

## Original Article

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# Age and growth of the Japanese butterflyfish *Psenopsis anomala* in the waters off north-eastern Taiwan

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## Abstract

The catch of Japanese butterflyfish, *Psenopsis anomala* in Taiwan is greater than those of any other nation; however, the biology, particularly the age and growth, of this economically important fish species is little known. This study describes the age and growth of *P. anomala* based on 734 specimens (340 females, 363 males, 31 unsexed) caught by trawl fishery in the north-eastern waters off Taiwan from March 2007 to July 2008. The age of specimens was estimated by counting the growth annuli in sagittal otoliths. The periodicity of annulus deposition on otolith was estimated to be one year with opaque zone deposited between July and August based on marginal increment analysis. The maximum age for both sexes was estimated to be ~4. The female portion of the population was dominated by the 3<sup>+</sup> age class, while the male portion was dominated by the 2<sub>∞</sub> age class. The parameters of the von Bertalanffy growth function with standard error estimated based on the observed length at age using a non-linear method are as follows:  $L_{\infty} = 25.47 \pm 0.65$  cm,  $k = 0.30 \pm 0.03$  year<sup>-1</sup>, and  $t_0 = -1.84 \pm 0.16$  year for females ( $n = 350$ ), and  $L_{\infty} = 22.39 \pm 0.45$  cm,  $k = 0.46 \pm 0.04$  year<sup>-1</sup>, and  $t_0 = -1.38 \pm 0.13$  year for males ( $n = 378$ ). The growth performances of *P. anomala* reported from different geographic regions were compared, and the potential influences of sample size distribution on the estimated growth parameters were further discussed.

## Introduction

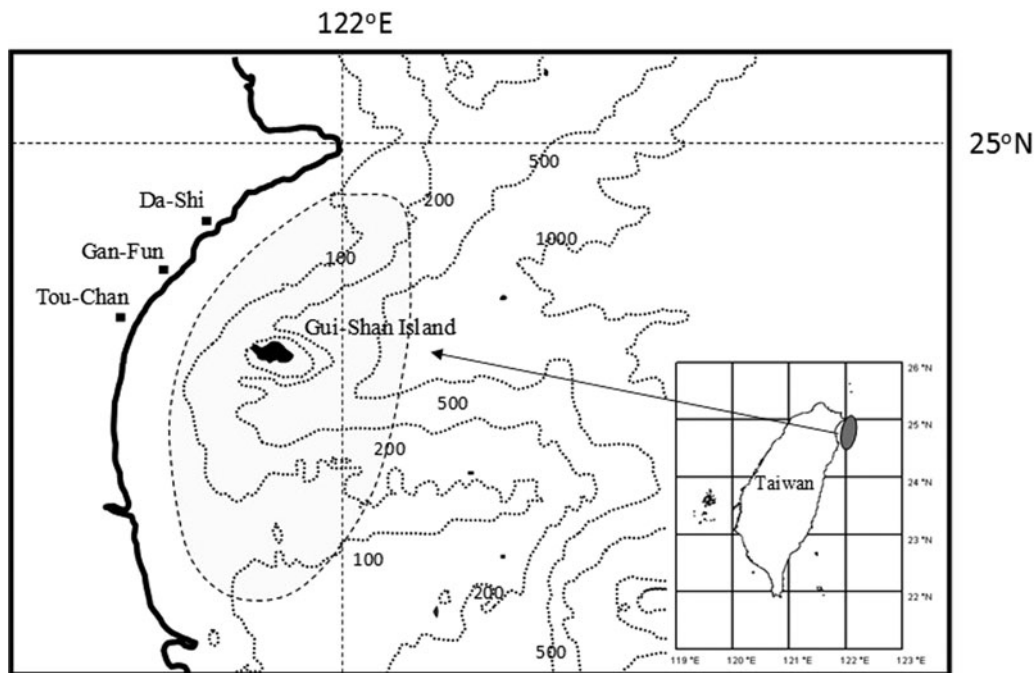
The Japanese butterflyfish *Psenopsis anomala* is an economically important demersal fish species that is widely distributed from southern Japan to the East China Sea and is commonly caught by trawl fishery along the north, north-east and west coasts of Taiwan (Wang & Chen, 1995). The average annual landings of this species in Taiwan was ~4700 mt between 1999 and 2008 (59% from offshore, 37.5% from far-sea and 3.4% from coastal fisheries), the largest landings of this species by any nation (Hwang, 2006).

The surrounding waters of Guei-Shan Island off north-eastern Taiwan is a traditional and important trawl fishing ground. The trawl fishery catch in this region accounts for 1/6 of the total coastal trawl catch of Taiwan. This region has been intensively fished over the past few decades, resulting in changes in the size and species composition of the catch (Wang *et al.*, 2013). Catches of several commercially important fish, such as the Japanese butterflyfish, black croaker *Atrubucca nibe*, bigeye *Priacanthus macracanthus*, yellow sea-bream *Dentex tumifrons*, red tilefish *Branchiostegus japonicus*, lizardfishes (Synodontidae) and Japanese barracuda *Sphyræna japonica*, are now dramatically decreased (Liu & Cheng, 1999; Wang *et al.*, 2007).

The catch statistics of *P. anomala* can be traced back to the 1970s when this species had not yet been intensively targeted by the coastal and offshore trawl fisheries. The estimated catch-per-unit-effort (CPUE) of *P. anomala* from these fisheries showed significant increases during the early 1980s and reached a peak in the late 1980s and early 1990s. It fell significantly thereafter and remained low in recent years (Wang *et al.*, 2015). The groundfish surveys conducted in 2006 by the Fisheries Research Institute, Taiwan, also showed a significant drop in the catch of *P. anomala* in the northern and north-eastern waters of Taiwan since the early 1990s (S. S. Chin, personal communication, October 2010).

Despite the economic importance of *P. anomala* and the potential impact from intensive fishing, little is known about the life history, population or fishery biology of this species or variations in these characteristics caused by natural or anthropogenic disturbances in the waters off Taiwan. An age and growth estimate of *P. anomala* was reported in Kii Channel, Japan in the early 1970s using annulus counting on scales (Sakamoto & Suzuki, 1974). Hu *et al.* (2006) also reported the growth, mortality and resource utilization of *P. anomala* in the East China Sea based on length frequency analyses. A preliminary study on the distribution pattern of *P. anomala* in Taiwan was conducted by Chen (1959). Wang & Chen (1989) described the gonad development based on a histological approach. The reproductive biology and energy storage cycle of this species were also described by Wang & Chen (1995) and Wu *et al.* (2012). However, no further studies on fishery biology have been carried out. A recent





**Fig. 1.** Map showing the bathymetric contours of the sampling site (shaded area) of this study. The numbers are isobaths in metres.

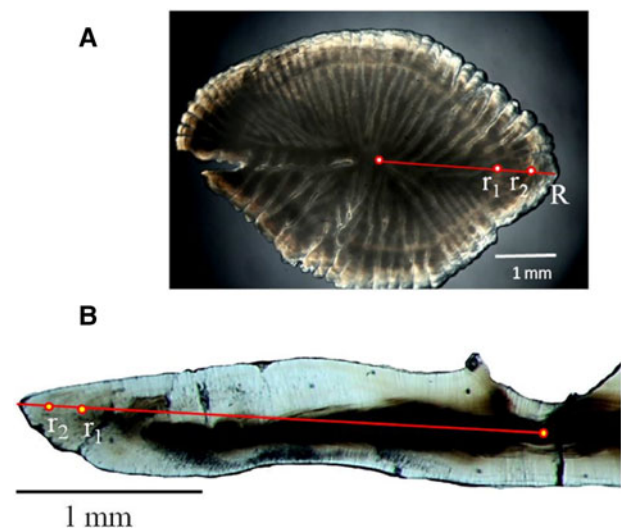
study on the possible fishing impacts on reproductive traits of this species (Wang *et al.*, 2015) concluded that changes in the population structure could not be evaluated due to a lack of age and growth information. The present study aims to estimate the age and growth structure of this species in the waters off north-eastern Taiwan by using otolith annulus counting. The results derived from this study can provide critical information for future stock assessment and management of this species in this region.

### Materials and methods

Samples of Japanese butterfish were opportunistically collected from catches of small bottom trawlers operated in waters surrounding Guei-Shan Island off north-eastern Taiwan on a bi-weekly basis from March 2007 to July 2008 (Figure 1). The operating depth of these vessels ranged from 50 to ~300 m, depending on the season and location. The mesh size used by these vessels was ~2.54 cm in the cod end.

All specimens brought to the laboratory were counted, the sex was identified, and measurements of total length (TL to the nearest 0.1 cm) and total weight (W to the nearest 0.01 g) of each individual were conducted. The sagittal otoliths were removed from all specimens, cleaned and stored dry. The relationship between total weight and total length was described using an allometric equation  $W = a \times TL^b$ . The difference in the log-transformed relationships between the sexes was examined using an analysis of covariance (ANCOVA).

Because thin-sectioned otoliths had faint rings, interpreting rings in thin sections required more judgement decisions than did whole otoliths (Figure 2) especially for older age classes when growth rings packed together, the whole otoliths were thus used. After being immersed in glycerine for 30 min with the distal face upward, annuli images of the otoliths were photographed by a digital camera (Moticam 2300) attached to a binocular microscope (Zeiss SV6, magnification: 20×) under transmitted light against a bright background. The otolith images were processed using image analysis software (Motic images plus 2.0) to produce ring counts and radial measurements. The nucleus and the opaque zones of otolith appeared as dark rings and the



**Fig. 2.** Photos of the (A) whole and (B) cross-sectioned otolith from two aged 2+ *P. anomala*. Lines showing the measured axis. R and  $r_n$  represent the otolith radius and the ring radius for the n age class.

translucent or haline zones as light rings. The combination of each opaque and subsequent translucent zone was considered to be an annulus (Figure 2A). Length and sex of the fish were unknown to the analyst who measured the otoliths using Motic images plus 2.0. A second reading was performed a month later by the same investigator. Annuli counts were accepted only if both counts were in agreement. A third count was carried out if the first two counts differed. If the third count did not agree with either of the previous two counts, the otolith sample was discarded.

The time and periodicity of annulus formation was estimated using the monthly changes in the marginal increment ratio (MIR) of the otoliths (Hass & Recksiek, 1995; Chiang *et al.*, 2004; Chen *et al.*, 2007). The MIR was calculated as:

$$\text{MIR} = \frac{R - r_n}{r_n - r_{n-1}}$$

**Table 1.** Sampling date, sex composition and range of total length (TL, cm) and body weight (BW, g) of *P. anomala* used in this study

Date	Sex			Total length (cm)	Body weight (g)
	Female	Male	Unsexed		
March 2007	16	8	–	18.0–23.0	77.37–179.62
April 2007	39	11	–	18.6–22.9	86.04–203.30
May 2007	25	17	–	12.9–23.7	44.05–189.46
June 2007	19	19	4	11.7–23.0	30.25–209.00
July 2007	–	14	26	10.0–23.2	18.05–219.54
August 2007	14	23	1	5.8–24.7	2.67–245.72
September 2007	15	32	–	13.1–24.0	35.04–209.77
October 2007	19	28	–	17.4–20.7	77.83–151.98
November 2007	32	24	–	16.5–21.2	63.17–147.84
December 2007	22	44	–	15.9–20.2	57.16–133.14
January 2008	20	39	–	16.3–20.6	65.07–136.10
February 2008	29	25	–	16.8–22.3	65.34–174.76
March 2008	24	27	–	17.5–21.7	81.28–144.53
April 2008	22	19	–	18.1–22.2	70.16–169.86
May 2008	11	2	–	18.8–21.5	100.39–158.78
June 2008	17	24	–	13.5–25.6	44.24–254.31
July 2008	16	7	–	18.5–22.7	92.31–181.45
Total	340	363	31	5.8–25.6	2.67–254.31

where  $R$  = otolith radius;  $r_n$  and  $r_{n-1}$  = the radius of ultimate and penultimate annuli.

The mean and standard error of the MIR were also computed for each month.

The index of the average percentage error (IAPE) (Beamish & Fournier, 1981), as shown below, was calculated to compare the reproducibility of age determination between the two readings:

$$\text{IAPE} = \frac{1}{N} \sum_{j=1}^N \left( \frac{1}{R} \sum_{i=1}^R \left( \frac{|X_{ij} - X_j|}{X_j} \right) \right) \times 100\%$$

where  $N$  is the number of fish whose ages were determined,  $R$  is the number of readings,  $X_{ij}$  is the  $i^{\text{th}}$  age determination of the  $j^{\text{th}}$  fish, and  $X_j$  is the mean age calculated for the  $j^{\text{th}}$  fish.

The relationship between TL and the otolith radius ( $R$ ) was estimated using a linear regression:  $TL = a + bR$ . An ANCOVA was used to compare the TL- $R$  relationship between sexes.

The von Bertalanffy growth function (VBGF) (von Bertalanffy, 1938) was fitted to the observed length at age data using non-linear (NLIN) procedure from the statistical package SAS (SAS Inc., 2008). The VBGF is described below:

$$L_t = L_{\infty} \{1 - \exp[-k(t - t_0)]\}$$

Where  $L_t$  is the length at age  $t$ ,  $L_{\infty}$  is the asymptotic length,  $k$  is the growth coefficient,  $t$  is the age (year from birth), and  $t_0$  is the theoretical age at length 0. A maximum likelihood ratio test was used for examining the difference of the VBGF between sexes (Kimura, 1980). Small individuals (i.e. age 0<sup>+</sup>) were generally rare, and their sex was difficult to determine. They are important however, for the estimation of growth, so small unsexed individuals were randomly assigned a sex based on the sex ratio obtained from the same size class when fitting the model. Finally, the growth performance index ( $\phi' = \log k + 2 \log L_{\infty}$ ) (Pauly & Munro, 1984)

was also used to compare the growth of *P. anomala* from different geographic regions.

## Results

In total, 734 specimens (340 females, 363 males, 31 unsexed) were collected. The total length and weight of the specimens ranged from 5.8 to 25.6 cm and 2.67 to 254.31 g, respectively (Table 1).

An analysis of covariance of the length-weight data suggested that the relationship between sexes significantly differed (ANCOVA) at the 5% level. Thus, the sex-specific W-TL relationships were described as follows:

$$\begin{aligned} \text{Females: } W &= 0.0248 \times TL^{2.838} \quad (n = 340, r^2 = 0.898) \\ \text{Males: } W &= 0.0424 \times TL^{2.647} \quad (n = 363, r^2 = 0.841) \end{aligned}$$

Although relatively high variabilities occurred on the relationships between otolith radius ( $R$ ) and TL for both sexes especially for small individuals, significant difference between sexes on the TL- $R$  relationship was found (ANCOVA,  $P < 0.05$ ); the equations were described separately as follows:

$$\begin{aligned} \text{Females: } TL &= -2.135 + 10.684R \quad (n = 340, r^2 = 0.704) \quad (\text{Figure 3A}) \\ \text{Males: } TL &= 0.884 + 8.862R \quad (n = 363, r^2 = 0.652) \quad (\text{Figure 3B}) \end{aligned}$$

The precision estimation provided an average IAPE of 5.13% for all the samples, indicating that the adopted ageing procedure yielded a reasonable level of consistency (or reproducibility) between readings (Campana, 2001).

Monthly changes in the otolith marginal increment ratio (MIR) showed that the lowest value occurred in August and gradually increased before reaching a peak in July. The result suggested that annulus was formed once a year and the opaque zone began to form between July and August (Figure 4).

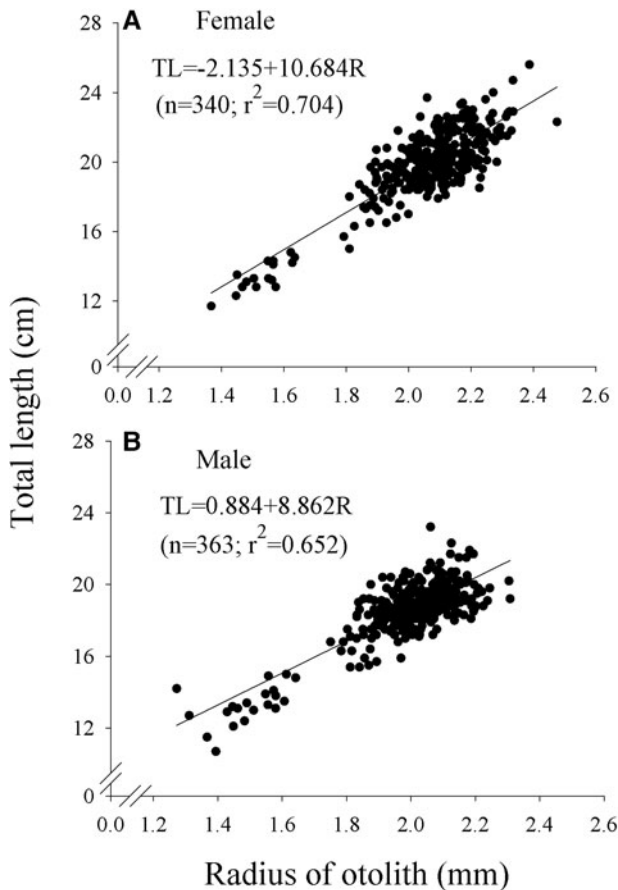


Fig. 3. Relationships between the total length (TL) and radius of otolith (R) for (A) female and (B) male *P. anomala*.

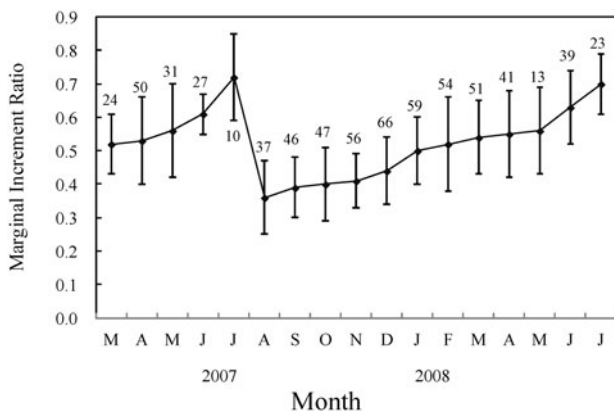


Fig. 4. Monthly changes in the marginal increment ratio (mean  $\pm$  1 SD) of the otolith of *P. anomala* (numbers represent the sample size of each month).

Opaque material was first observed in these months, but continued to be deposited in subsequent months.

The size distributions and the mean sizes for each ring group of female and male *P. anomala* are shown in Tables 2 & 3. The estimated maximum ages for both females and males were 4. Large individuals for the oldest age group in both sexes were rare. The dominant age class was 3<sup>+</sup> for females, accounting for 37.6% of the total, while together the age classes 2<sup>+</sup> (27.4%) and 4<sup>+</sup> (27.9%) accounted for another 55.3%. The age classes 0<sup>+</sup> and 1<sup>+</sup> only comprised ~7.1% of the catch (Table 2). The males however, were highly dominated by age class 2<sup>+</sup> fish, accounting for ~63.4% of the total. The age class 3<sup>+</sup> accounted for ~22.3%, and the remainder accounted for only 14.3% (Table 3).

Table 2. Age-length key, sample size (N), mean length (Mean), and standard deviation (SD) in cm for female *P. anomala*

TL(cm)	Age (year)				
	0 <sup>+</sup>	1 <sup>+</sup>	2 <sup>+</sup>	3 <sup>+</sup>	4 <sup>+</sup>
5-10					
10-11					
11-12	1				
12-13	4				
13-14	5				
14-15	7	1			
15-16		1			
16-17		4	1		
17-18		1	11		
18-19			41	4	
19-20			33	48	2
20-21			7	62	10
21-22				13	46
22-23				1	30
23-24					5
24-25					2
N	17	7	93	128	95
Mean	13.49	16.36	18.93	20.22	21.96
SD	0.86	0.82	0.81	0.69	0.89

The sex-specific von Bertalanffy growth functions estimated based on the observed TL at age data using the non-linear method were significantly different (maximum likelihood ratio test,  $P < 0.05$ ). The parameters of VBGF with standard error were estimated as:  $L_{\infty} = 25.47 \pm 0.65$  cm,  $k = 0.30 \pm 0.03$  year<sup>-1</sup>, and  $t_0 = -1.84 \pm 0.16$  year for females ( $n = 350$ , Figure 5A) and  $L_{\infty} = 22.39 \pm 0.45$  cm,  $k = 0.46 \pm 0.04$  year<sup>-1</sup>, and  $t_0 = -1.38 \pm 0.13$  year for males ( $n = 378$ , Figure 5B).

In addition, the growth equations in weight can also be obtained for both sexes. The equations were:

$$\text{Female: } W_t = 242.53(1 - e^{-0.30(t+1.34)})^{2.838} \quad (n = 350)$$

$$\text{Male: } W_t = 158.84(1 - e^{-0.46(t+1.38)})^{2.647} \quad (n = 378)$$

Based on the above estimation, the corresponding mean ages at first maturity for females and males derived from Wang & Chen (1995) were estimated to be ~1.0 and 0.71, respectively.

## Discussion

### Sample size distribution

Although the samples used in this study were opportunistically collected from the fish market each month, most of these individuals were between 17 and 20 cm TL and 18 and 22 cm TL for males and females, respectively. Individuals greater than 23 cm and less than 16 cm TL were rare. The lack of smaller individuals may be a consequence of discarding due to low commercial value, size selectivity of fishing gear or life stage-specific seasonal or vertical migration out of the fishing area.

Juvenile butterfish were found to aggregate and form a small shoal in shallow waters before they became demersal (Sakamoto & Suzuki, 1974). Based on the occurrence of the species in Kii



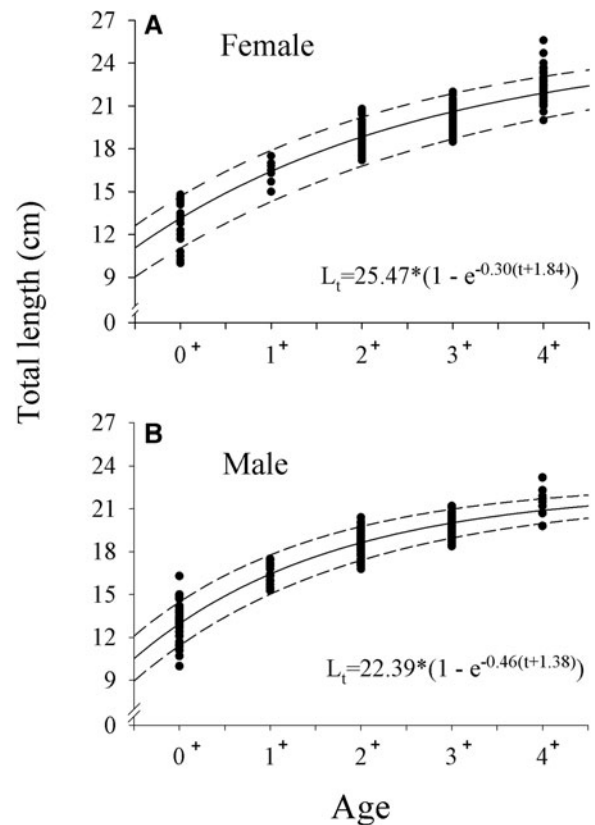
**Table 3.** Age-length key, sample size (N), mean length (Mean), and standard deviation (SD) in cm for male *P. anomala*

TL(cm)	Age (year)				
	0 <sup>+</sup>	1 <sup>+</sup>	2 <sup>+</sup>	3 <sup>+</sup>	4 <sup>+</sup>
5–10					
10–11	1				
11–12	1				
12–13	5				
13–14	8				
14–15	4				
15–16	1	6			
16–17		7	2		
17–18		7	39		
18–19			136	6	
19–20			49	45	2
20–21			4	28	2
21–22				2	6
22–23					1
23–24					1
24–25					
N	20	20	230	81	12
Mean	13.28	16.58	18.61	19.83	21.33
SD	1.09	0.73	0.66	0.59	0.98

Channel, Japan and juveniles collected by set nets, the authors suggested that *P. anomala* may migrate to shallow waters for spawning, and as a result, are less vulnerable to the bottom trawler. Moreover, Hu *et al.* (2006) also reported that the catch of *P. anomala* in the East China Sea peaked in August and September when the fish were closest to the near shore waters, indicating a possible onshore migration of the species during this time. These observations appear to coincide with a lower summer catch and a lack of juveniles in the surrounding waters off Taiwan (Wang & Chen, 1995; Wu *et al.*, 2012). As juvenile *P. anomala* also could not be found even in the refuse pile of trawlers, which comprised many small-size (<10 cm) and low value fishes, during our sampling period, the gear selectivity thus seemed to be an unlikely reason for this lower catch. Instead, it is likely that adult fish migrate either out of the sampling areas (i.e. to the coast of China) or to the shallow waters where larvae were hatched and stay there during this period.

### Annulus formation

As indicated above, thin-sectioned otoliths of butterfish had faint rings, thus, interpreting rings in thin sections required more judgement decisions than did whole otoliths, especially for older age classes because growth bands would be relatively tight together, meaning that an underestimate of true ages for these individuals could not be totally excluded. We tried the thin section method with various thicknesses, but the growth rings remained vague and not as clear as those from the whole otolith. The faint rings not only occurred near the otolith margin, but also were observed for all rings making identification difficult. Besides, the otolith of butterfish is very thin, adding another difficulty when reading compacted rings in thin sections. We also

**Fig. 5.** The growth curve in length (cm) for (A) female and (B) male *P. anomala* derived from the non-linear fitting method.

compared results of age readings from ~30 thin sectioned otoliths with those from the whole otoliths. The IAPE estimated from the former was much higher than the latter (i.e. ~11.1% vs 3.7%), and for those samples with consistent readings, two methods yielded the same result in ring counting. Thus, we decided to use the whole otolith for age estimation.

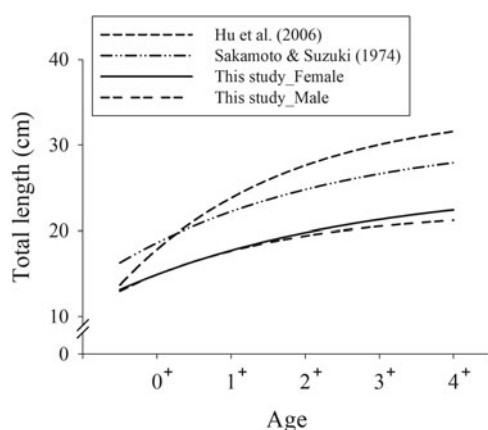
The annulus formation could be related to several possible causes, including a shortage of food, stress caused by migration and/or spawning, or changes in water temperature (Stevens, 1973; Campana, 1983; Pratt & Casey, 1983). Cheree *et al.* (2009) found that the annulus of the *Pomacanthus arcuatus* in the Florida Keys, USA was formed between May and September when the species spawned. Shimose & Tachihara (2005) also demonstrated that the annulus formation of *Lutjanus fulviflamma* was related to spawning rather than to changes in seasonal water temperature. Similarly, the annulus of *Choerodon schoenleinii* in the south-western waters of Okinawa, Japan was formed after the end of the spawning season (Akihiko *et al.*, 2010), indicating a possible influence of spawning. The formation of the annulus for *P. anomala* was between July and August, which coincides with the end of the spawning season (Wang & Chen, 1995; Wang *et al.*, 2015). The seasonal water temperature during this period remains high and stable (i.e. not in a transitional time of seasons). Thus, it is possible that the annulus formation of *P. anomala* results from a high physiological stress induced by spawning.

### Parameter estimates of growth model

In this study, the population of *P. anomala* was highly dominated by smaller individuals and younger age classes. The maximum observed size in this study was 25.6 cm for females and 23.2 cm TL for males, however, individuals larger than 23 cm for females (i.e.  $n=7$ ) and 22 cm TL for males (i.e.  $n=2$ ) were rare,

**Table 4.** Comparison of estimated parameters of the von Bertalanffy growth function from different geographic locations and years

Author	TL <sub>∞</sub> (cm)	k	t <sub>0</sub>	Sex	Material used	Sampling year	Region
Sakamoto & Suzuki (1974)	31.15	0.34	-1.674	Pooled	Scale	1970-1972	Kii Channel, Japan
Hu <i>et al.</i> (2006)	34.31	0.45	-0.63	Pooled	Length frequency	2001-2005	East China Sea
This study	25.27	0.31		Pooled	Otolith		North-eastern waters of Taiwan
	25.47	0.30	-1.84	Female	Otolith	2007-2008	
	22.39	0.46	-1.38	Male	Otolith		

**Fig. 6.** Comparison of growth curves for *P. anomala* derived from different studies.

accounting for only 2.1 and 0.6% of the samples, respectively. Although a relatively high variability of age reading for older age classes was observed, as the size ranges of the age 4<sup>+</sup> class for females (across 6 size classes in Table 2) was slightly larger than age classes of 2<sup>+</sup> and 3<sup>+</sup> (i.e. across 5 size classes), a few large individuals in the age 4<sup>+</sup> class were less likely to have a significant influence on the growth parameters estimate.

Besides, the NLIN method, which accounts for all individual variability, was believed to be more appropriate for the estimation of growth parameters (Vaughan & Kanciruk, 1982; Tetsuro *et al.*, 2008), the high dominance of smaller individuals and younger age classes (i.e. age 2<sup>+</sup> or 3<sup>+</sup>) of *P. anomala* may actually outweigh these size/age groups when fit to the growth model, and as a result, the asymptotic length is smaller than the largest sizes observed for both sexes.

In addition, both the maximum observed sizes (as indicated above) and the estimated asymptotic length of *P. anomala* in our study (25.47 cm TL for females and 22.39 cm TL for males) were smaller than those reported in other geographic regions (Table 4, Figure 6) (Sakamoto & Suzuki, 1974; Hu *et al.*, 2006). The largest individual observed and the asymptotic length estimated by Sakamoto & Suzuki (1974) in the Kii Channel, Japan was 21.60 and 24.32 cm FL, respectively, which is equal to ~27.67 and 31.15 cm TL (based on the conversion equation provided by the authors). Although the maximum size observed was not described, the asymptotic length estimated for the East China Sea was 26.78 FL (~34.31 cm TL) (Hu *et al.*, 2006). Apparently, the difference between the observed maximum sizes in these studies (25.60 cm vs 27.67 cm TL) was not as obvious as those seen for the estimated asymptotic lengths (25.47 vs 31.15 vs 34.31 cm TL) among the studies. The smaller asymptotic length especially for males also resulted in a higher estimated k in this study (0.46/year) compared with those reported by Sakamoto & Suzuki (1974) (0.34/year).

There are many possible explanations for these discrepancies. The differences may be due to the materials used to determine the age (i.e. scale vs length frequency vs otolith), and the influences of sampling years and sites across large geographic locations among studies (Table 4) also could not be excluded. Liu (unpublished data, 2009) reported that the growth of *Pagrus major* in southern Japan was faster than that reported in north-eastern Taiwan. The growth of *Scomber japonicus* in KuoSho, Japan was different from that in the East China Sea (Tetsuro *et al.*, 2008). In addition to these possibilities, the differences in the size distribution of the samples used among the studies could also be a cause. As described earlier, the maximum observed size in the Kii Channel was larger than that observed in our study, though the sample size used in both studies was large (i.e. more than 700 individuals) and the samples were collected across all seasons; thus, a small sample size or sampling bias is an unlikely reason for this discrepancy. Alternatively, if large individuals migrate to the shallow waters or to the coast of China for spawning (Hu *et al.*, 2006; Wang *et al.*, 2015), these fish would be less vulnerable to the bottom trawler and had little chance to be collected. Thus, further studies regarding the identification of stock structure of *P. anomala* and the migration patterns in the broad regions including the East China Sea and the surrounding waters of Taiwan are required and would provide valuable information for explaining these discrepancies.

### Growth performance

The index of growth performance ( $\phi$ ) is a useful parameter for comparing the growth of different populations of the same species and/or different species of the same order (Sparre *et al.*, 1987). Differences in growth rate could be due to genetic reasons but could also result from differences in food abundance and water temperature among geographic regions (Jia & Chen, 2011; Laurent *et al.*, 2012). Silva *et al.* (2008) showed that sardine growth performance is lower in the Mediterranean and declines across the north-eastern Atlantic from the English Channel to north Morocco. The decreased growth of Mediterranean sardines is possibly associated with the overall oligotrophy of this sea. The *Branchiostegus japonicus* found in the East China Sea and waters of Ji-Zhou Sea also showed a higher growth rate than those collected in the waters off north-eastern Taiwan (Liu *et al.*, 1996). Despite the potential influences of sampling gears used and size of fishes collected in studies discussed earlier, the estimated growth performance indices for *P. anomala* presented in this study were 2.29~2.36 for females and males. The  $\phi$  value for *P. anomala* in the Kii Channel, Japan was 2.52 (Sakamoto & Suzuki, 1974) and was 2.51 in the East China Sea (Hu *et al.*, 2006) for combined data from both sexes. Difference in growth performance among studies was likely due to the geographic variations (i.e. different latitude).

In conclusion, this study is the first attempt to provide information on the age and growth parameters of *P. anomala* in the waters off north-eastern Taiwan, which can be used as biological input parameters for future stock assessment of this species. Although a recent evaluation of the change in reproductive traits (including mean size of fish, size at first sexual maturity, energy reserve and fecundity) of *P. anomala* after decades of exploitation has been described (Wang *et al.*, 2015), it is not known whether such a change also implies changes in the population structure of the species. Thus, delineation of the stock structure and assessment of the stock status of this species in the surrounding waters of Taiwan is urgently needed. Such information would greatly improve our understanding of the fluctuations and ensure sustainable use of this highly exploited fish species in the region.

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