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ANALYSIS OF AGE AND GROWTH IN TWO EASTERN PACIFIC GROUPERS (SERRANIDAE: EPINEPHELINAE)

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ABSTRACT

In an attempt to characterize species specific-growth rates of two Eastern Pacific groupers, individuals from two sympatric species, *Epinephelus labriformis* (n = 173), and *Cephalopholis panamensis* (n = 127), were collected at various localities in Mexico and the Galápagos archipelago in 1997 and 1998. Sagittal otoliths were removed, and age of each individual was determined by direct visual inspection of annuli present following sectioning. Length/weight relationships were determined, and growth curves were generated using the von Bertalanffy growth model. The two species demonstrated similar growth rates, yet, as determined by the von Bertalanffy parameters, *E. labriformis* tended towards a larger size ($L_\infty = 3.18 \times 10^2$) than did *C. panamensis* ($L_\infty = 2.48 \times 10^2$). As both species were found to be used in artisinal fisheries, this information may be used to aid in the development of future management strategies as well as to provide possible explanations of ecological interactions among reef inhabitants.

The epinepheline serranids, or groupers, comprise one of the largest groups of fishes worldwide and are represented by 29 genera (Nelson, 1994). The economic importance of the grouper fishery has been acknowledged by various authors (e.g., Sadovy et al., 1992; Beets and Hixon, 1994; Bullock, et al.; 1992), as well as by the United Nations Food and Agriculture Organization (Heemstra and Randall, 1993). The over exploitation of the grouper fisheries, due in part to the behavioral adaptation in many species of forming spawning aggregations, imparts a sense of urgency in developing a comprehensive body of knowledge regarding the life histories of these fishes. In particular, age and growth and age at maturity must be regarded as essential pieces of information to properly assess the status of a fishery, as well as to establish guidelines to properly maintain the fishery.

The flag cabrilla, *Epinephelus labriformis*, ranges in the eastern Pacific from Cedros Island to Peru, including the Cocos, Revillagigedo, and Galápagos Island groups (Heemstra and Randall, 1993; Grove and Lavenberg, 1997; D. J. Pondella, pers. observ.). This species is a common, shallow-water reef dweller, although adults occur at depths of up to 30 m (Heemstra and Randall, 1993) and reaches a maximum length of 0.5 m (Gotshall, 1987). Of considerable importance to local artisinal fisheries, the flag cabrilla is taken commonly by hook and line, fish traps, and spear pole.

The pacific graysby, *Cephalopholis panamensis*, is sympatric with *E. labriformis* throughout most of its range. Extending in the Pacific ocean from the Gulf of California to Ecuador (including the Galápagos archipelago), *C. panamensis* exhibits similar habitat preference as *E. labriformis*, and may be found at depths of up to 76 m (Heemstra and Randall, 1993; Smith, 1971). Although *C. panamensis* reaches a maximum total length of only 30 cm, it is found occasionally in artisinal catches in rural areas of the world (D. J. Pondella, M. T. Craig, pers. observ.).

The information regarding the life histories of these two species is scarce, at best. Many authors have, however, contributed life history studies for several allied genera (e.g., Moe, 1969; Sadovy et al., 1992; Bullock et al., 1992; Sadovy and Severin, 1994; Schirripa and Burns, 1997; Potts and Manooch, 1995). With the exception of Shirripa and Burns (1997), the aforementioned studies utilized sagittal otolith data to assess the age of specimens taken and/or back calculate length-at-age. The absence of literature involving *E. labriformis* and *C. panamensis* is most likely due to their limited exposure in large-scale fisheries. The importance of developing a sound body of knowledge regarding these species should not, however, be underestimated; dwindling numbers of larger, more economically valuable fishes are constantly placing increased pressure on other reef inhabitants.

Methods

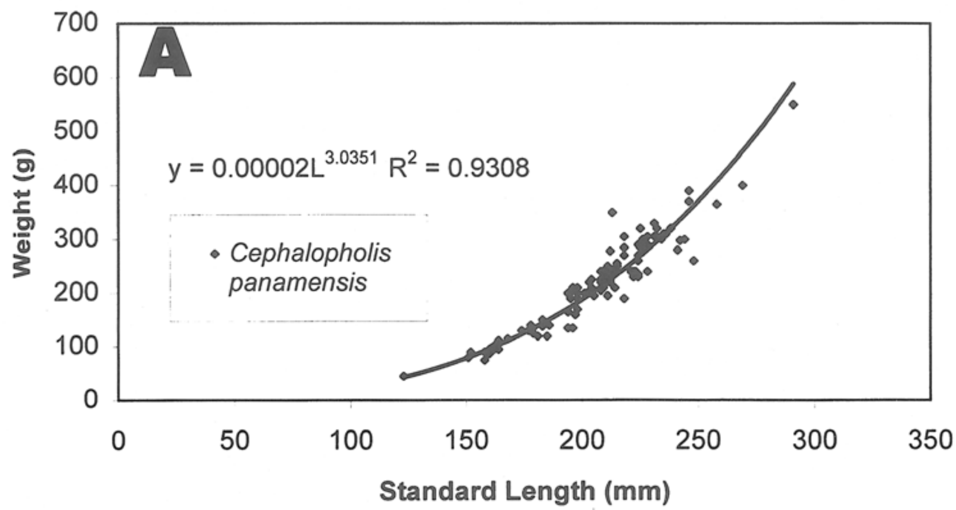
One hundred and thirty-three *E. labriformis* and 103 *C. panamensis* were collected by hook and line within Bahía de Banderas, Mexico, while aboard an artisinal fishing vessel at three separate locations during June, 1997: Punta de Mitra, Zero Bolas Cove, and the Marietas Islands (ca 20° 37′N, 105°15′W). A second group of *E. labriformis* (n = 40) was collected by hook and line from Isabella, Santa Cruz, and Floriana Island, Galápagos, Ecuador, in January 1998 (ca 0°30′S, 90° 30′W). An aditional group of *C. panamensis* (n = 24) was taken from Bahía de Los Angeles, Mexico, in June and September 1998 (ca 29°0′N, 113°39′W). Multiple localities were sampled in order to facilitate an increase in sample size. Standard length and weight were recorded immediately or soon after capture to the nearest millimeter and nearest gram, respectively. Gonads were examined visually for maturity stage.

Otoliths were removed using a novel method (L.G. Allen, pers. comm) described herein. First, the fish was placed on a hard surface with the ventral side exposed. The isthmus of the gills was severed, and gill arches were removed or pushed anteriorly. With a serrated knife, an incision was made perpendicular to the vertebral column through the parasphenoid bone at the base of the first gill arch. This cut was made so as to pierce the parasphenoid, yet so as only to score the sacculus. Pressure was than applied to both sides of the severed bone so as to break open the sacculus and expose the sagittal otoliths. For larger specimens, a table or sorting tray was frequently used for leverage while applying the same pressure. This new method greatly reduces the time spent locating the sagitta compared to traditional methods that entail entering through the dorsal surface of the skull (cf Cailliet et al., 1986).

The sagitta were mounted on wood blocks with cyanoacrylate adhesive and a 0.5 mm, dorsal-ventral section was taken using a Beuhler-Isomet double-bladed low speed saw. Many serranid fishes are known to lay down a single, opaque layer in the sagitta each year; such a layer is termed an annulus (plural: annuli) and the number of annuli present represents a direct measure of age (Allen et al., 1995; Sadovy et al., 1992; Sadovy and Severin, 1994). Sections were visually inspected while submerged in seawater in a petri dish with a black background using the aid of a dissecting microscope and the number of annuli present were recorded. Each otolith was read twice and those readings that did not agree were inspected until concordance was reached. Individuals which could not be resolved were excluded from the data set. Five of the 173 *E. labriformis* and one *C. panamensis* were excluded from the data sets due to the inability to resolve number of annuli present.

Length/weight relationships were determined using the power function in Microsoft Excel (ver 7.0) to characterize the linear growth of the two species. This equation is of the form $W = aL^b$, where W is weight in grams, L is standard length in millimeters, and *a* and *b* are constants. Age class frequency histograms were generated for both species at the separate locations. To evaluate growth rate of each species, the von Bertalanffy growth model was applied using the non-linear regression procedure in the computer program SYSTAT (SPSS Inc., Chicago, Illinois, ver 7.0). The model was of the form: $L_t = L_\infty(1-e^{-k(t-to)})$, where L_t = length at time t (years), L_∞ = theoretical maximum length (mm), K = constant expressing rate of approach to L_∞ (mm/year), and T_o = theoretical time at which L = 0 (von Bertalanffy, 1957; Ricker, 1975).

Apparent differences in the average length of *E. labriformis* from the Puerto Vallarta and Galápagos localities generated concern as to the pooling of data. To address this concern, mean length of the



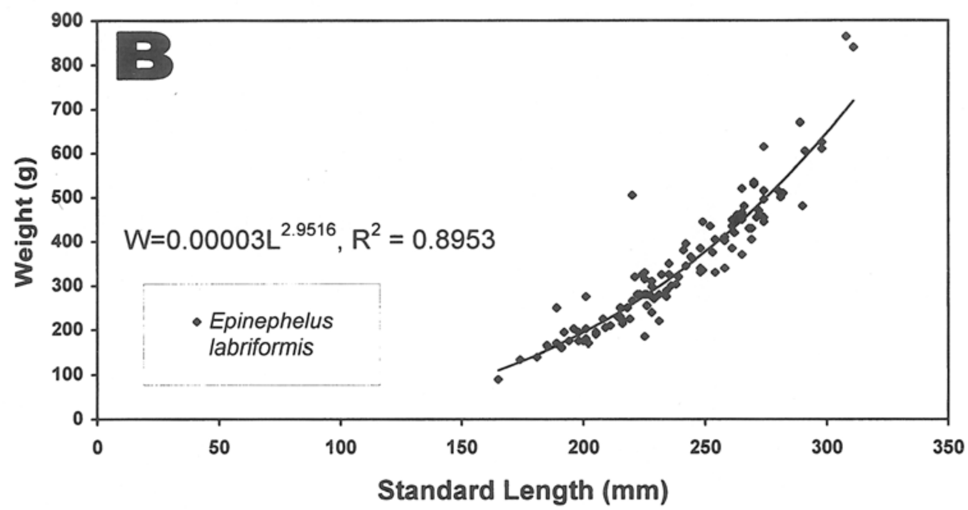


Figure 2. Length/weight relationship for (A) 124 *Cephalopholis panamensis*, (B) for 173 *Epinephelus labriformis*.

nance; rather, it demonstrated a cluster of individuals in age classes three to nine (104 of 173, Fig. 1B). Most individuals from the Puerto Vallarta population were determined to be sexually non-functional (i.e., immature or off-season). The range of age classes was 1 to 30.

All fish from the Puerto Vallarta population for each species were included in the determination of the length/weight relationship. *C. panamensis* fit the equation $W = 0.00002L^{3.0344}$, with more than 93% of the variance explained by the model ($r^2 = 0.9305$, Fig. 2A). *E. labriformis* fit the equation $W = 0.00003L^{2.9516}$, with more than 89% of the variance explained by the model ($r^2 = 0.8953$, Fig. 2B).

Both species demonstrated growth rates that were highly asymptotic (Figs. 3A,B). *C. panamensis* grew to approximately 160 mm standard length in the first year of growth, reaching a maximum 291 mm in an 4-yr-old fish; by comparison, *E. labriformis* reached approximately 200 mm in the first year, reaching a maximum 370 mm in a 23-yr-old fish. Von Bertalanffy parameters for both species are summarized in Table 1. The model fit the data points well as reflected by the coefficient of determination and regression analysis with ANOVA for each species (*E. labriformis,* raw $r^2 = 0.990$, F = 4547..69, $P << 0.001$, *C. panamensis,* raw $r^2 = 0.988$, F = 4008.31, $P << 0.001$). For the two populations of *E.*

Discussion

The age class distribution for *E. labriformis* from the Puerto Vallarta population is conspicuously lacking individuals in the upper range of the species length (see Fig. 3B; note also that Gotshall [1987] reported a maximum length for *E. labriformis* of 0.5 m [1.7 ft]). It is hypothesized that the observed artisinal fishing pressure placed on these fishes in Puerto Vallarta limits the number of individuals in the upper size classes. This same level of fishing pressure was not observed in the Galapagos; hence larger individuals were encountered in the population sampled (D. J. Pondella, M. T. Craig, pers. observ.).

The low representation of individuals in the upper size ranges of *C. panamensis* was also noted (Gotshall, 1987, reports the upper limit to 0.3 m [1 ft]). This may be attributed to ecological limitations, such as interspecific competition for niche space producing limitations in resources, as fishing pressure exerted upon *C. panamensis* in both Puerto Vallarta and Bahía de Los Angeles is lower than that placed upon larger, more valuable groupers.

The lack of functional gonads observed within both species, particularly the absence of mature males within *C. panamensis* and the absence of all mature individuals within *E. labriformis*, is probably due to sampling during a period of non-sexual activity. Many New World groupers are known to spawn during winter months (Smith, 1971; Beets and Hixon, 1994). This would explain the lack of sexually mature among individuals of *E. labriformis*. However, the presence of so many reproductively active females within *C. panamensis* suggest that those individuals observed as non-functional were spent males or early season males that had not yet fully developed. An alternative hypothesis is that *C. panamensis* and *E. labriformis* are employing protogynous hermaphroditism as a reproductive strategy, thus the lack of larger individuals leads to lack of mature males. Our data, however, neither support nor deny the presence of hermaphoditism in these fish.

The age and growth characteristics examined for the two species reflects a pattern of rapid first year growth followed by an asymptotic slowing of growth rate in the upper age classes. As compared to serranid fishes in the genus *Paralabrax*, *E. labriformis* is relatively fast growing (200 mm in first year), whereas *C. panamensis* (160 mm in first year) grows rather similarly to *P. clathratus* and *P. nebulifer* (165 mm and 166 mm in first year, [Allen, 1995]). The jewfish, *Epinephelus itajara*, has been reported at 200 mm in the first year (Bullock, et al., 1992). An exceptionally large grouper, *E. itajara* is considered slow growing in relation to its large size, yet the growth is comparable during the first year to the species examined here. The red hind, *Epinephelus guttatus*, reaches approximately 180–200 mm in the first year (Sadovy, et al., 1992), and the rock hind, *E. adscensionis,* has been reported to 200 mm in the first year (Potts and Manooch, 1995). The noted lack of collected individuals below 160 mm of both species is likely due to a bias in the hook and line sampling technique.

In the case of the Puerto Vallarta population of *E. labriformis*, nearly all individuals were in the lower age classes, whereas the Galápagos population was composed mainly of larger, older fish. To address the problem of grouping the two populations the "extra sum of squares" method was used as a means of comparing non-linear regression parameters which traditional ANOVA cannot (Ratkowski, 1983). The three parameters generated for each population demonstrated significant difference from one another, yet these differences are most likely an artifact of the low sample size from the Galápagos population and lack of overlap in age classes represented by the two data sets. Lack of represen-

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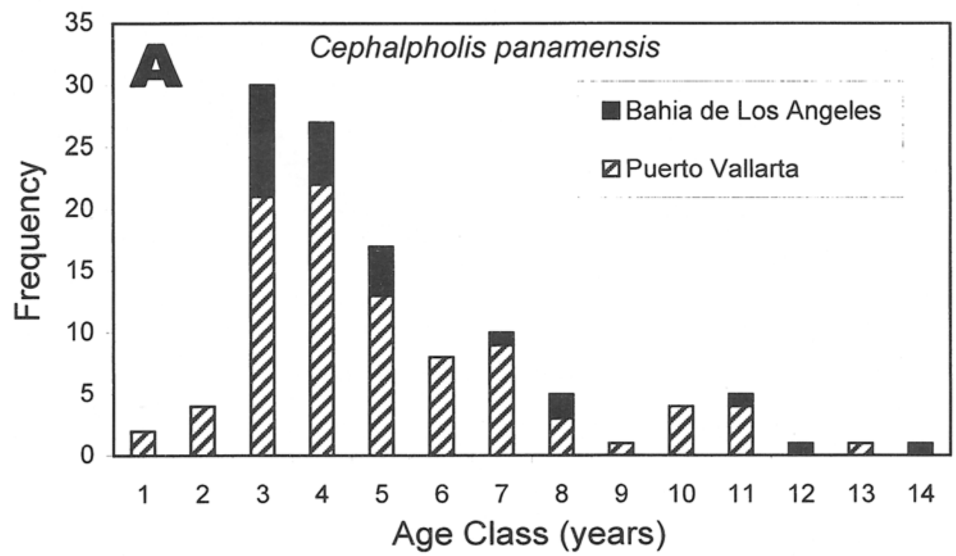
two populations were compared using a Mann-Whitney U-Test, and von Bertalanffy growth functions for each locality were compared to one another following Ratkowski (1983). Using a method known as "extra sum of squares" or the "conditional error principle" (Ratkowski, 1983) each of the three parameters generated by the Von Bertalanffy model was tested for significant difference from one another using the F-distribution. Significant difference between any of the parameters may indicate differences in the growth functions for the two populations. By examining each parameter individually, the observer is forced to recognize whether or not a single parameter is placing greater weight on the model as a whole, or if differences observed between two models can be accounted for by differences in the data sets themselves. This method allows one to test for the significance of observed differences in estimated parameters when performing non-linear regression modeling.

Results

C. panamensis showed considerable numerical dominance by fishes in the 3- and 4-yr classes (56 of 127, Fig. 1A), with most individuals from the Puerto Vallarta population observed as functional (i.e., ripe) females (67 of 103). The fish ranged in age from 1 to 14 yrs. *E. labriformis*, however, did not show such a narrow range of age class predomi-



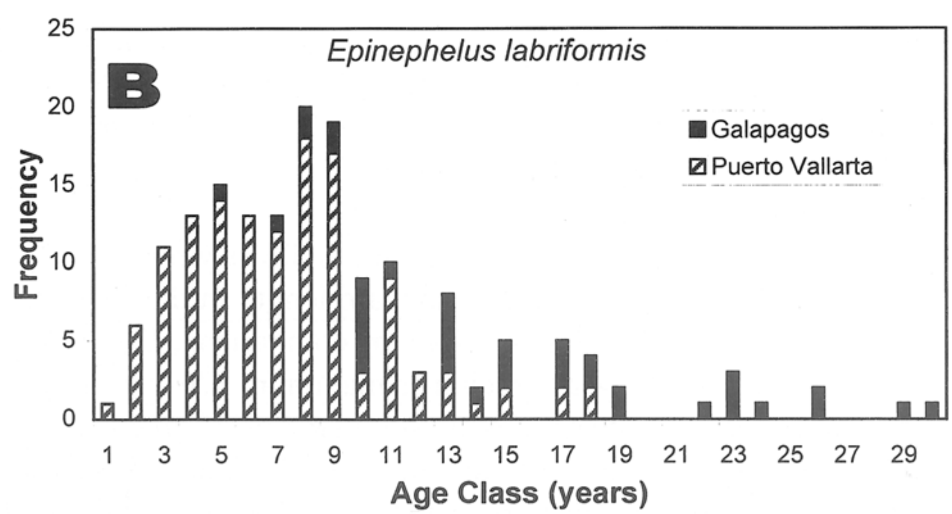
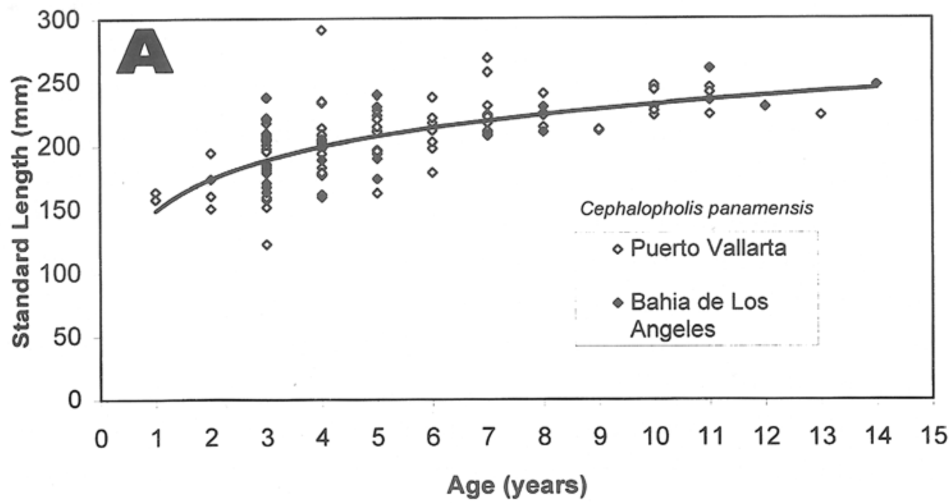


Figure 1. Age class frequency histograms for (A) 124 *Cephalopholis panamensis*, (B) 173 *Epinephelus labriformis*.



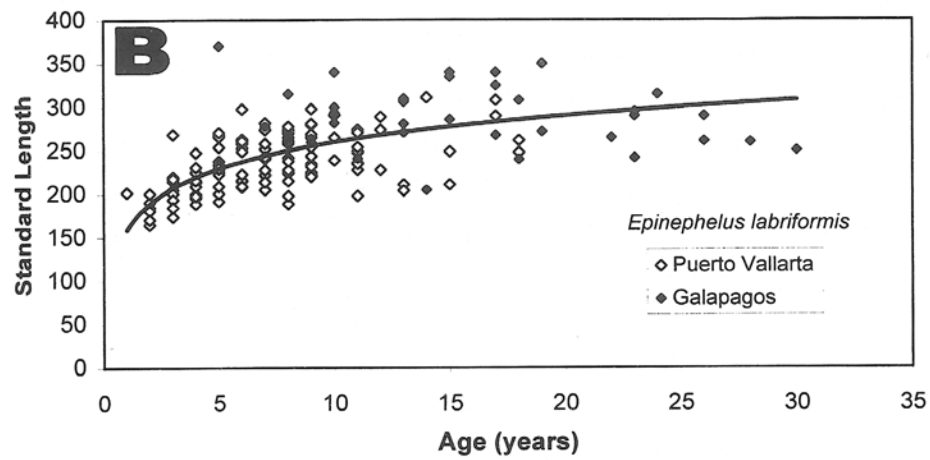


Figure 3. von Bertalanffy growth curves for (A)) 123 *Cephalopholis panamensis*. Open symbols represent fish from Puerto Vallarta; closed symbols, fish from Bahía de Los Angeles. (B) 168 *Epinephelus labriformis*. Open symbols represent fish from Puerto Vallarta; closed symbols, fish from Galápagos.

labriformis, all parameters estimated by the von Bertalanffy model demonstrated significant differences from one another at the 95% confidence level using the "extra sum of squares method (Ratkowski, 1983). In addition, the mean lengths of the two populations of *E. labriformis* differed significantly using the Mann-Whitney U-Test (T = 1895.50, P = 0.029).

Table 1. Von Bertalanffy parameters estimated for *Epinephelus labriformis* and *Cephalopholis panamensis*.

	Parameters Estimated		
Species	L_∞	K	T_o
E. labriformis (all)	317.773	0.090	–8.818
Galápagos	309.771	0.214	–0.170
Puerto Vallarta	256.165	0.318	–2.331
C. panamensis	249.047	0.196	–4.149

tation of individuals from all age classes results in the model searching for appropriate parameters without the necessary data points to do so. Absence of large individuals obviously affects estimation of L_{∞}, absence of smaller individuals will greatly effect T_0, and lack of a true combination of both will result in an inappropriate estimation of K. In view of the above, we opted to combine the two data sets from the separate localities despite the statistical differences observed among the parameters. It is our opinion that pooling of the data allows us to obtain a growth function that reflects a more accurate range of size classes for this species. Given the caveat concerning grouping the two data sets, we nevertheless propose this trend as a relationship that can be evaluated by future studies, and reiterate that the model explains the variance in the pooled data well as reflected be the coefficient of determination (raw $r^2 = 0.990$, see also Fig. 3B). The data for *C. panamensis* did not present such a problem, as individuals from the Bahía de Los Angeles population fell throughout the entire range of age classes observed in Puerto Vallarta population and combination of data sets appears easily justified.

Future studies should be aimed at testing various hypotheses for the observed difference in size ranges of *E. labriformis* from the two populations, as well as to collect individuals that are actively reproducing in an attempt to characterize which reproductive strategy is used. As noted above, one possible explanation for the disparity in size class distributions between the populations is the lack of fishing pressure on *E. labriformis* in the Galápagos and quite intense pressure in Puerto Vallarta (D. J. Pondella, M. T. Craig, pers. observ.). A second possibility is that an ecological factor, such as interspecific competition for niche space or limitation in resources, is keeping the individuals in the Puerto Vallarta population smaller. Fishing pressure on the larger individuals truncate the upper portion of the age distribution as seen in the data for the Puerto Vallarta population of *E. labriformis* (Fig. 1B). The conspicuous absence of younger fish from the Galápagos population may be a result of poor recruitment during these year classes. However, a larger sample size is needed in order to properly address this question.

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