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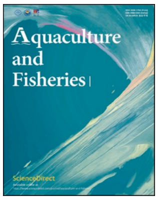

Original research article

# Age, growth and length-to-weight relationship of largehead hairtail (*Trichiurus lepturus*) in south-eastern Australia suggest a distinct population

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ABSTRACT

The age, growth rates and length to weight relationships for the south-eastern Australian population of largehead hairtail (*Trichiurus lepturus*) were investigated for the first time. Age was estimated by counting annuli in sectioned sagittal otoliths, with a maximum age of 8 years estimated for males and females. We found no significant differences in the growth rates of males and females over the size (12–78 cm pre-anal length (PL)) and age (0–8 years) ranges sampled. However, females in our collection were larger on average than males, and all fish sampled >60 cm PL were female, suggesting that females may grow to larger sizes than males and that sampling of greater numbers of larger and older fish may be required in future. *T. lepturus* growth was described by the von Bertalanffy growth function parameters $L_\infty = 74.89$ cm PL, $K = 0.13\text{yr}^{-1}$ and $t0 = -0.80$ yr, with the $L_\infty$ being amongst the largest reported for the species. Growth was variable, with the sizes at any given age spanning up to 50 cm PL. Female *T. lepturus* increased in body weight relative to length faster than males, as has been reported in other populations. The length/weight relationship for the south-eastern Australian population was significantly different, with almost no overlap, from that reported for *T. lepturus* in the Arabian Sea. The substantial differences in growth rates, maximum sizes and body morphometrics of *T. lepturus* from south-eastern Australia in comparison to other populations globally are consistent with the hypotheses that it represents a distinct population, although investigations using additional population markers are required to verify this.

## 1. Introduction

Knowledge of life-history traits and biological characteristics are important for the sustainable management of exploited fish (Chen et al., 2003; Francis et al., 2016; Thorson & Minte-Vera, 2016). Relatively basic information on growth rates and body morphometrics are important for stock assessments, understanding stock structure and stock productivity – the life history characteristics which determine the intrinsic rate of population increase (Hobday et al., 2011; Mohamed et al., 2021; Randall et al., 2013). Data to support these requirements are readily available through fishery-dependent sampling (Morgan & Burgess, 2005). Collection of otoliths to estimate age, followed by modelling growth rates using size-at-age data is common practice (Campana & Thorrold, 2001) as is collection of body morphometric data such as length-weight relationships. Length-weight relationships are utilized within stock assessment models, when converting average lengths to average weights, estimating body condition indices and for between region comparisons of population structure (Al-Nahdi et al., 2016; Haimovici & Canziani, 2000; Moutopoulos & Stergiou, 2002). The addition of such information can improve rudimentary, data poor assessments such as catch-only models (Pramesthy et al., 2022; Sekitar et al., 2015) to more sophisticated models that reduce uncertainty and the associated risks of overexploitation.

Largehead hairtail (*Trichiurus lepturus*) is one of the most important commercial fishery species worldwide, with fishery tonnage ranking in the top 10 globally, averaging more than 1,200,000 t p. a. 2015 to 2018 (FAO, 2020). A circumglobal species, the latitudinal distribution of *T. lepturus* extends from temperate waters at 60°N, through equatorial waters to southern temperate waters at 45°S (Al-Nahdi et al., 2009; Carvalho & Luque, 2011; Chiou et al., 2006; FAO, 2018; Shih et al., 2011). Data availability and assessment methods vary considerably between regions, with overfishing being reported in many areas (Ghosh et al., 2009; Kim et al., 2005; Watari et al., 2017; Zhang et al., 2018). The species is reported to be relatively short lived and fast growing (Del Toro, 2001); however, life-history traits are reported to vary among regions (Clain et al., 2021; James et al., 1978; Kwok & Ni, 1999; Lazarus

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& Sarma, 1991; Martins & Haimovici, 2000; Sheridan et al., 1984; Tampi et al., 1968; Thiagarajan et al., 1992; Wojciechowski, 1972). The wide geographic distribution and unresolved taxonomy of *T. lepturus* (Shih et al., 2011; Yi et al., 2022), suggests that local information is required to inform assessment and management.

Within Australia, *T. lepturus* has been reported in all states (Atlas of Living Australia website at http://www.ala.org.au. Accessed November 12, 2021.); however, mistaken reports of Trichiuridae species are common and therefore *T. lepturus* may have been over reported (Chakraborty et al., 2005). The only commercial fishery for *T. lepturus* in Australia exists along the east-coast (Stewart et al., 2015), and is relatively small compared to some global fisheries for *T. lepturus*. A commercial trawl and line fishery lands generally less than 50 tonnes p. a. of *T. lepturus* (Stewart et al., 2015); however, market price is relatively high. There is also an important recreational hook and line fishery for the species, generally located in the lower reaches of only a few marine dominated estuaries. The recreational and commercial fishery is characterized by large variations in catches annually, but the reasons for this variability are not known. Relatively little is known about the fishery including gear selectivity, there are no specific management regulations for the commercial harvest, no regulated minimum legal length or total allowable catch limits, and the only regulation on the recreational fishery is a bag limit of 10 fish per person per day (Stewart et al., 2015).

The aim of this study was to utilize fishery-dependant sampling to generate the first information on age and growth of *T. lepturus* in south-eastern Australia. We utilize this information, along with data on body morphometrics (Cadrin et al., 2014; Mwakiti et al., 2016; Rawat et al., 2017) to examine potential global differences between populations of *T. lepturus* and whether differences are consistent with the hypothesis of a distinct population in south-eastern Australia.

## 2. Materials and methods

### 2.1. Sample collection

All experimental procedures in this study were reviewed and approved by The Department of Primary Industries (Fisheries) Animal Care and Ethics Committee (ACEC REF 16/03). Samples were collected from the three major locations of the fishery for *T. lepturus* in the state of New South Wales (NSW) in south-eastern Australia. There were two estuarine sites and one coastal site: (1) the Hawkesbury River estuarine site (33.55° S; 151.33° E); (2) the Hunter River estuarine site (32.93°S, 151.78° E) and; (3) the Hunter River coastal site (32° S – 33° S, 151.80° E – 152.65° E) (Fig. 1).

Acknowledging potential biases in modelling growth from fishery dependent sampling (Schemmel et al., 2022), and with no information on the selectivity of gears within the NSW fishery for *T. lepturus*, we stratified sampling across multiple months, areas and methods. This approach supports ensuring sufficient representation of each size and age class to reflect the population being sampled (Bolser et al., 2018). We therefore sampled *T. lepturus* individuals from the south-east Australian commercial and recreational fisheries during a 20-month period, between September 2015 and April 2017. We aimed to collect a random sample of 10 fish from each of the three sites every two weeks from the commercial fishery; however, this varied depending on the operations of the fishery. Sampling was done at two commercial fishing seafood cooperatives, which provided access to all *T. lepturus* caught by the commercial fishery at the three study sites. We obtained hairtail by donation from recreational fishers from the Hawkesbury River estuarine site, the majority of which – 72 out of 90 – were from an annual recreational fishing competition for *T. lepturus*, held from the 30th of June to the July 3, 2016 at the Hawkesbury River estuarine site, the rest were ad hoc donations. We also obtained 32 recreationally-caught hairtail from the Hunter River estuarine site by donation from the NSW DPI – Fisheries compliance officers, following several catch seizures between mid-February and mid-April 2016 at the Hunter River estuarine site. To

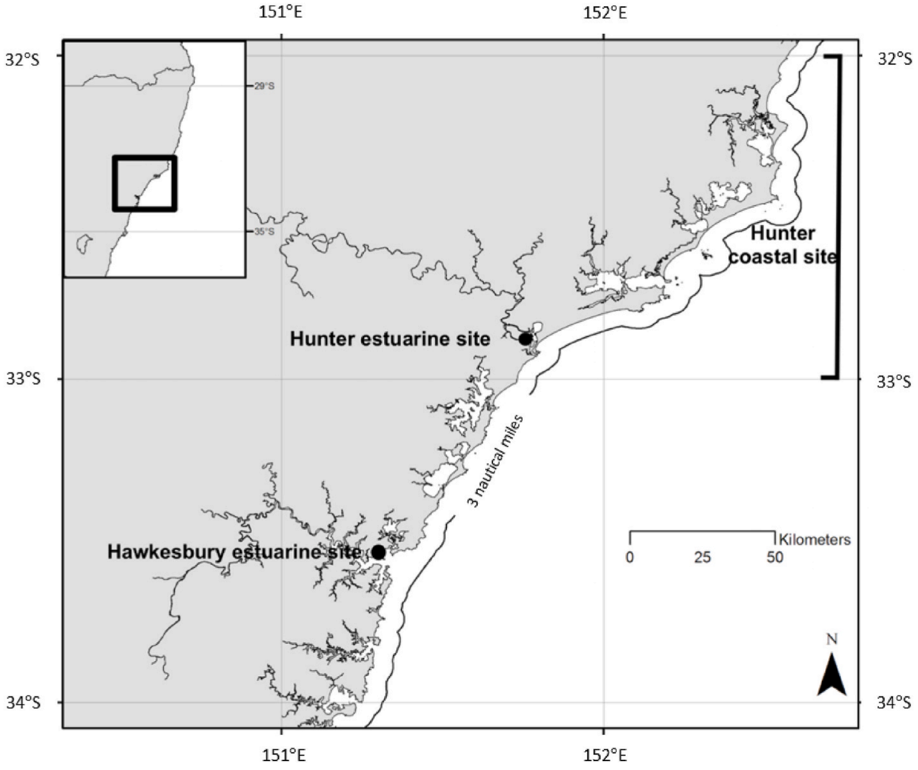

**Fig. 1.** Map of the south-eastern Australian coast showing the three sites from which *Trichiurus lepturus* were sampled between September 2015 and April 2017.

limit potential bias of small fish selected from recreational catch we acquired 46 small *T. lepturus* from an offshore research trawl observer program run by NSW Department of Primary Industries (DPI) – Fisheries. These individuals were caught as bycatch in four commercial trawl events that occurred in March, May, June and August of 2016. Sampling details are outlined in Table 1.

All the specimens collected during the present study were confirmed as *T. lepturus* by observing the diagnostic characters of dorsal fin color (Wang et al., 2017), gill cusps, and morphometrics including the horizontal distance between the posterior margin of the dermal eye and the first dorsal fin origin, and the dorsal margin of the concave line of the head in lateral view (Chakraborty et al., 2005; Tzeng et al., 2007). We recorded the pre-anal length (PL) of We were able to record the pre-anal length (PL) of 438 individuals to the nearest cm rounding down. PL, which is the measurement from the anterior extremity of the lower jaw to the anal vent, is a more reliable length measure than total length (TL) because the thin tail of *T. lepturus* is prone to damage (Al-Nahdi et al., 2009; Khan, 2006). We used the relationship between PL and TL of 362 fish – only using fish with intact tails – to estimate the TL of all individuals (see Results), to allow for direct comparisons with global studies that have reported TL. Additionally, we recorded the wet body weight of 401 individuals – only using intact fish, not fish that were partially processed e.g., headed or gutted – and assigned sex based on the identification of female ovaries or male testes for 367 of the individuals where identification of gonads was possible.

### 2.2. *Age estimation using sagittal otoliths*

The sagittal otoliths were excised, cleaned, and stored dry. One otolith from the extracted pair was weighed (to the nearest 0.00001 g) using an electronic balance (Sartorius Australia PTY LTD) and embedded in a block of epoxy resin. The left otolith was selected for embedding wherever possible but, when necessary, the right was used due to demonstrated consistency in the annual increments between otolith pairs of *T. lepturus* (Kwok & Ni, 2000; Shih et al., 2011). To expose the centre of the otolith at its core, a transverse section was taken using a single diamond-embedded blade on a Gemmasta high-speed saw. Otolith weights were recorded for 430 individuals, and ages were recorded for 418 individuals. Only otoliths with no breakage were weighed and only otoliths where it was possible to get a full cross-section of annual rings were aged.

The sections were then adhered to glass slides and ground down to a thickness of ~0.2 mm with 1200 grit polishing paper on a Struers model LaboPol-4 to reveal the otolith core (Campana, 2001). Kwok and Ni (2000) used the marginal increment method to validate the alternating opaque and hyaline growth increments on transverse sections of *T. lepturus* otoliths as annual increments. In the present study, the sections were viewed under reflected light on a black background. The methods of Kwok and Ni (2000) were followed to identify the first opaque increment and to count the opaque annual increments along the dorsal lobe to provide an age estimation in years. To avoid reading bias, each otolith was read without knowledge of the fish length, date and place of sampling. Also, interpretation bias was assessed by a second reader who read a random subset of approximately 10% of otoliths and the mean coefficient of variation (CV) was calculated and checked to be an acceptable level according to Campana (2001). The relationships between pre-anal length and otolith weight, and between estimated age and otolith weight were investigated.

### 2.3. *Length-weight analyses*

The length-weight relationship for *T. lepturus* in south-eastern Australia was estimated with non-linear regression, using equation $W = a\,PL^b$, where W is the body weight (g), PL is the body length (cm), 'a' is a coefficient related to body form and 'b' is the growth exponent (Chakravarty et al., 2012; Ghosh et al., 2009; Muhammad et al., 2017). Analysis of covariance (ANCOVA) was used to test whether the length-weight relationship differed between sexes. The data were log transformed prior to analysis to meet the assumption of linearity. A similar approach was used to test whether the length-weight relationship differed between the regions of south-eastern Australia and the Arabian Sea off Oman. We took length and weight data from a recently published research paper on *T. lepturus* in the Arabian sea, off Oman to make this global comparison (Al-Nahdi et al., 2016). We chose this region because it was the only region where raw data was available in full. We used the raw data from the Arabian Sea, off Oman to make a direct comparison with the length (estimated total length) and weight data from south-eastern Australia. The sex was not specified for the data published from Oman so the data for both sexes from south-eastern Australia were pooled for a regional comparison. In this analysis, region with two levels (Oman, NSW) was treated as the independent factor. The data were log transformed and truncated to approximately equal length ranges, between 66.69 cm TL and 134.28 cm TL, from each region.

### 2.4. *Growth*

The von Bertalanffy growth function (VBGF) was fitted to the length-at-age data using the equation $L_t = L_\infty\ [1 - e^{-k\,(t-t_o)}]$, where $L_t$ is length (cm) at age $t$, $L_\infty$ is the asymptotic length (cm PL), k is the rate at which the curve approaches $L_\infty$ (per year), $t$ is age (years), and $t_o$ is the theoretical age of the fish at zero length. The VBGF was fitted by minimizing the residual sums of squares. The curve was used to model growth for pooled sexes and then for males and females separately. The growth curves for both sexes were compared using the analysis of residual sums of squares (ARSS) method (Chen et al., 1992).

**Table 1**

*Trichiurus lepturus* sample size by site, fishing method and month between September 2015 and April 2017 off the south-eastern Australian coast. *Recreational catch.

| | Sample months | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | | | | | | | | | 2017 | | |
| **Sample sites** | **Sep** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Apr** |
| **Hawkesbury River** | | | | | | | | | | | | | |
| Prawn trawl | | | 14 | 20 | | | | | 20 | | | | |
| Hook and line* | | | 1 | 13 | 12 | 64 | | | | | | | |
| **Hunter River** | | | | | | | | | | | | | |
| Handline | | 20 | 13 | 32 | | | | 21 | | | 10 | | 1 |
| Hook and line* | | 32 | | | | | | | | | | | |
| **Hunter River** | | | | | | | | | | | | | |
| Handline | | | | | 7 | | | | 19 | 19 | 18 | 10 | |
| Fish trawl | 11 | | | 34 | 1 | | 20 | 7 | | | | | |
| Prawn trawl | | 1 | | | | | | | | | | | |

## 3. Results

### 3.1. Sample collection

In total, we sampled 439 *T. lepturus* individuals from NSW; 163 from the Hawkesbury River estuarine site, 129 from the Hunter River estuarine site and 147 from the Hunter Coastal site. The relationship between PL and TL was estimated as TL = 2.254 × PL + 17.322 ($R^2 = 0.9637$). Otoliths for age and growth analysis were successfully taken from 418 individuals ranging from 12 to 78 cm PL and 44 cm–193 cm estimated TL, the majority (86.53%) were between 30 and 60 cm PL.

### 3.2. Age estimation using sagittal otoliths

Sectioned sagittal otoliths, viewed under reflected light, had an opaque core and subsequent broad hyaline increments (Fig. 2). The mean coefficient of variation (CV) from the 10% second read on otoliths was 4.3% (Campana, 2001) Otolith annual increments indicated an age range from 0 years to a maximum of 8 years. Four years was the most numerous age group (27.51%). The relationship between otolith weight (OW) and PL was best described by the linear relationship OW = 0.0005 (PL) - 0.0056 (Fig. 3 $R^2 = 0.92$, $P < 0.001$). The relationship between OW and estimated age was described by the linear relationship OW = 0.0024 (age) + 0.0018 (Fig. 4, $R^2 = 0.48$, $P < 0.001$).

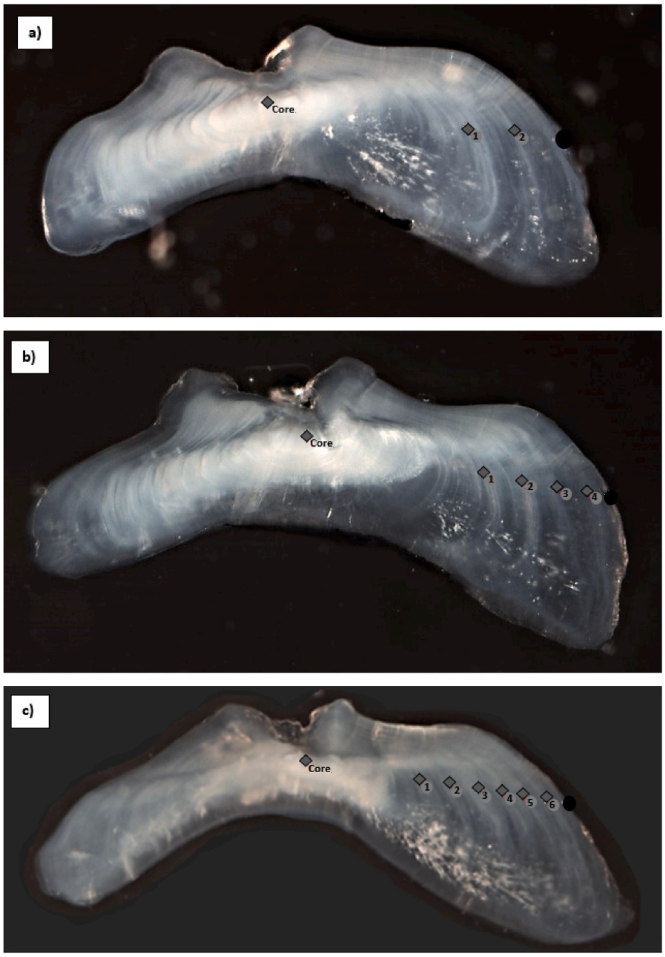

**Fig. 2.** Sectioned otoliths of *Trichiurus lepturus* viewed using reflected light at ×4 magnification. The numbered markers indicate fully formed annual increments. a) 29 cm PL female age 2, b): 32 cm PL female age 4, c): 36 cm PL female age 6.

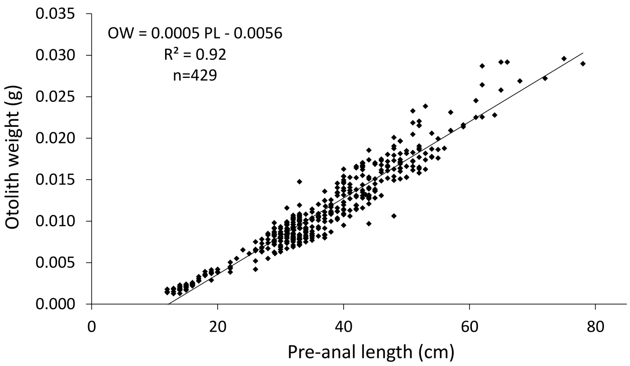

**Fig. 3.** Relationship between pre-anal length (PL) and otolith weight (OW) for *Trichiurus lepturus* collected from NSW between 2015 and 2017.

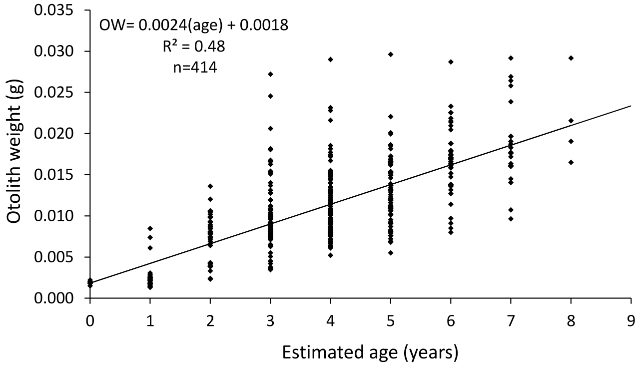

**Fig. 4.** Relationship between estimated age and otolith weight (OW) for *Trichiurus lepturus* collected from NSW between 2015 and 2017.

### 3.3. Length-weight relationships

The relationships between PL and body weight (BW) for males, females and pooled sexes were best described by the power relationships $BW = 0.0449 \cdot PL^{2.6296}$, $BW = 0.0172 \cdot PL^{2.8909}$ and $W = 0.0149 \cdot PL^{2.93}$, respectively. For the length-weight comparison between sexes, the weight of females increased faster with length relative to males (Fig. 5, ANCOVA, $F_{1,\ 290} = 6.884$, $P = 0.009$).

For the length-weight comparison between south-eastern Australia and the Arabian Sea, the rate of weight increase with length did not differ between regions (Fig. 6, ANCOVA, $F_{1,1434} = 3.689$, $P = 0.055$).

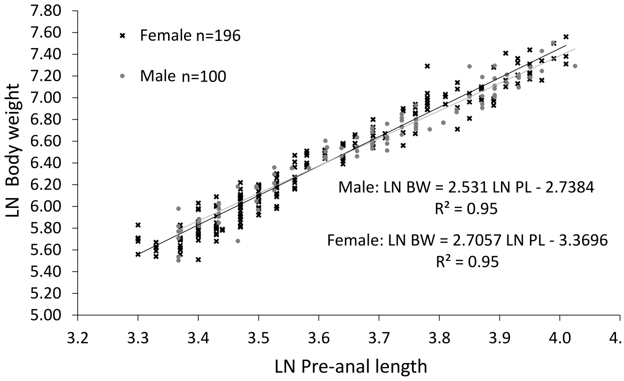

**Fig. 5.** Comparison of the pre-anal length (PL) to body weight (BW) between male and female *Trichiurus lepturus* collected from NSW between 2015 and 2017.

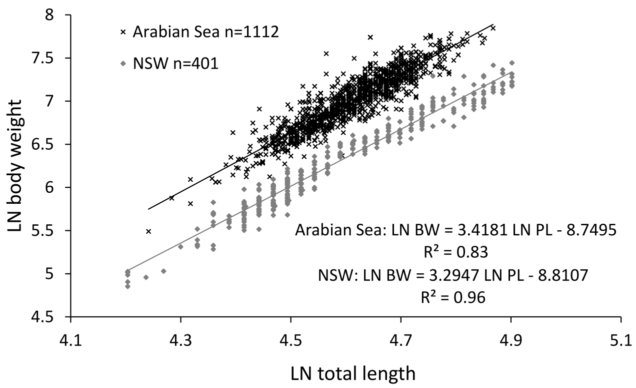

**Fig. 6.** Comparison of the total length (TL) to body weight (BW) relationships for *Trichiurus lepturus* from NSW and the Arabian Sea. Data for the Arabian Sea were taken from Al-Nahdi et al. (2016).

The *T. lepturus* from the Arabian Sea were heavier at any given total length compared with *T. lepturus* from NSW across the length range examined (Fig. 6, ANCOVA, $F_{1,1434} = 5474.790$, $P < 0.001$). Due to the truncation of the data sets, conclusions on the effect of region on length-weight relationships can only be drawn for individuals between 66.69 cm and 134.28 cm TL.

### 3.4. Growth

Fitted von Bertalanffy growth function (VBGF) parameters indicated the growth of male and female *T. lepturus* were not significantly different (ARSS, $F_{3, 324} = 2.38$, $P = 0.0694$), so males and females were combined in the same curve (Fig. 7). VBGF parameters for *T. lepturus* in NSW were $L_{\propto} = 74.9$ PL/186.1 TL, $K = 0.1329$ per year and $t_0 = -0.7992$ year. Individuals reached on average 17, 28, 35, 37, 41, 48, 51 and 56 cm PL by the end of years 1, 2, 3, 4, 5, 6, 7, 8 respectively.

## 4. Discussion

### 4.1. Age and growth

The maximum age estimated during the present study was 8 years for both males and females, with most samples ranging from age 0 to 6. The largest fish sampled during the present study was 78 cm PL (193 cm TL), substantially smaller than the reported maximum size of 234 cm TL (approximately 96 cm PL) from south-eastern Australia (Hutchins & Swainston, 1986). Consequently, it is probable that *T. lepturus* in south-eastern Australia can attain ages considerably greater than 8 years. A larger sample collection is recommended in future to sample across a broader range of size and age and allow for the edge interpretation of hairtail otoliths so the annuli count can be converted to age class (Francis et al., 1992). The linear relationship between OW and PL indicates that otoliths of *T. lepturus* in NSW grow linearly with somatic (body) growth. The linear relationship between OW and estimated age also gives the indication that otoliths continuously increase in weight throughout the life of the individual, although the relationship was weaker with age than length.

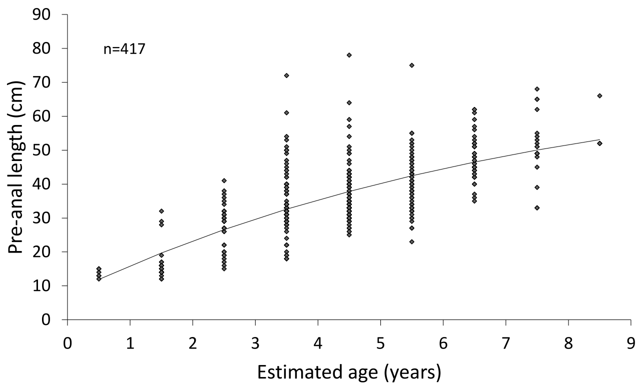

**Fig. 7.** Von Bertalanffy growth function fitted to length at age data for *Trichiurus lepturus* collected from NSW between 2015 and 2017.

The age range found in south-eastern Australia was similar to the age range reported in Oman where Al-Nahdi et al. (2009) reported a maximum of 7 annuli. In the south-east China Sea, there was also a maximum of 7 annuli and the $t_{\max}$ (age at 95% of asymptotic length) was estimated at 15 years (Shih et al., 2011). Most of the age and growth information reported on *T. lepturus* is based on length data using modal progression analysis and inverse interpolation of the Von Bertalanffy growth equation. *T. lepturus* in south-eastern Australia grow rapidly, reaching on average around 37 cm PL (101 cm total length) after 4 years. This is consistent with the conclusion from studies on other populations of *T. lepturus* (Kwok & Ni, 2000; Shih et al., 2011), and infers that they are a relatively productive species (Hobday et al., 2011; Mohamed et al., 2021). Nevertheless, the Brody growth rate coefficient we estimated for *T. lepturus* in south-eastern Australia ($K = 0.13$ per year), is amongst the slowest reported (Table 2). This finding suggests that the south-eastern Australian population may be less productive than elsewhere (Hobday et al., 2011; Mohamed et al., 2021). In contrast to growth rate, $L_\infty$ in the current study is one of the highest reported to date, exceeded only in South America (Table 2, Rossi-Wongtschowski et al., 2006; Milessi, 2008). These findings should be considered as being preliminary for the south-eastern population given that our study is the first to estimate age and growth in the region. In addition, the VBGF parameters $K$ and $L_\infty$ are strongly negatively correlated (Cummings et al., 2016).

We found no significant difference in growth rate between males and females, consistent with the findings of Shih et al. (2011) in the south-east China sea, but different to the findings of Kwok and Ni (2000) who reported that male *T. lepturus* from the South China Sea grew more slowly but to larger sizes than females. Differences in growth rates between the sexes have been reported for other related species, including *Trichiurus japonicus*, with females growing faster and attaining greater lengths than males (Ozawa, 1996; Shih et al., 2011). Female *T. lepturus* collected in our study measured at larger lengths on average than males, and all fish sampled >60 cm PL were female. Given that the maximum age for both sexes recorded here was 8 years, there remains the potential that females do grow to larger sizes than males, but more data is needed to test this hypothesis. Significant differences in sex ratios in landings have also been reported within this population (Clain et al., 2021), suggesting complex gender-based differences in behaviour that could result in growth differences.

Growth rates in teleosts are affected by environmental factors such as water temperature (Rountrey et al., 2014). Average water temperatures for the south-eastern Australian population are substantially colder than populations in more tropical areas (Clain et al., 2021) and may explain the relatively slow growth observed. Despite this slower growth, the population in the cooler-waters of south-eastern Australia grow to a large size (at least 234 cm TL, Hutchins & Swainston, 1986). Similarly, *T. lepturus* from more southern populations also grow relatively large (e.g., Argentina, Milessi, 2008; Table 2). These observations are consistent with Bergmann's rule, whereby body size increases with decreasing temperature and increasing latitude (Bergmann, 1848). This has been shown to occur in other marine fish (Fernández-Torres et al., 2018; Saunders & Tarling, 2018), however, the biological advantages remain unclear. The slower growth rate and larger body size together for *T. lepturus* in south-eastern Australia are consistent with the Temperature-Size Rule for ectotherms (Atkinson, 1995).

**Table 2**
Growth parameters of *Trichiurus lepturus* collected from NSW between 2015 and 2017 and other global locations, presented in order of latitude from north to south. *Citation not seen, referenced on Froese, R. and D. Pauly. Editors. 2018. FishBase. World Wide Web electronic publication. www.fishbase.org, (11/2018).

| Latitude | Country | $L_\infty$ (cm) | K (per yr) | $t_0$ (yr) | n | Citation |
|---|---|---|---|---|---|---|
| 35.49° N | China | 70.8 PL | 0.110 | −2.8200 | – | *(Lin & Zhang, 1981) |
| 34.08° N | Japan | 56.8 PL | 0.2610 | −0.6435 | 3739 | *(Sakamoto, 1976) |
| 34.87° N | Japan | 43.4 PL | 0.2826 | −0.4130 | 505 | *(Kosaka, 1967) |
| 30.40° N | China | 76.6 PL | 0.1390 | −0.2660 | 869 | *(Hamada, 1971) |
| 22°N-25°N | Taiwan | 86.9 PL | 0.182 | −2.161 | – | Shih et al. (2011) |
| 20.91°N | India | 134.1 TL | 0.29 | −0.275 | 6489 | Ghosh et al. (2009) |
| 17.69° N | India | 106.8 TL | 0.6117 | −0.1399 | 5976 | Reuben et al. (1997) |
| 17.50°N | Oman | 127.4 TL | 0.399 | −0.9815 | 10,740 | Al-Nahdi et al. (2009) |
| 16°N-17°N | India | 145.4 TL | 0.29 | −0.20 | – | Narasimham (1972) |
| 16.99° N | India | 128.2 TL | 0.72 | −0.003 | – | Abdussamad et al. (2006) |
| 25.43° S | Brazil | 245.0 TL | 0.27 | – | – | *(Rossi-Wongtschowski et al., 2006) |
| 25°S- 33°S | South Africa | 146.8 TL | 0.292 | – | – | Torres and Pauly (1991) |
| 32°S-34°S | Australia | 74.9 PL 186.1 TL | 0.1277 | −0.7992 | 417 | Current Study in NSW |
| 34°S-41°S | Argentina | 234.0 TL | 0.550 | – | – | Milessi (2008) |

### 4.2. Length/weight relationship

The weight of females in south-eastern Australia increased faster with length relative to males. This finding is similar to that of Al-Nahdi et al. (2009) who also reported a significant difference in the length/weight relationship for *T. lepturus* from the Arabian Sea, and of Wojciechowski (1972), who concluded that females from the Mauritania shelf grew to be heavier than males at similar lengths after sexual maturity. It is not known what biological advantage a heavier body weight would confer for female *T. lepturus*; however, it may be related to reproduction and egg production. Clain et al. (2021) reported that the average male gonadosomatic index was approximately an order of magnitude smaller than for females, suggesting that females allocate considerably more resources into gamete production than males. Al-Nahdi et al. (2009) found significant seasonal effects on the length/weight relationship for *T. lepturus* and it is possible that the findings in our study were driven by greater female ovary size during the approximately 7 month spawning season between March and September (Clain et al., 2021). In future, more intensive sampling in terms of greater numbers and size ranges for length/weight relationships of males and females outside of the spawning season may assist in answering this question. Due to the truncation of the data sets in the current study, conclusions on the effect of sex on length-weight relationships can only be drawn for individuals between 27.11 and 56.26 cm PL and therefore, more intensive sampling to cover a greater size range of both males and females could reveal further insights into the length/weight relationships between sexes.

The analysis of the length/weight relationship for *T. lepturus* in south-eastern Australia, and comparison with that published for *T. lepturus* from the Arabian Sea (Al-Nahdi et al., 2016) indicated substantial and significant differences. The datasets from each region almost had no crossover, with fish from south-eastern Australia being considerably lighter (approximately half) than fish from the Arabian Sea at any given length. Such a major difference in weight at any given length are consistent with the hypothesis of a distinct population in south-eastern Australia (Cadrin et al., 2014; Mwakiti et al., 2016; Rawat et al., 2017); however, comparisons of additional population markers between the two regions are required to confirm this conclusion. Despite the FAO finding that *T. lepturus* is a circum-global species (Nakamura, 1993), more recent work is reporting genetically and morphologically distinct populations from different parts of the world (Chakraborty et al., 2005). It is becoming increasingly evident that the population of *T. lepturus* in south-eastern Australia differs from other populations in terms of its general biology, morphology, fisheries and likely ecology, suggesting further review of the species complex *T. lepturus* is warranted.

## CRediT author statement

All authors contributed to the study conceptualization, design, Methodology, the formal analysis, Investigation and funding acquisition. The material preparation, Data curation, Project administration and the original draft preparation were performed by Chantelle Clain. Reviews and editing were performed by John Stewart, Ashley Fowler and Sandra Diamond. All authors read and approved the final manuscript.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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