First Biometric Relationship and Seasonal Condition Factors of *Sebastes zonatus* Chen and Barsukov, 1976 and *Thamnaconus modestus* (Günther, 1877) Inhabiting the Waters of Ulleung-do and Dokdo

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ABSTRACT This study is the first to report the biometric information between the length and weight relationships (LWR) and seasonal body condition factors (*K*) of *Sebastes zonatus* Chen & Barsukov, 1976 and *Thamnaconus modestus* (Günther, 1877) inhabiting the waters off Ulleung-do and Dokdo. The LWRs in spring and summer, and all seasons combined were highly correlated ($r^2 > 0.959$), and the regression slopes of LWRs were significantly different between the spring and summer in both species. The body conditions of the two fish were significantly higher during the spring than during the summer, reflecting their fatness in relation to spawning. The results from this study contribute to the understanding of the biology of *S. zonatus* and *T. modestus* and provide useful data for the development of conservation and management plans for these species.

Key words: Rockfishes, filefishes, LWR, body condition factor, East Sea

INTRODUCTION

Body morphometric data of fishes are useful tools in fisheries sciences because fish species (intraspecific units) and populations (stocks) often have unique morphological characteristics that can be identified and compared via morphometric relationships (King, 1995; Froese, 1998; Park *et al*., 2018). Among the morphometric data, the exponential parameter *b* and intercept *a* of length-weight relationships (LWRs) are applicable for assessing fish stocks and populations (Ricker, 1968), because stock assessment models require information about the body weight (e.g., biomass) of populations to estimate and regulate optimal catches of fish stocks (Breen *et al*., 2003; Froese *et al*.,

2014). Morphometric relationships (e.g., length-weight and length-length relationships) also can be used for comparing relative growths between taxonomically similar fish species and/or estimating alternative growth patterns of understudied fish species (Kwak and Park, 2016; Park *et al*., 2017). Fulton's condition factor is widely used to measure the health of overall fish body and assess seasonal patterns in the body condition of the individual fish (Le Cren, 1951; Froese, 2006) because heavier fish of a given length are in better condition than lighter fish (Bagenal and Tesch, 1978).

Sebastes zonatus and *Thamnaconus modestus* are reef-associated subtropical and/or temperate marine fish species inhabiting shallow coastal regions (Nakabo, 2002; Kim *et al*., 2005), and belong to the families Sebastidae (rockfishes) and Monacanthidae (filefishes), respectively. They are mainly distributed in the Northwest Pacific region, especially the seas surrounding the Korean Peninsula and

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Japanese islands, as well as the East China Sea (Froese and Pauly, 2022). *Sebastes zonatus* was previously regarded as a color scheme for *S. vulpes* but was differentiated by Chen and Barsukov (1976). However, because of its similar shape to *S. vulpes*, the species is still regarded as a color variation and is often misclassified as *S. vulpes*. This species is only abundant around Ulleung-do and Dokdo coastal regions (Chung *et al*., 2015), but rarely occurred in other coastal habitats of Korean Peninsula.

Thamnaconus modestus is one of the major commercial fish species harvested from coastal fisheries in the southern and southeastern seas of South Korea. The commercial landings of *T. modestus* have gradually decreased since the 1980s due to several reasons including overfishing (Kim *et al*., 2016). However, a lack of fisheries data for these species makes difficult the formulation of management strategies. Several studies have documented the biology and ecology of the species globally (e.g., Baeck *et al*., 2012b; Kim *et al*., 2016; Choi *et al*., 2020; Goto and Takanashi, 2020), but there is a lack of information regarding the biometric relationships and seasonal body condition factors of the two species. Only a few studies reported their age and growth (Kim *et al*., 2016; Goto and Takanashi, 2020).

This study provides the first biometric information (e.g., LWR) and seasonal body conditions of *S. zonatus* and *T. modestus* inhabiting the waters off Ulleung-do and Dokdo. Moreover, this study will serve as baseline data to support future studies on the life history and evaluate the status of fisheries resources of these species.

MATERIALS AND METHODS

1. Sample collection

Sampling was conducted in the waters off Ulleung-do and Dokdo, Korea (37°28′N, 130°54′E and 37°14′N, 131°51′E, respectively). Fish samples of bycatch were collected during the spring (April) and summer (August) over three consecutive years (2020~2022) at depths between 30 m and 140 m using a bottom gillnet (75 m length, 2 m height, and 90 mm mesh). The individuals were snap-frozen and transported to the laboratory immediately after the collection. For each specimen, total length (TL) and wet body weight (BW) were measured to the nearest millimeter and gram, respectively.

2. Data analysis

For each species, the allometric equation of the length-weight function, $BW = a\,TL^b$, was fitted to the data using linear regressions of log10-transformed data, where a and b are the intercept and allometric coefficient, respectively (Brodziak, 2012). The standard errors (SE) of parameters a and b and the statistical significance level of r^2 for the LWRs were estimated. Extreme outliers were removed before fitting the linear regression according to the suggestion of Froese *et al*. (2011). The LWRs values were summarized for each season (spring and summer) and all seasons combined. Differences in b values from the isometric value of the three were tested using the Student's t-test. A full factorial analysis of covariance (ANCOVA) was used to test the effect of the categorical factor of seasons on the relationship between body weight and total length.

Fulton's condition factor (K) was calculated for each fish using the equation $K = 100 \times BW/TL^3$ (Pauly, 1984; Froese, 2006). Differences in body condition were examined with respect to the season. Since there was no evidence of heteroscedasticity (P>0.05), a Student's t-test was used to assess if the b values were significantly different from isometric growth ($b = 3$), as well as differences in body condition factor between spring and summer. All statistical analyses were performed using the SYSTAT software (Systat version 18.0, SPSS Inc., Chicago, IL, USA). An assumed significance level of 0.05 was used in all statistical analyses.

RESULTS

Length-weight regressions were performed on 109 *S. zonatus* specimens and 236 *T. modestus* specimens. The estimated parameters of LWRs and their descriptive statistics by season and all seasons combined are provided in Table 1. All LWRs were highly significant (P<0.05), with r^2 values ranging from 0.985 to 0.990 for *S. zonatus* and 0.959 to 968 for *T. modestus*. Estimated b values ranged from 2.997 during the summer to 3.194 during the spring for *S. zonatus*, while it was between 2.937 (summer) and 3.072 (spring) for *T. modestus*. Overall, the b value of the LWRs was higher than 3 (Student's t-test, P<0.05) for *S. zonatus* exhibiting positive allometric growth, while the b value of *T. modestus* was lower than 3 (P<0.05), exhibiting negative allometric growth. Seasonally, the b values did not differ significantly from 3 (P>0.05) for *S. zonatus* in the summer and *T. modestus* in the spring, showing isometric growth (Table 1). ANCOVA results revealed that the slopes (allometric coefficient) of the LWRs were significantly different between the spring and summer for both *S. zonatus* and *T. modestus* (Fig. 1; P<0.05).

The mean Fulton's body condition of *S. zonatus* and

Table 1. Length-weight relationship (LWR) parameters of *Sebastes zonatus* and *Thamnaconus modestus* inhabiting the waters off Ulleung-do and Dokdo

| Species	Factors	N	TL (cm)	BW (g)	$W = a L^b$					Growth type	ANCOVA
					a	SE	b	SE	r^2		
Sebastes zonatus Chen and Barsukov, 1976	Season										<0.001
	Spring	73	20.3~42.5	162.0~1,659.1	0.0099	0.122	3.194	0.083	0.977	+ A	
	Summer	36	13.6~39.4	44.9~1,271.9	0.0177	0.103	2.997	0.073	0.990	I	
	Total	109	13.6~42.5	44.9~1,659.1	0.0119	0.078	3.133	0.054	0.985	+ A	
Thamnaconus modestus (Günther, 1877)	Season										<0.001
	Spring	117	18.6~42.6	90.4~1,074.5	0.011	0.073	3.072	0.053	0.968	I	
	Summer	119	21.0~40.4	124.3~893.0	0.016	0.080	2.937	0.055	0.961	− A	
	Total	236	18.6~42.6	90.4~1,074.5	0.020	0.055	2.876	0.039	0.959	− A	
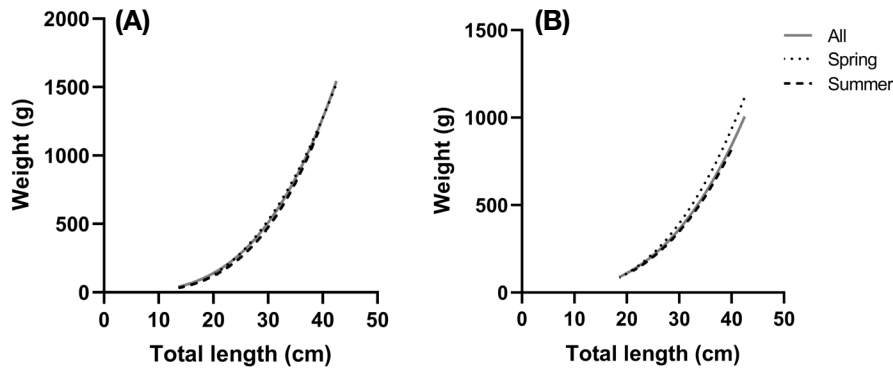
Fig. 1. Power fitted curve of each length-weigh relationship for all specimens during spring and summer of *Sebastes zonatus* (A) and *Thamnaconus modestus* (B).
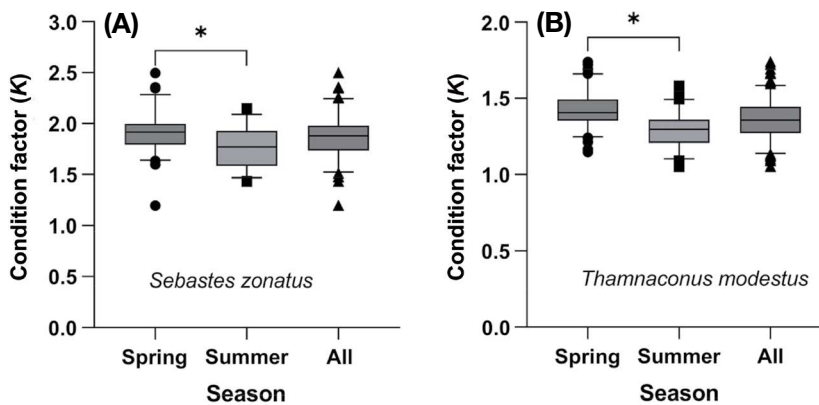

Fig. 2. Box plots of condition factors for *Sebastes zonatus* (A) and *Thamnaconus modestus* (B) during spring and summer, and all seasons combined. Asterisk indicates significant differences at P=0.05.

T. modestus ranged from 1.196 to 2.495 (mean±SD= 1.869±0.211) and 1.051 to 1.738 (mean±SD=1.358± 0.130), respectively. The body conditions were significant- ly different between the spring and summer for both spe- cies, showing consistently higher values during the spring (Student's t-test, both P<0.05; Fig. 2).

DISCUSSION

This study provides the first report of LWR for *S. zonatus* and *T. modestus*. The estimated *b* values of LWRs from this study were within the range of 2.5 and 3.5, which was observed for most fish species (Froese, 2006). *S. zonatus* and *T. modestus* showed different growth patterns wherein the *b* values of the two species were significantly different from that of the isometric value of '3' (i.e., overall, 3.133 vs. 2.876), with positive or negative allometric growth patterns, respectively (Froese, 2006). Positive and negative allometric growths indicate that the fishes become "heavier or lighter for its length" as they grow larger, respectively (Ricker, 1968). Therefore, *S. zonatus* gains more weight than its length, while *T. modestus* grow more in length than in weight. In addition, results for intercepts (*a*) of LWRs indicate that the body shape of *S. zonatus* was close to 'Fusiform' while *T. modestus* was close to the 'Short and deep' categories (Froese, 2006).

The regression models estimated the maximum length measurements of the fish beyond those previously recorded. The maximum size of the *S. zonatus* and *T. modestus* (42.5 cm TL and 42.6 cm TL, respectively) collected in this study were comparable to that of the previous records in FishBase (Froese and Pauly, 2022) and other literature (e.g., Kim *et al*., 2016; Goto and Takanashi, 2020). The maximum length of *S. zonatus* was 37.0 cm SL in FishBase, and 35.9 cm SL by Goto and Takanashi (2020).

As the former studies did not provide the total length of *S. zonatus*, we estimated it using length-length regression of morphologically similar *S. vulpes* (Baeck *et al*., 2012a). As a result, the estimated maximum total length of *S. zonatus* is approximately between 42.0 and 44.0 cm, which is similar to or slightly higher than that recorded in this study. The maximum length of *T. modestus* was recorded as 36.1 cm TL in FishBase, and Kim *et al*. (2016) recently reported it as 42.1 cm TL. Therefore, this is the first study that reports the maximum lengths for *T. modestus* and provides new records of the two species to update size information in FishBase, a global biological database of fish species.

The allometric coefficients (*b* values) of LWR of *S. zonatus* and *T. modestus* were significantly higher during the spring. Higher *b* values indicate a tendency towards positive allometric growth, which implies an increase in either body condition, height, and width rather than in length (Froese, 2006). Moutopoulos *et al*. (2013) reported significantly higher *b* values in the LWRs of several fish species during the spawning period. This might be due to the presence of a large number of mature individuals (large-sized specimens) with higher rates of increase in BW than in body length (TL) during spawning periods (Hossain *et al*., 2013).

Additionally, better body conditions were recorded during the spring. Seasonal changes in body conditions are usually driven by food availability, environmental conditions, and reproductive status (Weatherley and Gill, 1987; Chellappa *et al*., 1995). In many fishes, Fulton's condition factor differs seasonally because of fluctuations in food supply and consequent changes in food reserves of fish (Hossain, 2010; Lavergne *et al*., 2013) as well as a reproduction (Brosset *et al*., 2017). Vazzoler and Vazzoler (1965) stated that the condition factor does not merely reflect the feeding condition of the adult stage, but also includes the state of gonadal development based on the consumption of fat reserves during the spawning period. An increase in the condition towards the spawning season and a sharp decline after spawning are general patterns in adult fish (Le Cren, 1951). On the other hand, a decrease in body condition factors during spawning periods reflects changes in feeding patterns, which could be a behavioral response to certain stressors (Brown *et al*., 1987), such as guarding eggs and offspring in some goby species (Colombini *et al*., 1996; Baeck and Park, 2015). The spawning seasons of *S. zonatus* and *T. modestus* occur during spring, which coincides with our colder sampling season (Kim *et al*., 2016; Choi *et al*., 2020; Goto and Takanashi, 2020). Therefore, such seasonal changes in LWR parameters and condition factors may reflect spawning-related variations in body conditions for both species.

CONCLUSION

This study provides the first biometric data on LWRs and seasonal body condition factors of *S. zonatus* and *T. modestes*, which are abundant in coastal fish assemblages in both Ulleung-do and Dokdo. These results contribute to future conservation studies of the species and could be useful information for fishery biologists seeking management plans for the species in Korea.

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REFERENCES

Baeck, G.W. and J.M. Park. 2015. Length-weight and length-length relationships and seasonal condition factors for two mudskippers, *Periophthalmus modestus* (Cantor, 1842) and *P. magnuspinnatus* (Lee, Choi & Ryu, 1995) (Gobiidae), on tidal flats of Korea. J. Appl. Ichthyol., 31: 261-264. https://doi.org/10.1111/jai.12655.

Baeck, G.W., J.M. Jeong, Y.M. Yeo, S.H. Huh and J.M. Park. 2012a. Length-weight and length-length relationships for 10 species of scorpionfishes (Scorpaenidae) on the south coast of Korea. J. Appl. Ichthyol., 28: 677-679. https://doi.org/10.1111/j.1439-0426.2012.01956.x.

Baeck, G.W., J.M. Park, J.M. Jeong, S.J. Ye and Y.S. An. 2012b. Feeding habits of black scraper, *Thamnaconus modestus* in the coastal waters of Geomun-do, Korea. Korean J. Ichthyol., 24: 272-277.

Bagenal, T.B. and A.T. Tesch. 1978. Age and growth. Methods for assessment of fish production in fresh waters (3rd edn). In: Bagenal, T. (ed.), IBP Handbook No. 3. Blackwell Scientific Publications, Oxford, UK, pp. 101-136.

Breen, P.A., S.W. Kim and N.L. Andrew. 2003. A length-based Bayesian stock assessment model for the New Zealand abalone *Haliotis iris*. Mar. Freshw. Res., 54: 619-634. https://doi.org/10.1071/MF02174.

Brodziak, J. 2012. Fitting length-weight relationships with linear regression using the log-transformed allometric model with bias-correction. Pacific Islands Fisheries Science Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish Sci Cent Admin Rep H-12-03:4 p.

Brosset, P., J.M. Fromentin, E. Van Beveren, J. Lloret, V. Marques, G. Basilone, A. Bonanno, P. Carpi, F. Donato, V. Čikeš Kečg, A. De Felice, R. Ferreri, D. Gašparević, A. Giráldez, A. Gücü, M. Iglesias, I. Leonori, I. Palomera, S. Somarakis, V. Tičina, P. Torres, A. Ventero, B. Zorica, F. Ménard and C. Saraux. 2017. Spatio-temporal patterns and environmental controls of small pelagic fish body condition from contrasted Mediterranean areas. Prog. Oceanogr., 151: 149-162. https://doi.org/10.1016/j.pocean.2016.12.002.

Brown, J.A., P.H. Johansen, P.W. Colgan and R.A. Mathers. 1987. Impairment of early feeding behaviour of largemouth bass by pentachlorophenol exposure: a preliminary assessment. Trans. Am. Fish. Soc., 16: 71-78. https://doi.org/10.1577/1548-8659(1987)116<71:IOEFBO>2.0.CO;2.

Chellappa, S., F.A. Huntingford, R.H.C. Strang and R.Y. Thomson. 1995. Condition factor and hepatosomatic index as estimates of energy status in male three-spined stickleback. J. Fish Biol., 47: 775-787. https://doi.org/10.1111/j.1095-8649.1995.tb06002.x.

Chen, L.C. and V.V. Barsukov. 1976. A study of the western North Pacific *Sebastes vulpes* species complex (Scorpaenidae), with description of a new species. Jap. J. Ichthyol., 23: 1-8. https://doi.org/10.11369/jji1950.23.1.

Choi, J.H., B.S. Jeon, J.W. Kim, J.H. Lee, Y.J. Im and H.W. Lee. 2020. Maturation and spawning of the filefish *Thamnaconus modestus* in coastal waters of Korea. Korean J. Fish. Aquat. Sci., 53: 27-35. https://doi.org/10.5657/KFAS.2020.0027.

Chung, S., H.K. Cha, J.B. Lee, H.W. Lee and J.H. Yang. 2015. Species composition of the catches collected by trammel net in the coastal waters off Ulleungdo of Korea. J. Korean Soc. Fish. Ocean Technol., 51: 567-575. https://doi.org/10.3796/KSFT.2015.51.4.567.

Colombini, I., R. Berti, A. Nocita and L. Chelazzi. 1996. Foraging strategy of the mudskipper *Periophthalmus sobrinus* Eggert in a Kenyan mangrove. J. Exp. Mar. Biol. Ecol., 197: 219-235. https://doi.org/10.1016/0022-0981(95)00160-3.

Froese, R. 1998. Length-weight relationships for 18 less-studied fish species. J. Appl. Ichthyol., 14: 117-118. https://doi.org/10.1111/j.1439-0426.1998.tb00626.x.

Froese, R. 2006. Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. J. Appl. Ichthyol., 22: 241-253. https://doi.org/10.1111/j.1439-0426.2006.00805.x.

Froese, R. and D. Pauly. 2022. FishBase. World Wide Web electronic publication. https://www.fishbase.org (Accessed on 30 October 2022).

Froese, R., A.C. Tsikliras and K.I. Stergiou. 2011. Editorial note on weight-length relations of fishes. Acta Ichthyol. Piscat., 41: 261-263. https://doi.org/10.3750/AIP2011.41.4.01.

Froese, R., J.T. Thorson and R.B. Reyes Jr. 2014. A Bayesian approach for estimating length-weight relationships in fishes. J. Appl. Ichthyol., 30: 78-85. https://doi.org/10.1111/jai.12299.

Goto, T. and A. Takanashi. 2020. Age, growth and maturation of a rockfish species, *Sebastes zonatus*, in the Pacific coastal area off the Sanriku, northeastern Honshu, Japan. Bul. Jap. Soc. Fish. Oceanogr., 84: 100-109. https://doi.org/10.34423/jsfo.84.2_100.

Hossain, M.Y. 2010. Length-weight, length-length relationships and condition factor of three Schibid catfishes from the Padma River, Northwestern Bangladesh. Asian Fish. Sci., 23: 329-339. https://doi.org/10.17693/yunusae.v17i31121.339920.

Hossain, M.Y., M.S. Arefin, M.S. Mohmud, M.I. Hossain, M.A.S. Jewel, M.M. Rahman, F. Ahamed, Z.F. Ahmed and J. Ohtomi. 2012. Length-weight relationships, condition factor, gonadosomatic index-based size at first sexual maturity, spawning season and fecundity of *Aspidoparia morar* (Cyprinidae) in the Jamuna River (Brahmaputra River distributary), northern Bangladesh. J. Appl. Ichthyol., 29: 1166-1169. https://doi.org/10.1111/jai.12127.

Kim, A., H. Bae, H.G. Kim and C.W. Oh. 2016. Age and growth of filefish, *Thamnaconus modestus* (Günther, 1877) off the Jeju Island of Korea. Ocean Sci. J., 51: 355-362. https://doi.org/10.1007/s12601-016-0031-y.

Kim, I.S., Y. Choi, C.I. Lee, Y.J. Lee, B.J. Kim and J.H. Kim. 2005. Illustrated book of Korean fishes. Kyo-Hak Publ., Seoul,

Korea, 615pp.

King, M. 1995. Fisheries biology, assessment and management. Fishing News Books. Blackwell Science, Oxford, UK, 341pp.

Kwak, S.N. and J.M. Park. 2016. Length-weight and length-length relationships for six flounder species (Pleuronectiformes) from the eastern coast of Korea. J. Appl. Ichthyol., 32: 160-162. https://doi.org/10.1111/jai.12932.

Lavergne, E., U. Zajonz and L. Sellin. 2013. Length-weight relationship and seasonal effects of the Summer Monsoon on condition factor of *Terapon jarbua* (Forsskål, 1775) from the wider Gulf of Aden including Socotra Island. J. Appl. Ichthyol., 29: 274-277. https://doi.org/10.1111/j.1439-0426.2012.02018.x.

Le Cren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). J Anim. Ecol., 201-219. https://doi.org/10.2307/1540.

Moutopoulos, D.K., A. Ramfos, A. Mouka and G. Katselis. 2013. Length-weight relations of 34 fish species caught by small-scale fishery in Korinthiakos Gulf (central Greece). Acta Ichthyol. Piscat., 43: 57-64. https://doi.org/10.3750/AIP2013.43.1.08.

Nakabo, T. 2002. Scorpaenidae. In: Fishes of Japan with pictorial keys to the species (2nd ed). Tokai University Press, Tokai, Japan, pp. 565-595.

Park, J.M., T.F. Gaston, R. Riedel and J.E. Williamson. 2018. Biometric relationships between body and otolith measurements in nine demersal fishes from north-eastern Tasmanian waters, Australia. J. Appl. Ichthyol., 34: 801-805. https://doi.org/10.1111/jai.13612.

Pauly, D. 2002. Fish population dynamics in tropical waters: a manual for use with programmable calculators. International Center for Living Aquatic Resources Management, Manila, Philippine, 325 pp.

Ricker, W.E. 1968. Methods for assessment of fish production in freshwaters. Blackwell Scientific Publications, Oxford, UK, 313pp.

Vazzoler, A.D.M. and G. Vazzoler. 1965. Relation between condition factor and sexual development in *Sardinella aurita* (Cuv. & Val. 1847). An. Acad. Bras. Ciênc., 37: 353-359.

Weatherley, A.H. and H.S. Gill. 1987. The biology of fish growth. Academic Press, London, UK, 443pp.

울릉도와 독도에 출현하는 띠볼락(*Sebastes zonatus* Chen and Barsukov, 1976)과 말쥐치(*Thamnaconus modestus* (Günther, 1877))의 생물역학적 관계와 계절적 비만도지수의 첫 보고

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요   약 : 본 연구는 울릉도와 독도 해역에 서식하는 띠볼락(*Sebastes zonatus* Chen and Barsukov, 1976)과 말쥐치 (*Thamnaconus modestus* (Günther, 1877))의 체장-체중 관계 (LWR)와 계절적 비만도지수 (*K*) 정보를 국내 최초로 보고하였다. 두 종의 체장-체중 관계는 모든 계절에 높은 상관성을 보였으며 ($r^2 > 0.959$), LWR 회귀 기울기는 두 종 모두 저수온기와 고수온기 사이에 유의하게 차이가 있었다. 두 종의 비만도지수는 저수온기에 고수온기보다 현저히 높아 산란기와 관련된 비만도 증가를 반영하였다. 본 연구의 결과는 띠볼락과 말쥐치의 생물학적 특성을 이해하고 향후 두 어종에 대한 보존 및 관리 계획 개발에 유용한 자료를 제공할 것이다.

찾아보기 낱말 : 양볼락과, 쥐치과, 체장-체중 관계, 비만도 지수, 동해