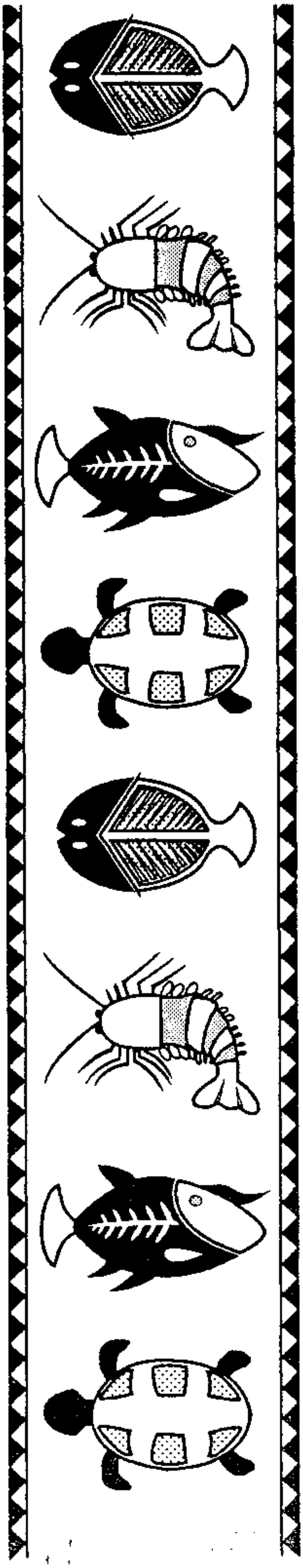

ISSN 1018-3116

Inshore Fisheries Research Project
Technical Document No. 6

A PRELIMINARY ASSESSMENT OF THE STATUS OF INSHORE CORAL REEF FISH STOCKS IN PALAU

South Pacific Commission
Noumea, New Caledonia

SOUTH PACIFIC COMMISSION

A PRELIMINARY ASSESSMENT OF THE STATUS OF INSHORE CORAL REEF FISH STOCKS IN PALAU

Inshore Fisheries Research Project
Technical Document No. 6

by

Anne Kitalong[1] & Paul Dalzell[2]

1. Marine Resources Division
P.O. Box 100
Koror
Palau 96940

2. South Pacific Commission
B.P. D5
Noumea Cedex
New Caledonia

Printed with financial assistance from
the Government of the United Kingdom

165/'94

South Pacific Commission
Noumea, New Caledonia
1994

Original text: English

South Pacific Commission Cataloguing in publication data

Kitalong, Anne
A preliminary assessment of the status of inshore coral reef fish stocks in Palau / by Anne Kitalong and Paul Dalzell.
(Inshore Fisheries Research Project technical document no. 6)

1. Fishery resources--Palau 2. Fishery management-Palau
3. Stock assessment --Palau I. Dalzell, Paul
II. South Pacific Commission Inshore Fisheries Research Project III. Title IV. Series

639.209966 AACR2
ISBN 982-203-365-6

Prepared for publication and printed at
South Pacific Commission headquarters,
Noumea, New Caledonia, 1994

SUMMARY

An analysis was made of length frequency data collected between 1990 and 1991 from landings of commercial reef fish in Koror. Most samples were collected from the main landing site at the Palau Federation of Fishing Associations (PFFA). Commercial landings data for reef fish species at PFFA between 1976 and 1990 were also summarised and used as supplementary information for this preliminary assessment.

The length data were used to generate life-history parameters which in turn were used to assess the status of the stocks and the optimum minimum sizes at first capture. The data suggested that at present Palau's reef fish stocks are only moderately exploited, with observed minimum capture lengths similar to optimum capture lengths predicted from the length-frequency data. The notable exception was the humphead wrasse or **maml** *(Cheilinus undulatus),* for which the average size at first capture considerably lower than the optimum generated from length-frequency analysis.

A nominal estimate was made of reef fish yield in Palau, based on an empirical subsistence catch figure and the volume of commercial landings. The results suggested that Palau's reef fish stocks were moderately exploited and supported conclusions derived from length-frequency data analysis.

Based on the analysis of length-frequency data, an initial minimum mesh size of three inches is suggested for **kesokes,** and other seine and gill nets deployed in Palau. Specific conservation measures may be necessary for certain species such as **maml** and the large parrotfish or **kemedukl** *{Bolbometopon muricatum).* It was recommended that a size limit of 70 cm be imposed on catches of **maml** and that exports of both species be prohibited.

The data presented here for other reef species may also useful for setting size limits if required, in conjunction with the conservation measures proposed by Johannes[1] for a range of reef fish species in Palau.

Collection of further data is recommended to corroborate the initial conclusions gained from this preliminary study. Further attempts should also be made to estimate the total reef fish harvest, including the subsistence catch and the volume of non-commercial reef fish exports from Palau.

---

1 Johannes, R.E. 1991. Some suggested management initiatives in Palau's nearshore fisheries, and the relevance of traditional management. Consultancy Report, Marine Resources Division, Palau and South Pacific Commission, Noumea, New Caledonia.

RESUME

Une analyse a été faite des données de fréquence de tailles, recueillies entre 1990 et 1991 à partir des quantités de poissons de récif d'importance commerciale débarquées à Koror. La plupart des échantillons ont été prélevés au principal point de débarquement, que constitue la Fédération des associations de pêcheurs de Palau (PFFA). Les données concernant les quantités de poissons de récif d'importance commerciale débarquées à la PFFA entre 1976 et 1990 ont également été récapitulées et utilisées comme information complémentaire aux fins de cette première évaluation.

Les données de fréquence de tailles ont permis d'établir les paramètres du cycle de vie, lesquels ont à leur tour permis d'évaluer l'état des stocks et la taille minimale à la première capture. Ces données ont également permis de conclure qu'en l'état actuel des choses, les stocks de poissons de récif à Palau ne sont exploités que modérément, la longueur minimale des captures observée des captures étant semblable à la longueur optimale, déterminée à partir des données de fréquence des tailles. Le napoléon ou **maml** *(Cheilinus undulatus)* est la seule grande exception, dont la taille moyenne à la première capture a été considérablement inférieure à la taille optimale dérivée de l'analyse des données de fréquence des tailles.

Une évaluation nominale des prises de poisson de récif débarquées à Palau a été faite à partir de données empiriques sur les prises destinées à l'autoconsommation et du volume des prises de la pêche industrielle. Les résultats ont permis de constater que les stocks de poissons de récif à Palau étaient modérément exploités et d'étayer les conclusions de l'analyse des données de la fréquence des tailles.

A partir de cette analyse des données, il a été proposé dans un premier temps un maillage minimum de trois pouces pour les kesokes (filets) et autres sennes et filets maillants utilisés à Palau. L'adoption de mesures spéciales pourrait se révéler nécessaire pour protéger certaines espèces comme le **maml** et le gros perroquet à bosse, dit **kemedukl** *(Bolbometopon muricatum).* Il a donc été recommandé de limiter à 70 cm la taille des prises de **maml** et d'interdire les exportations des deux espèces.

Les données présentées sur les autres espèces récifales dans le document qui fait l'objet du présent résumé pourraient également se révéler utiles s'il devenait nécessaire d'imposer des limites pour la taille des prises d'individus de ces espèces et de prendre les mesures de protection proposées par Johannes[2] dans son ouvrage pour une variété d'espèces récifales à Palau.

Il est recommandé de recueillir des informations complémentaires pour corroborer les conclusions de cette étude préliminaire. Il conviendrait également de s'employer à évaluer une nouvelle fois la totalité des prises de poissons de récif, et notamment les prises destinées à l'autoconsommation et le volume des exportations de prises non commercialisables effectuées par Palau.

2. Johannes, R.E. 1991. Some suggested management initiatives in Palau's nearshore fisheries, and the relevance of traditional management. Consultancy Report, Marine Resources Division, Palau and South Pacific Commission, Noumea, New Caledonia.

ACKNOWLEDGEMENTS

The Republic of Palau's Division of Marine Resources (MRD) initiated this project and the South Pacific Commission (SPC) provided technical assistance. We especially thank Mr Noah Idechong, Chief of Marine Resources Division, for his support and review of this manuscript. Mr David Hamm of the U.S. National Marine Fisheries Service set up the initial data collection system for MRD. Many of the staff members, especially Ms Evelyn Oiterong, Mr Steven Patris, Mr Augusto Nauro and Mr Masubed Tkel, have spent hours measuring fish and inputting data.

CONTENTS

TABLES

FIGURES

INTRODUCTION

The Republic of Palau lies in the Western Pacific Ocean, between 131°-135°E and 2°-8°N, and forms the western boundary of Micronesia (Fig 1). Most of the islands that form the Palau Archipelago are fringed with coral reefs. To the west there is a barrier reef that extends in a north—south direction for about 440 km. Harvests of reef fish have a been a traditional source of animal protein for Palauans and continue to form a major component of the diet. A strong domestic demand for fish from the local population, the growing tourist and restaurant industry-has formed an additional market for the disposal of reef fish catches. Further, the growing demand for reef fish from overseas markets has led to the development of exports of reef fish to Guam and Saipan.

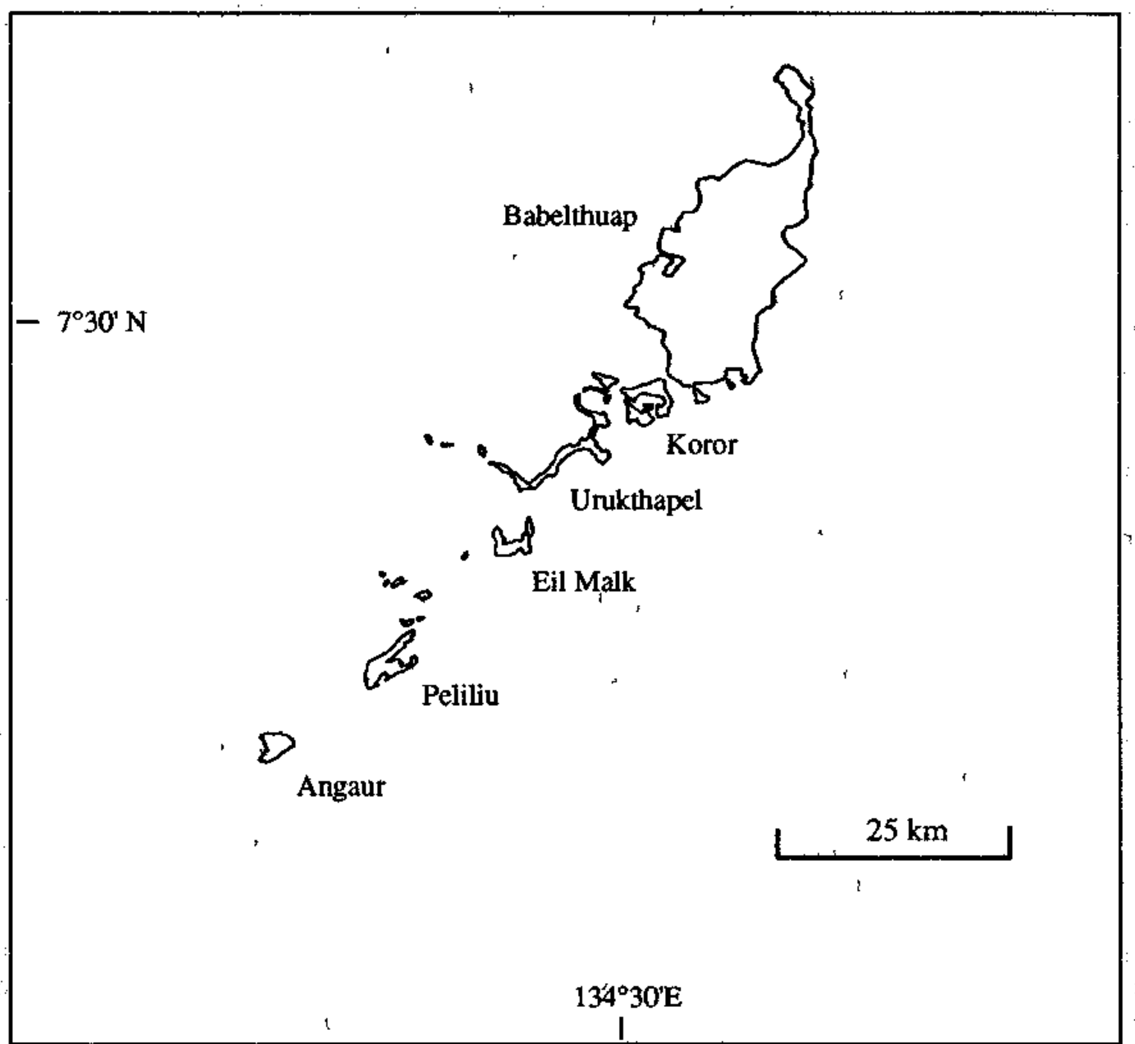

Figure 1. Map of the Palau Archipelago showing the major islands

Despite the importance of reef fish in the subsistence and domestic economies, there is relatively little written information on the, status of reef fish stocks in PaJau. The only documented stock assessment of an inshore species is a study on the small stolephorid anchovy, *Encrasicholina heteroloba* (= *Stolephorus heterolobus),* used for live bait by the now defunct pole-and-line fishery (Muller 1976). Some studies have been carried out on the biology of rabbitfish (Siganidae) in Palau (Drew 1973; May et al. 1974; Hasse et al. 1977), but these,have not addressed the question of the effects of exploitation on these or any other, reef fish populations.

Such limited information on inshore reef fish stocks is common throughout Micronesia and indeed in the rest of the tropical Pacific. Izumi (1988) presents a convenient summary of the published and unpublished documents concerning Palau's fisheries, including reef fish stocks. More recently Preston (1990) has reviewed most of the relevant information on inshore reef fisheries in Palau with the aim of formulating management proposals for the conservation of these stocks. Perhaps the most notable study of reef fisheries in Palau is the documentation during the 1970s of Palauans' rich heritage of traditional fisheries knowledge by R.E. Johannes in his book *Words of the Lagoon* (Johannes 1981). In the summaries of the principal target fishes in the inshore fishery, Johannes noted that Palauans expressed concern about the declining abundance of certain species.

Recently, Johannes (1991) carried out a short-term follow-up study of Palau's inshore fisheries and found that fishermen were still worried about the declining abundance of the same species reported in the earlier study. Preston (1990) recommended that a regular collection of length-frequency data be undertaken by the Palau Marine Resources Division to obtain estimates of growth and mortality parameters for the commonly exploited species, particularly those about which fishermen had expressed concern.

In this report, we present results of the analysis of length data collected between 1990 and 1991 and, where possible, make comparisons with length-frequency data collected during the early 1980s. The results were used in combination with a 14-year time series of commercial catch data to assess the status of the commonly exploited species and to make management recommendations for the conservation of these stocks.

METHODS

Fishing methods and data collection

Most catch and length-frequency data were collected at the Palau Federation of Fishing Associations (PFFA) fish market, located at Malakal on Koror. Catch and length-frequency data were also collected from several smaller markets. Data on landings at the PFFA have been recorded since 1976 through copies of receipts issued at each financial transaction. Species names are recorded in Palauan, along with the name of the fisherman landing the catch. Some species are grouped under a collective grouping, but most of the important catch components are recorded singly. Summaries of the PFFA data are included in this report to show the composition of the landings and the trends in the volumes landed. These data do not represent the total commercial catch but account for between 50 and 70 per cent of landings from commercial fishing.

Johannes (1981) has documented the different gears employed by Palauans to catch fish. The principal gears used by commercial fishermen are nets, spears, handlines and trolling lines. The most common net-fishing method employed by commercial fishermen is the V-shaped stationary barrier net, known locally as **kesokes.** The **kesokes** is set on the reef flat to catch fish as they move into deeper water during the tidal ebb. Mesh sizes employed to construct **kesokes** are variable but fishermen landing catches into PFFA reportedly use 2.5 inch (6.35 cm) mesh net for the terminal portion of the kesokes.

Spearfishing underwater is common in Palau. Palauans make their own spear-guns rather than buying expensive commercially manufactured models. Two types of spear-gun are manufactured: a short model (0.75—1.0 m) used predominantly for night fishing in shallow water and a longer model (2.0—2.5 m) for fishing during the day in deeper water. Spearfishing is normally practised with snorkels but recently, some fishermen have taken to using SCUBA gear to extend the range of fishing into depths beyond those accessible to free diving.

Handline fishing is carried out with monofilament nylon fishing lines (18—23 kg breaking strain) wound onto home-made reels or a piece of wood. Hook sizes commonly employed for handlining are Mustad

Nos. 5, 6 and 7. Baits employed for handline fishing include tuna, squid, octopus, sardines and sea cucumber.

Length-frequency analysis

Length data on 44 reef fish species were collected at the PFFA fish market between February 1990 and April 1991. Lengths were measured to the nearest 0.1 cm from the snout tip to the caudal fork, except for fish with a rounded or truncate tail, for which total length was recorded. Length frequencies were then aggregated on a monthly basis in 1.0, 2.0 or 5.0 cm length classes, depending on the species and the maximum size attained.

Length-frequency data were analysed with the ELEFAN suite of programs (Pauly 1987) to determine growth, mortality and recruitment parameters, and to compute relative yield-per-recruit estimates for different sizes at recruitment to the fishery.

The following protocol was adopted using the ELEFAN approach. Growth in Palauan reef fish was assumed to conform to the von Bertalanffy growth function (VGBF) which takes the form for growth in length of:

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

L_t - LSI - e^)

where L_μ is the asymptotic length, K is a growth coefficient, Lt is length at time t and t_o is the origin of the growth curve.

Weatherall (1986) showed that the asymptotic length, L_μ, can be determined from length-frequency data by plotting the mean lengths (L_m) of a successive series of partially overlapping subsamples against the minimum cutoff length of each length class (L_c). Pauly (1986) suggested a modification of this method where L_m — L_c was plotted on L_c. This gives a descending line with an intercept on the ordinate equivalent to L_μ. This modification of Weatherall's method is incorporated into the ELEFAN suite within the ELEFAN II program.

The asymptotic length for each species set considered here was estimated from the application of Weatherall's method to the length-frequency data. These were used as inputs into the computer ELEFAN I along with values of K for the same or similar species taken from the literature. The program ELEFAN I will fit a growth curve to restructured sequential length-frequency data by iteration given seeded values of L_μ and K. The restructuring of the length-frequency data is achieved by the use of a simple high-pass filter or running average described by Pauly & David (1981).

After growth parameters had been estimated, the values of L_μ, and K were used to convert the length classes to relative ages and the summed frequencies to length-converted catch-curves. The descending slope of the right-hand limb of these catch-curves takes the form:

$$Log_e(Ni/\Delta t) = a + bt$$

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

This routine is a function of ELEFAN II. An estimate of the natural mortality rate (M) is also computed in the same routine from the empirical equation of Pauly (1980):

$$Log_{10}M = -0.0066 - Log_{10}L_{\mu} + 0.6543Log_{10}K + 0.4634Log_{10}T$$

where $L\mu$, and K are the parameters of the von Bertalanffy equation and T is the mean environmental temperature, here set at 28 ° C.

From the estimation of Z and M, ELEFAN II estimates the fishing mortality rate from:

$$F = Z - M$$

and the exploitation rate (E) from:

$$E = F/Z$$

Following the estimation of mortality rates from the length-converted catch-curve, the ascending limb can be used to generate a resultant curve which expresses the interaction of gear selection with recruitment. The slope of the descending limb of the catch-curve is projected backwards, accounting for the decrease in fishing mortality to zero at the smallest size-classes. This generates a series of expected frequencies for the length-classes prior to full recruitment. The ratio of the observed values of the left hand-limb of the catch curve to the expected values from the backward projection generates points that can then be used to construct a logistic ('S'—shaped) curve or ogive.

The probability of retention by the fishing gear becomes greater as fish size increases, up to the apex of the catch-curve, where 100 per cent of the fish are retained. The average length at first capture (L_c) or minimum capture length, is conventionally defined as the length at which 50 per cent of the fish are retained by the gear, and can be read off from the selection ogive. This procedure is performed automatically as a sub-routine of ELEFAN II.

The relative yield per recruit (YPR) (Beverton & Holt 1957) for each species was calculated for a range of L_c values to determine the optimum first capture length for each species. The optimum minimum first capture length is the size at which the relative yield per recruit is maximised. The relative yield per recruit was estimated from:

$$YPR = E(1 - c)^{M/K} \left\{ \frac{1 - 3(1 - c)}{1 + (1 - E)/(M/K)} + \frac{3(1 - c)^2}{1 + 2(1 - E)/(M/K)} - \frac{(1 - c)^2}{1 + 3(1 - E)/(M/K)} \right\}$$

where $c = Lc/L_{\mu}$. This model is a simplified version of the yield-per-recruit formulation developed by Beverton & Holt (1966),in which the only inputs for each species are c and M/K. This version of the model assumes a 'knife-edge selection' in which, above a certain critical length, all fish in a given stock are equally vulnerable to the fishing gear.

RESULTS

Length-frequency analysis

General

For eight reef species sufficient length-frequency data were available for estimation of growth parameters with ELEFAN I. A summary of monthly sample sizes for these is given in Appendix I, together with length data for the large parrotfish, *Bolbometopon muricatum* and the wrasse, *Cheilinus undulatus,* for which some analyses were also attempted. Although the samples for these species were rather small, declines in their catches after peak landings in the mid-1980s have prompted concerns about the conservation of these stocks. This is particularly important for *B. muricatum,* which accounted for about 10 per cent of the total landings at PFFA between 1976 and 1990. The wrasse, *C. undulatus,* has traditional social significance; it is considered to be the best quality fish in Palau and is served to clan chiefs during ritual gatherings.

Growth and mortality parameters

Estimates of growth and mortality rates generated from the application of ELEFAN I to the length-frequency data sets are summarised in Table 1. Estimates of L_{μ}, could be computed for *B. muricatum* and *C. undulatus,* but, as well as the fact that only a small sample was available, their size and probable growth rates make them unsuitable for use with ELEFAN I. Monthly growth increments in the length data are probably too small and for the larger size-classes, a small length range may contain a wide variety of different year-classes. Instead, an arbitrary value of K = 0.1 was used, which is comparable to the growth coefficient of similar large, slow-growing tropical demersal fish[3].

Table 1: Growth and mortality parameters for ten reef fish species caught by commercial fishing in Palau

Species	L_∞	K	Z	M	F	E
Bolbometopon muricatum	106.4	0.100	0.398	0.278	.0.120	0.302
Cheilinus undulatus	137.5	0.100	0.479	0.259	0.220	0.459
Hipposcarus longiceps	43.9	0.500	1.667	1.020	0.647	0.388
Lethrinus ramak	34.5	0.380	1.486	0.912	0.574	0.386
Lutjanus gibbus	39.8	0.400	1.144	0.906	0.238	0.208
Naso lituratus	35.1	0.350	1.683	0.860	0.823	0.489
Naso unicornis	57.0	0.140	0.683	0.413	0.270	0.395
Siganus argenteus	31.0	0.750	3.077	1.466	1.611	0.524
Siganus canaliculatus	28.1	1.950	5.717	2.816	2.901	0.507
Siganus lineatus	33.6	0.600	2.739	1.239	1.500	0.548

The length-converted catch-curves for the different reef fishes are shown in Figure 2. The exploitation rates of the different reef fishes ranged from a low of 0.2 for *L. gibbus* to 0.55 for *S. lineatus,* with a mean of 0.42. Gulland (1971) has suggested that when the fishing mortality rate is equivalent to the

3 Recent studies on the age and growth of *Cheilinus undulatus* from the Australian Great Barrier Reef (G. McPherson, Northern Fisheries Research Centre, Cairns, Australia, pers. comm.) and *Bolbometopon muricatum* from New Caledonia (Couture & Chauvet 1994) indicate life-spans for these fishes of about 25 years, with K values in the range 0.02-0.1.

natural mortality rate (F = M), a stock is optimally exploited or that E_{opt} = 0.5. More recently, Pauly (1984), based on Beddington & Cooke (1983), suggested a more conservative optimal exploitation rate, when the fishing mortality rate is 40 per cent of the natural mortality rate or E_{opl} = 0.3. From the exploitation rates reported here, most species would appear to be at or below the optimum fishing mortality defined by Gulland (1971) but above the optimum fishing mortality defined by Pauly (1984). Overall, the results suggest that reef fish stocks in Palau are at, or approaching, the optimum level of exploitation.

Optimum capture length and optimum mesh size

The first-capture length (L_c) at which the YPR was maximised and the actual length at first capture observed from the length-frequency data are given in Table 2. The YPR model predicts that yields will be maximised at lengths between 50 and 65 per cent of the asymptotic length. For *S. argenteus, L. ramak, H. longiceps,* and especially *C. undulatus,* the predicted optimum first-capture lengths are larger than the L_c values observed in the fishery.

The differences between the predicted and observed values for the siganids, emperor and parrotfish are small and suggest that raising the first capture length would have a minimal impact on yields. However, the difference in predicted and observed values is much higher for the wrasse and may have an impact on yields. Interestingly, the predicted optimum length at first capture for *N. unicornis* is much lower than found in the length-frequency data. This may be a consequence of the flat-topped catch curve (Figure 2) for this species and the concomitant difficulty in deciding the point at which fish are fully recruited to the fishery.

Table 2: Optimum minimum first-capture lengths from yieid-per-recruit analysis, observed minimum capture lengths, depth ratios, selection factors and optimum mesh sizes **for ten reef fish species in commercial fish landings in Palau**

Species	Optimum minimum first-capture length (cm)	Observed minimum first-capture length (cm)	Depth ratio	Selection factor	Predicted optimum mesh size (inches)
Bolbometopon muricatum	53.2	69.9	2.29	2.1	10.0
Cheilinus undulatus	68.8	48.9	2.30	2.0	13.5
Hipposcarus longiceps	26.3	25.5	2.57	2.2	4.7
Lethrinus ramak	18.3	17.3	2.70	2.2	3.3
Lutjanus gibbus	19.0	20.5	2.33	2.0	3.2
Naso lituivtus	19.3	21.3	2.02	1.9	3.9
Naso unicornis	28.5	42.3	2.22	2.0	5.0
Siganus argenteus	18.6	16.7	2.28	2.0	3.7
Siganus canaliculatus	21.8	24.1	2.43	2.2	3.9
Siganus lineatus	20.1	24.4	2.22	2.0	3.6

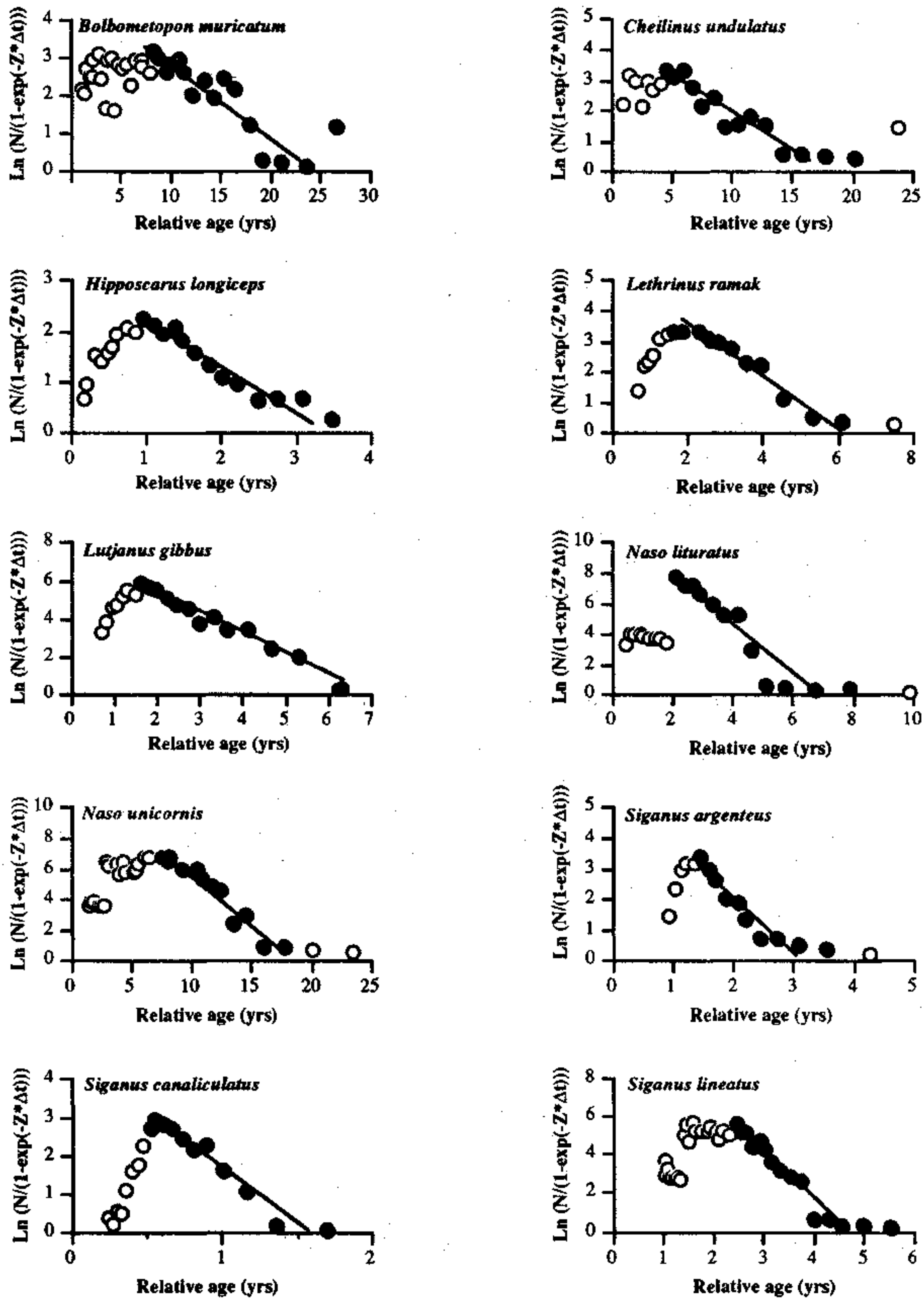

Figure 2. Length-converted catch-curves for ten species of reef fish caught by commercial fishing in Palau, 1990-1991. Open circles not used in calculating regressions.

This analysis can be taken beyond the generation of optimum average first-capture lengths if mesh selection factors are known. The optimum capture length is proportional to the mesh size of the net employed; the proportionality constant is called the selection factor (SF). When known, it can be used with the optimum capture length to estimate the mesh size that would generate L_c from:

***LJSF - mesh** size*

As no selectivity experiments have been carried out on **kesokes or** other types of fishing net at Palau, selection factors for the different species were estimated by the empirical graphical method of Pauly (1984) in which the depth ratio (standard length/maximum body depth) is estimated , and the selection factor can then be read from a curve or nomogram that relates SF to the depth ratio (see Chapter 3, Pauly 1984). Depth ratios for the species included in this study were estimated from measurements taken from taxonomic drawings, and these and the selection factors are included in Table 2.

From these figures the mesh size generating L_c, or optimum mesh size, was computed. This is shown in Table 2 (converted into inches, since mesh sizes of nets in Palau are measured in inches rather than centimetres). The optimum mesh sizes predicted for the large parrotfish, *B. muricatum* and the wrasse, *C. undulatus,* are naturally very large, given the maximum sizes of these species. However, these species are generally captured by spearfishing rather than nets. For the eight smaller species, the optimum mesh sizes ranged from 3.2 to 5.0 inches, with a simple mean of 3.9 inches. Computation of a weighted mean based on the relative contribution of each species to the annual commercial catch yields the same figure.

Comparison of contemporary length frequencies with historical data

The length data collected between 1990 and 1991 were compared with data collected for the same species between 1982 and 1984 (Appendix II). As the samples for each year were generally small, the data for the three earlier years were pooled to form a single length-frequency distribution. These data and the more recent data sets were converted into percentages for direct comparison (Figure 3). There was very little difference between the two sets of length data in mean lengths for the different species, although it should be stressed that, on average, the earlier samples are about only one third to one quarter the size of the contemporary samples.

Landings

Commercial landings

The mean percentage composition by family taxon of the PFFA landings data between 1976 and 1990 is given in Table 3. It is based on annual data contained in Appendix III. No data were available for 1982, the first three months of 1983 or the last three months of 1987. About 76 per cent of the landings (1976—1990) are from six families: the Scaridae (parrotfish), Acanthuridae (surgeonfish), Lethrinidae (emperors) -Lutjanidae (snappers), Siganidae (rabbitfish)) and Serranidae (groupers). The top ten species in the PFFA landings (1976—1990) are shown in Figure 4. They account for 67 per cent of the total. Unfortunately, the records for groupers at the PFFA are separated only to the generic level, i.e. *Epinephelus* spp. and *Plectropomus* spp. Based on observations during 1990 and 1991 by the senior author, the dominant groupers landed at PFFA are *Epinephelus microdon, E. fuscoguttatus* and *Plectropomus areolatus.*

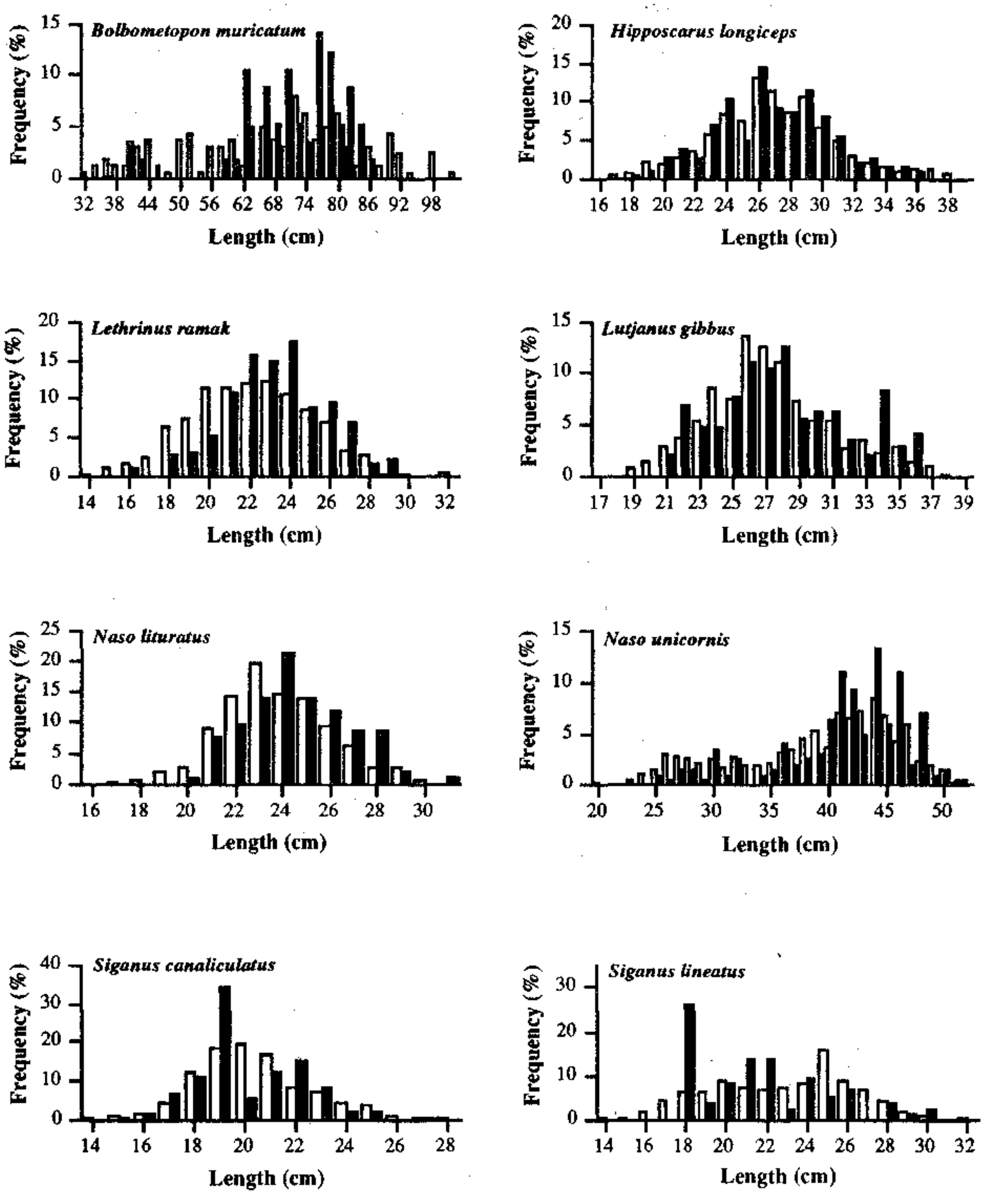

Figure 3. Length-frequency data for eight reef fish species captured by commercial fishing in Palau, 1982-1984 (•) and 1990-1991 (•)

Table 3: Composition of commercial reef fish landings at PFFA between 1976 and 1990.

Family	Percentage composition		
	1976-1983	**1984-1990**	**1976-1990**
Acanthuridae	14.12	12.88	13.66
Carangidae	2.63	4.01	3.57
Gerridae	0.73	0.24	0.44
Haemulidae	0.23	0.13	0.20
Holocentridae	0.39	0.13	0.21
Labridae	1.03	0.78	0.92
Lethrinidae	11.93	13.87	13.52
Lutjanidae	8.54	13.53	11.99
Mugilidae	1.93	0.53	1.06
Mullidae	1.01	1.16	1.09
Scaridae	16.29	18.68	17.88
Serranidae	9.09	9.25	9.05
Siganidae	11.55	10.48	10.35
Others	20.52	14.32	16.05

Annual landings at PFFA (1976—1990) are shown in Figure 5. Annual landings at PFFA have ranged from 62 to 287 tonnes, with an average of 144.5 tons. They showed a tendancy to increase between 1976 and 1985, followed by a decline between 1986 and 1990. (Figure 5). The annual patterns of landings for snappers (Lutjanidae), emperors (Lethrinidae), parrotfish (Scaridae), jacks (Carangidae), groupers (Serranidae) and surgeonfish (Acanthuridae) show broadly similar trends to the total landed volume, with a major peak in the mid-1980s and a smaller peak between 1979 and 1980.

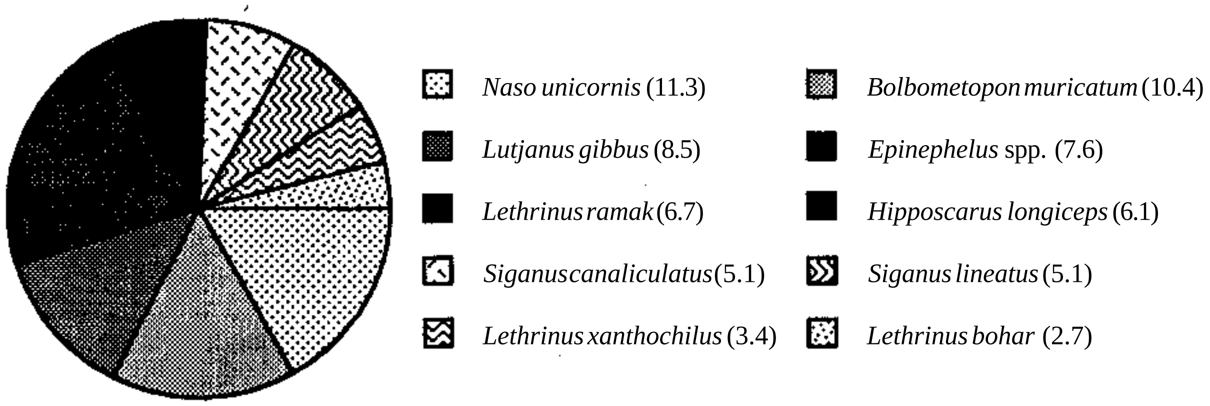

Figure 4. The ten commonest species in the commercial reef fish landings in Palau, 1976-1990

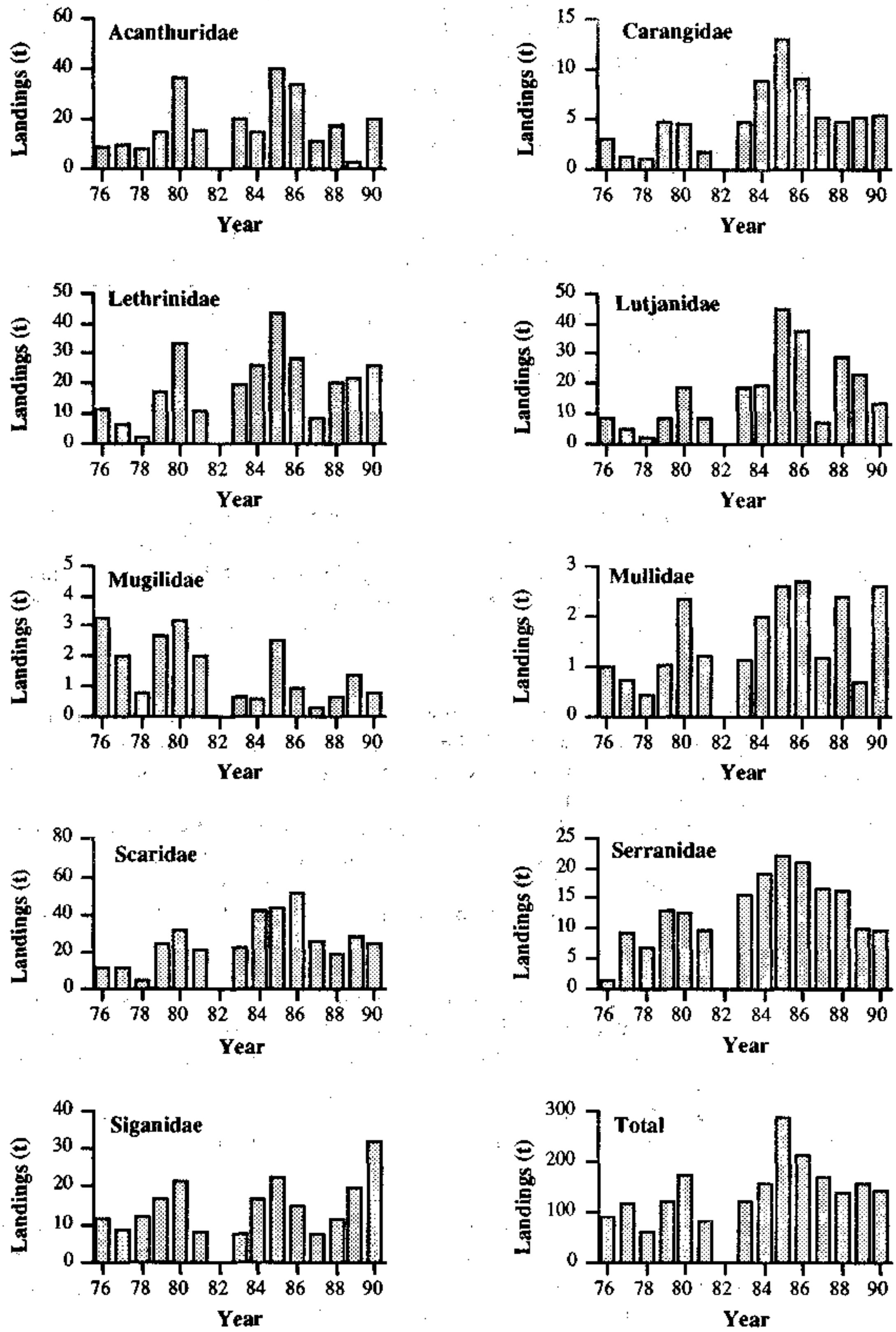

Figure 5. Annual landings at PFFA of reef fish caught by commercial fishermen, 1976-1990

The composition of the reef fish catch landed at PFFA between 1976 and 1990 has remained more or less constant. The average composition of the landings in the first part (1976—1983) of this 15-year period is very similar to the composition between 1984 and 1990 (Table 3). Johannes (1991) lists those species of fish perceived by Palauan fishermen to be getting scarcer. They include *Herklotsichthys quadrimaculatus, Crenimugil crenilabis, Plectropomus* spp., *Epinephelus* spp., *Siganus canaliculatus, S. lineatus, Bolbometopon muricatum, Cheilinus undulatus, Naso lituratus* and *N. unicornis.* The herring, *Herklotsichthys quadrimaculatus,* is not harvested commercially, but data on landings are available for all the other species (Appendix IV).

Commercial landings of *Crenimugil crenilabis* have undergone a long-term decline from the onset of the 1980s (Figure 6). Other species, such as *Naso unicornis, Epinephelus* spp., *Chelinus undulatus* and *Bolbometopon muricatum,* have shown more recent declines in landed volume after pronounced peaks in landings during the mid-1980s (Figure 5). By contrast, landings *of Siganus canaliculatus, S. lineatus, Plectropomus* spp and *N. lituratus* have shown an opposite trend, with increased volumes landed towards the end of the 1980s and at the start of the next decade.

Subsistence catches

Initial estimates of subsistence fisheries production were given by Perron et al. (1983). They were based on a household survey carried out by MRD in 1975, which included questions on the amount offish consumed per week. From these data Perron et al. estimated that the average annual per capita consumption of fish in Palau was 141 kg. The total population of Palau in 1990 was estimated at 14,291. Using this figure, the per capita fish consumption translates to a total production of about 2,015 t/yr.

Sampson (1986) and Preston (1990) have both commented that the per capita consumption quoted by Perron et al. is too high. Sampson suggested 50 kg as a more reasonable estimate. This converts to a total production rate of 715 t/yr. A further adjustment to account for bones, scales and internal organs not consumed, which form about a third of the fish body-weight (Johannes 1981), results in an estimated subsistence production of 1074 t/yr. Preston quotes estimates offish consumption from other Pacific islands that range from 19 to 34 kg/person/yr, with a mean of 22.7 kg. For Palau, this converts to a total subsistence consumption of 325 t/yr, equivalent to a fish wet weight of 488 t/yr. Subsistence fisheries production in Palau could therefore be within the range of 488 to 1074 t/yr, averaging 780 t/yr.

Given the uncertainty surrounding these production estimates, it is probably most realistic to suggest that the subsistence fisheries production for Palau may lie somewhere between 500 and 1100 t/yr. Not all of this production is reef fish. Tuna and other large pelagic fish are caught by trolling on the open sea, away from the reef. The expense of fuel and lures probably prevents the large pelagic fishery being an important source of subsistence production. Troll fishing is thought to be more of a recreational pastime, limited mainly to weekends. However, seasonal tuna runs do provide large landings in close proximity to the reefs.

Palauan men and women harvest a variety of fishes and invertebrates from the nearshore reef areas. Matthews and Oiterong (1991) investigated the role of women in the subsistence production of Palau. They found that, in some instances, women were the major providers of animal protein to their households. However, the quantities involved and the proportion of the total subsistence catch harvested by women remain unknown at present.

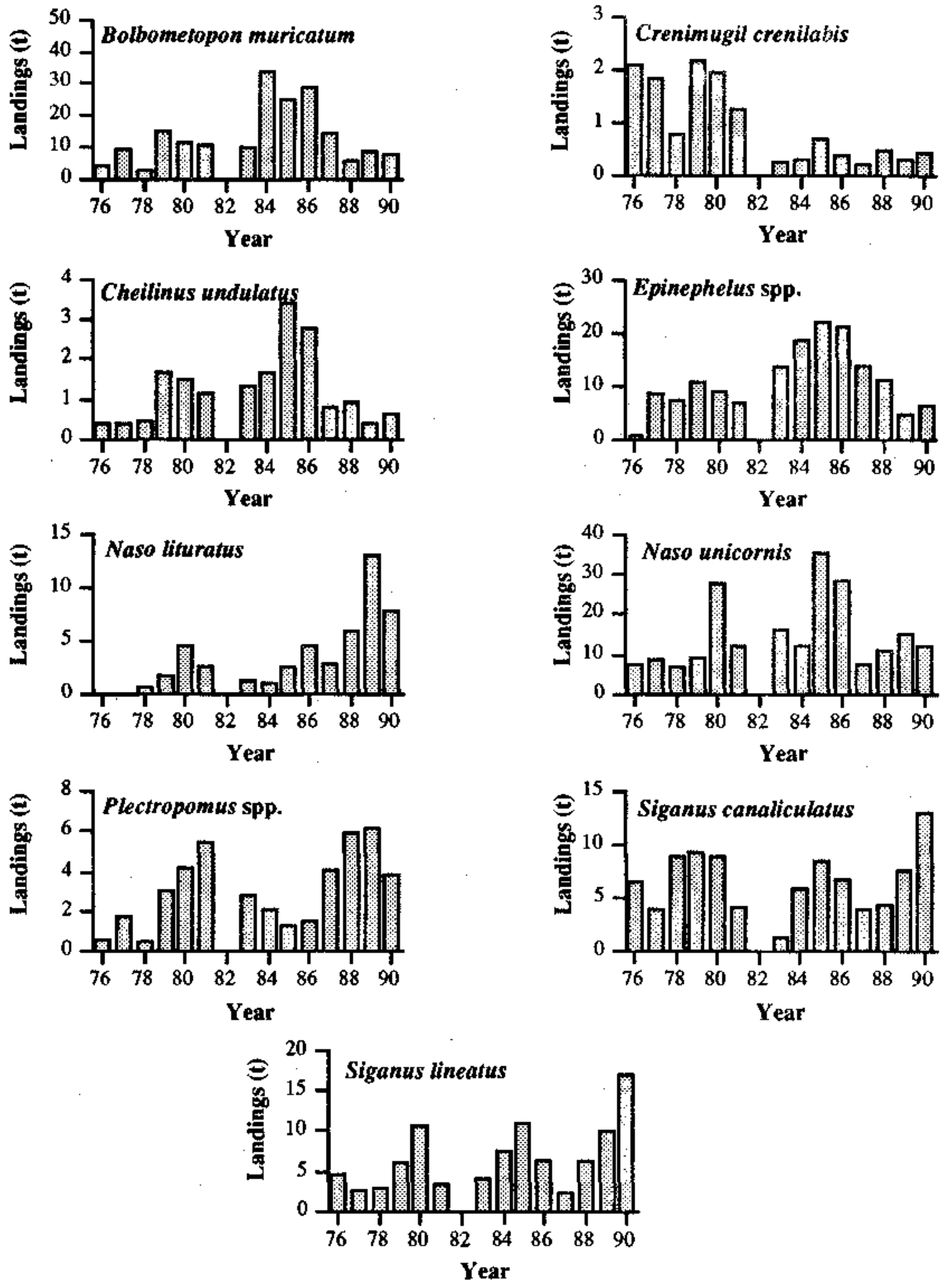

Figure 6. Annual landings at PFFA of selected reef fish species, 1976-1990

DISCUSSION

In this report, we have tried to present a contemporary account of the present status of reef fish resources in Palau and suggest ways in which this information can be used to manage the fishery. Length-frequency data collected over a period of one year were used to generate information on life-history parameters. Most of the length-frequency data was collected at one central location on Palau (PFFA), with about one third of landings coming mainly from Koror State (Anon 1991). Given the relatively small samples used for the length-frequency analysis, it was not possible to break down the data by location of capture and they were pooled for the whole of Palau.

Growth parameter estimates for all except two species in this study were generated from the application of ELEFAN I to length-frequency data. Many of the reef fisheries in Palau are seasonal, with bimodal peaks in spring and fall. There are several months in all but one data set where there are no samples. Sample sizes tend to be small; only the *Siganus canaliculatus* data set contained length measurements for over one thousand fish. Comparative estimates of growth parameters from elsewhere suggest that the results from the application of ELEFAN I are reasonable. However, apart from the rabbitfish, growth rates are slow and further studies may benefit from the application of more mathematically rigorous length-based analytical programs such as MULTIFAN (Fournier et al. 1990) or the MIXTURE routine (Macdonald & Pitcher 1979). A limited series of investigations might be carried out to determine whether otoliths or another skeletal structure would be suitable for ageing the important component species in the catch and provide supportive evidence for the length-frequency analysis.

A key assumption in the length-frequency analysis is that the length distributions are not biased from the effects of gear selectivity and that they represent the size-frequencies of the natural populations. Rabbitfish, surgeonfish, snappers, emperors and the parrotfish, *Hipposcarus longiceps*, are captured by kesokes. The groupers, however, while also captured in **kesokes** tend mainly to be taken by handline fishing. The large parrotfish, *Bolbometopon muricatum*, is caught almost exclusively by spear fishing. Large specimens of the wrasse, *Cheilinus undulatus*, are taken by spearfishing, and smaller specimens are captured both by spears and handlines. However, hook size can also exert some effect on the size ranges captured by handlines. Ralston (1982) observed the effect of hook selection on handline catches of snappers and groupers from Hawaii and found that small hooks were almost as efficient as large hooks for catching large fish. Ralston suggested that hook selectivity is similar to the selection ogive or S-shaped curve observed for trawls and seines.

Selectivity of the kesokes is mainly a function of mesh size, particularly in the apex or 'cod-end' of the net. Pauly's (1984) empirical method for estimating selection factors is derived from trawl data and it is assumed here that mesh selectivity for the **kesokes** is similar to that of trawls, though it is a static rather than mobile gear. This assumption is probably reasonable given that the **kesoke** net simply acts as a barrier and fish are not snagged or 'gilled' as with a gillnet. The optimum lengths generated from the YPR model provide some guidelines on minimum sizes taken by the fishery and the possible consequences of catching fish at sizes smaller than the optimum. However, it should be clearly understood that these results are only as good as the data used to achieve them. Given the quality of the present data and the use of *ad hoc* or empirical methods, some judgement is necessary before using this information to frame conservation and regulatory legislation.

Further, the Palau reef fishery is a multispecies fishery and any minimum mesh size will have to be a compromise between the optimum first-capture lengths of the component species. In this study we have looked at only ten species taken in the Palau reef fishery. Anon (1991) lists eight further species that make significant contributions to commercial reef fish landings, and about 80 species in total that comprise the commercial fishery. Gross differences in size and hence in optimum capture length are evident even at the generic level, for example between *Lutjanus gibbus* (max. length ~ 45 cm) and *L. bohar* (max. length ~ 75 cm), and *Lethrinus ramak* (max. length ~ 34 cm) and *L. olivaceus* (= *miniatus*) (max. length ~ 100 cm). Attempts to determine the optimum mesh size for tropical multi-species trawl fisheries using a multi-species YPR approach have been made by Sainsbury (1984) and Silvestre (1986). These methods need more demanding data than were available for the present study. However, if sufficient data were available from the Palau fishery it might be possible to carry out an equivalent analysis for kesokes and other nets used to capture reef fish.

The analyses presented here for eight of the ten species in the reef fish catch indicate that optimum mesh sizes range from about 3.2 to 5.0 inches, with a mean of 3.9 inches. However, for five of these species *(Siganus lineatus, S. canaliculatus, Lutjanus gibbus, Naso unicornis* and *N. lituratus),* the optimum minimum capture length generated from YPR analysis is smaller than the minimum capture length presently observed in the fishery (Table 2). It would be prudent, therefore, to set an initial minimum mesh size of not less than three inches for the kesokes in Palau, with the option of increasing the size should this be warranted by the future performance of the fishery. We note that a three-inch mesh-size limit for kesokes, gill nets and seine nets has also been recommended by Johannes (1991), based on more generalised observations of fishing in Palau.

It should be clearly understood that optimum length generated from the YPR analysis is derived simply from the computation of the maximum relative yield for a combination of a given M/K ratio and length at entry into the fishery. Fish stocks are part of a complex biological system and factors such as the minimum spawning size and between-year variation in recruitment are not taken into consideration in the YPR analysis described above. The predicted maximum YPR may be achieved at biomass levels which are only a fraction of the original standing stock and where individual catches per unit of effort are correspondingly low. Regulation of fishing effort may also be necessary, to ensure that recruitment overfishing does not occur. Johannes (1991) has also recommended some limitation of effort in Palau in the form of closed seasons for rabbitfish and groupers, in tandem with mesh regulations.

If length-frequency data collection is to be continued, greater emphasis should be placed on the origin of landings when measurements are recorded. Although it appears from the foregoing discussion that selection effects may not be of critical importance for the analyses presented here, there are still some problems that need addressing. For example, the frequency distribution-for *Naso unicornis* is clearly biased towards larger individuals in the catch and has a relatively large minimum capture length. Similar uncertainty surrounds the size frequencies for *Cheilinus undulatus,* as handlines and spears may catch predominantly small and large specimens respectively.

Although the data on landings from PFFA extend over a 14-year period, they concern only commercial landings and represent about 50 per cent of total commercial production. The trends apparent in these data may be only partially indicative of the dynamics operating in the fishery as a whole. Only a few direct records of fishing effort have been made, so CPUE cannot be computed. The absence of direct measures of fishing effort also precludes observations on the effects of technological innovation on changes in fishing power. A good example of this is the use by spear fishermen of SCUBA gear, which permits them to stay underwater for longer periods and fish at greater depths.

It is important to stress here that the PFFA data extend only from 1976 to the present, representing only a fraction of the time that Palau's reef fish stocks have been exploited. The population of Palau before European contact was believed to be around 40,000—50,000 people (Semper 1873), who would presumably have a large demand for reef fish. Records from the period of the Japanese Administration of Palau for the years 1936—1938 report commercial harvests of reef fish of between 200 and 330 t annually (Izumi 1991 and pers. comm.), with landings possibly as high as 500 t in years prior to 1935. Further, Johannes (1991) comments that, following the end of World War II, fish stocks had been severely depleted to supply the large Japanese population in Palau and necessitated the introduction of customary regulation of fishing. Palau's shallow-reef fish stocks are thus far from being in a pristine or virgin state.

Estimation of contemporary yields from Palau's reefs must by necessity be speculative. Subsistence production is currently thought to lie between 500 and 1100 t/yr. Commercial reef fisheries production during 1990 was about 278 mt (Anon 1991) of which about 110 t was exported overseas. An unknown amount of fish is also exported as passenger luggage. Nominal fish production from Palau's coral reefs is therefore in the order of 750 to 1350 t/yr. Shallow reef (depth < 20 m in Palau) extends over an area of 450 km^2; the area of shallow lagoon is 1033.5 km^2. This gives a nominal yield of 1.7 to 3.0 $t/km^2/yr$ from the reef area, or a yield from reef and lagoon combined of 0.50 to 0.91 $t/km^2/yr$.

Munro & Williams (1986) and Russ (1991) have compiled information on yields of different reef fisheries from around the world. These range from a low yield of 0.42 $t/km^2/yr$ in northern Papua New Guinea to a high yield of 36.9 t/km^2 from a small island reef in the Philippines, with a mean yield of 7.7 $t/km^2/yr$ (95% CL = 3.0 $t/km^2/yr$). Caution must be exercised in making comparisons with other reef fishery yields. Yield is a function of fishing effort; low yields such as those in northern Papua New Guinea result from low levels of fishing effort in this location, and not from resource depletion. Secondly, the choice of area fished and maximum depth of fishing will greatly influence the magnitude of a yield from a given location.

Contemporary estimates of exploitation rates of the dominant species suggest that stocks are being moderately exploited, but this needs to be verified further by more rigorous sampling of landings. Anecdotal information collected by Johannes (1981, 1991) clearly suggests that fishermen are concerned with the scarcity of certain fishes but this is hard to quantify given the nature of the information. As a fishery approaches the point of optimum exploitation, the catch rates will fall by between one half and one third of their original levels, although catch volumes may approach a maximum (see references cited in Sparre et al. 1989). Such declines may be perceived by the fishermen as indications of overfishing, when in fact the fishery is at or approaching its most productive state.

Preston (1990) has recommended a programme of catch sampling and data acquisition for Palau's DMR to provide quantitative information for management. Part of this programme was instituted during 1990 and 1991 and has provided data for analysis here. This first year of data collection has permitted some preliminary conclusions about the status of Palau's reef fish stocks but is also indicative of the need to improve the quality of the data. If the present length-frequency data-sampling of commercial catches is to continue, there needs to be greater effort put into improving the quality of the data. Although the length data collected so far can be segregated by fishing grounds, the sample sizes are too small to be used for analysis. Greater numbers of fish will need to be measured to remedy this. Information also needs to be collected on the minimum spawning sizes of the dominant species in the commercial catch, for comparison with the optimum capture lengths suggested from the YPR analysis. These suggestions do not deviate from the programme outlined by Preston (1990), but focus on the technical aspects of data collection. Other approaches might be adopted to improve the quality of management information from biological sampling, particularly with respect to estimating age and growth rates for major component species in the catch.

The principal conclusions from this study are that Palau's reef fish stocks appear to be moderately to optimally exploited, although fishermen perceive declines in abundance of key species and are concerned about overfishing. Johannes (1991) has proposed a series of management measures based on interviews with fishermen and observations in Palau. These include the establishment of protected areas where species are known to form spawning aggregations, closed seasons on certain species that extend over part or all of the spawning season, and banning of spearfishing with SCUBA gear. Our findings reported here support Johannes' suggestion that a three-inch minimum mesh size for kesokes be introduced. In addition, it is suggested that a minimum commercial size limit of 70 cm be introduced on the wrasse, *Cheilinus undulatus,* and that exports of this species and the large parrotfish, *Bolbometopon muricatum,* be prohibited.

Finally, although we have made some estimate of the nominal fisheries production from Palau's coral reefs, this is necessarily speculative given the present status of data on landings. Some doubt has been cast on the magnitude of subsistence production estimated by Perron et al. (1983). Both stock assessment and management regulation or control on commercial reef fisheries must take into account the size of harvests from the subsistence fisheries, and the main target species of subsistence fishing. It is beyond the scope of this report to discuss this in detail here, except to note that contemporary information on subsistence harvests is required to present a complete picture of the scale of reef fish exploitation in Palau.

REFERENCES

Anon. 1991. 1990 Annual Report. Ministry of Natural Resources, Division of Marine Resources, Koror, Palau, 40 pp.

Beddington J.R. & J.G. Cooke. 1983. The potential yield of fish stocks. FAO Fisheries Technical Paper 242, 47 pp.

Beverton, R.J.H. & S.J. Holt. 1957. On the dynamics of exploited fish populations. Fisheries Investigations, Ministry of Agriculture Fisheries and Food of the United Kingdom, Series 2, (19), 533 pp.

Beverton, R.J.H. & S.J. Holt. 1966. Manual of methods for fish stock assessment. Part 2. Tables of yield functions. FAO Fisheries Technical Paper No. 38 (Rev. 1), 67 pp.

Couture, E. & C. Chauvet. 1994. Croissance du perroquet à bosse *(Bolbometopon muricatum)* et son exploitation en Nouvelle-Calédonie. Information Paper No. 4, 25th Regional Technical Meeting on Fisheries, South Pacific Commission, Noumea, New Caledonia, 4 pp.

Drew, A. W. 1973. The comparative ecology of *Siganus lineatus* and *Siganus canaliculatus:* two fishes of the Palau Islands (Pisces: Siganidae). Master's thesis, Northern Illinois University, 46 pp.

Fournier, D.A., J.R. Siebert, J. Majkowski & J. Hampton. 1990. MULTIFAN: a likelihood based method for estimating growth parameters and age composition from multiple length-frequency data sets, illustrated by using data from southern bluefin tuna *(Thunnus maccoyi)*. Canadian Journal of Fisheries and Aquatic Sciences. 47, 301—317.

Gulland, J.A. 1971. The potential yield of fish stocks. Fishing News Books, Surrey, England, 425 pp.

Hasse, J.J., B.B. Madraisau & J.P. McVey. 1977. Some aspects of the life history of *Siganus canaliculatus* (Park) (Pisces: Siganidae) in Palau. Micronesica 13(2), 297—312.

Izumi, M. 1988. Palau Marine Resources Bibliography. FAO/UNDP Regional Fishery Support Programme, Document 88/2, 243 pp.

Izumi, M. 1991. Bibliographic survey in Micronesia. Fisheries Newsletter, South Pacific Commission. Noumea, 59, 2—4.

Johannes, R.E. 1981. Words of the lagoon. University of California Press, Berkeley, 245 pp.

Johannes, R.E. 1991. Some suggested management initiatives in Palau's nearshore fisheries, and the relevance of traditional management. Consultancy Report, Marine Resources Division, Palau and South Pacific Commission, Noumea, New Caledonia.

Macdonald, P.D.M. & T.J. Pitcher. 1979. Age groups from size frequency data: a versatile and efficient method of analyzing distribution mixtures. Journal of the Fisheries Research Board of Canada, 36, 1066-1072.

Matthews E. & E. Oiterong 1991. The role of women in the fisheries of Palau. Marine Resources Division Technical Report 91.10, 72 pp.

May R.C., D. Popper & J.P. McVey. 1974. Rearing and larval development of *Siganus canaliculatus* (Park) (Pisces: Siganidae). Micronesica 10 (2), 285-298.

Muller, R. 1976. Population biology of *Stolephorus heterolobus* (Pisces : Engraulidae) from Palau, Western Caroline Islands. Ph.D. thesis, University of Hawaii, 174 pp.

Munro, J.L. & **D.M.** Williams .1986. Assessment and management of coral reef fisheries: biological, environmental and social aspects. Proceedings of the Fifth International Coral Reef Congress, Tahiti, May & June 1975, Vol 5, 545-581.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil International pour 1' Exploration de la Mer. 39, 175-192.

Pauly, D. 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Studies & Reviews, 8, ICLARM, Manila, 325 pp.

Pauly, D. 1986. On improving operation and use of the ELEFAN programmes. Part II. Improving the estimation of L,. Fishbyte 4 (1), 18-20.

Pauly. D. 1987. A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates. ICLARM Conference Proceedings 13, 7—34.

Pauly, D. & N. David. 1981. A BASIC programme for the objective extraction of growth parameters from length-frequency data. Meeresforschung (Reports on Marine Research), 28 (4), 205—211.

Pauly, D. & J.L. Munro. 1984. Once more on the comparison of growth in fish and invertebrates. Fishbyte 2 (1), 21.

Pauly, D. & M. Soriano. 1986. Some practical extensions to Beverton & Holt's relative yield-per-recruit model. In J.L. Maclean, L. Dizon & L. Hosillos (eds.) The First Asian Fisheries Forum. Asian Fisheries Society, Manila, 491—495.

Perron, F.E., A.M. Nauro & S.J. Patris. 1983. The Palau reef fish production study: a baseline study of the commercial reef fishing industry in Palau and a blueprint for the development of a permanent fisheries management system. Division of Marine Resources, Koror, 117 pp.

Preston, G. 1990. Inshore fishery resource management in Palau. South Pacific Commission, Inshore Fisheries Research Project, mimeo, pag. var.

Ralston, S. 1982. Influence of hook size in the Hawaiian deep-sea handline fishery. Canadian Journal of Fisheries and Aquatic Sciences 39, 1297—1302.

Russ, G. 1991. Coral reef fisheries: effects and yields. In P.F. Sale (ed.) The ecology of fishes on coral reefs. Academic Press, London, 601—637.

Sainsbury, K.J. 1984. Optimal mesh size for tropical multispecies trawl fisheries. Journal du Conseil International pour 1' Exploration de la Mer, 41, 129—139.

Sampson, E. 1986. The fisheries sector in Palau. Direction for policy, project development and external assistance. FAO South Pacific Regional Fisheries Development Programmeme, RAS/85/004, 57 pp.

Semper, K. 1873. Die Palau-Inseln im Stillen Ozean. Leipzig.

Silvestre, G.T. 1986. Assessment of the multispecies demersal stock of the Samar Sea. University of the Philippines, Department of Marine Fisheries, Technical Report No. 7. 65 pp.

P. Sparre, E. Ursin & S. Venema. 1989. Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper No. 306.1, 337 pp.

Weatherall, J.A. 1986. A new method for estimating growth and mortality parameters from length-frequency data. Fishbyte 4(1), 12—15.

APPENDICES

Appendix I

MONTHLY LENGTH-FREQUENCY DATA FOR SELECTED REEF FISH FROM PALAU, 1990-1991

Bolbometopon muricatum

	Sampling date						
Length class (cm)	**15/4/90**	**15/5/90**	**15/9/90**	**15/10/90**	**15/12/90**	**15/5/90**	**Total**
32				1			1
34				1			1
36				2	1		3
38					2		2
40			2				2
42				2	3		5
44	1			1	4		6
46		1	1				2
48					1		1
50			3		3		6
52		1	3	1	2		7
54			1				1
56		1			1	3	5
58	1		1			3	5
60	1	3			1	1	6
62		2					2
64	1	3				4	8
66	1	4			1	2	8
68	2	3		1			6
70	1	4					5
72	1	12					13
74	2	6		2			10
76		4		2			6
78		7		1			8
80	1	7		1	1		10
82	1	4					5
84	1	1					2
86		5					5
88	1	1					2
90	2	4			1		7
92	1	3					4
94	1						1
96							0
98		1			3		4
100							
102	1						
Total	20	77	11	15	24	13	159

Cheilinus undulatus

Length class (cm)	Sampling date									
	15/4/90	15/5/90	15/7/90	15/9/90	15/10/90	15/12/90	15/5/91	15/8/91	15/9/91	Total
20				1		1				2
25			1	2	10					13
30	1		1		5					7
35	1					1				2
40	2				1	2		6		11
45			2	1	1	1			2	7
50	1	1			1	1		3	2	9
55		1	9	1	1	1	5	3	2	23
60	2	1	8	1				3	2	17
65	3	3	11				6	1	2	26
70	3		1		1		2	1	1	9
75		1	2							3
80		1	1				2		1	5
85		1								1
90		1								1
95			2							2
100	1		2							3
105										0
110										0
115	1									1
120										0
125			2							2
130										0
135			1							1
Total	15	10	43	6	20	7	15	17	12	145

Hipposcarus longiceps

	Sampling date							
Length class (cm)	**15/3/90**	**15/4/90**	**15/8/90**	**15/9/90**	**15/10/90**	**15/11/90**	**15/12/90**	**Total**
								0
19	2							2
20	4							4
21	9	1					2	12
22	3	1	1	1	2		2	10
23	2	3		3	1		6	15
24	1	2	2	3	7	1	3	19
25	1	6	2	12	3		5	29
26		4	4	14	11	1	12	46
27	2	8	2	15	8	4	4	43
28	8	14	3	27	3	1	11	67
29	14	18	1	10	9	1	8	61
30	9	13	1	7	10	1	5	46
31	3	30		3	10		9	55
32	3	21		4	5		2	35
33	3	13		1	6		3	26
34	1	3	2	1	3		6	16
35	3	5			1		2	11
36		6	1	1			1	9
37		4					1	5
38		7						7
39		3					4	7
40		2			1		1	4
41								0
42								0
43								0
44							1	1
Total	68	164	19	102	80	9	88	530

Lethrinus ramak

	Sampling date							
Length (cm)	**15/3/90**	**15/4/90**	**15/5/90**	**15/9/90**	**15/10/90**	**15/12/90**	**15/2/91**	**Total**
16							1	1
17							5	5
18	4						4	8
19	8						4	12
20	8	11		3	7		3	32
21	0	6		18	9	1	3	37
22	4	12	2	20	15	4		57
23	1	12	6	10	13	10	4	56
24	0		7	7	25	18	2	59
25	1	15	9	10	14	10	1	60
26	1	2	7	10	10	22		52
27	1	3	8	5	13	13		43
28	1	2	6	6	5	14		34
29		1	3	1	3	6		14
30				8	4	2		14
31	1							1
32			1					1
33								0
34			2					2
Total	:10	64	51	98	118	100	27	488

Lutjanus gibbus

	Sampling date										
Length class (cm)	**15/4/90**	**15/5/90**	**15/8/90**	**15/9/90**	**15/10/90**	**15/11/90**	**15/12/90**	**15/4/91**	**15/5/91**	**15/7/91**	**Total**
19					4						4
20					3		4				7
21		1		2	6		6				15
22		1		2	7	2	5		3		20
23	2	4	1	1	9	1	6	1	2	2	29
24	4	6	3	10	13			1	1	7	45
25	4	6	1	11	6	2	1	2		7	40
26	8	14	3	10	13	4	7	3	5	5	72
27	10	6	4	13	13	3	1	1	5	10	66
28	8	7	1	18	9		4		4	7	58
29	4	1	1	12	6		3	1	7	3	38
30	2	7		9			1	4	1	4	28
31	1	6	1	5	1		5	2		7	28
32	2	3	1	6				1		1	14
33	2		1	9	2		1			4	19
34	1	4		6	1						12
35	1	1		2			3	2		6	15
36				2	2					3	7
37			1					2		2	5
38										1	1
Total	49	67	18	118	95	12	47	20	28	69	523

Naso lituratus

Length class (cm)	15/3/90	15/4/90	15/9/90	15/10/90	15/12/90	15/2/91	Total
13			1				1
14							0
15							0
16							0
17						1	1
18			1	2			3
19				5	4		9
20	2	2	1	4	2		11
21	3	15	4	8	8		38
22	5	25	6	9	15	1	61
23	4	44	4	19	9	3	83
24	2	35	6	13	5	1	62
25	3	31	4	11	6	4	59
26		26	2	9	0	2	39
27		19		6	2		27
28		4		7	1		12
29		3		7		2	12
30				2			2
31							0
32							0
33							0
34							0
35		1					1
Total	19	205	29	102	52	14	421

Naso unicornis

Length class (cm)	Sampling date 15/3/90	15/4/90	15/5/90	15/12/90	15/1/91	15/4/91	15/8/91	15/9/91	Total
20		1							1
21									0
22									0
23				3					3
24				6					6
25				9					9
26	1			16	1				18
27	2	2		9	4				17
28	1	3		9	3				16
29	1	3		7	2				13
30		3		10	2				15
31	1	3		6				1	11
32		9		6	1			1	17
33	2	4		1		2	1	1	11
34		8		1		1		1	11
35	3	4		1		1	3	5	17
36	1	7		5		1		2	16
37	5	3		5		2	3	4	22
38	3	9		4		3	4	12	35
39	5	6	1	1		5	2	5	25
40	4	7		2		2	2	8	25
41	3	17	2	2	2	5	3	6	40
42		16	3		1	3	10	13	46
43	1	8	3	2	1	5	10	13	43
44		10	3	2	1	7	15	8	46
45		7	3	6	2	5	9	8	40
46		3	2	1	1	3	8	9	27
47				3	3	7	13	1	27
48				2	3	1	7	2	15
49					1	5	3	1	10
50				1		4	3		8
51						1			1
52							3		3
53									0
54									0
55									0
56					1				1
Total	33	133	17	120	29	63	99	101	595

Siganus argenteus

Length class (cm)	Sampling date 15/2/90	15/4/90	15/7/90	15/10/90	15/11/90	15/12/90	Total
15						0	0
16	1	1				2	4
17	5	2	0	1		8	16
18	7	6	1	4		13	31
19	8	9	2	15	1	14	49
20	10	10	4	23	2	17	66
21	6	12	4	26	9	10	67
22	3	7	5	32	14	6	67
23	1	4	3	19	15	2	44
24	1	1	2	10	19	1	34
25	0	1	1	3	11	0	16
26	0	1	0	3	6	0	10
27	0	0	0	1	2	0	3
28	0	0	0	1	2	0	3
29	0	0	0	1	1	0	2
30	0	0	1	2	0	0	3
Total	42	54	23	141	82	73	415

Siganuscanaliculatus

Length class (cm)	Sampling date										
	15/2/90	15/3/90	15/4/90	15/7/90	15/9/90	15/10/90	15/12/90	15/1/91	15/3/91	15/4/91	Total
95		1									1
10.0		0								1	1
10.5		0									0
11.0		0		1							1
11.5		0									0
12.0		0									0
12.5		1	2								3
13.0		1	1								2
13.5		0	1								1
14.0		4	0						1		5
14.5		4	1					3	2		10
15.0		8	0					1	2		11
15.5	3	5	1	1		1		1	4		16
16.0	0	4	1					1	7	1	14
16.5	0	13	1	1	2	2		5	12	5	41
17.0	1	3	3	2		1		7	14	13	44
17.5	1	21	10	4	5	19	2	11	9	12	94
18.0	0	5	5	9	3	13		12	9	23	79
18.5	3	18	14	14	11	11		9	13	40	133
19.0	0	6	4	12	3	9	4	4	8	39	89
19.5	2	28	18	11	8	13	2	8	11	37	138
20.0	0	8	3	6	5	8	1	13	3	49	96
20.5	3	28	24	10	4	8	5	21	2	41	146
21.0	0	2	3	1	4	4		8	2	31	55
21.5	1	15	10	1	1	4	4	14	1	14	65
22.0		0	3		5	3	3	9	1	12	36
22.5		5	7		1	2	2	9		22	48
23.0		1	1	2	1	1		5		7	18
23.5		1	1		1	1	2	4		9	19
24.0		1	0		1		1			9	12
24,5			1				1	1		13	16
25.0							1			14	15
25.5						1				5	6
26.0										7	7
26.5				1						2	3
27.0											0
27.5					1					3	4
Total	14	183	115	76	56	101	28	146	101	409	1229

Siganus lineatus

Length class (cm)	Sampling date 15/2/90	15/4/90	15/7/90	15/10/90	15/11/90	15/12/90	Total
14.5		2					2
15.0		1					1
15.5		2					2
16.0		0					0
16.5		1	2				3
17.0			5		1		6
17.5			9		2		11
18.0		2	3		2		7
18.5	3	5	7		2		17
19.0		3	1		5		9
19.5	3	7	4		3	1	18
20.0		1	1		7		9
20.5	4	10	2		7		23
21.0		6		1	7	1	15
21.5		7			8		15
22.0		5		1	10		16
22.5	1	8		3	7		19
23.0		4		4	2		10
23.5		11		5	2		18
24.0		4		8			12
24.5	1	7		8		5	21
25.0		3		9		2	14
25.5	1	11		22		4	38
26.0		5		18		4	27
26.5	1	10		13		1	25
27.0		3		8		2	13
27.5		3		7		2	12
28.0		5		9		2	16
28.5	1	4		6		1	12
29.0		1		6			7
29.5		1		3			4
30.0		1		3			4
30.5		2		2			4
31.0							0
31.5							0
32.0							0
32.5							0
33.0		1		1			2
Total	15	136	34	137	65	25	412

Appendix II

LENGTH-FREQUENCY DATA FOR SELECTED REEF FISH SPECIES IN PALAU, 1982-1984

Length class (cm)	*B. muricatum*	*H. longiceps*	*L. gibbus*	*L. ramak*	*N. lituratus*	*N. unicornis*	*S. canaliculatus*	*S. lineatus*
8								
9								
10								
11								
12								
13								
14								
15							1	
16							2	
17							10	
18				2			17	19
19							52	3
20		1		5	1		8	6
21		2	3	6	7		19	10
22		5	10	10	9		23	10
23		7	7	21	13		13	2
24		5	7	30	20		3	7
25		13	11	28	13	2	3	4
26		19	16	33	11	1		5
27		9	15	17	8	3	1	
28		27	18	18	8	3		3
29		17	8	13	2	1		1
30		16	9	3		7		2
31		21	9	4	1	2		
32		15	5			5		
33		10	3			0		
34		4	12			2		
35		5	4			3		
36		3	6			8		
37		3				4		
38		2				5		
39						6		
40	2					13		
41						22		
42	1					19		
43						10		
44						27		
45						12		
46						22		
47						4		
48						14		
49						2		
50						3		
51						1		
52								
53								
54								
55								
56								
57								
58	1							
59								
60	1							

Length class (cm)	*B. muricatum*	*H. longiceps*	*L. gibbus*	*L. ramak*	*N. lituratus*	*N. unicornis*	*S. canaliadatus*	*S. lineatus*
61								
62	6							
63								
64								
65								
66	5							
67								
68	3							
69								
70	6							
71								
72	3							
73								
74	2							
75								
76	8							
77								
78	7							
79								
80	3							
81								
82	5							
83								
84	3							
85								
86	1							
87								
88								
89								
90								
91								
92								
93								
94								
95								
96								
97								
98								
99								
100								
101								
102								
Total	57	184	143	190	93	201	152	72

Appendix III

ANNUAL LANDINGS OF REEF FISH TO THE PFFA FISH MARKET, 1976-1990[1]

	Year													
Family	76	77	78	79	80	81	83	84	85	86	87	88	89	90
Acanthuridae	8.27	8.95	7.91	14.62	36.17	15.42	20.16	14.96	39.97	33.89	10.79	16.89	2.78	19.91
Carangidae	3.01	1.28	0.98	4.65	4.52	1.59	4.82	8.95	12.98	9.10	5.08	4.64	5.22	5.32
Gerridae	2.01	0.88	0.09	1.22	0.72	0.43	0.10	029	1.74	0.39	0.0	0.21	0.46	0.29
Haemulidae	0.00	0.04	0.15	0.41	0.59	0.15	0.56	0.55	1.47	0.06	0.00	0.00	0.00	0.00
Holocentridae	0.03	0.12	0.01	0.27	0.13	1.58	0.39	0.66	0.53	0.39	0.02	0.00	0.03	0.13
Labridae	0.57	0.42	0.44	1.74	1.53	1.17	2.11	1.69	3.46	2.75	0.79	0.91	0.41	0.64
Lethrinidae	11.37	6.12	1.87	17.08	33.13	10.83	19.21	25.76	42.95	28.12	8.67	20.41	21.86	25.95
Lutjanidae	8.33	4.57	1.77	8.56	18.56	8.33	18.84	19.07	44.98	37.4	7.08	28.49	23.10	13.24
Mugilidae	3.24	2.02	0.80	2.65	3.16	1.98	0.61	0.59	2.52	0.92	0.2	0.62	1.39	0.75
Mullidae	1.01	0.74	0.43	1.03	2.32	1.21	1.11	1.98	2.59	2.68	1.17	2.39	0.67	2.61
Scaridae	11.41	11.67	5.49	24.60	31.18	21.14	21.81	42.01	43.61	51.6	25.33	19.15	28.24	24.18
Serranidae	1.54	9.16	6.96	12.88	12.63	9.59	15.49	19.23	21.98	20.91	16.52	16.07	10.23	9.71
Siganidae	11.53	8.66	11.91	16.60	21.03	7.76	7.22	16.64	22.67	15.20	7.1	11.72	19.64	31.51
Others	29.68	62.47	22.78	14.02	5.60	0.62	6.53	3.67	45.64	8.15	85.46	16.44	15.07	8.14
Total	92.32	117.09	61.58	120.32	171.28	81.79	118.95	156.06	287.08	211.65	168.39	137.94	154.11	142.38

1. No data are available on 1982 landings.

Appendix IV

ANNUAL LANDINGS OF SELECTED REEF FISH SPECIES TO PFFA FISH MARKET, 1976-1990[1]

Year	16	77	78	79	80	81	83	84	85	86	87	88	89	90
Bolbometopon muricatum	4.02	9.43	2.45	15.15	11.27	10.77	10.25	33.65	25.23	28.93	14.26	5.57	8.69	7.47
Cheilinus undulatus	0.37	0.42	0.44	1.65	1.5	1.17	1.33	1.65	3.41	2.75	0.79	0.91	0.41	0.64
Crenimugil crenilabis	2.07	1.83	0.77	2.15	1.93	1.25	0.23	0.28	0.7	0.37	0.2	0.45	0.28	0.42
Epinephelus spp.	0.85	8.52	7.39	10.8	9.09	6.82	13.64	18.75	22.16	21.02	13.64	11.36	4.55	6.25
Naso lituratus	0.02	0.01	0.56	1.79	4.47	2.53	1.34	0.98	2.48	4.6	2.76	5.92	13.04	7.81
Naso unicomis	7.68	8.56	6.74	8.98	27.4	11.79	16.04	11.98	35.28	28.38	7.52	10.77	14.72	12.01
Plectropomus spp.	0.63	1.69	0.42	2.96	4.23	5.5	2.75	2.11	1.2	1.48	4.02	5.92	6.13	3.8
Siganus canaliculatus	6.54	3.91	9.05	9.44	8.96	4.29	1.28	5.9	8.61	6.81	3.93	4.35	7.77	13.17
Siganus lineatus	4.52	2.67	2.84	6.11	10.6	3.33	3.88	7.48	10.9	6.25	2.12	6.24	10.05	16.99

1. No data are available on 1982 landings.