THE BIOLOGY, COMMUNITY STRUCTURE, GROWTH AND ARTISANAL CATCH OF PARROTFISHES OF AMERICAN SAMOA

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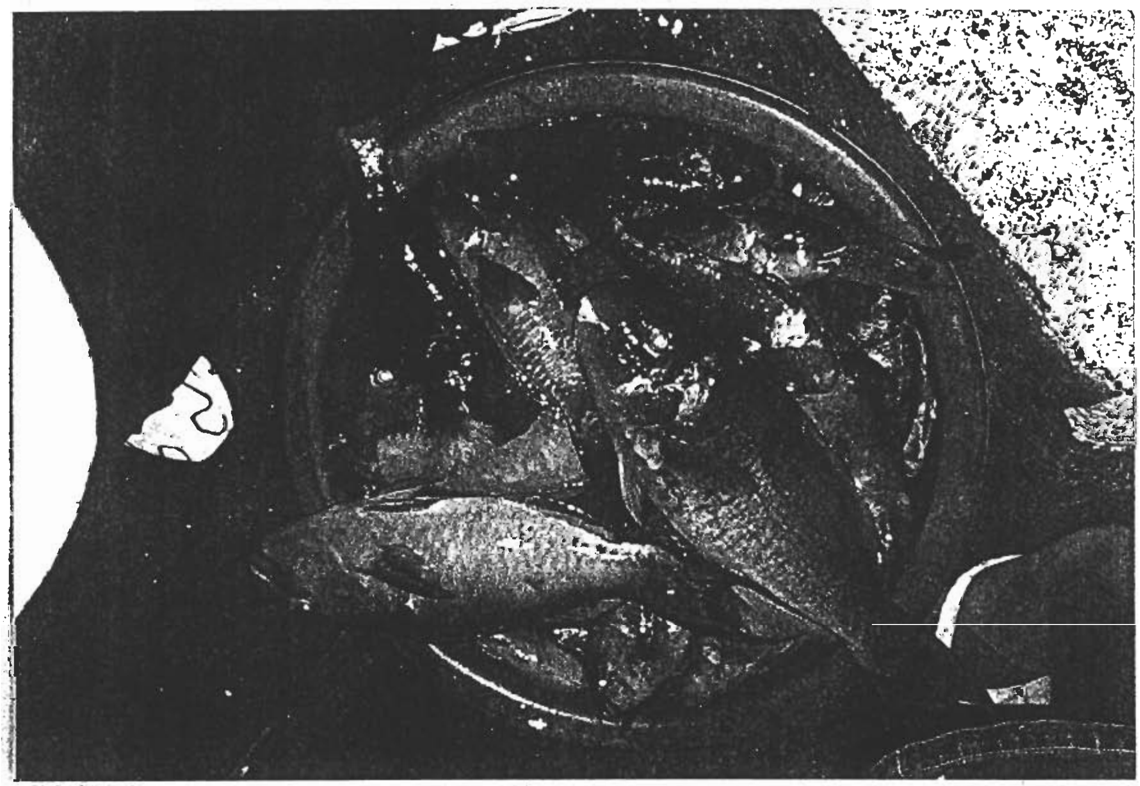
July 1998



Parrotfish caught by artisanal nighttime spear fishermen.

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SUMMARY

Analysis of catch statistics, growth data, fisheries models, and reproductive data suggests that populations of parrotfish in American Samoa may be threatened from over-fishing. Higher fishing pressure due to the introduction of SCUBA methods is likely to have increased exploitation rates of some species close to or beyond maximum sustainable yield (MSY). Given that;

- the mean size of large species of parrotfishes may be declining;
- the total estimated annual yield is close to MSY for the entire parrotfish stock;
- some parrotfish species may be over exploited;
- large, slow growing species are being caught before they reach sexual maturity;
- that SCUBA spearfishing accounts for up to an estimated 89% of the total annual yield,

it is recommendation of this study that the use of SCUBA spearfishing be outlawed.

MANAGEMENT RECOMMEDATIONS

1. SCUBA fishing should cease as soon as possible. Free diving should be allowed to continue, and does provide fishermen with a way to make a living. Banning SCUBA fishing may reduce boat-based diving activities due to the cost of chartering, and this should reduce illegal fishing in the many less accessible areas within the National Park boundary.

2. Artisanal catches should be monitored for effort, catch per unit effort (CPUE), and length-frequencies of key reef species such as surgeonfishes, parrotfishes and groupers. The inshore subsistence fishery survey should be re-established as estimates of exploitation are reliant on estimates of the total yield of the fishery.

Furthermore, a time series of inshore subsistence data provides a basis for analysis of relative changes in CPUE.

3 Market activities should be centralized, at present data collection is extremely difficult due to the fragmented nature of the market fishery. DMWR personnel are not able to measure all fish for sale in stores on any one day. If fishermen were required to sell or auction fish at a central market to retailers, then length-frequencies, weights and interviews could be obtained with less effort.

4. Shoreline development, reclamation, dredging or practices that affect water quality in lagoons should be actively discouraged, as these areas are important nursery grounds for juvenile parrotfishes.

5. DMWR should promote and assist with the identification, and implementation of village-based marine protected areas for yield enhancement and scientific research.

INTRODUCTION

American Samoa is located in the tropical South Pacific Ocean at 14°S, 171°W. Tutuila is the largest of the five islands in the territory with a population of 59, 600 in 1997 (D.P.O. statistics). This island is surrounded by a narrow fringing reef and has few lagoons (Fig. 1). The south coast is exposed to trade winds for approximately half the year, and the north coast is subject to swells and wind generated from tropical depressions during the wet season.

American Samoan tropical reef assemblages are characterized by a rich and diverse array of fish species (Wass, 1984, Ponwith, 1992). These fish resources have always been an integral component of Samoan culture and economy. The three types of fisheries that exist in American Samoa are for pelagic species, deep-water bottomfish, and inshore reef fish and invertebrates. Inshore fish comprise a significant proportion of the total catch. For example, the combined fisheries annual harvest in 1991 of 578,000 lb was valued at $993,000 (Craig et al., 1993), and inshore reef fish constituted 80% of the value of this resource. The artisanal and subsistence fisheries are two inter-related fisheries harvesting this resource. The principal methods employed by subsistence reef fishers are; gill netting, rod and reel, throw netting, handline, bamboo pole, gleaning and free diving. Surgeonfishes (Acanthuridae), parrotfishes (Scaridae), and groupers (Serranidae) together accounted for the greatest proportion of subsistence and artisanal catches (Saucerman, 1995).

As a result of a rapidly growing human population, fisheries in American Samoa are under increasing pressure from over-exploitation. Over four years the total estimated pounds of inshore reef fish caught decreased from 695,800 lb in 1991, to 191,600 lb in 1994, along with a decline in total CPUE (Saucerman, 1995). There has also been an up-scaling in fishing technology with the introduction of SCUBA into the artisanal fishery during.1994. A market survey initiated at this time found that a significant proportion of the total inshore fish catch was caught during the night, and sold in small stores around

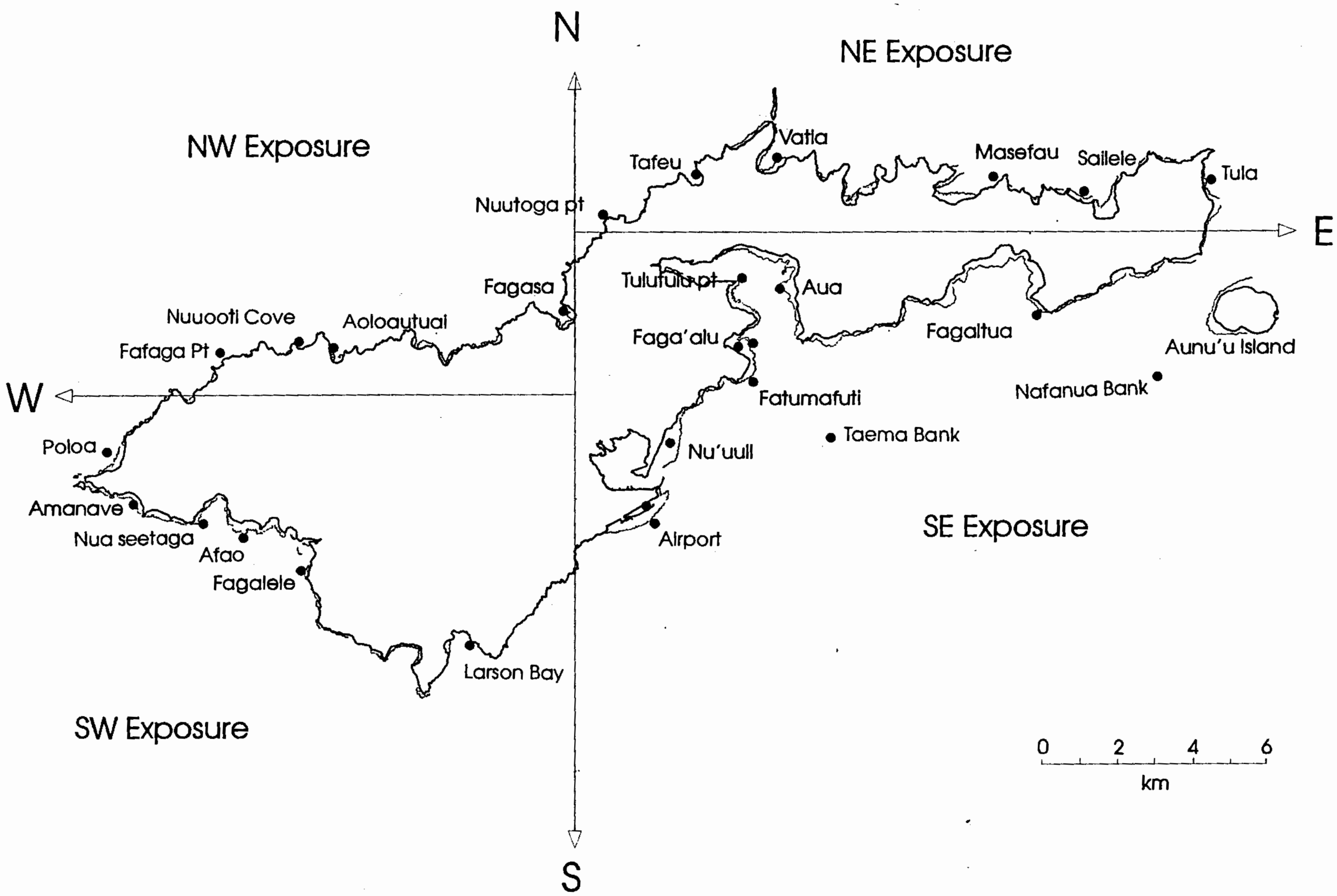

Figure 1. Map of Tutuila showing approximate location of survey sites.

the island. Surgeonfishes and parrotfishes and were the most important families by weight in SCUBA catches (Saucerman, 1995).

Parrotfish and surgeonfishes sleep in refuges at night, which makes them vulnerable (especially the brightly colored terminal phase male scarids) to spearfishers. Introduction of SCUBA technology is making the problem worse by allowing fishermen to dive deeper for longer. They are able to catch fish that were previously afforded some sanctuary at depth. The practice of fishing at night is likely to have a significant effect on the inshore subsistence fishery. Therefore, before management decisions can be made and implemented, American Samoan fisheries managers need to compile biological data on key reef species that are important both economically and ecologically

Herbivores such as surgeonfishes and parrotfishes have been demonstrated to be important in structuring coral reef ecosystems (Brock, 1979; McClanahan, 1995; Hart et al., 1996). Depletion in numbers of these fishes can result in increased filamentous algal production, with a simultaneous decrease in coral and coraline algal recruitment vital to the survival of the coral reefs. Samoan reefs must recover from such events as hurricanes, an *Acanthaster* (Crown-of-Thorns starfish) infestation, and increased sediment loading and pollution due to human activities. Therefore, the potential depletion of key reef fishes should be given serious attention.

The primary objective of this project was to determine the biology, distribution, abundance and life history of parrotfish, a key reef species in American Samoa, and to quantify the impact of fishing pressure on this key reef species. To achieve this objective this study was divided into the following three sections;

1) to characterize the scarid community using visual counts. Size estimates and counts were used to determine relative species abundance, size-frequency and biomass representative sites around Tutuila. This information was used to identify species

assemblages, variation in fish distribution with depth and location, and to estimate total standing stock.

2) to monitor inshore catches from the nighttime spear fishery. Analysis of data from this section of the study was used to estimate catch-per-unit-effort (CPUE) for SCUBA vrs free-diving methods, relative abundance of species in fisheries catches, length frequencies, changes in mean size through time and total catch estimates.

3) To collect biological information on parrotfish by sampling fish at regular intervals throughout the year from selected sites on the reef. Data from this study was used to determine size-at-maturity, spawning seasonality, age structure and mortality.

METHODS & MATERIALS

A. COMMUNITY CHARACTERISTICS

Characterization of the parrotfish community

Visual counts and size estimates were used to calculate the density, biomass, and species composition of parrotfishes on Tutuila. A total of 26 sites were chosen to be representative of SE, SW, NE & NW exposures (Fig. 1). These sites were divided into 3 main habitat categories; reef fronts (of varying exposure), offshore banks, and lagoons. Three depths of 3, 10 and 20m were sampled where possible within each site (transects were run at 20m on offshore banks and 3m in lagoons). Parrotfishes were counted using visual census techniques along five replicate 50 x 5m transects at each depth within each site, a total of 2500 m^2 per depth. Transect lengths were measured consecutively, and all counts were made by a single observer to reduce bias. These methods were modified from Green (1996) by increasing the belt transect width from 3 to 5m in order to yield a larger sample size of the large mobile scarids. Since surveys were performed at all times throughout the year, juveniles of less than 7 cm were excluded from the data set to reduce bias associated minimum length (Bellwood & Alcala, 1988).

For each site fish density was converted to biomass for each species using length-weight constants following the function;

$$W(i) = q*L(i)^b$$

The constants were derived for each species from market survey data of spear fishermen's catches (Appendix I).

Parrotfish species richness, density, and biomass were then compared among sites and between habitats using 2-way Analysis of Variance. Transformations to normalize data were carried out where appropriate. Cluster analysis was carried out on fish density (number of fish per hectare) following methods outlined in Field et. al. (1982). A dendrogram was used to identify sites with similar species assemblages.

Calculation of total reef area and estimate of total standing stock

The total reef area (km^2) from the reef crest was measured from scanned images of the U.S. Geological Survey map "Marine Topography of Offshore Tutuila Island, Samoa" (MSG-85-022). The area between the reef crest and the 20m isobath for the whole of Tutuila and Aunu'u, and for the Airport, Nu'uuli and Faga'alu lagoons was calculated using CAS image analysis software (CID, Inc WA 98682-5703 USA). A square outline was applied to the chart and the X,Y axes measured to compensate for any distortion. The area of the square calculated from the chart was compared to the area calculated from the software to cross-check for measurement error.

Total biomass estimates from a number of transects were averaged to give a mean total parrotfish biomass for each site. The mean of these site totals was then multiplied by the total reef area to calculate total standing stock of parrotfishes for Tutuila Island.

B. CATCH CHARACTERISTICS

Biological characteristics of the catch

Parrotfishes in spearfish catches were measured at stores over 17 months by DMWR personnel from October 1996 to June 1998. All species were identified following scientific nomenclature of genus/species (italicized). Fish were also indexed by Samoan names and common names, see Appendix II. Intensive sampling was carried out over three periods of four to six week each Feb/Mar 1997; Sept/Oct 1997 and May 1998, to determine if any changes occurred in mean size and catch per unit effort (CPUE) for the duration of the study.

Due to the fragmented nature of the market, 3 major stores were targeted the majority of the time in order to maximize the number of interviews and fish weighed. Other smaller stores were visited periodically (3 stores). Parrotfish were identified to species, their fork length (cm) was measured to the nearest mm, and weight was recorded to the nearest 5 grams, as they were emptied from the store owner's scales. Species composition, relative abundance, length-frequencies and length-weight relationships were derived from this data.

Length-frequencies were calculated for 10 of the most abundant species (initial phase, female and male fish combined) in the catch for 3 sampling periods; February - March 1997 (2641 fish), September - October 1997 (2027 fish), and May 1998 (2074 fish). Length-frequencies for the remaining eight species were derived from the total catch. Length-weight constants were derived from a sub-sample of 3994 fish measured between October 1996 and September 1997 (appendix I). These constants were then used to back-calculate weights of individual fish for subsequent fish length measurements.

Where possible fishermen's catches were kept separate, and the fisherman were interviewed to determine method employed, effort, and approximate location fished. Methods were separated into free-diving and SCUBA diving and effort was determined for free divers by the number of hours they spent in the water. Effort was calculated for SCUBA divers by the number of tanks of air that they used (an assumption was made that an 80 cuft tank would last an experienced diver an hour for a dive that varied in depth from 20-80 ft).

An estimate of the total catch of scarids by artisanal spearfishermen over a 12 month period from January 1997 to January 1998 was made by calculating the mean number of SCUBA and freedivers and the average number of days fished per month. The total annual artisanal catch was then calculated following the formula;

Mean no. divers x mean no. hours fished/month x mean CPUE (method) x 12

C. BIOLOGICAL CHARACTERISTICS

Growth and mortality

Parrotfish were speared during the period October 1996 to April 1998 from varying locations around Tutuila, depending on weather and time of year. Fish were identified to species, weighed to the nearest gram and their fork lengths (FL) measured. Fork lengths were then converted to standard length (SL) for growth studies, assuming that SL was 84.5% of FL (Choat, pers. comm.). Sagittal otoliths were removed from the head of the fish, washed in water, then isopropanol, and placed in a 50°C oven to dry for 24hrs. They were then weighed to the nearest 0.0001 gm and otoliths from 359 fish were sent off-island to be read for growth increments following methods described for estimating age of scarids by Choat et al (1997). Growth data were fitted to the von Bertalanffy growth function (VBGF);

$$l_t = L_\infty[1\text{-exp.-}K(t\text{-}t_0)],$$

where l_t = length at age t,

L_∞ = asymptotic length,

K = growth coefficient,

t_0 = time when length should theoretically be zero.

Marquardt's algorithm was used to fit size-at-age date to the VBGF for non-seasonal growth (Gayanilo et. al., 1996).

Total mortality (Z) was estimated from length-converted catch curves (Pauly, 1983) and Beverton and Holt's (1956) relationship between mortality rate and mean length of fish in the catch:

$$Z = K * (L_\infty - \bar{L})/(L_\infty - L')$$

Where; L' = size above which the fish are fully recruited into the fishery, $\bar{L}$ = mean length of fish greater than L', and K = growth constant.

Natural mortality (M) was estimated using two empirical equations:

1) $\log M = -0.0152 - 0.279 \ln(L_\infty) + 0.6757 \ln(K) + 0.4687 \ln(T)$ (Pauly, 1980)

Where T is the average water temperature for 1997 (Pago Harbor - NOAA station) of 27.13 °C.

2) $\ln (M/K) = 0.30 \ln(T) - 0.22$ (Longhurst & Pauly, 1987)

* all calculations were run on FAO FiSat computer software (Gayanilo et al., 1996)

<u>Reproduction</u>

Gonads were removed from fish to determine sex and size-at-maturity. Gonads were scored visually according to methods used by Matsuura et. al. (1987) and West (1990) for males;

Maturity Stage	Macroscopic appearance
1 Immature	Testes barely visible as slender translucent cords.
2 Developing immature	Testes creamy red in appearance, slightly enlarged, recognizable as a testis.
3 Developing	testes creamy white and soft.
4 Mature	Testes greatly enlarged, and milt flows when fish is stripped.
5 Spent	Flaccid, empty, often bloodshot.

and females;

1 Immature	
2 Unyolked	
3 Yolked	Oocytes visible through ovary wall, translucent in appearance
4 Ripe	Oocytes visible through ovary wall, translucent in appearance
5 Spent	Flaccid empty, often bloodshot in appearance, containing a small number of remnant eggs

Seasonal spawning patterns were determined from monthly gonadal somatic index (GSI = 10^2 x gonad weight/whole body weight). Due to small sample sizes, all were pooled (n = 359).

<u>Age validation studies</u>

Fish were collected for tagging from the Airport lagoon using gill nets. Nets were set an hour before dusk as close as possible to *Acropora* thickets. A total of 12 live fish were removed from nets and transported in coolers with aerated seawater to the clam hatchery tanks at Fogagogo. The fish were measured to the nearest millimeter, and tagged with individually numbered T-bar anchor tags, inserted between the dorsal pterygiophores. Following a 2 week acclimatization period each fish was injected in the visceral cavity with a solution of oxytetracycline and saline with a dosage of 50 mg kg^{-1} body weight (McFarlane & Beamish, 1987). Dosage was calculated from length-weight relationships shown in appendix 1.

RESULTS

A. COMMUNITY CHARACTERISTICS

Characterization of the parrotfish population

A total of 3115 parrotfishes belonging to 18 species were counted from 26 locations around Tutuila Island (Fig. 1). Small species of parrotfishes were most abundant in visual surveys. *Scarus pyrrhurus* (appendix II) was the most common of the species recorded, followed by *Chlorurus sordidus*, *S. psittacus, S. forsteni*, and *Calotomus,* respectively (Fig. 2). *Scarus rubroviolaceous,* and *Chlorurus gibbus* were the most abundant large parrotfishes.

Cluster analysis of visual counts based on species density at each of 16 sites, divided sites into three groups at the 60% similarity level (Fig 3). Fagasa, Nuuooti Cove, Aoloau and Tafeu on the north coast clustered into group 1 (with the exception of Sailele) with dominant species *S. pyrrhurus*, *S. niger* and *S. forsteni*. *Chlorurus sordidus*, juvenile scarids and *S. spinus* were dominant groups from sites on the south side of the island which clustered into group 2. Group 3 was composed of sites close to the harbor entrance and lagoons. Unidentified juvenile scarids and sub-adult *C. sordidus* and *S. oviceps* were the dominant species in group 3. Lagoon sites appeared to have low species diversity in comparison to all other sites investigated (Fig. 4).

Scarid density varied significantly among depths on the reef front ($p < 0.001$, df = 2, 10; ANOVA). Density was highest at 3m and decreased with depth to 20m. Also, there were high densities of parrotfishes at lagoon and offshore bank sites (Fig. 5a). Biomass, however, varied little with depth on the reef front ($p = 0.081$, df = 2,10; ANOVA), and was similar to lagoon habitats (Fig. 5 b). Offshore banks had the greatest biomass of fish.

Fish density ($p < 0.001$, df = 20,132 ANOVA) and biomass ($p < 0.01$, df = 20, 132 ANOVA) varied significantly with site. Of the reef front sites, Fagalele, Fagiatua, Faga'alu and Nua seetaga had the highest density and biomass of scarids (Figs. 6 a,b). Larson Bay, and the offshore banks Taema and Nafanua had a high biomass, but low density of fish. Density and biomass in the lagoons varied widely, the airport lagoon had a very high density and biomass of fish, where Nu'uuli and Faga'alu lagoons had relatively high numbers of fish, but low biomass.

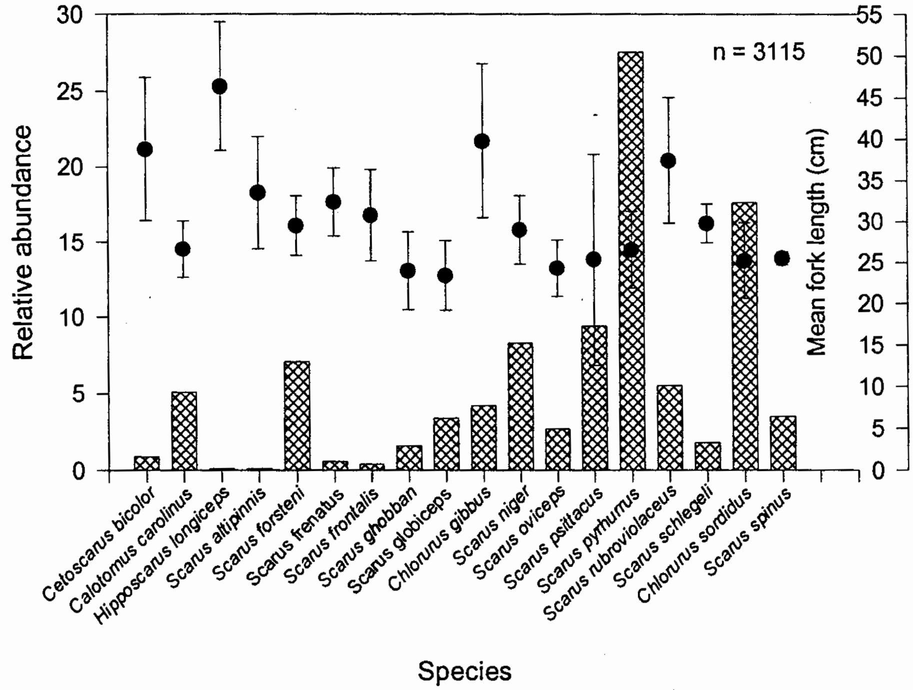

Figure 2. Relative abundance (excluding juveniles) and mean size (± 1 s.d.) of parrotfish counted at 26 sites on Tutuila island. Relative abundance is shown in bar graph and mean size is represented by points with error bars.

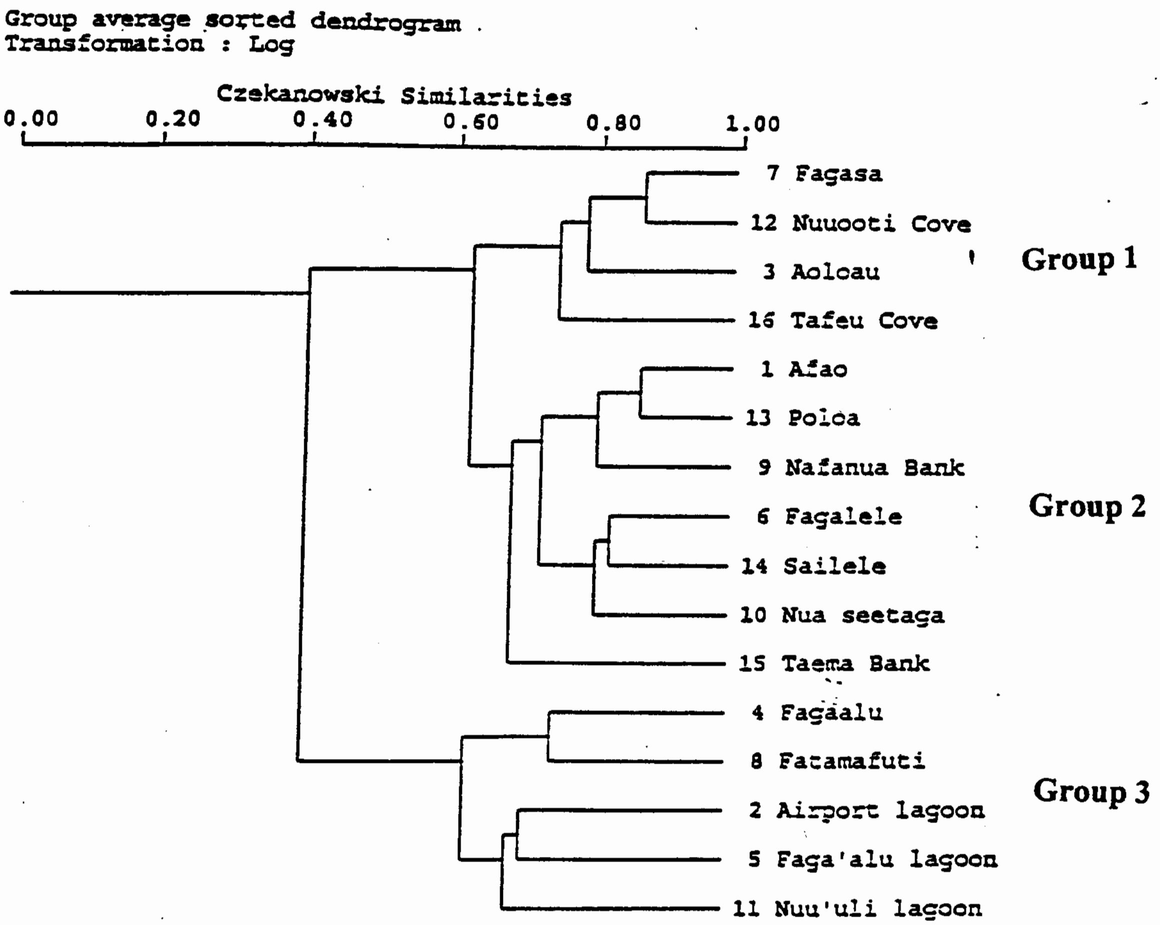

Figure 3. Numerical trellis diagram of % similarities and Chekanowski dendrogram from cluster analysis based on the density of each species at survey sites.

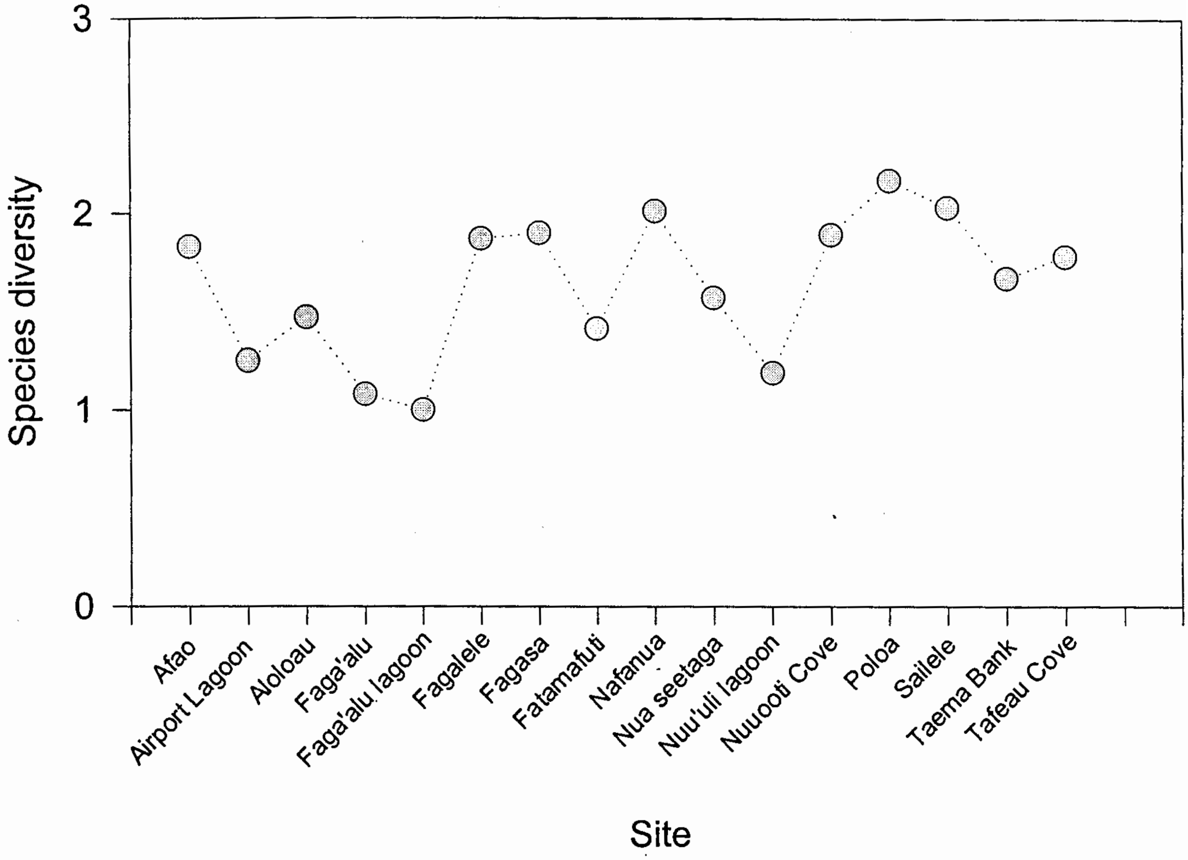

Figure 4. Parrotfish species diversity at 16 sites on Tutuila Island.

Estimate of Reef Area and Total Standing Biomass

The total reef area from the reef crest to 20m, including 3 major lagoons (Airport, Nuu'uli and Faga'alu) and offshore banks <20m depth was estimated to be 22.75 km^2. The total standing stock of scarids was estimated to be 189 ± 36.2 (95% C.I.) metric tons. This estimate was derived by expanding the mean biomass of site means (83.16 ± 15.9 $kg^{-1}ha^{-1}$) for the total reef area calculated above (refer appendix III for site means).

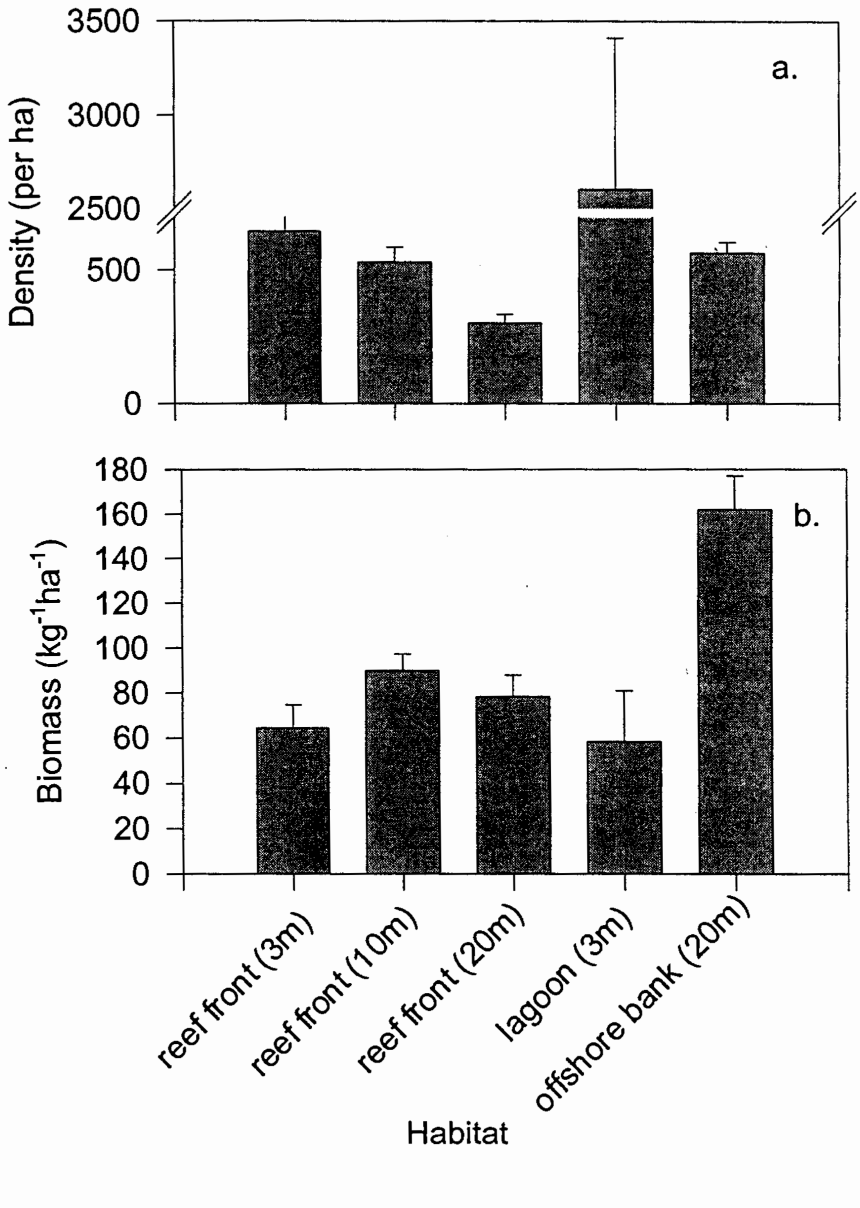

Figure 5a,b. Mean density and biomass (± 1 s.e.) of parrotfishes surveyed at three depths within 11 fringing reef sites, 3 lagoon sites, and 2 offshore banks.

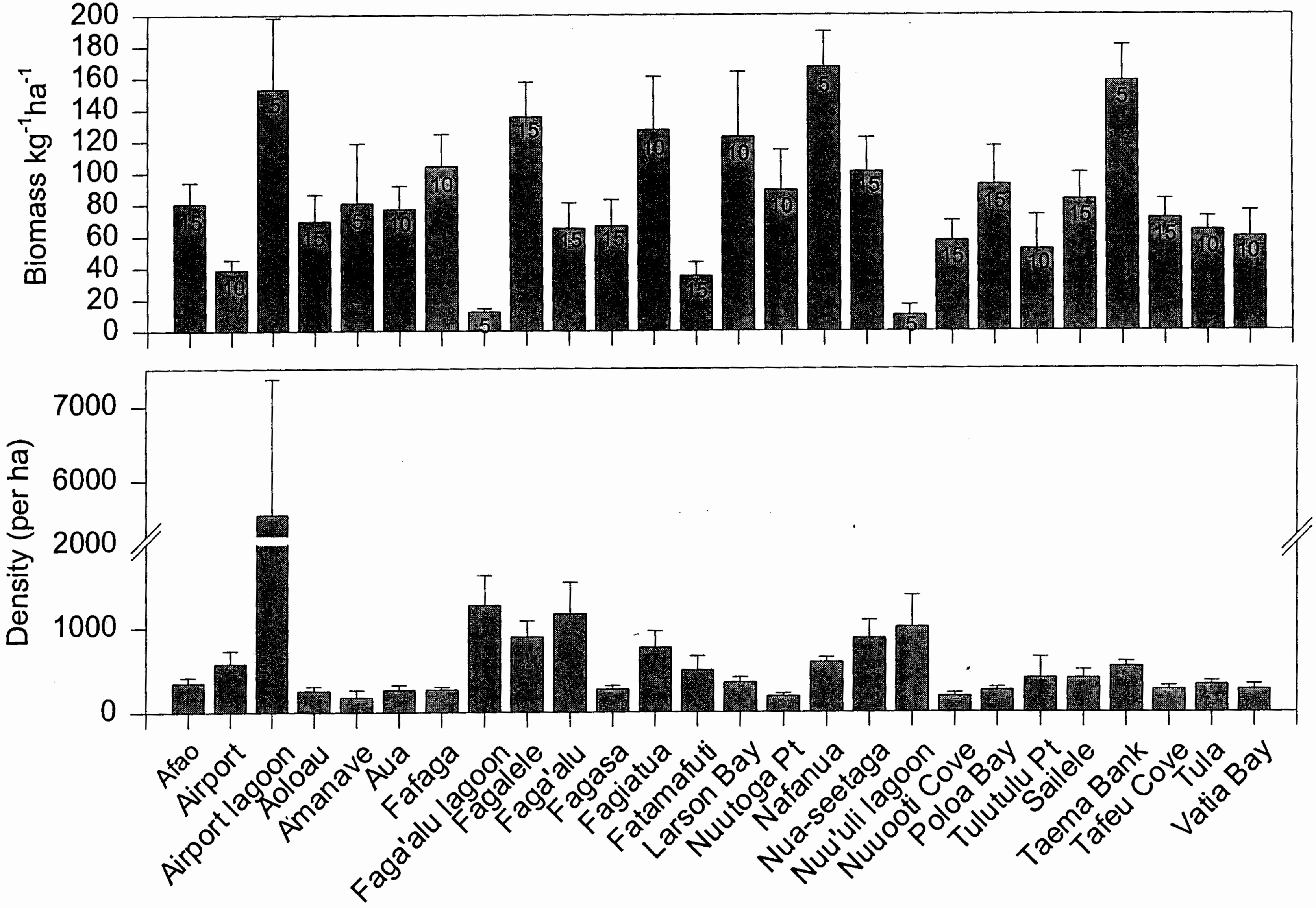

Figure 6a,b Mean biomass and density (± 1 s.e.) of parrotfish counted at 26 sites on Tutuila. Values on bars represent the number of transects run at each location.

B. CATCH CHARACTERISTICS

Biological Characteristics of the Catch

Species composition

A total of 7937 parrotfish were measured in the artisanal fishery during the period of this study. The most common species of parrotfish in spearfish catches was *Scarus pyrrhurus* followed by *S. rubroviolaceous*, *S. oviceps*, *S. forsteni*, *Chlorurus sordidus* (Fig. 7 , see appendix II for species identification). The species that grew to the largest maximum size in the fishery were *Hipposcarus longiceps* (58 cm), *Chlorurus gibbus* (56 cm), and *Scarus rubroviolaceous* (55 cm).

With the exception of *S. schlageli*, free divers caught all the same species as SCUBA fishermen. SCUBA spearfishers caught a greater proportion of *S. forsteni* and *S. pyrrhurus,* but proportionally fewer *Calotomus carolinus*, *S. frenatus, S. frontalis, S. ghobban* and *S. rubroviolaceous* (Fig. 8). The relative abundance of all species except *S. rubroviolaceous* varied little between surveys (Fig. 9).

Comparison of mean size of 7 of the most abundant scarid species over 15 months showed that there was no significant change in mean size of the small scarid species in the catch through time (Fig. 10). However, the mean size of the two species in the fishery that grow to a large size, *C. gibbus* and *S. rubroviolaceous*, decreased significantly ($P < .001$, 1-way ANOVA) from Feb/March 1997 to May 1998.

Effort/Catch per Unit Effort

Effort varied little over time, an average of 3.3 ± 0.61 free divers and 11.28 ± 1.74 (95% C.I.) SCUBA fishermen were recorded from stores from February 1997 to May 1998. The average number of trips per week between February 1997 and May 1998 was 4.16 ±

0.65. SCUBA fishermen fished an average of 5.15 ± 0.12 hours/trip, and free divers fished an average of 6.4 ± 0.23 hours per trip.

The catch per unit effort (CPUE), measured as kilograms of parrotfish fished per hour was significantly greater for SCUBA spearfishermen than for free divers ($T = 1.65$, $P < 0.001$). A total of 243 SCUBA divers caught an average of 2.20 ± 0.17 $kg^{-1}hr^{-1}$ compared to 0.64 ± 0.10 $kg^{-1}hr^{-1}$ (95% C.I.) for 138 free diver catches. CPUE of SCUBA spearfishermen's catches increased significantly between the first catch survey in February/March 1997 and the last in May 1998 (ANOVA; $P < 0.01$, df = 2,192). Free diver's CPUE did not vary significantly(ANOVA; $P = 0.592$, df = 2,101) over the period of this study (Fig. 11).

Spatial Distribution of Effort

A breakdown of the frequency of visitation by area shows that the south side of the island was visited the majority of the time over the duration of the 3 sampling periods (Fig. 12). Spearfishers fished within the American Samoa National Park Boundary at the Pola and Vatia 9% of the time. During February to March 1997 the majority of spearfishing was concentrated on the south-eastern side of the island, in September/October 1997 fishing was localized on the north-eastern and south-western sides of the island. Fishing was also concentrated N.E. and S.W. sides in May and June 1998, however, the N.W. coast was visited more frequently than in previous months (Fig. 13).

Length-frequency/weight distributions

The size frequencies for all species with the exception of *S. rubroviolaceous* did not show consistent or distinguishable modes that could be related to specific cohorts for analysis of modal progression. Therefore, growth curves and growth parameters were calculated from more reliable length-at-age data.

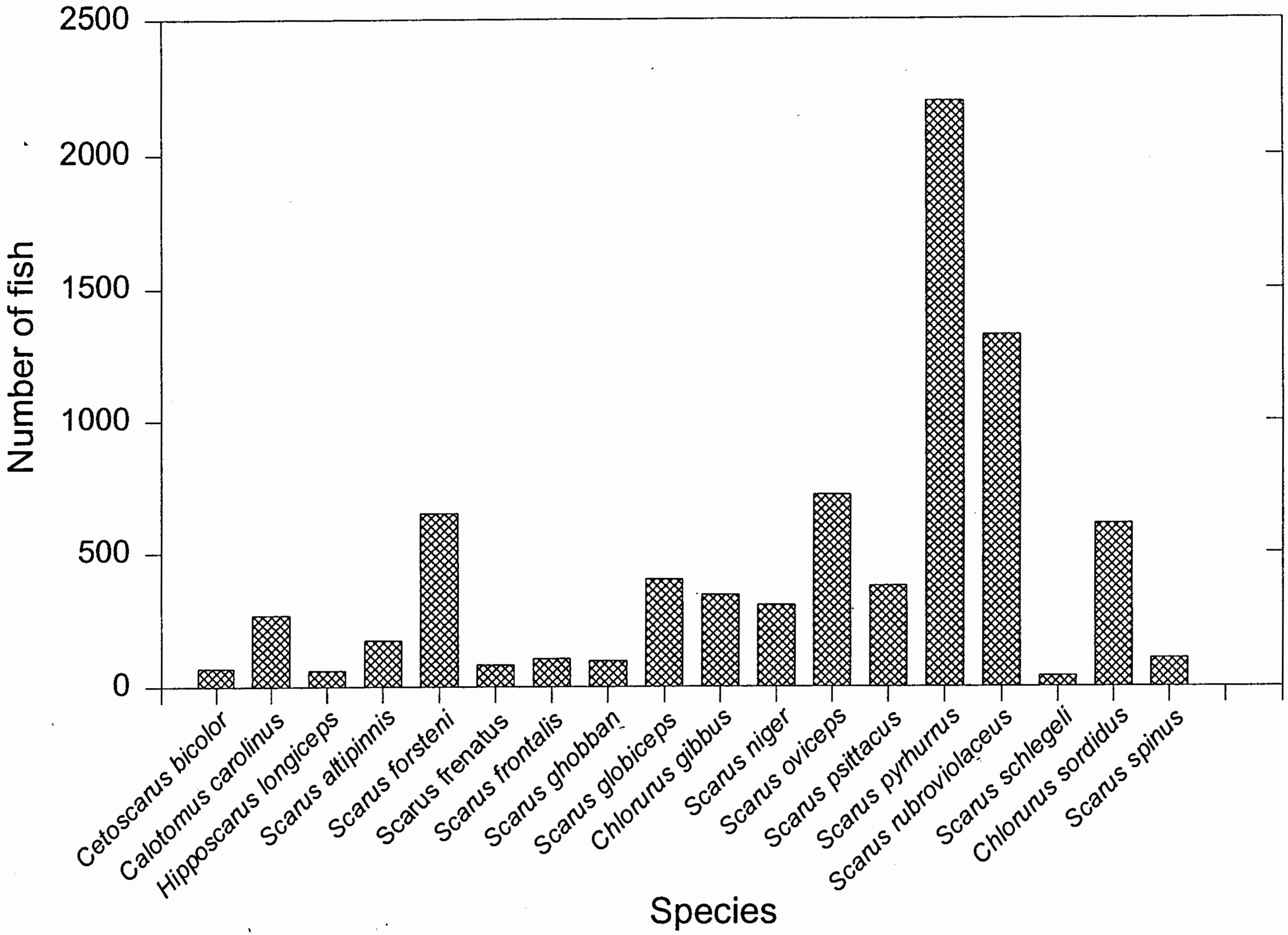

Figure 7. Catch composition of artisanal spearfishers sampled from October 1996 to May 1998.

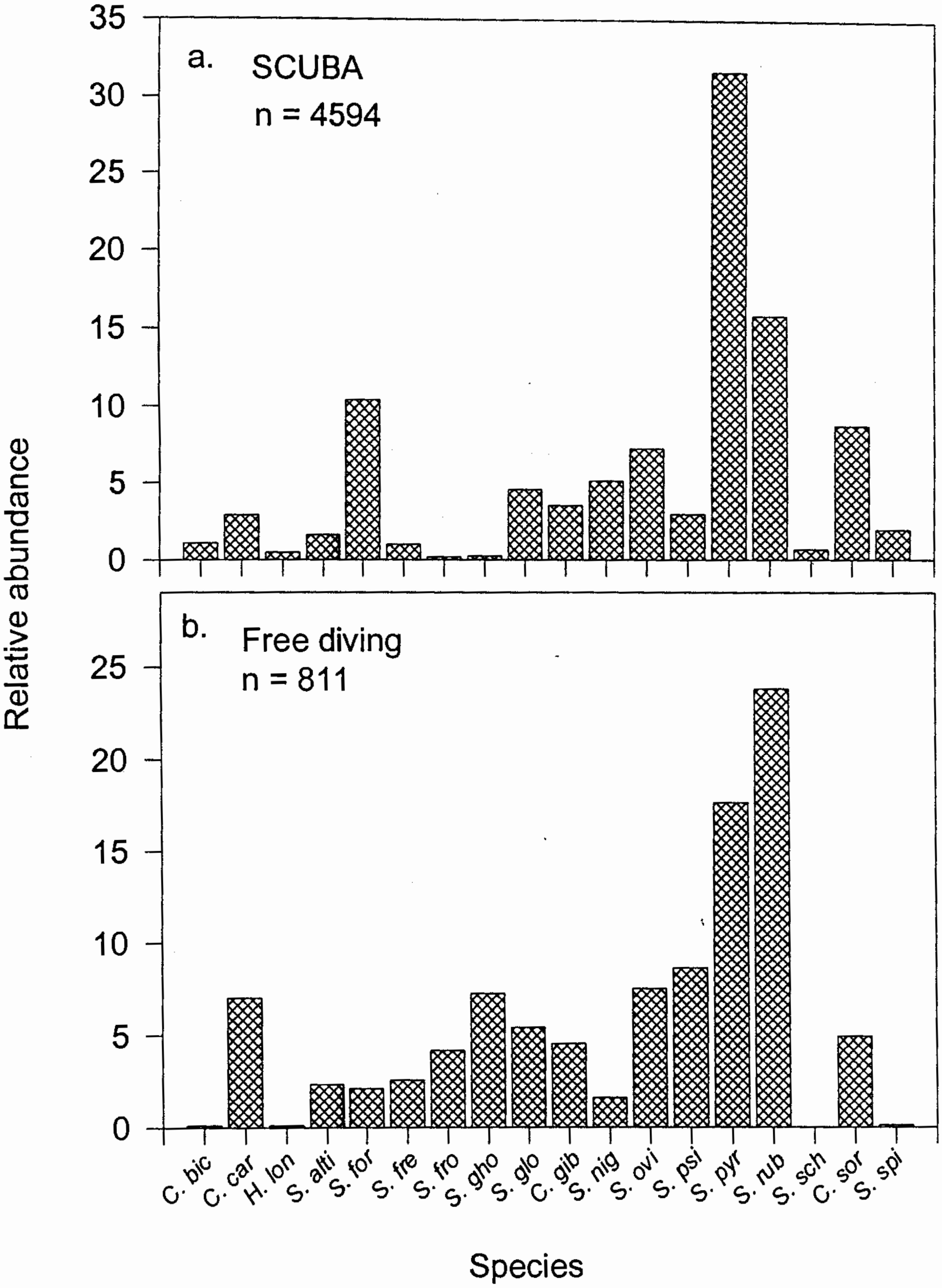

Figure 8 a,b. Catch composition of species by SCUBA and free diving methods

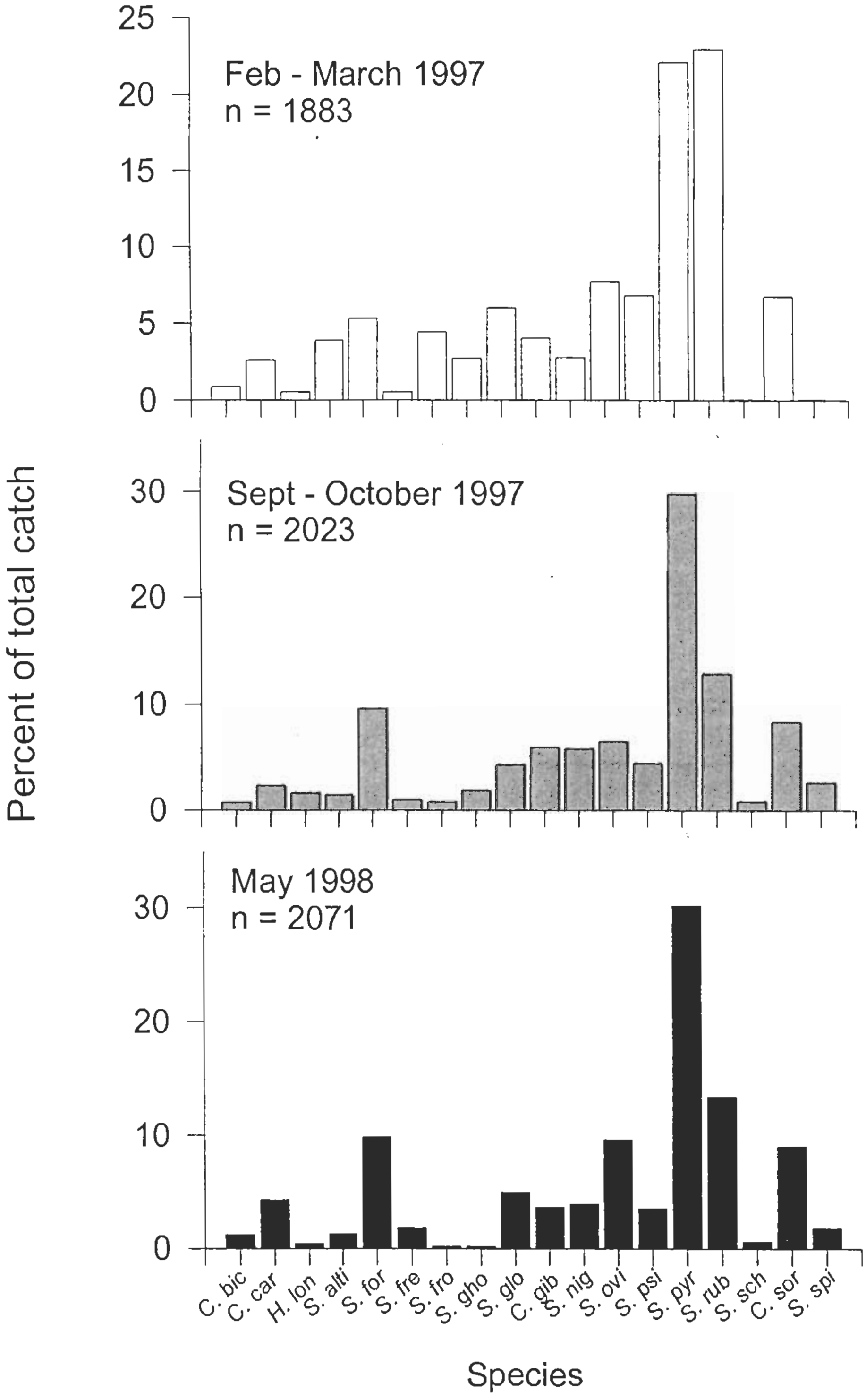

Figure 9. Catch composition of parrotfishes in the artisanal fishery for three surveys

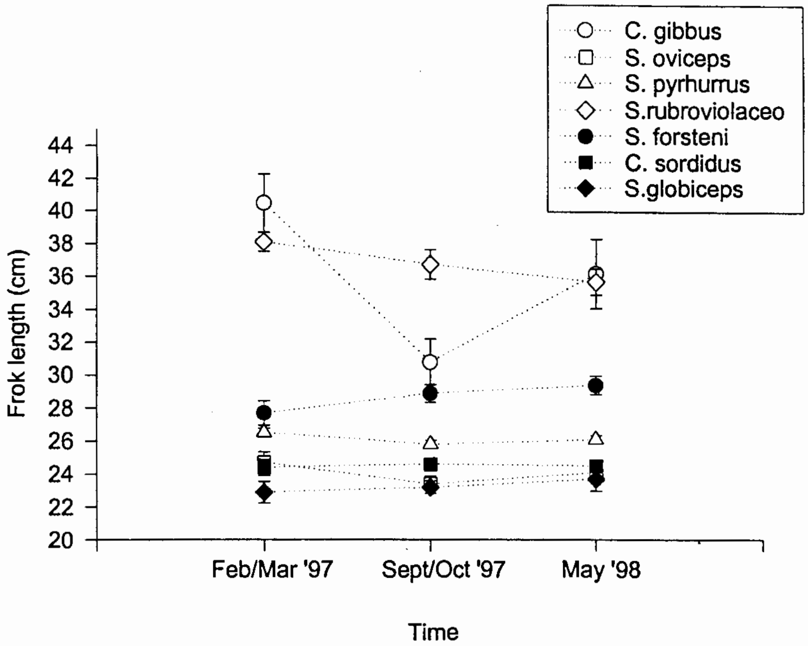

Figure 10. Mean size (± 95% C.I.) of 7 of the most abundant species of parrotfish in the artisanal catch.

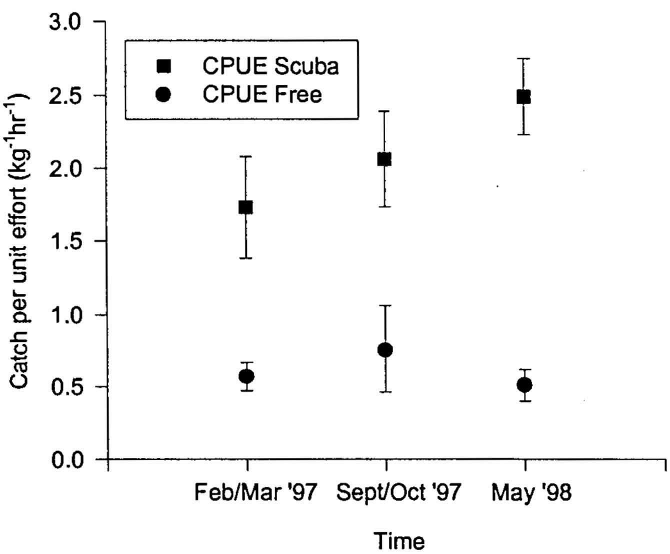

Figure 11. Mean CPUE (± 95% C.I.) of SCUBA and free divers in the artisanal fishery.

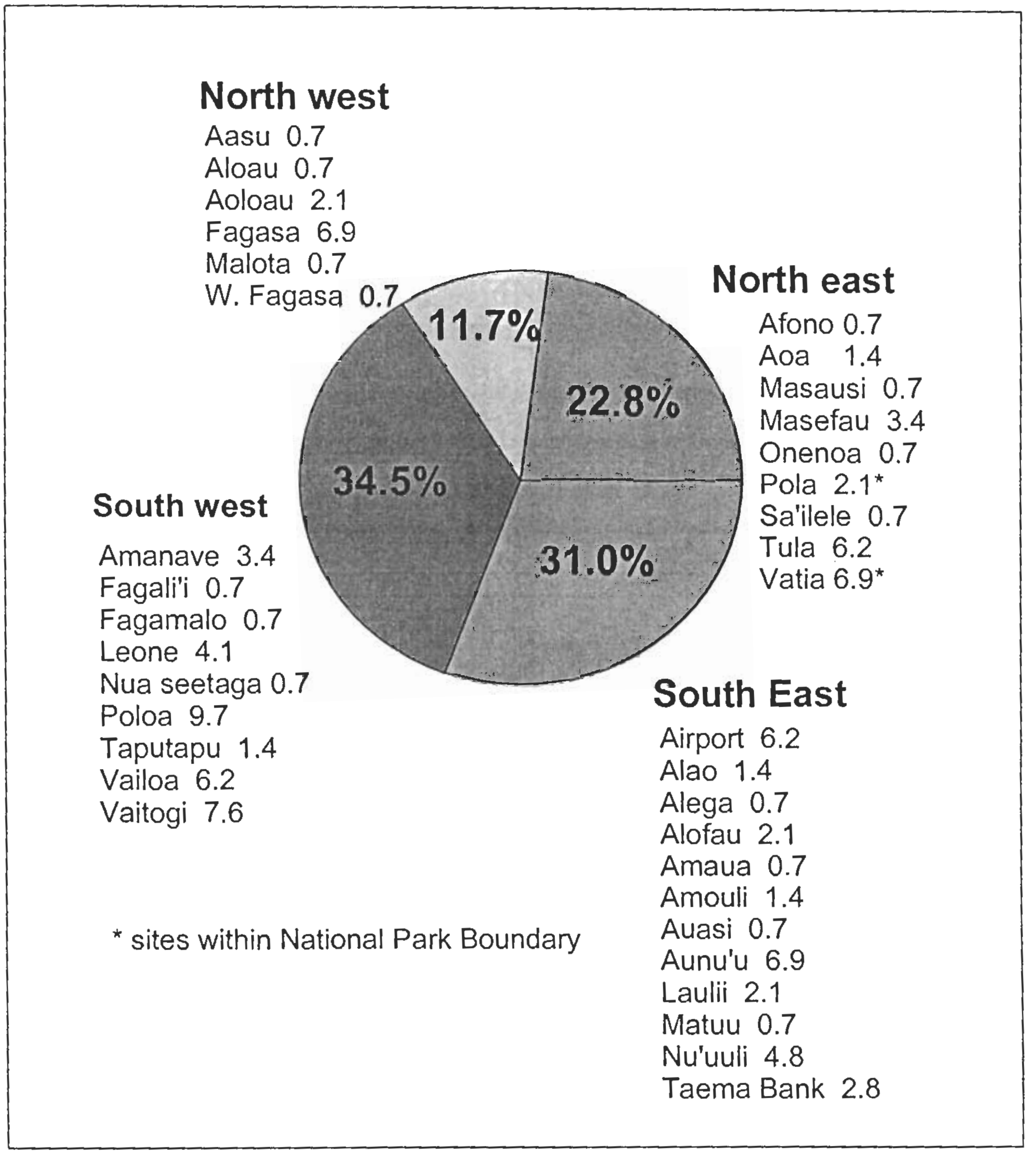

Figure 12. Spatial distribution of spearfishing effort in the artisanal fishery from October 1996 to May 1998.

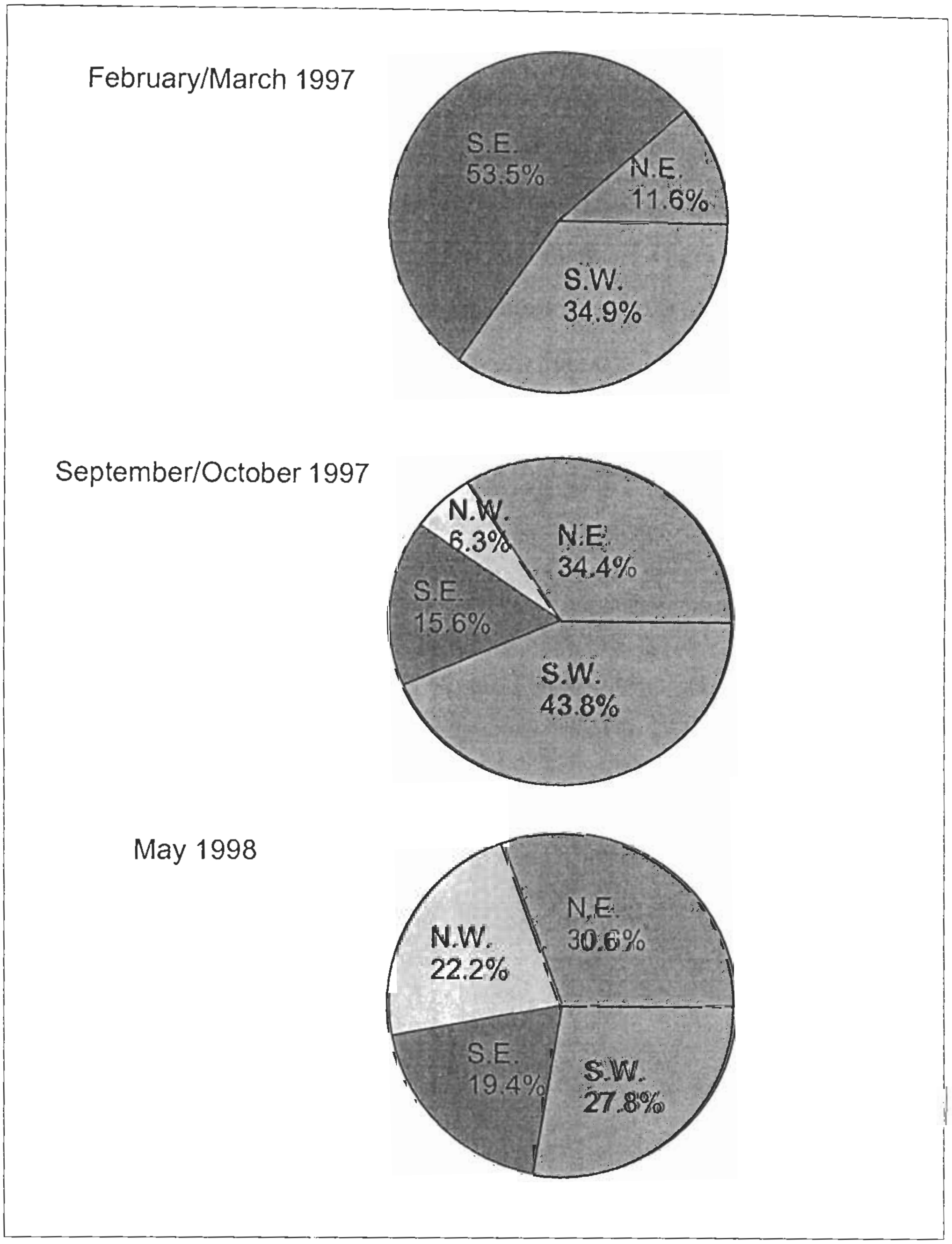

Figure 13. Spatial distribution of spearfishing effort for three survey periods

The majority of fish caught were recruited into the fishery at greater than 20cm fork length, with the exception of *C. sordidus* and *S. oviceps* (appendix IV). *Cetoscarus bicolor* had a distinctly bimodal size distribution between 28-38cm and 43-50cm fork length. The larger mode was made up entirely of male fish. Length-weight constants were derived from a sub-sample of 3994 fish measured between October 1996 and September 1997 (appendix I). These constants were then used to back-calculate weights of individual fish for subsequent fish length measurements.

Estimate of total scarid catch for 1997 to 1998

Based on the CPUE and effort, the expanded total catch of scarids (all species combined) in the market fishery was estimated to be 27.7 ± 2.1 metric tons per year for SCUBA fishermen, and 2.9 ± 0.46 mt /yr for free divers.

C. BIOLOGICAL CHARACTERISTICS

Size-at-maturity and spawning seasonality

A total of 359 parrotfish were caught from varying locations around Tutuila from December 1996 to April 1998. Sexes were pooled for estimation of size-at-maturity due to low sample numbers of individual species. Data is presented for individual species where an adequate size range and sample size of fish were obtained. Fifty percent of *Scarus sordidus, S. psittacus, S. oviceps, S. globiceps, Chlorurus gibbus,* and *S. niger* individuals reached sexual maturity at approximately 17, 19, 21, 17, 30 and 19 fork length (cm), respectively (Figs. 14 a-f). The approximate age of fish at 50% maturity ranged from 1 - 2 years (Table 1).

Table 1. Size and age at maturity of parrotfish speared from December 1996 - April 1998.

Species	Fork length (cm) 50% mature	Age (yrs)
Scarus sordidus	17	1
Scarus psittacus	19	1
Scarus oviceps	21	1-2
Scarus globiceps	17	*
Chlorurus gibbus	30	2
Scarus niger	19	*

* insufficient size-at-age data to accurately determine age

The gonadosomatic index (GSI) for all species and sexes combined appeared to be lowest during the months of April - October 1997 , with the exception of August (Fig. 15)..

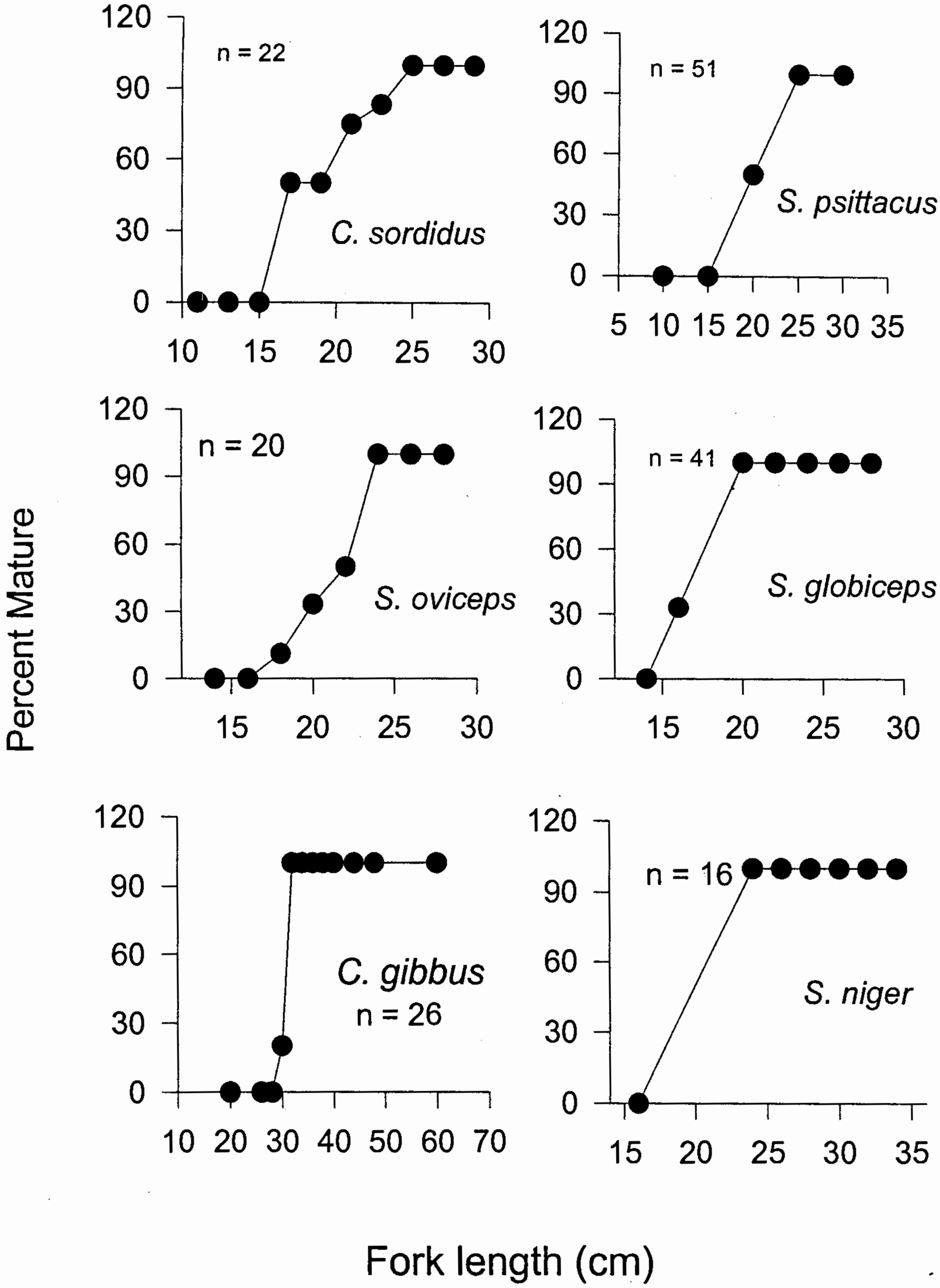

Figure 14. Size-at-maturity plots for six species of parrotfishes sampled from Tutuila. Male and female fish were combined due to the low number of samples.

Size-at-age, growth and mortality

Due to circumstances beyond the control of this study only a sub-sample of 112 sagittal otoliths from a total of 359 fish were sectioned and examined for annulus formation. Growth parameters were only calculated and curves fitted for *Chlorurus gibbus*, *C. sordidus* and *Scarus rubroviolaceous*, and *S. psittacus*. Growth curves for the remaining species will be appended to this report when data is available.

Growth of parrotfish could be separated into to two groups; species that grew to a large size and grew relatively slowly (*C. gibbus* and *S. rubroviolaceous*), and smaller species

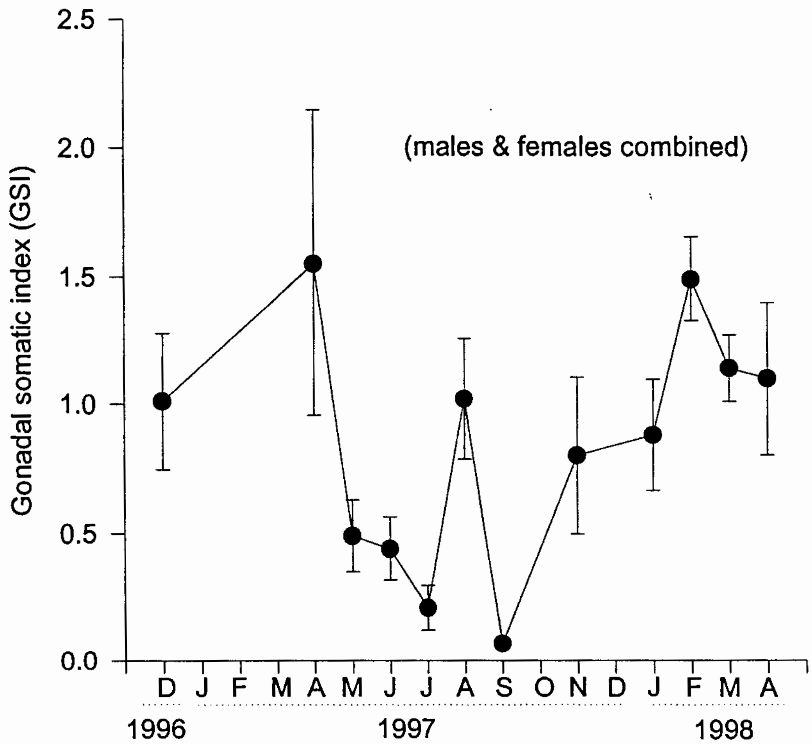

Figure 15. Monthly gonadosomatic index (mean ± 1 s.e.) for all parrotfish species (sexes pooled).

that grew rapidly attaining 60-80% of their total growth by the end of their first year. All species were reached maximum ages of between 12 and 20 years .

The Pacific Steephead *Chlorurus gibbus* was one of the largest scarids sampled in the fishery. Maximum size of *C. gibbus* taken in the fishery (S.L. = 46.7 cm) agreed closely with L_∞ estimated from the von Bertalanffy growth function (L_∞ = 46.8 cm, K = 0.427, t_o = 0.123, r^2 = 0.948) fitted to size-at-age data. This species reached a maximum age of up to 15 years (Fig. 16). Total mortality (Z) estimated from a length-converted catch curve (Pauly, 1983) was 0.56, which agreed closely with estimates of Z using Beverton Holt's relationship based on length data (Z = 0.55, K = 0.427, L_∞ = 46.8, L_c = 30.3 cm, L' = 17.5). Natural mortality (M) was estimated to be 0.936 using Pauly & Longhurst's (1987) empirical equation. Both this value, and M derived from Pauly's M equation (Pauly, 1980) and Rikhter and Evanov's method (Rikhter & Evanov, 1976), M = 0.89 & 0.84, respectively, were greater than total mortality (Z = 0.56).

The Redlip parrotfish *Scarus rubroviolaceous* attained a similar maximum size to *C. gibbus* with individuals reaching an estimated age of 14 years (Fig. 17). The maximum size measured for this species (SL = 47.3 cm) was slightly greater than L_∞ calculated from the VBGF (L_∞ = 42.9 cm, K = 0.342, t_o = -0.75, r^2 = 0.926). Total mortality from the length-converted catch curve and Beverton-Holt's relationship was Z = 0.74 and 0.54 respectively. Natural mortality (M) estimated using Pauly & Longhurst's empirical formula (M = 0.98) was greater than total mortality (Z).

Chlorurus sordidus was the smallest of the scarids that was analyzed for size-at-age and growth curves. The largest measurement for this species (SL = 30.8 cm) was greater than L_∞ estimated from the VBGF for all ages combined (L_∞ = 25.6 cm, K = 0.442, t_o = -0.756, r^2 = 0.934). Therefore, a separate VBGF growth curve was generated for adult fish (50% of the population mature, Tm50% = 1.34 yr) to derive a more realistic approximation of L_∞ (ages 2 - 9, L_∞ = 28.74 cm, K = 0.1, t_o = -10.0, r^2 = 0.5) and age frequency (Fig. 18). Fish grew rapidly, reaching approximately 60-70% of their total growth after two years. It was possible to calculate a growth curve for juvenile fish due to the lack of size-at-age data for fish less than 2 years of age. Total mortality was estimated from the length converted catch curve, and Beverton-Holt's equation ($Z = 0.42$ and 0.42), respectively. Natural mortality derived for adult fish using Longhurst & Pauly's equation ($K= 0.105$, $T = 27.13\ ^{o}C$) was 0.23. The exploitation rate $E = F/Z$, was calculated to be 0.45.

Scarus psittacus also grew rapidly, reaching asymptotic size after the first year of growth ($L_{\infty} = 21.7$, $K = 1.653$, $T_{o} = -0.29$, $r^{2} = 0.770$)(Fig 19). However, L_{∞} was significantly less than the maximum size of fish measured the catch (SL = 27.8 cm).

It is anticipated that growth curves this species and *S. altipinnis*, *S. pyrrhurus* and *S. oviceps* (Fig. 20) will be resolved when additional otoliths have been read. The age of all species showed a good relationship between fish age and sagittal otolith weight.

Age Validation study

Tetracycline labeled parrotfish in tanks at Foagaogo will be sacrificed in January 1999. Results from this study will then be appended to this report.

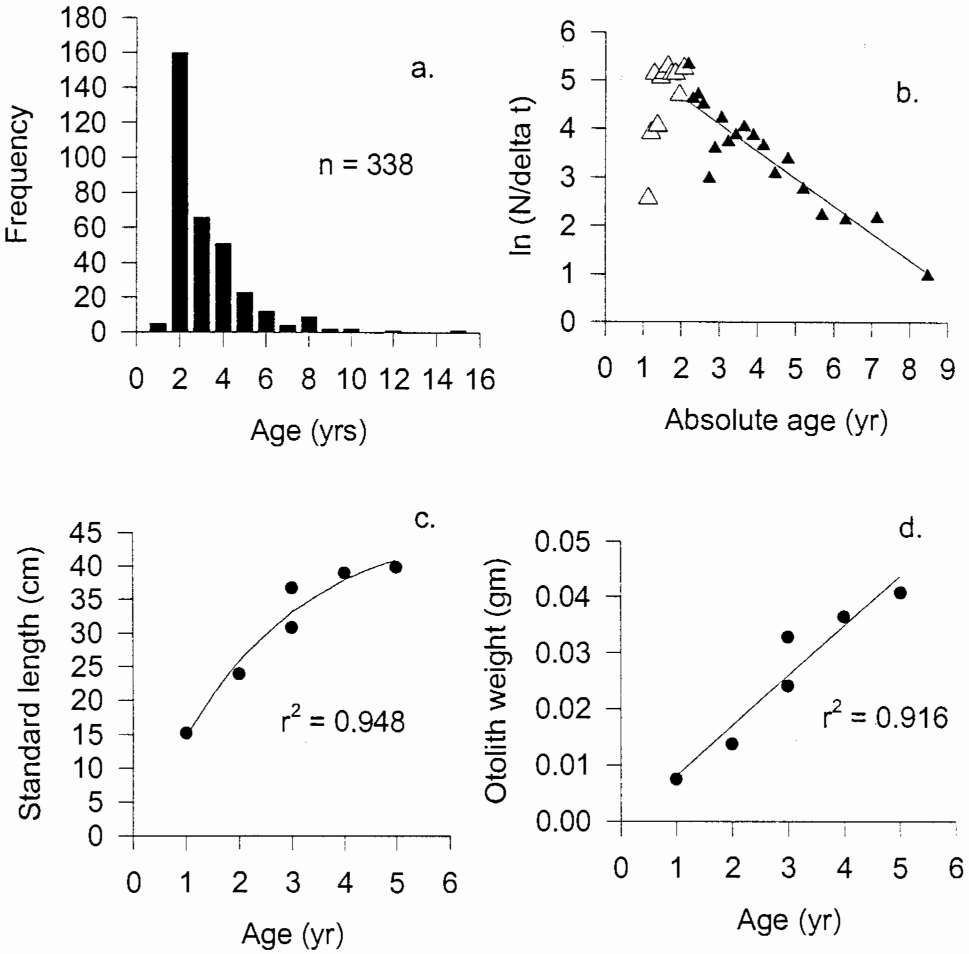

Figure 16 a. Age structure, b. length-converted catch curve, c. VBGF growth curve (L_∞ = 46.8, K = 0.427, T_o = 0.123), and d. relationship between sagittal otolith weight and age of *C. gibbus*.

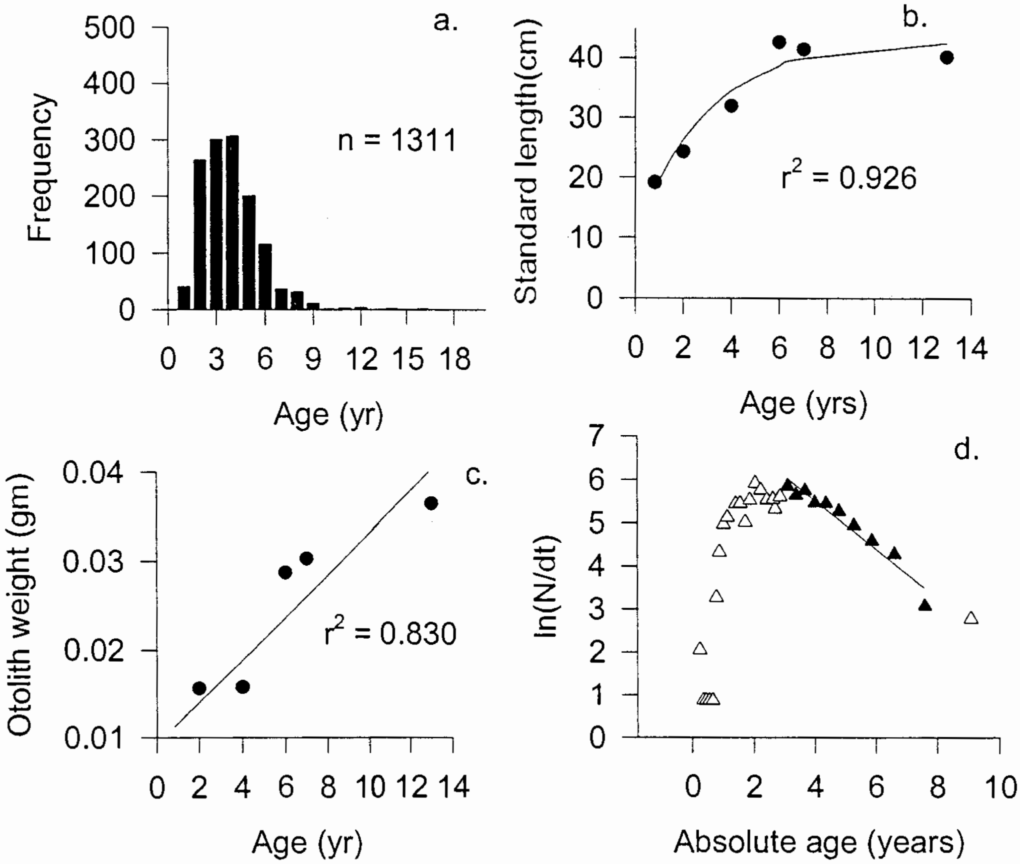

Figure 17 a. Age structure, b. VBGF growth curve ($L_\infty = 42.9$, $K = 0.342$, $T_o = -0.753$), c. relationship between sagittal otolith weight and age, and d. length-converted catch curve of *S. rubroviolaceous*.

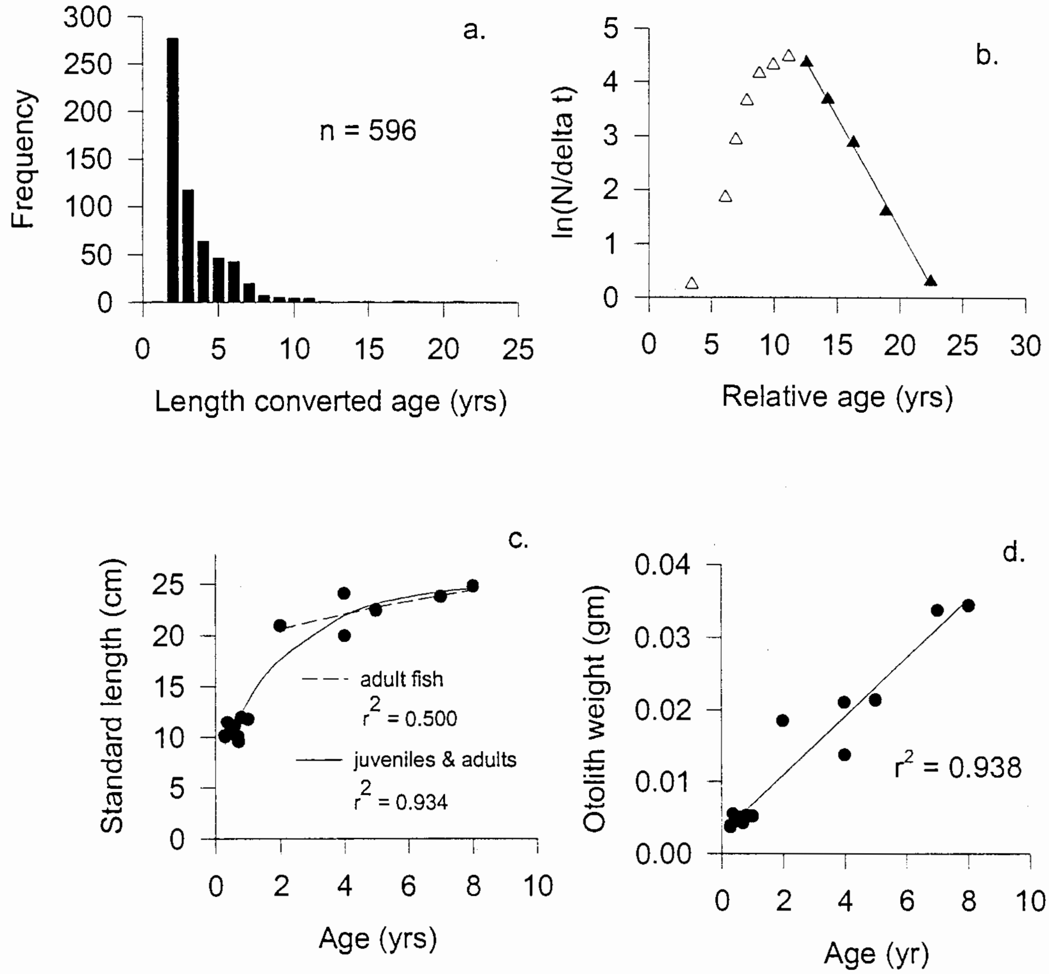

Figure 18 a. Age structure, b. VBGF growth curve for juveniles and adult fish (L_∞ = 25.1, K = 0.442, T_o = -0.756) and for adults only (L_∞ = 28.7, K = 0.105, T_o = -10.0), c. relationship between sagittal otolith weight and age, and d. length-converted catch curve of *C. sordidus*.

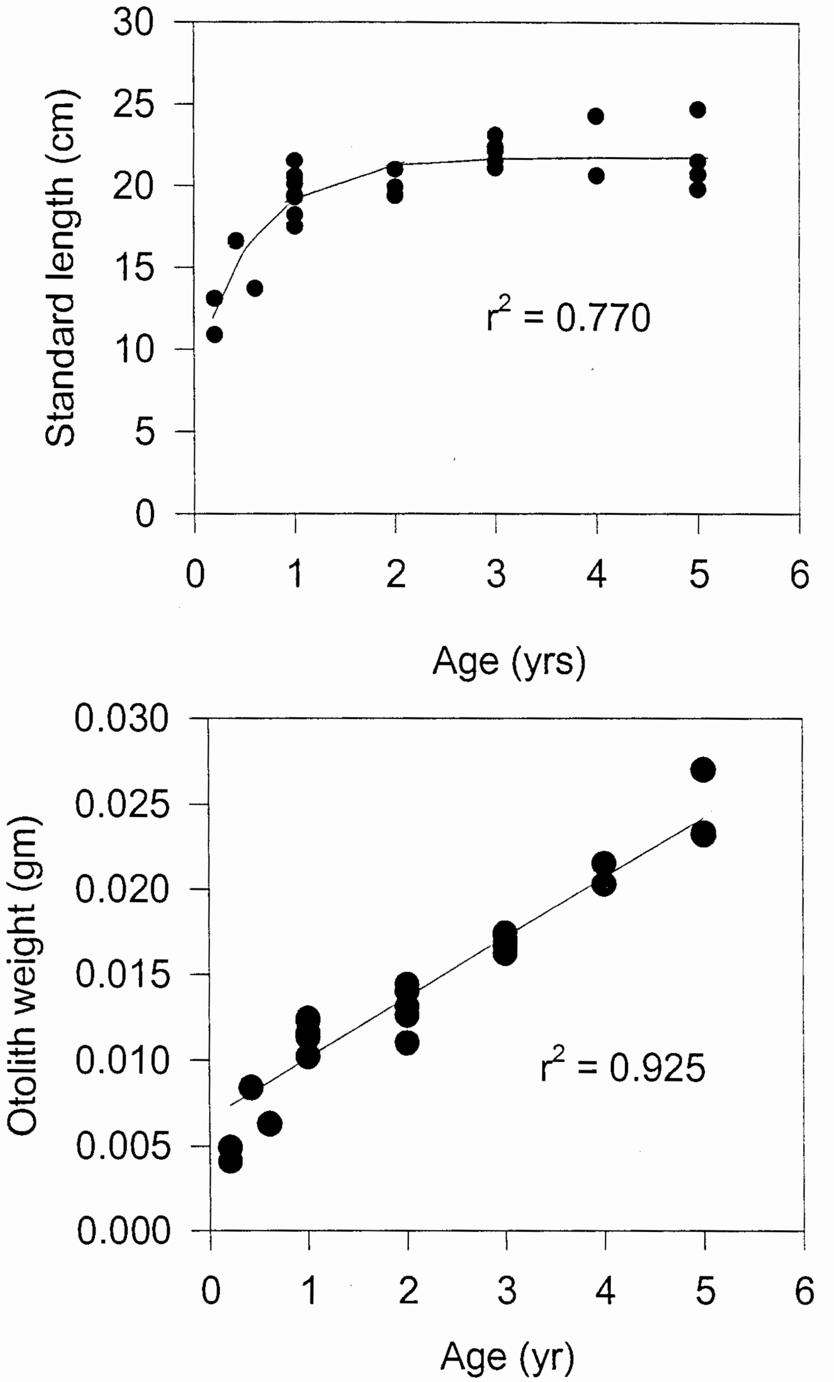

Figure 19. VGBF growth curve (L_∞ =21.7, K =1.653, T_0 =-0.29), and relationship between otolith weight and age for *S. psittacus*.

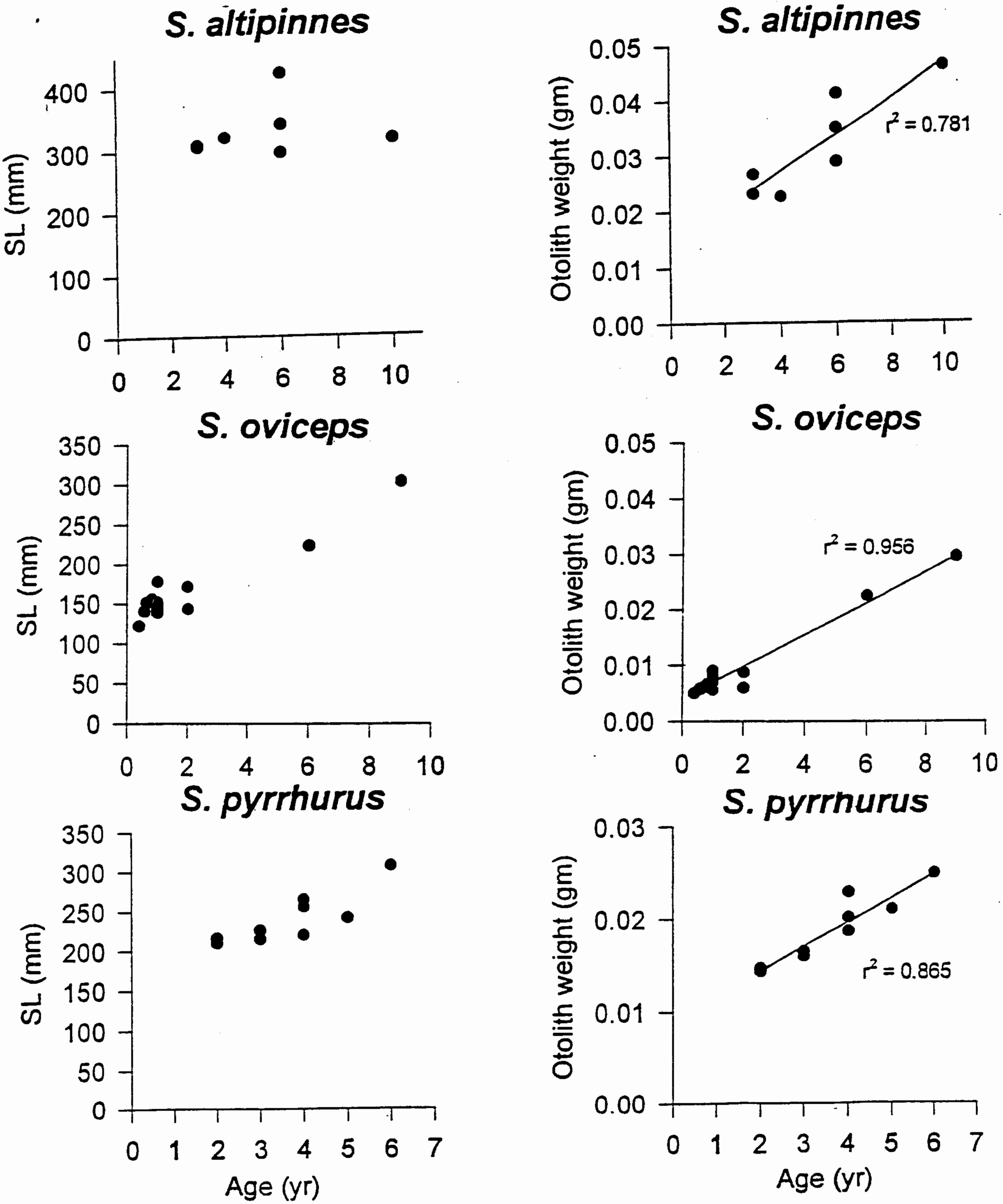

Figure 20. Size-at-age and relationship between otolith weight and age for *S. altipinnus*, *S. oviceps* and *S. pyrhurrus*.

DISCUSSION

A. COMMUNITY CHARACTERISTICS

Biological characteristics of the parrotfish community

The American Samoan parrotfish community is composed of a range of 18 species comprising 6 genera. Species range in size from small parrotfishes such as *Scarus spinus* which attain a maximum size of 30 cm, to large parrotfish such as *Chlorurus gibbus* which can grow to 58 cm (Fig. 2). The species diversity of parrotfishes on Tutuila reefs is similar to that of the other islands of volcanic origin in the Samoan archipelago (Green, 1996). The fringing reef area that these parrotfish inhabit represents only 15% of the total land mass of Tutuila. Due to the relatively small area of habitat this population may be particularly susceptible to human impacts such as pollution or overfishing.

Parrotfishes occupy a range of habitats from lagoons, harbor and bays, to exposed reef fronts and offshore banks. Total density and biomass of parrotfishes varied considerably between locations, but little within habitats investigated (Fig. 5). Offshore banks had the greatest biomass of fish, possibly due to the banks receiving less fishing pressure. These areas are only visited infrequently when weather conditions allow.

Species diversity appeared lowest in lagoon areas such as Faga'alu, Nuu'uli, and the Airport (Fig. 4). However, this may be due to the fact that these areas were dominated by large numbers of unidentified juveniles, and small initial phase parrotfish such as *C. sordidus* and *S. oviceps*. These sites appeared to be a significant nursery, and as such are especially important areas which should be protected from sedimentation, pollution, dredging, and land reclamation.

Remaining sites were also clustered at the 60% level of similarity into a 'north coast' species assemblage dominated by *S. pyrrhurus*, *S. niger* and *S. forsteni*. The 'south coast' assemblage was dominated by *C. sordidus*, *S. spinus* and unidentified juveniles. This species distribution may have been related to the habitat preferences of these species. Mundy (1996) noted that that many sites on the north side of the island with near vertical reef fronts had low coral species diversity and cover, in comparison with many sites on the south coast which were gently sloping and had a higher diversity and abundance of corals. Visual observations and nighttime sampling of parrotfish, confirmed that *S. pyrrhurus* juveniles and adults were mostly observed and caught on exposed reef fronts with low coral cover, whereas, *C. sordidus* was dominant in areas with high coral cover. Therefore, any conservation area should include sites on both sides of the island. In addition, future design or analysis of fishery surveys should at least be stratified by north-south exposure to account for differences in parrotfish communities.

B. CATCH CHARACTERISITCS

Biological characteristics of the catch

Parrotfish species composition in the artisanal nighttime spearfish catch was similar to the relative abundance of parrotfish quantified in the wild population, with the exception of *S. rubroviolaceous*. For this species, a proportionally greater number were observed in the catch than were observed in the wild. Terminal phase males of this species grow to a large size (> 50cm), are obvious at night as they are brightly colored, and are often found sleeping in the open (pers. obs.). It is possible that this species and other large terminal phase male parrotfish such as *C. gibbus* are prone to relatively higher fishing mortality than the small cryptic species that are able to hide in corals. However, low observed numbers may also to some extent be related to the negative reaction of *S. rubroviolaceous* to divers during visual surveys (Bellwood & Alcala, 1988). Interestingly, the relative abundance of this species in diver's catches appeared to decline over the period of this study.

Differences in the catch composition of parrotfish between SCUBA and free divers was primarily correlated with depth and areas fished. Scuba fishermen caught proportionally more *S. forsteni* than free divers (Fig. 8). Adults of this species usually inhabit high-relief seaward outer reef slopes (Meyers, 1989), which are found predominantly on the north side of Tutuila, and are mostly accessible only by boat . *Calotomus carolinus, S. frenatus*, *S. frontalis* and *S. ghobban* were more common in the free diver's catch. These species often inhabit shallow bays, sandy areas, reef flats and 'avas' which free divers can reach easily from the shore.

While fishing effort and CPUE varied little over the course of the study, results showed that the mean size of the larger species such as *C. gibbus* and *S. rubroviolaceous* decreased significantly through time (Fig 10). Examination of the catch of *C. gibbus* and *S. rubroviolaceous* showed that the majority of fish were caught from the same areas on all three sample periods so the result is not a function of fishing different populations. Therefore, the decrease in mean size of these species may be a true reflection of fishing pressure. Future sampling should be stratified to account for seasonal changes in fishing and carried-out over a longer time frame.

The total standing crop of parrotfish was estimated by visual census in 1997 to be 189 mt. If the subsistence catch for 1995 of 4.8 mt is carried through (data is not available for 1997) and added to the estimated total artisanal catch of 30.6 mt in 1997, the resulting total represents 18.7% of the standing crop. This percentage of standing crop can be considered as 'heavy' when compared with fishing pressure on Philippine reefs (Russ & St John, 1988). Also, this yield approaches the maximum sustainable yield (MSY) of 53.9 mt calculated for exploited fish stocks following Cadima's formula, $MSY = 0.5 * Z * B$ (Sparre & Venema (1992) for exploited fish stocks ($\bar{Z} = 0.57$, $B = 189$).

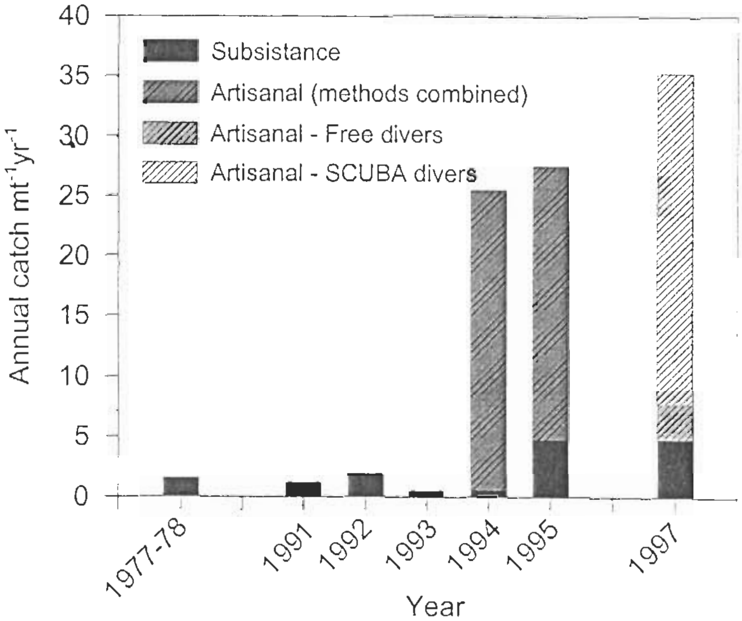

Figure 21. Estimated annual harvest of parrotfish on Tutuila island. Historical data taken from Wass (1980), Ponwith (1991), M^{c}Connaughey (1993), and Saucerman (1995, 1996).

Recent evidence shows that the annual yield of scarids in the fishery has increased by as much as 15 fold since 1994 (Fig. 21). The total annual catch of scarids during 1977-78 calculated by Wass (1980) as 1.5 mt, and total annual catches estimated from the inshore creel survey remained fairly consistent from 1991 through to 1994. However, the artisanal reef fishery in 1994, quantified for the first time by Saucerman (1995), showed that artisanal night spearfishing caught 98% of the annual parrotfish catch of 25mt. Similarly, this study found that the annual yield of parrotfish was as high as 33.2 mt, and that SCUBA divers caught 89% this catch. Therefore, nighttime SCUBA spearfishing represents the major proportion of the pressure on the fishery.

C. BIOLOGICAL CHARACTERISTICS

Size-at-age, growth, mortality and reproductive size

The presence of readable consistent bands on parrotfish otoliths, and size-at-age data from Samoan parrotfishes, were consistent with growth data from populations of parrotfish and surgeonfish at similar latitudes in the Western Pacific (Choat et. al. 1996). Results suggest that these aging techniques are applicable to American Samoan reef fishes, however some validation of the observed growth increments is necessary. It is anticipated that this information will be available in the near future, assuming survival of the tetracycline labeled fish in the hatchery at Fogagogo.

From size-at-age data, American Samoan parrotfishes can be categorized into two growth classes. Small fast growing species such as *C. sordidus* and *S. psittacus* attain most of their adult size during the first 1-2 years of age, whereas species such as *C. gibbus* and *S. rubroviolaceous* show slower continuous growth to a large size, with little evidence of an asymptotic size.

Parrotfishes in this study reached sexual maturity at a relatively young age when compared to the surgeonfish *Acanthurus lineatus* studied by Craig (1996) in American Samoa. Some of the smaller species such as *C. sordidus* were between 1-2 years of age and less than 18 cm long when 50% reached sexual maturity. In comparison, slower growing *C. gibbus* individuals matured at between 2 and 3 years of age. Many of these fish are caught by spearfishermen before they reach sexual maturity. Catching these under-age fish is likely to have a major effect on the number of young fish on the reef in the future.

C. sordidus and *S. psittacus* grew rapidly attaining 60-80% of their maximum size in the first year of growth. *C. sordidus* was relatively long lived attaining an age of up to 20 years. Similar growth was observed by Craig (1996) for the herbivorous surgeonfish

Acanthurus lineatus (alogo) in American Samoa. He found that standard applications of growth models were inappropriate for populations exhibiting these growth characteristics, and concluded that double von Bertalanffy growth (VBGF) curves were better suited for describing the growth of these fish. In the present study a reliable estimate of growth for juvenile fish was not possible due to the paucity of young age fish, however a VGBF curve was fitted to size-at-age data for adult *C. sordidus* based on size at 50% maturity. Estimates of L_∞ from this growth curve closely approximated the maximum size of fish measured in the fishery. In comparison, single VBGF growth curves closely approximated the growth of large species such as *S. rubroviolaceous* and *C. gibbus*. The maximum size of fish recorded in the fishery was close to L_∞ generated for these growth curves..

Similar trends in growth were evident for some Australian parrotfishes from the Great Barrier Reef (Choat et. al., 1996), where *C. gibbus* had continuous growth, and *C. sordidus* grew rapidly reaching asymptotic size at an early age. Both Tutuila species fall close to growth curves calculated for these species on the GBR However, growth patterns also varied geographically between species. *S. psittacus* grew slowly on the GBR, but extremely rapidly in American Samoa. Therefore, estimates of growth parameters based on the growth of a species should be applied to fisheries models with great caution when extrapolated to geographically isolated populations.

There was a high correlation between sagittal otolith weight and age for all species investigated in this study (r^2 = 0.78 - 0.96). This relationship appears to extend to a wide range of tropical reef species (Williams et. al. 1995; Choat & Axe, 1996, Newman et. al., 1996; Choat et. al., 1996). The sectioning and reading of sagittal otoliths involves labor and expense, however once established, the relationship between otolith weight and age of parrotfishes can be used to age a large sample of fish, and obtain accurate estimates growth parameters.

Estimates of total mortality (Z) from length converted catch-curves for individual parrotfish species showed Z to vary between 0.42 - 0.74. This parrotfish mortality is double that of *Acanthurus lineatus* (alogo) in American Samoa, calculated by Craig (1996). Estimates of parrotfish natural mortality (M = 0.74 - 0.95), derived from an equation by Longhurst & Pauly (1987) based on average water temperature, equaled or exceeded total mortality. Estimates of M derived from empirical equations embody a high degree of variability, and are often over estimated for tropical reef species (Russ & St John, 1988, Williams et. al., 1995, Newman et. al., 1996). Clearly, M from these equations is not representative of natural mortality rates of parrotfish in American Samoa, and it is likely M for the species investigated in this study is considerably lower than calculated.

Other studies of tropical reef fishes have found that natural mortality rates can be relatively low. For example, (Newman et. al., 1996) demonstrated that the instantaneous rate of natural mortality for unexploited populations of snappers was as low as 0.24. As most fish populations in the Samoan archipelago are exploited to some degree, the creation of marine protected areas both for comparative studies of natural mortality, and for yield enhancement (Russ et al., 1992; Russ & Alcala, 1996), are considered essential for monitoring and management of Samoan reef fish populations.

When natural mortality was calculated for only adult *C. sordidus* (Z = 0.42, K = 0.105) using Pauly & Longhurst's equation, the exploitation rate E (= F/Z) was estimated to be 0.45. Pauly (1984) suggested that when fishing mortality rate is 40 percent of the natural mortality, a stock is optimally exploited (E_{opt} = 0.3). On this basis, the *C. sordidus* population is being exploited at a greater than optimum level. Furthermore, if stocks of fast growing *C. sordidus* are being over exploited, then the slow growing species such as *C. gibbus* and *S. rubroviolaceous* may be greatly over exploited.

CONCLUSION

In conclusion, the evidence from this study suggests that fishing pressure on parrotfish is heavy, primarily as a result of recent nighttime SCUBA spearfishing. The two species most likely to be over fished are *C. gibbus* and *S. rubroviolaceous* for the following reasons. Firstly, the populations of these species are in decline. Secondly, they grow to a large size and terminal males are obvious to divers at night, and therefore subject to higher fishing mortality than smaller species. Thirdly, they grow relatively slowly, maturing at a size above that at which they are caught by spearfishers. Fourthly, the average size of individuals caught has declined over the period of this study. Finally, these results are further substantiated by anecdotal evidence from Samoan people that schools of laea (large *C. gibbus* adults often school together, Meyers, 1989) frequently observed off the reef crest in previous years are no longer seen.

AKNOWLEDGEMENTS

There are so many people that made this project possible that it is hard to know where to begin. Firstly, I wish to thank Ray Tulafono and Tanielu Su'a for providing me with the opportunity to perform this study. Secondly, I would especially like to thank Marsh Uele, Lyrlene Esau, Poasa Tofaeono and Elia Henry for their assistance with field and laboratory work. Without their skills this study would not have been possible. I also thank Kitara Vaiau for all of his advice and help with diving operations, and Michelle Martin for her help with fish transects. I would like to acknowledge the financial support provided by the Federal Aid in Fish Restoration Act. Many thanks to Alison Green, Suesan Saucerman, and Nancy Dashbach for sharing their intimate knowledge of American Samoa's reefs and reef fish populations. Lastly, I would like to give special thanks to my wife Joanna Martin, who had to endure my irregular working hours, and for her unfailing support.

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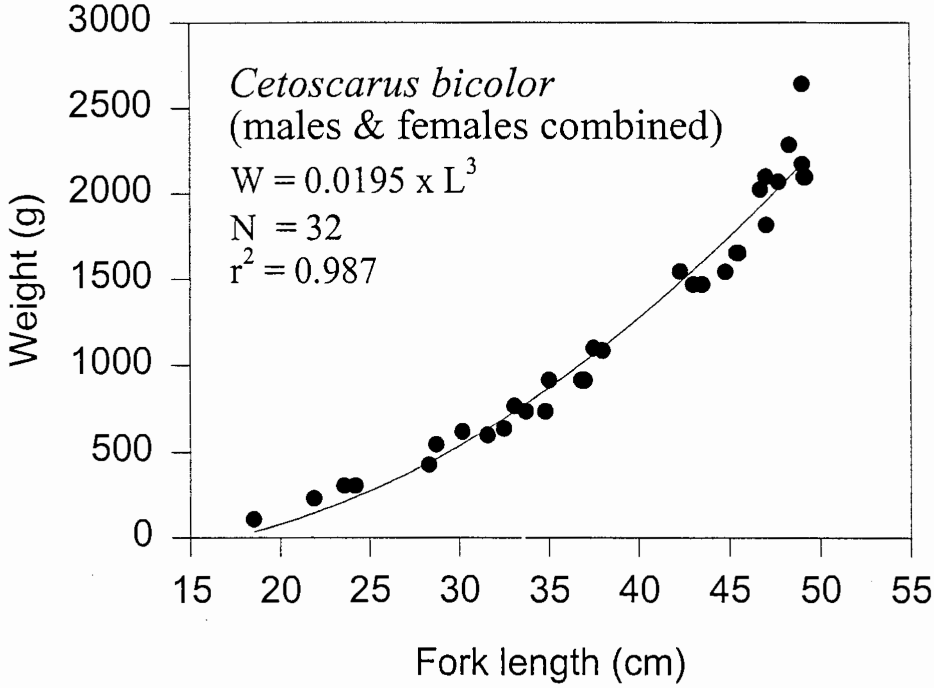
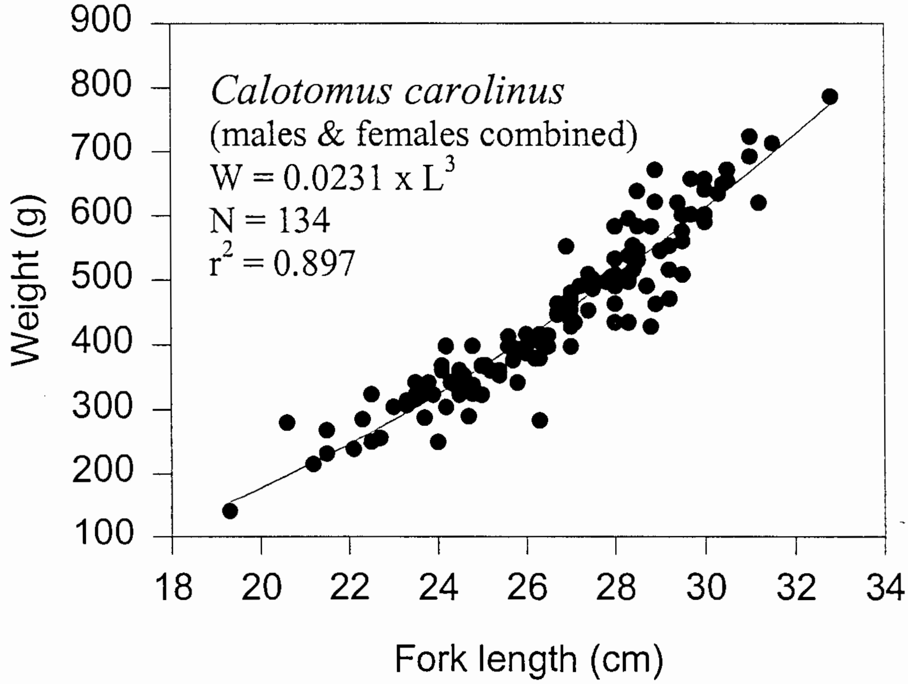
Appendix I. Length-weight regression constants for for scarids caught in the spear fishery on Tutuila Island during 1997.

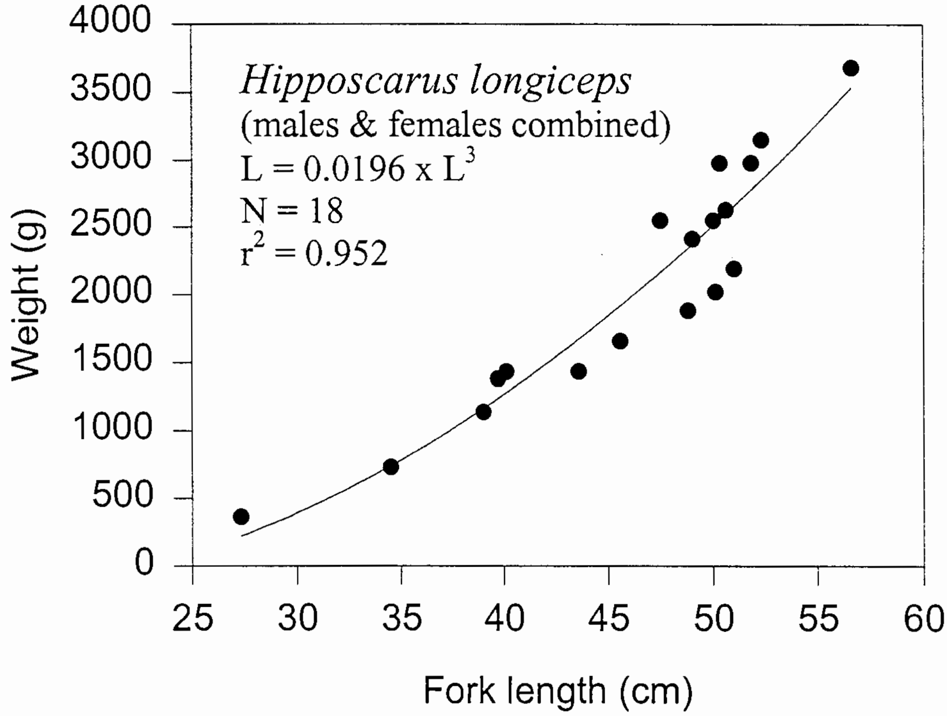
Species	Reg. constant	N	r^2
Cetoscarus bicolor	0.0195	32	0.987
Calotomus carolinus	0.0231	134	0.897
Hipposcarus longiceps	0.0196	18	0.952
Scarus altipinnus	0.022	122	0.958
S. forsteni	0.022	251	0.880
S. frenatus	0.0216	21	0.976
S. frontalis	0.0221	93	0.961
S. ghobban	0.0231	58	0.942
S. globiceps	0.0231	233	0.918
Chlorurus gibbus	0.0219	173	0.953
S. niger	0.0223	121	0.887
S. oviceps	0.0241	385	0.885
S. psittacus	0.0226	259	0.800
S. pyrhurrus	0.0225	1022	0.882
S. rubroviolaceous	0.0205	775	0.930
S. schlageli	0.0189	10	0.369
Chlorurus sordidus	0.0227	264	0.934
Scarus spinus	0.0208	23	0.772

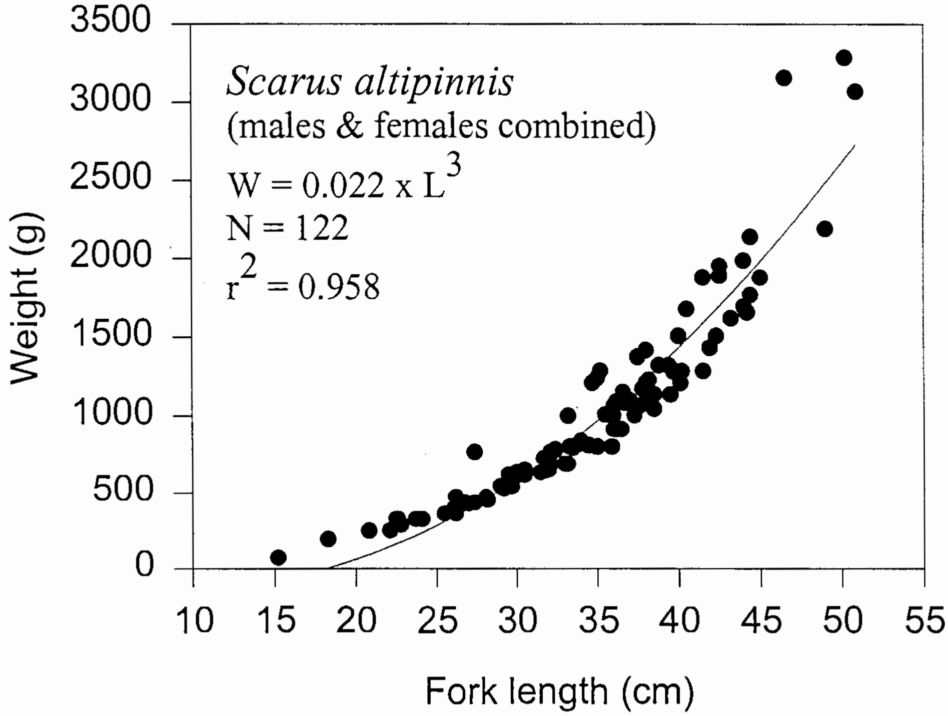
Appendix I. Length-weight relationships of parrotfishes in the spearfish catch from Tutuila Island.





Appendix I cont.





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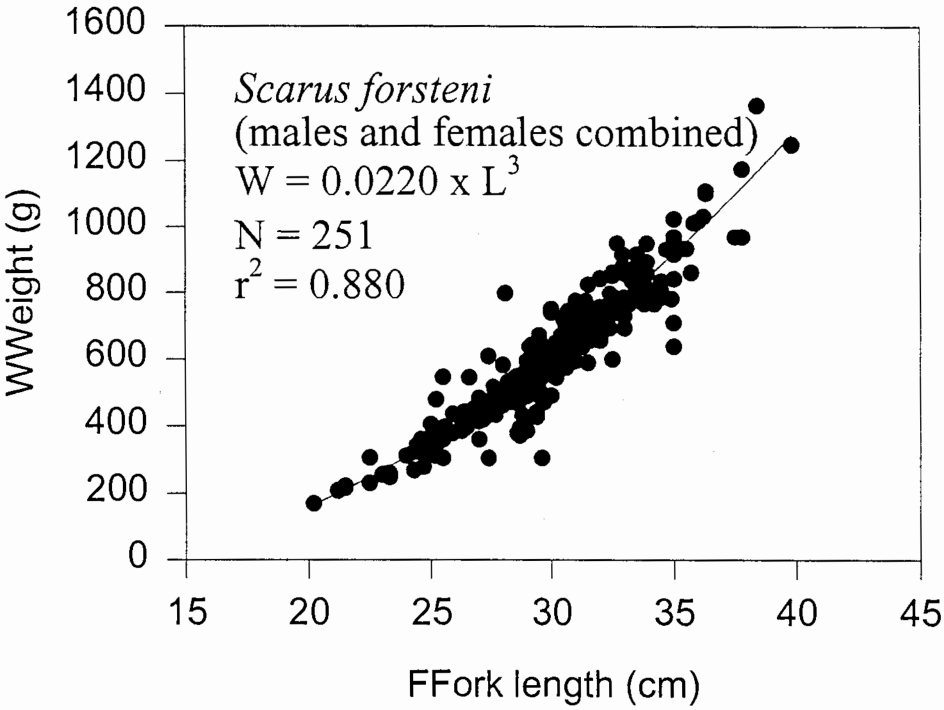

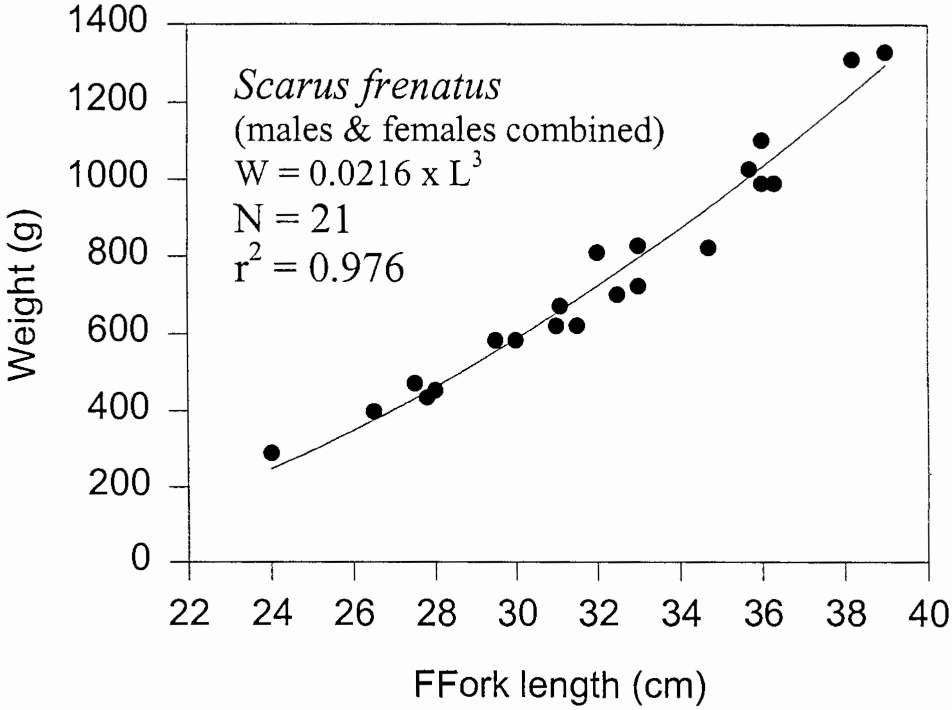

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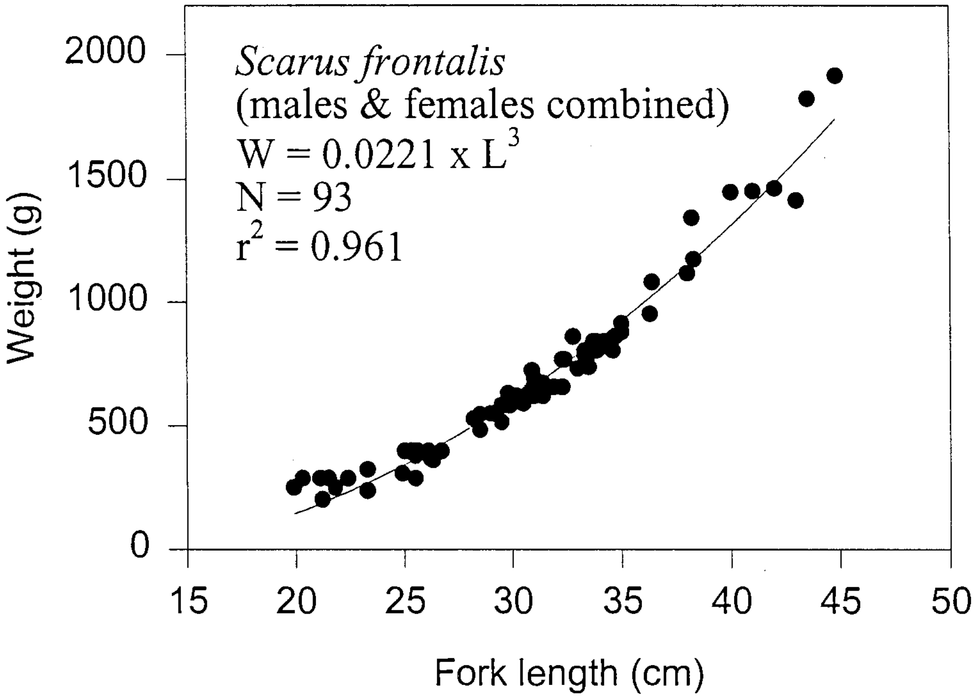

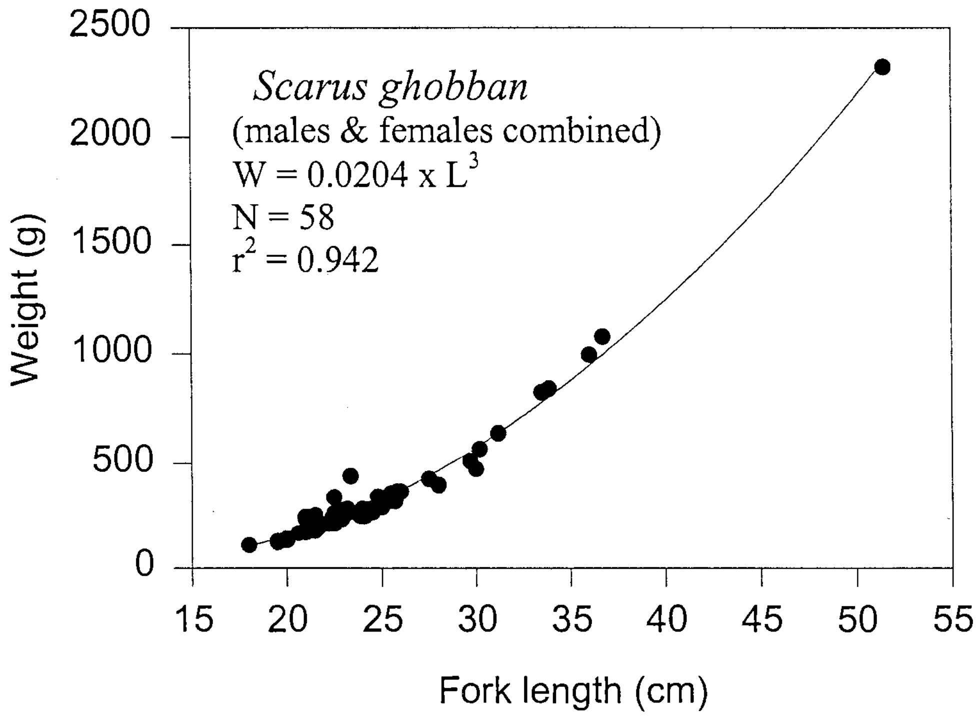

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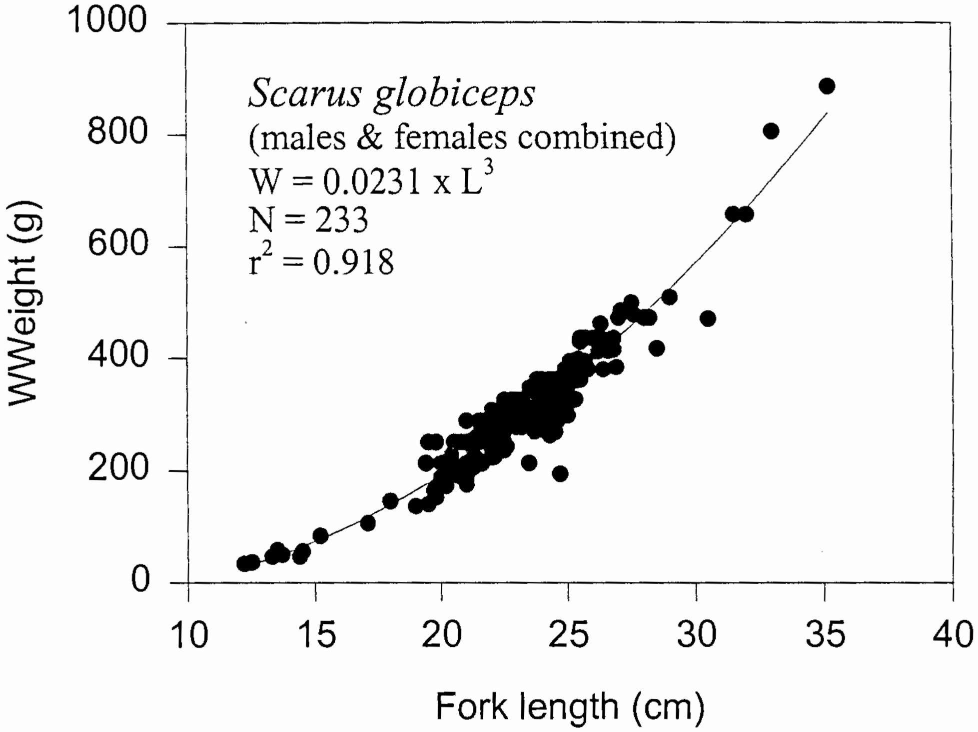

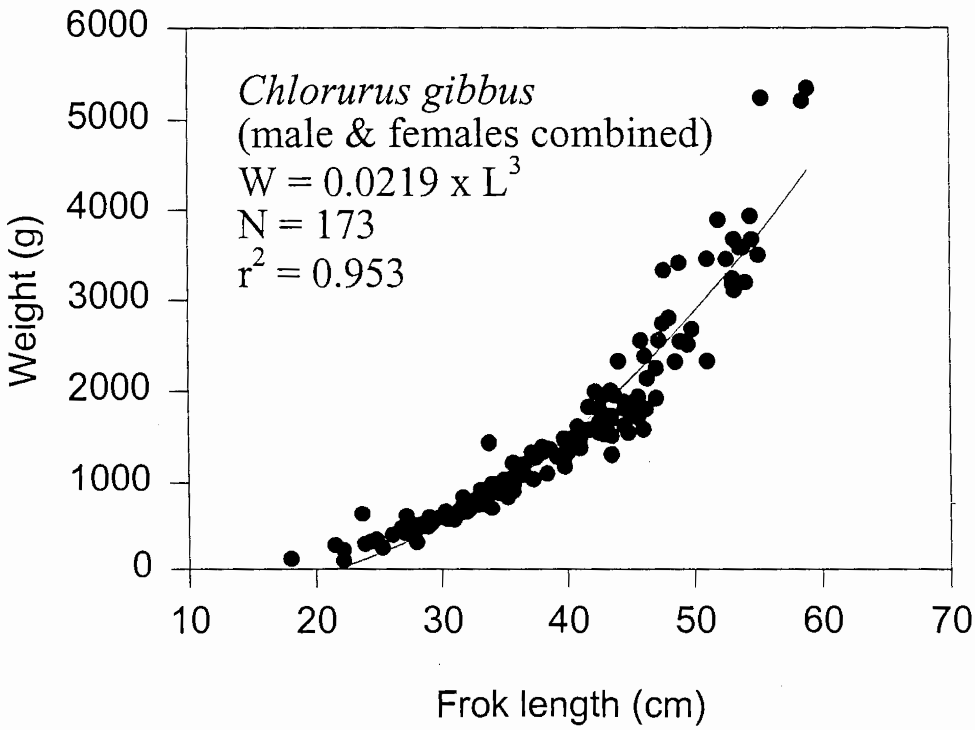

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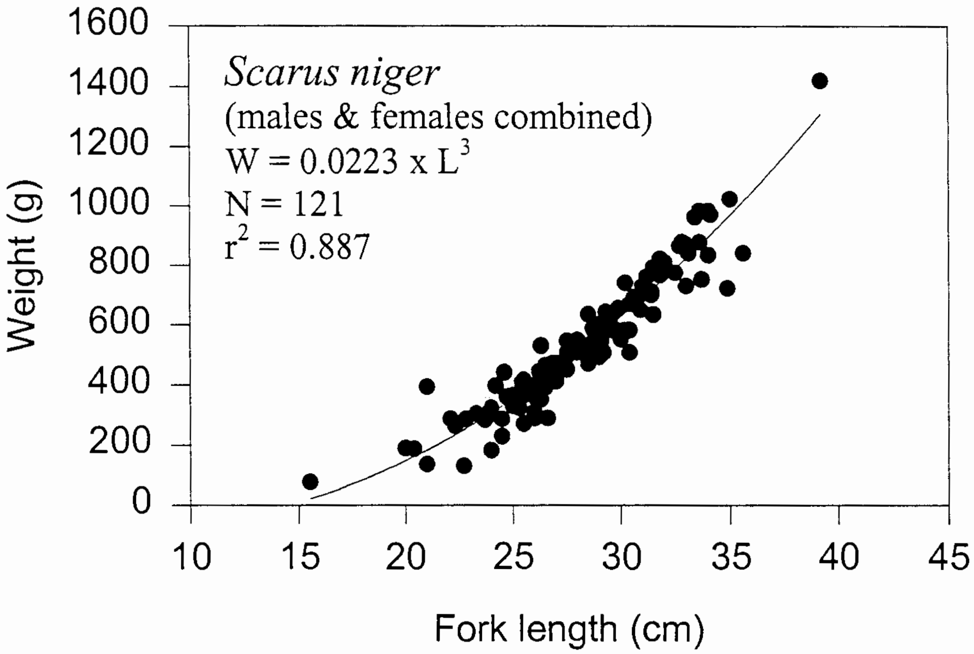

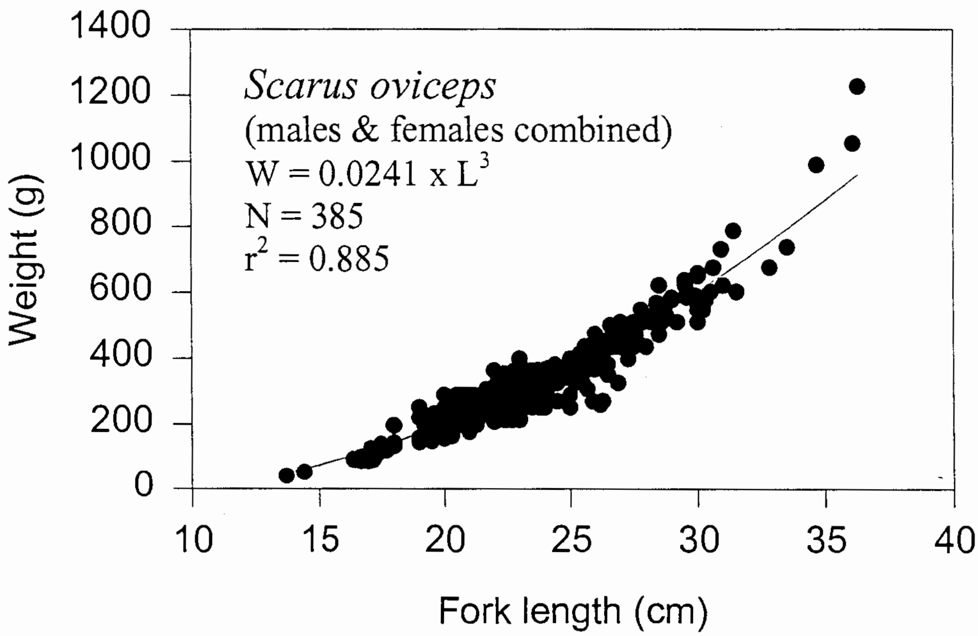

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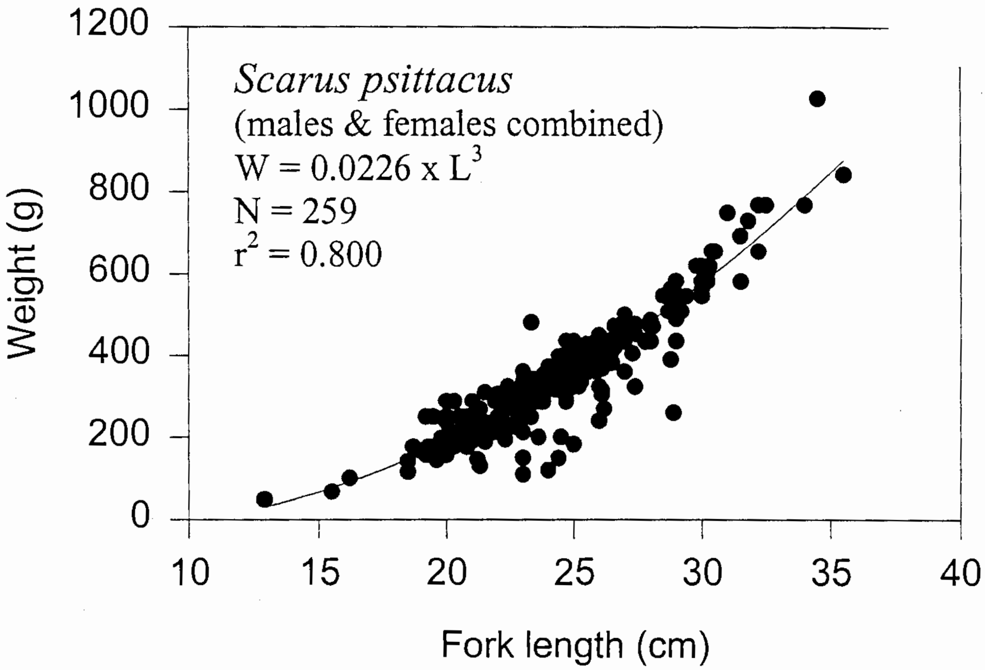
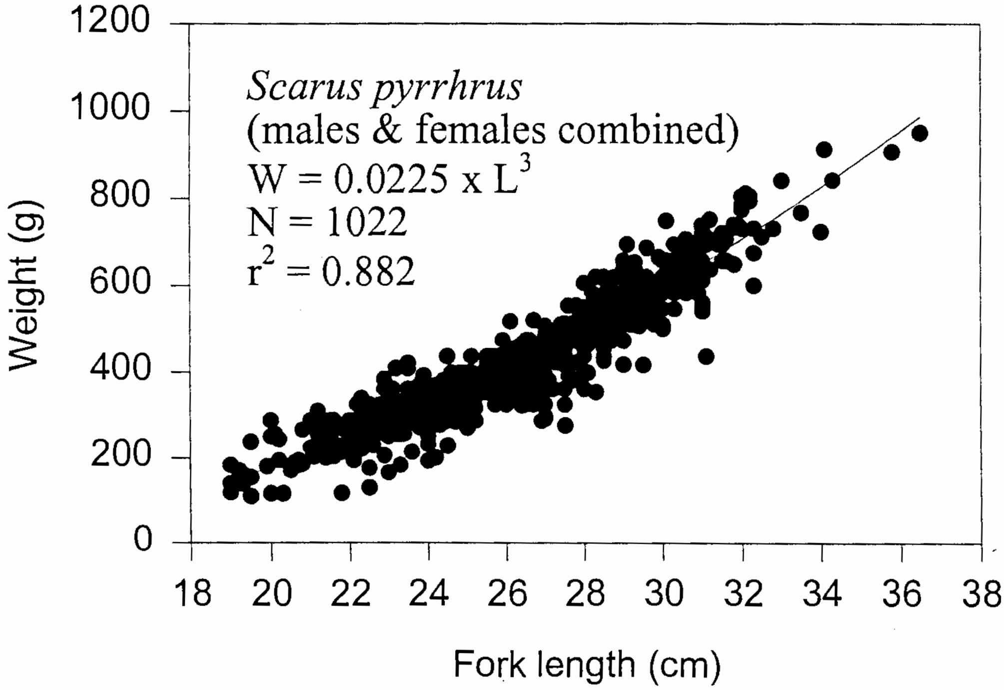
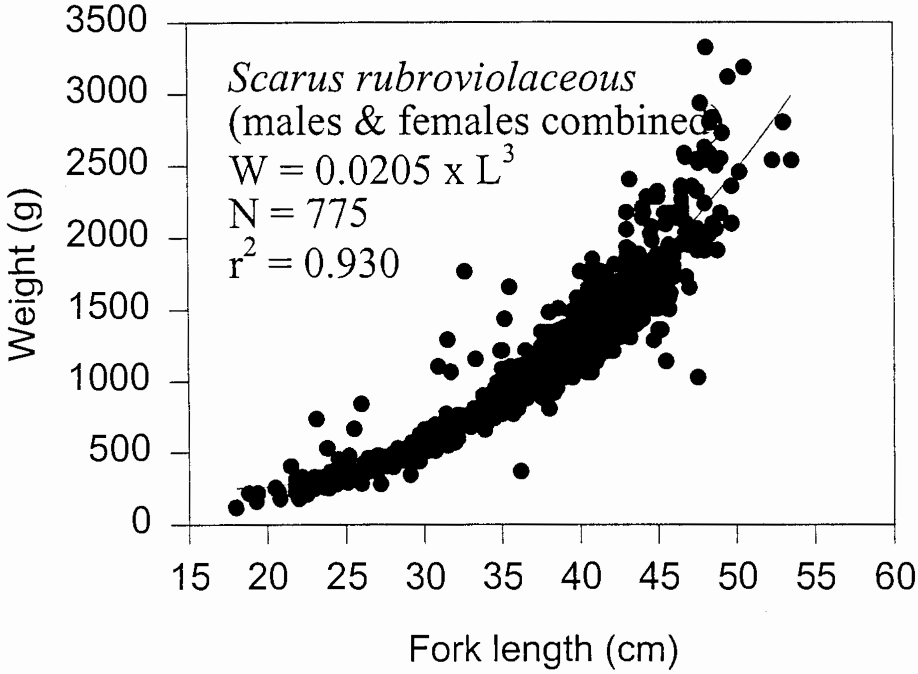
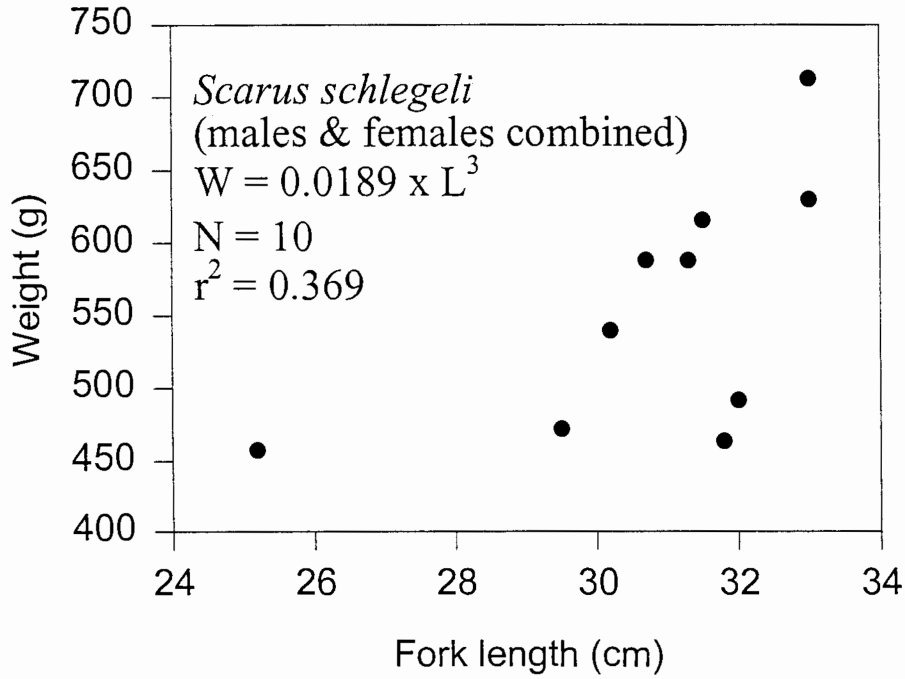
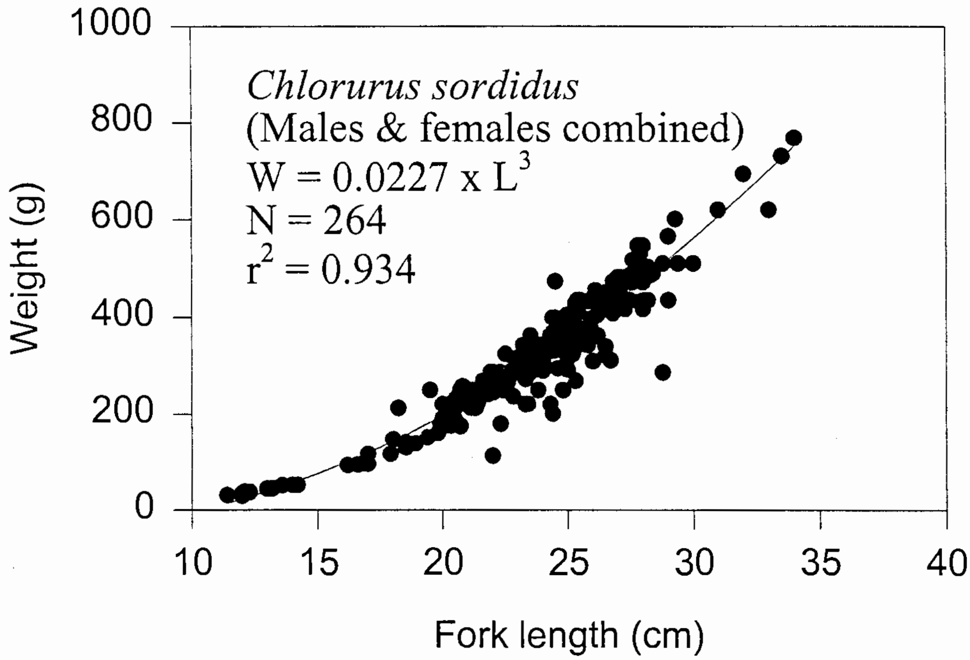


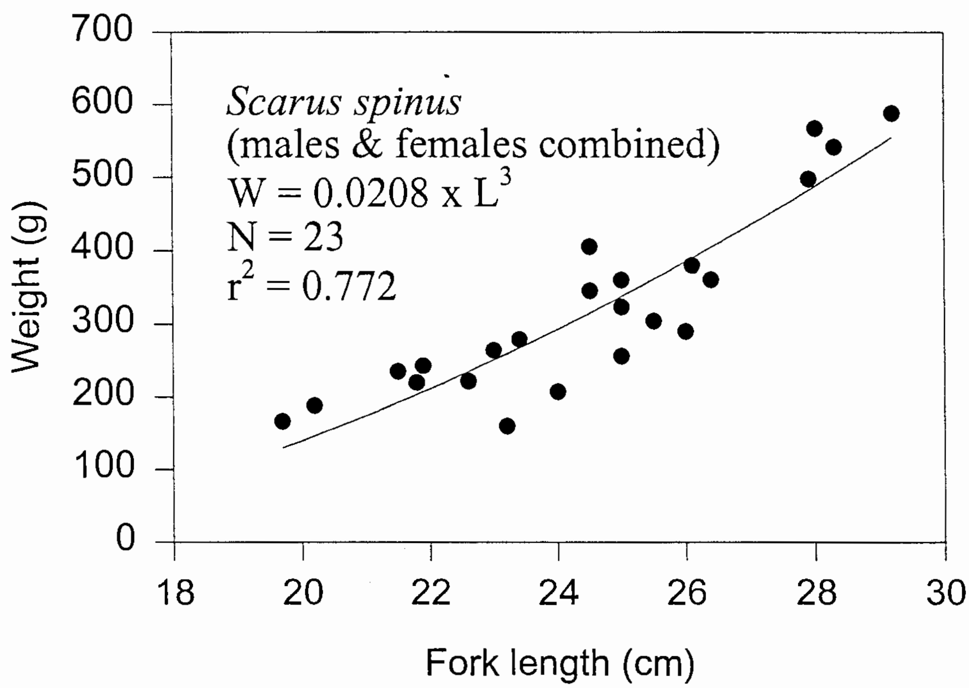



Scarus rubroviolaceous
(males & females combined)
W = 0.0205 x L3
N = 775
r2 = 0.930
Weight (g)
Fork length (cm)
0
500
1000
1500
2000
2500
3000
3500
15
20
25
30
35
40
45
50
55
60


Scarus schlegeli
(males & females combined)
W = 0.0189 x L3
N = 10
r2 = 0.369
Weight (g)
Fork length (cm)
400
450
500
550
600
650
700
750
24
26
28
30
32
34

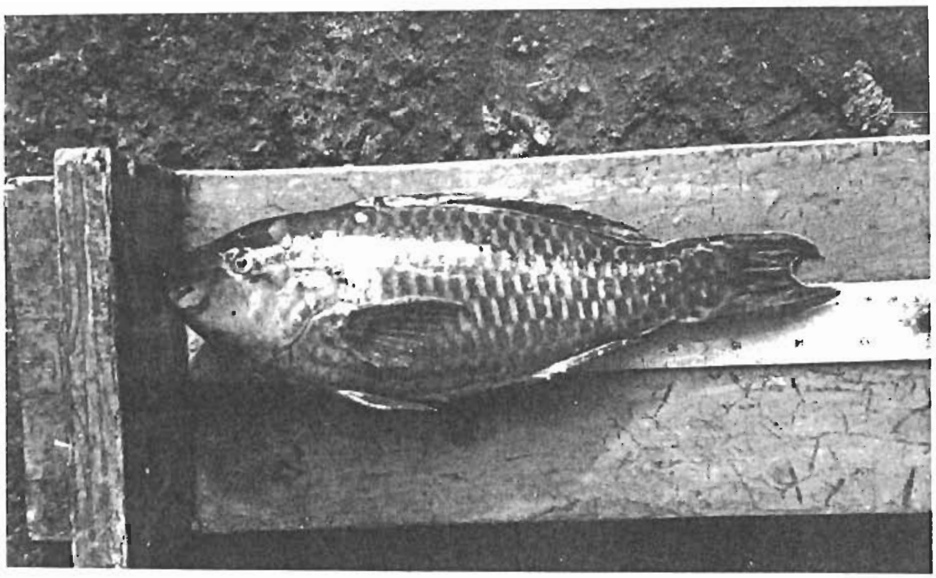
Appendix I cont.



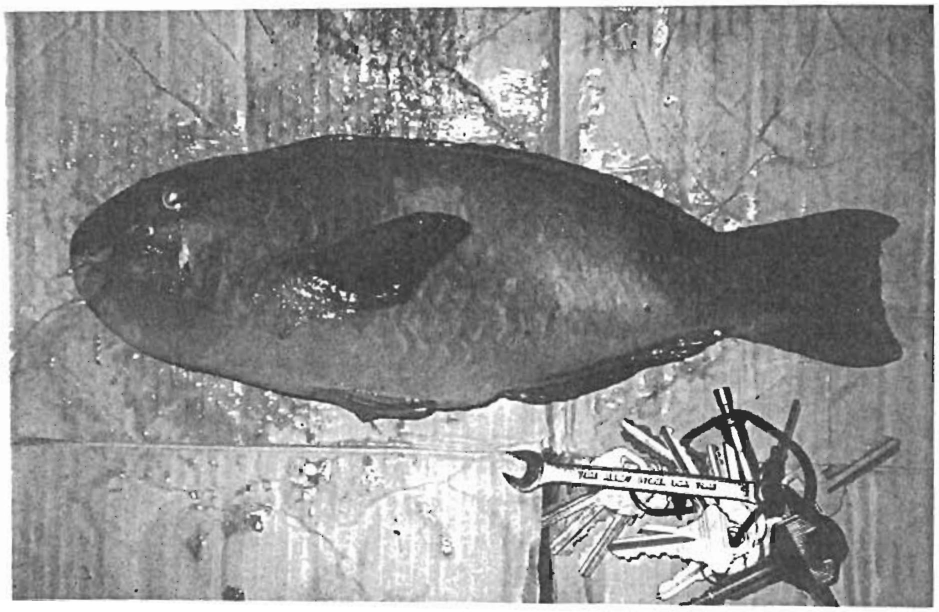


Appendix II

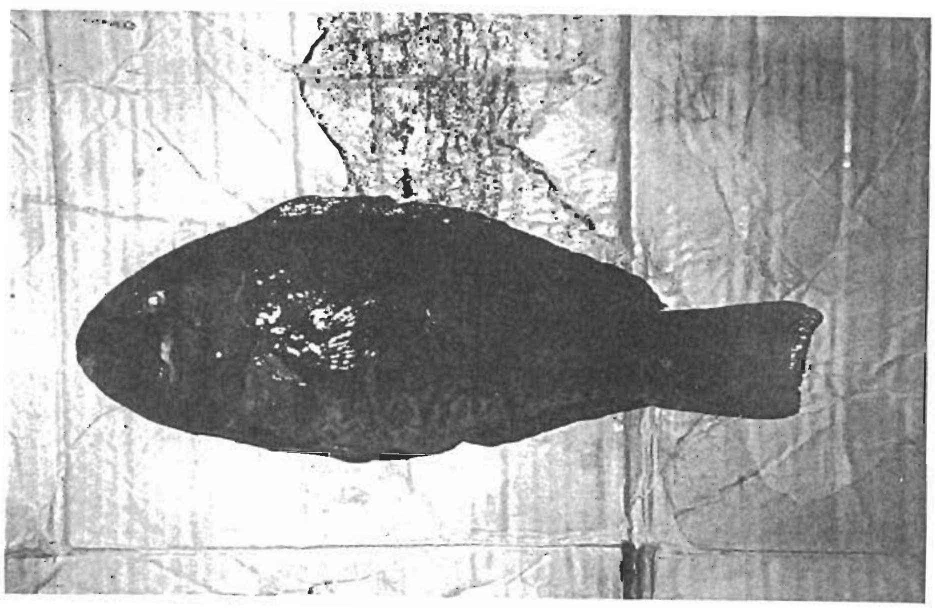
Identification guide to Scaridae of American Samoa. These photographs and descriptions are designed as a guide for reference to species discussed in this report, and also for future identification of scarids in artisanal catch. For detailed taxonomic descriptions refer to Choat & Randall (1986), Randall & Choat (1980), and Meyers, (1991). Scientific names are given in italics, followed by Samoan names in bold after Wass (1984), and common names are in brackets. Maximum fork lengths (F.L.) recorded from market data during 1996-1998 are given below in centimeters.



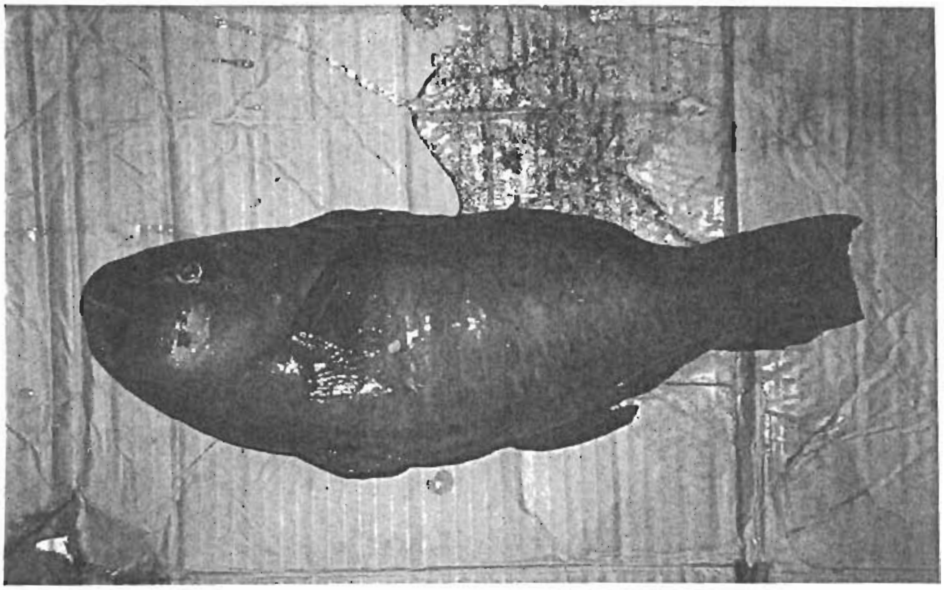
Scarus psittacus; **Laea-matapua'a** (Palenose parrotfish)
F.L. to 32 cm
Terminal phase male; distinguished by dark purple cap on snout and a slight depression forming the snout in front of the eye; lunate caudal fin.



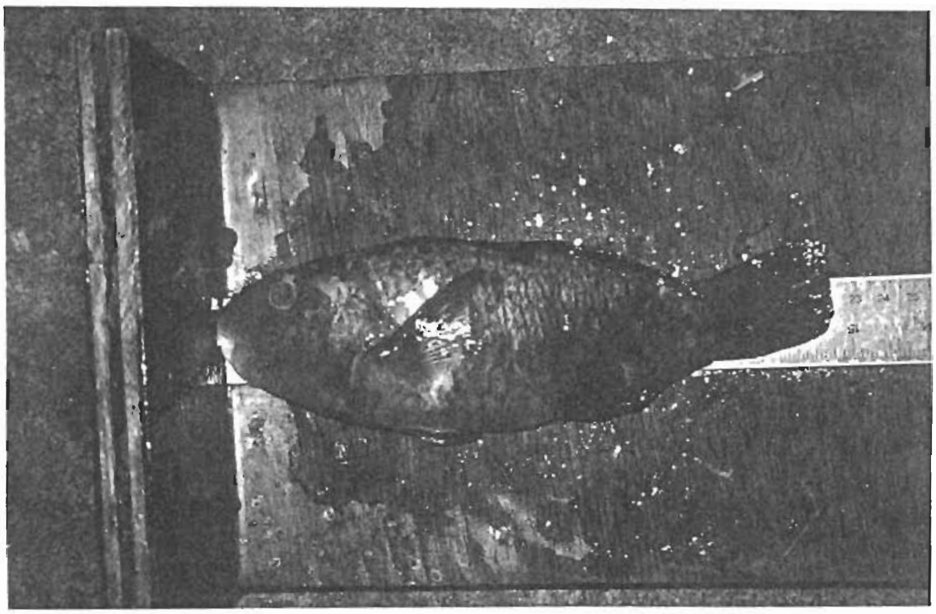
Scarus pyrrhurus **Laea-ulusama**
FL to 32 cm
Terminal phase male; this species is the most common species found on the reef front and consequently in catches; can be easily distinguished from *Chlorurus sordidus* by a bright yellow patch in the middle of the body with a distinct demarcation posteriorly to green on the caudal fin, and an oblique line from yellow to bright purple at the anterior end; the pectoral fin is also purple with a green dorsal margin.



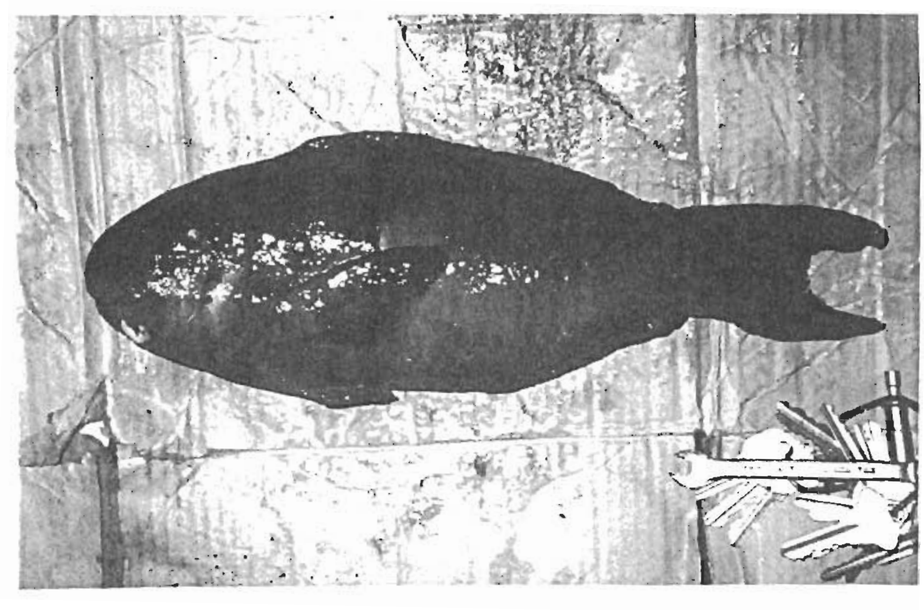
Scarus pyrrhurus **Fuga-si'umu**
Initial phase; these fish are easily distinguishable from other species initial phases by a red/orange caudal fin; pale blotches on this individual are not seen in freshly caught or live fish.



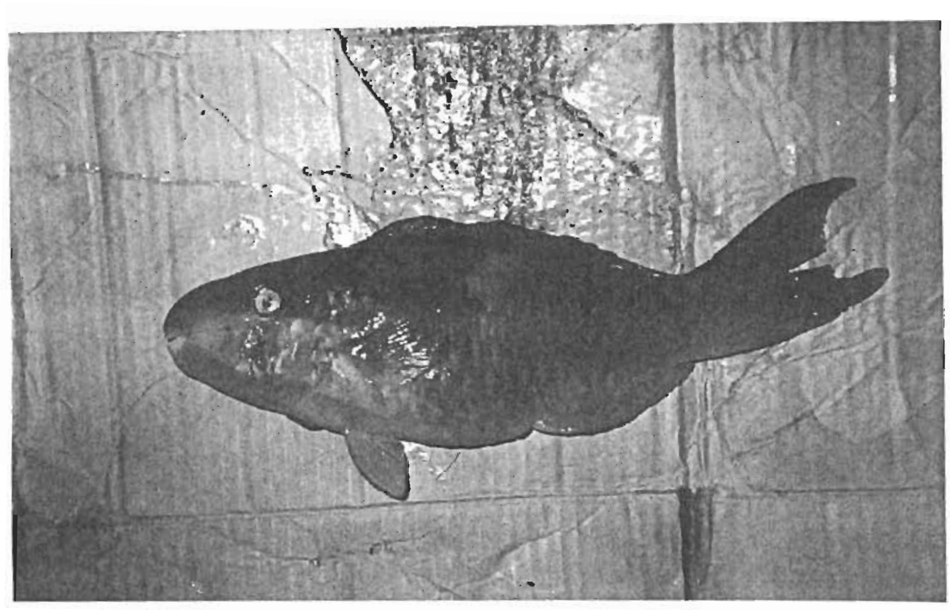
Chlorurus sordidus **Fugasi-tuavela** or **laea-tuavela** (Bullethead parrotfish)
FL to 32 cm
Terminal phase male; this relatively small species can be distinguished from *S. Pyrrhurus* terminal males by an indistinct yellow/tan patch anterior of the blue caudal peduncle; in this species there is no purple coloration on the body or pectoral fins; two to three pale blue bars can be distinguished on the abdomen.



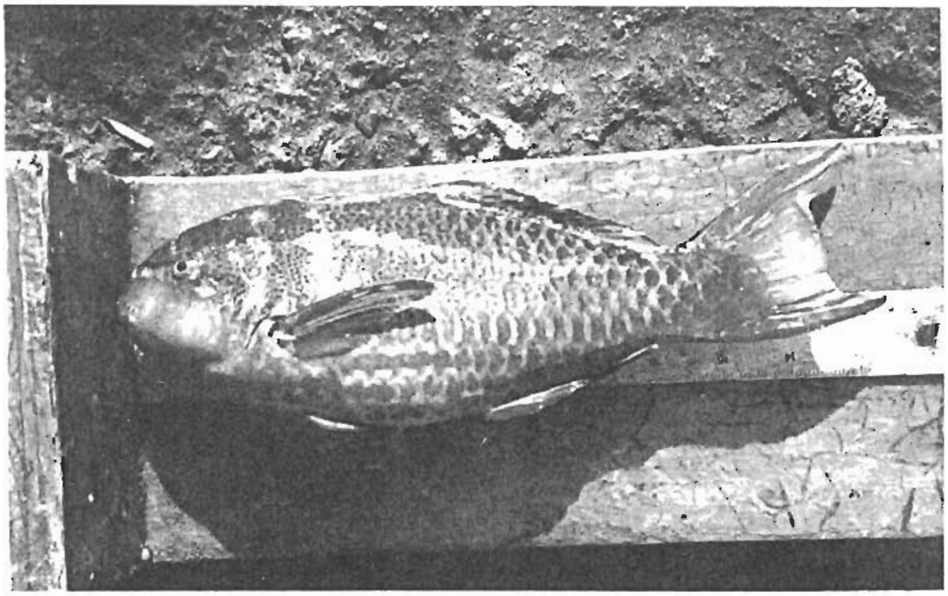
Chlorurus sordidus **Fuga-gutumu** (Bullethead Parrotfish)
Initial phase; highly variable in coloration, especially when observed alive; brown to gray; can have a white bar on the caudal peduncle with a black spot in the center, or small light spots posteriorly; dead specimens are easily recognizable a red tinge on the cheek and around the mouth.



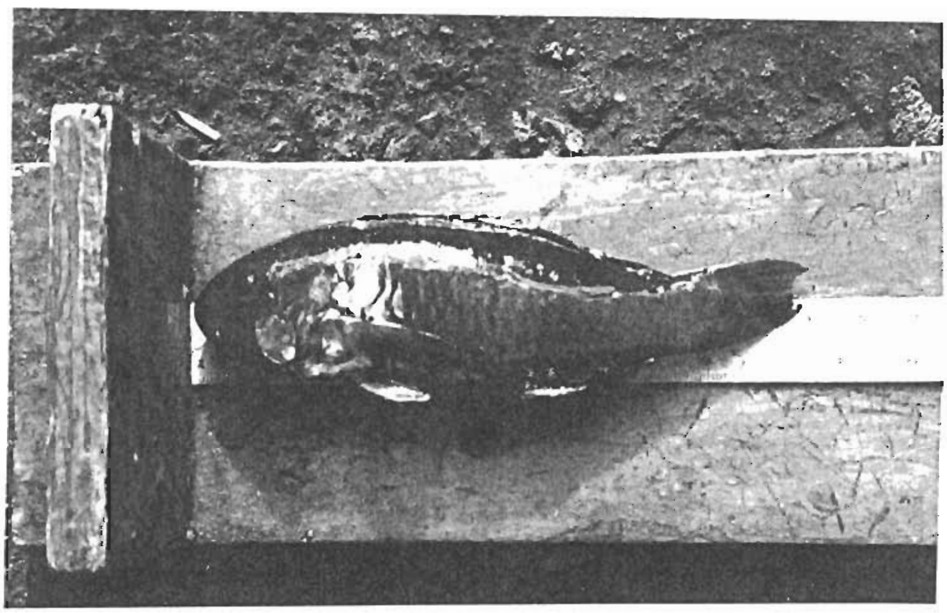
Scarus oviceps **Laea-tuavela** (Dark Capped Parrotfish)
FL to 32 cm
Terminal male; easily recognizable by a dark purple/blue cap that extends from above the pectoral fin on the dorsal side; lunate caudal fin.



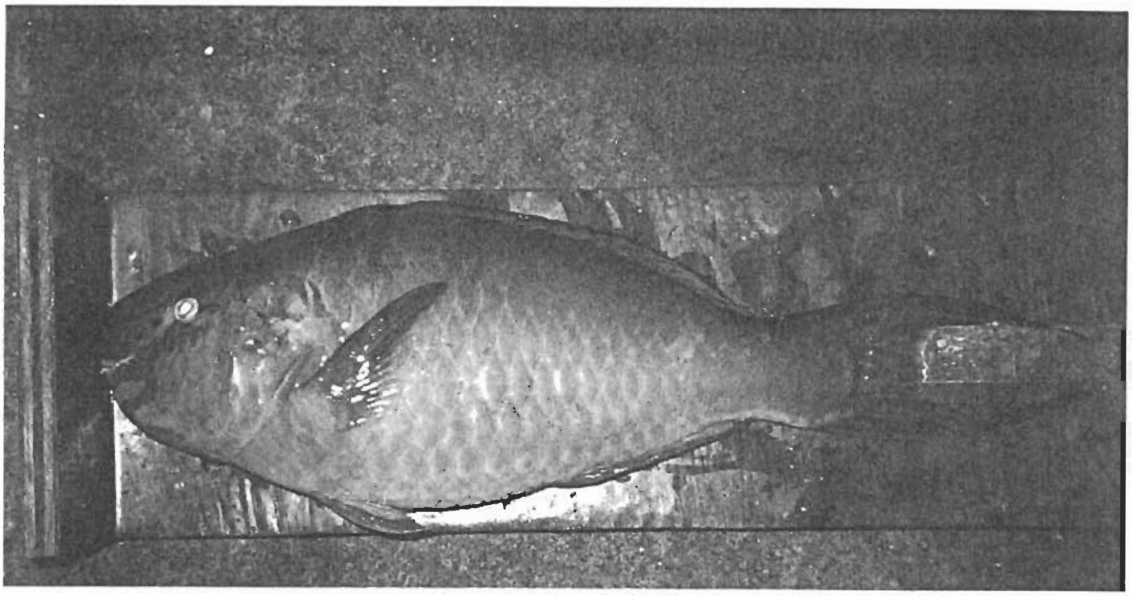
Scarus oviceps **Fuga-alosina** (Dark-capped parrotfish)
Initial phase; a gray cap extends dorsally from the mouth to above pectoral fins; a diagonal yellow strip runs forwards down the body from midway along the dorsal fin below the eye to the mouth; pectoral and anal fins can be tinged a salmon pink color.



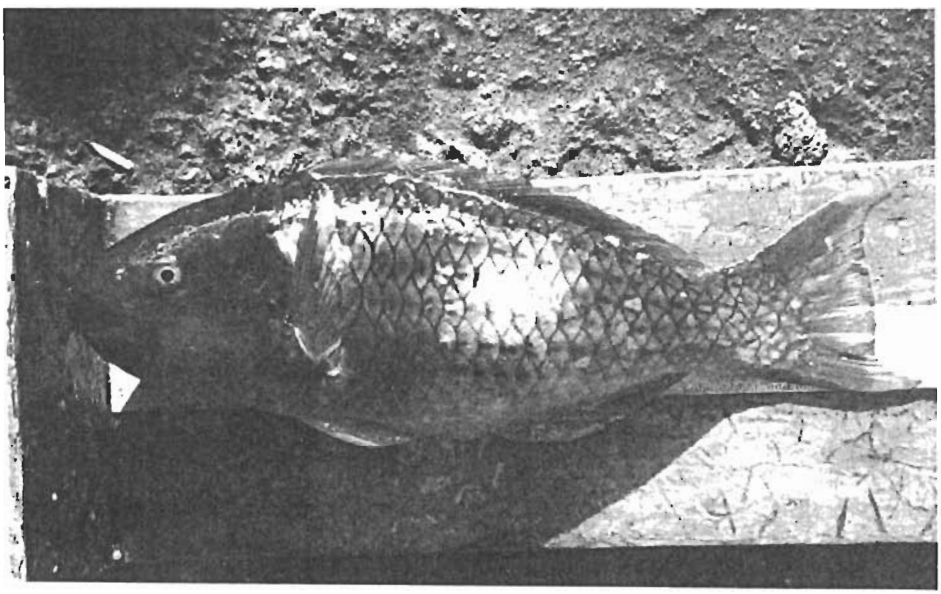
Scarus globiceps (roundhead parrotfish, violet-lined parrotfish)
F.L. to 33 cm
Terminal phase male; 3 blue bars on belly below pectoral fin; head, upper half of preoperculum and anterior half of body covered with blue speckles on a purple background; caudal fin emarginate; snout rounded.



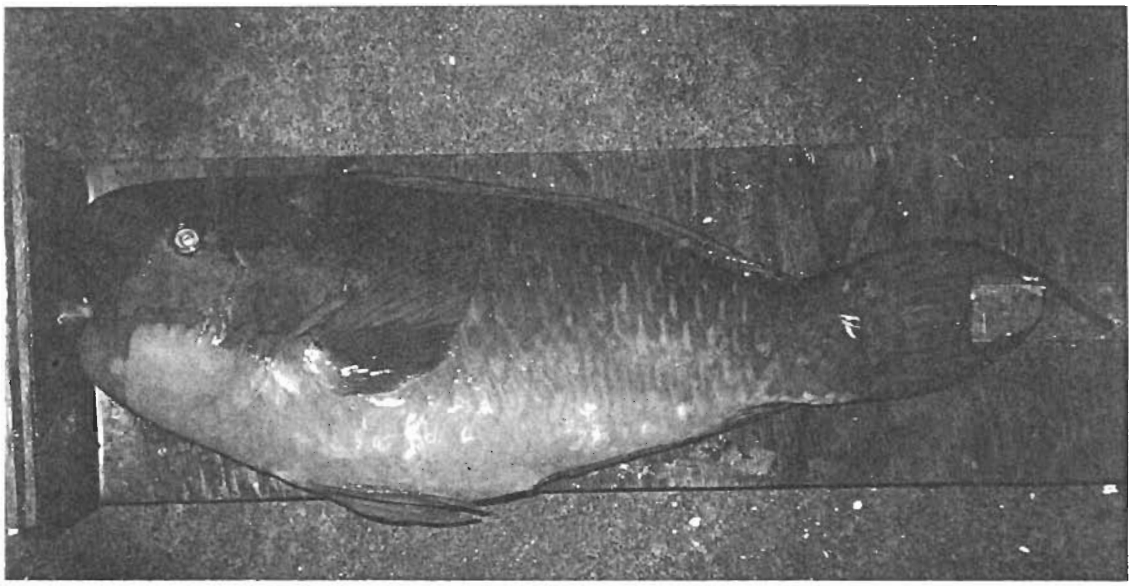
Scarus globiceps (roundhead parrotfish, violet-lined parrotfish)
Initial phase; These fish are difficult to distinguish from initial phase *S. psittacus,* but can be identified by 3 horizontal white bars on the belly extending from below the pectoral fins to the anal fins.



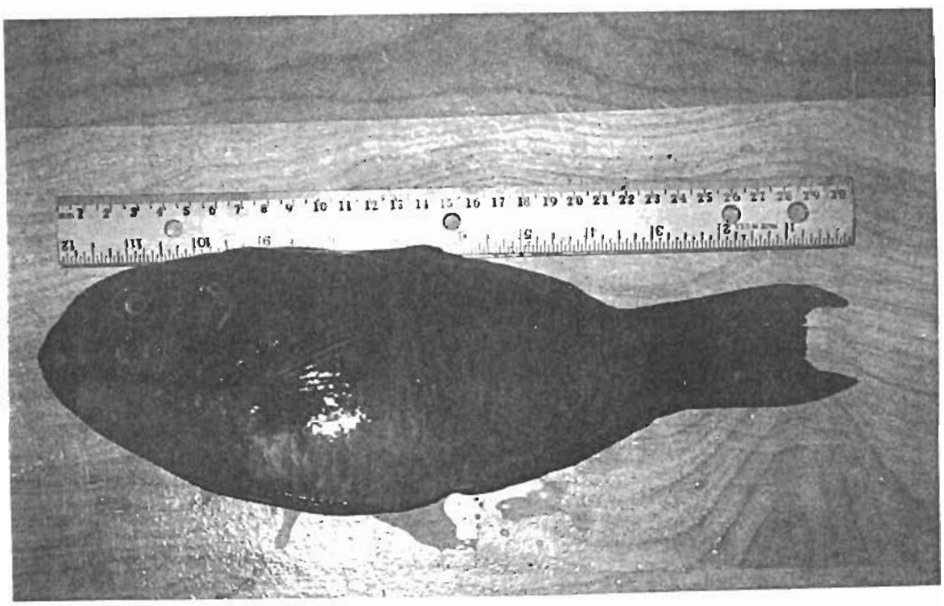
Scarus rubroviolaceous **Laea-mala** (Redlip parrotfish)
FL to 56 cm
Terminal phase male; lunate caudal; both phases of this large species have a bicolored appearance, with the anterior half abruptly dark, this is not so evident in dead specimens, especially males; angular snout ('gibbus forehead') 2/3 distance between eye and snout; large specimens can have elongate tail filaments.



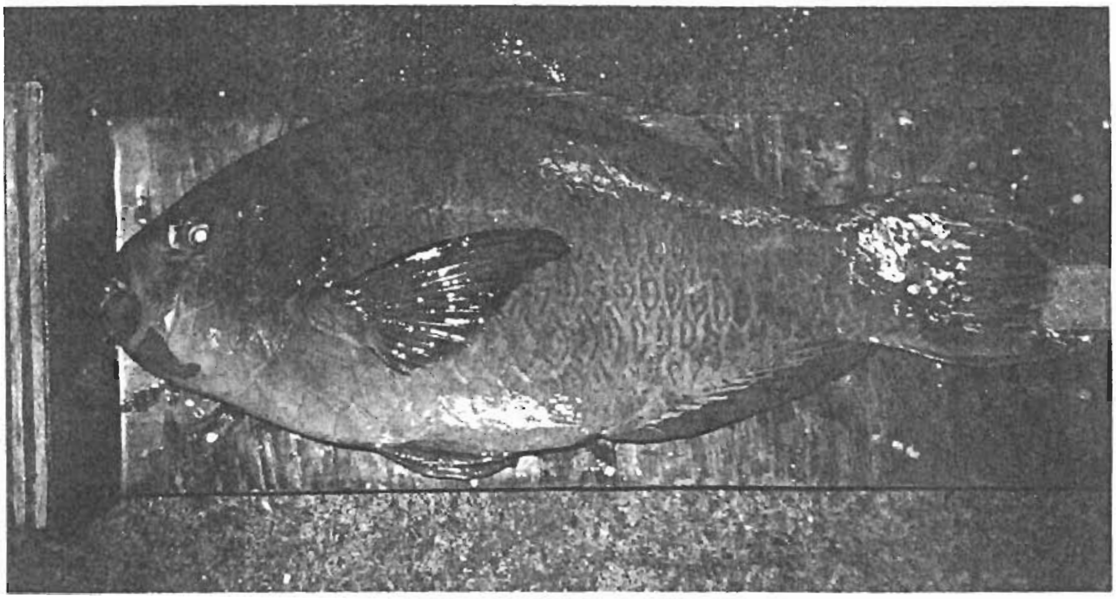
Scarus rubroviolaceous **Laea-mea** (Redlip parrotfish)
Initial phase; red fins; red/brown body with marbled scales, noticeably darker anterior half of body; 'gibbus forehead', but not as pronounced as in large males.



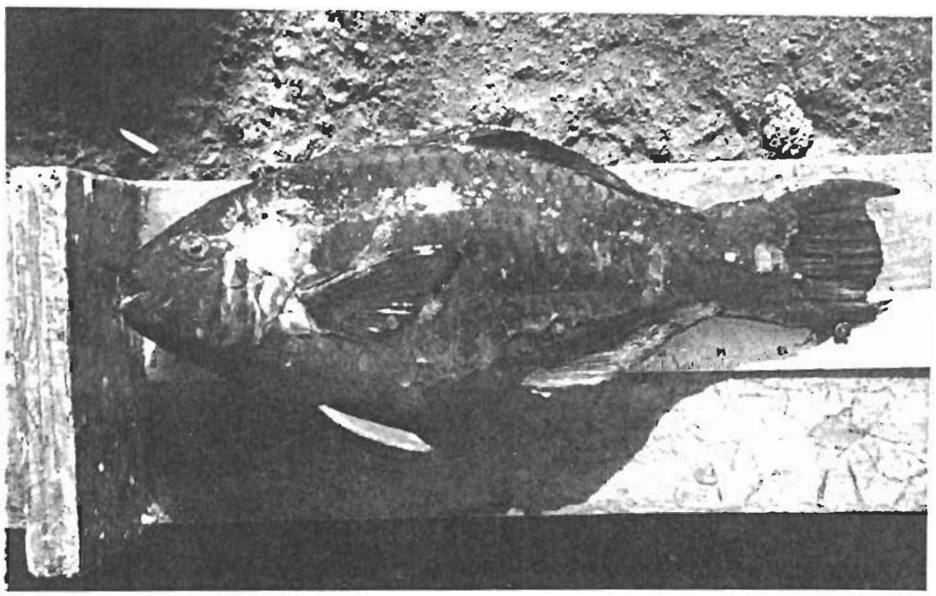
Chlorurus ~~*gibbus*~~ microrhinos **Ulumato, Galo** (Pacific Steephead Parrotfish)
FL to 58 cm
Terminal phase male; Larger of the species in American Samoa; bright blue on the dorsal half of the body; blue patch and streak extending from the corner of the mouth to the pectoral fin; large adults develop 'gibbus' forehead that drops steeply from eye level down to the mouth; long tail filaments.



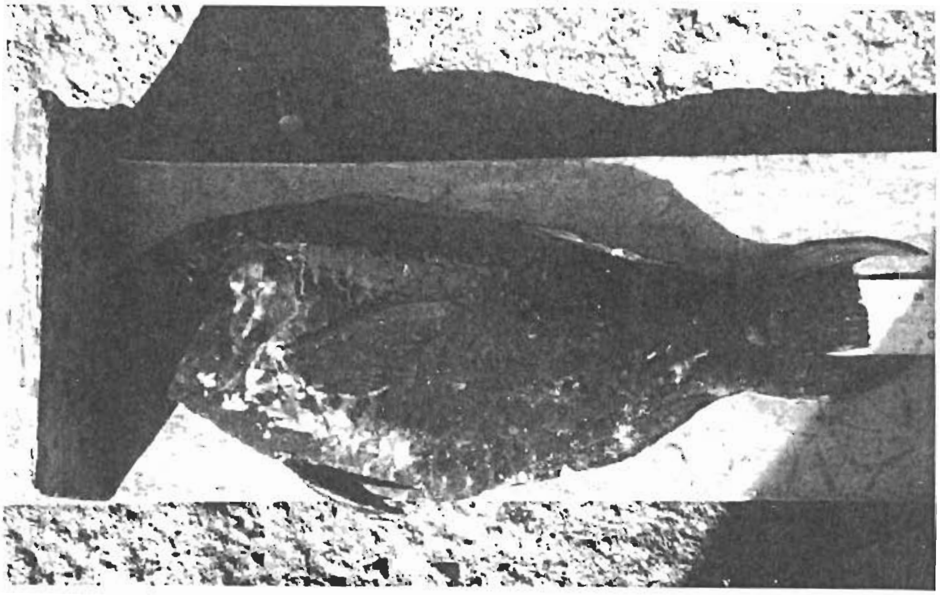
Chlorurus gibbus **Fugasi, laea** (Pacific Steephead Parrotfish)
Juvenile/initial phase; Dorsal profile of small individuals strongly convex; usually a dull blue/gray color, becoming brighter blue with age; head profile increases with age; occasional red colored initial phase fish has been observed.



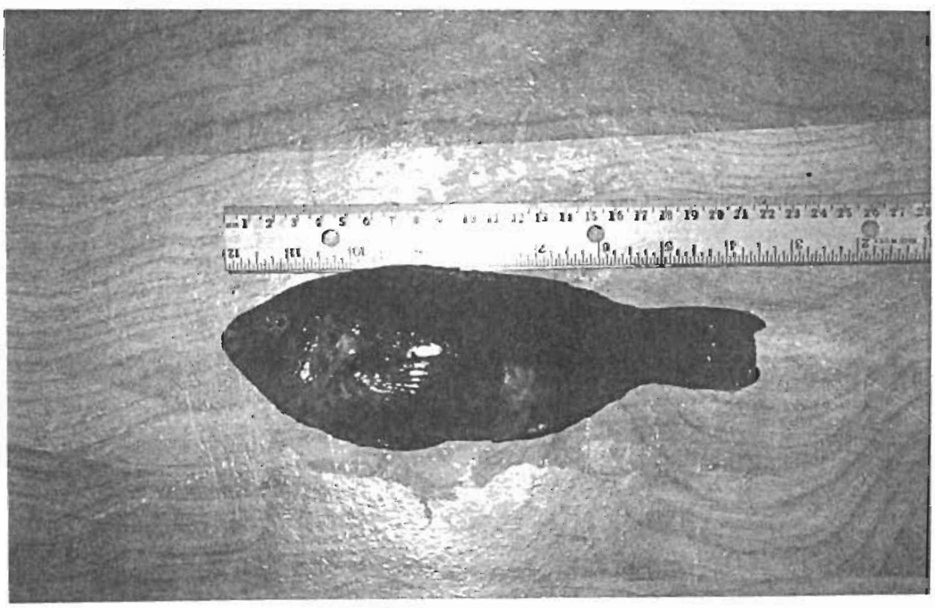
Scarus altipinnus (Filament-finned parrotfish)
FL to 52 cm
Terminal phase male; elongate dorsal filament is present in the middle of the dorsal fin rays in both initial phase and terminal phase males; the dental plates of both phases are dark blue-green, double emarginate tail (broadly rounded in the center).



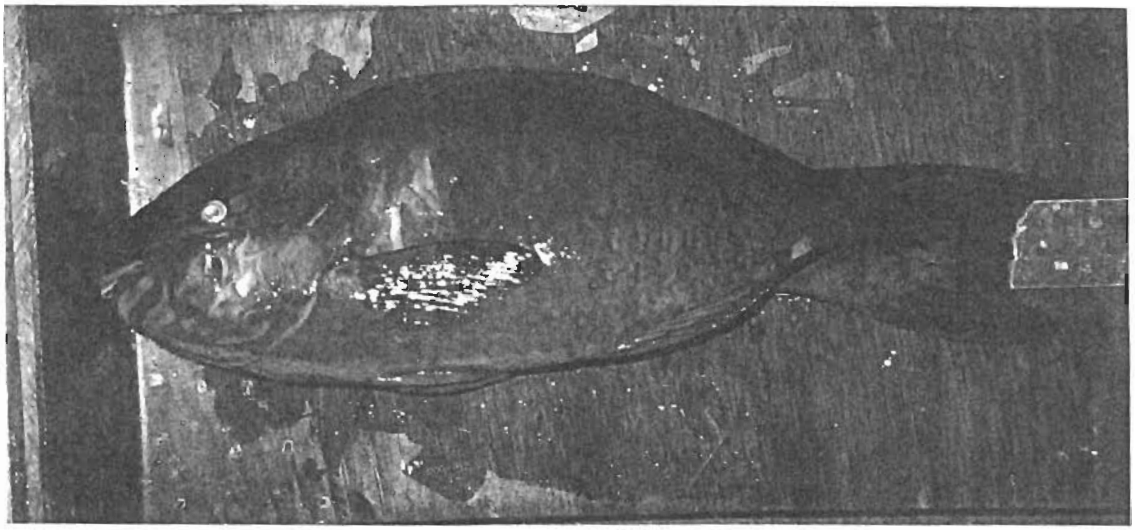
Scarus altipinnus (Filament-finned parrotfish)
Initial phase; as above but red-brown in color, often with a series of pale spots along the side of the body.



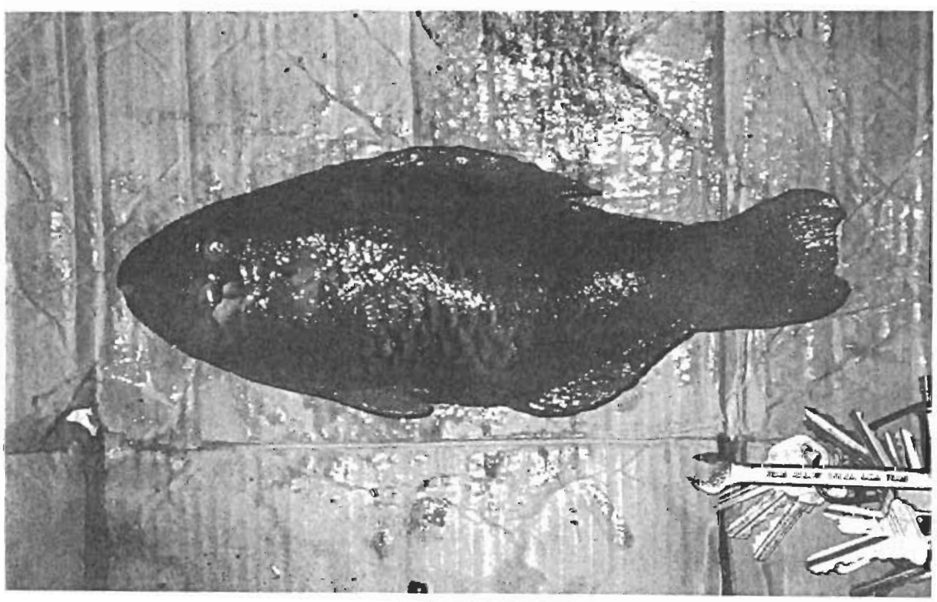
Scarus niger **Laea-pala** (Black parrotfish)
FL to 38 cm
Terminal phase male; distinctive dark green coloration, with a small black-edged bright green spot (not visible in this specimen) behind upper end of gill opening; blue-green dental plates; double emarginate caudal fin with long filaments.



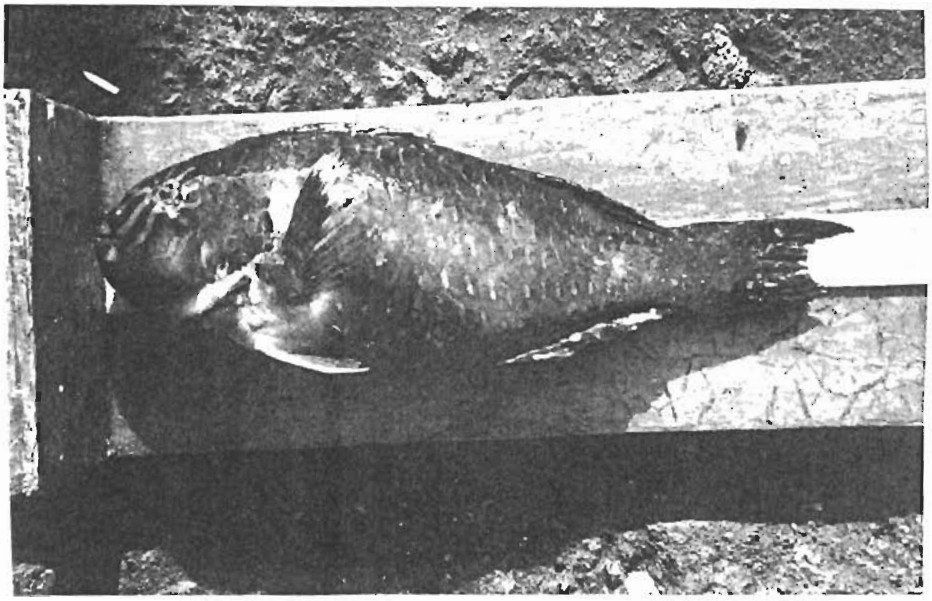
Scarus niger **Fuga-pala** (Black parrotfish)
Initial phase; greenish brown body with small black spots; head orange brown, becoming orange-red anteriorly.



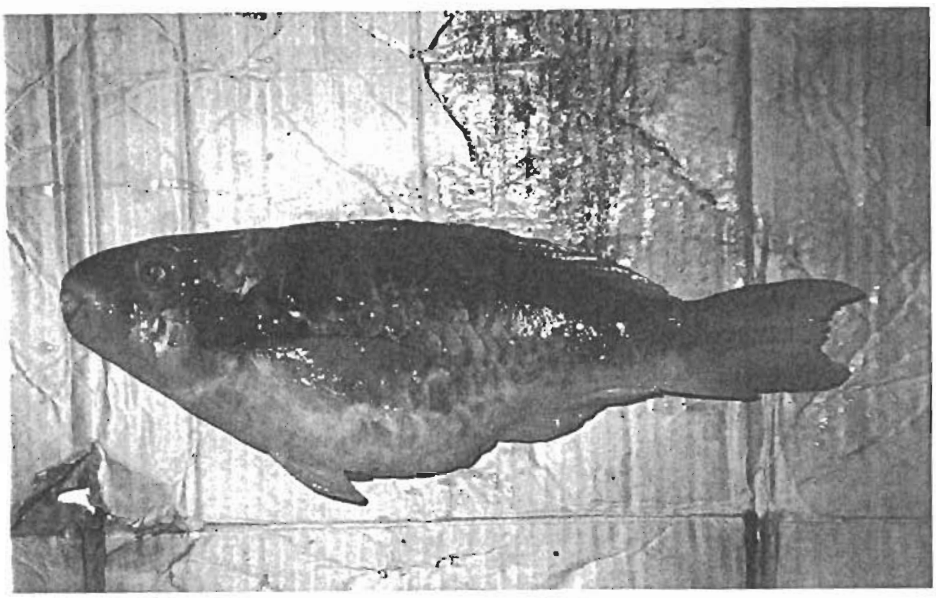
Scarus frenatus **Laea-si'umoana** (Vermiculate parrotfish)
FL to 43 cm
Terminal phase male; this species has distinctive markings, having a green caudal peduncle; marbled scales; dental plates blue/green and lunate caudal fin.



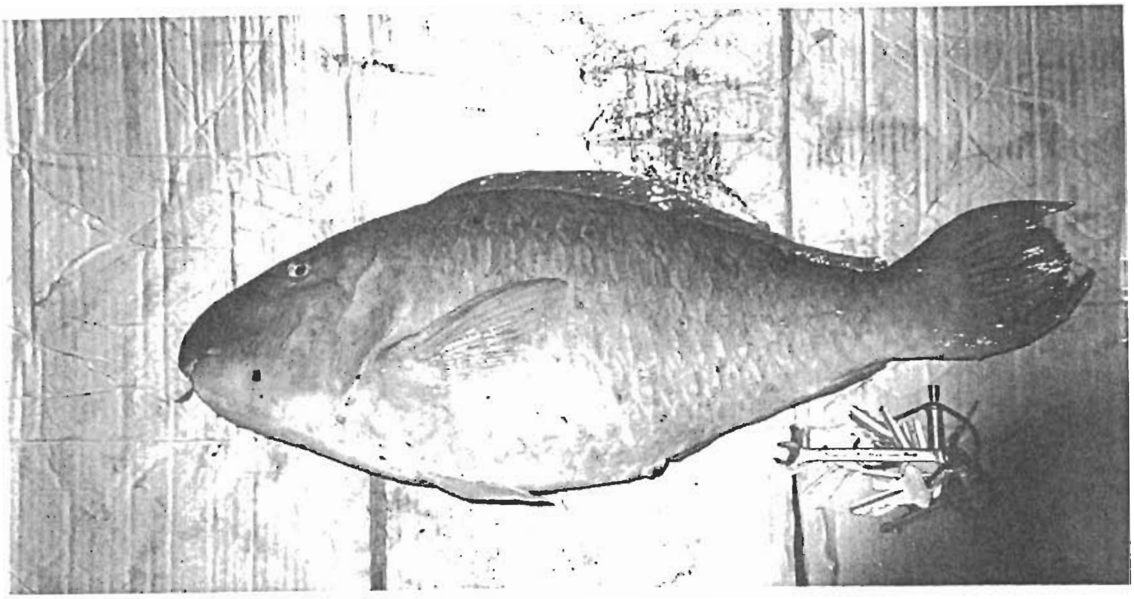
Scarus frenatus **Laea-mea** (Vermiculate parrotfish)
Initial phase; red/brown color with broad with longitudinal dark brown stripes, primarily on the dorsal side of the body; fins red and a light patch on the caudal peduncle.



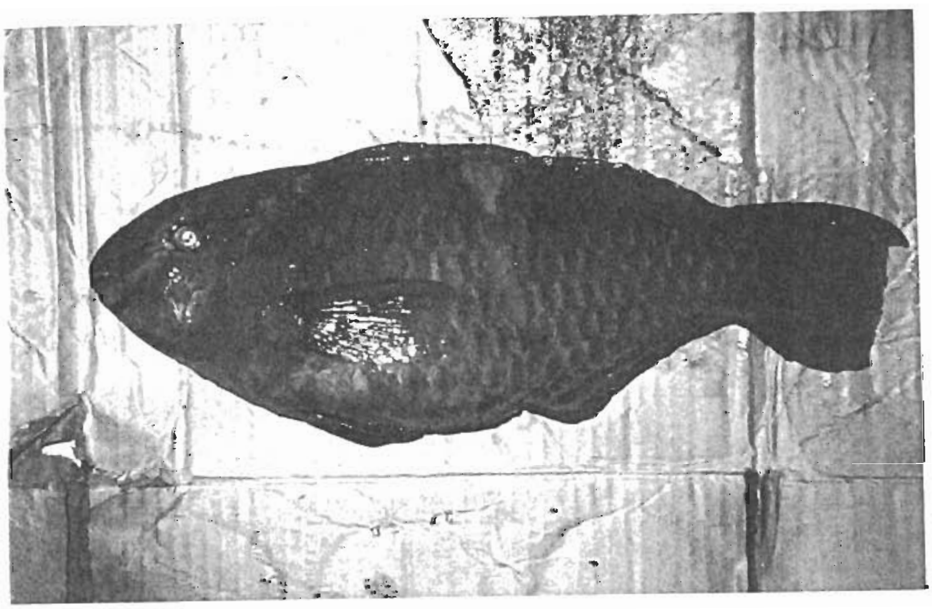
Calotomus calrolinus **Fuga-valea** (Bucktooth parrotfish*)*
FL to 37 cm
Terminal male; easily distinguished from *Scarus* species by icisiform teeth in upper and lower jaw; emarginate caudal fin with white margin; star pattern radiates from orbit; become greener with age. Initial phase; red/brown color.



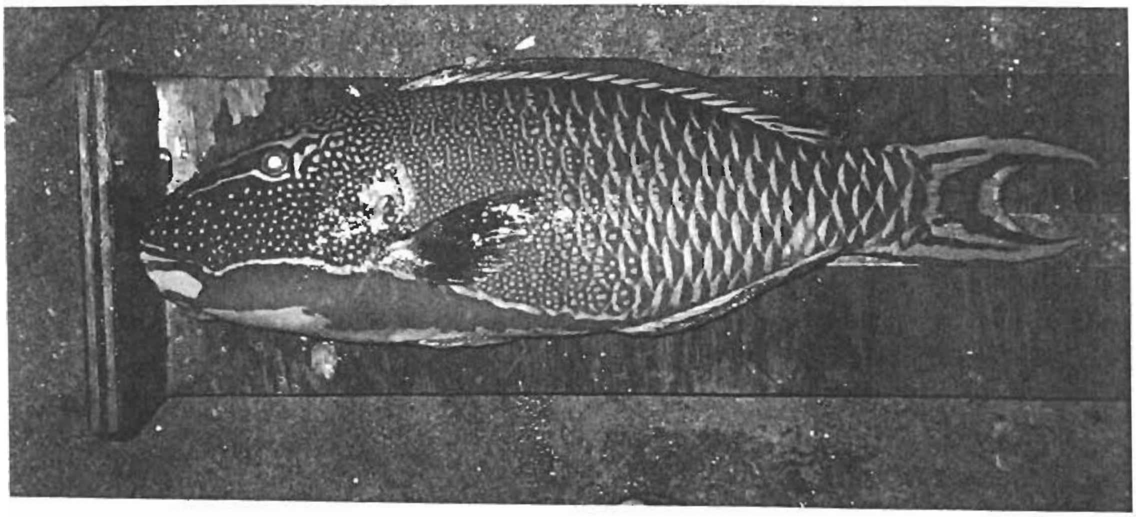
Scarus forsteni **Fuga-alomu** Forsten's parrotfish)
FL to 43 cm
Initial phase; light red/brown with broad blue band along side of body, often a patch of yellow in the middle of the band.; a white spot frequently near tip of pectoral fin in life; Terminal Male: green, scales of body edged in salmon; lips edged in salmon pink; pectoral fins blue/green with median streak of purplish orange; lunate tail with blue crescent on margin.



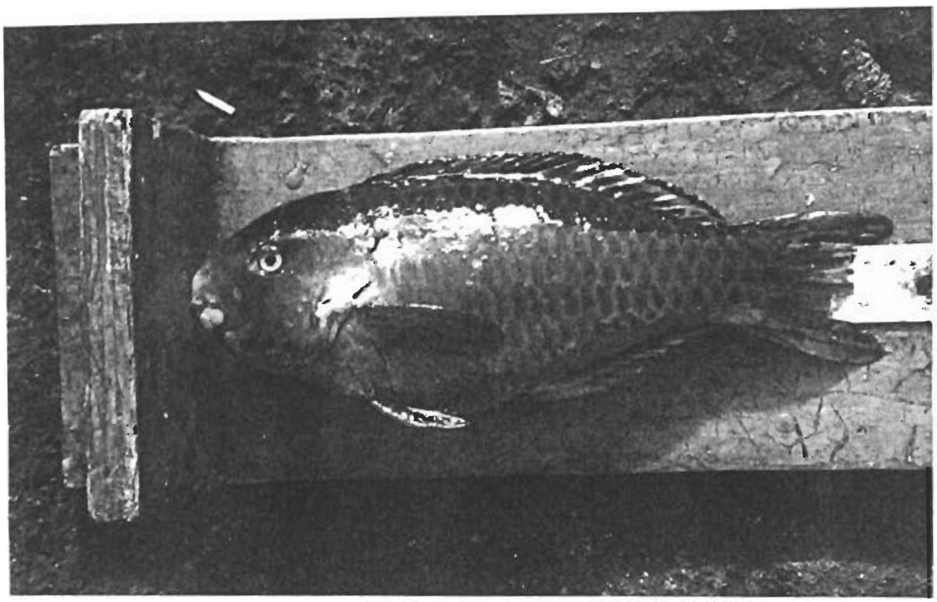
Hipposcarus longiceps **Laea-ulapokea** (Pacific longnose parrotfish)
FL to 57 cm
Terminal phase male; angular snout; light blue and green, often darker dorsally; caudal double emarginate.
Initial phase; whitish/gray with a yellowish tail.



Scarus schlegeli **Laea-tusi** (Yellow band parrotfish)
FL to 34 cm
Terminal male; dark green, suffused with purple on dorsal side, vertical streak half-way down body, yellow below dorsal fine to light blue medially.
Initial phase; olivaceous brown, up to 5 curved pale vertical bars.



Cetoscarus bicolor **Laea-mamanu, laea-usi** (Bicolor parrotfish)
FL to 50 cm
Terminal phase; attractive species is distinctive; blue with orange spots anteriorly, scale margins orange dorsally, dorsal profile of head slightly and evenly convex.
Initial phase; **Fuga-sina, mamanu** reddish yellow on back; scales on side of body edged and spotted with black.



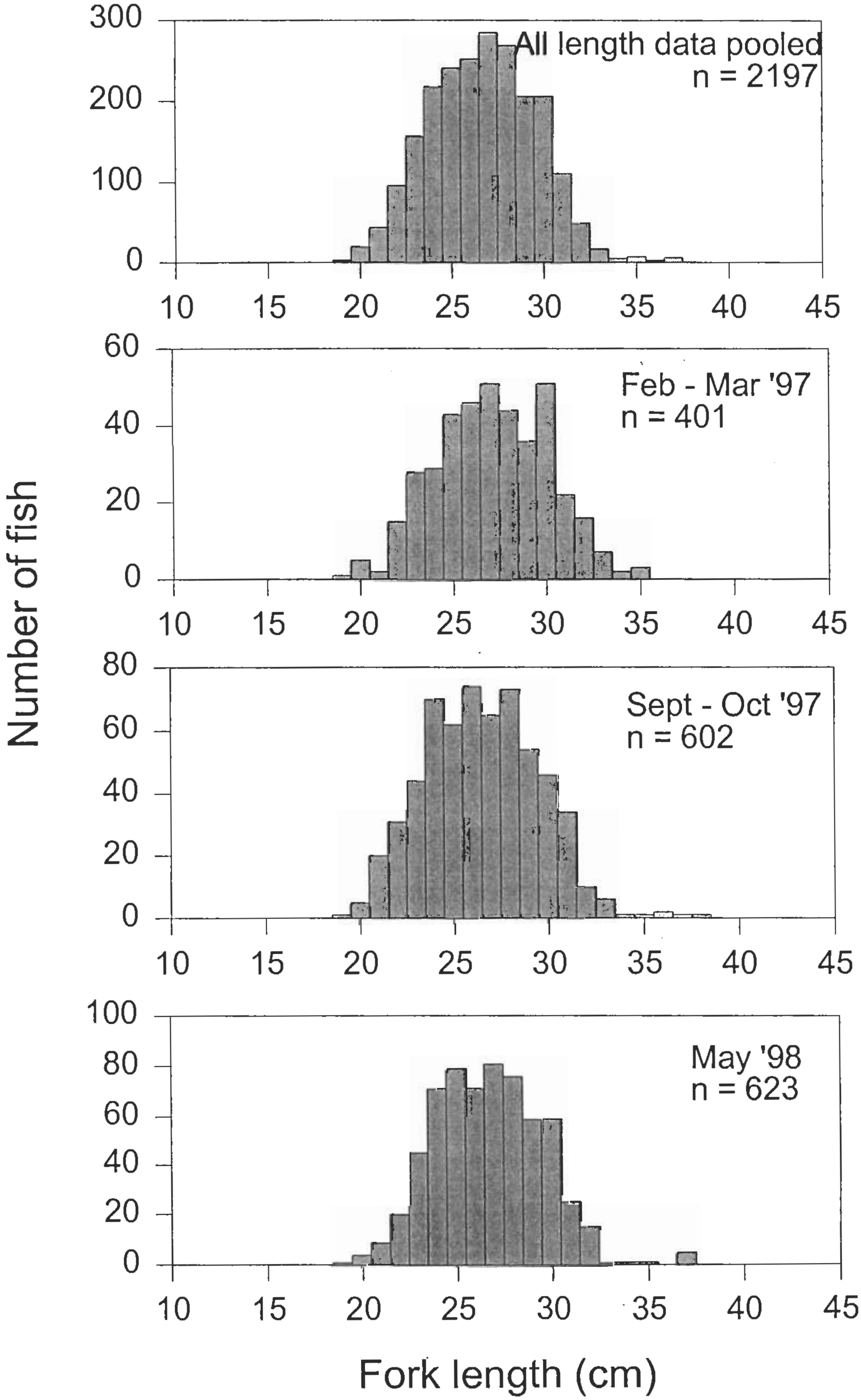
Scarus spinus **Fuga-a'au** (Pigmy parrotfish)
FL to 29 cm
Terminal male; caudal emarginate; small fish with a stout body and rounded head; snout with a distinct green/yellow patch.
Initial phase; dark brown with 4 - 5 pale bars on body.

Appendix III. Mean biomass of parrotfish (species pooled) from 26 sites around Tutuila Island.

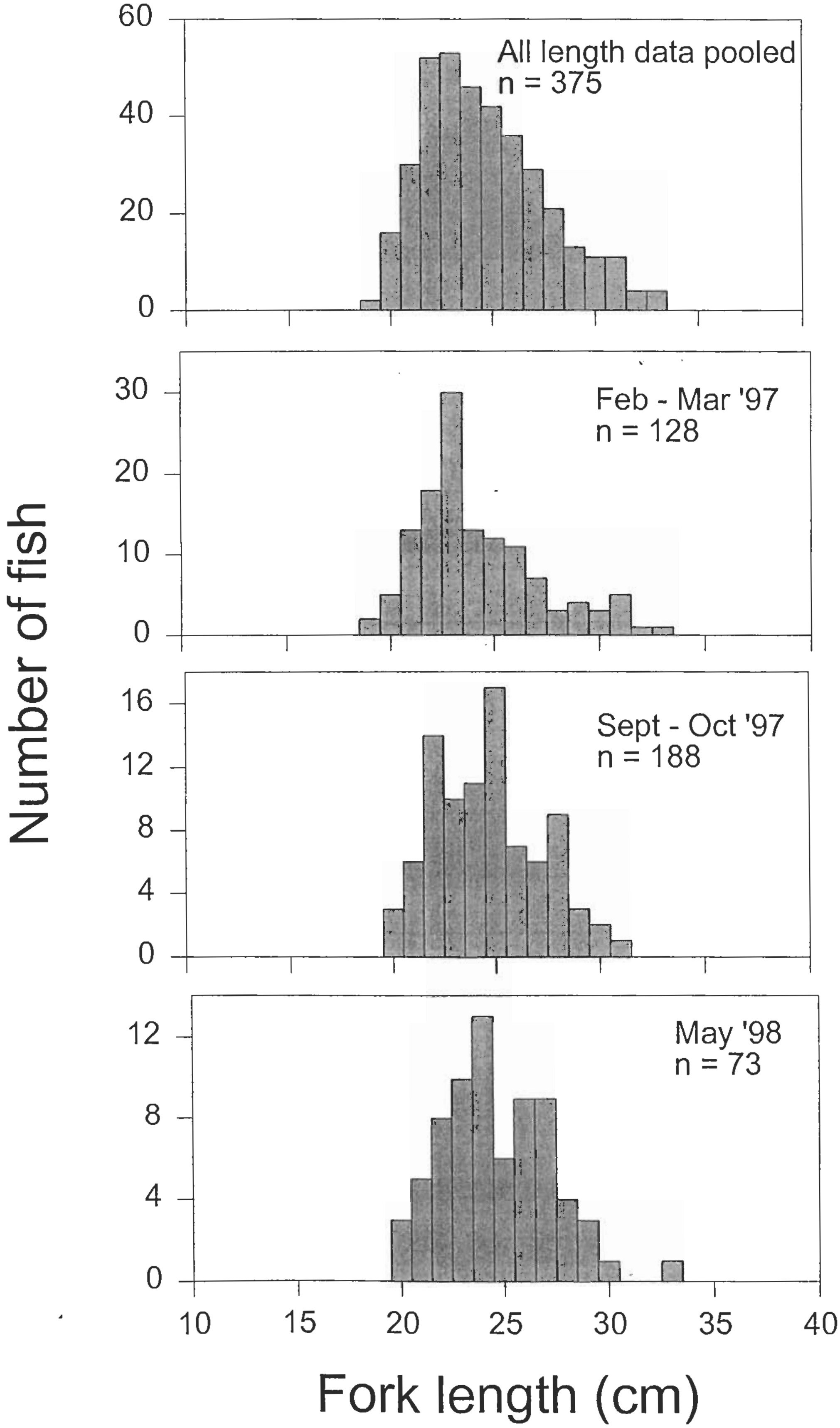
Site	Mean biomass ($kg^{-1}ha^{-1}$)	se	n
Afao	80.50	13.59	15
Airport	38.81	6.57	10
Airport lagoon	152.27	43.39	5
Aoloau	69.15	17.09	15
Amanave	80.46	38.14	5
Aua	76.86	14.95	10
Fafaga	104.00	20.37	10
Faga'alu lagoon	12.30	2.18	5
Fagalele	135.23	21.90	15
Faga'alu	64.57	16.03	15
Fagasa	66.01	16.73	15
Fagiatua	127.09	33.53	10
Fatamafuti	34.91	8.63	15
Larson Bay	122.41	41.00	10
Nuutoga pt	88.65	25.37	10
Nua seetaga	100.50	24.42	15
Nuu'uli lagoon	9.95	6.62	5
Nuuooti Cove	56.57	12.05	15
Poloa	92.14	24.38	15
Tulutulu pt	51.09	21.59	10
Sailele	82.46	17.21	15
Taema bank	157.73	22.47	5
Tafeu Cove	70.44	12.31	15
Tula	63.04	8.44	10
Vatia	58.54	16.6	10

Grand Mean 83.16 ± 15.9 $kg^{-1}ha^{-1}$ (95% C.I.)

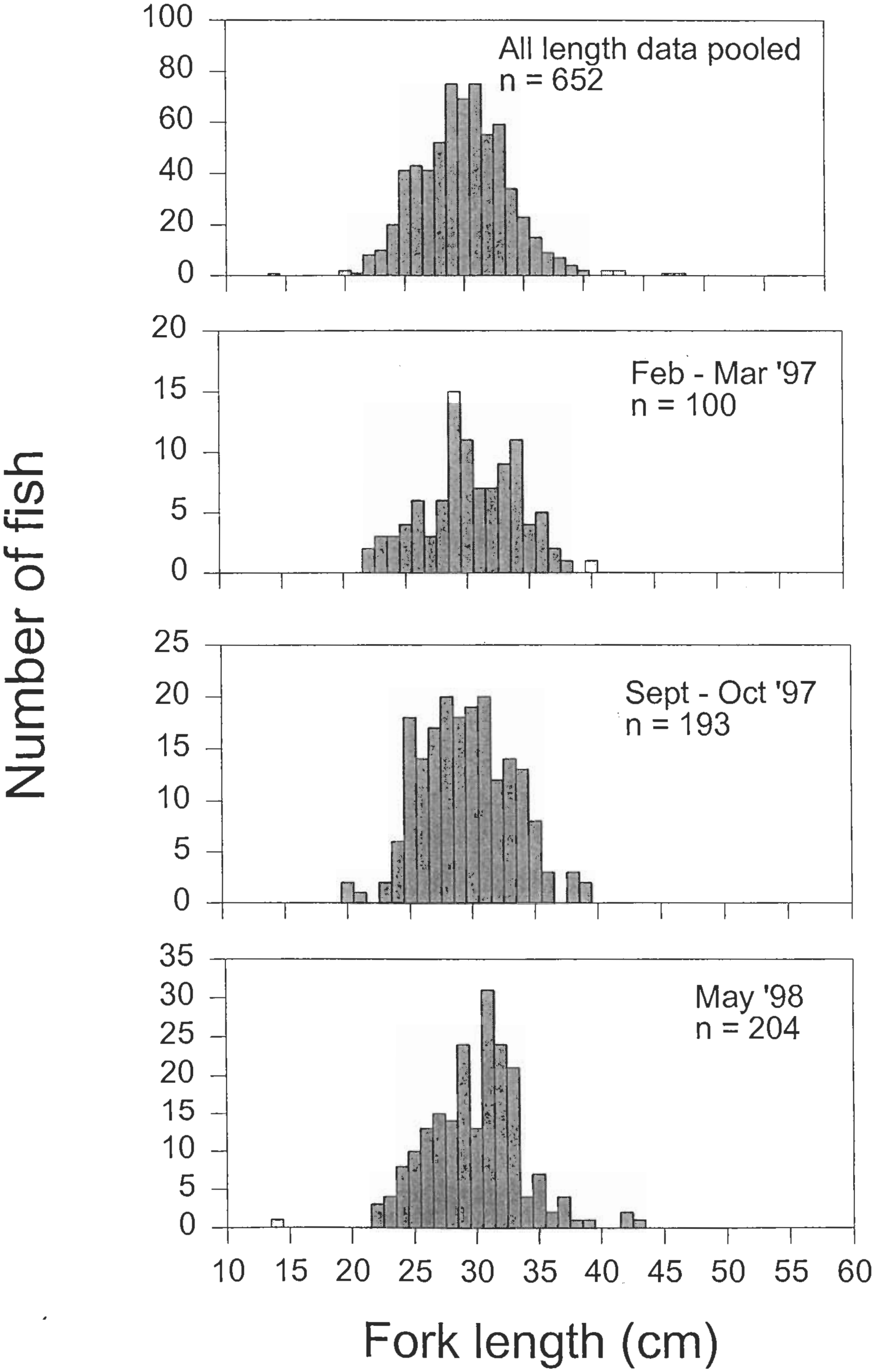
Appendix IV. Length-frequency distributions of *S. pyrhurrus*



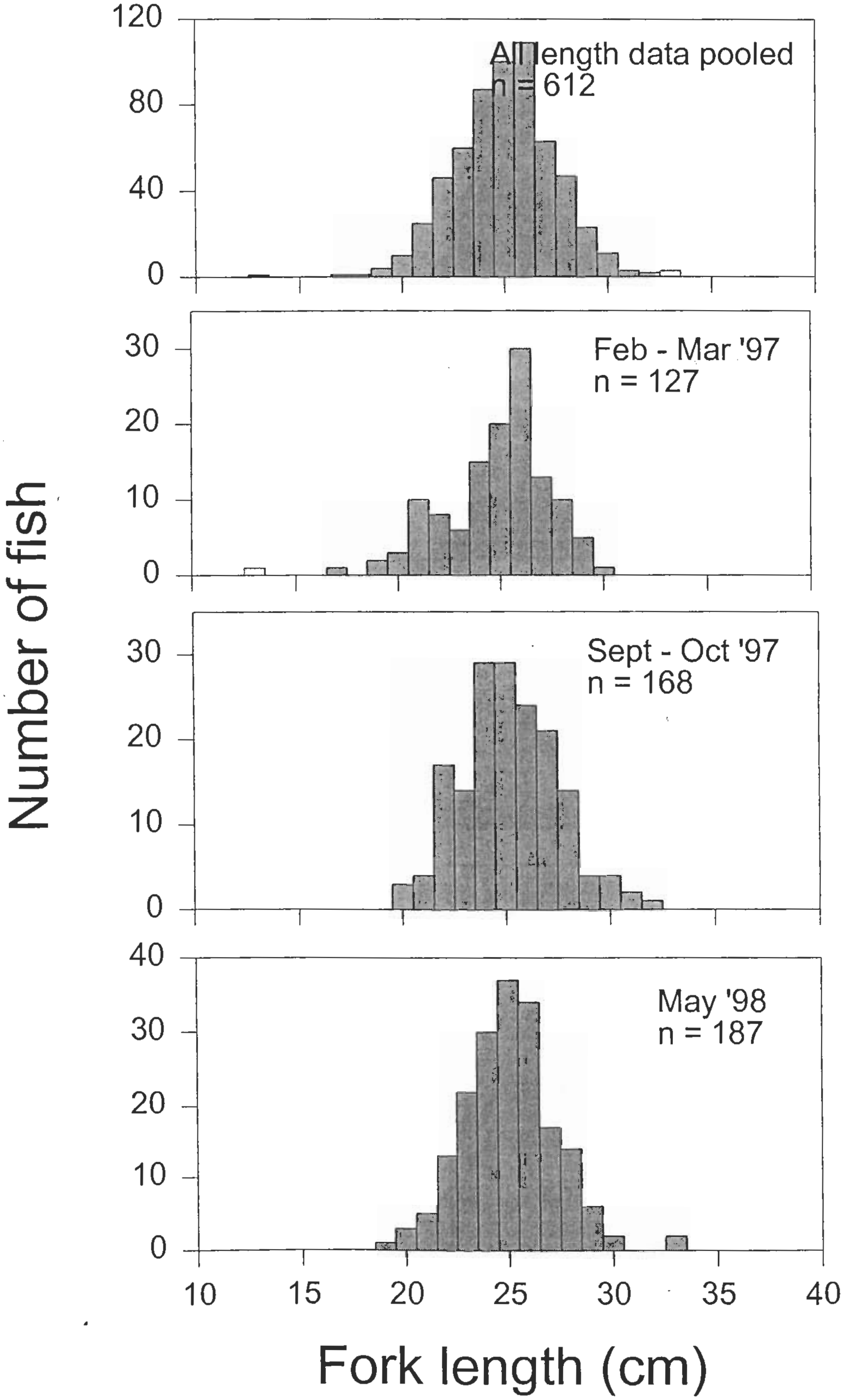
Appendix IV. Length-frequency distributions of *S. psittacus.*



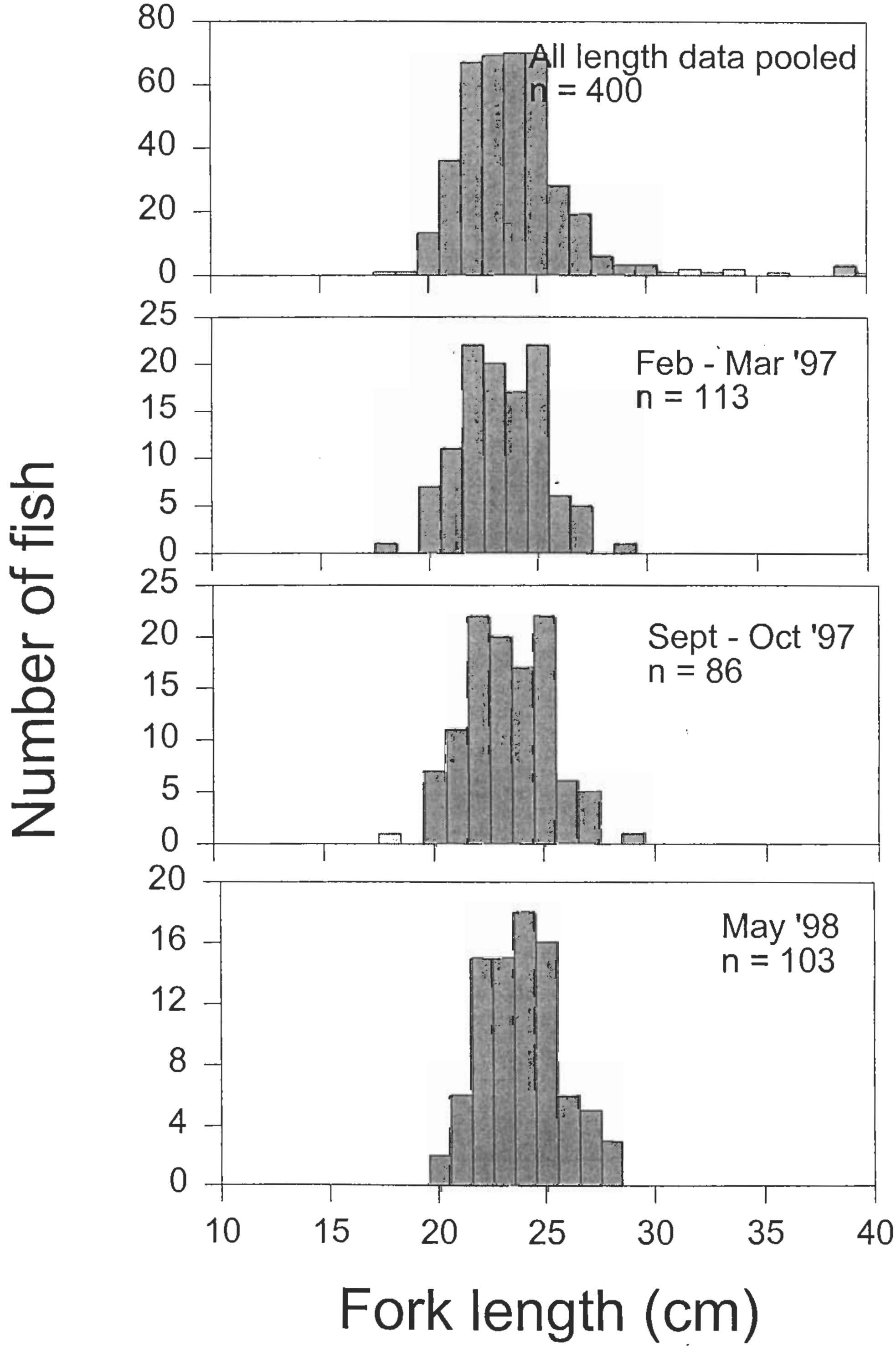
Appendix IV. Length-frequency distributions of *S. forsteni*.



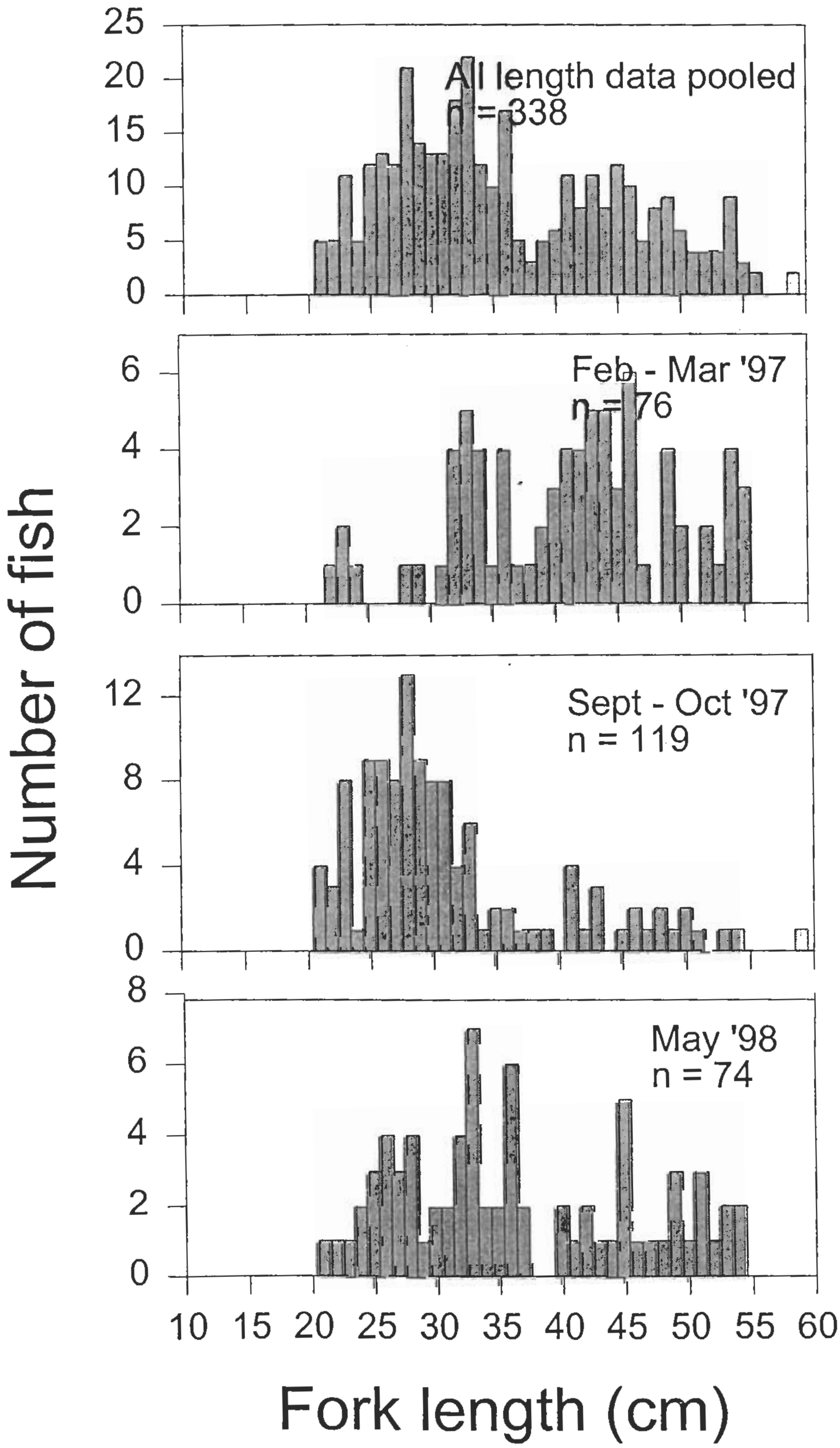
Appendix IV. Length-frequency distributions of *C. sordidus*.



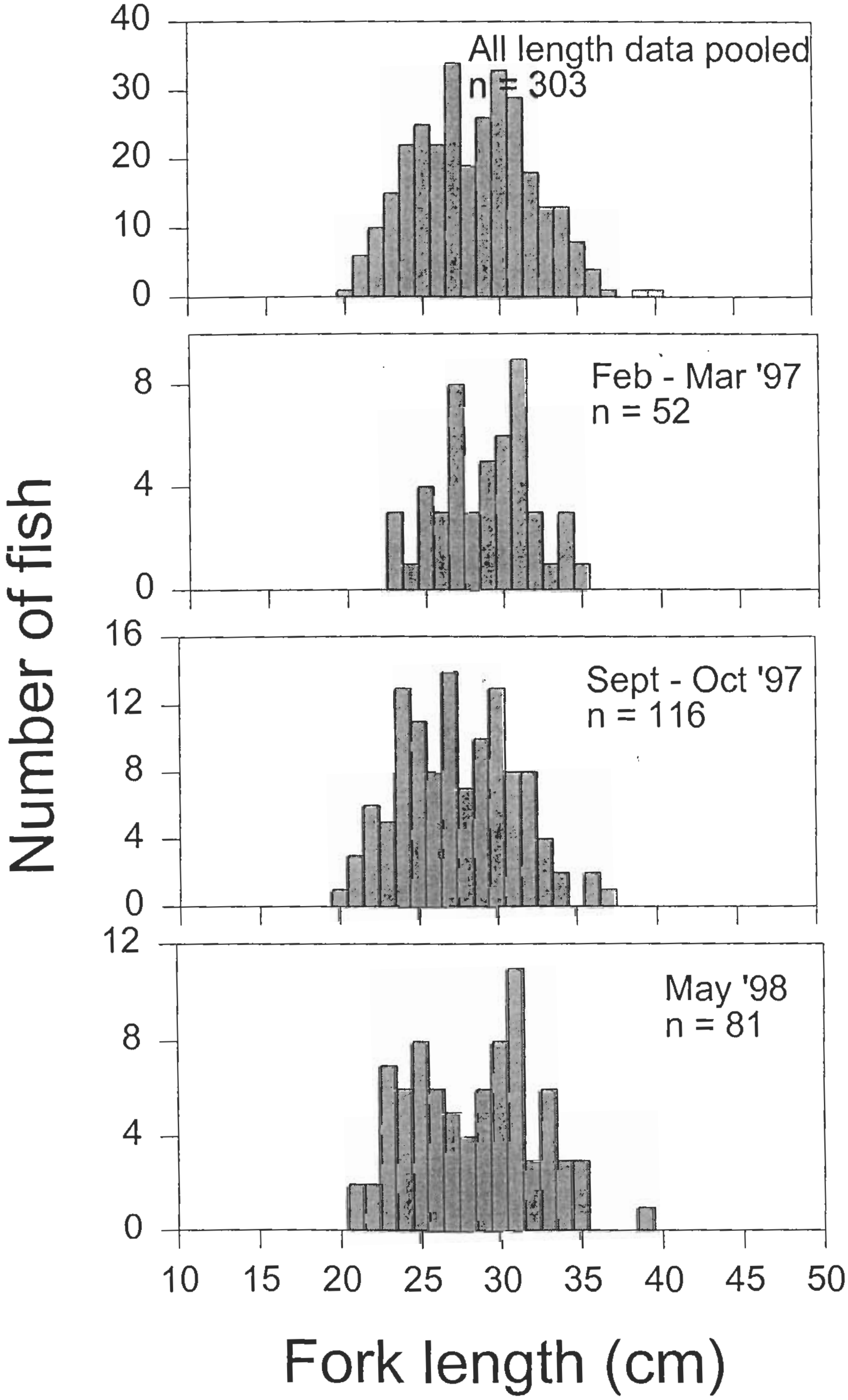
Appendix IV. Length-frequency distributions of *S. globiceps*.



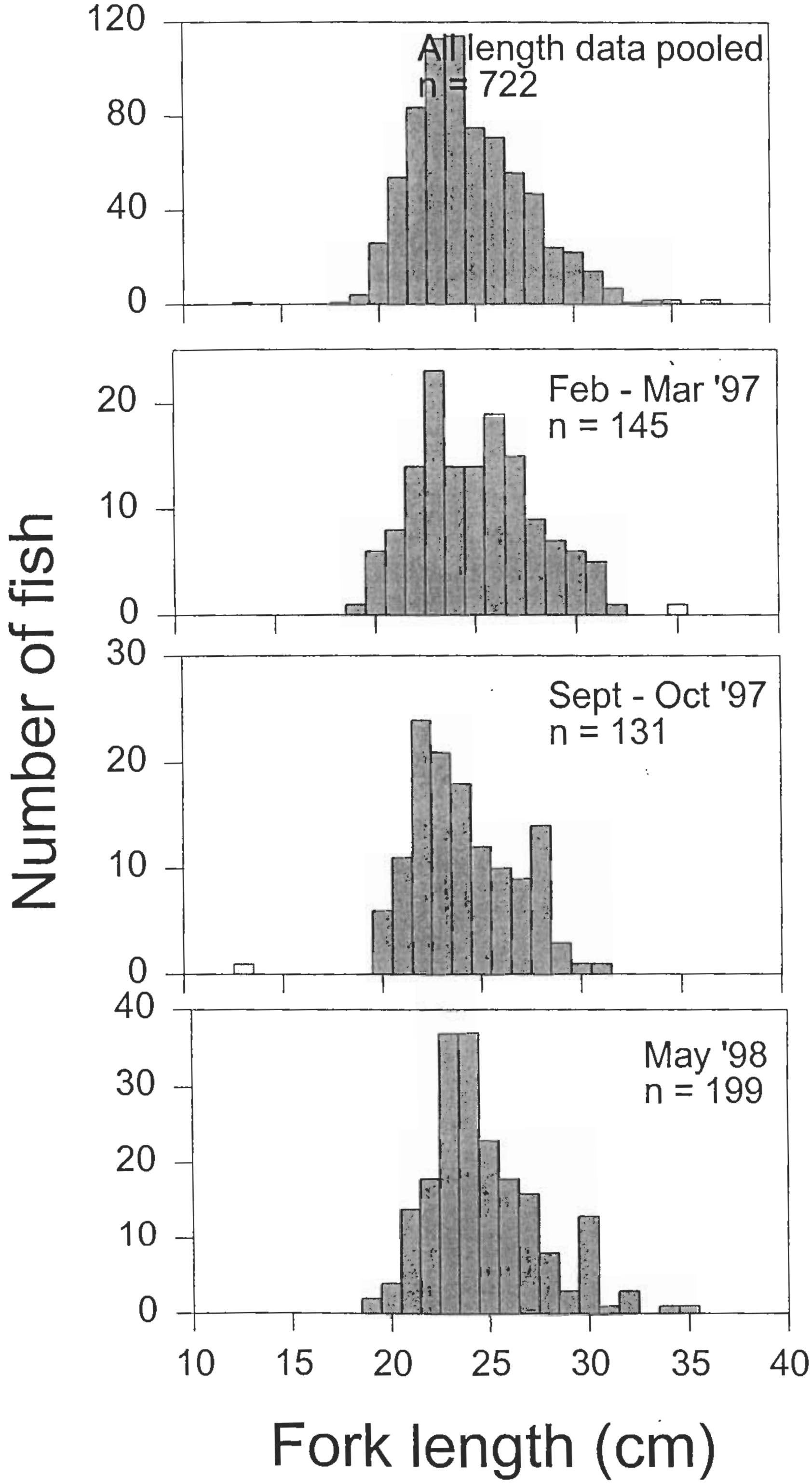
Appendix IV. Length-frequency distributions of *C. gibbus*



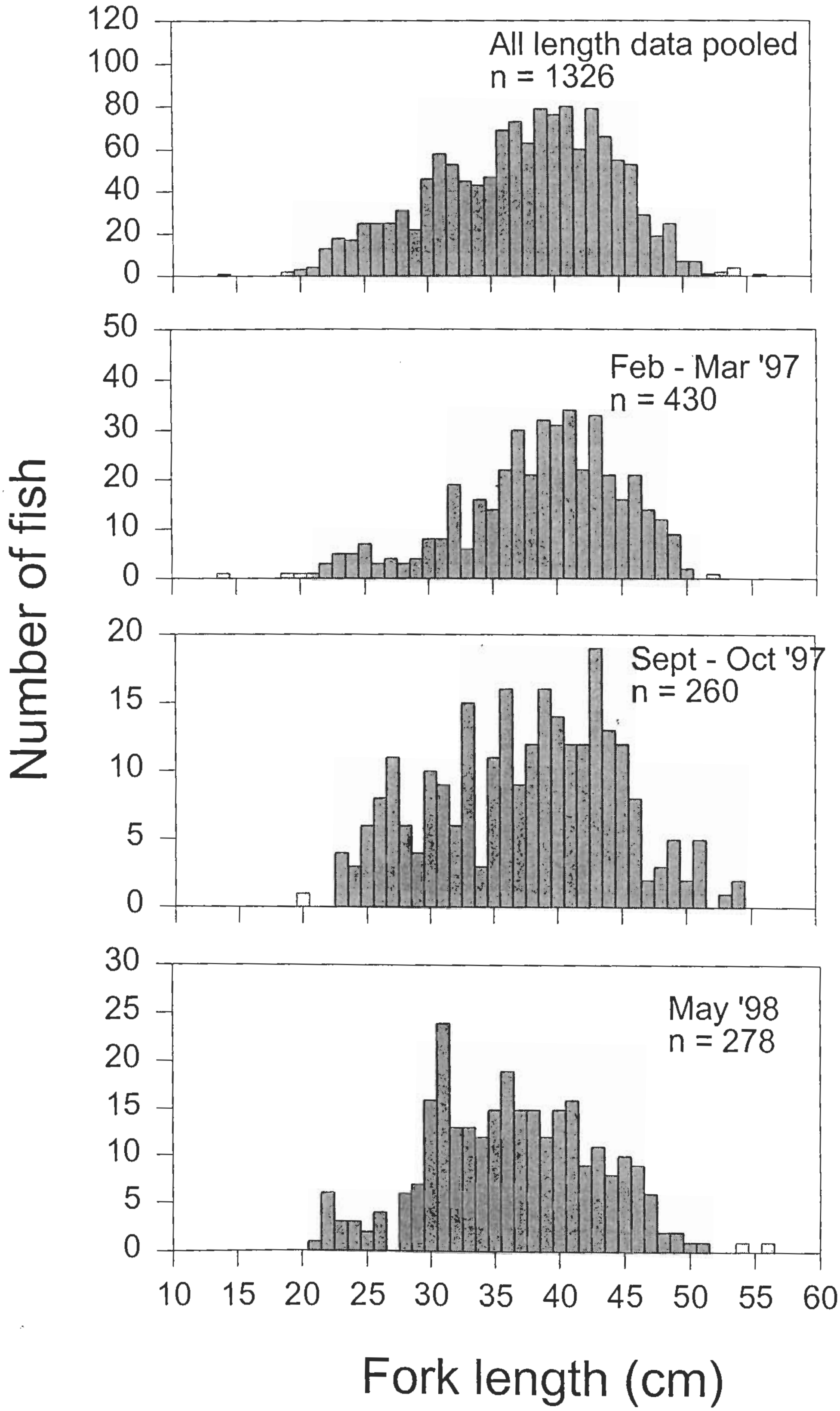
Appendix IV. Length-frequency distributions of *S. niger.*



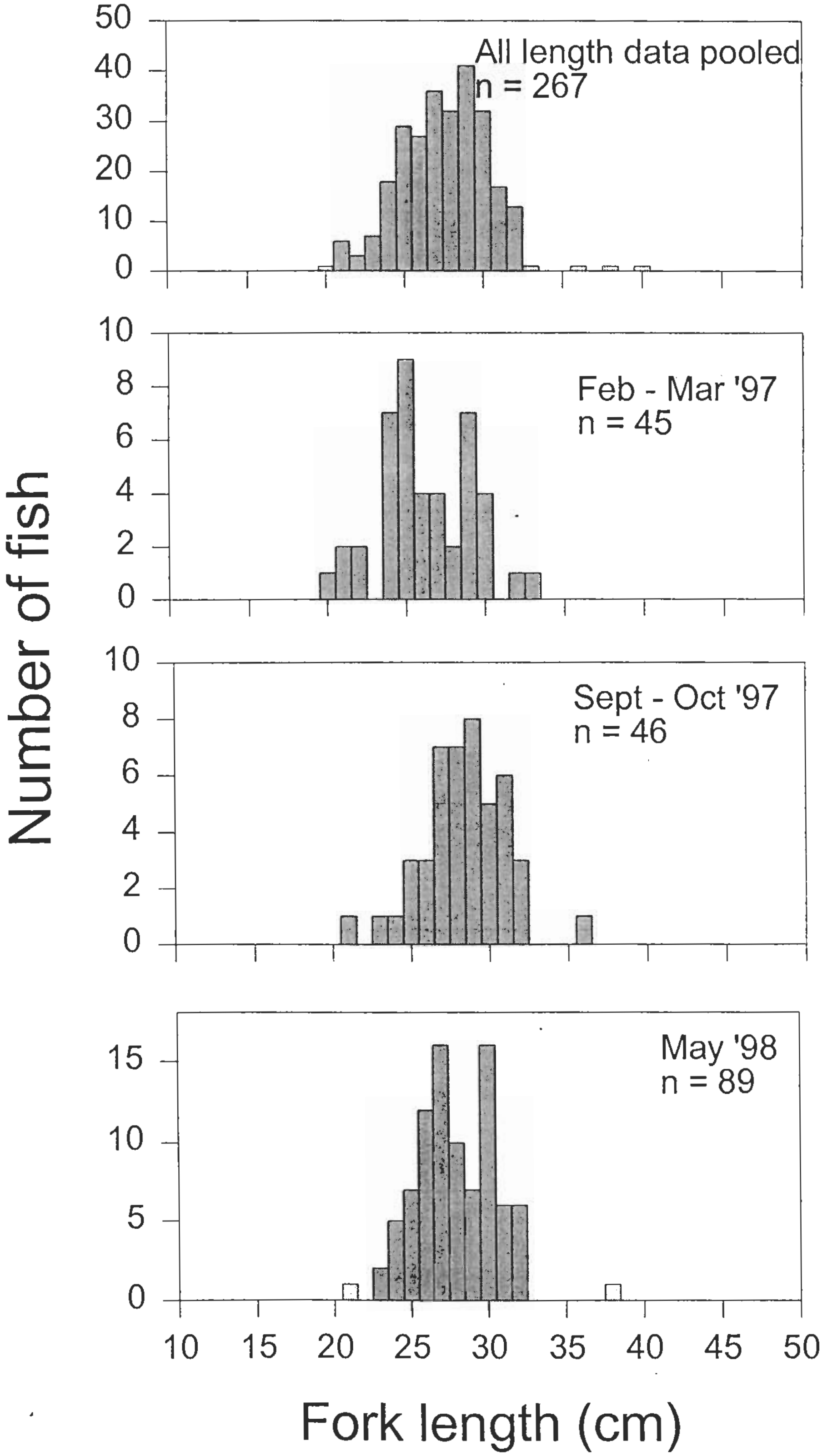
Appendix IV. Length frequency distributions of *S. oviceps*.



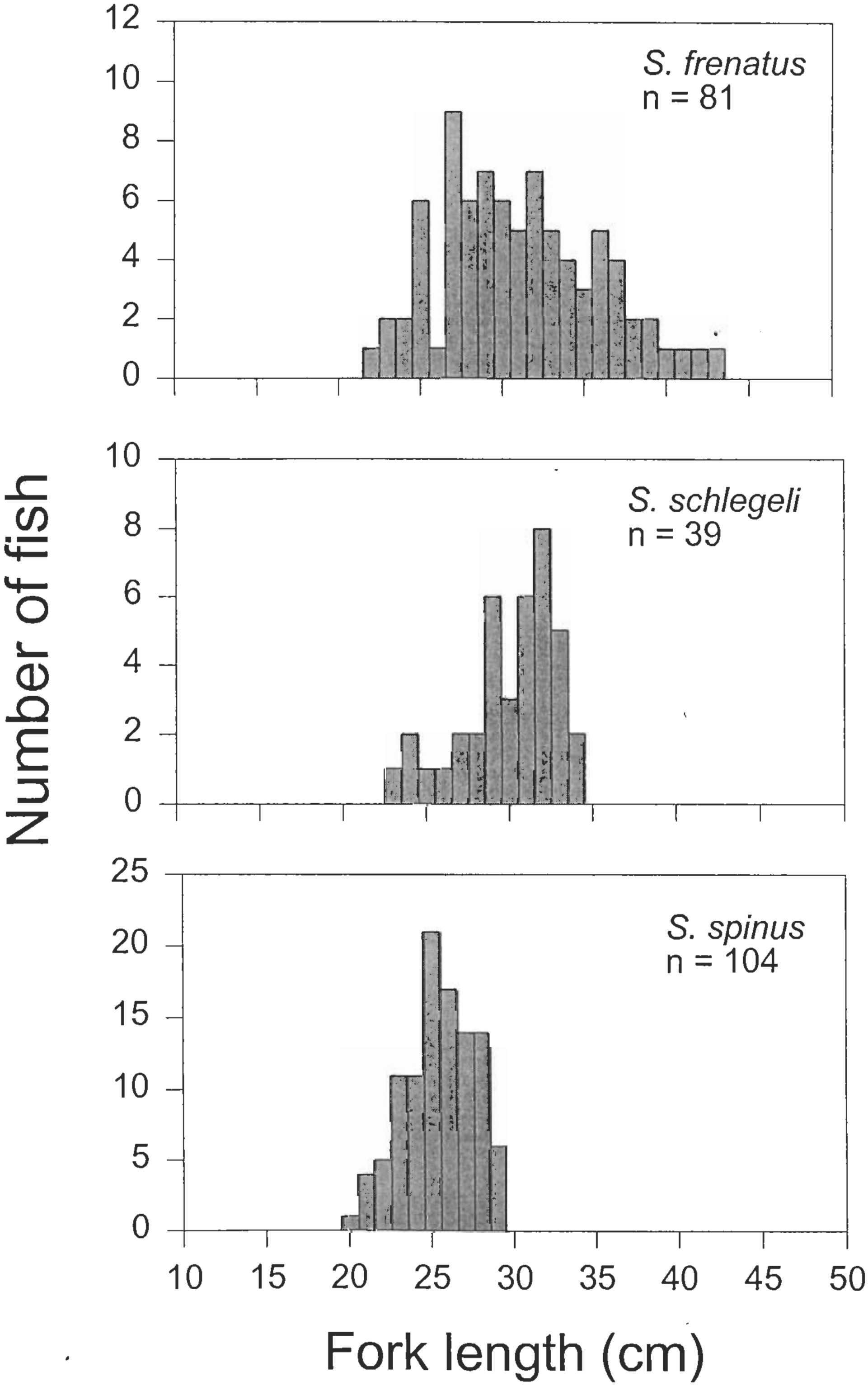
Appendix IV. Length-frequency distributions of *S. rubroviolaceous*



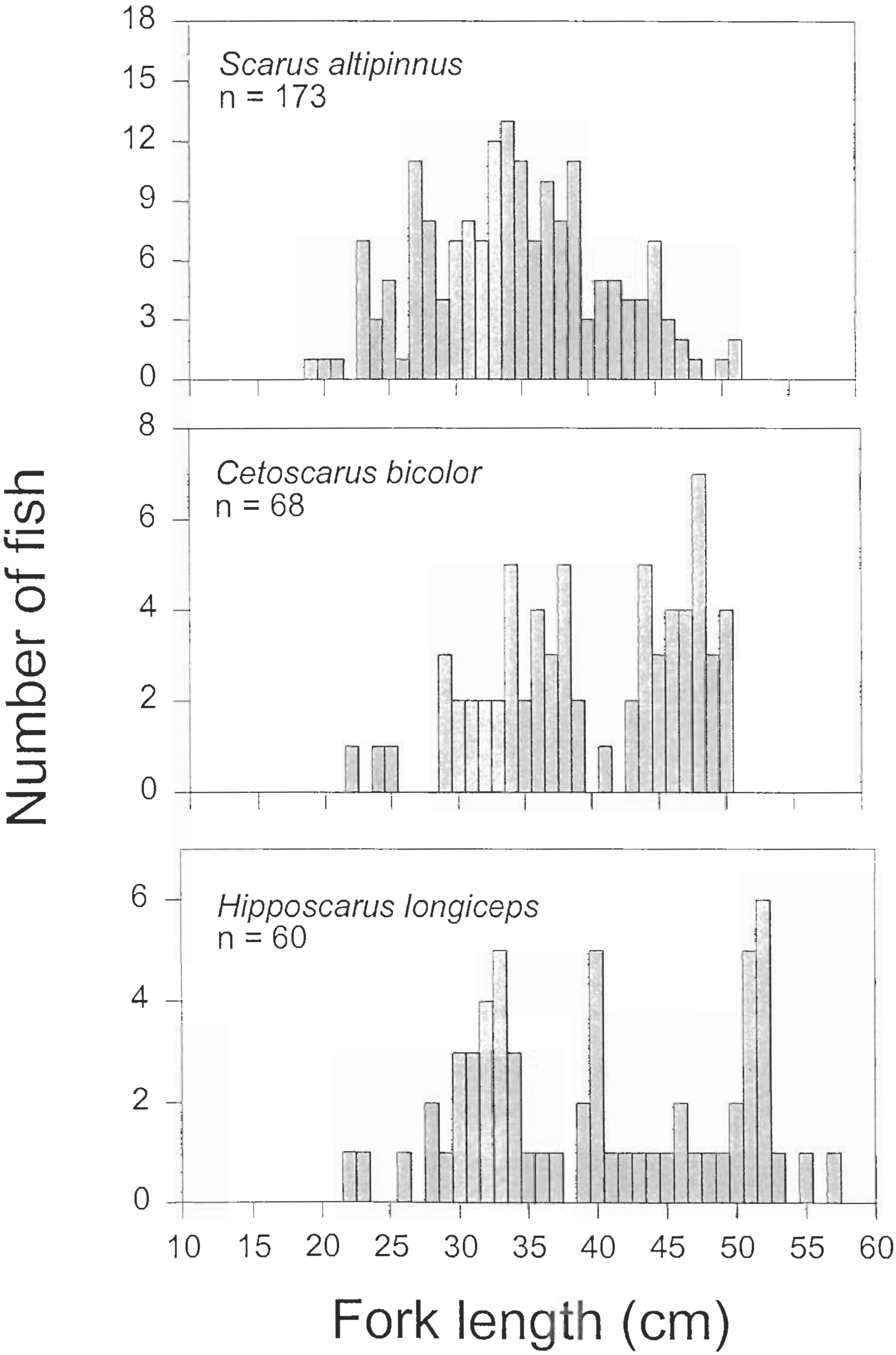
Appendix IV. Length-frequency distributions of *C. carloinus*.



Appendix IV. Length-freuency distributions.



Appendix IV. Length-frequency distributions.



Appendix IV. Length-frequency distributions