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AGE DETERMINATION OF A TROPICAL REEF BUTTERFLYFISH UTILIZING DAILY GROWTH RINGS OF OTOLITHS

The recent economic expansion of the aquarium fish industry in Hawaii has raised questions concerning the judicious exploitation of reef resources (Pellegrin 1973; Randall 1973; Reese 1973). However, appropriate management strategies cannot be implemented until sufficient biological data have been gathered, allowing a characterization of exploited populations of fishes. The relative paucity of such information concerning the vast majority of reef species underscores the need for future research.

Studies pertaining to the age and growth of fishes are especially useful in the analysis of exploited stocks. Unfortunately, efforts to age tropical fishes in the past have proved to be largely unsuccessful and/or involve considerable expenditures in time and effort (Pannella 1974). However, the recent studies of Pannella (1971, 1974) have initiated the development of a technique for determining the age of tropical fishes without having to resort to more elaborate approaches such as the Peterson method of ageing. Panella has provided evidence that many species of both temperate and tropical fishes deposit lamellae on their otoliths with a diel periodicity. These lamellae are visible as rings or circuli after the otolith has been properly prepared. In the absence of annuli, these rings may be used to age fish. A recent investigation by Struhsaker and Uchiyama (1976) using this technique was successful in ageing the Hawaiian anchovy (*Stolephorus purpureus*) and in showing the daily nature of these lamellae.

This paper reports on studies of the age and growth of the Hawaiian endemic millet-seed butterflyfish, *Chaetodon miliaris* Quoy and Gaimard (Perciforms: Chaetodontidae), using this approach. Butterflyfishes are exceptionally attractive and are heavily exploited by the aquarium industry in Hawaii. This study was initiated in order to obtain information useful to state regulatory agencies in the management of reef fish stocks.

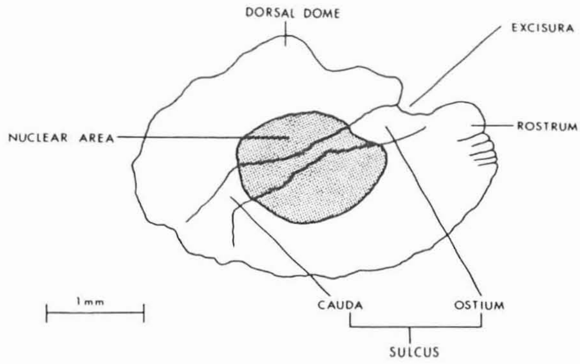

FIGURE 1.–Schematic representation of the left sagitta of a 94-mm *Chaetodon miliaris* viewed medially.

Methods

All fish were collected by spearing around the island of Oahu, Hawaii, during 1974 and were measured to the nearest millimeter standard length (SL) while still fresh. Next, the otoliths were extracted by means of a horizontal section through the cranium above the eyes. Of the three otoliths on each side, only the largest, the sagitta, was studied. Figure 1 depicts a left sagitta of a 94-mm *C. miliaris* viewed medially. After both sagittae were removed, all membranes and endolymph were carefully teased way under a dissecting microscope. The otoliths were then rinsed in water and placed in a 2% aqueous solution of HCl for several minutes of etching. They were then rinsed again, thoroughly dried, and finally mounted in depressions of glass slides where they were immersed in euparal (an aromatic oil which acts as a clearing agent) and covered with glass cover slips. After clearing for 2 wk, the otoliths were ready for reading. Otoliths were read from the nucleus outward along their long axis with a compound binocular microscope utilizing transmitted light at a magnification of 400× (Figure 2). The rings in each sagitta were counted twice, using a hand counter, and the average of the four readings obtained from each specimen was used to estimate the age of the fish in days.

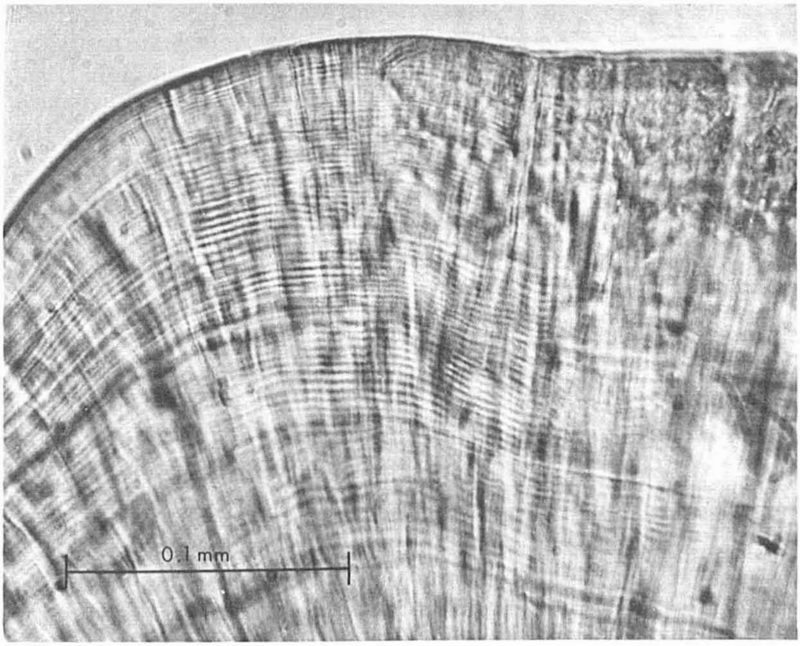

FIGURE 2.–Internal ring structure of the otolith of *Chaetodon miliaris* specimen number 11. Not all the rings are visible in this photograph.

Results

The counts of rings within otoliths are summarized in Table 1. The average number of rings for each fish has been rounded to the nearest integer.

On the assumption that one ring is equal to one day's growth (Pannella 1971, 1974; Struhsaker and Uchiyama 1976), the data were fitted to the von Bertalanffy growth equation employing the techniques of Allen (1966). This model states:

$$l_t = L_\infty (1 - e^{-K(t - t_0)}) \quad (1)$$

where l_t = length at time t

L_∞ = the average length of a group of fish grown for an infinite period of time

K = a growth parameter which describes the rate at which l_t is approaching L_∞

t_0 = the back calculated X intercept or the time at which size was zero.

The data are plotted along the calculated von Bertalanffy growth curve in Figure 3. The calculated growth equation for the data in this report is:

$$l_t = 127(1 - e^{-0.0031(t+30)}) \quad (2)$$

when size is expressed as SL in millimeters and time is expressed in days. Alternatively, when time is expressed in years, the equation becomes:

$$l_t = 127(1 - e^{-1.13(t+0.082)}). \quad (3)$$

The estimated asymptotic size of 127 mm SL is a reasonable figure. Of 345 *C. miliaris* examined in another study (Ralston 1975), 4 were larger than this size. Of those, three were 131 mm SL or less, while the fourth was 137 mm SL. Because L_∞ can be thought of as an average, if sampling is intensive enough, one would expect to find individuals of a larger size. Of all the fish sampled in this earlier study, only 1.2% were larger than the estimated growth ceiling of the von Bertalanffy model as determined from the otoliths of the 15 individuals reported on here.

TABLE 1.–The number of rings counted in the otoliths of *Chaetodon miliaris* collected around Oahu, Hawaii, 1974.

Specimen	Date of capture	Standard length (mm)	Mean number of rings	Range of counts
1	7 June	27	35	32-38
2	18 June	29	71	65-74
3	7 June	32	51	48-52
4	11 July	35	108	99-115
5	11 July	42	133	124-138
6	1 Oct.	44	118	110-122
7	5 Oct.	50	115	107-121
8	1 Oct.	52	138	134-141
9	5 Oct.	56	147	141-153
10	5 Oct.	66	169	162-178
11	5 Oct.	70	227	215-238
12	5 Oct.	71	228	219-235
13	5 Oct.	71	221	216-227
14	1 Dec.	86	322	307-333
15	1 Dec.	87	375	362-391

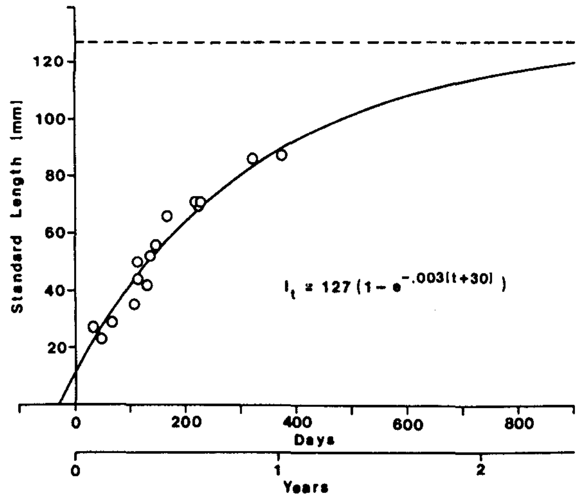

FIGURE 3.–The von Bertalanffy growth curve in length fitted to 15 individuals of *Chaetodon miliaris* aged by means of otoliths.

The growth of *C. miliaris* is very fast. The estimated growth parameter, K, of the von Bertalanffy equation describes how quickly growth proceeds. Large values of K are associated with rapid growth. Beverton and Holt (1959) presented values of K for 57 species of fishes and of those, only 6 species have K values exceeding that of *C. miliaris*.

It should also be noted that only fish which were less than 90 mm SL are reported on here. It was found that the otoliths of larger fish became increasingly difficult to read. Not only do the otoliths become thicker, but the peripheral ring increments become smaller with growth. For these reasons, larger fish could not be reliably aged in this study.

Discussion

On 2 August 1966, Wass (1967) defaunated a small patch reef in Kaneohe Bay, Hawaii, while studying the repopulation rates of various species of fishes. In so doing, he sampled 476 *C. miliaris* in 1 day. He gave a size-frequency distribution, suitable for the Peterson method of ageing, which is reproduced in Figure 4.

The first mode centered on 7 cm total length (TL) could well represent a recently recruited cohort. A size of 70 mm TL corresponds to a length of 58 mm SL for *C. miliaris* (Ralston 1975). Spawning in this species is known to occur between December and April but peaks around the end of February or the beginning of March (Ralston 1975). Consequently, about 155 days elapsed between the time of peak spawning for this species and the date of capture of these 476 specimens. Assuming growth according to Figure 3, after 155 days of growth, juvenile *C. miliaris* are estimated to be 55 mm SL. This size corresponds closely with the first mode of Wass' size-frequency distribution (58 mm SL or 70 mm TL), thus corroborating Figure 3.

Further evidence in support of the von Bertalanffy growth curve and therefore, the interpretation of otolith ring patterns, comes from examining the size at which *C. miliaris* first reproduce. Ralston (in press) reported that both male and female *C. miliaris* reached reproductive maturity at a size of about 90 mm SL. Referring to Figure 3, fish of this size are about 1 yr old. If spawning is periodic, as it is in *C. miliaris* (Ralston 1975), one expects the onset of reproductive maturity to occur after some multiple of the interval between spawning periods has elapsed. One year is one such interval and *C. miliaris* becomes reproductive during the first spawning season after birth.

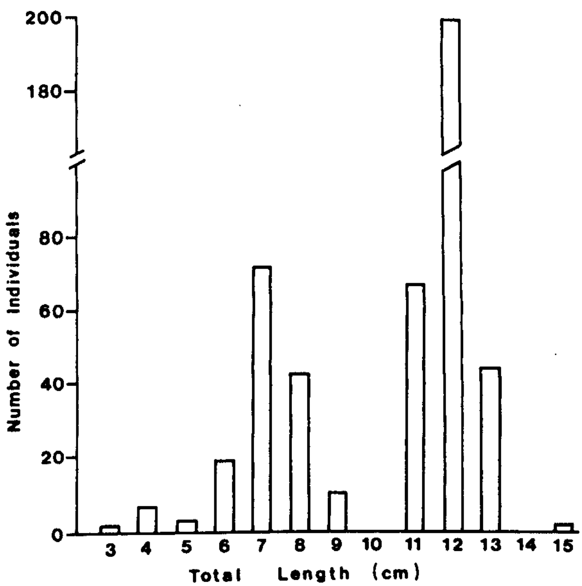

FIGURE 4.–Size-frequency distribution of *Chaetodon miliaris* collected by Wass (1967) in Kaneohe Bay. (Redrawn from his figure 7.)

Evidence presented here in the form of interpretation of the data of Wass (1967) and examination of age at maturity substantiate the growth of *C. miliaris* as described by the von Bertalanffy curve of Figure 3. These in turn confirm the accuracy and utility of employing the diel lamellae in the otoliths of fishes as growth chronometers. Although a new and as yet somewhat untried technique, Pannella's method of age determination offers the potential to age fishes in situations where this was not feasible in the past.

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AN EPIBENTHIC SAMPLER USED TO STUDY THE ONTOGENY OF VERTICAL MIGRATION OF *PANDALUS JORDANI* (DECAPODA, CARIDEA)[1]

Pandalus jordani Rathbun, like many other species of pandalid shrimps, undergo regular diel changes in their vertical distribution (Tegelberg and Smith 1957; Alverson et al. 1960; Pearcy 1970, 1972; Robinson in press). Little is known, however, about the vertical distribution and diel migrations of larval and juvenile shrimp, or at what stage of the life history vertical migration and benthic existence are initiated.

Berkeley (1930) found that size or age of larval *P. danae* increased with increasing depth in a semienclosed embayment in British Columbia. Pearcy (1972) published the only information on day/night differences in benthic occurrence of juvenile *P. jordani*. Using a plankton net mounted on a beam trawl, he collected more juveniles (<7.0 mm in carapace length) near the bottom during day than night.

In order to sample the water column completely, it was necessary to supplement plankton tows with a discrete, quantitative sample on or just off the bottom. Various methods have been used for this purpose but we thought that all of them were inadequate for the present study. Many epibenthic samplers do not have an opening/closing device and therefore are subject to contamination from the water column above (Russell 1928; Frolander and Pratt 1962; Pearcy 1972; Beardsley 1973). Others are only capable of collecting small samples, in relatively shallow water (Clutter 1965; Macer 1967). In others the opening/closing device seems inefficient or overly complex (Bossanyi 1951; Wickstead 1953; Macer 1967; Hesthagen 1970). Design criteria for the sampler used in this study were: a simple, substrate activated, opening/closing device capable of quantitatively sampling in depths greater than 150 m and sampling at least 500 m^3 of water with no loss of filtration efficiency.

Epibenthic Sampler Design

The epibenthic sampler consists of a sled and a box, to which are attached a plankton net and a substrate-actuated opening/closing device (Figure 1). The frame of the sled was welded from flat steel strap (5.1 × 0.6 cm). The runners (23 × 0.6 cm mild steel plate) are joined across the front by a piece of the same steel bent to conform to the front of the sled. This serves to carry the sled over small obstructions on the seabed and further protect the door of the box when it is in the open position. A bumper bar (5.1 × 0.6 cm) was also fitted across the front of the sled to prevent large obstacles from entering the mouth of the sampler. Two brackets on either side of the sled serve as attachment points for the box. The six different positions allow the box to be positioned from 2.5 to 22.9 cm off the bottom. Two pieces of strap (5.1 × 0.6 cm) were welded along the top of the frame with nine holes to provide various attachment points for the towing bridle. In addition, four pairs of towing points were placed around the front of the frame.

The box (106.7 × 45.7 × 53.3 cm), made of 3.2-mm mild steel plate, is reinforced in front by steel strap (2.5 × 0.32 cm), forming a lip around the mouth of the box (Figure 1B). The box is further reinforced by L stock (2.5 × 0.32 cm) placed around the box 10 cm from the rear edge. Attach-

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