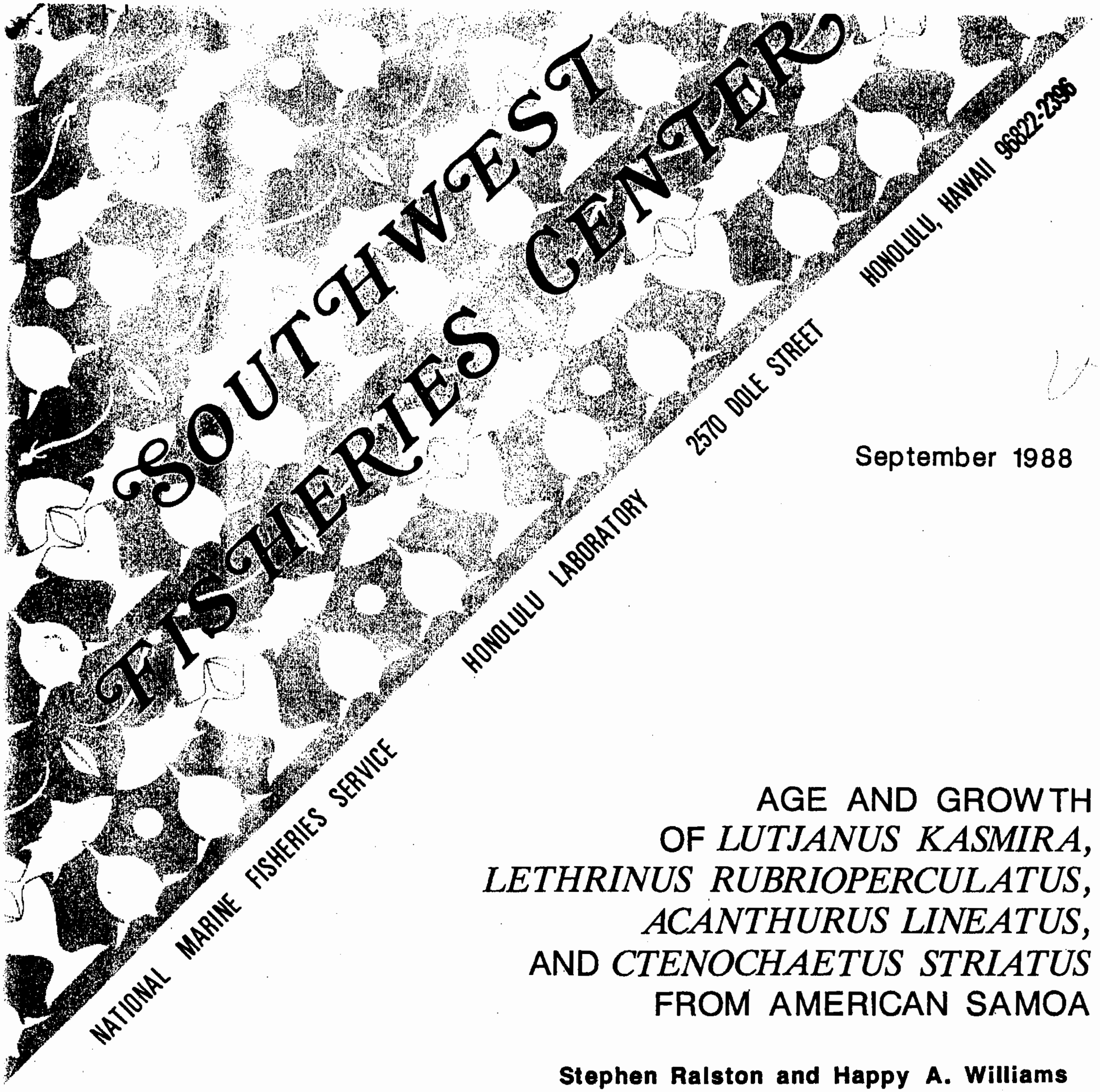

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AGE AND GROWTH OF *LUTJANUS KASMIRA*, *LETHRINUS RUBRIOPERCULATUS*, *ACANTHURUS LINEATUS*, AND *CTENOCHAETUS STRIATUS* FROM AMERICAN SAMOA

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INTRODUCTION

In September 1986, the Southwest Fisheries Center Honolulu Laboratory (HL) entered into a cooperative research program with the Office of Marine and Wildlife Resources (OMWR), Government of American Samoa, to assess the condition of certain nearshore reef fish and offshore bottom fish stocks. The overall design of the stock assessment program was multifaceted, involving several independent lines of research. A particularly important component was to pursue age and growth studies of stocks that potentially or actually were evidencing significant exploitation effects. Information obtained on growth dynamics could then be used in formulating yield models, which in turn would be useful in developing management strategies for adversely impacted stocks.

This study reports on the preliminary findings of the age and growth portion of the collaborative assessment undertaken by the OMWR and the HL. In particular, growth patterns of four nearshore reef species from American Samoa are described and illustrated. As a group, these fishes comprise a substantial portion of the local fresh fish market (Hamm and Quach 1988). They include the savane (Lutjanidae: *Lutjanus kasmira*), filoa (Lethrinidae: *Lethrinus rubrioperculatus*), and two acanthurids, alogo (*Acanthurus lineatus*) and poge (*Ctenochaetus striatus*).

MATERIALS AND METHODS

Otoliths were collected from selected fish by OMWR staff in Pago Pago, American Samoa. Samples were obtained from as broad a size range of fish as feasible. When otoliths (sagittae) were removed, the fork length (FL mm) of the fish was measured, sex was determined if possible by gross examination of the gonads, and other pertinent collection data were recorded. After an adequate number of samples ($N \approx 50$) had been obtained for each species, the otoliths were mailed to the HL for detailed examination of daily increment microstructure.

In the laboratory, otolith samples were prepared and analyzed in the manner described by Ralston and Williams (1989). In brief, frontal sections through the focus were viewed with a compound microscope, and the widths (μm) of presumptive daily increments were measured, providing estimates of otolith growth rate (μm/d) at numerous points between the focus and postrostrum. These growth rate data were then related to the radial length of the otolith by measuring the distance to the focus along the postrostral growth axis at each point sampled. The data were then numerically integrated, yielding estimates of age (yr) at regular increments to the radius of otolith length (ΔOL). For the larger species (*Lutjanus kasmira* and *Lethrinus rubrioperculatus*, ΔOL was set equal to 500 μm, whereas for the smaller surgeonfishes (*A. lineatus* and *C. striatus*), ΔOL was reduced to 250 μm. The equivalent FL, following each growth increment to the otolith, was then estimated from a double logarithmic regression of FL on the radial distance separating the focus and the otolith margin (i.e., total otolith length). Finally, these data (ordered pairs of age and FL) were fitted to the von Bertalanffy growth equation (Ricker 1979), providing estimates of the parameters L_∞, K, and t_0. A detailed description of the method, including a discussion of data partitioning and statistical weighting, is provided in Ralston and Williams (1989).

RESULTS

A total of 1,977 measurements of otolith growth rate (daily increment width) were obtained from *Lutjanus kasmira* samples (Table 1, Fig. 1A, upper panel). Sample sizes for *Lethrinus rubrioperculatus*, *A. lineatus*, and *C. striatus* were 2,843, 2,350, and 292, respectively (Table 1, Fig. 1B-D). Provided in the table are the estimates of mean growth rate for each ΔOL growth increment to the otolith. Note that, among the first three species, otolith growth rates near the focus (i.e., otolith lengths <250 μm) were low, but these rose quickly to a maximum at otolith lengths of about 500 μm (Fig. 1A-C, upper panels). Thereafter, otolith growth rates of all four species showed a more or less monotonic decline with increasing otolith length.

The growth rate data were integrated (Table 1) to provide estimates of age upon completion of growth through each increment in otolith length. Predicted FL's are also provided, derived from the least squares regressions presented in the middle panels of Fig. 1A-D (see also Table 2). Lastly, the resulting fits of the von Bertalanffy growth equation, to the age-length data collected from each species, are shown in the lower panels of Fig. 1A-D, and the estimates of the model's parameters are given in Table 3.

DISCUSSION

Assuming the periodicity of the marks we measured was daily, the data presented here provide a beginning for future stock assessments of *Lutjanus kasmira*, *Lethrinus rubrioperculatus*, *A. lineatus*, and *C. striatus* in American Samoa. Estimates of the parameters of the von Bertalanffy growth equation (Table 3) are very useful in modeling the effects of fishing (e.g., Beverton and Holt 1957; Morgan 1987). The method we used to estimate these parameters (Ralston and Williams 1989), particularly L_∞ and K, has a number of advantages over some of the other alternatives available, including objectivity and cost-effectiveness. Still, the estimation procedure is somewhat sensitive to irregularities in sample structure and to spatial variations within the otolith regarding the clarity of daily increments. This sensitivity is exemplified when results obtained from *A. lineatus* are examined more closely.

The data presented in Table 2 show that specimens of *A. lineatus* ranged in size from 123 to 200 mm FL. Thus, superficially, it would seem that the *A. lineatus* sample was representative of a broad range in growth. However, the sagittae extracted from these fish only ranged in length from 3,452 to 4,532 μm. The span of otolith growth was substantially diminished relative to total variation in FL. Moreover, daily increments for this species could be reliably distinguished only at otolith lengths less than 2,500 μm (upper panel, Fig. 1C). At more extreme distances from the focus, the characteristic bipartite structure of daily increments could not be resolved with the equipment we used. In combination, these two problems were exacerbated; the increment width data were only suitable for predicting the very youngest stages of growth, while the regression of FL on otolith length was developed from data representing only the older stages. As a result, the four predictions of *A. lineatus* FL (56-90 mm) provided in Table 1, are all extrapolations of the regression to sizes smaller than actually measured. We therefore view the von Bertalanffy parameter estimates for this species cautiously.

In contrast to the statistical problems encountered during analysis of data from *A. lineatus*, none of the analyses of the remaining three species was similarly confounded. Presumptive daily increments were resolved throughout the otoliths of both *Lutjanus kasmira* and *C. striatus*. Although increments could not be distinguished at the distal extremity of the largest *Lethrinus rubrioperculatus* otoliths (i.e., from 5,500 to 9,500 μm), we measured whole otoliths as small as 3,534 μm for this species. This size is much smaller than the largest otolith lengths used in the numerical integration (see Table 1 and Fig. 1B).

A small amount of length-frequency data concerning these species is available from a market sampling program that was started as part of the cooperative assessment agreement between the OMWR and the HL. Sample sizes for each species obtained so far are *Lutjanus kasmira*, $N = 239$; *Lethrinus rubrioperculatus*, $N = 89$; *A. lineatus*, $N = 474$; and *C. striatus*, $N = 69$ (D. Itano, OMWR, pers. commun.). It is informative to select from these data the largest measured specimen of each species and to compare its size (FL_{max}) with estimates of L_∞ derived from the study of increment microstructure (Table 3). The relevant statistics are *Lutjanus kasmira*, $FL_{max} = 297$ mm; *Lethrinus rubrioperculatus*, $FL_{max} = 342$ mm; *A. lineatus*, $FL_{max} = 230$ mm; and *C. striatus*, $FL_{max} = 210$ mm. When these figures are expressed as a percentage of the estimated L_∞, we get 100, 111, 135, and 82% for the four species, respectively. In no case is there an extreme disparity between values of FL_{max} and L_∞, although *A. lineatus* departs from expectation more than the others, perhaps because of the reasons outlined above. Likewise, the small sample of *C. striatus* may have been responsible for the relatively low value of FL_{max} for this species.

These comparisons underscore the importance of acquiring growth information from sources other than otolith microstructure. For example, under certain conditions, application of the regression method of Wetherall et al. (1987) to length-frequency data provides robust estimates of L_∞ and θ (the ratio of total mortality rate to von Bertalanffy growth coefficient). Ralston and Williams (1988) used this approach to estimate L_∞ for seven bottom fish species in the Mariana Archipelago. They then constrained the von Bertalanffy equation, fitted to age and length data derived from the study of otoliths, to conform to L_∞ values estimated from length-frequency data. The resulting growth curves were composites of information obtained from otolith microstructure and length-frequency analysis. Essentially, the length-frequency data were used to estimate L_∞ and otolith microstructure to estimate K and t_0. We recommend that a similar approach be taken to stock assessment in American Samoa, as more complete length-frequency data become available.

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Table 1.--Summary of mean otolith growth rates, integrated age, and predicted fork lengths for key commercial reef fishes in American Samoa (see text for further explanation).

Otolith length interval (μm)	*N*	Mean otolith growth rate (μm/d)	Internal duration (d)	Age (yr)	Predicted fork length (mm)	Statistical weight
Lutjanus kasmira						
0- 500	147	19.8081	25.242	0.06911	--	--
500-1,000	110	25.0038	19.997	0.12386	--	--
1,000-1,500	148	14.9358	33.477	0.21551	--	--
1,500-2,000	91	15.0205	33.288	0.30665	--	--
2,000-2,500	96	6.7996	73.534	0.50797	--	--
2,500-3,000	82	5.3208	93.971	0.76525	--	--
3,000-3,500	168	4.4956	111.219	1.06976	179.838	0.22573
3,500-4,000	234	4.0805	122.533	1.40523	192.964	0.22135
4,000-4,500	271	4.1386	120.815	1.73601	205.336	0.21736
4,500-5,000	247	4.0200	124.379	2.07654	217.073	0.21349
5,000-5,500	248	3.3494	149.281	2.48525	228.267	0.21055
5,500-6,000	110	3.5121	142.365	2.87502	238.990	0.20602
6,000-6,500	25	2.2708	220.187	3.47786	249.298	0.20098
Lethrinus rubrioperculatus						
0- 500	291	23.6514	21.140	0.05788	--	--
500-1,000	341	16.8679	29.642	0.13903	--	--
1,000-1,500	261	6.2335	80.211	0.35864	--	--
1,500-2,000	258	5.7694	86.664	0.59591	--	--
2,000-2,500	312	4.7081	106.200	0.88667	74.469	0.60196
2,500-3,000	316	4.2996	116.289	1.20506	90.691	0.57383
3,000-3,500	402	3.7833	132.159	1.56689	107.135	0.55444
3,500-4,000	209	3.3458	149.439	1.97603	123.771	0.53321
4,000-4,500	301	3.1340	159.543	2.41284	140.577	0.51804
4,500-5,000	122	2.5598	195.325	2.94761	157.535	0.50093
5,000-5,500	30	2.7703	180.484	3.44174	174.631	0.46642
Acanthurus lineatus						
0- 250	173	14.2376	17.559	0.04807	--	--
250- 500	189	20.2312	12.357	0.08191	--	--
500- 750	132	18.9626	13.184	0.11800	--	--
750-1,000	186	13.5800	18.409	0.16840	--	--
1,000-1,250	351	5.9434	42.064	0.28357	--	--
1,250-1,500	321	4.1750	59.880	0.44751	--	--
1,500-1,750	349	3.5710	70.009	0.63919	56.385	0.45252
1,750-2,000	342	2.7978	89.356	0.88383	67.051	0.44256
2,000-2,250	227	2.6098	95.794	1.14610	78.122	0.43174
2,250-2,500	80	2.0842	119.947	1.47449	89.566	0.41821

Table 1.--Continued.

Otolith length interval (μm)	*N*	Mean otolith growth rate (μm/d)	Internal duration (d)	Age (yr)	Predicted fork length (mm)	Statistical weight
			Ctenochaetus striatus			
0- 250	15	16.4269	15.219	0.04167	--	--
250- 500	14	17.9395	13.936	0.07982	--	--
500- 750	17	12.7849	19.554	0.13336	--	--
750-1,000	20	9.6069	26.023	0.20461	--	--
1,000-1,250	27	5.9073	42.321	0.32047	--	--
1,250-1,500	40	3.4265	72.960	0.52023	--	--
1,500-1,750	48	3.1124	80.323	0.74014	113.141	0.09424
1,750-2,000	48	2.6074	95.880	1.00264	128.316	0.09310
2,000-2,250	19	2.4241	103.132	1.28500	143.381	0.09152
2,250-2,500	35	1.9164	130.454	1.64216	158.351	0.09070
2,500-2,750	7	1.6721	149.515	2.05151	173.235	0.08923
2,750-3,000	2	1.5909	157.143	2.48175	188.041	0.08676

Table 2.--Summary of least squares linear regressions of the natural logarithm of fork length (mm) on the natural logarithm of total otolith length (μm). SE = standard error of the estimate.

Species	Otolith length Min.	Otolith length Max.	Fork length Min.	Fork length Max.	*N*	Slope	SE	Intercept	SE	r^2
Lutjanus kasmira	3,483	6,244	175	255	56	0.52758	(0.0862)	0.88673	(0.7371)	0.410
Lethrinus rubrioperculatus	3,534	9,578	131	332	75	1.08097	(0.0513)	-4.14718	(0.4597)	0.859
Acanthurus lineatus	3,452	4,532	123	200	42	1.29743	(0.1642)	-5.65621	(1.3656)	0.609
Ctenochaetus striatus	1,581	3,060	99	210	107	0.94253	(0.0623)	-2.30962	(0.4844)	0.685

Table 3.--Summary of nonlinear von Bertalanffy least squares regressions of fork length (mm) on age (yr). SE = standard error of the estimate.

Species	*N*	L_∞ (mm)	SE	*K* (yr^{-1})	SE	t_o (yr)	SE
Lutjanus kasmira	7	296	(7.43)	0.384	(0.0369)	-1.349	(0.144)
Lethrinus rubrioperculatus	7	308	(19.97)	0.216	(0.0239)	-0.400	(0.056)
Acanthurus lineatus	4	170	(25.93)	0.416	(0.1124)	-0.329	(0.085)
Ctenochaetus striatus	6	256	(10.36)	0.424	(0.0435)	-0.643	(0.074)

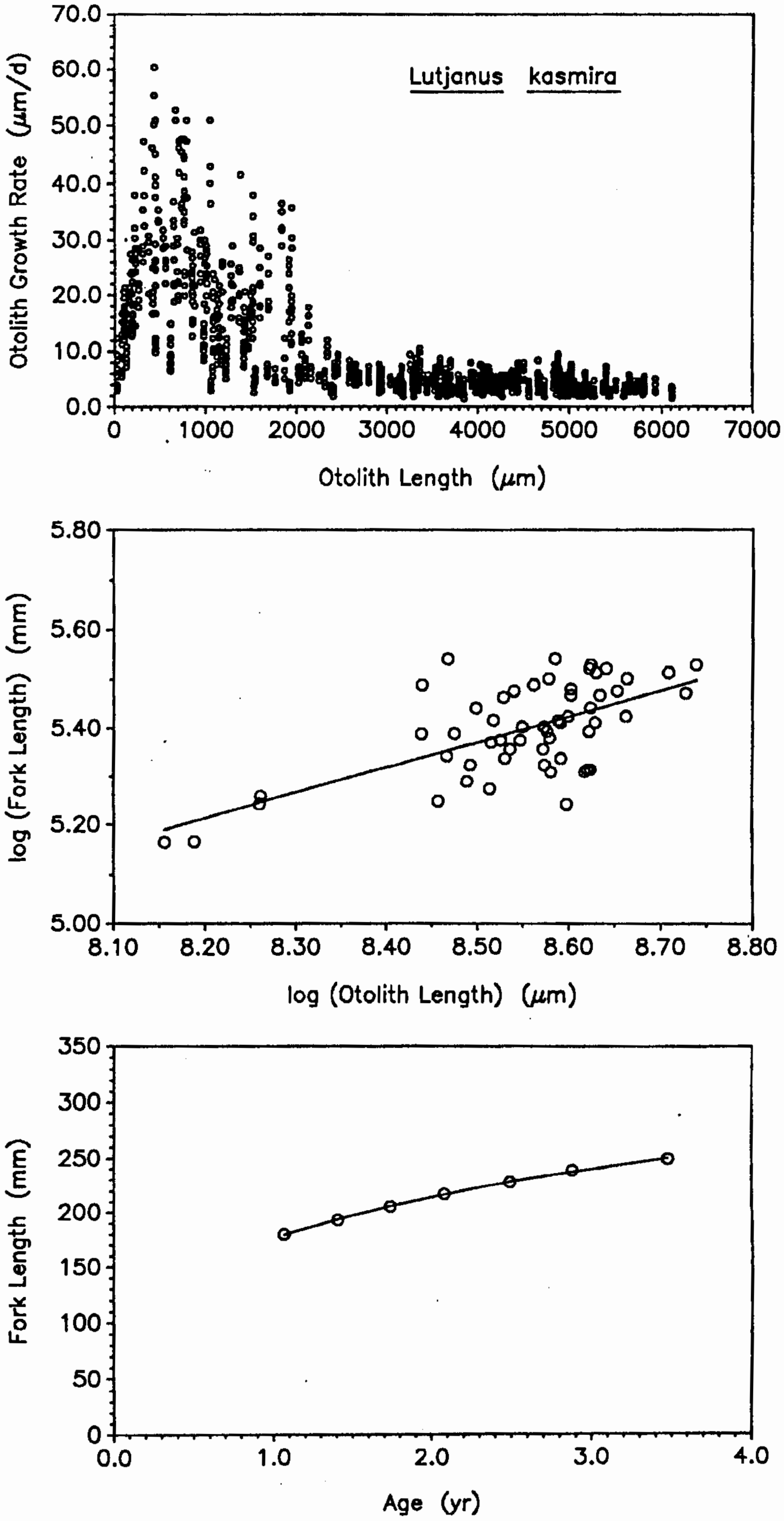

Figure 1.--Analysis of otolith microstructure to study the growth of four reef fishes in American Samoa (see text for further explanation). (A) *Lutjanus kasmira*.

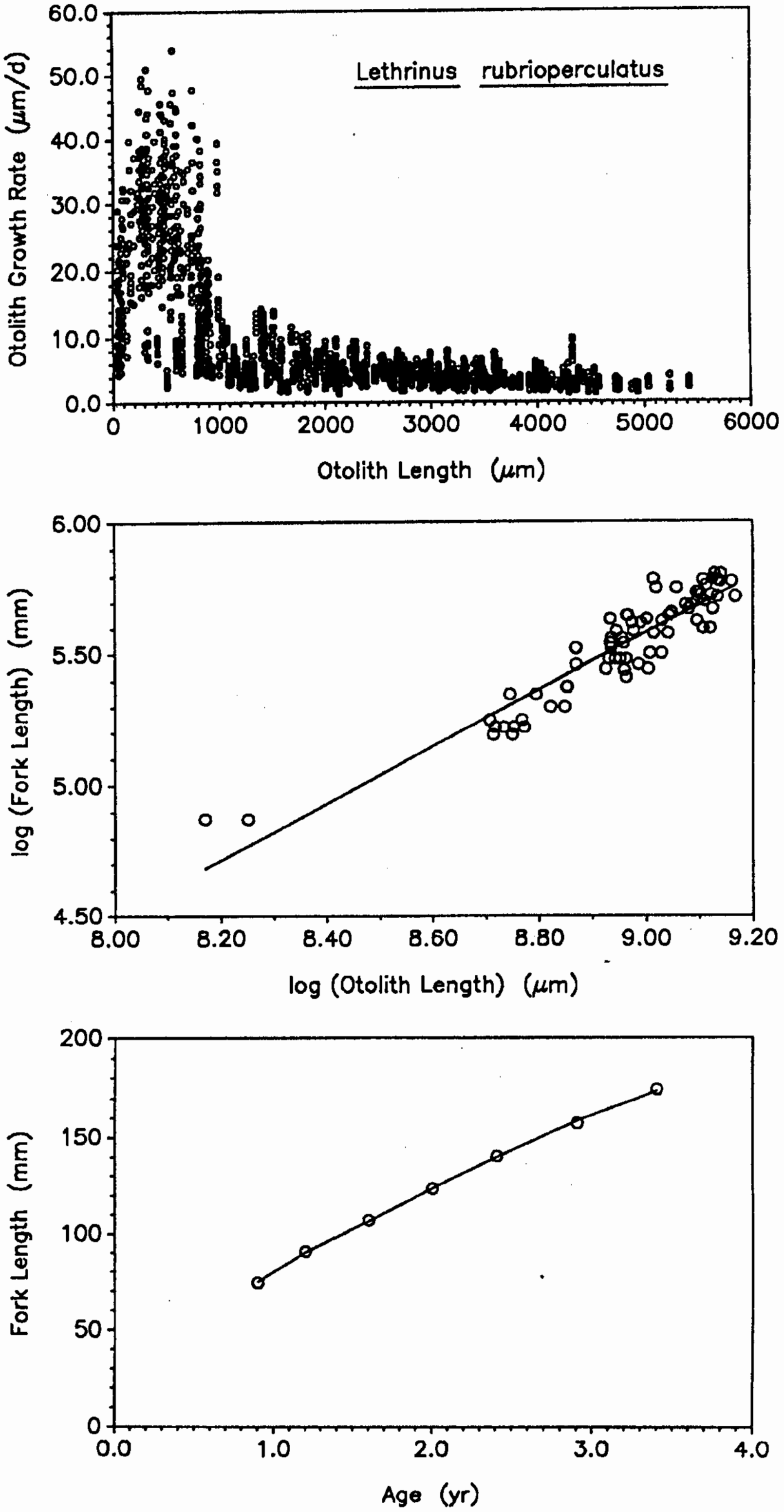

Figure 1.--Continued. (B) *Lethrinus rubrioperculatus*.

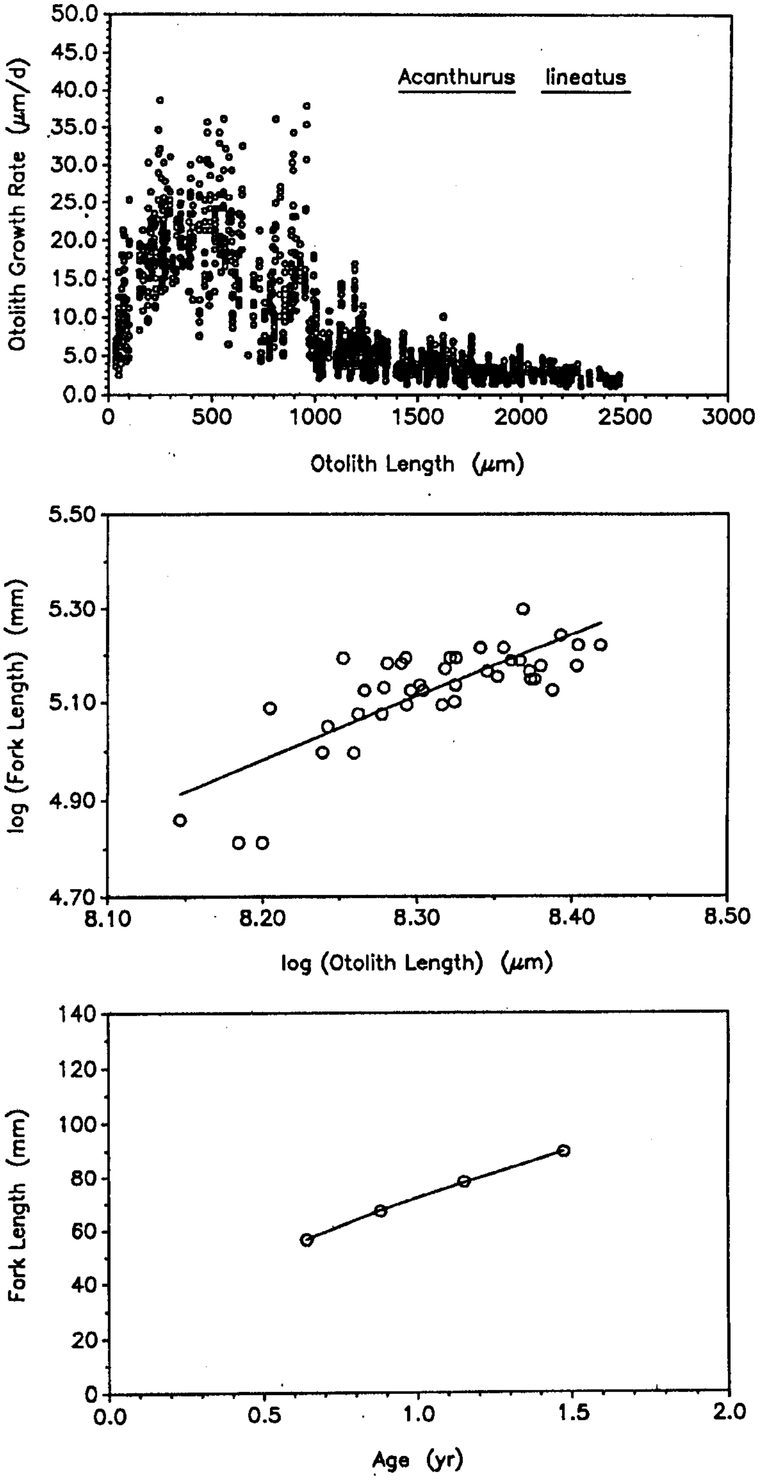

Figure 1.--Continued. (C) *Acanthurus lineatus*.

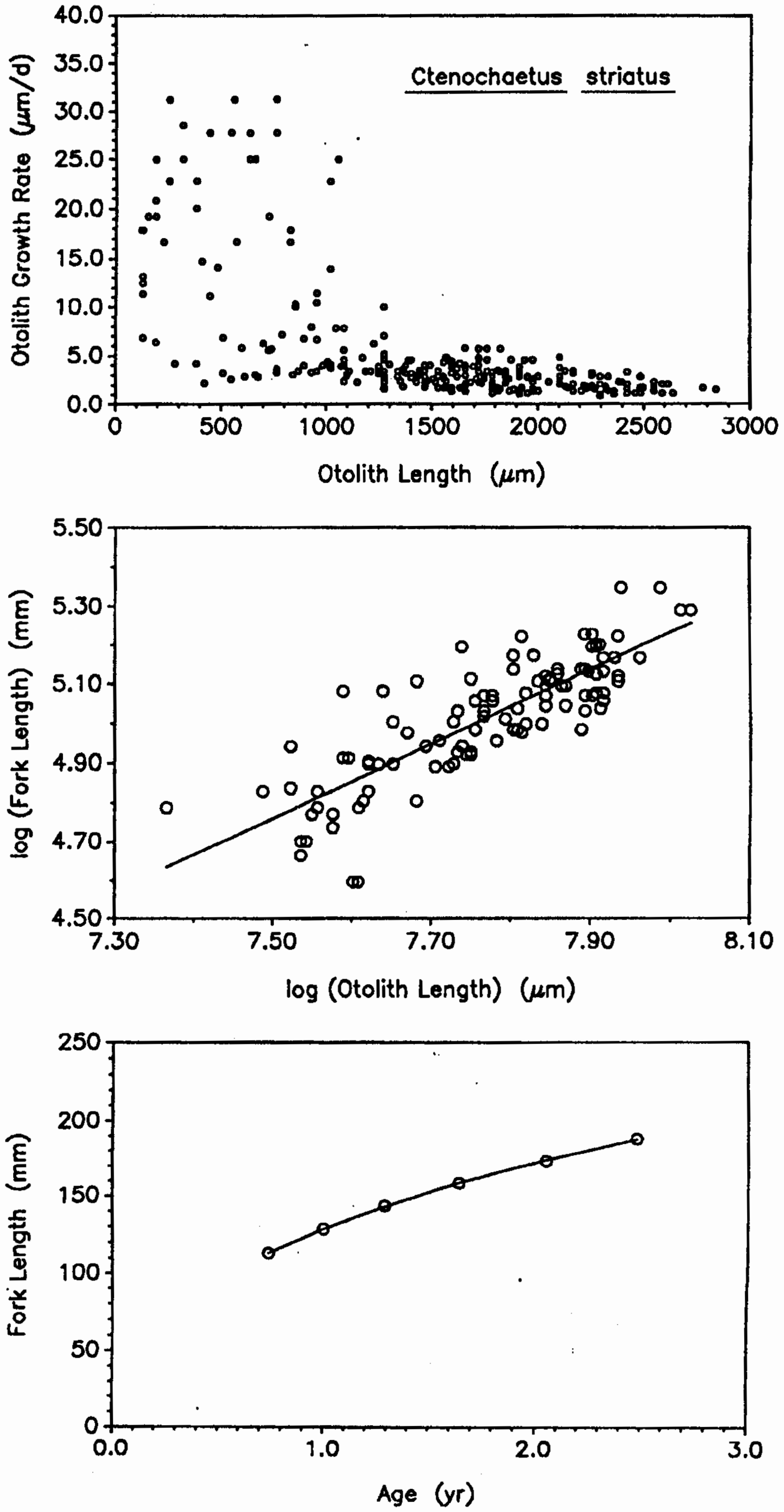

Figure 1.--Continued. (D) *Ctenochaetus striatus*.