PRELIMINARY ESTIMATES OF THE GROWTH AND MORTALITY OF THREE TUNA BAITFISH SPECIES, *Herklotsichthys quadrimaculatus* AND *Spratelloides delicatulus* (Clupeidae) AND *Rhabdamia gracilis* (Apogonidae) FROM FIJIAN WATERS

P. Dalzell[1], S. Sharma[2]
and
J. Prakash[2]

Tuna and Billfish Assessment Programme
Technical Report No. 20

South Pacific Commission
Noumea, New Caledonia
October 1987

64/88

Original text : English

1. DPI Fisheries Laboratory
P.O. Box 101
Kavieng
Papua New Guinea

2. Fisheries Division
Ministry of Primary Industry
P.O. Box 358
Suva
Fiji

South Pacific Commission Cataloguing–in–publication data

Dalzell, P.

Preliminary estimates of the growth and mortality of three tuna baitfish species *Herklotsichthys quadrimaculatus* and *Spratelloides delicatulus* (Clupeidae) and *Rhabdamia gracilis* (Apogonidae) from Fijian waters / P. Dalzell, S. Sharma and J. Prakash.

(Tuna and Billfish Assessment Programme technical report ; no. 20)

1. Baitfish – Oceania 2. Tuna fisheries – Research – Oceania
I. Sharman, S. II. Prakash, J. III. Title IV. Series

639.2758 AACR2
ISBN 982-203-090-8

Prepared for publication and printed at
South Pacific Commission headquarters, Noumea, New Caledonia, 1987

ABSTRACT

The age and growth rates of three Fijian baitfish species, *Herklotsichthys quadrimaculatus*, *Spratelloides delicatulus* and *Rhabdamia gracilis* were determined by counts of daily growth rings in the otoliths. Analysis of length frequency data for *H. quadrimaculatus* and *S. delicatulus* also produced comparable estimates of growth parameters. Both *H. quadrimaculatus* and *R. gracilis* are annual species with a maximum life span of about one year. The maximum life span of *S. delicatulus* is about six months. The natural mortality rates of all three species were estimated by an empirical method whilst a length converted catch curve was used to derive the total mortality rate of *S. delicatulus*. The results are discussed with respect to continued exploitation of Fiji's baitfish resources.

TABLE OF CONTENTS

Page

ABSTRACT . . . iii
LIST OF TABLES . . . vi
LIST OF FIGURES . . . vi
1.0 INTRODUCTION . . . 1
2.0 MATERIALS AND METHODS . . . 1
    2.1 Length Frequency Data . . . 1
    2.2 Sagittal Increment Counts . . . 4
    2.3 Mortality Rates . . . 4
3.0 RESULTS . . . 5
    3.1 Age and Growth . . . 5
        3.1.1 *H. quadrimaculatus* . . . 5
        3.1.2 *R. gracilis* . . . 7
        3.1.3 *S. delicatulus* . . . 9
    3.2 Mortality Rates . . . 10
        3.2.1 *H. quadrimaculatus* . . . 10
        3.2.2 *R. gracilis* . . . 11
        3.2.3 *S. delicatulus* . . . 11
4.0 DISCUSSION . . . 13
ACKNOWLEDGEMENTS . . . 13
REFERENCES . . . 13

LIST OF TABLES

Table Page

1 Data for the calculation of von Bertalanffy growth curve parameters for *H. quadrimaculatus* from Fijian waters derived from modal progression analysis 5
2 Results from the analysis of *H. quadrimaculatus* from Fijian waters length frequency data with the computer program Elefan I 5
3 Daily growth increment counts of the sagittae of *H. quadrimaculatus* from Fijian waters 6
4 Comparison of population parameters derived for *H. quadrimaculatus* from Fijian waters 7
5 Comparison of predicted age at length estimates for populations of *H. quadrimaculatus* from Hawaii, Fiji and New Caledonia 7
6 Data from counts of the daily growth increments of the sagittae of *R. gracilis* from Fijian waters 8
7 Growth parameters derived by Elefan I from length frequency data for *S. delicatulus* from Fijian waters 9
8 Data from sagittal increment counts for *S. delicatulus* from Fijian waters . . 9
9 Growth parameter estimates for *S. delicatulus* (Fiji) and *S. gracilis* (PNG) by different methods 10
10 Data for the construction of a length converted catch curve for *S. delicatulus* from Fijian waters 12

LIST OF FIGURES

Figure Page

1 Length frequency data for *H. quadrimaculatus* from Savusavu Bay (1982) used to obtain growth parameters 2
2 Length frequency data for *S. delicatulus* from Fijian waters (1982) used to obtain growth parameters 3
3 Relationship between length and age obtained from counts of the daily growth increments of the sagittae for *H. quadrimaculatus* from Fijian waters 6
4 Relationship between length and age obtained from counts of the daily growth increments of the sagittae for *R. gracilis* from Fijian waters 8
5 Relationship between length and age obtained from counts of the daily growth increments of the sagittae for *S. delicatulus* from Fijian waters . . 10
6 Combined length frequency distribution for *H. quadrimaculatus* from Savusavu Bay (1982) 11
7 Length converted catch curve for *S. delicatulus* from Fijian waters . . . 12

PRELIMINARY ESTIMATES OF THE GROWTH AND MORTALITY OF THREE TUNA BAITFISH SPECIES, *Herklotsichthys quadrimaculatus* AND *Spratelloides delicatulus* (Clupeidae) AND *Rhabdamia gracilis* (Apogonidae) FROM FIJIAN WATERS

1.0 INTRODUCTION

The domestic pole-and-line skipjack tuna fishery in Fijian waters was established in 1976. Concurrent with the start of the tuna fishery was the catching of live bait, necessary for the operation of pole-and-line fishing. Unlike other bait fisheries in the tropical Western and Central Pacific, Fijian bait catches are dominated by seven species groupings (Lewis *et al* 1983). Catches elsewhere in the region tend to be dominated by only two or three species; for example stolephorid anchovies in Palau (Muller 1976), stolephorid anchovies and sprats of the genus Spratelloides in Papua New Guinea (Dalzell and Wankowski 1980; Dalzell 1984) and stolephorid anchovies and *Herklotsichthys quadrimaculatus* in the Solomon Islands (Argue and Kearney 1982).

Recently, attention has been focussed on the biology of the major component species of the Fijian bait fishery (Lewis *et al* 1983). However, there is very little data on the age, growth and mortality of these species. Munch-Petersen (1983) produced preliminary estimates of the growth and mortality of *Spratelloides delicatulus* from length frequency data. This paper presents preliminary estimates of age, growth and mortality rates for two other species from the Fijian bait fishery, *H. quadrimaculatus* and *Rhabdamia gracilis*. Data for *S. delicatulus* were also analysed for comparison with results obtained by Munch-Petersen (1983). The results for all three species are discussed with respect to their biological characteristics and implications for management.

2.0 MATERIALS AND METHODS

Two methods were employed in this study to obtain age and growth parameters; length frequency analysis and counts of the daily growth increments of the sagittae (Panella 1970). No length data were collected for *R. gracilis* and only sagittal increment counts were used to age this species.

2.1 Length Frequency Data

The method of baitfish capture and biological data collection are described in detail by Lewis *et al* (1983). Essentially, bait capture is made by a stick held lift net or bouki-ami operated at night in conjunction with 1-2kW submersible lamps which aggregate the baitfish. The bouki-ami is mounted from the side of the tuna fishing vessel and has a stretched mesh size of 1.2 cm. A regular baitfish sampling programme by Fisheries Division staff was under taken during the 1981–82 fishing season (Lewis *et al* 1983). The most consistent set of samples were obtained from Savusavu Bay on Vanua Levu (16°5′S, 179°20′E and Ovalau Island 17°38′S, 178°51′E).

Of the two sets of length frequency data for *H. quadrimaculatus*, those from Savusavu Bay were judged to be the most suitable for length frequency analysis. There was no break in the samples from March to September 1982 and a clear modal progression was evident (Figure 1). The samples were collected at approximately monthly intervals and the standard length (SL) measured to the nearest 0.1 cm. To facilitate the length frequency analysis the length data were grouped in 0.5 cm length classes.

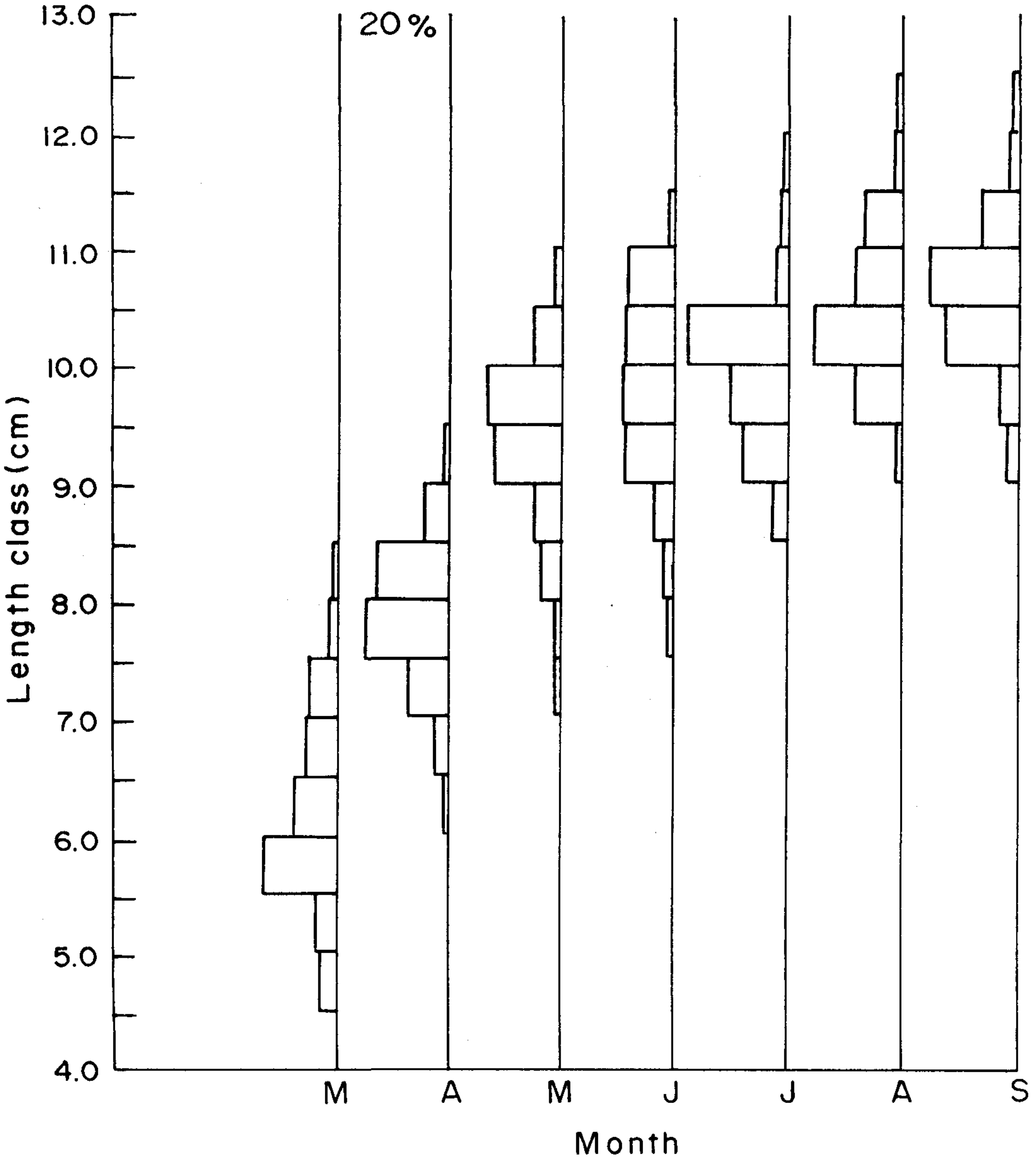

FIGURE 1. LENGTH FREQUENCY DATA FOR *H. quadrimaculatus* FROM SAVUSAVU BAY (1982) USED TO OBTAIN GROWTH PARAMETERS

Length frequency data for *S. delicatulus* from Ovalau and Savusavu were combined for each month to increase the sample sizes. The length frequency data for *S. delicatulus* was generally highly polymodal (Lewis *et al* 1983) and difficult to analyse. However, when the data from February to May 1982 were grouped in 0.5 cm length classes a clear modal progression was evident that proved amenable to analysis (Figure 2).

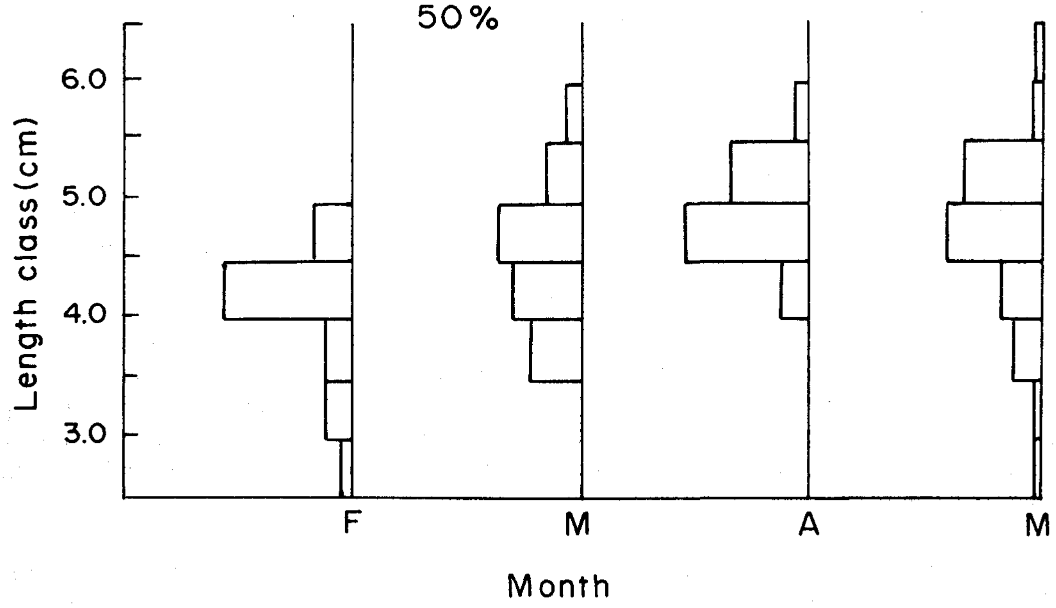

FIGURE 2. LENGTH FREQUENCY DATA FOR *S. delicatulus* FROM FIJIAN WATERS (1982) USED TO OBTAIN GROWTH PARAMETERS

Modal progression analysis was initially applied to the data for *H. quadrimaculatus*. The mean lengths of each sample were calculated and used as the link points for the progression. The von Bertalanffy growth curve was used as a general description of the growth of *H. quadrimaculatus* and the curve takes the form:

$$L_t = L_\infty[1 - e^{-K(t-t_0)}]$$

L_∞ = asymptotic length

K = a growth constant

t_0 = curve origin

L_t = length at t.

The growth curve was fitted to the modal progression data by the iterative regression technique of Beverton (in Ricker 1975), where the curve equation is linearised such that:

$$log_e(L_\infty - L_t) = Log_e L_\infty + Kt_0 - Kt.$$

A plot of $log_e(L_\infty - L_t)$ against t should be linear. Trial values of L_∞ are used until the best fit to the line is obtained. The slope of the line is K and t_0 is determined from the y axis intercept which is equal to $log_e(L_\infty + Kt_0)$.

Another method of analysing the length data for *H. quadrimaculatus* and *S. delicatulus* was by the computer program ELEFAN I (Pauly and David 1980, 1981). The program fits a von Bertalanffy growth curve to length data, given trial values of L_∞ and K. An interesting feature of this program is that it is able to account for seasonal variation in the growth rate of the species in question. This option was deemed appropriate for the data for *H. quadrimaculatus* in this instance as it covers a seven–month time span and Fiji lies approximately 15 – 20°S with a distinct cool season in the middle of the year.

2.2 Sagittal Increment Counts

Specimens of *H. quadrimaculatus* were obtained from Levuka (Ovalau Island) during May 1984. Eleven specimens representing the size range in the sample 6.6 – 9.5 cm SL were selected for the daily increment counts. The cranial region was then cut away and immersed in water in a petri-dish. The sagittae were dissected out of the cranial region with a pair of fine needles then placed on a microscope slide and dried. The axial lengths of the sagittae were measured with an eyepiece micrometer mounted in a dissecting microscope. Prior to counting the daily increments, the sagittae were ground and polished on fine emery paper (800 grit). Finally, the sagittae were mounted in microscope immersion oil for viewing at 1000 x magnification. In all instances it was possible to discern a clear track of growth increments from the nucleus to the sagittal margin.

Ten specimens of *R. gracilis* ranging from 2.9 – 4.6 cm SL and eight specimens of *S. delicatulus* ranging from 2.3 – 5.5 cm SL were obtained from bait catches made in the Lomaiviti group of islands to the east of Viti Levu. The sagittae of both species were extracted and measured as described above for *H. quadrimaculatus*. The sagittae of *S. delicatulus* required no grinding and polishing as the daily growth rings were clearly discernible. In contrast, the sagittae of *R. gracilis* were very robust and required more grinding to achieve a section thin enough for viewing. The clarity of the daily growth increments of this species was generally very poor and were usually observable only in patches. Counts of the increments in these patches were made along a single track to obtain a mean number per unit length of sagitta. From this an overall mean figure of the increment density was calculated based on the length of the track between the nucleus and the margin. Several counts were made at different distances from the nucleus to obtain the overall mean figure.

2.3 Mortality Rates

A representative length frequency distribution for a fish species during a given year may be converted to a relative age frequency distribution or catch curve, given values of L_∞ and K (Pauly and Ingles 1981; Gulland 1983). The slope of the descending right-hand limb of such a curve is the total mortality rate (Z). The curve is constructed by plotting $log_e\ N/\Delta t$ against t, where N is the number of fish in a given age class and t is relative age. The values of Δt represent the time needed for the fish to grow through a given length age class and corrects for the fact that fish growth is not linear, resulting in the accumulation of several age classes in the larger length classes.

Pauly's (1980) empirical method was used to estimate annual natural mortality rate (M); Pauly's method relates natural mortality, growth parameters (K and L_∞) and mean environmental temperature (T) such that:

$$log_{10}M = -0.0066 - 0.279 log_{10}L_\infty + 0.6543 log_{10}K + 0.4634 log_{10}T.$$

and is based on 175 sets of M, K, L_∞ and T values. An estimate of $T = 27.3°C$ was derived from temperature recordings made by the Fijian pole-and-line tuna fleet during 1981 and 1982.

3.0 RESULTS

3.1 Age and Growth

3.1.1 *H. quadrimaculatus*

The length frequency data for *H. quadrimaculatus* from Savusavu used to estimate growth parameters are shown in Figure 1 and Table 1. The best fit to the data was obtained with $L_\infty = 13$ cm which provided a K value of 2.02/yr ($r^2 = 0.90$). A summary of the analysis of the same length frequency data for *H. quadrimaculatus* by ELEFAN I is given in Table 2. The results from this method were $L_\infty = 13.1$ cm, $K = 2.02$/yr, with a period of slower growth in midyear as indicated by the value of the Winter Point (WP = 0.5).

TABLE 1. DATA FOR THE CALCULATION OF VON BERTALANFFY GROWTH CURVE PARAMETERS FOR *H. QUADRIMACULATUS* FROM FIJIAN WATERS DERIVED FROM MODAL PROGRESSION ANALYSIS

Age (months)	L	$Log_e(L_\infty - L_t)$
t	5.8	1.974
t+1	7.8	1.649
t+2	9.4	1.281
t+3	9.8	1.163
t+4	9.9	1.131
t+5	10.4	0.955
t+6	10.5	0.916

TABLE 2. RESULTS FROM THE ANALYSIS OF *H. QUADRIMACULATUS* FROM FIJIAN WATERS LENGTH FREQUENCY DATA WITH THE COMPUTER PROGRAM ELEFAN I

Explained sum of peaks (ESP) = 6.938
Available sum of peaks (ASP) = 8.698
R (ESP/ASP) = 0.797
K = 2.02
L_∞ = 13.10
Winter point (WP) = 0.5
Intensity of seasonal oscillation (C) = 0.2

The data and results from the sagittal increment counts for *H. quadrimaculatus* are given in Table 3. The relationship between otolith length (OL) and standard length (SL) was linear (OL = 54.2 + 5.420 SL, $r^2 = 0.876$). A von Bertalanffy curve was fitted to the age at length data by Beverton's method (Figure 3). The best fit ($r^2 = 0.95$) was obtained with $L_\infty = 12.6$ cm which gave a K value of 2.00/yr. The origin of the growth curve, t_0, was –0.13.

TABLE 3. DAILY GROWTH INCREMENT COUNTS OF THE SAGITTAE OF *H. QUADRIMACULATUS* FROM FIJIAN WATERS

Length (cm)	Otolith length graticule units)	Age (days)
7.7	95	120
7.8	92	139
8.3	100	165
8.1	99	148
10.3	112	255
6.6	89	95
7.4	98	113
7.4	96	117
9.0	103	211
9.5	103	209
9.4	105	196

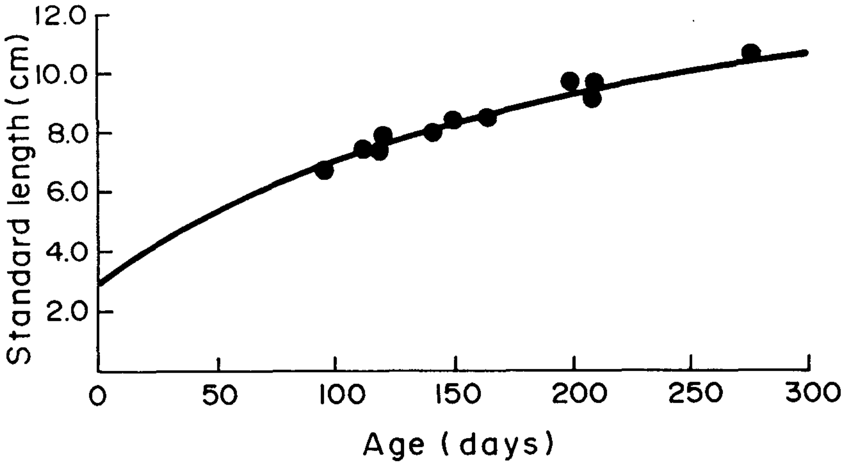

FIGURE 3. RELATIONSHIP BETWEEN LENGTH AND AGE OBTAINED FROM COUNTS OF THE DAILY GROWTH INCREMENTS OF THE SAGITTAE FOR *H. quadrimaculatus* FROM FIJIAN WATERS

The results from the length frequency analysis and the sagittal increment counts are included in Table 4 for comparison. It is clear that the derived values of L_∞ and K are all reasonably close. It must be emphasised, however, that these results were based essentially on the analysis of data from adult specimens; no fish smaller than 7.2 cm for example were included in the sagittal increment counts.

Williams and Clarke (1983) studied the age and growth of *H. quadrimaculatus* from Hawaiian waters and provided evidence to support the assumption of a daily periodicity of ring deposition in the sagittae of this species. These authors also suggested that male and female *H. quadrimaculatus* may have different growth rates once sexual maturity has been attained. A two-cycle Gompertz-type model was used by Williams and Clarke (1983) to describe the growth of *H. quadrimaculatus*, since this model accounted for differences in the juvenile and adult phases of the life history. The growth of *H. quadrimaculatus* was also studied by Conand (1984), who used length frequency data, supported by sagittal increment counts, to derive the parameters of the von Bertalanffy growth curve. Conand's (1984) parameter estimates were, $L_\infty = 12.5$, $K = 3.61/\text{yr}$, $t_0 = 0.007/\text{yr}$.

TABLE 4. COMPARISON OF POPULATION PARAMETERS DERIVED FOR *H. QUADRIMACULATUS* FROM FIJIAN WATERS

Method of growth parameter estimation	L_∞	K	M
Modal Progression	13.0	2.01	3.52
ELEFAN I	13.1	2.02	3.53
Otoliths	12.6	2.00	3.54

A comparison of the predicted lengths at various ages for the Hawaiian, Fijian and New Caledonian populations of adult *H. quadrimaculatus* is given in Table 5. There are some differences between the predicted length at age in the three populations. This may be due to innate differences between the three populations of *H. quadrimaculatus*, geographical variation between sampling localities, differences in the methodology used to estimate growth parameters or a combination thereof.

TABLE 5. COMPARISON OF PREDICTED AGE AT LENGTH ESTIMATES FOR POPULATIONS OF *H. QUADRIMACULATUS* FROM HAWAII, FIJI AND NEW CALEDONIA. All lengths given as standard length.

Age (days)	L_t(Ha)	L_t	L_t(N.C.)
80	4.2	6.8	5.8
100	5.3	7.5	6.7
120	6.4	8.1	7.3
140	7.3	8.7	7.9
160	8.1	9.2	8.4
180	8.9	9.6	8.8
200	9.5	10.0	9.1
220	9.9	10.3	9.4
240	10.4	10.6	9.5
260	10.7	10.9	9.7
280	10.9	11.1	9.9
300	11.1	11.4	10.0

3.1.2 *R. gracilis*

The results of the sagittal increment counts for *R. gracilis* are summarised in Table 6. The relationship between otolith length and standard length was linear (OL = 32.70x – 38.0 SL, $r^2 = 0.86$). A von Bertalanffy growth curve was fitted to the age at length data (Figure 4) and the best fit ($r^2 = 0.94$) was obtained with $L_\infty = 5.0$ cm and $K = 2.67/\text{yr}$. The estimated value of t_0 was –0.08 yrs.

TABLE 6. DATA FROM COUNTS OF THE DAILY GROWTH INCREMENTS OF THE SAGITTAE OF *R. GRACILIS* FROM FIJIAN WATERS

Length (cm)	Otolith length (graticule units)	Age (days)
3.7	75	122
4.5	120	271
3.0	63	115
3.3	70	138
3.9	77	159
2.9	65	96
4.1	97	216
4.1	98	192
4.6	117	322
4.0	83	207

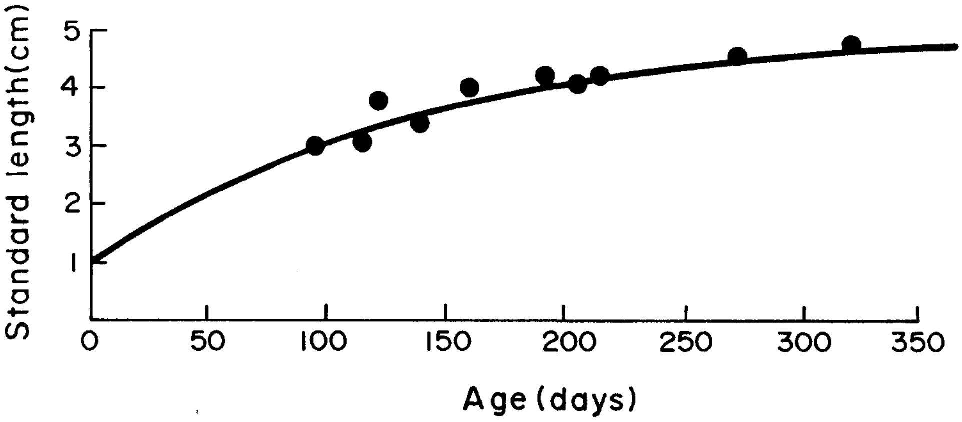

FIGURE 4. RELATIONSHIP BETWEEN LENGTH AND AGE OBTAINED FROM COUNTS OF THE DAILY GROWTH INCREMENTS OF THE SAGITTAE FOR *R. gracilis* FROM FIJIAN WATERS

The same caveat applies to the analysis of *R. gracilis* as to that for *H. quadrimaculatus*. No fish smaller than 2.9 cm were available for daily increment counts and the growth curve was based almost entirely on the growth of adult fish.

Ralston and Miyamoto (1981) have given details of a method for making an estimate of the number of sagittal daily increments in cases where the growth record in the otolith is only partially visible. Unlike the method used here, Ralston and Miyamoto's (1981) procedure takes account of the diminishing size of increment width with distance from the nucleus. The present estimates of length at age for *R. gracilis* presented here are acknowledged to be only approximations that may be subsequently improved upon by the application of Ralston and Miyamoto's (1981) method.

3.1.3 *S. delicatulus*

The length frequency data for *S. delicatulus* analysed by ELEFAN I is shown in Figure 2 and a summary of the results obtained is given in Table 7. The estimates of L_∞ and K obtained by ELEFAN I are similar to those derived from modal progression analysis by Munch-Petersen (1983).

TABLE 7. GROWTH PARAMETERS DERIVED BY ELEFAN I FROM LENGTH FREQUENCY DATA FOR *S. DELICATULUS* FROM FIJIAN WATERS

Explained sum of peaks (ESP) = 2.046
Available sum of peaks (ASP) = 3.999
R (ESP/ASP) = 0.513
K = 4.38/yr
L_∞ = 7.3 cm

The sagittal increment data for *S. delicatulus* are presented in Table 8. The relationship between otolith length and standard length was linear (OL = 11.45 + 1.073 SL, $r^2 = 0.94$). A von Bertalanffy curve was fitted to the data by the method described previously (Figure 5). The best fit ($r^2 = 0.94$) was obtained with $L_\infty = 7.3$ cm which gave $K = 4.58$/yr. The estimated value of t_0 was –0.023 yrs.

TABLE 8. DATA FROM SAGITTAL INCREMENT COUNTS FOR *S. DELICATULUS* FROM FIJIAN WATERS

Length	Otolith length (graticule units)	Age (days)
4.3	62	52
3.9	62	46
5.0	63	74
5.5	71	106
4.7	65	79
2.3	39	23
2.5	36	22
2.4	36	35

Table 9 summarises all estimates of growth parameters for *S. delicatulus* and also includes estimates of L_∞ and K from a related species, *S. gracilis* from Papua New Guinea, which were determined by modal progression analysis, ELEFAN I and sagittal increment counts. It is clear that in both instances, three different methods have provided similar estimates of L_∞ and K and that the two species have similar growth parameters.

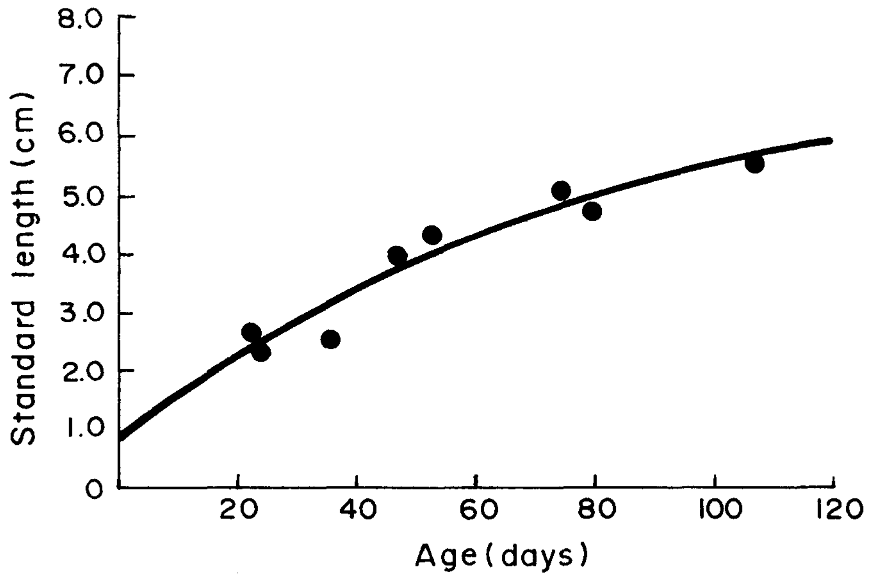

FIGURE 5. RELATIONSHIP BETWEEN LENGTH AND AGE OBTAINED FROM COUNTS OF THE DAILY GROWTH INCREMENTS OF THE SAGITTAE FOR *S. delicatulus* FROM FIJIAN WATERS

TABLE 9. GROWTH PARAMETER ESTIMATES FOR *S. DELICATULUS* (FIJI) AND *S. GRACILIS* (PNG) BY DIFFERENT METHODS

Species	Location	L_∞	K/day	Method	Author
S. delicatulus	Fiji	7.5	4.38	Modes	Munch-Petersen (1983)
S. delicatulus	Fiji	7.3	4.38	ELEFAN I	This report
S. delicatulus	Fiji	7.3	4.74	Otoliths	This report
S. gracilis	PNG	8.3	4.38	Modes	Dalzell & Wankowski (1980
S. gracilis	PNG	7.6	4.38	ELEFAN I	Dalzell (1984)
S. gracilis	PNG	7.9	4.38	Otoliths	Dalzell (unpub. data)

3.2 Mortality Rates

3.2.1 *H. quadrimaculatus*

The combined length frequency distribution for *H. quadrimaculatus* from Savusavu Bay during 1982 is shown in Figure 6. This length distribution was not suitable for the estimation of the total mortality rate from either a catch curve or a mean length equation such as that of Beverton and Holt (1957). The small mesh size of the fishing gear ensures full retention of the fish at the size *H. quadrimaculatus* are first captured. Thus it is unlikely that mesh selection accounts for the bias in size frequency distribution towards fish which are close to the maximum size. Williams and Clarke (1983) reported that in Hawaiian waters, adult

H. quadrimaculatus migrated offshore at night. Juveniles remained within a few hundred metres of the shore, whereas adults have been recorded up to 10 km from the coast. The same behavioural phenomenon may be occurring in Fijian waters and account for the size frequency distribution recorded from Savusavu Bay.

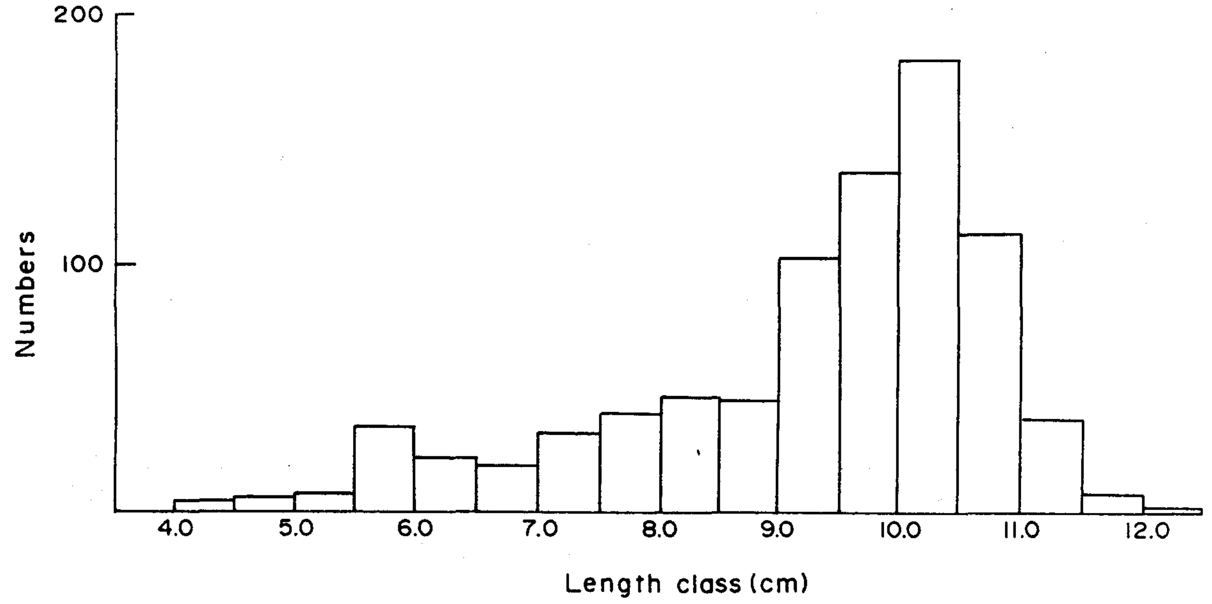

FIGURE 6. COMBINED LENGTH FREQUENCY DISTRIBUTION FOR *H. quadrimaculatus* FROM SAVUSAVU BAY (1982)

The empirical estimates of M calculated from Pauly's (1980) method, for each set of growth parameters, are included in Table 4. The catch and effort data from Savusavu Bay during 1981–1982 fishing season show that this bait ground was only lightly fished and yielded over this period a catch of only 5.94 tonnes, 4.51 tonnes of which was caught in March 1982 (Lewis *et al* 1983). From species composition data given by Lewis *et al* (1983), 24% of this catch or 1.44 tonnes was *H. quadrimaculatus*. Such a small catch would not be expected to contribute significantly to the total annual mortality for this species.

3.2.2 *R. gracilis*

There was no comparable data for *R. gracilis* as no length frequency data were collected from any bait ground. An empirical estimate of the natural mortality rate from Pauly's (1980) equation gave a value of $M = 5.53/\text{yr}$. It would be superfluous to comment further on this species without more information except to note that 5.53 is very large.

3.2.3 *S. delicatulus*

The catch curve for *S. delicatulus* from Fijian waters during 1982 is shown in Figure 7, based on the data in Table 10. The catch curve exhibits a pronounced curvature of the right-hand limb which suggests there is a progressive increase in the total mortality of larger and hence older fish. Such a catch curve appears to be characteristic of tropical and sub-tropical clupeoid fishes (Dalzell 1983; Pauly 1984).

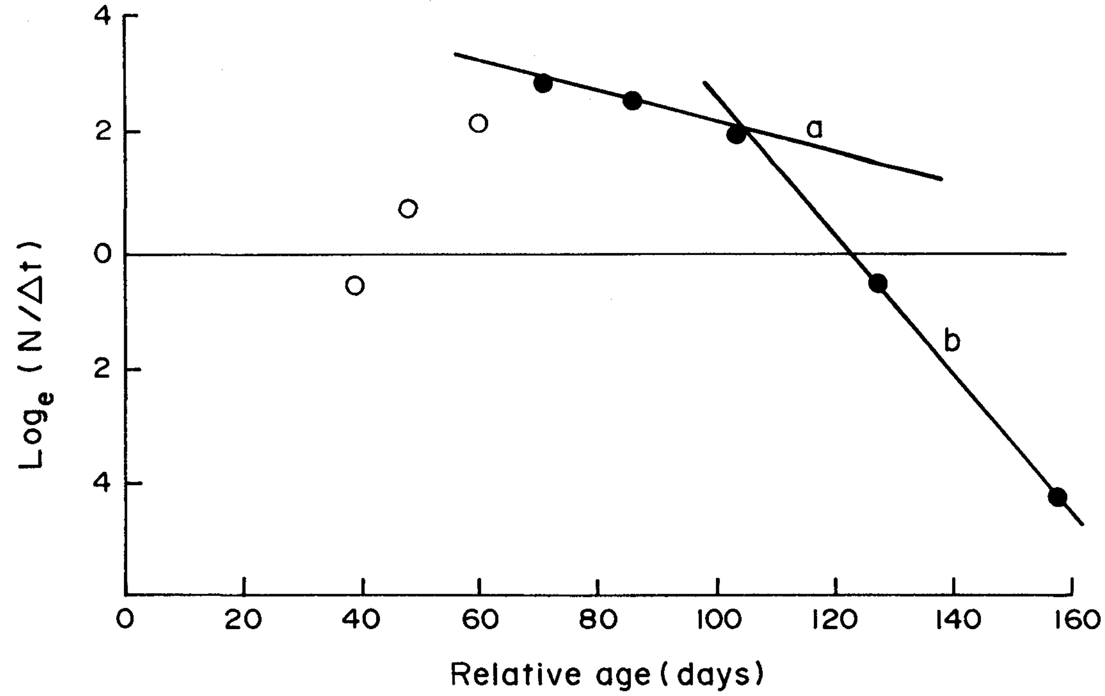

FIGURE 7. LENGTH CONVERTED CATCH CURVE FOR *S. delicatulus* FROM FIJIAN WATERS. Lines a and b represent two possible interpretations of the descending limb of the curve (see text). Open circles not used in regressions.

TABLE 10. DATA FOR THE CONTRUCTION OF A LENGTH CONVERTED CATCH CURVE FOR *S. DELICATULUS* FROM FIJIAN WATERS

Length class	Mid length (cm)	*N*	*Log N/t*	*t* (rel)
2.5 - 2.9	2.7	0.8	-0.537	38.5
3.0 - 3.4	3.2	2.9	0.69	48.1
3.5 - 3.9	3.7	12.7	2.034	59.9
4.0 - 4.4	4.2	32.2	2.819	71.4
4.5 - 4.9	4.7	29.4	2.549	86.0
5.0 - 5.4	5.2	20.0	1.948	103.8
5.5 - 5.9	5.7	2.1	-0.567	126.5
6.0 - 6.5	6.2	0.6	-4.163	157.7

The two possible interpretations of the right-hand limb of the catch curve are also included in Figure 7. The estimate of total mortality from line a is $Z = 9.9/\mathrm{yr}$ which is similar to that of Munch-Petersen (1983) who performed a similar analysis to derive $Z = 10.3/\mathrm{yr}$ for this species. Both these analyses combined length frequency data from several locations, assuming mortality rates were similar. An estimate of total mortality from line b gives $Z = 41.4/\mathrm{yr}$, which is an unrealistic figure even for a short-lived species such as *S. delicatulus*. The growth parameters derived here for *S. delicatulus* used in conjunction with Pauly's (1980) formulation for natural mortality gave $M = 6.9/\mathrm{yr}$. No other estimates have been made elsewhere for *S. delicatulus*.

4.0 DISCUSSION

All three species investigated here have short life spans. *H. quadrimaculatus* and *R. gracilis* are annual species with life spans probably ranging between 10–12 months, whilst the maximum life expectancy of *S. delicatulus* is possibly about six months. As Gulland (1983) has pointed out, the consequences of a short life span and concomitant high natural mortality rate means that many fish will die before completing much of their growth. It will pay therefore to fish relatively hard and with a low size at first capture so as to catch the fish before they die of natural causes.

Unlike *H. quadrimaculatus* and *S. delicatulus*, *R. gracilis* is a mouth brooder, in common with other apogonids. As such, this species is likely to have a low fecundity. Further, removal of the adults should presumably have a direct effect on recruitment since the continued survival of the adults is necessary for the protection of the newly hatched larvae. If *R. gracilis* assumes greater importance in the Fijian bait fishery as indicated by Lewis *et al* (1983) then these aspects of the biology of the species should be considered.

Management of a complex multi-species fishery such as the Fijian bait fishery must ultimately be a compromise between what is realistically and practically possible, and the need to conserve the various components of the bait catch and the biology of the component stocks. The Fijian pole-and-line fishery is modest in comparison with others in the Pacific. The total bait catch between 1976-1981 amounted to about 560 tonnes, caught over a wide area of the country. The total bait catch in Papua New Guinea waters over the same period was 9,400 tonnes, approximately 60% of which came from two areas alone, the Ysabel Passage and Cape Lambert (Dalzell 1984). A better comparison would be catch in relation to biomass which would give a better indication of the level of exploitation, however, there are at present no data for the biomass densities from the Fijian bait grounds.

The limitations of the Fijian bait fishery are due to the highly seasonal nature of the fishery (Lewis *et al* 1983) and a lack of bait grounds with the same productivity as found in Papua New Guinea. Consequently, it is unlikely that there are bait stocks in Fijian waters that are being over exploited at present. Further, the pole-and-line fleet in Fiji has been reduced from 13 in 1983 to a present level of 6 vessels and it appears that any future expansion will be gradual.

ACKNOWLEDGEMENTS

This study was made possible by funding from the South Pacific Commission for Economic Cooperation. The manuscript was reviewed by Drs. Tony Lewis, Ray Hilborn, and Daniel Pauly who made many helpful comments and suggestions.

REFERENCES

Argue, A.W. and R.E. Kearney (1982). An assessment of the skipjack and baitfish resources of the Solomon Islands. South Pacific Commission, Skipjack Survey and Assessment Programme, Final Country Report No. 3, Noumea, New Caledonia: 77 pp.

Beverton, R.J.H. and S.J. Holt (1957). On the dynamics of exploited fish populations. UK Minist. Ag. Fish. Invest. (Ser. 2) 19: 533 pp.

Conand, F. (1984). Ressources en appât vivant de Nouvelle-Calédonie. Rapport de synthèse Mars 1980 à Juin 1983. Centre ORSTOM de Nouméa: 93 pp.

Dalzell, P. (1983). Raw data and preliminary results for an analysis of the population dynamics of PNG baitfish. Dept. of Primary Industry, Fisheries Research and Surveys Branch, Port Moresby, Res. Rep. No. 83-04: 79 pp.

Dalzell, P. (1984). The population biology and management of baitfish in Papua New Guinea waters. Dept. of Primary Industry, Fisheries Research and Surveys Branch, Port Moresby, Res. Rep. 84-05: 59pp.

Dalzell, P.J. and J.W.J. Wanskowski (1980). The biology, population dynamics, and fisheries dynamics of exploited stocks of three baitfish species, *Stolephorus heterolobus, S. devisi* and *Spratelloides gracilis* in Ysabel Passage, New Ireland Province, Papua New Guinea. Dept. of Primary Industry, Res. Bull. No. 22, Port Moresby: 124 pp.

Gulland, J.A. (1983). Fish stock assessment. FAO/Wiley series on food and agriculture, Vol. I: 223 pp.

Lewis, A.D., S. Sharma, J. Prakash and B. Tikomainiusiladi (1983). The Fiji bait fishery 1981-82, with notes on the biology of the gold spot herring *Herklotsichthys quadrimaculatus* (Clupeidae), and the blue sprat *Spratelloides delicatulus* (Dussumieriidae). Tech. Rep. No. 6, Fish. Div. (MAF), Fiji: 50 pp.

Muller, R.G. (1976). Population biology of *Stolephorus heterolobus* (Pisces: Engraulidae) in Palau, Western Caroline Islands. PhD. Thesis, Univ. Hawaii, Honolulu: 174 pp.

Munch-Petersen, S. (1983). On the growth and mortality of the blue sprat, *Spratelloides delicatulus* in Fijian waters. Inst. Marine Resources, Univ. South Pacific, Suva, Fiji, Res. Rep.: 22 pp.

Panella, G. (1970). Fish otoliths: daily growth layers and periodical patterns. Science (Washington, D.C. 173): 283-308.

Pauly, D. (1980). On the interrelationships between natural mortality, growth and mean environmental temperature in 175 fish stocks. J. du Conseil Int. Explor. Mer., 39 (3): 175-192.

Pauly, D. and N. David (1980). ELEFAN I: users instructions and program listings. Mimeo: pag. var.

Pauly, D. and N. David (1981). ELEFAN I: a BASIC program for the objective extraction of growth parameters from length data. Meeresforch. 28 (4): 205-211.

Pauly, D. and J. Ingles (1981). Aspects of the growth and natural mortality of exploited reef fishes. In Proc. IVth Int. Coral Reef Symp., Manila 1981. Vol. I: 89-98.

Ralston, S. and G.T. Miyamoto (1981). Estimation of the age of a tropical reef fish using the density of daily growth increments. In Proc. IVth Int. Coral Reef Symp., Manila 1981, Vol. I: 83-88.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res., Bd. Canada. 191: 38 pp.

Williams, V.R. and T. A. Clarke (1983). Reproduction, growth and other aspects of the biology of the gold spot herring *Herklotsichthys quadrimaculatus* (Clupeidae), a recent introduction to Hawaii. Fish. Bull. (U.S.), 81 (3): 587-597.