733	0.055	0.759	7.71
195	200	197.5	93	0.787	0.063	0.818	7.30
200	205	202.5	83	0.850	0.073	0.885	7.03
205	210	207.5	61	0.923	0.089	0.965	6.53
210	215	212.5	37	1.012	0.112	1.064	5.80
215	220	217.5	40	1.124	0.152	1.193	5.57
220	225	222.5	17	1.276	0.238	1.379	4.27
225	230	227.5	6	1.514	0.586	1.714	2.33
230	235	232.5	2	2.100	-	-	-
235	240	237.5	3	-	-	-	-

The length-converted catch curve in Figure 4 is fitted through data which exclude;

a) the initial ascending data points which represent groups of individuals which are either not fully recruited or are too small to be totally vulnerable to the fishing method used,

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b) data points from mean ages with very small sample sizes (say less then 10 individuals), and,

c) data points close to L_∞, where the relationship between length and age becomes uncertain.

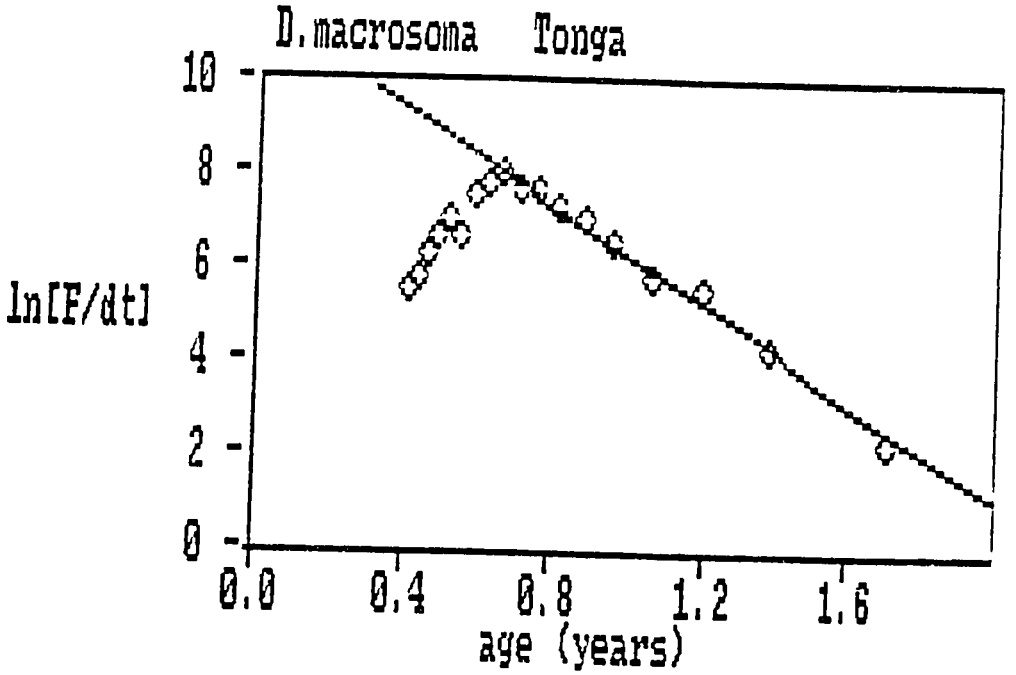

Figure 4: A length-converted catch curve for the scad, *Decapterus macrosoma*. The instaneous mortality rate estimated from the slope of the regression line is $Z = 5.3yr^{-1}$.

The mortality rates obtained in the above analyses are high (greater than 90% per year), but not uncommon in small inshore pelagic fish. The analyses, however, will provide misleading results if larger fish are migrating out of the sampling area, in which case mortality rates will be overestimated.

7.0 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 5).

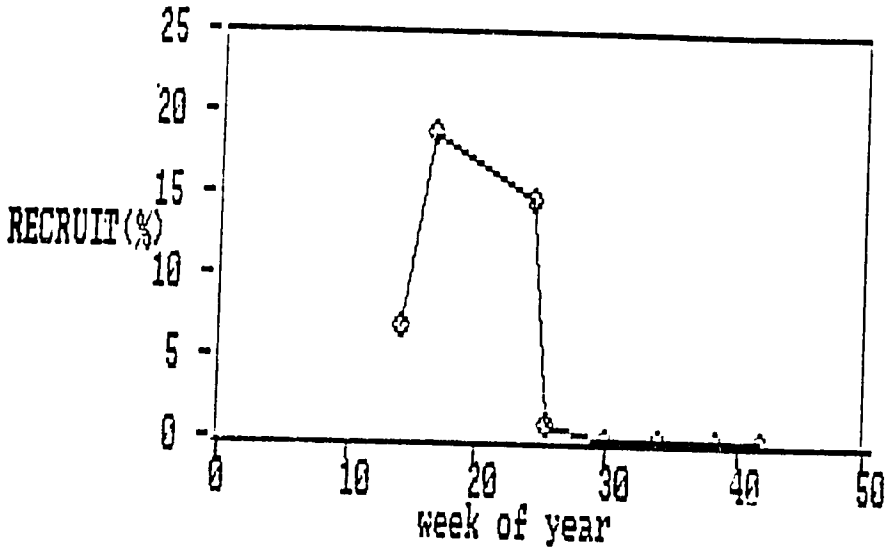

Figure 5: Numbers of individuals in the smallest five length classes of the scad, *Decapterus macarellus*, in samples taken in Vava'u, Tonga.

Results from samples of the four major species (Table 5) suggest that small individuals appear in the catches at different times of the year for each of the four main species. This has particular implications in the development of a fishery. For each of the component species, catch rates are likely to be high after recruitment, and decrease over succeeding months; in the case of multi-species stocks, decreasing catch rates in one species may be compensated for by increasing catch rates in other species.

Table 5: Recruitment periods estimated by the numbers of small individuals (those in the smallest five length classes) in samples of four major species found in surveys in Vava'u.

SPECIES		RECRUITMENT
spotted sardine	*Amblygaster sirm*	???? to May
scad	*Decapterus macrosoma*	September to ????
spotted herring	*Decapterus macarellus*	April to June
	Herklosichtys sp.	???? to May

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8.0 REPRODUCTION

Often in fisheries work, only the female ovaries are studied , as these are larger and more easily examined than male testes; it is also assumed that development of both ovaries and testes are synchronous.

Ovaries may be examined microscopically, and classified into various developmental stages. One such classification is shown in Table 6, although it should be noted that gonad development is continuous, and all such staging is somewhat artificial. Whichever classification is used, there is some merit in defining as few stages as possible; the main interest in fisheries studies is in determining the time when the majority of the population is in the final ripe and spawning stages.

Table 6: Stages of reproductive development showing the appearance of ovary and eggs.

	STAGE	DESCRIPTION	OVARY	EGGS
INACTIVE	I	Resting	undeveloped	none(few residual)
ACTIVE	II	Developing	expanding	opaque eggs
RIPE	III	Ripe	fills body	transparent eggs free
	IV	Spawning	cavity	eggs in ovary
SPENT	V	Resorption	shrinking/slack	residual eggs

Ovaries taken from samples of females collected at intervals throughout the year may be classified into developmental stages, and the percentages of each can be plotted by month in a histogram.

An alternative method of following the reproductive cycle involves estimating a gonad or gonosomatic index (GI or DSI). This index, which assumes that an ovary increases in size with the total mass of the animal (TM);

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

9.0 COMMENTS

Only 23 fishing trips have been completed since April 1993, an average of less than one night's fishing per week. This has resulted in disappointing progress in the collection of catch-per-unit-effort data over a lunar month to determine lunar vulnerability, in running depletion experiments to estimate stocks sizes, and in fishing over a wider geographic area to suggest distribution. At present, crew members have little incentive to go fishing at the period of the full moon (when catch rates are believed to be low), and to commit themselves to the considerable physical effort involved in handling the heavy purse seine net over a sustained period; a depletion experiment is likely to require fishing over at least 10 days (excluding the weekend which is sacrosanct under local customs).

The parts of the planned program inadequately covered are;

A. AREA (GENERAL) SURVEYS:

AIM: To determine the distribution of species by area.

METHOD: Carry out fishing at as many locations as possible during the year on a full-time basis.

B. LUNAR MONTH SURVEY:

AIM: To determine the vulnerability of species in relation to the lunar period.

METHOD: Carry out fishing at one preferred fishing location over one full lunar month (over 28 days, from one new moon through the full moon to the next new moon). In order not to deplete the local population, a large fishing area should be selected, and fishing should be carried out on approximately every second or third day.

C. INTENSIVE FISHING SURVEY:

AIMS:

a) to determine the catchability coefficient, q, of the sampling gear,

b) to provide approximate estimates of local stock size.

METHOD: Carry out intensive fishing in a selected bay over a short time period (as many hauls as possible in approximately 10 consecutive nights - from 5 days before the new moon to 5 days after the new moon). The bay must be selected on the basis that it approximates an isolated stock (in order that migration in or out of the bay may be considered minimal); the

time period must be kept short (in order that the effects of natural mortality may be ignored), and the fishing effort should be massive enough to effectively reduce local stock numbers. Although this experiment may be confounded due to the difficulty of accepting inherent assumptions, the importance of potential results justifies the small amount of field time (less than 1 week) involved.

The estimation of sustainable yield for such pelagic, and presumably highly mobile, stocks is likely to be difficult. However, it is believed that the proposed survey program will provide sufficient information to allow a judgement on whether or not sufficient resources exist to support a baitfishery, and suggest a level at which stocks may be sustainably exploited.

10.0 KEY REFERENCES

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TABLE 1.

TUNA CATCH SUMMARY

TONGA LONGLINE PROJECT

OCTOBER - DECEMBER 1992

TRIP	RETURN	NO OF	NO OF	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		WAHOO		OTHER	
NO	DATE	DAYS	SETS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
DM9	1/10	1	4	8	112	4	85	0	0	0	0	4	27	0	0	0	0
DM10	2/10	1	2	1	6	0	0	0	0	0	0	1	6	0	0	0	0
DM11	6/10	2	3	18	347	1	13	13	254	0	0	3	22.8	0	0	1	57
DM12	7/10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM13	8/10	1	2	4	40	0	0	0	0	0	0	0	0	0	0	4	40
DM14	16/10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM15	22/10	3	0	85	248	63	185	0	0	0	0	1	4	0	0	21	59
DM16	26/10	1	5	4	55	0	0	2	46	0	0	2	9	0	0	0	0
DM17	27/10	1	6	2	26	1	12	1	14	0	0	0	0	0	0	0	0
DM18	29/10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM19	6/11	2	6	8	62	0	0	0	0	0	0	3	16	4	14	1	32
DM20	10/11	1	4	6	53	0	0	0	0	0	0	6	53	0	0	0	0
DM21	11/11	1	7	16	89.5	1	3.5	0	0	0	0	11	65	4	21	0	0
DM22	16/11	1	2	13	59	7	21	0	0	0	0	3	20	3	18	0	0
DM23	19/11	3	0	45	138	30	90	0	0	0	0	1	6	0	0	14	42
DM24	25/11	3	0	29	165	14	60	0	0	0	0	0	0	3	21	12	84
DM25	30/11	1	0	40	139	13	87	0	0	0	0	1	4	0	0	26	48
DM26	1/12	1	0	18	138	7	43	0	0	0	0	0	0	2	11	9	84
DM27	3/12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM28	7/12	1	0	14	80	7	69	0	0	0	0	0	0	0	0	7	11
DM29	8/12	1	0	17	49	5	15	0	0	0	0	1	4	2	12	9	18
DM30	14/12	1	8	34	509	24	343	7	160	0	0	0	0	0	0	3	5.5
DM31	17/12	1	7	1	30	0	0	0	0	0	0	0	0	0	0	1	30
DM32	21/12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		32	53	363	2345	177	1027	23	474	0	0	37	237	18	97	108	511
AVES			1.7	11.3	73.3	5.5	32.1	0.7	14.8	0.0	0.0	1.2	7.4	0.6	3.0	3.4	16.0

TABLE 2.

TUNA CATCH SUMMARY

TONGA LONGLINE PROJECT

OCTOBER - DECEMBER 1992

TRIP	RETURN	NO OF	NO OF	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		WAHOO		OTHER	
NO	DATE	DAYS	SETS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
A10	4/10	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A11	7/10	1	4	3	26	0	0	0	0	0	0	3	26	0	0	0	0
A12	14/10	1	4	4	36.35	0	0	0	0	0	0	4	36.4	0	0	0	0
A13	15/10	1	0	5	34.95	0	0	0	0	0	0	3	19.4	3	15.6	0	0
A14	17/11	1	4	12	98	0	0	0	0	0	0	0	0	8	49	4	49
A15	10/12	1	5	42	106	0	0	0	0	0	0	0	0	1	15	41	91
					KGS												
TOTAL		6	23	66	301.3	0	0	0	0	0	0	10	81.8	12	79.6	45	140
AVES		3.83	11	50.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	13.6	2.0	13.3	7.5	23.3