Ocean Sci. J. (2016) 51(3):355–362
http://dx.doi.org/10.1007/s12601-016-0031-y

Available online at http://link.springer.com
SpringerLink

pISSN 1738-5261
eISSN 2005-7172

Article

Age and Growth of Filefish, *Thamnaconus modestus* (Günther, 1877) off the Jeju Island of Korea

AhReum Kim[1], HoJin Bae[1], Hyeong-Gi Kim[2], and Chul-Woong Oh[1*]

[1]*Department of Marine Biology, College of Fisheries Sciences, Pukyong National University, Busan 48513, Korea*
[2]*National Oceanography Centre, University of Southampton, Southampton SO14 3ZH, UK*

Received 9 December 2015; Revised 9 April 2016; Accepted 8 June 2016

Abstract – The age and growth of filefish, *Thamnaconus modestus* (Günther 1877) in the southern waters of Korea were investigated. Samples were collected with commercial trawl catches during the period from May 2009 to December 2011. Of the 2,626 specimens collected, the sex ratio was not significantly different from 1:1 ($P > 0.05$). The total length ranged from 11.3 to 42.1 cm. The gonadosomatic index for both sexes was the highest in May to June, indicating that May to June is the main spawning period. The length of females at sexual maturity was 25.92 cm. The length-weight relationship of the filefish was $TW = 0.0121TL^{3.0536}$ ($n = 1,692$, $r^2 = 0.9034$, $P < 0.001$). The age of the sampled individuals was estimated by counting growth rings recorded on the 5th vertebrae; ages ranged from 0 to 9 years. The filefish of the same age displayed a high individual variation in total length. Length-at-age data were fitted by using the Von Bertalanffy growth model. The estimated Von Bertalanffy growth parameters were $L_\infty = 42.04$ cm, $k = 0.21$ year^{-1} and $t_0 = -1.56$ for females, $L_\infty = 41.20$ cm, $k = 0.18$ year^{-1} and $t_0 = -2.36$ for males, and $L_\infty = 43.16$ cm, $k = 0.17$ year^{-1} and $t_0 = -2.18$ for the combination of both male and female. These data can be used as useful biological information for the future fishery management of filefish resources in Korean waters.

Key words – *Thamnaconus modestus*, filefish, vertebrate, Von Bertalanffy

1. Introduction

The filefish *Thamnaconus modestus* is the most abundant of the 12 monacanthid species in Korea (Choi et al. 2002). The species is distributed in the coastal waters of Korea, southern China, Hokkaido (Japan), and inhabits a depth range of 50–110 m within a temperature range of 10–28°C (Choi et al. 2002). The scientific name of this species was *Navadon modestus* but it was changed to *T. modestus*. In recent years *T. modestus* has become one of the most important commercial species in the southern waters of Korea (NFRDI 2009). Despite its economic importance, little basic biological information is available for management of the filefish fishery. Landings of the species from trawl fisheries have yielded up to 300,000 tons since the 1980s (NFRDI 2009). There was a rapid decline in the catches of filefish in the 1990s as a result of overfishing to meet the demand for processed filefish as food (NFRDI 2009). Since then the landings have been approximately 2,000 tons per year; the lowest documented catch was 933 tons in 2002 (Fig. 1). The rapid reduction in filefish landings indicates that research necessary for proper resource management is urgently needed.

Many studies on the population biology of monacanthids have been conducted worldwide, especially with respect to age and growth. In Japan, studies of the filefish *N. modestus* have focused on catch, growth, and fisheries' characteristics in the Seto Inland Sea (Kakuda 1976, 1979; Kobata 1981), mortality in Iki channel (Yasunaga et al. 1984), spawning and growth in Niigata prefecture (Ikehara 1976) and the relationship between feeding rate and growth rate (Suzuki 1976). Ishida and Tanaka (1983) studied growth and maturation of the small allied filefish species *Rudarius ercodes* in Odawa Bay, Japan. In Australia, studies have been conducted into biological parameters and the commercial fishery potential of the ocean leatherjacket *Nelusetta ayraudi* (Miller 2007), and Kawase (2008) studied the reproductive biology of the black reef leather jacket *Eubalichthys bucephalys*. Peristiwady and Geistdoerfer (1991) reported on the biology of *Monacanthus tomentosus*

*Corresponding author. E-mail: ohcw@pknu.ac.kr

Fig. 1. Annual landings of filefish by fishing gear in Korea from 1980 to 2014

in Kotania Bay, Indonesia, and age determination and growth have been investigated for *Stephanolepis hispidus* in the Canary Islands (Manvera-Rodrígues and Castro-Hernández 2004) and for *S. diaspros* in Egypt (EL-Ganainy and Sabra 2008). Although some research has explored the age and growth of monacanthids, only one such study has been conducted in Korea (Park 1985).

As *T. modestus* does not have suitable characteristics for age determination, such as otolith or scales, it is difficult to accurately assess filefish age for use in the management of this fishery (Park 1985). The *T. modestus* otolith is too small to determine age, and their scales are easily degraded. For these reasons, Park (1985) examined growth rings of the vertebrae, hypural bone, mesoethmoid and pelvic bone to establish a suitable characteristic for age determination in this filefish, and concluded that the vertebrae were the most appropriate. Mancera-Rodríguez and Castro-Hernández (2004) also investigated growth rings in the anterior dorsal spine, and found good agreement between the length-at-age determined through direct observation of sectioned spines and ages determined using the length-based method, which validates the age measurements (EL-Ganainy and Sabra 2008). Unfortunately, age determination using the anterior dorsal spine involves a more complicated processing method than that using other parts. Thus, in this study the vertebrae of *T. modestus* were used to estimate fish age, based on the alternating opaque and translucent zones visible within the vertebrae structure.

The purposes of this study were to determine the age of *T. modestus* off Jeju Island, Korea, to estimate its growth parameters, and to provide biological information including age, growth rate, the length–weight relationship and size at maturity for this species in Korean waters.

2. Materials and Methods

Monthly random samples of *Thamnaconus modestus* were collected from the commercial trawl catches landed during the period from May 2009 to December 2011 off the Jeju Island of Korea except for December 2009 and January to March 2010 (Fig. 2). The total 1,698 specimens captured throughout the sampling months were conveyed in thermos cool boxes to the laboratory for analysis. For each fish, total length (TL) was measured (0.1 cm), total body weight (TW) and gonad weight (GW) recorded (0.01 g). A gonadosomatic index (GSI) was calculated for each sex as:

$$\mathrm{GSI} = \frac{\mathrm{GW}}{\mathrm{TW}} \times 100$$

Each female fish was assigned a maturity stage: immature, maturing, mature, running ripe and spent. Specimens lacking developed gonads were classified as immature. The length at 50% of female attained maturity was calculated by a logistic model for maximum likelihood procedures (Roa et al. 1999). A simple Chi-squared test was used for testing the sex ratio. The length-weight relationship was described by the equation $\mathrm{TW} = a\mathrm{TL}^b$. Analysis of covariance (ANCOVA) test was employed to compare the difference between the regression equations. The Kolmogorov-Smirnov two-sample

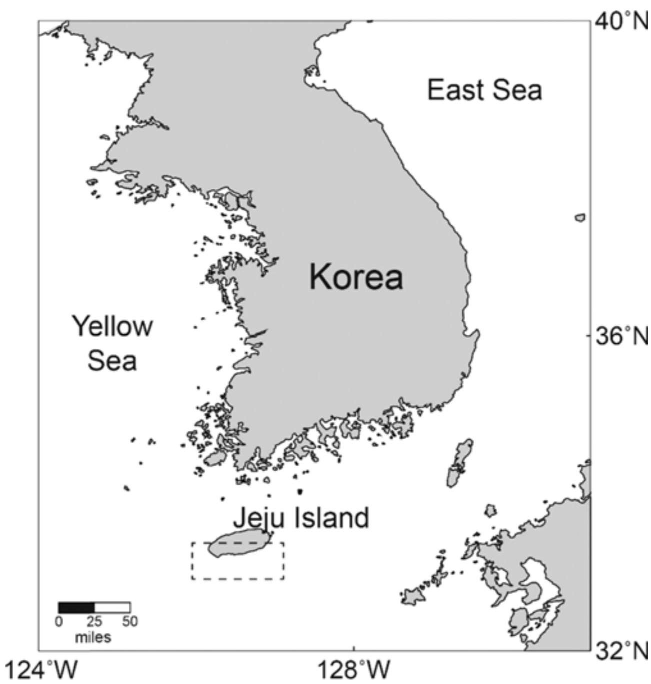

Fig. 2. Sampling area of *Thamnaconus modestus* off Jeju Island

test was used to analyze size frequency distributions of both sexes. Mean lengths of males and females were tested using *t*-test. Prior to using the *t*-test, data were tested for normality (Minitab v.12).

The vertebrae of 476 female individuals were taken for age and growth studies, those of 433 male were used. Fishes were randomly selected and vertebrae were excised. Vertebrae of filefish were excised from the 4^{th} to 9^{th} section of each fish. Prior to examination, each collected vertebra was cleaned with 4% solution of potassium hydroxide and a 70% solution of ethanol, and then dried. The growth rings of each vertebra were counted twice by the same reader using a stereoscopic microscope (magnification of 10× to 20×) (Carl Zeiss Discovery v.8) with an interval of two months. The marginal index (MI) was calculated as:

$$MI = \frac{R - r_n}{r_n - r_{n-1}} \times 10$$

where R is the diameter length of vertebra, r_n is n-th diameter length of vertebra, r_{n-1} is (n-1)-th diameter length of vertebra, n is the last ring number upper than 2.

Length at age was calculated by the Von Bertalanffy growth function (VBGF)

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

where L_t (cm) is the total length at age t, L_∞ (cm) is the asymptotic length, k (year^{-1}) is the body growth coefficient, and t_0 (age) is the hypothetical age of the fish at zero length (Beverton and Holt 1957). The VBGF estimates the relationship between total length and age in the growth model of fish. It has led to large variations in growth in the early life stage in previous studies because the expected total length is not considered at age 0 (Jung and Hwang 2010). The total length at age 0 was assumed as the total length of hatching larvae in this study, and the total length is 2.7 mm (Lee et al. 2000c). The growth performance Index (φ') used to compare the growth rate of each species and growth performance index is

$$\varphi' = 2\log L_\infty + \log k$$

where L_∞ and k are the asymptotic length and growth constant of Von Bertanlanffy growth parameter, respectively.

3. Results

A total of 1,698 *Thamnaconus modestus* individuals were

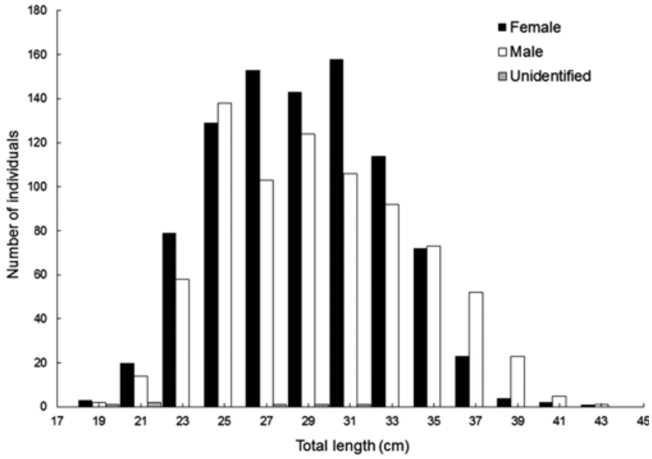

Fig. 3. Length frequency distribution of *Thamnaconus modestus* off Jeju Island

sampled, including 901 females, 791 males and 6 specimens for which the sex was unidentified. The male–female sex ratio was not significantly different from 1:1 ($\chi^2 = 7.151$, $P > 0.05$). The fish length ranged from 11.3 to 42.1 cm, and the mass from 17.43 to 1,051.2 g. The length frequency distribution showed the highest frequency was in the size class 25–27 cm. Although the mean lengths of females and males were not significantly different ($F = 2.31$, $df = 1$, $P > 0.05$), there was a significant difference between the size frequency distributions for males and females ($Z = 1.807$, $P < 0.05$) (Fig. 3).

The monthly change in GSI for both sexes indicates the spawning period and there was a slightly different pattern in GSI interannually. In females, the values of GSI peaked in May 2009, 2010 and in June 2011 (Fig. 4). There was a significant difference in males among months examined but the higher values were observed in May and June during study period. Thus, the spawning period of *T. modestus* was May to June. Based on five maturity stages, the first mature females were observed at a length of 20.8 cm, and the length at sexual maturity ($L_{50\%}$) of females was estimated to be 25.92 cm (Fig. 5). The length–weight relationship for males was described by the parameters $a = 0.0117$ and $b = 3.0671$ ($r^2 = 0.9108$, $P < 0.001$, $n = 791$), and for females by the parameters $a = 0.0136$ and $b = 2.9905$ ($r^2 = 0.9154$, $P < 0.001$, $n = 901$) (Fig. 6). The slope and intercept of the relationship between sexes were not significantly different (ANCOVA, $P > 0.05$). Therefore, the calculated length–weight relationship of all fish combined was $TW = 0.0121TL^{3.0426}$ ($r^2 = 0.9034$, $P < 0.001$, $n = 1692$). The b value in the relationship indicates that the slope of the combined sexes displays an allometric form, with the 95% confidence interval for the b value being 2.9950–3.0900.

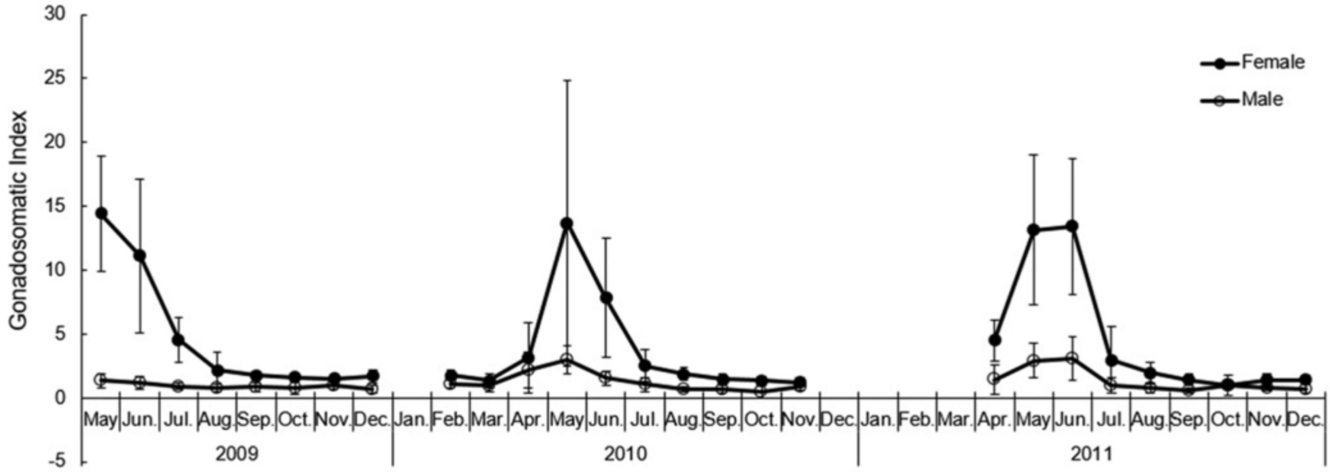

Fig. 4. Monthly changes in the gonadosomatic index of *Thamnaconus modestus* in Jeju Isaland

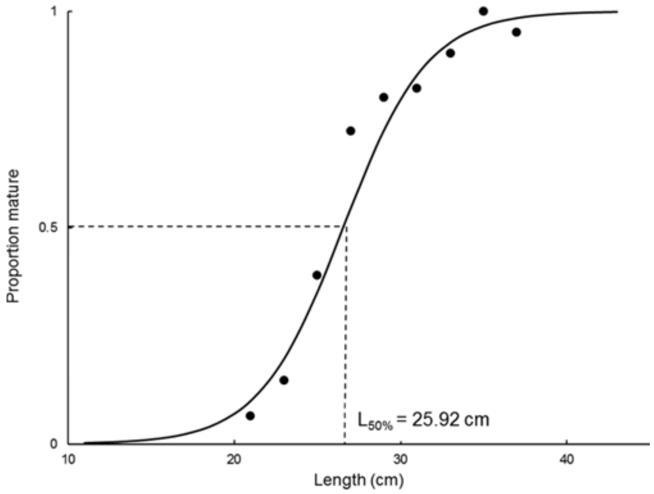

Fig. 5. The logistic curve relating the proportion mature individuals to length for *Thamnaconus modestus* off Jeju Island

The 909 individuals of *T. modestus* used for age determination comprised 433 males and 476 females, and age was estimated by counting annuli in vertebrae (Fig. 7) This analysis revealed 10 age classes including the age 0 group, which was represented by 18 individuals. The oldest *T. modestus* male and female were estimated to be 9 and 7 years old, respectively. Age classes 3 and 4 were dominant in the total catch (Table 1). There was a significant difference in the mean age between males and females ($F = 4.99$, $df = 1$, $P < 0.05$), and the age distribution was highly significantly different between the sexes ($Z = 1.919$, $P < 0.001$).

The MI of *T. modestus* presented the lowest value in February (Fig. 8). The result asserts that the ring would form once between January and March per year, so the ring could be considered the annual ring. The Von Bertalanffy

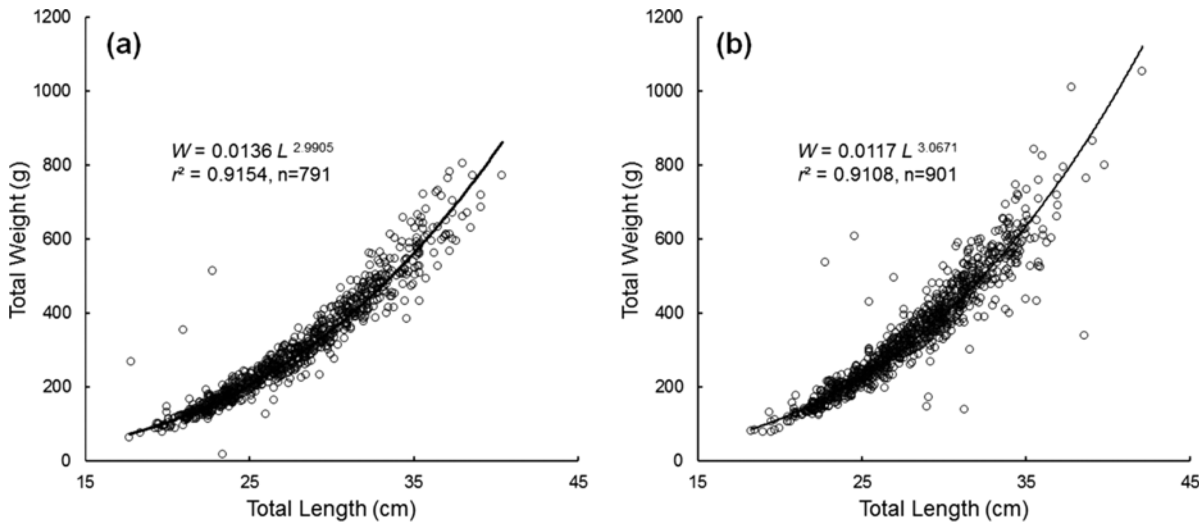

Fig. 6. The relationship between total length and total weight of *Thamnaconus modestus* off Jeju Island: (a) male and (b) females

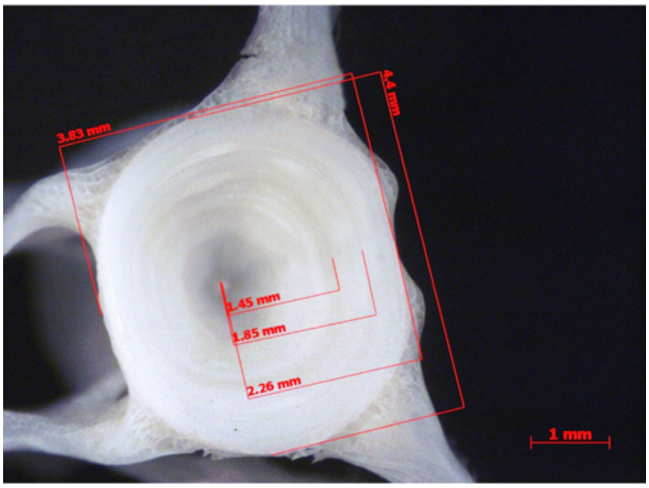

Fig. 7. The vertebra of 3-year-old *Thamnaconus modestus*

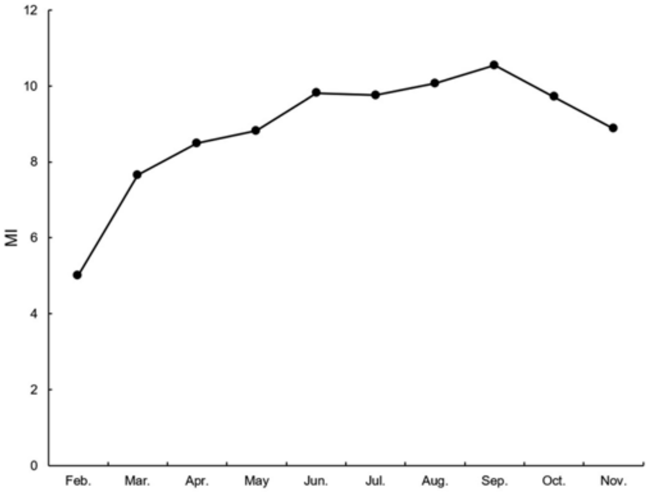

Fig. 8. Monthly variation of the marginal index (MI) of *Thamnaconus modestus* in Jeju Island

growth parameters were estimated for the combined sample, and included the asymptotic length (L_∞; 43.16 cm), the growth coefficient (k; 0.17 year^{-1}) and the hypothetical age of the fish at zero length (t_0; –2.18 year). Based on the Von Bertalanffy growth equation, the L_∞, k and t_0 values for *T. modestus* were calculated to be respectively 42.04 cm, 0.21 year^{-1} and –1.56 for females, and 41.20 cm, 0.18 year^{-1} and –2.36 for males. Fig. 9 shows the Von Bertalanffy age–total length growth curve relationships for *T. modestus* off Jeju Island. The female fish were estimated to be 0–7 years old, while the male fish were estimated to be 0–9 years old. Up to approximately 3 years of age the growth rate (based on total length) of males was higher than that of females, after which the total length of females increased more rapidly than that of males.

Table 1. Length at age data of *Thamnaconus modestus* (N = 921) off Jeju Island

Length intervals (cm)	Age										
	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	Total
17–19	2	22									24
19–21	14	34	14	6	12						80
21–23		12	25	4	5						46
23–25	2	11	16	39	24						92
25–27			4	58	31	1					94
27–29			0	14	56	8					78
29–31			14	55	59	14					142
31–33			12	4	56	22					94
33–35				8	70	58	16				152
35–37				6	28	30	14	5			83
37–39								2	9	1	12
39–41						1	7	4			12
41–43											0
Total	18	79	85	194	341	134	37	11	9	1	909
%	1.98	8.69	9.35	21.34	37.51	14.74	4.07	1.21	0.99	0.11	
Mean TL (cm)	19.77	20.28	25.33	27.58	30.28	33.54	35.93	37.75	38.60	38.60	
SD TL	1.39	1.64	4.13	3.35	3.89	2.22	2.08	1.98	0.00	0.00	
Mean TW (g)	98.96	102.41	248.75	303.79	435.39	552.07	638.77	683.62	772.49	772.49	
SD TW	20.43	62.74	148.40	119.34	161.16	114.85	91.36	124.83	0.00	0.00	

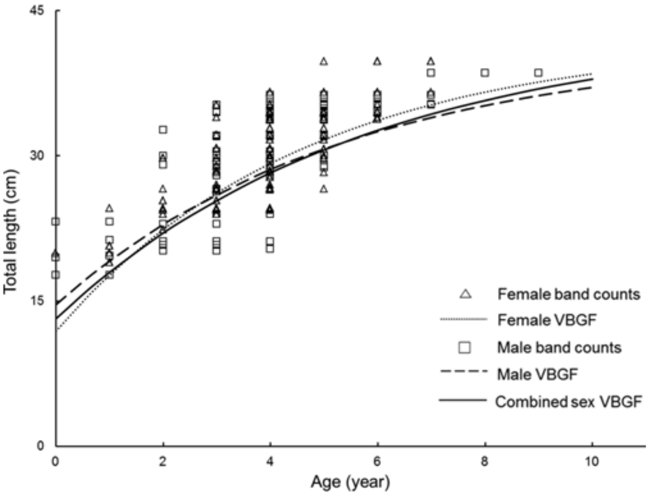

Fig. 9. The Von Bertalanffy growth function (VBGF) for female (L_∞ = 42.04 cm, k = 0.21 year^{-1}, t_0 = -1.56 year), male (L_∞ = 41.20 cm, k = 0.18 year^{-1}, t_0 = -2.36 year) and combined sex (L_∞ = 43.16 cm, k = 0.17 year^{-1}, t_0 = -2.18 year) of *Thamnaconus modestus* off Jeju Island

4. Discussion

Monacanthid fishes are captured in great numbers in commercial fisheries throughout Asia, primarily by large trawling vessels (Park 1985). Historical catch information suggests that the filefish stocks in Korea were reduced during the 1980s, when they were targeted by these vessels (NFRDI 2009). These data indicate that filefish are vulnerable to overfishing and that any further increase in fishing activities may cause stock to decline.

In this study, the spawning period of *Thamnaconus modestus* was estimated to be between April and June. Similar results have been reported in previous studies (Choi and Park 1982; Park 1985; Lee et al. 2000a, 2000b; Kwon et al. 2011). Park (1985) reported that the spawning period of *T. modestus* was estimated to be from May to June in the East Sea and Yellow Sea, and April to June in the southern sea of Korea. Lee et al. (2000b) also reported that the spawning period was estimated to be from April to June in Jeju Island. Combing the results of previous studies and this study, the spawning period of *T. modestus* was ascertained to be from May to June. The length at maturity was estimated to be 25.92 cm in this study. The length at sexual maturity of the same species was estimated by Park (1985) to be 21 cm. Age and length at maturity could be affected by the following factors: (1) resource availability, (2) habitats and (3) fishing gears. First, with regard to resource availability, some fishes show a higher reproductive rate than others that live in food-scarce areas or have a small population size (Diana 1951). Second, with regard to habitats, the difference between habitats in terms of environmental conditions can affect the length at sexual maturity. Finally, fishing gears also affect how the length at maturity is calculated due to various mesh sizes (Sary et al. 1997). In this study, we assumed that there could be a difference in length at maturity because of different gears between studies. In the study of Park (1985), a variety of fishing gears such as purse seine, danish seine and trawl were used, and these fishing gears had different mesh sizes, respectively. On the other hand, a commercial trawl with the same mesh size was only employed in this study. For this reason, the fish size of the Park (1985)'s study appeared to be smaller than that of this study. This means that the length of maturity of Park (1985)'s study was underestimated because of the small size fish. In some cases, owing to small fish, size at maturity could be underestimated compared to that of the original population.

The vertebrae of *T. modestus* showed distinct patterns of alternating hyaline and opaque bands, as occur in other fishes. The patterns of *T. modestus* were created once at their vertebrae per year, so it is considered that the ring is an annual ring and the same as the one noted by Park (1985). The nine annuli found in the vertebrae indicated age classes from 0 to 9. Alternating bands of hyaline and opaque zones have been reported in other studies, based on a variety of methods. Peristiwady and Geistdoerfer (1991) reported five age classes (1–5 years) for *Monacanthus tomestosus* in Indonesia, based on the length frequency histogram, and Miller et al. (2010) estimated six age classes (ages 1–6) for *Nelusetta ayraudi* in Australia, based on counts of otolith growth rings. The L_∞ and k values are not an indication of the growth rate. The growth performance index (φ'), based on the Von Bertalanffy growth parameters, has been estimated for monacanthids worldwide (Table 2), and *T. modestus* shows better growth than other filefish. The L_∞ and k values indicate the relative growth rates of fish, and can be affected by environmental conditions and population size among different filefish habitats.

This study revealed that the length (25.92 cm) at the cross point of the VBGF between male and female *T. modestus* was similar to that at 50% sexual maturity. It is important to develop an alternative approach to the estimation of the length of female fish at 50% sexual maturity. Estimates of length are generally calculated using the gonad stage, so it is impossible to estimate the length at 50% sexual maturity in the

Table 2. Comparision of Von Bertalanffy growth parameters of family monacanthidae reported around the world

Species	Parameters				Authors	Region
	L_∞ (cm)	k (year^{-1})	t_0 (year)	φ'		
Navodon modestus	37.8	0.168	-2.262	2.38	Park (1985)	Korea
Monacanthus tomentosus	11.79	0.86	-	2.08	Peristiwady and Geistdoerfer (1991)	Indonesia
Stephanolepis hispidus	25.7 (female) 27.4 (male)	0.40	-	2.42 (f) 2.48(m)	Mancera-Rodríguez and Castro-Hernández (2004)	Canary Island
Nelusetta ayruadii	59.1	0.377	-0.247	3.11	Miller et al. (2010)	Australia
Stephanolepis diaspros	27.83	0.350	-0.499	2.43	EL-Ganainy and Sabra (2008)	Egypt
Thamnaconus modestus	46.19 (female) 41.20 (male)	0.21 0.19	-1.560 -2.363	2.57 2.51	This study	Korea

absence of gonads. Unlike previous methods, in this study the length could be estimated using the VBGF, even when gonads were not present. However, this approach must be statistically assessed through further studies. If verified, it may prove useful in estimating the length of fish at 50% sexual maturity in the absence of gonads.

In Korea there are presently no regulations restricting the sizes of *T. modestus* permitted to be caught. The results of this study will enable fisheries managers to set a minimum legal filefish size to ensure that stocks are maintained. For example, those who set policies regarding the protection of filefish should require that the catch taken by both recreational and trawl fishers be limited to that consistent with sustainable management. Policies related to a minimum legal length may also be helpful in protecting the fish in its early stages of life. Because filefish are vulnerable to overexploitation, especially in Korean waters, it will be important to maintain their habitat. In addition, continued monitoring of the sizes and ages of filefish in landings is required to investigate changes in population structure, which result from the current increasing level of exploitation. It may also be necessary to require modification of some fishing equipment, such as regulating the mesh size of nets to reduce the incidental capture of *T. modestus* less than 26 cm in size, which is a little larger than the length at 50% sexual maturity.

In conclusion, this research provides biological information necessary for the future assessment of filefish stocks, including information required for sustainable management of those stocks in the southern waters of Korea.

Acknowledgements

We especially would like to thank Dr. Jong-Hun Na for commenting on an early manuscript. We are also grateful to the students of the Marine Ecology Laboratory at Pukyong National University for their great assistance. This work was supported by a Research Grant of Pukyong National University (2016 Year).

References

Beamish RJ, Fournier DA (1981) A method for comparing the precision of a set of age determination. Can J Fish Aquat Sci **38**:982–983

Berry FH, Vogele LE (1959) Fishes (Monacanthidae) of the western North Atlantic. Fish Bull (Wash D C) **181**:1–109

Beverton RJH, Holt SJ (1957) On the dynamics of exploited fish populations. Fisheries Investigations Series II, vol 19, 553 p

Campana SE, Annand MC, McMillan JI (1995) Graphical and statistical methods for determining the consistency of age determinations. T Am Fish Soc **124**:131–138

Campana SE (2001) Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. J Fish Biol **59**:197–242

Chang WYB (1982) A statistical method for evaluating the reproducibility of age determination. Can J Fish Aquat Sci **39**:1208–1210

Choi SH, Park CS (1982) Maturity and spawning of file fish, *Navodon modestus* (Gunther), in the southern waters of Korea. Bull Nat Fish Res Dev Agency **30**:73–80 (in Korean)

Choi Y, Kim JH, Park JY (2002) Marine fishes of Korea. Kyo-Hak, Seoul, 646 p

Diana JS (1951) Biology and ecology of fishes, 2nd edition. Cooper, Traverse City, 498 p

EL-Ganainy AA, Sabra MMM (2008) Age, growth, mortality and yield per recruit of the filefish *Stephanolepis diaspros* (Fraser-Brunner, 1940) (Pisces: Monacanthidae), in the Gulf of Suez, Egypt. J Fish Aquat Sci **3**(4):252–560

Francis RICC (1990) Back-calculated of fish length: a critical review. J Fish Biol **36**:833–902

Ikehara K (1976) Notes on the spawining and growth of *Navodon modestus* (GUNTHER) in the near-shore waters of Niigata prefecture. Bull Jap Sea Reg Fish Res Lab **27**:41–50

Ishida Y, Tanaka S (1983) Growth and maturation of the small filefish *Rudarius ercodes* in Odawa Bay. Bull Jap Soc Sci Fish **49**(4):547–553

Jung SG, Hwang SD (2010) Fisheries resource assessment study comparing fish growth equation: view the mackerel. In: Proceedings of the Korean Society for Industrial and Applied Mathematics, Busan, 3–4 Dec 2010

Kakuda S (1976) On the catch of *Navodon modestus* (Gunther) in the Seto Inland Sea. J Fac Fish Anim Husb Hiroshima Univ **15**:219–231

Kakuda S (1979) On the growth of the File-fish, *Navodon modestus*, in the Seto Inland Sea. J Facul Appl Biol Sci Hiroshima Univ **18**:197–205

Kawase H (2008) Reproductive ecology of the black reef leatherjacket, *Eubalichthys bucephalus* (Monacanthidae) in temperate Australia. Ichthyol Res **55**:294–298

King M (2007) Fisheries biology, assessment and management, second edition. Blackwell, Oxford, 382 p

Kobata T (1981) Ecological studies on important fish in Sagami Bay. 1-2. On fisheries characteristics of *Navodon modestus* (Günther) caught in the waters off Seisho District. Bull Kanagawa Prefect Fish Exp Stn **3**:29–37

Kwon HC, Lee JB, Zhang CI, Lee DW, Choi YM (2011) Maturation and Spawning of Filefish, *Stephanolepis cirrhifer* in the East Sea of Korea. Korean J Ichthyol **23**(2):111–118

Lee SJ, Go YB, Lee YD (2000a) Annual Reproductive cycle of the file fish, *Stephanolepis cirrhifer*, on the Southern Coast of Cheju Island. Korean J Ichthyol **12**(1):62–70

Lee SJ, Go YB, Lee YD, Jung JH, Han CH (2000b) Annual Reproductive cycle of file fish, *Thamnaconus modestus*, on the Southern Coast of Cheju Island. Korean J Ichthyol **12**(1): 71–84.

Lee SJ, Go YB, Choi YC (2000c) Egg development and morphological changes of larvae of the file fish, *Thamnaconus modestus*. Korean J Ichthyol **12**(3):208–214

Mancera-Rodriguez NJ, Castro-Hernandez JJ (2004) Age and growth of *Stephanolepis hispidus* (Linnaeus, 1766) (Pisces: Monacanthidae), in the Canary Islands area. Fish Res **66**:381–386

Miller ME (2007) Key biological parameters and commercial fishery for ocean leatherjackets '*Nelusetta ayraudi*' (Monacanthidae) off the coast of New South Wales, Australia. M.D. Thesis, University of Wollongong, 150 p

Miller ME, Stewart J (2009) The commercial fishery for ocean leatherjackets (*Nelusetta ayraudi*, Monacanthidae) in New South Wales, Australia. Asian Fish Sci **22**:257–264

Miller ME, Stewart J, West RJ (2010) Using otoliths to estimate age and growth of a large Australian endemic monocanthid, *Nelusetta ayraudi* (Quoy and Gaimard, 1824). Environ Biol Fish **88**:263–271

Nelson JS (2006) Fishes of the world, 4th edition. John Wiley and Sons, New Jersey, 601 p

NFRDI (2009) Research on actual fisheries state and biological characteristic of *Thamnaconus modestus*, 2009. National Fisheries Research and Development Institute, Busan, NFRDI Research Paper, 100 p (in Korean)

Oh CW (2012) Biostatistics: choice and application of statistical method and interpretation. Kyobo books, Seoul, 192 p

Park BH (1985) Studies on the fishery biology of the filefish *Navodon modestus* (Gunther) in the Korean waters. Ph.D. Thesis, Pukyong National University, 66 p (in Korean)

Pauly D (1980) A selection of simple methods for the assessment of tropical fish stocks. FAO, Rome, FAO Fisheries Circular No. 729, 54 p

Pauly D (1983) Some simple methods for the assessment of tropical fish stocks. FAO, Rome, FAO Fisheries Technical Paper No. 234, 52 p

Peristiwady T, Geistdoerfer P (1991) Biological aspects of *Monacanthus tomentosus* (Monacanthidae) in the seagrass beds of Kotania Bay, West Seram, Moluccas, Indonesia. Mar Biol **109**:135–139

Roa R, Ernst B, Tapia F (1999) Estimation of size at sexual maturity: evaluation of analytical and resampling procedures. Fish Bull (Wash D C) **97**:570–580

Sary Z, Oxenford HA, Woodley JD (1997) Effects of an increase in trap mesh size on an overexploited coral reef fishery at Discovery Bay, Jamaica. Mar Ecol-Prog Ser **154**:107–120

Suzuki T (1976) Relationship between feeding rates and growth rates of filefish, *Navodon modestus* (GUNTHER). Bull Jpn Sea Reg Fish Res Lab **27**:51–57

Yasunaga N, Yasumoto S, Hirakawa E, Tsukahara JI (1984) On the massive mortality of oval filefish (*Navodon modestus*) caused by *Pastuerella piscicida*. Fish Pathol **19**(1):51–55

Zar JH (2010) Biostatistical analysis. Pearson Education, 944 p

Zhang CI (2010) Marine fisheries resouce ecology. Pukyong National University Press, South Korea, 561 p