New Zealand Journal of Marine and Freshwater Research

RESEARCH ARTICLE OPEN ACCESS

Age- and Growth-Based Life-History Traits of Striated Surgeonfish (*Ctenochaetus striatus*) and Achilles Tang (*Acanthurus achilles*) from Miti'āro, Cook Islands

Antony Vavia[1,2] | Elizabeth D. L. Trip[3] | Valerio Visconti[4] | Julian Lilkendey[1,5] | Jingjing Zhang[1,6] | Charlie Owen[1] | Armagan Sabetian[1]

[1]School of Science, Auckland University of Technology, Auckland, New Zealand | [2]Te Puna Vai Mārama: Cook Islands Centre for Research, Rarotonga, Cook Islands | [3]HalieuMer, Arzon, France | [4]Fisheries and Aquaculture, Centre for Fisheries and Aquaculture Science (Cefas), Lowestoft, UK | [5]Leibniz Centre for Tropical Marine Research (ZMT), Bremen, Germany | [6]The New Zealand Institute for Plant and Food Research Limited, Auckland, New Zealand

Correspondence: Antony Vavia (antony.vavia@aut.ac.nz)

Received: 13 February 2026 | **Revised:** 15 May 2026 | **Accepted:** 3 June 2026

Keywords: *Acanthurus achilles* | age | Cook Islands | *Ctenochaetus striatus* | growth | population dynamics | surgeonfish

ABSTRACT

Striated surgeonfish (*Ctenochaetus striatus*) and Achilles tang (*Acanthurus achilles*) are two surgeonfish species commonly harvested for subsistence on Miti'āro, Cook Islands. Using individuals collected by local fishers, this study provides the first age- and growth-based assessment of these species from Miti'āro. Age and size distribution of *C. striatus* ranged from 1 to 27 years and 105–250 mm (FL), respectively. Age and size distribution of A. *achilles* ranged from 0 to 9 years and 137–215 mm (FL), respectively. Von Bertalanffy growth function (VBGF) models estimated asymptotic lengths of 185.18 mm for *C. striatus* and 183.11 mm for *A. achilles*. Likelihood ratio tests and 95% confidence ellipses of VBGF parameters ($L\infty$ and K) indicated no significant differences in growth between males and females for either species. Length–weight analyses showed *C. striatus* exhibited slightly negative allometric growth, while *A. achilles* displayed an isometric relationship. Annual mortality was estimated at ~36% for both species. These findings provide new insights into the life-history and population dynamics of key reef fish targeted for subsistence in the Cook Islands.

1 | Introduction

Establishing age- and growth-based life-history parameters of targeted species is an essential element for fisheries management. Within the Pacific, subsistence- and artisanal-based fishing remains understudied despite the importance of small-scale fisheries (SSF) (Cohen and Alexander 2013; Kittinger 2013). Coastal communities within small Pacific Island nations are increasingly faced with food security and wellbeing issues due to their localised dependency on natural resources (Bell et al. 2009; Kittinger 2013; Islam and Berkes 2016; Pauly and Zeller 2016; Vaughan and Ayers 2016). Therefore, the effective management and conservation of coastal reef fisheries is key to the long-term viability and survival of coastal communities in the Pacific Islands.

The Cook Islands consists of 15 island groups in the Southwest Pacific, spread between 9° and 22° latitude, across an exclusive economic zone (EEZ) of over 1.8 million square kilometres. Although the fisheries sector contributes relatively little to the Gross Domestic Product, subsistence fishing remains an important source of food and livelihood for households, particularly in the outer islands (Cook Islands Statistics Office 2022). Surveys have shown that subsistence, artisanal and commercial-based

fishing accounted for 55%, 35% and 10% of total fishing effort, respectively (Munro Solomona et al. 2009). However, there is currently a paucity of information at both qualitative and quantitative scales in the coastal reef fisheries of Cook Islands. This includes baseline population dynamics parameters of many targeted species, including growth, longevity and life-history information.

Surgeonfish (Acanthuridae) are one of most abundant families on coral reefs and are widely targeted in the Pacific by subsistence and artisanal fishers (Craig and Axe 1997; Rhodes et al. 2008; Ochavillo et al. 2011; Foo et al. 2020; Tebbett et al. 2022). Acanthurids are an important functional group of coral reef fishes, with their constant grazing maintaining healthy algal turf communities and supporting coral reef resilience (Bellwood et al. 2014; Marshell and Mumby 2015). Striated surgeonfish (*Ctenochaetus striatus*) are a widely distributed species across the Indo-Pacific oceans (except around Hawai'i) (Choat and Axe 1996; Trip et al. 2008; Ochavillo et al. 2011), while Achilles tang (*Acanthurus achilles*) has been widely observed across the entire Pacific Ocean (Friedlander 2004; Walsh et al. 2020). In terms of foraging strategy, *C. striatus* functions primarily as a brusher, whereas *A. achilles* has been observed to adopt a cropping strategy; both species typically inhabit coral reef flats as well as shallow forereefs and reef crests (Nemeth and Appeldoorn 2009; Tebbett et al. 2022).

The decline of Acanthurids has been linked to ecosystem changes, including trophic cascades (Hughes 1994; Mumby et al. 2006; O'leary and Mcclanahan 2010). Fishing pressure of certain reef fish species in the Cook Islands is thought to have fluctuated over recent decades. Amongst the many commonly targeted reef fish, *C. striatus* was considered one of the highest risk of reef fish associated with ciguatera poisoning in Rarotonga, driving a transition from targeting reef to more pelagic fisheries in the 1990s and early 2000s (Munro Solomona et al. 2009; Rongo and van Woesik 2011). However, reef fisheries on the outer island of Miti'āro continue to contribute largely to local food security—surgeonfish being amongst the popular targets (Vavia 2026). As there are large gaps in life-history data of important reef fish in the Cook Islands, this study set out to investigate the age- and growth-based life-history traits of *C. striatus* and *A. achilles*, two prevalent and commonly caught surgeonfish species on Miti'āro.

2 | Materials and Methods

2.1 | Study Location and Sampling

Miti'āro (19.8775° S, 157.7020° W) is an exposed oceanic island that receives intense wave action, particularly on the northern and eastern sides of the island. The island is surrounded by a fringing reef that supports the highest diversity of corals within the Cook Islands (Rongo et al. 2013; Kora et al. 2018).

In total, 138 *C. striatus* and 131 *A. achilles* were collected by local spear fishers between March 2020 and May 2021. Individuals were targeted using snorkel and spear during daytime, mainly from the western reefs of the island adjacent to the Miti'āro Harbour (Te Ao Motu) between the reef crest and outer slopes of the forereef. After collection, each fish was weighed to the nearest gram (g) and measured for fork length (mm) to the nearest 0.1 mm, before dissection for otolith extraction, and gonadal tissue fixation in 10% buffered formalin.

2.2 | Age Estimation

Following extraction, sagittal otoliths were cleaned, rinsed in distilled water, air-dried, weighed to the nearest 0.0001 g and stored for later age determination. Age estimates were derived from thin transverse sections of sagittal otoliths following established protocols (Secor et al. 1995; Choat and Axe 1996). These sections were obtained by grinding down the otoliths using a 3000-grit wet diamond disc. They were then adhered to glass slides and coated using Crystalbond for clear examination of the opaque growth increments along a linear transect from the otolith core to the distal margin using a camera-mounted compound microscope at 40× magnification. The interpretation of opaque and translucent band pairs as annual growth increments in Acanthurid otoliths is consistent with previous validations (Choat and Axe 1996; Trip et al. 2008).

Increment counts were conducted independently and blind by the lead and senior authors. In cases where initial readings differed, a third count was undertaken, after which the mean of the two closest readings was adopted as the final age estimate. Because otolith accretion continues throughout the lifespan of teleost fishes, otolith mass is expected to increase with age (Labropoulou and Papaconstantinou 2000). The relationship between sagittal otolith weight and estimated age was examined using least squares regression.

2.3 | Histological Analysis

Conspicuous gonads were excised from the ventroposterior portion of the body cavity and weighed to the nearest 0.01 g and then preserved in 10% buffered formalin. The samples were placed into processing cassettes and initially stored overnight in 70% ethanol. Following this, they were processed using a LEICA ASP300S tissue processor, where dehydration was achieved through a graded alcohol series and xylene. The tissues were subsequently embedded in paraffin wax, frozen and prepared for microtomy. Thin transverse sections (5 μm) were obtained and stained following standard protocols with Harris's haematoxylin and Young's eosin erythrosine. Histological classification of gonad structure followed the diagnostic criteria for female and male as described by Longenecker and Langston (2018) and Longenecker et al. (2020). In total, the sexual characteristics of 96 *C. striatus* and 85 *A. achilles* were histologically established.

2.4 | Population Parameters

Size and age frequency distributions were examined to characterise growth patterns and longevity in *C. striatus* and *A. achilles*. Instantaneous total mortality (Z) for each species was estimated using age-based catch curve analysis. Survivorship (S) was calculated as $S = \exp(-a)$, where a represents the absolute value of the

slope of the fitted linear regression ($y = ax + b$), and mortality was subsequently derived as $Z = 100\text{-}S$ following Beverton and Holt (1957).

Length–weight relationships for *C. striatus* and *A. achilles* were modelled using the equation $W = a \times L^b$ (Ricker 1973), where W denotes the total weight (g), L is the total length (mm), a is the intercept (initial growth coefficient), and b represents the growth exponent. Isometric growth is indicated when b approximates 3.0, whereas values less than 3.0 reflect negative allometric growth and values greater than 3.0 indicate positive allometry. Analysis of covariance (ANCOVA) was applied to test for differences in length–weight relationships between sexes within each species.

Growth trajectories describing the relationship between size and age in *C. striatus* and *A. achilles* were estimated using the von Bertalanffy growth function (VBGF), applied both to pooled samples and separately by sex (Kimura 1980). The model expressed as $L(t) = L_\infty\ [1 - \exp^{-K\ (t\ -\ t0)}]$, where $L(t)$ represents the expected length at age t, L_∞ is the mean asymptotic length of the population, K is the growth coefficient describing the rate at which asymptotic size is approached, and t_0 is the hypothetical age at which length is zero. Because very young individuals were underrepresented in the sample, size at settlement was fixed at 47 mm (forked length) for both species, based on published estimates (Stobutzki and Bellwood 1997; Trip et al. 2008; Ochavillo et al. 2011).

Sex-based differences in von Bertalanffy growth parameters were evaluated using likelihood ratio tests (LRTs) and by constructing 95% confidence ellipses using the corresponding K and $L\infty$ parameter estimates (Kimura 1980; Cerrato 1990). Growth equivalence between males and females was assessed under the null hypothesis of no difference, with statistical significance evaluated at an α level of 0.05. Degrees of freedom (q) reflected the number of parameters constrained in each comparison. Ninety-five percent confidence ellipses were constructed using the corresponding K and $L\infty$ parameter estimates to facilitate visual and statistical comparison of growth curves within species (Kimura 1980; Cerrato 1990).

3 | Results

Of the total 138 *C. striatus* and 131 *A. achilles* that were collected during years 2020 and 2021, 42 and 46 individuals, respectively, could not be sexed. Across all individuals, *C. striatus* ranged from 105 to 250 mm in size and 31.1–353.5 g in weight, while *A. achilles* ranged from 137 to 215 mm and 68.5–306.0 g. Ages ranged from 1 to 27 years for *C. striatus* and 0–9 years for *A. achilles*. Population parameters can be found in Table 1.

The relationship between length and weight was deemed to be slightly negatively allometric for *C. striatus* and generally isometric for *A. achilles* (see b values in Table 1). ANCOVA did not detect any significant differences in length–weight relationships between males and females for *C. striatus* ($p = 0.18$) or *A. achilles* ($p = 0.26$). Mortality estimates based on age-based catch curves of all individuals sampled revealed an annual survivorship rate of approximately 64% for both species, which means respective populations experienced a decline of approximately 36% per year (see Table 1).

Age and size classes for *C. striatus* and *A. achilles* are summarised in Figure 1, with *C. striatus* dominated by 3- and 4-year-olds (175–184 mm) and A. achilles by 2-year-olds (157–166 mm). The relationship between otolith weight and estimated age for both species was moderate (see R^2 values in Table 1). The oldest *C. striatus* were estimated to be 27 years old, while the oldest *A. achilles* was estimated to be 9 years old.

There was an asymptotic relationship between age and size in both species. VBGF analysis showed that *C. striatus* had asymptotic lengths ($L\infty$) of 185.18 mm (males) and 177.17 mm (females), with corresponding growth coefficients (K) of 0.87 and 1.15, respectively. In *A. achilles*, $L\infty$ was 177.32 mm (males) and 191.24 mm (females), with k values of 1.56 and 1.04, respectively (Figure 2). Growth dynamics partitioned by sex are shown in Table 1. LRT conducted to compare growth parameters between males and females revealed statistically insignificant difference ($p > 0.05$). Confidence ellipses constructed around $L\infty$ and k for *C. striatus* and *A. achilles* revealed overlapping regions between males and females, indicating no significant sex-specific differences in growth parameters (Figure 3).

Histological analysis identified male and female specimens across all age and size categories. This finding, along with the lack of any bisexual specimens, indicates a gonochoric sexual development pathway for both species. There were no observed sexually immature specimens, which prohibited conducting age- or size-at-maturity analyses. This was due to our relatively small sample size and lack of very small or young specimens; our youngest individual identified being less than 1 year. The size selectivity inclined towards targeting larger individuals is to be expected as our samples came from local fishers who tend to target for sustenance purposes. It is also possible that some immature specimens went undetected as the identification of sexual morphologies was often challenging, particularly during out of spawning seasons when gonadal development appeared inconspicuous.

4 | Discussion

Acanthurids are often highly exploited by artisanal and subsistence fisheries (Craig et al. 1997, 2008; Rhodes et al. 2008; Nañola et al. 2011; Ford et al. 2016; Tebbett et al. 2022). In Mitiʻāro, Acanthurids are a popular choice for the local subsistence-based fishery (Vavia 2023). By filling gaps in life-history information of *C. striatus* and *A. achilles* in the Cook Islands, our findings contribute valuable baseline data to the limited knowledge of coral reef fish population dynamics in the region. To date, only one age- and size-based study of surgeonfish has been conducted in the Cook Islands, focusing on *C. striatus* in Rarotonga (Manarangi-Trott 2000), located approximately 264 km southwest of Mitiʻāro. In comparison, our findings indicate that *C. striatus* in Mitiʻāro attain larger maximum size, exhibit greater longevity and reach asymptotic size earlier than their Rarotongan counterparts. Relative to other South Pacific

TABLE 1 | Population parameter values of best fit models for *Ctenochaetus striatus* and *Acanthurus achilles*; growth parameters of von Bertalanffy growth function (VBGF) showing overall and sex-specific growth characteristics, length–weight relationship fitted to a power curve, mortality estimates calculated from age-based catch curves, otolith weight–age relationship fitted to a linear regression and sex ratio.

Function	Parameters	*C. striatus*	*A. achilles*
VBGF			
	$L\infty$ (mm)	185.18	183.11
	K	0.87	1.26
	t_0	−0.33	−0.23
	n	138	131
Male VBGF			
	$L\infty$ (mm)	186.44	177.32
	K	0.87	1.56
	t_0	−0.33	−0.19
	n	50	40
Female VBGF			
	$L\infty$ (mm)	177.17	191.24
	K	1.15	1.04
	t_0	−0.33	−0.27
	n	46	45
Length–weight relationship			
	a	7×10^{-5}	2×10^{-5}
	b	2.81	3.05
Male length–weight relationship			
	a	5×10^{-5}	3×10^{-5}
	b	2.86	2.97
Female length–weight relationship			
	a	5×10^{-5}	2×10^{-5}
	b	2.88	3.09
Other parameters			
Morality, yr^{-1}	Z (%)	35.9	36.5
Otolith weight–age relationship	R^2	0.75	0.84
Sex ratio	Male:female	1:1.1	0.89:1

populations, our estimated asymptotic length for overall population ($L\infty = 185$ mm) is similar to that reported for Mo'orea (178 mm; Trip et al. 2008). More broadly, the Miti'āro results fall within the established Indo-Pacific ranges for *C. striatus* age and size distributions (Trip et al. 2008, 2014b). Because the population dynamics of *C. striatus* have proposed to be strongly influenced by local habitat dynamics, particularly with respect to body size (Ochavillo et al. 2011), localised studies such as ours offer valuable insights for refining our understanding of population dynamics.

To date, there have been no investigations on the population dynamics of *A. achilles* in the Cook Islands. However, comparisons with a recent comprehensive analysis of *A. achilles* from Hawai'i (Grabowski et al. 2025) have revealed some key similarities and differences. In terms of growth partitioned by sex, our findings concur with Grabowski et al. (2025), which cite females as reaching a larger asymptotic length than males. However, our fork-length $L\infty$ estimates were smaller than those reported by Grabowski et al. (2025) but were more in line with those reported by Morat et al. (2020) from French Polynesia. Another point of difference was the length–weight relationship, where *A. achilles* from Hawai'i were reported to display a strongly negative allometric relationship ($b = 2.64$), whereas in Miti'āro, we reported a near-isometric relationship between body size and weight ($b = 3.05$). The most striking difference was the estimation of maximum age, where Grabowski et al. (2025) reported an age distribution significantly older (0–39 years) than ours (0–9 years). However, this could be due to our significantly smaller sample size.

Since only sexually mature individuals were recorded in this study, even amongst the youngest and smallest age and size classes, this finding indicates that the population may be renewing itself at a pace sufficient to tolerate current levels of exploitation (Taylor et al. 2019). Interestingly, our data suggests that the youngest *A. achilles* individuals matured within their first year (<1 year), which may be symptomatic of high levels of fishing

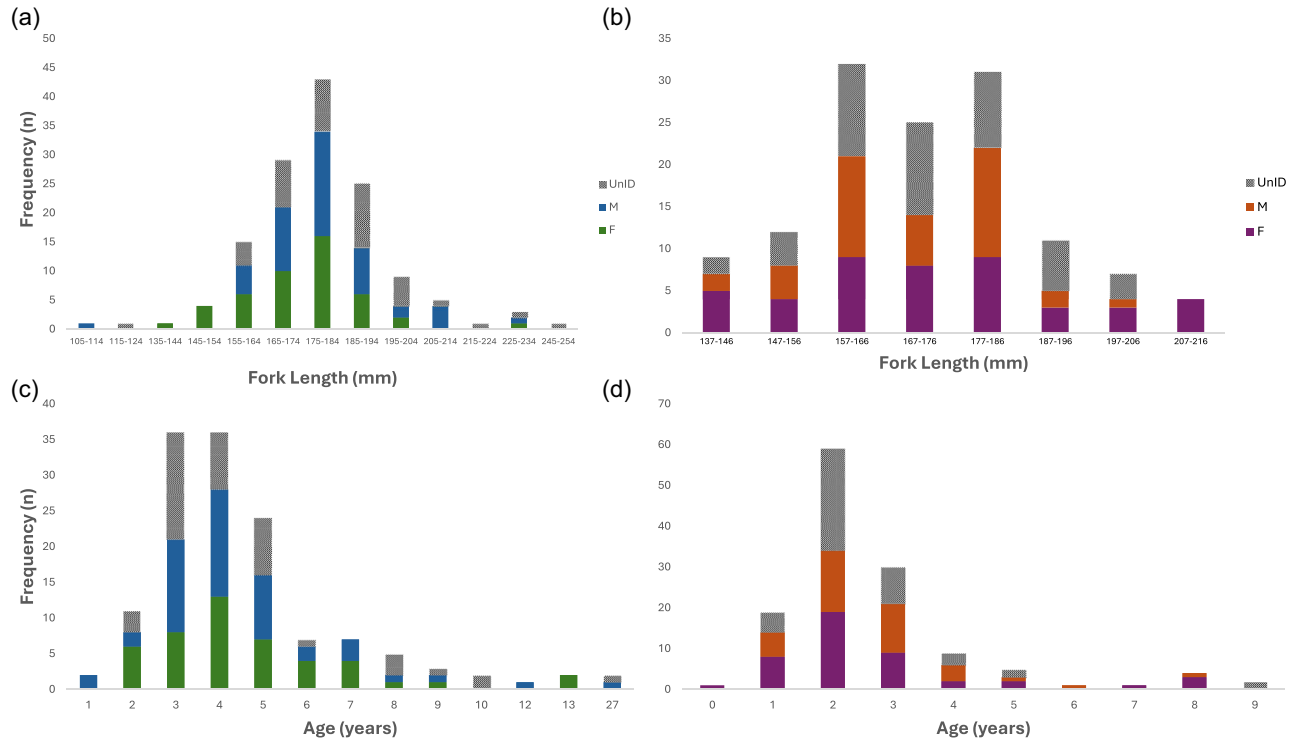

FIGURE 1 | Size and age frequency distributions of *Ctenochaetus striatus* and *Acanthurus achilles* from Miti'āro Island, Cook Islands. Panels (a,c) show the size and age frequency distributions of *C. striatus*, respectively, while panels (b,d) show the size and age frequency distributions of *A. achilles*, respectively. Each species is separated by sex and includes individuals of unidentified sex. No *C. striatus* individuals between 13 and 27 years of age were observed.

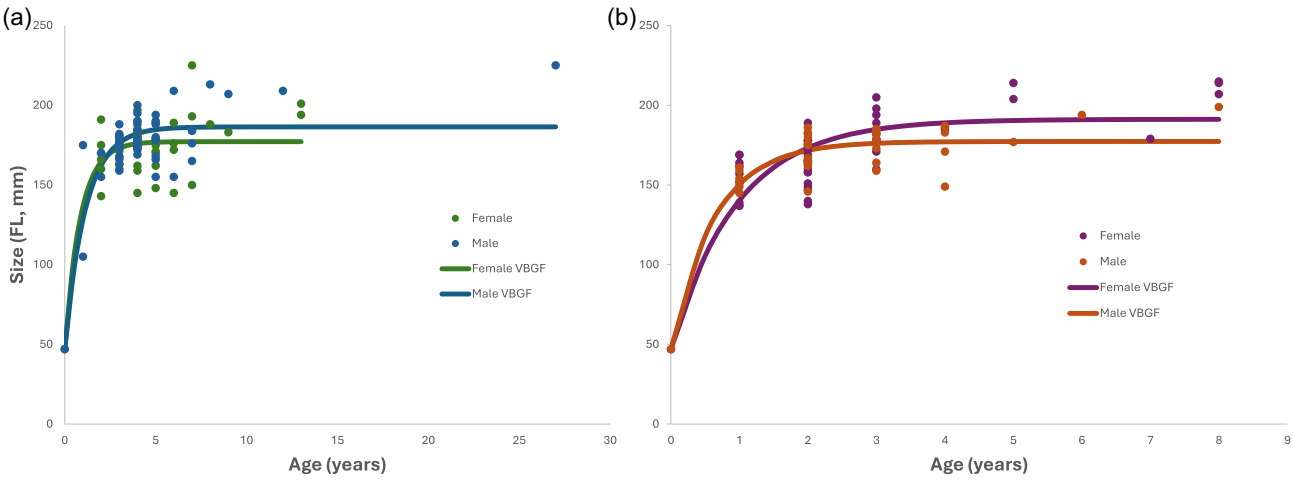

FIGURE 2 | Von Bertalanffy growth trajectories of *Ctenochaetus striatus* (a) and *Acanthurus achilles* (b) from Miti'āro Island, Cook Islands, separated by sex. Parameters are presented in Table 1.

pressure. Maturation as early as within a year is consistent with observations reported by Grabowski et al. (2025) for *A. achilles*. Given the influence of fishing activity on maturity rates, further investigation across fishing pressure and latitudinal gradients within the Cook Islands may provide valuable insight. Nevertheless, early sexual maturity in coral reef fishes is not uncommon and has been documented in several Pacific species. Sabetian (2010) reported that the parrotfish *Scarus ghobban* from the Solomon Islands reached sexual maturity soon after its first year of life. Similarly, histological analyses of *C. striatus* from American Samoa suggested that 50% of males and females matured between 2 and 3 years of age (Ochavillo et al. 2011).

This study identified two key life-history traits that align with patterns reported for Acanthurids in the literature: rapid early growth and early sexual maturation (Trip et al. 2008, 2014b; Grabowski et al. 2025). From an evolutionary perspective, rapid early-life growth likely reduces vulnerability to predation by allowing individuals to reach a size refuge more

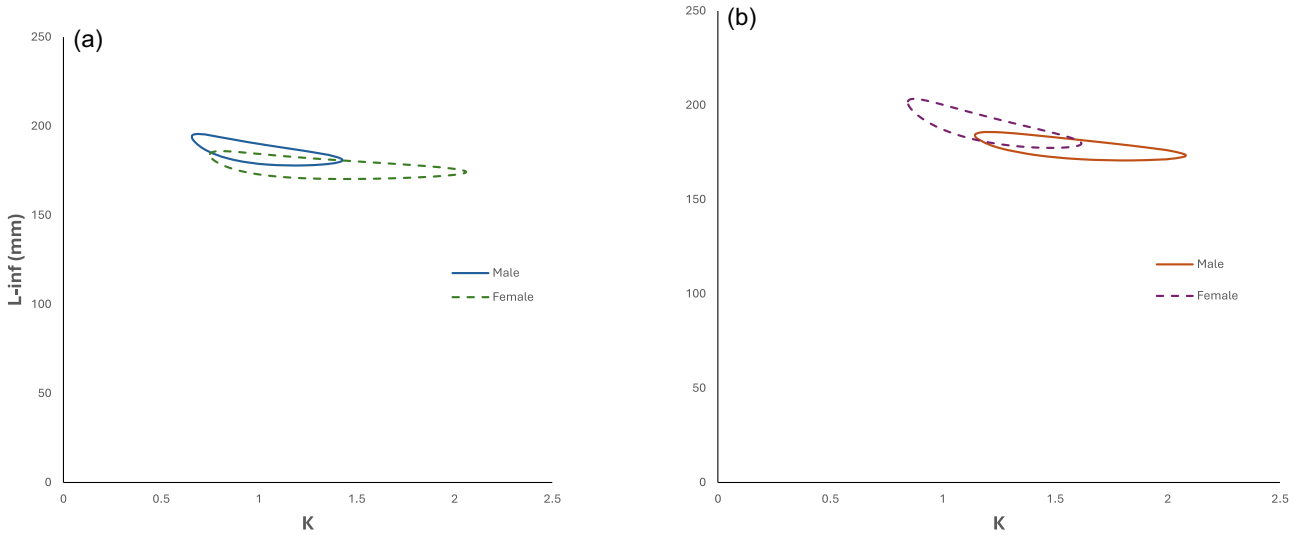

FIGURE 3 | Comparison of VBGF parameters for male and female populations of *Ctenochaetus striatus* (a) and *Acanthurus achilles* (b), showing 95% confidence regions around least squares estimate of K and $L\infty$.

quickly, thereby increasing the probability of survival to reproductive age. Similarly, early maturation ensures that individuals can contribute to the gene pool even under conditions of high natural mortality or environmental variability, enhancing population resilience. Together, these traits could reflect adaptive strategies that balance the trade-offs between survival and reproduction in dynamic coral reef environments. Latitudinal variation in population dynamics has been well documented in teleosts (Trip et al. 2008, 2014a). Although the geographical setting of Mitiʻāro may not represent the typical characteristics of most fringing coral reef habitats, or coastal reef fisheries, it does provide a unique case study of a stand-alone oceanic island with a subsistence-based fishery. Notably, this study represents the first age-based demographic investigation of any reef fish species from Mitiʻāro.

The results presented here provide baseline information that can be used to inform future comparative analyses and broader fisheries management decisions. Expanding such research across other outer islands of the Cook Islands would facilitate the development of a comprehensive, nationwide database on fishery-relevant coral reef fishes.

Acknowledgments

We would like to acknowledge the people of Mitiʻāro, especially to all the fishers without whom this research would not be possible. We also extend our gratitude to the peer reviewers for their valuable suggestions and constructive critiques, which significantly improved the quality of this publication.

Open access publishing facilitated by Auckland University of Technology, as part of the Wiley - Auckland University of Technology agreement via the Council of Australasian University Librarians.

Funding

The authors have nothing to report.

References

Bell, J. D., M. Kronen, A. Vunisea, et al. 2009. "Planning the use of Fish for Food Security in the Pacific." *Marine Policy* 33: 64–76. https://doi.org/10.1016/j.marpol.2008.04.002.

Bellwood, D. R., C. H. R. Goatley, S. J. Brandl, and O. Bellwood. 2014. "Fifty Million Years of Herbivory on Coral Reefs: Fossils, Fish and Functional Innovations." Proceedings of the Royal Society B: Biological Sciences, 281, no, 1781: 20133046. https://doi.org/10.1098/rspb.2013.3046.

Beverton, R. J. H., and S. J. Holt. 1957. "On the Dynamics of Exploited Fish Populations." *Fisheries Investigations* 19: 1–533.

Cerrato, R. M. 1990. "Interpretable Statistical Tests for Growth Comparisons Using Parameters in the Von Bertalanffy Equation." *Canadian Journal of Fisheries and Aquatic Sciences* 47: 1416–1426. https://doi.org/10.1139/f90-160.

Choat, J. H., and L. M. Axe. 1996. "Growth and Longevity in Acanthurid Fishes; an Analysis of Otolith Increments." *Marine Ecology Progress Series* 134: 15–26. https://doi.org/10.3354/meps134015.

Cohen, P. J., and T. J. Alexander. 2013. "Catch Rates, Composition and Fish Size from Reefs Managed with Periodically-Harvested Closures." *PLoS ONE* 8: e73383. https://doi.org/10.1371/journal.pone.0073383.

Cook Islands Statistics Office. 2022. "Census of Population and Dwellings." Accessed May 21, 2023. http://www.mfem.gov.ck/statistics.

Craig, P. C., and L. M. Axe. 1997. "Population Biology and Harvest of the Coral Reef Surgeonfish." *Fishery Bulletin* 95: 680–693.

Craig, P., P. Green, and F. Tuilagi. 2008. "Subsistence Harvest of Coral Reef Resources in the Outer Islands of American Samoa: Modern, Historic and Prehistoric Catches." *Fisheries Research*, 89, no. 3, 230–240. https://doi.org/10.1016/j.fishres.2007.08.018.

Foo, S. A., W. J. Walsh, J. Lecky, S. Marcoux, and G. P. Asner. 2020. "Impacts of Pollution, Fishing Pressure, and Reef Rugosity on Resource Fish Biomass in West Hawaiʻi." *The Bulletin of the Ecological Society of America* 101: 1–4. https://doi.org/10.1002/bes2.1778.

Ford, A. K., S. Bejarano, A. Marshell, and P. J. Mumby. 2016. "Linking the Biology and Ecology of Key Herbivorous Unicornfish to Fisheries

Management in the Pacific." *Aquatic Conservation: Marine and Freshwater Ecosystems* 26: 790–805. https://doi.org/10.1002/aqc.2623.

Friedlander, A. M. 2004. "Status of Hawai'i's Coastal Fisheries in the New Millennium", revised. Proceedings of the 2001 Fisheries Symposium sponsored by the American Fisheries Society, Hawai'i Chapter. Honolulu (HI): American Fisheries Society, Hawai'i Chapter. [accessed 29 Jul 26].

Grabowski, T. B., R. Masse, D. McSwain, et al. 2025. "Age, Growth, and Reproductive Biology of Achilles Tang (*Acanthurus achilles*) around Hawai'i Island, USA." *Environmental Biology of Fishes* 108: 1–15. https://doi.org/10.1007/s10641-024-01578-3.

Hughes, T. 1994. "Catastrophes, Phase Shift, and Largescale Degradation of a Caribbean Coral Reef." *Science* 265: 1547–1551.

Islam, D., and F. Berkes. 2016. "Indigenous Peoples' Fisheries and Food Security: A Case from Northern Canada." *Food Security* 8: 815–826. https://doi.org/10.1007/s12571-016-0594-6.

Kimura, D. K. 1980. "Likelihood Methods for the Von Bertalanffy Growth Curve." *Fishery Bulletin* 77: 765–776.

Kittinger, J. N. 2013. "Human Dimensions of Small-Scale and Traditional Fisheries in the Asia-Pacific Region." *Pacific Science* 67: 315–325. https://doi.org/10.2984/67.3.1.

Kora, J., L. Ainley, and K. Morejohn. 2018. *Mitiaro Nearshore Invertebrate & Finfish Assessment Government of the Cook Islands*. Ministry of Marine Resources.

Labropoulou, M., and C. Papaconstantinou. 2000. "Comparison of Otolith Growth and Somatic Growth in Two Macrourid Fishes." *Fisheries Research* 46: 177–188. https://doi.org/10.1016/S0165-7836(00)00144-2.

Longenecker, K., and R. Langston. 2018. *The Jungle Histology Atlas of Gonad Stages in Coral-Ree Fishes*. 4th ed. 52. Pacific Biological Survey.

Longenecker, K., R. Langston, and E. C. Franklin. 2020. "Standard Operating Procedure for Histology-Based Rapid Reproductive Analysis of Tropical Fishes." Report Prepared by the University of Hawaii at Manoa (UHM) for Tetra Tech's Supplemental Technical Assistance to the USAID SEA Project and Walton Family Foundation.

Manarangi-Trott, L. 2000. "Maito (Ctenochaetus striatus) Its Age and Growth Characteristics and the Effects of Fishing Pressure in Rarotonga, Cook Islands." Doctoral diss., Honours Thesis, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney.

Marshell, A., and P. J. Mumby. 2015. "The Role of Surgeonfish (Acanthuridae) in Maintaining Algal Turf Biomass on Coral Reefs." *Journal of Experimental Marine Biology and Ecology*, 473, 152–160. https://doi.org/10.1016/j.jembe.2015.09.002.

Morat, F., J. Wicquart, N. M. D. Schiettekatte, et al. 2020. "Individual Back-Calculated Size-at-Age Based on Otoliths from Pacific Coral Reef Fish Species." *Scientific Data* 7: 370. https://doi.org/10.1038/s41597-020-00711-y.

Mumby, P., C. Dahlgren, A. Harborne, et al. 2006. "Fishing, Trophic Cascades, and the Process of Grazing on Coral Reefs." *Science* 311: 94–98. https://doi.org/10.1126/science.1118875.

Munro Solomona, D., T. Tuatai, V. Vuki, and M. Koroa. 2009. "Decadal Changes in Subsistence Fishing and Seafood Consumption Patterns on Rarotonga, Cook Islands." *SPC Women In Fisheries Information Bulletin* 19: 19–27.

Nañola, C. L., P. M. Aliño, and K. E. Carpenter. 2011. "Exploitation-Related Reef Fish Species Richness Depletion in the Epicenter of Marine Biodiversity." *Environmental Biology of Fishes* 90: 405–420. https://doi.org/10.1007/s10641-010-9750-6.

Nemeth, M., and R. Appeldoorn. 2009. "The Distribution of Herbivorous Coral Reef Fishes Within fore-Reef Habitats: The Role of Depth, Light and Rugosity." *Caribbean Journal of Science* 45: 247–253. https://doi.org/10.18475/cjos.v45i2.a11.

Ochavillo, D., S. Tofaeono, M. Sabater, and E. L. Trip. 2011. "Population Structure of *Ctenochaetus striatus* (Acanthuridae) in Tutuila, American Samoa: The use of Size-at-Age Data in Multi-Scale Population Size Surveys." *Fisheries Research* 107: 14–21. https://doi.org/10.1016/j.fishres.2010.10.001.

O'Leary, J. K., and T. R. McClanahan. 2010. "Trophic Cascades Result in Large-Scale Coralline Algae Loss through Differential Grazer Effects." *Ecology* 91: 3584–3597.

Pauly, D., and D. Zeller. 2016. "Catch Reconstructions Reveal that Global Marine Fisheries Catches Are Higher than Reported and Declining." *Nature Communications* 7: 10244. https://doi.org/10.1038/ncomms10244.

Rhodes, K. L., M. H. Tupper, and C. B. Wichilmel. 2008. "Characterization and Management of the Commercial Sector of the Pohnpei Coral Reef Fishery, Micronesia." *Coral Reefs* 27: 443–454. https://doi.org/10.1007/s00338-007-0331-x.

Ricker, W. E. 1973. "Linear Regressions in Fishery Research." *Journal of the Fisheries Research Board of Canada* 30: 409–434. https://doi.org/10.1139/f73-072.

Rongo, T., J. Evans, K. Passfield, et al. 2013. *Coral Reef Survey of Aitutaki, Manuae, Mitiaro, Takutea, and Atiu in the Southern Cook Islands*. Cook Islands Marine Park.

Rongo, T., and R. van Woesik. 2011. "Ciguatera Poisoning in Rarotonga, Southern Cook Islands." *Harmful Algae* 10: 345–355. https://doi.org/10.1016/j.hal.2010.11.005.

Sabetian, A. 2010. "Parrotfish Fisheries and Population Dynamics: A Case-Study from Solomon Islands." Ph.D. Diss., James Cook University, Townsville, Australia.

Secor, D. H., J. M. Dean, and S. E. Campana. 1995. *Recent Developments in Fish Otolith Research*. University of South Carolina Press.

Stobutzki, I. C., and D. R. Bellwood. 1997. "Sustained Swimming Abilities of the Late Pelagic Stages of Coral Reef Fishes." *Marine Ecology Progress Series* 149: 35–41.

Taylor, B. M., J. H. Choat, E. E. DeMartini, et al. 2019. "Demographic Plasticity Facilitates Ecological and Economic Resilience in a Commercially Important Reef Fish." *Journal of Animal Ecology* 88: 1888–1900. https://doi.org/10.1111/1365-2656.13095.

Tebbett, S. B., A. C. Siqueira, and D. R. Bellwood. 2022. "The Functional Roles of Surgeonfishes on Coral Reefs: Past, Present and Future." *Reviews in Fish Biology and Fisheries* 32: 387–439. https://doi.org/10.1007/s11160-021-09692-6.

Trip, E. L., J. H. Choat, D. T. Wilson, and D. R. Robertson. 2008. "Inter-Oceanic Analysis of Demographic Variation in a Widely Distributed Indo-Pacific Coral Reef Fish." *Marine Ecology Progress Series* 373: 97–109. https://doi.org/10.3354/meps07755.

Trip, E. D. L., K. D. Clements, D. Raubenheimer, and J. H. Choat. 2014a. "Temperature-Related Variation in Growth Rate, Size, Maturation and Life Span in a Marine Herbivorous Fish over a Latitudinal Gradient." *Journal of Animal Ecology* 83: 866–875. https://doi.org/10.1111/1365-2656.12183.

Trip, E. D. L., P. Craig, A. Green, and J. H. Choat. 2014b. "Recruitment Dynamics and First Year Growth of the Coral Reef Surgeonfish *Ctenochaetus striatus*, with Implications for Acanthurid Growth Models." *Coral Reefs* 33: 879–889. https://doi.org/10.1007/s00338-014-1182-x.

Vaughan, M. B., and A. L. Ayers. 2016. "Customary Access: Sustaining Local Control of Fishing and Food on Kaua'i's North Shore." *Food, Culture & Society* 19: 517–538. https://doi.org/10.1080/15528014.2016.1208339.

Vavia, A. 2023. "Pacific Island Coastal Reef Fisheries: A Case Study from Mitiaro, Cook Islands." PhD diss., Auckland University of Technology, Auckland, New Zealand.

Vavia, A. 2026. "Mārara Te Tai: Towards a Mitiʻāro Marine Ecology." *JPS* 134: 467–496.

Walsh, W. J., S. Cotton, L. Jackson, et al. 2020. Findings and recommendations of effectiveness of the West Hawai'i Regional Fishery Management Area (WHRFMA). Honolulu (HI): Department of Land and Natural Resources, Division of Aquatic Resources, State of Hawaii. Report No.: HRS188. 107 p. Accessed Jul 26, 2026, https://dlnr.hawaii.gov/dar/files/2020/05/ar_hrs188_2020.pdf.