Received: 5 September 2016 | Accepted: 6 September 2016

DOI: 10.1111/jai.13246

ORIGINAL ARTICLE

WILEY Journal of Applied Ichthyology DWK

Estimates on age, growth and mortality of the French angelfish *Pomacanthus paru* (Bloch, 1787) (Teleostei: Pomacanthidae) in the southwestern Atlantic

C. V. Feitosa* | M. E. Araújo | B. P. Ferreira

Departamento de Oceanografia, CTG, Universidade Federal de Pernambuco, Recife, Pernambuco, Brazil

Correspondence
Carol V. Feitosa, Departamento de Oceanografia, CTG, Universidade Federal de Pernambuco, Recife, Pernambuco, Brazil.
Email: carol_feitosa@ufc.br

*Present address: Instituto de Ciências do Mar (Labomar), Universidade Federal do Ceará, Fortaleza, Ceará, Brazil

Summary

The aim of the present study was to determine age, growth and mortality of the French angelfish *Pomacanthus paru*. Age was solely determined by sectioned otoliths. All tetracycline-treated otoliths were 1 year of age and revealed a clear fluorescent mark when observed under UV light. Otolith weight increased exponentially with standard length, and linearly with age, indicating that otolith growth continues with age and is independent of size. Age of fish in the sample ranged from 1 to 27 years. The von Bertalanffy growth equation was $TL_t = 36.33\ (1 - e^{-0.12\ (t + 0)})$. Total rate mortality ($Z$) was estimated to be 0.10. Attaining maximal size slowly, *P. paru* has a long life expectancy. Most linear growth is achieved within approximately 74% of the lifetime of the fish. Besides being an important ornamental species, *P. paru* has been commonly captured for decades as bycatch in trap fisheries. These growth parameters should be used with the purpose of managing fisheries targeting this species before more meaningful limits can be imposed. In the aquarium trade management, it is suggested that conservationist issues should be based on capture-per-area and the establishment of protected areas.

1 | INTRODUCTION

Considered the most appropriate structure for age determination (Six & Horton, 1977), otoliths are calcium carbonate secretions in aragonite crystal form (Degens, Deuser, & Haedrich, 1969). The first studies were developed for temperate fish populations (Brothers, 1980), which have seasonally controlled periods of growth and spawning. Due to the lack of seasonality in tropical waters, the use of the otolith method for age determination began as a complex process. However, Longhurst and Pauly (1987) stated that the growth of tropical fishes follows expected seasonal patterns, which can be observed using length frequency data or the analysis of seasonal bands in otoliths.

Age and growth studies are crucial to understanding the life history traits of fish species, in response to environmental variations, fishing pressures and subsequent recruitment success (Aliaume, Zerbi, Joyeux, & Miller, 2000; Dee & Radtke, 1989).

Information on growth of coral reef fishes is limited to a few families (Choat & Axe, 1996; Lek, Fairclough, Hall, Hesp, & Potter, 2012; Stewart & Hughes, 2010). For the family Pomacanthidae, estimates from age-at-length data are only available for two species – *Pomacanthus imperator* (Bloch, 1787) (Chung & Woo, 1999) and *Pomacanthus arcuatus* (Linnaeus, 1758) (Steward, DeMaria, & Shenker, 2009). For *P. imerator* the age readings were based on scales, which are prone to error (Erickson, 1983; Williams & Bedford, 1974).

The French angelfish *Pomacanthus paru* (Bloch, 1787) occurs from Florida, the Bahamas and the northern Gulf of Mexico south to Brazil (Menezes, Buckup, Figueiredo, & Moura, 2003). Maximal length reported for this species is 41 cm (Cervigón, 1993). It is distributed in waters from 5 to 100 m, with juveniles and sub-adults being more frequent in shallow waters. This species is an omnivore, with sponges as its main food item (Randall, 1967). It is a gonochoric species (Feitosa, Marques, Araújo, & Ferreira, 2016) where it seems that adults normally form stable pairs, although in areas where the fish is more abundant, it is known to form small harems (Michael, 2004; Thresher, 1984).

Pomacanthid species are harvested for the Brazilian aquarium trade and *P. paru* is frequently exported (Monteiro-Neto et al., 2003; Nottingham, Cunha, & Monteiro-Neto, 2000), but is also captured as bycatch (Feitosa, Ferreira, & Araújo, 2008). Management measures for this species are restricted to a Federal Act (56/04) established in 2004 with the purpose of managing the aquarium trade through the establishment of export quotas.

In the present study, age and growth of *P. paru* were studied through the validation and examination of annual marks in *sagittae* otoliths while also estimating the rate of total mortality (*Z*).

2 | MATERIALS AND METHODS

2.1 | Sampling design

The fish were sampled from commercial boats from the Itamaracá Island Fishing Colony, located on Pilar beach (7°45′17.80″S; 34°49′26.46″W), Itamaracá, state of Pernambuco, Brazil (Figure 1). These fish were caught as bycatch during trap fishery activities. Sampling was performed weekly from March 2006 to February 2007. As fishes smaller than 10 cm are not captured in this type of fishery, such individuals were bought from fish collectors between September 2006 and February 2007.

2.2 | Otolith ageing

Fish were measured for total length [TL (cm)] and standard length [SL (cm)] and weighed (g). The largest otoliths (*sagittae*) were removed, washed in running water and stored dry in Eppendorf tubes for analysis. Whenever possible, the left otolith was used for both whole and sectioned views. Rings were counted for whole otoliths by immersion in 100% ethanol in watch glasses, the concave side upward. Viewed under a binocular microscope, the opaque bands were counted on the distal surface, from the nucleus to the dorsal side. Prior to sectioning, all pairs were measured and weighed to the nearest 0.01 g. The otoliths were embedded in an epoxy resin prior to reading. Each otolith was sectioned transversely (circa 0.3 mm thick) with a low-speed saw. Sections were mounted on microscope slides with Histomount mounting media and observed for opaque bands under a dissecting microscope with reflected light.

To assess the precision of the readings, two independent readers counted age marks on whole and sectioned otoliths with no knowledge of fish size for a subsample of 50 otolith sections (21%). With these results, the index of average percentage error (IAPE) between readers was calculated (Beamish & Fournier, 1981). When the readers diverged by more than 10% for a given otolith section, the readings were repeated. The data were included in the analysis only when the IAPE was below 10%.

To provide accuracy of otolith readings, a validation experiment with six individuals was performed. As individuals sampled for this test were smaller than 6 cm, the specimens were marked by immersion in a solution of tetracycline and seawater (Beamish & McFarlane, 1987), with an initial concentration of 100 mg L^{-1}. Subsequently, every four hours the same concentration was added to the solution until reaching the maximal concentration of 500 mg L^{-1}. The fish were kept in this solution for 12 hr (Hernaman, Munday, & Schläppy, 2000). Thereafter, they remained in an aquarium for 1.5 years (salinity 30‰; temperature 28°C). These otoliths were sectioned in the same way as the unlabeled

FIGURE 1 Landing location of trap fishery commercial boats from Itamaracá Island

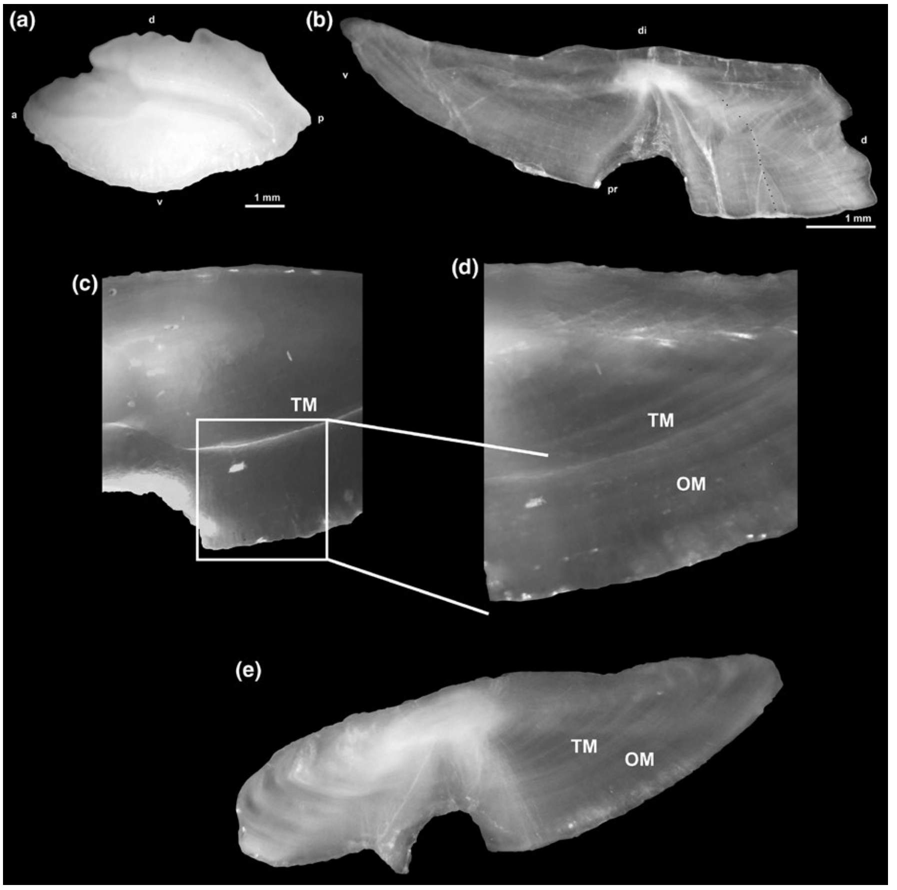

FIGURE 2 *Pomacanthus paru* otoliths: (a) whole and (b) sectioned 8- and 19-year-old fish, respectively; (c) treated with tetracycline (UV light) and (d) under an external light source and UV light with zoom; (e) view of whole otolith under an external light source and UV light (a, anterior; p, posterior; d, dorsal; v, ventral; di, distal; pr, proximal; TM, tetracycline mark; OM, opaque mark)

ones and analyzed under a microscope with an ultraviolet light source to detect the fluorescent mark. An external fiber-optic light was coupled to the microscope in order to observe the opaque bands and fluorescent marks simultaneously (Ferreira & Russ, 1992).

Growth was investigated by fitting the von Bertalanffy (1938) growth function to size-at-age data using the nonlinear optimization method on the Kaleidagraph 4.0 software program. The model was fitted with the data pooled for gender. The growth function is defined as: $TL = L\infty\ (1 - e^{-K\,(T - T0)})$, in which TL and T are total length (TL; cm) and age (years) of the fish respectively, L∞ is the asymptotic TL, K is the growth coefficient representing how fast L∞ is reached, and $T0$ is the theoretical age at which TL = 0. The paired t test was used to compare the weight of left and right *sagittae* otolith ($\alpha = 0.05$). The relationship between otolith weight, standard length and age was determined through simple linear regression analysis.

Parameters "*a*" and "*b*" of the length–weight relationship were obtained by the formula $WT = A.\ SL^{b}$, by fitting log-transformed data to a linear regression model $\ln WT = \ln A + b \ln SL$, assessing the significant difference in relation to its parameter value, $b = 3$, by means of the Student's t test ($p < .05$) through the free software R. (R Core Team, 2013).

Mortality rates (Z) were estimated from age-based catch curve method of Beverton and Holt (1957) and Chapman and Robson (1960). The natural logarithm of the number of fish in each age class (NT) was plotted against their corresponding age (t) and (Z) was estimated from the descending slope, b.

3 | RESULTS

In French angelfish, the *sagittae* otolith is the largest and oval in shape, with a pointed rostrum. It is laterally compressed, with a heterosucoid sulcus acusticus (Figure 2a). A pattern of opaque and translucent bands can be recognized and counted on whole and sectioned otoliths (Figure 2B). Nevertheless, counting opaque bands on whole otoliths is a complex task due to the overlapping of bands at the margins in larger fish and regular divergence in counts between different otolith regions, mainly in the dorsal area. Due to these complexities, the age of *P. paru* was determined only on sectioned otoliths. The sections of all treated otoliths revealed an opaque band between a clear fluorescent mark and the edge when observed under an external light source and UV light (Figure 2C, 2D, 2E). Observations from all of the sections support the hypothesis that the annulus is formed once a year. All treated French angelfish were 1^{+} year old.

Otoliths ranged in weight from 0.002 (7.81 cm, 16 g, 4-year-old fish) to 0.169 g (38.64 cm, 1.396 g, 26-year-old fish). There was no significant difference between the weight of the left and right otolith (paired t test, $n = 153$, $p > .05$). The exponential relationship between otolith weight and standard length follows the equation $OW = 0.0047e^{0.1096\,SL}$ ($r^2 = .90$, $n = 183$), in which OW is otolith weight (g) and SL is standard length (cm) (Figure 3A). The confidence interval for b parameter (CI 95%) was between 0.08090 and 0.09422, $p < .05$. Otolith weight increased linearly with age and was described by the

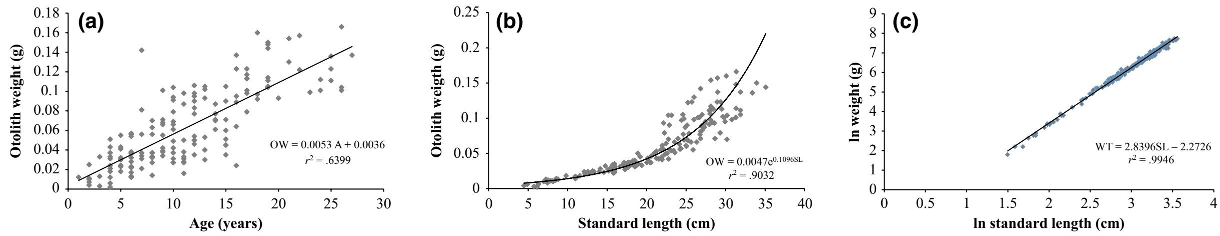

FIGURE 3 Relationship between sagittae otolith weight and standard length (n = 183): (a) otolith weight and age (n = 166) and (b) weight to length (n = 232); (c) *Pomacanthus paru* samples captured 2006–2007. SL, standard length (cm), OW, otolith weight, A, age years, W, total weight (g)

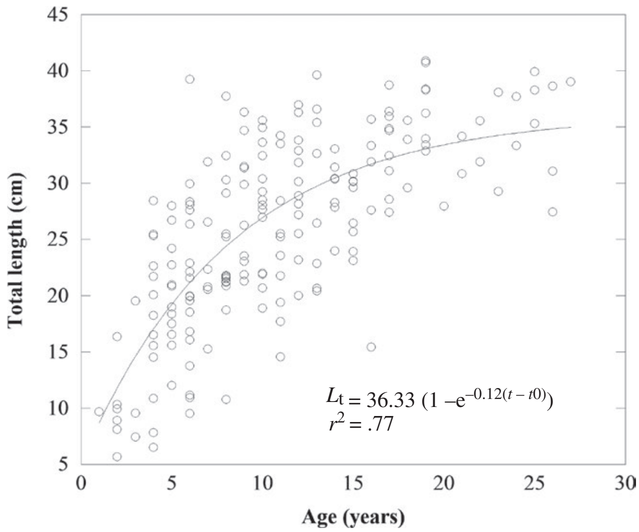

FIGURE 4 Von Bertalanffy growth curve fitted to standard length-at-age for *Pomacanthus paru* (n = 187) from samples captured 2006–2007

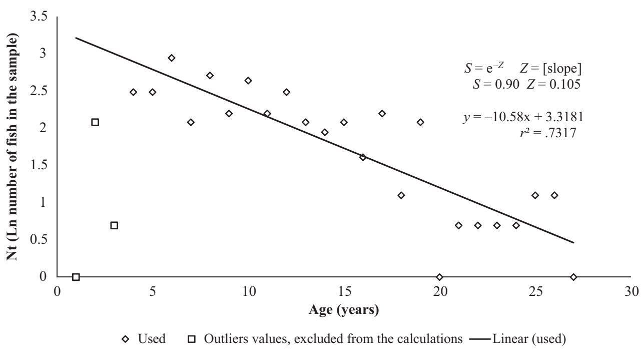

FIGURE 5 Catch-curve based on observed age for *Pomacanthus paru* (n = 187) samples captured 2006–2007. Ages 1–3 were excluded (outliers), because they were considered as not fully recruited to the gear (traps). S, annual survivorship; Z, total rate mortality

equation OW = 0.0053 SL + 0.0036 (r^2 = .64, n = 166) (Figure 3B). The parameter b was between 0.0046 and 0.0059 with 95% confidence and p < .05. The relationship of total weight to standard length is $W = 0.1192SL^{2.794}$ (r^2 = .98, n = 232) (Figure 3C). These results show that *P. paru* exhibit allometric growth (p < .005) with the parameter (b) between 2.8138 and 2.8688, with 95% confidence.

Age of the specimens in the sample ranged from 1 to 27 years (Figure 4). A total of 2.3% of the otolith sections were unreadable and not included in the analysis. The average percentage error between readers was 9.80%. French angelfish are long-lived (to >27 years) and attain maximal size slowly. The plots were fitted best by the von Bertalanffy growth function: $LT = 36.33\ (1 - e^{-0.12\ (t + 0)})$. ($r^2$ = .77, n = 187). The total rate mortality (Z), estimated using ages 4–27, was 0.10, representing an annual survivorship of 90% (Figure 5).

4 | DISCUSSION

In the present study, *sagittae* otoliths from *Pomacanthus paru* exhibited a regular pattern of annual opaque and translucent bands, the readings of which were highly repeatable, with an average read error of 9.8%. Based on the increments observed in the sectioned *sagittae* otoliths, ageing of tropical fishes may be reliably interpreted as having annual periodicity (Choat & Robertson, 2002).

The relationship between otolith weight and age was linear. This suggests that otolith growth is continuous with age and is independent of fish size. It seems that this is a general rule of fish growth, as this pattern has been observed in several other species (Araújo & Martins, 2006; Dee & Radtke, 1989; Schwamborn & Ferreira, 2002). Bands were deposited annually and the weight of otoliths increased throughout the lifetime of the fish, thereby fulfilling the fundamental criteria required for ageing (Fowler & Doherty, 1992).

Using size distributions of trap catches of the gray angelfish, *Pomacanthus arcuatus*, based on moderate samples from the unexploited sites of Pedro Bank and the Porto Royal reefs, Aiken (1983) determined that 60 cm total length is the asymptotic length. Unique research that used counting in sectioned otoliths for angelfish was performed and published by Steward et al. (2009) for the gray angelfish *P. arcuatus* from the lower Florida Keys: the maximum estimated age was 24 years and the von Bertalanffy growth equation for females was $LT = 32.51\ (1 - e^{-0.0601\ (t + 0.828)})$ and males $LT = 38.85\ (1 - e^{-0.383\ (t + 0.923)})$. The values obtained for longevity, L∞ were similar to the results of this research.

Pomacanthus paru grows slowly in a pattern that is shared with other reef fishes (e.g. Serranids, Haemulids and Lutjanids); these families have K values ranging from 0.10 to 0.22 and maximal ages ranging from 9 to 16 years (Matheson, Huntsman, & Manooch, 1986; Munro & Polunin, 1997). However, *P. paru* attains an age of 10 years or more.

The low *K* value and long life among demersal fishes suggests that these characteristics are associated to evolutionary success in the reef environment (Huntsman, 1981). According to Matheson et al. (1986), long life and relatively large body size maximize gamete and zygote production and allow reef fishes to overcome the apparently low possibility of the pelagic offspring encountering a favorable habitat to settle. Conversely, Cuban coastal reef fishes, such as Haemulids and Lutjanids, have a shorter life expectancy and a relatively fast growth rate, with species reaching between 35% and 50% of maximal size in the first year of life, according to Claro and García-Arteaga (2001), who suggest that these characteristics are related to adaptive mechanisms for avoiding predation on juveniles.

The high longevity of *P. paru* and other Pomacanthids, as well as their late sexual maturity are angelfish characteristics that render them vulnerable to extinction (Chung & Woo, 1999; Feitosa et al., 2016; Roberts & Hawkins, 1999). As large-body species require a long time to grow, their population renewal is least likely to occur quickly (Chung & Woo, 1999). The data used to estimate total mortality was from the trap fishery where this species is caught as bycatch, and the value for total mortality considered low. However, the mortality rate established here was the first estimate, and a larger sample would be necessary to represent the population more efficiently, mainly for the older fishes.

Pomaanthus paru and other Pomacanthids are heavily exploited by the aquarium trade (Monteiro-Neto et al., 2003; Wood, 2001a). The family Pomacanthidae alone comprises 46% of exports by value (Pyle, 1993), with more than 21 species harvested (Wood, 2001a). The French angelfish is the second most exported species in the Brazilian aquarium trade (Monteiro-Neto et al., 2003; Nottingham et al., 2000). In the USA (state of Florida), this species is managed through size regulations (Wood, 2001b). In Brazil, a Federal Act (56/04) was established in 2004 with the purpose of managing fishery activities targeting this species through the establishment of export quotas. Individuals of *P. paru* and other species collected for the aquarium trade are generally under 10 cm SL and rarely reach as much as 20 cm, which represents juveniles and young adults that have likely not reached sexual maturity (Wood, 2001b).

Chung and Woo (1999) affirm that it was fortunate that the commercial exploitation of *P. imperator* has only focused on relatively small specimens for the aquarium trade. Individuals longer than 25 cm (SL) are rarely exploited and specimens up to 29.6 cm (SL) are still reproductively active, and thus these fish constitute an important breeding stock if younger individuals are overexploited. This is not the case for *P. paru*. Besides the impact from the ornamental fish trade, this species has been commonly caught as bycatch in trap fisheries for decades (Aiken, 1983; Feitosa et al., 2008). However, in this kind of fishery, more than 70% of individuals caught are fit for reproduction (Feitosa et al., 2008). Thus, it is possible that this species suffers fishing pressure in all length ranges and that this impact could threaten the population structure.

Ornamental fish species are an important part of the bycatch from trap fishery (Feitosa et al., 2008). These species are caught and usually returned to the sea – many still alive, according to the fishermen. Survival of these individuals is doubtful, as decompression problems have often been reported. This paper contributes to the knowledge on the life history traits of *P. paru*, such as growth rates and age at sexual maturity. Both are minimal requirements for effective fishery management regarding a given species. In the case of the aquarium trade management, where most commercialized fishes are juveniles and under 10 cm SL, it can be suggested that conservation issues should be based on quantitative data (capture) per area as well as the establishment of protected areas.

ACKNOWLEDGEMENTS

This study was sponsored by the Brazilian Scientific Council – Conselho Nacional de Pesquisa e Desenvolvimento (CNPq) and Pernambuco State Scientific Council – Fundação de Amparo à Ciência e Tecnologia do Estado de Pernambuco (FACEPE).

REFERENCES

Aiken, K. (1983) The biology, ecology and bionomics of the butterfly and angelfishes, Chaetodontidae. In: J. L. Munro (Ed.), *Caribbean coral reef fisheries resource* (pp. 155–165). Manila, Philippines: ICLARM studies and reviews 7, 283p. (ISBN 0115-4389).

Aliaume, C., Zerbi, A., Joyeux, J. C., & Miller, J. M. (2000). Growth of juvenile *Centropomus undecimalis* in a tropical island. *Environmental Biology of Fishes*, *59*, 299–308.

Araújo, J. N., & Martins, A. S. (2006) Age and growth of coney (*Cephalopholis fulva*), from the central coast of Brazil. *Journal of the Marine Biological Association of the United Kingdom 86*, 187–191.

Beamish, R. J., & Fournier, D. A. (1981). A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Aquatic Sciences*, *38*, 982–983.

Beamish, R. J., & McFarlane, G. A. (1987). The forgotten requirements for age validation in fisheries biology. *Transactions of the American Fisheries Society*, *112*, 735–743.

von Bertalanffy, L. (1938) A quantitative theory of organic growth (inquiries on growth laws II). *Human Biology 10*, 181–213.

Beverton, R. J. H., & Holt, S. J. (1957) On the dynamics of exploited fish populations. On the Dynamics of Exploited Fish Populations. Gt. Britain, Fishery Invest., Ser. II, Vol. *19*. 533 p.

Brothers, E.B. (1980). Age and growth studies on tropical fishes. In S.B. Saila & P.M. Roedel (Eds.), *Stock assessment for tropical small-scale fisheries. Proceedings of an international workshop held September 19–21, 1979 at the University of Rhode Island, Kingston*, (pp. 119–136). R.I. International Center for Marine Resource Development, University of Rhode Island, Kingston.

Cervigón, F. (1993) Pomacanthidae. (pp. 339–346). In: *Los Peces Marinos de Venezuela*. Venezuela: Fundación Científica Los Roques, 497p. (ISBN 9800713425).

Chapman, D. G., & Robson, D. S. (1960). The analysis of a catch curve. *Biometrics*, *16*, 354–368.

Choat, J. H., & Axe, L. M. (1996). Growth and longevity in acanthurid fishes, an analysis of otolith increments. *Marine Ecology Progress Series*, *134*, 15–26.

Choat, J. H., & Robertson, R. (2002) Age-based studies. (pp. 57–80). In: P. Sale (Ed.) *Coral Reef Fishes: Dynamics and diversity in a complex ecosystem*. San Diego, USA: Academic Press. 549p. (ISBN 0-12-615185-7)

Chung, K. C., & Woo, N. Y. S. (1999). Age and growth by scale analysis of *Pomacanthus imperator* (Teleostei: Pomacanthidae) from Dongsha Isllands, southern Chine. *Environmental Biology of Fishes*, *55*, 399–412.

Claro, R., & García-Arteaga, J. P. (2001) Growth patterns of fishes of the Cuban shelf. In: R. Claro, K. C. Lindeman & L. R. Parenti (Eds.), *Ecology of the Marine Fishes of Cuba* (pp.149–178). Washington, USA: Smithsonian Institution Press. 253p. (ISBN 1560989858).

Dee, A. J., & Radtke, R. L. (1989). Age and growth of the brick soldierfish, *Myripristis amaena*. *Coral Reefs*, *8*, 79–85.

Degens, E. T., Deuser, W. G., & Haedrich, R. L. (1969). Molecular structure and composition of fish otoliths. *Marine Biology*, *2*, 105–113.

Erickson, C. M. (1983). Age determination of Manitoban walleyes using otoliths, dorsal spines, and scales. *North American Journal of Fisheries Management*, *3*, 176–181.

Feitosa, C. V., Ferreira, B. P., & Araújo, M. E. (2008). A rapid new method for assessing sustainability of ornamental fish by-catch from coral reefs. *Marine & Freshwater Research*, *59*, 1092–1100.

Feitosa, C. V., Marques, S., Araújo, M. E., & Ferreira, B. P. (2016). Reproduction of French angelfish *Pomacanthus paru* (Teleostei: Pomacanthidae) and implications for management of the ornamental fish trade in Brazil. *Marine & Freshwater Research*, *67*, 586–593.

Ferreira, B. P., & Russ, G. R. (1992). Age, growth and mortality of the inshore coral trout, *Plectropomus maculatus* (Pisces: Serranidae) from the Central Great Barrier Reef, Australia. *Marine and Freshwater Research*, *43*, 1301–1312.

Fowler, A. J., & Doherty, P. J. (1992). Validation of annual growth increments in the otoliths of two species of damselfish from southern Great Barrier Reef. *Australian Journal of Marine and Freshwater Research*, *43*, 1057–1068.

Hernaman, V., Munday, P. L., & Schläppy, M. L. (2000). Validation of otolith growth-increment periodicity in tropical gobies. *Marine Biology*, *137*, 715–726.

Huntsman, G. R. (1981). Ecological considerations influencing the management of reef fishes in artificial reefs. *Sea Grant Report*, *41*, 167–175.

Lek, E., Fairclough, D. V., Hall, N. G., Hesp, S. A., & Potter, I. C. (2012). Do the maximum sizes, ages and patterns of growth of three reef-dwelling labrid species at two latitudes differ in a manner conforming to the metabolic theory of ecology? *Journal of Fish Biology*, *81*, 1936–1962.

Longhurst, A. R., & Pauly, D. (1987) Dynamics of tropical fish populations. In: *Ecology of Tropical Oceans* (pp. 300–306). Orlando: Academic Press, 407p. (ISBN 978-0-12-455562-4).

Matheson, R. H., Huntsman, G. R., & Manooch, C. S. (1986). Age, growth, mortality, food and reproduction of the scamp, *Mycteroperca phenax*, collected off North Carolina and South Carolina. *Bulletin of Marine Science*, *38*, 300–312.

Menezes, N. A., Buckup, P. A., Figueiredo, J. L., & Moura, R. L. (2003) *Catálogo das espécies de peixes marinhos do Brasil*. São Paulo: Museu de Zoologia USP. 160p. (ISBN 85-87735-02-0)

Michael, S. W. (2004) Family Pomacanthidae/Angelfishes. In: *Angelfishes and Butterflyfishes* (pp. 296–323). New Jersey: T.F.H. Publications. 344p. (ISBN 1890087696).

Monteiro-Neto, C., Cunha, F. E. A., Nottingham, M. C., Araújo, M. E., Rosa, I. L., & Barros, G. M. L. (2003). Analysis of the marine ornamental fish trade at Ceará State, northeast Brazil. *Biodiversity and Conservation*, *12*, 1287–1295.

Munro, J. L., & Polunin, N. C. V. (1997) A decade of progress in coral reef fisheries research: 1986–1995. Proceedings of the 8th International Coral Reef Symposium *2*, 2003–2008.

Nottingham, M. C., Cunha, F. E., & Monteiro-Neto, C. (2000) Captura de peixes ornamentais marinhos no Ceará. *Arquivos Ciências do Mar*, *33*, 113–118.

Pyle, R. L. (1993) Marine aquarium fish. In: A. Wright (Eds.) Nearshore Marine Resources of the South Pacific. Information for fisheries development and management (pp. 135–176). L. Hill. Institute of Pacific Studies, Suva: Institute of Pacific Studies; Honiara: Forum Fisheries Agency; [Halifax], Canada. 710p. (ISBN 9820200822)

R Core Team (2013). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org/.

Randall, J. E. (1967). Food habits of reef fishes of the West Indies. Stud. Trop. Oceanogr. Miami, *5*, 665–847.

Roberts, C. M., & Hawkins, J. P. (1999). Extinction risk in the sea. *Trends in Ecology & Evolution*, *14*, 241–246.

Schwamborn, S. H. L., & Ferreira, B. P. (2002). Age structure and growth of the dusky damselfish, *Stegastes fuscus*, from Tamandaré reefs, Pernambuco, Brazil. *Environmental Biology of Fishes*, *63*, 79–88.

Six, L. D., & Horton, H. F. (1977). Analysis of age determination methods for yellowtail rockfish, canary rockfish, and black rockfish off Oregon. *Fishery Bulletin*, *75*, 405–414.

Steward, C. A., DeMaria, K. D., & Shenker, J. M. (2009). Using otolith morphometrics to quickly and inexpensively predict age in the gray angelfish (*Pomacanthus arcuatus*). *Fisheries Research*, *99*, 123–129.

Stewart, J., & Hughes, J. M. (2010). Life-history traits of the southern hemisphere eastern red scorpionfish, *Scorpaena cardinalis* (Scorpaenidae: Scorpaeninae). *Marine & Freshwater Research*, *61*, 1290–1297.

Thresher, R. E. (1984) Angelfishes. In: *Reproduction in reef fishes* (pp. 244–261). New Jersey, USA: TFH Publications, 399p. (ISBN 0876668082).

Williams, T., & Bedford, B. C. (1974) The use of otoliths for age determination. In: T. B. Bagenal (Ed.) *Ageing of fish* (pp. 114–123). Old Woking: Gresham Press, 234p. (ISBN 0950212113).

Wood, E. M. (2001a). *Collection of coral reef fish for aquaria: Global trade, conservation issues and management strategies*. UK: Marine Conservation Society. 80p.

Wood, E. M. (2001b). Global advances in conservation and management of marine ornamental resources. *Aquarium Sciences and Conservation*, *3*, 65–77.

How to cite this article: Feitosa CV, Araújo ME, and Ferreira BP. Estimates on age, growth and mortality of the French angelfish *Pomacanthus paru* (Bloch, 1787) (Teleostei: Pomacanthidae) in the southwestern Atlantic. *J Appl Ichthyol*. 2017;33:409–414. https://doi.org/10.1111/jai.13246