

# AGE, GROWTH AND MORTALITY OF REDTHROAT EMPEROR *LETHRINUS MINIATUS* (PISCES: LETHRINIDAE) FROM THE SOUTHERN GREAT BARRIER REEF, QUEENSLAND, AUSTRALIA

*Ian W. Brown and Wayne D. Sumpton*

## ABSTRACT

Fractional age estimates were derived from thin-sectioned otoliths of redthroat emperor (*Lethrinus miniatus*) from two locations in the southern Great Barrier Reef, Australia, and were validated using marginal increment analysis. Whole otoliths of fish up to about 6 yrs of age provided reliable age estimates, but in older fish whole otoliths underestimated age, probably as a result of allometry in otolith growth. Von Bertalanffy growth parameter estimates from the Capricorn-Bunker population ( $L_{\infty} = 52.1$ ;  $k = 0.23$ ;  $t_0 = -1.43$ ) are considered representative of the species in this latitude of the Great Barrier Reef. Mean lengths of the early age-classes of fish from the Swain Reefs were overestimated because of fishery selectivity, leading to biases in the growth parameters  $k$  (0.19) and  $t_0$  (-2.74). The instantaneous rate of total mortality ( $Z$ ), calculated from age-based catch curves, was significantly higher for the Capricorn-Bunker Group population (0.70) than for the Swain Reefs population (0.43), probably because of historical differences in exploitation levels between the two areas.

The redthroat emperor *Lethrinus miniatus*, previously referred to as *L. chrysostomus* (Richardson) (Randall et al., 1990), occurs in association with tropical and equatorial coral reefs in the western Pacific and eastern Indian Oceans (Carpenter and Allen, 1989; Walker, 1975; Loubens, 1978). It is exploited throughout its range, and forms the basis of important handline fisheries around Norfolk Island (Church, 1985) and along Queensland's Great Barrier Reef (GBR), particularly in the south (Trainor, 1991). Of the GBR line fishery's target demersal species, *L. miniatus* ranks second in importance only to the coral trout *Plectropomus leopardus* (Brown, 1993), with annual commercial catches in the vicinity of 500 t and worth about AUS\$2.5 million.

Studies of the age and growth of *L. miniatus* in the central GBR (Walker, 1975), New Caledonia (Loubens, 1978, 1980) and Norfolk Is. (Church, 1985) have produced substantially different growth parameter estimates. While these may be due to real geographical differences in growth characteristics between the study areas, they may equally have been an artifact of the methods of sampling or age determination. Otoliths are generally considered more reliable than scales for age estimation (Beamish and McFarlane, 1987; Francis et al., 1992), particularly in older fish, in which the margins of scales can be eroded, leading to a reduction in the number of visible growth rings and a consequent underestimation of age. In certain lethriniid species otolith sections are considered more reliable than whole otoliths (Loubens, 1978) because disproportionate thickening of otoliths resulting from allometric growth can obscure growth rings near the margins, again biasing the estimated age downward. On the other hand Milton et al. (1995) concluded, from radiometric ageing studies in some tropical lutjanids, that visual interpretation of otolith structure may actually lead to overestimation of age. This raised questions about the reliability of the only documented estimates of age and growth for GBR stocks of *L. miniatus* (Walker, 1975) and consequently the estimates of total mortality derived by Williams and Russ (1994) from Walker's (1975) age-structured catch curves.

In this study we aged *L. miniatus* using whole and sectioned otoliths, compared the two methods, and validated the ageing technique by marginal increment analysis. We estimated growth parameters and instantaneous rates of total mortality for populations from two locations in the southern part of the GBR, compared them with other available data, and investigated the source of observed differences in growth patterns between the two areas.

## MATERIALS AND METHODS

**STUDY AREAS.**—Samples of *L. miniatus* were collected from the Swain Reefs and the Capricorn-Bunker Group (Fig. 1) in the southern GBR, between August 1989 and February 1991. The Swain Reef complex covers an area of about 15,300 km<sup>2</sup> between 21°30' and 22°20' S. Most of the reefs are exposed at low tide, but there are also poorly-charted submerged coral shoals. Accumulated sand on some of the reefs has resulted in the development of cays, but there are no permanent islands. In contrast, the Capricorn-Bunker Group (23°10'–24°00' S) comprises 15 permanent vegetated island cays and seven major emergent reefs, and covers a much smaller area (about 2550 km<sup>2</sup>).

**METHODS.**—*L. miniatus* were collected from the Capricorn-Bunker Group primarily from research sampling, while those from the Swain Reefs were purchased from commercial fishermen, generally in the form of frozen frames or skeletons.

The fork length (FL) of each fish or frame was measured to the nearest half-centimeter prior to otolith extraction. Total body weights (TW), standard lengths (SL) and total lengths (TL) of a subset of the fish captured during the course of research sampling operations were also measured. From these data we estimated the length-weight and TL-FL-SL relationships by linear regression to allow comparisons between our estimates and those from other sources. Otoliths were extracted via a horizontal cranial incision, cleaned, and stored dry in plastic vials.

Whole otoliths were immersed in vegetable oil in a small petri dish with a black background (Loubens, 1978), and examined under a low-power dissecting microscope with incident light provided by a twin fiber-optic source. Each pair of whole otoliths was read independently on two separate occasions, usually by two readers. Subsequently one otolith of each pair (the left, unless it was missing or damaged) was embedded in polyester resin and sectioned transversely through the focal region at a thickness of 300  $\mu$ m. The sections were mounted permanently on microscope slides using either Canada balsam, polyester resin, or DPX mounting medium.

Otolith sections were initially read three times by at least two different readers, but as the readers' skill improved and the precision of the estimates increased, replication was reduced to two. Where all estimates were the same, or where two were the same and the third varied by only 1 yr, the modal estimate was accepted as the final age. In all other circumstances a final assessment was done by one reader (IWB). The precision of age estimates derived from whole and sectioned otoliths were calculated according to the index of average percentage error (IAPE) of Beamish and Fournier (1981). Bias between the two methods (i.e., relative accuracy) was examined by testing whether the slope of the regression of whole-otolith age on section age was significantly different from unity.

Interpretation of the periodicity of presumed annual growth rings was validated by examination of temporal patterns in the deposition of opaque and translucent material at the otolith margin. Because insufficient material was available to examine each age-class separately, data were pooled into two groups: young (<6 yrs) and old ( $\geq$ 6 yrs) fish. Initial subsamples of about 20 otolith sections in each of 10 groups spanning a 1-yr time interval were drawn randomly from a subset of the otolith collection which had been scored highly on a subjective 5-point readability scale. In cases where the data for old fish in particular temporal groups were insufficient for analysis, sample sizes were increased by another random subsampling. The sections were examined in random order by one reader without reference to collection date or other sampling details, and a record made of whether the otolith margin was translucent or opaque. It was often necessary (particularly with

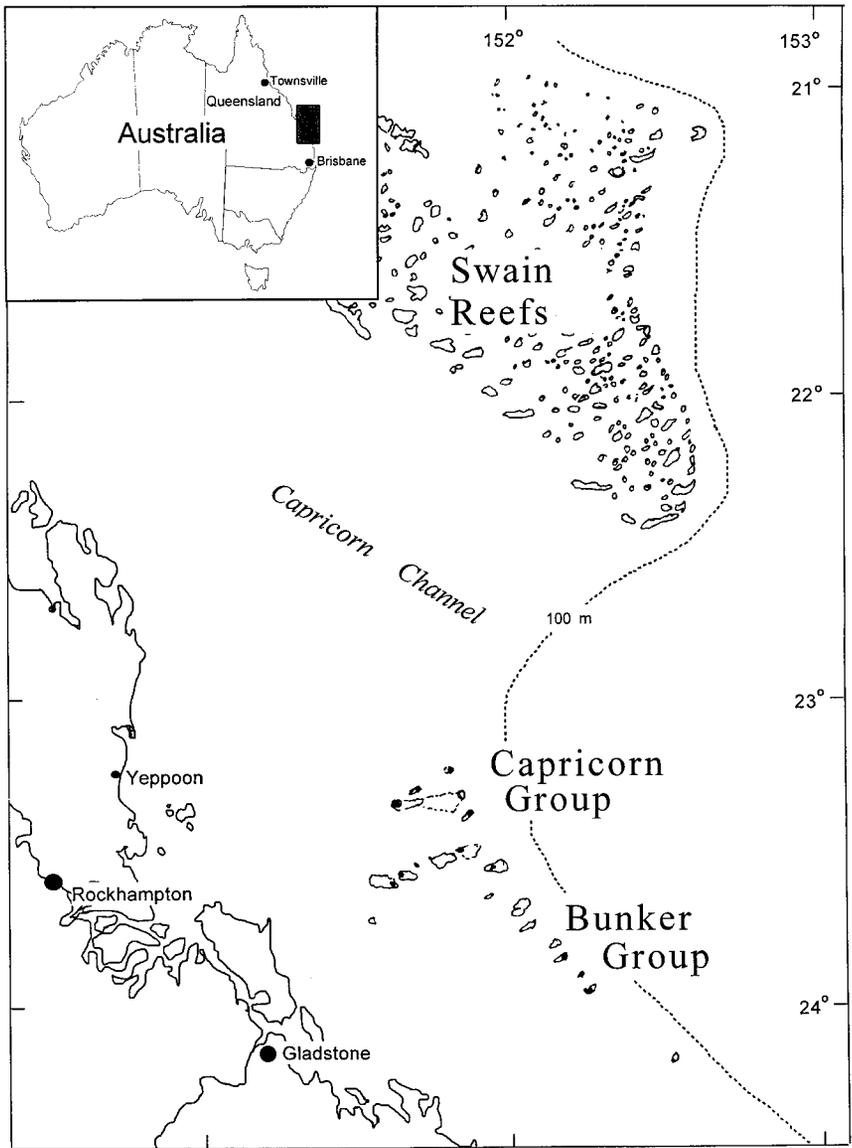


Figure 1. The Swain Reefs and Capricorn-Bunker Groups (southern Great Barrier Reef) from which samples of redthroat emperor (*L. miniatus*) were obtained.

older individuals) to examine several parts of the section corresponding to the otolith's proximal surface before the appearance of the margin could be classified satisfactorily. Temporal changes in the appearance of the otolith margin were examined graphically by plotting the proportion of translucent-edged otoliths in each seasonal group.

Integer ages were adjusted to fractional ages by adding the proportion of a year that had elapsed between the species' nominal birthday (as determined from marginal increment and reproductive data) and the sampling date.

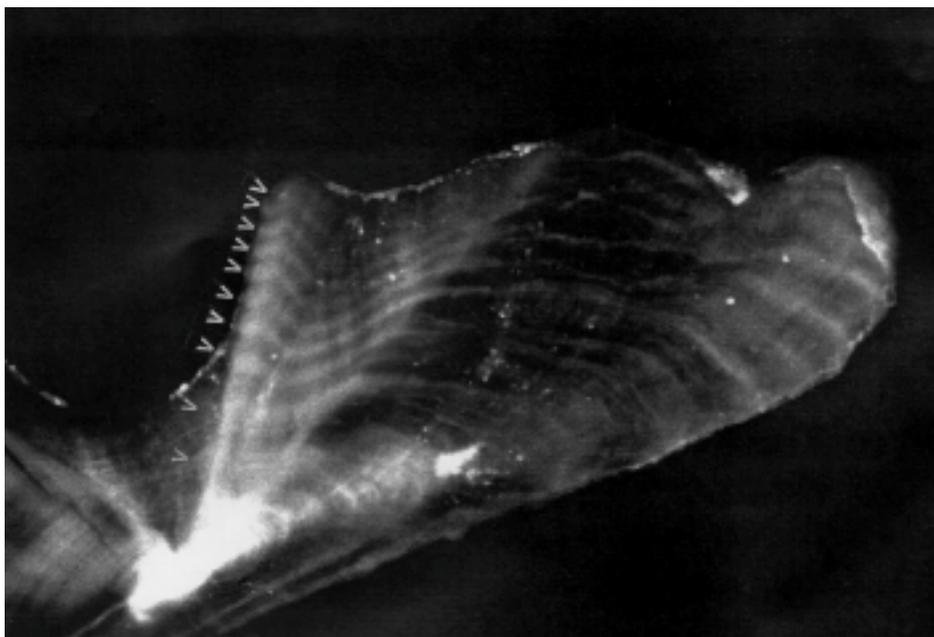


Figure 2. Section of a sagittal otolith of *L. miniatus* illuminated with incident light. Annual growth bands along the *sulcus* wall are indicated by the arrow-heads. The specimen came from a 47 cm FL fish from the Swain Reefs, and was estimated to have been 10 yr old.

Growth parameters were then estimated from the fractional length-at-age data using a non-linear curve-fitting procedure (Fig-P; BioSoft®, Cambridge). The instantaneous rate of total mortality ( $Z$ ) was estimated from age-structured catch curves—i.e., the regression of  $\ln(N_a)$  on  $a$ , where  $N_a$  is the number of individuals in each (fully recruited) age class  $a$  (Ricker, 1975). Differences in  $Z$  between the two populations were tested using a regression slope  $t$ -test.

## RESULTS

**AGE ESTIMATION.**—Growth rings were discernable in about 98% of the whole and sectioned otolith preparations. Banding structure in the sections was consistently distinct along the ridged dorsal wall of the *sulcus acousticus* (Fig. 2), and ring counts were therefore derived primarily from this region of the otolith. The slope of the regression of whole-otolith integer age on section integer age ( $b = 0.839$ ) was significantly different from unity ( $t = 30.19$ ;  $P < 0.0001$ ), indicating a bias between the two methods. Figure 3, however, shows that the bias was not consistent across all age-classes. In fish younger than about 3 yrs there was a tendency for the difference between whole-otolith age and section age to be slightly negative, possibly because of a lack of clarity of the first annulus in the sections, leading to underestimation of age. Between ages 3 and 6 the two methods provided very similar estimates, with the difference ( $D$ ) being only marginally greater than zero. However from about 7 yrs onward there was a consistent upward trend in  $D$ , signifying a progressive tendency for age estimates from sections to exceed those from whole otoliths. The ratio of otolith thickness to otolith length increased consistently and significantly ( $t = 5.95$ ;  $P < 0.0001$ ) over the observed range of fork lengths (Fig. 4), confirming

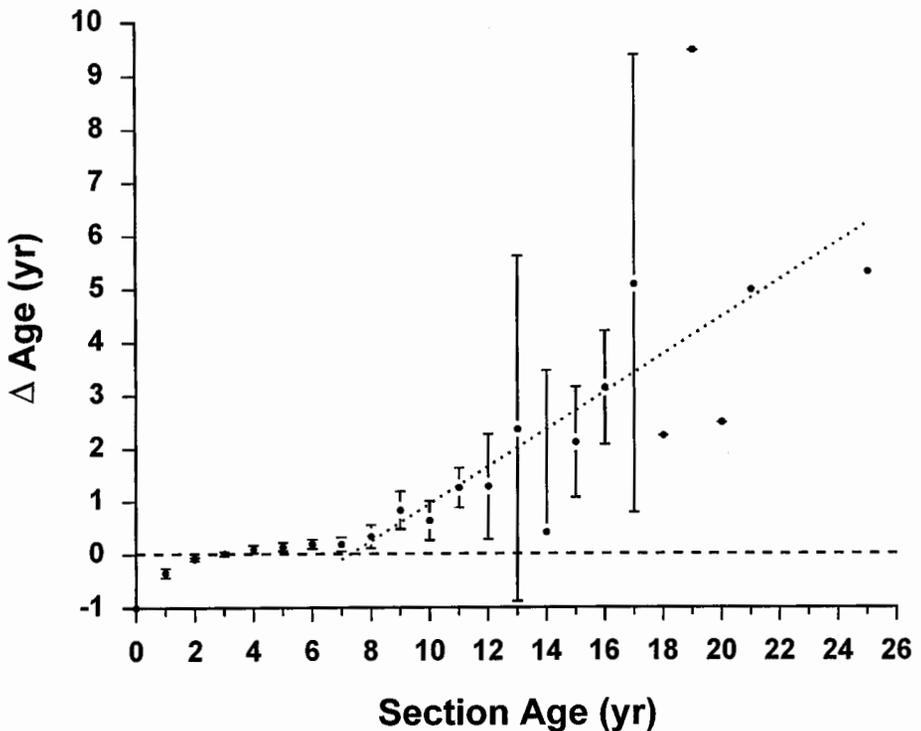


Figure 3. Bias in estimates of the age of *L. miniatus* between whole and sectioned otolith readings. Mean differences between the two methods are plotted against sectioned otolith readings, showing 95% confidence intervals. The dotted regression line relates to section ages  $\geq 7$  yr.

allometry in the growth of otolith shape in this species. Age determination for subsequent growth parameter estimation was therefore based entirely on sectioned otolith data.

**PRECISION ESTIMATES.**—The index of average percentage error (IAPE) was calculated for age estimates derived during the early and latter parts of the study separately, to determine whether there was a trend towards increasing precision with time. In samples collected prior to June 1992 ( $n = 594$ ) the IAPE for whole otolith readings was somewhat higher than that for sections (4.95% and 3.83%, respectively), indicating greater precision from the sections. Indices for both whole and sectioned otolith readings were lower in material examined after June 1992 (3.71% and 3.10%, respectively;  $n = 981$ ), suggesting an improvement in reading consistency.

**VALIDATION OF AGE ESTIMATES.**—Marginal increment analysis provided a clear validation of our age estimation technique. The two age groups tested ( $<6$  yrs and  $\geq 6$  yrs) exhibited very similar seasonal patterns of change in otolith edge structure (Fig. 5). Marginal translucent zones were found in the otoliths of a very high percentage of fish sampled during the period February/March to September. The proportion of translucent-edged otoliths then dropped rapidly to the lowest point (in November), and began increasing again from December through to the following February. January 1 was chosen as the nominal birthday because it followed a period of slow growth which corresponded closely to the peak of reproductive activity as estimated by cyclic changes in gonosomatic index (unpubl. data).

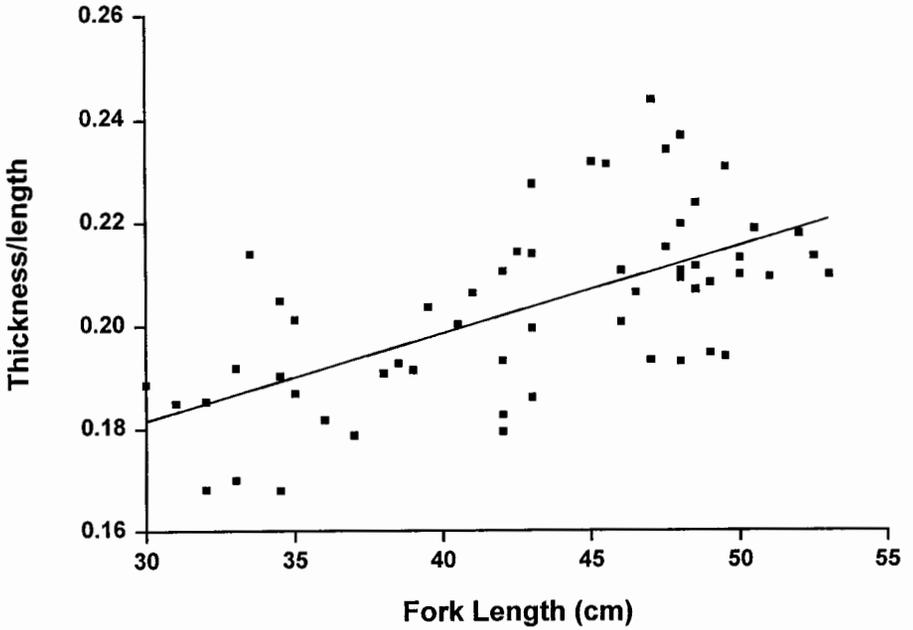


Figure 4. Relationship between fork length and the ratio of otolith thickness to otolith length in *L. miniatus*.

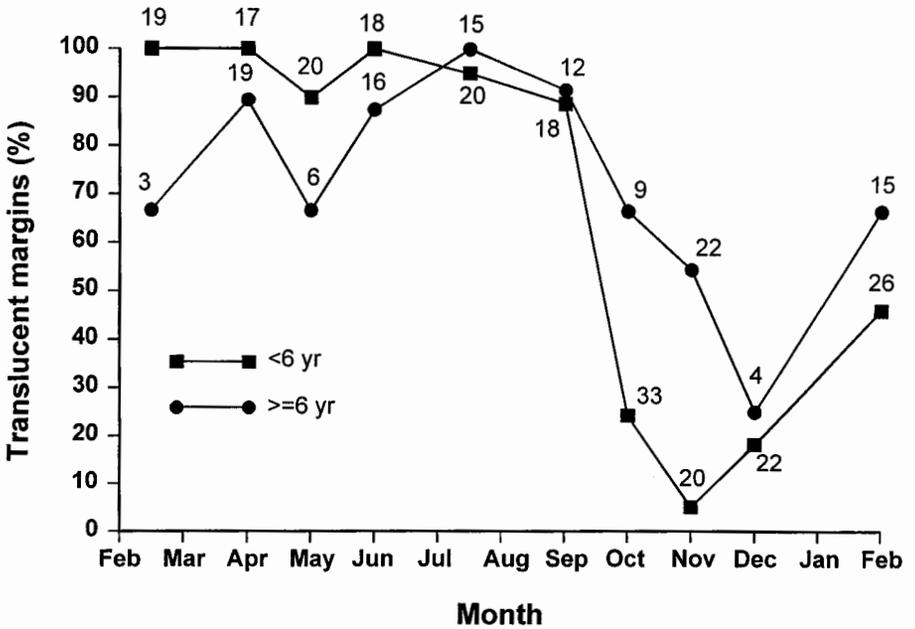


Figure 5. Seasonal pattern in the proportion of otoliths with translucent margins from young (<6 yr) and old ( $\geq 6$  yr) *L. miniatus*. Sample sizes are shown.

Table 1. Estimates of von Bertalanffy growth model parameters for *L. miniatus* from the Swain Reefs and the Capricorn-Bunker Group (southern Great Barrier Reef), based on fractional age readings from sectioned otoliths.

Area	$L_{\infty}$	k	$t_0$	$r^2$	df
Swain Reefs	51.73	0.188	-2.744	0.687	1129
Capricorn-Bunker Group	52.06	0.229	-1.428	0.767	769

GROWTH PARAMETER ESTIMATION.—Growth parameters were estimated separately for Swain Reefs and Capricorn-Bunker Group samples. Although the values of  $L_{\infty}$  were almost identical, the Swain Reefs population appeared to be characterized by a rather lower k and larger negative  $t_0$  (Table 1). Inspection of the mean length-at-age data (Table 2) indicated that 1- and 2-yr-old fish from the Swains were significantly larger (by 3 cm and

Table 2. Predicted and observed mean lengths-at-age, with associated standard errors, of *L. miniatus* from the southern Great Barrier Reef. Also shown are the results of t-tests of the difference in mean length-at-age between the two collecting areas, and associated probability levels. Note that the predicted lengths were estimated using growth parameters derived from the Capricorn-Bunker Group data only.

Age (yr)	Predicted length (cm)	Swain Reefs			Capricorn-Bunker Group			t	P
		Mean	n	SE	Mean	n	SE		
1	22.3	29.0	3	0.76	25.9	72	0.23	2.73	0.008 **
2	28.4	33.6	162	0.18	31.4	332	0.14	9.57	0.000 ***
3	33.3	35.6	324	0.14	36.2	182	0.19	2.22	0.027 *
4	37.2	38.5	159	0.25	39.3	40	0.61	1.43	0.153
5	40.2	40.9	138	0.30	41.2	31	0.67	0.39	0.694
6	42.7	42.5	89	0.37	44.4	25	0.68	2.49	0.014 *
7	44.6	44.8	55	0.44	46.2	9	0.92	1.25	0.217
8	46.1	45.7	38	0.53	47.8	2	2.75	0.86	0.396
9	47.4	47.3	21	0.57	50.3	3	1.17	1.93	0.067
10	48.3	48.1	14	0.94	n.d.	0			
11	49.1	48.9	14	0.74	50.3	2	0.75	0.68	0.505
12	49.7	50.2	8	0.78	51.3	3	1.01	0.80	0.446
13	50.2	49.2	5	2.02	48.0	1			
14	50.6	51.8	2	0.75	46.5	1			
15	50.9	48.8	2	1.75	48.8	3	2.13	0.03	0.980
16	51.2	48.3	3	0.88	54.5	1			
17	51.4	49.7	3	2.17	53.0	1			
18	51.5	49.3	2	2.75					
19	51.6	48.0	1						
20	51.7	48.0	1						
21	51.8	46.5	2	0.50					
22	51.9								
23	51.9								
24	52.0								
25	52.0				52.0	1			

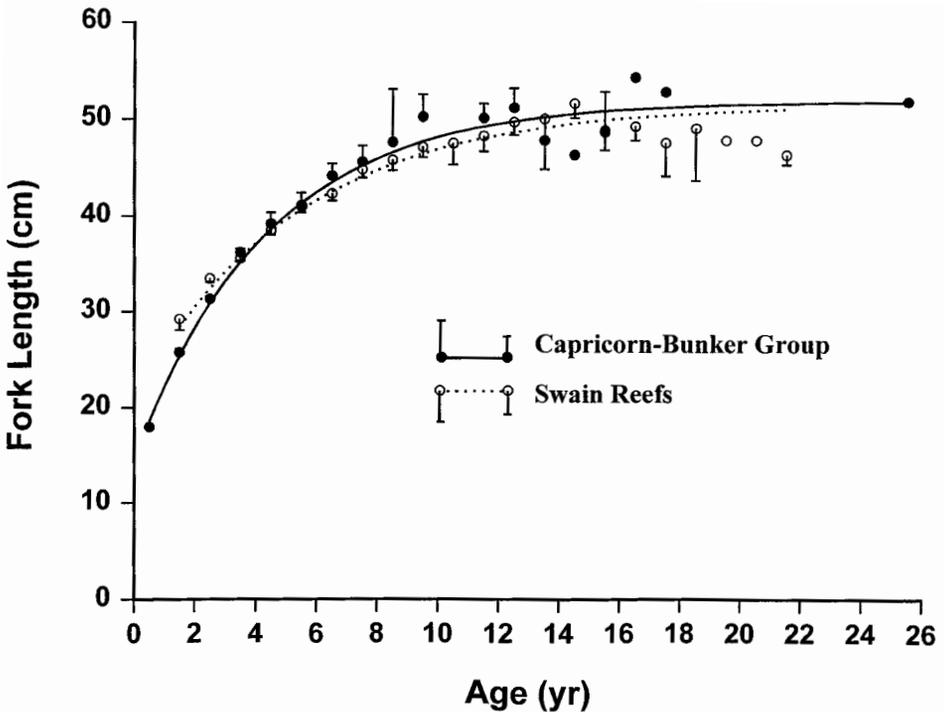


Figure 6. Von Bertalanffy growth curves for *L. miniatus* from two localities in the southern Great Barrier Reef. Mean lengths-at-age and associated 95% confidence intervals are shown. Note: symbols representing integer ages have been offset to the right by 0.5 yr to more closely correspond to the position of the curves, which are based on fractional ages.

2 cm, respectively) than their counterparts from the Capricorn-Bunker Group. In contrast, the mean lengths of most age-classes including and above age 3 from the Swain Reefs were slightly less than those from the Capricorn-Bunker Group (Fig. 6), although in only two cases were the differences statistically significant (Table 2).

**TOTAL MORTALITY RATE.**—The youngest fully-recruited age classes, as indicated by the log-transformed frequency-at-age data (catch curves), were 3 yrs in the Swain sample and 2 yrs in the Capricorn-Bunker sample (Fig. 7). Although a consistent trend in  $Z$  was evident up to about age 15 in the Swain Reefs population, we excluded ages >10 yrs because of poor and variable representation of older age groups in the Capricorn-Bunker Group samples. In both populations there appeared to be more very old fish than might have been expected on the basis of the mid-age mortality gradient. The estimated total mortality rate for the Capricorn-Bunker population of *L. miniatus* ( $Z = 0.70$ ;  $r^2 = 0.92$ ) was much greater than that for the Swains population ( $Z = 0.43$ ;  $r^2 = 0.99$ ), the difference between regression slopes being very highly significant ( $t = 2.80$ ;  $P = 0.017$  with 11 df).

## DISCUSSION

Otoliths can be used successfully for determining the age of redthroat emperor (*L. miniatus*), but estimates can differ significantly depending on whether whole otoliths or

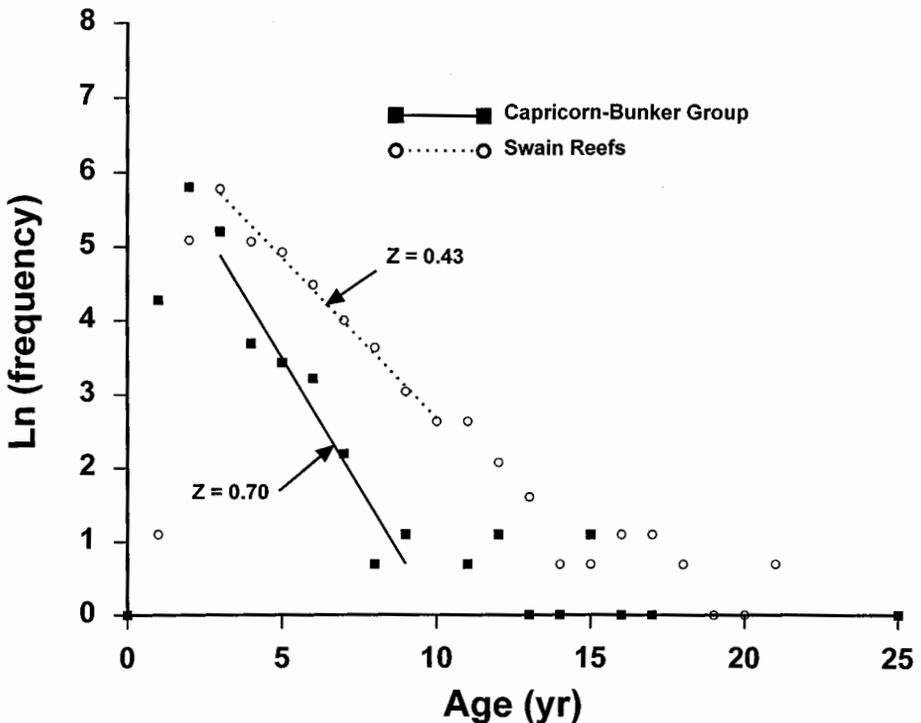


Figure 7. Catch curves and total mortality rate estimates for *L. miniatus* from the Swain Reefs and the Capricorn-Bunker Group.

thin sections are used. Whole preparations from larger fish underestimated age by as much as 30–40% with respect to sections. Various authors (Irie, 1960; Loubens, 1978; Boehlert, 1985) have concluded that whole otoliths can lead to lower age estimates than sections, because of a tendency for the thickness of the otolith, as it grows, to progressively obscure its internal structure. However Milton et al. (1995) reported that sections overestimated the age of some tropical lutjanid snapper species. We found that the otoliths of *L. miniatus* increase in thickness at a greater rate than in length, confirming Loubens' (1978) findings in relation to several species of lethrind in New Caledonia. This is consistent with the hypothesis that whole otolith ages are biased downward, rather than section ages being biased upward. We believe that while whole otoliths can be used satisfactorily for fish less than 5- or 6-yr old, at ages greater than this the whole otolith method may result in serious underestimation of age.

The precision of age estimates derived from both whole and sectioned otoliths of *L. miniatus* was relatively high, compared for example with the coral trout *Plectropomus leopardus*, another important demersal species on the Great Barrier Reef. Ferreira and Russ (1994) reported IAPEs of 6.7% and 12.1% for whole and sectioned otoliths of coral trout from the northern GBR. The difference between species is probably a reflection of the ease with which redthroat emperor otoliths can be read and interpreted compared to those of the coral trout. We found a reduction in IAPE (i.e., an increase in the precision of estimates) throughout the study, presumably as a result of increasing skill amongst the

readers, none of whom had had significant experience in otolith interpretation before the investigation commenced. During the latter part of the study there was very little difference in the precision of estimates derived from whole and sectioned otoliths.

Analysis of periodicity in the appearance of otolith margins indicated that broad bands of translucent material (under incident illumination) are laid down between February–March and September, while narrower opaque bands or growth checks occur most frequently in November–December. This single cycle of deposition confirms our interpretation of the annual nature of the growth rings or bands counted in the thin transverse otolith sections. It also indicates that growth is most rapid during autumn and winter, and slows to a minimum in late spring and early summer. These data are in broad agreement with those reported by Walker (1975) and Church (1985). Walker (1975) concluded, from examination of scale margins of *L. miniatus* from the Townsville region, that growth increments were greatest during June and July, and least during October and November. The slight difference between our results and those of Walker (1975) may be due to a lag in water temperature changes between the study areas, which are separated by more than 370 km in latitude. Populations of *L. miniatus* around Norfolk Island likewise showed maximum scale marginal increments between May and about September–October, and growth checks appeared between December and January (Church, 1985). Our results suggest that younger fish respond sooner than older individuals to the cues responsible for seasonal reduction in growth rate. While this may be a real effect, it could also have been partly due to observer error in assigning edge status to old fish, in which the outermost otolith checks are very close together and more difficult to categorise.

While the differences in growth parameter estimates for *L. miniatus* between the Swain Reefs and the Capricorn-Bunker Group could conceivably be due to the existence of two stocks, or to differing ecological factors (such as food availability) affecting growth, the most likely cause relates to differences in the way samples were collected. Fish from the Swain Reefs were obtained mainly from commercial fishing operations and were subject to minimum legal size restrictions, while those from the Capricorn-Bunker Group were collected during research cruises and were not thus constrained. As only those individuals in the upper part of the size distribution of the (partially recruited) age class would be retained in the catch, mean lengths-at-age for the age 2 and 3 fish obtained from the commercial samples are likely to be even more upward-biased than would normally have resulted from the selectivity characteristics of handline fishing.

Three previous studies provide comparative estimates of the growth parameters of *L. miniatus* from length-at-age data. Walker (1975) first estimated  $L_{\infty}$  from the Ford-Walford plot of  $L_{t+1}$  on  $L_t$ , then  $k$  and  $t_0$  from the slope and intercept respectively of the regression of  $\log(L_{\infty} - L_t)$  on  $t$ . We converted Walker's (1975) tabulated mean standard lengths-at-age to fork lengths, using the conversion formula  $FL = 0.596 + (1.143 \times SL)$ , and re-fitted the growth curve to the converted means to enable comparison with our results. The growth parameters are approximated as  $FL_{\infty} = 68.8$ ,  $k = 0.16$ , and  $t_0 = -2.47$  (Table 3). Walker (1975) reported that the oldest fish in the Townsville sample of *L. miniatus* (based on scale readings) was 7 yrs, and the largest fish, a 7 yr-old, was 48.7 cm SL (56.3 cm FL equivalent). The relatively low maximum age, and the fact that the converted  $L_{\infty}$  was very much greater than the reported  $L_{\max}$ , suggests that the ages of older fish may have been seriously underestimated as a result of the use of scales.

Church (1985) used FL in a scale-based estimation of growth rates in *L. miniatus* populations around Norfolk Is., and estimated the growth parameters of male and female fish

Table 3. Estimates of von Bertalanffy growth parameters for *L. miniatus* from Townsville (Walker, 1975), Norfolk Island (Church, 1985) and New Caledonia (Loubens, 1980). Standard errors where available are shown in brackets.

Reference	Sex	$L_{\infty}$	k	$t_0$	Comments
<sup>1</sup> Tsv	m+f	58.5	0.174	-2.26	SL
<sup>2</sup> Tsv	m+f	68.8	0.163	-2.47	SL converted to FL
<sup>3</sup> N.I.	f	65.70 [2.67]	0.109 [0.009]	-2.30 [0.12]	FL, back-calculated
<sup>3</sup> N.I.	m	68.33 [1.65]	0.111 [0.006]	-2.26 [0.10]	FL, back-calculated
<sup>3</sup> N.I.	m+f	69.90 [1.56]	0.103 [0.005]	-2.30 [0.08]	FL, back-calculated
<sup>4</sup> N.I.	f	117.54	0.038	-5.04	From tabulated data
<sup>4</sup> N.I.	m	90.26	0.071	-2.53	From tabulated data
<sup>5</sup> N.C.	f	45.7	0.272	-	SL, back-calculated
<sup>5</sup> N.C.	m	48.9	0.263	-	SL, back-calculated

<sup>1</sup>Walker, 1975 (Townsville). <sup>2</sup>After Walker, 1975 (Townsville). <sup>3</sup>Church 1985 (Norfolk Island). <sup>4</sup>After Church, 1985 (Norfolk Island). <sup>5</sup>Loubens, 1980 (New Caledonia).

separately (Table 3) from back-calculated lengths using a single scale from each fish. The tabulated length-at-scale-age data in Church (1985) showed relatively little curvature, and fitting the von Bertalanffy growth model to these data using standard nonlinear procedures resulted in elevated asymptotic lengths (females: 117.5 cm; males: 90.3 cm) and correspondingly large negative values of  $t_0$  (-5.04 and -2.53) (Table 3). The lack of curvature in the data was reflected in very low estimates of k (females: 0.04; males: 0.07). Church's (1985) growth estimates, however, were based on back-calculated lengths-at-age, which resulted in parameter values far less extreme than those obtained by our analysis of the raw length-at-age data. For example  $L_{\infty}$ , k, and  $t_0$  for female *L. miniatus* were estimated to be 65.7 cm, 0.109, and -2.3 yr respectively (Table 3). The asymptotic lengths were, nevertheless, still greater than  $L_{\max}$  (by 11.3% and 3.5% for females and males respectively), again suggesting that there may have been some underestimation of the ages of larger fish.

Loubens (1980) estimated growth parameters for *L. chrysostomus* (= *L. miniatus*) in New Caledonia using adjusted back-calculated length-at-age data derived from whole otolith examination. The estimates of standard length  $L_{\infty}$  (Table 3) approximated fork lengths of 55.7 and 52.2 cm for males and females, respectively, using the regression parameters listed in Loubens (1980). These were consistent with our results for the Swains and Capricorn-Bunker Group but considerably lower than those for Townsville (Walker 1975) or Norfolk Island (Church 1985) (Table 3). Loubens' estimates of K (0.26 and 0.27 for males and females, respectively) approximated the estimate we obtained for the Capricorn-Bunker Group population (0.23).

Walker (1975) remarked on the very rapid initial growth of *L. miniatus*, indicating that they could attain a mean length of 25.2 cm (SL) at the end of their first year. He noted the possibility that during the first year no annulus may have formed or that it was difficult to see, so that all fish in his study may have been 1 yr older than he estimated. The observed mean length at age 1 for the Capricorn-Bunker population (25.9 cm FL) was somewhat less than the 29.4 cm FL equivalent of Walker's estimate. However it is probably still an overestimate of the actual mean size of 1-yr-olds because of the likelihood of size-selec-

tivity of the handline fishing method. The probability of capture among 1-yr-old redthroat emperors is almost certainly a function of size, with larger, faster-growing members of the age class being more vulnerable to fishing mortality. Unbiased estimates of the mean lengths of the first couple of age classes will probably not be available until the juvenile habitat of this species is identified and representative samples obtained.

Assuming that natural mortality rates in the Capricorn-Bunker Group and the Swain Reefs are similar, our data suggest that populations of *L. miniatus* in the former area are subject to a very much higher level of fishing mortality (F) than those in the latter. This may not be surprising, considering the difference in accessibility between the two areas. Parts of the Capricorn-Bunker Group (comprising a number of cays providing sheltered anchorages) are less than 75 km from the major coastal city of Gladstone, whereas the distance between the mainland and the nearest part of the Swain Reefs (a maze of tidally-submerged reefs) is about 185 km. Our estimates of total mortality from the accessible and remote populations ( $Z = 0.70$  and  $0.43$ , respectively) provide an interesting parallel to the situation reported by Church (1985) in relation to two populations of *L. miniatus* in the vicinity of Norfolk Is. ( $29^{\circ}\text{S}$ ,  $168^{\circ}\text{E}$ ). Total mortality in the population within 22 km of Norfolk Island's main boat access point was estimated to be 0.89, but was significantly lower (0.37) in the more remote population between 22 and 40 km offshore (Church, 1985).

From catch curves presented by Walker (1975), Williams and Russ (1994) estimated  $Z$  for *L. miniatus* in the vicinity of Townsville ( $19^{\circ}\text{S}$ ;  $147^{\circ}30'\text{E}$ ) to be 0.74, which is very close to our estimate (0.70) from the Capricorn-Bunker population. Fishing pressure on the Townsville population of *L. miniatus* may well have been quite high during the time of Walker's study, but we believe it was probably less than it is now, two decades later, in the Capricorn-Bunker Group. Assuming similar rates of natural mortality between Townsville and the southern GBR, we therefore attribute the high value of  $Z$  based on Walker's (1975) data to a significant underestimation of the ages of larger fish resulting from the use of scales, rather than to a high level of fishing mortality.

The catch curves for both areas (Swain Reefs and Capricorn-Bunker Group) were characterised by a relatively constant logarithmic rate of decline in age-class abundance between full recruitment and about 10 yrs. Although in relatively low abundance, there appeared to be more fish older than 10 yrs than might have been expected on the basis of the catch-curve regression line. This may have been the result of selective targeting of areas likely to yield larger fish (a distinct possibility in the case of the commercial catch samples, but less so in the case of the research samples) or a real reduction in total mortality rate above that particular age.

#### ACKNOWLEDGMENTS

Thanks are due to L. Mikula and S. Jackson for their assistance in preparing and reading otoliths. The boat-handling and fishing expertise of B. Davidson, skipper of the Department's R.V. WARREGO is acknowledged with thanks. Particular gratitude is extended to professional fishermen J. Clark, M. Lonergan and L. Hayward for providing a regular supply of fish frames from remote parts of the Swain Reefs. We also thank D. Mayer for assisting with the analyses, and two anonymous reviewers for suggestions which have improved the text. The work was part of a larger program supported financially by the Australian Fisheries Research and Development Corporation.

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DATE SUBMITTED: October 4, 1995.

DATE ACCEPTED: November 18, 1996.

ADDRESS: *Queensland Department of Primary Industries, Southern Fisheries Centre, P.O. Box 76, Deception Bay, Queensland 4508, Australia.*