# Seasonal Variations In Species Composition And Community Structure In The Eastern Coast of South Korea

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# Seasonal variations in species composition and community structure in the eastern coast of South Korea

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## Abstract

The seasonal variations in species composition of set net fisheries were investigated in the eastern coast of Korea, from 2007 to 2008. In total, 51 species were found that were classified into 15 orders and 33 families. The water temperature of the study area was 0.1–2.1 °C during the study period, which was higher than the average water temperature in the last decade. Monthly variation in the number of species peaked twice, in May (spring) and November (autumn) when the water temperature increased and decreased, respectively, and monthly variation in the number of individuals showed a remarkably high trend in winter and autumn and was mainly caused by large migratory species. Based on the cluster analysis of the 18 most dominant species with more than 0.4% of the total number of individuals, we divided the species composition and community structure into three groups: fishes with temporary appearance (Group A), fishes with long-term appearance (Group B), and dominant pelagic fishes appearing with long-term appearance (Group C). We could conclude that seasonal variation in the fish community structure was mainly caused by pelagic migration of species under high water temperature conditions during the study period.



**Key words:** Fish species composition, fishery production, seasonal variations, eastern coastal Korea

## Introduction

The fish fauna in the East Sea of Korea was reported to consist of approximately 450 coastal settlement species, bathypelagic species, and migratory species. Except for bathypelagic species, most fish species travel between the coast and the mainland and migrate seasonally from the south to the north regions[1,2,3]. These species include commercially important fish species (approximately 50 species), such as *Gadus macrocephalus*, *Theragra chalcogramma*, and *Clupea pallasii*, that are known as cold water fish, and cephalopods, such as *T. pacificus*, all of which are widely distributed in the eastern coast of Korea[3]. However, the distribution of these representative species and the subsequent fishery production has changed due to climate change. The fishery production of *T. chalcogramma* comprised approximately 22% of the total fishery production in the 1990s, which rapidly decreased to less than 1% in 2000. However, the fishery production of *T. pacificus* accounted for 26% of the total production in 1990, which increased to 39% in 2000[4], thus, indicating that the fishery production of *T. pacificus* increased, but that of *T. chalcogramma* and *C. saira* decreased after the 1990s[3]. Accordingly, fishery production on the eastern coast of Korea increased from 150,000 metric tons (MT) in the early 1960s to 275,000 MT in the early 1980s; however, it decreased to 150 000 MT in the late 1980s, whereas in the 1990s, it frequently varied from 200,000 to 250,000 MT[5].

Previous studies have reported that large variations in fishery biomass and production were caused by short- and long-term influences of climatic regime shifts, such as thermal front movement towards the north, increase in the average surface ocean temperature, and extended movement of the Kuroshio Current[6,7,8]. After the 1990s, scientific and industrial research in the eastern coast of Korea has shifted focused to fishing grounds due to the irregular appearance of large migratory fishes and subtropical fishes that were difficult to observe in the past decades[9]. The appearance of warm water fish species and subtropical fish species has been recently increasing; therefore, multidimensional observations are necessary to assess these changes in the fish communities that occur due to climate regime shifts in fishery grounds.

This study aimed to determine the seasonal variations of fish communities captured in set nets installed in the coastal waters of Yangyang, Gangwon-do coast, for two years to provide fundamental information on the temporal patterns of fish species composition on the eastern coast of the Korean Peninsula.

## Results

**Water temperature. Fig. 3** shows the annual changes in the water temperature during the sampling period. The water temperature fluctuated from 7.8 °C to 22.9 °C in 2007 and from 8.0 °C to 23.8 °C in 2008. The temperature was the lowest from January to February (7.8–8.2 °C). Subsequently, the temperature gradually increased during March–May and June–August, with the water temperature maintained at 20 °C and above. The highest water temperature was recorded at 22.9 °C in August 2007 and at 23.8 °C in August 2008. The temperature decreased from October onwards in both years, reaching 10 °C in December 2008. The water temperature was overall higher by 0.1–1.8 °C in 2007 and by 0.6–2.1 °C in 2008 (except for 0.3 °C lower in July and 0.7 °C lower in November) than the average water temperature in the last decade (**Fig. 3**).

**Species composition.** During the study period, 51 species belonging to 35 families in 17 orders were observed in the set nets in the study area. A total of 48 fish species from 33 families in 15 orders and three cephalopod species belonging to two families in two orders were recorded in 2007 and 2008 (**Table 1 and Supplementary Table S1**). In total, 1,402,709 individuals of fish were captured during the entire study period.

Fish and cephalopods accounted for 49.6% and 50.4% of the total species, respectively (**Supplementary Table S1**). Order Perciformes had the highest appearance rate (21 species from 12 families), followed by Order Scorpaeniformes (five species from four families), Order Tetraodontiformes (four species from three families), Order Clupeiformes (three species from two families), and Order Pleuronectiformes (three species from two families) (**Table 1**).

**Monthly variations in fish species.** The average daily number of species was 3–11 (**Fig. 4**). A high number of species was observed from April to June in both years, with 10–11 species in 2007 and, 9–11 species in 2008. Further, the number of species peaked in May in both years. Another peak was recorded in November, with nine species and 13 species in 2007 and 2008, respectively. Moreover, a low number of species was recorded in February (four) and July (five) 2007 and in February (five) and August (four) 2008.

In 2007, the average daily number ranged from 518 individuals in July to 10,562 individuals in February (**Fig. 4**). February, March, and October recorded more than 10,000 individuals (**Supplementary Table S1**). The changes in the monthly recorded individual numbers were caused by 92,552 individuals of *T. pacificus* (73.0%) and 33 486 individuals of *P. azonus* (26.4%) in February, 71 176 individuals of *P. azonus* (69.2%) and 17 864 individuals of *T. pacificus* (17.4%) in March, and 89 616 individuals of *T. pacificus* (65.6%)

and 28,468 individuals of *S. quinqueradiata* (20.8%) in October. In 2008, the number of individuals ranged from 390 in September to 14 078 in April (**Fig. 4**). Further, January, September, and November 2008, recorded more than 10,000 individuals (**Supplementary Table S1**), which was contributed by 95,440 individuals of *T. pacificus* (92.5%) and 4,882 individuals of *S. quinqueradiata* (4.7%) in January, 108,431 individuals of *T. pacificus* (64.2%) and 53 184 individuals of *S. japonicus* (31.5%) in September, and 56,880 individuals of *T. japonicus* (40.0%) and 23,391 individuals of *S. quinqueradiata* (15.3%) in November (**Supplementary Table S1**).

The peaks in species diversity were recorded in June (H'=1.59) and November (H'=1.49) in 2007, and in April (H'=1.72) and December (H'=1.34) in 2008. The lowest diversity was recorded in February (H'=0.21) in 2007 and January (H'=0.41) in 2008. The diversity index gradually increased or repeat increased and decreased from March to June, decreased from July to September, and subsequently, increased from October to November for both 2007 and 2008 (**Fig. 4**).

**Analysis of fish community.** Cluster analysis for species composition and related time points showed three distinct time points in the Q-mode analysis, and three groups of fish assemblages in the R-mode analysis.

The Q-mode analysis divided the time points into three significantly different groups (**Fig. 5**): Group A comprised February, March, and April of both 2007 and 2008, along with May 2007. Group B comprised May 2008, and June and July of both 2007 and 2008. Group C comprised August and January 2008, and September, October, November, and December of both 2007 and 2008.

The R-mode analysis of fish assemblages formed three groups (**Fig. 5**): Group A includes *C. saira*, *Acanthopagrus schlegeli*, and *Konosirus punctatus* that sporadically appeared from April to July, and from October to December for both 2007 and 2008; and *Hyperoglyphe japonica*, *Thamnaconus modestus*, and *T. japonicus* that appeared temporarily from August to December. Group B included *Tribolodon taczanowskii*, *Lophiomus setigerus*, *Sebastes schlegelii*, *Takifugu chinensis*, *Paralichthys olivaceus*, *Mugil cephalus*, and *S. cirrhifer*, all of which appeared for a long duration during the entire study period, except from July to September. In addition, this group included *P. azonus* and *Oncorhynchus masou* that appeared from February to July. Group C included *S. quinqueradiata*, which intensively appeared from August to December, and *T. pacificus*, which appeared throughout the year.

## Discussion

Gangwon-do is located in the central eastern coast of Korea, where the sea conditions can change according to changes in the location of the polar front[10]. The East Sea of Korea, including the coastal waters of Gangwon-do, has a unique hydrology, with a combination of both North Korean cold currents and Tsushima warm currents; therefore, the temporal and spatial distribution of hydrological factors, such as water temperature and salinity, is complex[11]. Short- and long-term information on changes in the fishery catches in this region is required for sustainable resource management and utilization. Thus, this study analyzed the seasonal variations in the fish species composition in the coastal waters of Gangwon-do for two years (2007 and 2008) using set nets.

A total of 51 fish species were identified during the study period (**Table 1**). These species can be divided into 19 pelagic fish species, including *S. quinqueradiata*, *S. japonicus*, and *T. japonicus*, and 32 semi-demersal and demersal fish species, such as *S. schlegelii*, *P. olivaceus*, and *Pleuronectes schrenki* (**Supplementary Table S1**). The set net method is a passive fishing method that involves waiting for the fish to appear. It is strongly influenced by local environmental conditions that directly affect the fish arrival and their movements. This method can provide significant information on the distribution and characteristics of migratory fish, mainly because these species are highly mobile and travel in clusters[12,13]. This study provides data on the seasonal composition characteristics of migratory pelagic fish species, which have a high catch rate.

Monthly variations in the number of species peaked in May and November when the water temperature increased and decreased, respectively (**Figs. 3 and 4**). The number of species was higher in spring (April–June) and autumn (October–December) than in summer (July–September) and winter (January–March) during the study period. These results were similar to those obtained in a previous study that used gill nets in the coastal waters off Shinsudo in Shamchonpo in the south of the east coast of the Korean Peninsula[14]. Previous studies that conducted surveys in November, February, May, and August using set nets reported that the number of species peaked in November in the coastal waters of Hupo, Gyeongsanbuk-do, south of the east coast of Korea, and in the coastal waters of Jangho, Gangwon-do (Kang et al. 2014)15. In addition, Ryu et al. (2005)16 observed a peak in October in Oho of the Gangwon-do coastal waters during surveys conducted in May, August, October, and January. During the study period, the two peaks, with the highest number of species in May and November, were evidently influenced by the entry of migratory fish species, such as *Engraulis japonicus*, *Konosirus punctaus*, *Seriola lalandi*, *Seriola quinqueradiata*, *Scomber japonicas*, and *Scomberomorus niphonius* (**Fig. 4 and Supplementary Table S1**).

Previously, 34–89 fish species were captured in a set net on the east coast of Korea in the

Gyeongsangbuk-do coastal waters from 1993 to 2005 and 39–103 species were captured in the Gangwon-do coastal waters from 1998 to 2005 (**Table 2**). In this study, 49 and 46 species were recorded in 2007 and 2008, respectively, in Yangyang, indicating a low level of appearance compared with that observed in previous studies. The number of species in each region varied significantly; however these variations could not be examined comprehensively based on the time and location of the observations (**Table 2**). Regarding the previous seasonal variations of dominant species, fish species mainly appeared on the Yangyang coast during winter. *C. pallasii* was the dominant species during 1998–2003, specifically from winter to spring in 2002. Further, *Lophius litulon* started appearing along with *C. pallasii*, and in 2003. *T. pacificus* was also one of the dominant species from 2005. This species was also recorded as a major dominant species in the present study (**Table 2**). In spring, *M. cephalus* was dominant from 2000 to 2002, *P. azonus* and *M. cephalus* were dominant in 2003 and 2005, and *T. pacificus* and *M. cephalus* were dominant in Yangyang in this study (**Table 2**). In the summer of 1998, *S. quinqueradiata* and *T. japonicus* alternately appeared as dominant species from 1998 to 2003; however, *T. pacificus* and *S. quinqueradiata* dominated in 2005. Similarly, these two species were also recorded as the dominant species in this study (**Table 2**). After the autumn of 1998, *T. pacificus* was repeatedly recorded as the dominant species, and this trend continued throughout the study period (**Table 2**). Further, the caught period of *T. pacificus* was remarkably extended, making it a dominant species in all seasons after 2005. *T. pacificus* is a major commercial species widely distributed in the waters around Korea and Japan, and shows extensive seasonal migrations[17,18]. Moreover, the population of *T. pacificus* is known to increase when the spawning area increases with increasing water temperatures (18–23 °C)[19]. The water temperatures of Yangyang during the study period were higher by 0.1–1.8 °C in 2007 and 0.6–2.1 °C in 2008 than the average water temperature since the last decade (**Fig. 3**). Therefore, it is presumed that the high water temperature observed during this study increased the spawning area of *T. pacificus,* thereby resulting in this species being dominant in all seasons.

Monthly variations in the number of individuals of species were high in winter and autumn. The highest daily average number of appearances was observed in February 2007 and September 2008. In addition, the cumulative number of individuals exceeded 10 000 in February, March, and October 2007, and in January, September, and November 2008. During this period, the cumulative population of the first and second dominant species was 55.3% to 99.4%, respectively. *T. pacificus* was the first dominant species during the entire study period, followed by *P. azonus* in February and March 2007, *S. quinqueradiata* in October 2007 and January 2008, and *S. japonicus* and *S. quinqueradiata* in September and November 2008. *P.*

*azonus* has a high catch record, and is a dominant species from winter to spring on the east coast of Korea[4,20,21]; however, this species was the second dominant species that appeared from February to April 2007, and March 2008 (**Supplementary Table S1**). These observations were similar to those reported in previous studies[4,20]. In addition, *P. azonus* influenced  the number of individuals of fishes, such as *T. pacific*, *S. japonicus*, and *S. quinqueradiata*, that were classified as small and large pelagic fish in Korean waters[8]. These species along with *P. azonus* are affected by warm waters in winter. Further, the trends in the changes in the diversity index were similar to those of the monthly variations in the number of species. A high species number was observed in spring and autumn, with equal proportions of many species. Moreover, a low number was observed in winter and summer, with some species in major proportions.

The dominant species (more than 0.4% of the total number of observed species) were divided into three groups through cluster analysis. Group A included species that appeared temporarily and sporadically in spring to autumn, and those that appeared intensively in summer to autumn (**Fig. 5**). In this group, *C. saira* and *T. japonicus* were representative migratory small pelagic fishes of the East Sea that migrate north in spring and summer and south in autumn and winter[8,22]. *A. schlegeli* and *K. punctatus* observed in spring and autumn was found to contribute to increasing the community similarity with *C. saira*, with a high catch in spring, and with other main catch species, such as *H. japonica*, *T. modestus*, *and T. japonicas*, in autumn. Group B comprised fish species that appeared for a long duration and almost the entire study period, except summer (July to September); additionally, this group included species that appeared intensively from winter to spring. In this group, small pelagic fish species, such as *M. cephalus* and *S. cirrhifer*, whose distribution is highly affected by warm currents[8,22] were found throughout the study period. Further, resident species, such *as T. taczanowskii*, *L. setigerus*, *S. schlegelii*, *T. chinensis*, *P. olivaceus*, *M. cephalus*, and *S. cirrhifer*, were observed during the study period and divided in the same group as *O. masou* and *P. azonus*, which appeared intensively from winter to spring. Group C consisted of species that accounted for 64% of the total species (**Supplementary Table S1**), and were recorded throughout the study period or intensively from summer to autumn. This group comprised species, such as *T. pacificus*, *S. quinqueradiata*, and *S. japonicus*, which are representative warm current migratory fish species travelling towards the south/north depending on the season; additionally, these species typically migrate seasonally along the east coast of the Korean Peninsula[23,24,25,26,27]. Such an extensive distribution is largely dependent on the annual changes in the sea conditions[28]. *T. pacificus* was a migratory species that consistently appeared throughout the entire study period, and also represented the major residing species. *S. quinqueradiata* and *S. japonicus* appeared throughout the entire period, except from February to April (**Fig. 5**). An increase or decrease in fish resources is related to the water temperature and periods of plankton growth[29]; additionally, it can be presumed that there is a difference in the distribution of migratory species depending on the influence of a warm current, which in turn is a critical aspect that should be considered during the study period[25]. In previous studies, the water temperature was observed to increase by 2.59 °C in the surface waters of Tsushima and by 0.35 °C in the East Sea water[11]. In addition, the water temperature at a depth of 20 m, as observed through the satellite image data (NOAA/AVHRR), increased by 0.83 °C in the East Sea from 2000 to 2009[30]. Therefore, the increased water temperature during this study as confirmed by our observations would have affected the fish community structure.

The analysis of seasonal variations in the species composition of fishes captured along the Yangyang coast in the central part of the East Sea of Korea indicated that major migratory pelagic fishes were the dominant species throughout the study period and showed high catch rates. It is presumed to be the period when the water temperature increase of the warm current strongly influenced this sea area along with other factors that could affect the appearance of pelagic fishes; however, understanding the overall characteristics of fish resources using only selective data from the catchment nets of pelagic fish species may act as a limitation. Nevertheless, the results of this study on the seasonal variations of the species compositions of set net fisheries can serve as important baseline information for improving the predictability of future changes in the fishery resources, thereby facilitating sustainable management in the region.

## Materials and methods

This study was conducted using three sets of set nets that were installed to capture fish from the middle to upper regions of the sea in Yangyang, East Coast of Korea (37°58'27″ N, 128°47'18″ E; 37°58'21″ N, 128°47'24″ E; 37°58'18″ N, 128° 47'24″ E, respectively) (**Fig. 1**). The dimensions of the fishing nets were 148 × 34.5 m (L× W), with a mesh size of 33 mm × 33 mm (**Fig. 2**). Fishing data from February 2007 to December 2008 were collected from logbooks that had compiled information on set net fisheries at the three points. This study did not require ethical approval as we do use fishing data. The daily sampling data recorded the number of species, individuals, and species levels. Subsequently, a species checklist was created based on the number of species and individuals of each species. To identify fish species and their ecological characteristics, we used the studies by Nelson[31] and Kim et al.[32] as references, while the characteristics of cephalopod distribution and identification were assessed using KORDI[33] as a reference. The daily water temperature data during the sampling period were taken from the Sokcho Tide Station of the National Oceanographic Research Institute[34]. The daily number of individuals of the captured fishes was averaged for each month and subsequently, the monthly averages were compared to assess the quantitative changes. Further, Shannon-Weiner index (H'; 1963)[35] was used to calculate the fish species diversity with the software primer 6 (Primer-E Ltd., Plymouth, UK).

Out of the 51 species recorded, data of the 18 most abundant species, that is, species with more than 0.4% of the total abundance, were used for cluster analysis based on the temporal distribution of fish species composition and abundance. Cluster analysis was performed to determine the groups of related species composition components (R-mode) and those of related time points (Q-mode) using the MVSP shareware computer package (Multivariate Statistical Package, MVSP Shareware 3.0).

## References


1. Gong, Y. & Son, S.-J. A study for ocean thermal front in the East Sea of Korea. *Bull. Nat'l Fish Res. Dev. Agency* **28**, 25–54 (1982).
2. Kim, Y. S. & Nam, M. M. Fish fauna in the East Sea. In: Son Y.M. (ed.), Current and Preservation of Korean fishes. *The Korean Ichthyological Society* 5–36 (2003).
3. MOMAF (Ministry of Maritime Affairs and Fisheries). Relationship and dynamics between climate change and fishery resources in the East Sea of Korea. *MOMAF, Korea*, 144–157 (2003).
4. NFRDI (National Fisheries Research & Development Institute). Korean coastal and offshore fishery census. NFRDI, Korea. *NFRDI Technical report (in Korean)*, 87–208 (2004).
5. Chun, Y.-Y., Hwang, S.-J., Hur, Y.-H. & Han, K.-H. Characteristics of the distribution of ichthyoplankton along the eastern coast of Korea. *J. Kor. Soc. Fish Res.* **6**, 112–115 (2004).
6. Zhang, C. I., Lee, J. B., Kim, S. & Oh, J.-H. Climatic regime shift and their impact on marine ecosystem and fisheries resources in Korean waters. *Prog. Ocean* **47**, 171–190 (2000).
7. Zhang, C. I. & Lee, J. B. Stock assessment and management implications of horse mackerel (*Trachurus japonicus*) in Korean Waters, based on the relationships between recruitment and the ocean environment. *Prog. Ocean* **49**, 513–537 (2001).
8. Zhang, C. I., Lee, J. B., Seo, Y. I., Yoon, S. C. & Kim, S. Variations in the abundance of fisheries resources and ecosystem structure in the Japan/East Sea. *Pro. Ocean* **61**, 245–

265 (2004).

9. KOSTAT (Statistics Korea). The changes in catches of major fish species due to climate (water temperature) changes (in Korean). Statistics Korea, Daejeon. http://kostat.go.kr/portal/korea/kor_nw/1/index.board?bmode (2019).

10. Kim, I.-N. & Lee, T.-S. Summer hydrographic features of the East Sea analyzed by the optimum multiparameter method. *Ocean and Polar Res.* **26**, 581–594 (2004).

11. Yoon, S. C., Youn, S. H., Sim, M. J. & Yoon, Y. Y. Characteristics and variation trend of water mass in offshore of the east coast of Korea during last 10 years. *J. Korean Soc. Mar. Environ. Energy* **20**, 193–199 (2017).

12. Lee, J.-H., Youm, M.-G. & Park, B. S. Fundamental studies on the migrating course of fish around the set net (3). *J. Kor. Soc. Fish. Tech.* **24**, 71–77 (1988).

13. Kim, Y. H., Kim, J.B. & Chang, D. S. Seasonal variation of abundance and species composition of fishes caught by set net in the coastal waters off Yosu, Korea. *J. Korean Fish Soc.* **36**, 120–128 (2003).

14. Kim, C.-K. & Kang, Y.-J. Fish assemblage collected by gill net in the coastal shallow water off Shinsudo, Samchonpo. *Bull Korean Soc. Fish Tech.* **24**, 99–110 (1991).

15. Kang, J.-H. *et al.* Comparison of fish species collected by set net at Hupo in Gyeong-Sang-Buk-Do, and Jangho in Gang-Won-do, Korea. *Kor. J. Fish Aquat. Sci.* **47**, 424–430 (2014).

16. Ryu, J. H., Kim, P.-K., Kim, J. K. & Kim, H. J. Seasonal variation of species composition of fishes collected by gill net and set net in the middle East Sea of Korea. *Kor. J. Ichthyol.* **17**, 279–286 (2005).

17. Nakamura, Y. & Sakurai, Y. Age determination from daily growth increments in statoliths of some groups of Japanese common squid, *Todarodes pacificus*, In: Recent Advances in Cephalopod Fisheries Biology, T Okutani, RK O'Dor and T Kubodera, eds. *Tokai University Press, Tokyo, Japan*, 339–344 (1993).

18. Kidokoro, H. *et al.* Impact of a climate regime shift on the migration of Japanese common squid (*Todarodes pacificus*) in the Sea of Japan. *ICES J. Mar. Sci.* **67**, 1314–1322 (2010).

19. Sakurai, Y., Kiyofuju, H., Saitoh, S., Goto, T. & Hiyama, Y. Change in inferred spawning areas of *Todarodes pacificus* (Cephalopoda: Ommastrephidae) due to changing environmental conditions. *ICES J. Mar. Sci.* **57**, 24–30 (2000).

20. NFRDI (National Fisheries Research & Development Institute). Korean coastal and offshore fishery census. NFRDI, Korea. NFRDI Technical report (in Korean), 63–102 (2006).

21. Yang, J.-H. *et al.* Age and growth of the Okhotsk atka mackerel, *Pleurogrammus azonus*

in the coastal of Gangwon-do, East Sea. *J. Korean Soc. Fish Ocean Technol.* **54**, 54–64 (2018).

22. NIFS (National Institute of Fisheries Science) Fisheries Life Resources Information Center. Busan. http://www.nifs.go.kr/frecenter (2021).
23. Choi, Y., Zhang, C., Lee, J., Kim, J. & Cha, H. Stock assessment and management implications of chub mackerel, *Scomber japonicus* in Korean waters. *J. Kor. Soc. Fish Res.* **6**, 90–100 (2004).
24. Han, H.-S. & Lee, B.-H. On shoals of the yellow tail migration to the East Sea of Korea. *Bull. Fish Res. Dev. Agency* **12**, 27–36 (1974).
25. Kim, Y.-H. & Kang, Y.-J. Population analysis of the common squid, Todarodes pacificus Steenstrup in Korean Waters. *J. Kor. Fish Soc.* **28**, 163–173 (1995).
26. Kim, J. *et al.* Characteristics of catch fluctuation and distribution of yellow tail, *Seriola quinqueradiata*, TEMMINCK et SCHLEGEL, in Korean Waters. *Bull. Kor. Soc. Fish Tech.* **38**, 11–19 (2002).
27. Kang, Y.-J, Kim, Y.-H., Hong, Y.-K., Park, J.-Y. & Park, K.-Y. A population genetic analysis of the common squid, *Todarodes pacificus* Steenstrup in the Korean Waters. *J. Kor. Fish Soc.* **29**, 320–331 (1996).
28. Choi, K.-H., Hwang, S.-N. & Kim, J.-I. Fishing condition of common Squid (Todarodes pacificus Steenstrup) in Korean Waters. I. Spatio-temporal distribution of common squid related to the Changes in Oceanographic Conditions. *J. Kor. Fish Soc.* **30**, 513–522 (1997).
29. Kim, Y.-H., Moon, C.-H., Choi, K. & Lee, C.-I. Relationship between squid (*Todarodes pacificus*) catch by sea block and marine environment in the East Sea during 1980s and 1990s. *J. Korean Soc. Mar. Environ. Saf.* **3**, 259–268 (2010).
30. Oh, S.-Y., Jang, S.-W. & Yoon, H.-J. Variation of catch of anchovy and saury due to oceanic climate change in the Korean seas. *J. Korea Inst. Inf. Commun. Eng.* **15**, 740–746 (2010).
31. Nelson, J. S. Fishes of the World. 3rd edn. *John Wiley & Sons, New York*, 1–600 (1994).
32. Kim, I.-S. *et al.* Illustrated Book of Korean Fishes. *Kyo-Hak Publishing Co., Seoul, Korea*, 615 (2005).
33. KORDI (Korea Ocean Research Development Institute) The Encyclopaedia of fish and seafood. In: squid, octioys etc. *Sambo print co*, 6–33 (2004).
34. KHOA (Korea Hydrographic and Oceanographic Agency) Results of coastal oceanographic observation. Korea Hydrographic and Oceanorgraphic Agency, Busan. http://www.khog.go.kr/oceangrid/gis/category/reference/distribution (2021).

35. Shannon, C. E. & Wiener, W. The mathematical theory of communication. *Illinois Univ Press, Urban*, 1–125 (1963).

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## Author contributions

J.H. performed the most of the experiments and collected the data; D.H.K. and H.S.P. designed the research plan and discussed the results; Y.U.C. wrote the paper.

## Competing interests

The authors have no competing financial interests to declare.

## Additional information

The following are the Supplementary data to this article.

**Table 1.** Fish species captured by set nets in the coastal waters of Yangyang from February 2007 to December 2008.

| Order | Family | Genus | Species |
|---|---|---|---|
| Fishes | | | |
| Carcharhiniformes | 1 | 1 | 1 |
| Anguilliformes | 1 | 1 | 1 |
| Clupeiformes | 2 | 3 | 3 |
| Cypriniformes | 1 | 1 | 1 |
| Sakmoniformes | 1 | 1 | 2 |
| Gardiformes | 1 | 1 | 1 |
| Lophiiformes | 1 | 1 | 1 |
| Atheriniformes | 1 | 1 | 1 |
| Beloniformes | 1 | 2 | 2 |
| Beryciformes | 1 | 1 | 1 |
| Gasterosteiformes | 1 | 1 | 1 |
| Scorpaeniformes | 4 | 5 | 5 |
| Perciformes | 12 | 20 | 21 |
| Pleuronectiformes | 2 | 3 | 3 |
| Tetraodoniformes | 3 | 4 | 4 |
| Cephalopods | | | |
| Octopoda | 1 | 1 | 1 |
| Teuthoidea | 1 | 2 | 2 |
| Total | 35 | 49 | 51 |

**Table 2.** Seasonal variations of dominant species of fishes captured by set nets from the East Sea of Korea.

| Study area | Year | No. of species | Dominant species: Winter (Jan.–Mar.) | Spring (Apr.–Jun) | Summer (Jul.–Sep.) | Autumn (Oct.–Dec.) | Reference |
|---|---|---|---|---|---|---|---|
| Gangwondo | | | | | | | |
| Goseong | 2005 | 73 | *Mugil cephalus, Hemitripterus villosus, Lophius litulon* | *Pleurogrammus azonus, Mugil cephalus* | *Todarodes pacificus* | *Psenopsis anomala, Pleurogrammus azonus, Arctoscopus japonicus* | NFRDI, 2006 |
| | 1998 | 103 | *Oncorhynchus gorbuscha, Clupea pallasii* | *Pleurogrammus azonus, Seriola quinqueradiata, Acanthopagrus schlegeli* | *Cleisthenes pinetorum, Seriola quinqueradiata* | *Stephanolepis cirrhifer, Sebastes schlegelii, Todarodes pacificus* | NFRDI, 2004 |
| | 1999 | 64 | *Clupea pallasii, Thamnaconus modestus* | *Todarodes pacificus, Thamnaconus modestus* | *Thamnaconus modestus* | *Konosirus punctatus, Stephanolepis cirrhifer, Trachurus japonicus* | NFRDI, 2004 |
| | 2000 | 56 | *Clupea pallasii* | *Mugil cephalus, Clupea pallasii, Acanthopagrus schlegeli* | *Mugil cephalus, Trachurus japonicus* | *Stephanolepis cirrhifer, Todarodes pacificus, Ditrema temminckii* | NFRDI, 2004 |
| | 2001 | 40 | *Clupea pallasii, Pleurogrammus azonus, Mugil cephalus* | *Mugil cephalus, Stephanolepis cirrhifer, Seriola quinqueradiata* | *Seriola quinqueradiata* | *Seriola quinqueradiata, Oncorhynchus masou, Todarodes pacificus* | NFRDI, 2004 |
| Yangyang | 2002 | 54 | *Lophius litulon, Clupea pallasii, Aptocyclus ventricosus* | *Mugil cephalus, Lophius litulon, Cleisthenes pinetorum* | *Trachurus japonicus, Scomber japonicus* | *Acanthopagrus schlegeli, Konosirus punctatus* | NFRDI, 2004 |
| | 2003 | 39 | *Lophius litulon, Clupea pallasii* | *Pleurogrammus azonus, Mugil cephalus, Lophius litulon* | *Trachurus japonicus, Thamnaconus modestus* | *Psenopsis anomala, Trachurus japonicus* | NFRDI, 2004 |
| | 2005 | 70 | *Todarodes pacificus, Clupea pallasii, Lophius litulon* | *Pleurogrammus azonus, Todarodes pacificus, Mugil cephalus* | *Todarodes pacificus, Seriola quinqueradiata* | *Scomber japonicus, Engraulis japonicus, Mugil cephalus* | NFRDI, 2006 |
| | 2007 | 49 | *Todarodes pacificus, Pleurogrammus azonus, Mugil cephalus* | *Todarodes pacificus, Pleurogrammus azonus, Mugil cephalus,* | *Scomber japonicus,Todarodes pacificus, Stephanolepis cirrhifer* | *Todarodes pacificus, Seriola quinqueradiata, Stephanolepis cirrhifer* | Present study |
| | 2008 | 46 | *Todarodes pacificus, Pleurogrammus azonus, Oncorhynchus masou* | *Todarodes pacificus, Mugil cephalus, Stephanolepis cirrhifer* | *Todarodes pacificus, Scomber japonicus, Seriola quinqueradiata* | *Todarodes pacificus, Trachurus japonicus, Seriola quinqueradiata* | Present study |

**Table 2.** Continued.

| Study area | Year | No. of species | Dominant species | | | | Reference |
|---|---|---|---|---|---|---|---|
| | | | **Winter (Jan.–Mar.)** | **Spring (Apr.–Jun.)** | **Summer (Jul.–Sep.)** | **Autumn (Oct.–Dec.)** | |
| Gyeongsangbukdo | | | | | | | |
| Uljin | 2005 | 50 | *Todarodes pacificus, Konosirus punctatus, Tribolodon taczanowskii* | *Todarodes pacificus* | *Todarodes pacificus, Scomber japonicus* | *Auxis rochei, Konosirus punctatus, Todarodes pacificus* | NFRDI, 2006 |
| Heunghae | 1993 | 61 | *Todarodes pacificus, Etrumeus teres* | *Todarodes pacificus, Engraulis japonicus* | *Todarodes pacificus, Tamnaconus modestus, Trachurus iaponicus* | *Scomber japonicus, Loligo bleekeri, Todarodes pacificus* | NFRDA, 1995 |
| Heunghae | 1994 | 57 | *Todarodes pacificus, Pampus echinogaster, Loligo bleekeri* | *Todarodes pacificus, Cololabis saira* | *Scomber japonicus, Trachurus japonicus* | *Todarodes pacificus,Trachurus japonicus, Trichiurus lepturus* | NFRDA, 1995 |
| Heunghae | 1995 | 86 | *Todarodes pacificus, Clupea pallasii* | *Todarodes pacificus, Engraulis japonicus* | *Trachurus iaponicus, Scomber japonicus* | *Todarodes pacificus, Trachurus iaponicus, Scomber japonicus* | NFRDA, 1996 |
| Guryongpo | 2001 | 34 | *Konosirus punctatus, Ditrema temminckii, Mugil cephalus* | *Ditrema temminckii, Mugil cephalus, Todarodes pacificus* | *Todarodes pacificus, Seriola quinqueradiata, Mugil cephalus* | *Todarodes pacificus, Mugil cephalus, Seriola quinqueradiata* | NFRDI, 2004 |
| Guryongpo | 2003 | 79 | – | *Engraulis japonicus, Trachurus japonicus* | *Trachurus japonicus, Engraulis japonicus* | *Engraulis japonicus, Trachurus japonicus* | NFRDI, 2004 |
| Guryongpo | 2005 | 53 | *Engraulis japonicus, Mugil cephalus* | *Engraulis japonicus, Trachurus japonicus* | *Trachurus japonicus, Engraulis japonicus* | *Engraulis japonicus, Sebastes schlegelii, Todarodes pacificus* | NFRDI, 2006 |
| Ulsan | 1998 | 89 | *Engraulis japonicus, Pampus echinogaster* | *Cololabis saira, Pleurogrammus azonus, Engraulis japonicus* | *Scomber japonicus, Trachurus japonicus* | *Trachurus japonicus, Tamnaconus modestus, Scomber japonicus* | Han et al. 2002 |

(–) denotes the lack of data.

## Figure legends

**Figure 1.** Map showing the location of the set nets in the coastal waters of Yangyang.

**Figure 2.** Schematic diagram of the set net fishery structure.

**Figure 3.** Monthly variations in the mean water temperature during the study period (2007–2008) in the coastal waters of Yangyang and the last decade (1999–2008) in the coastal waters of Sokcho.

**Figure 4.** Monthly variations in number of species, number of individuals, and diversity (H') of fishes captured by set nets in the Yangyang coastal areas from February 2007 to December 2008.

**Figure 5.** Cluster dendrograms based on cluster analysis and relative abundance of the 18 most dominant fish species in each month in the coastal waters of Yangyang from February 2007 to December 2008. (a) R-mode cluster dendrogram and (b) and Q-mode dendrogram. Monthly expressions are simplified in the form as 7–2 (February 2007).

Figure 1

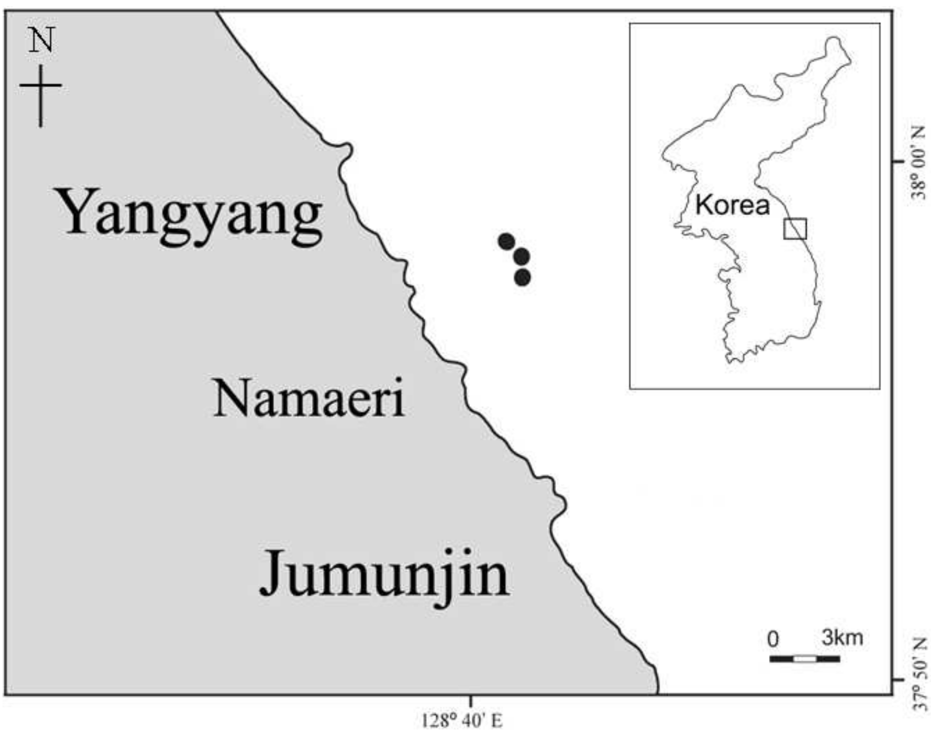


**Figure 2**

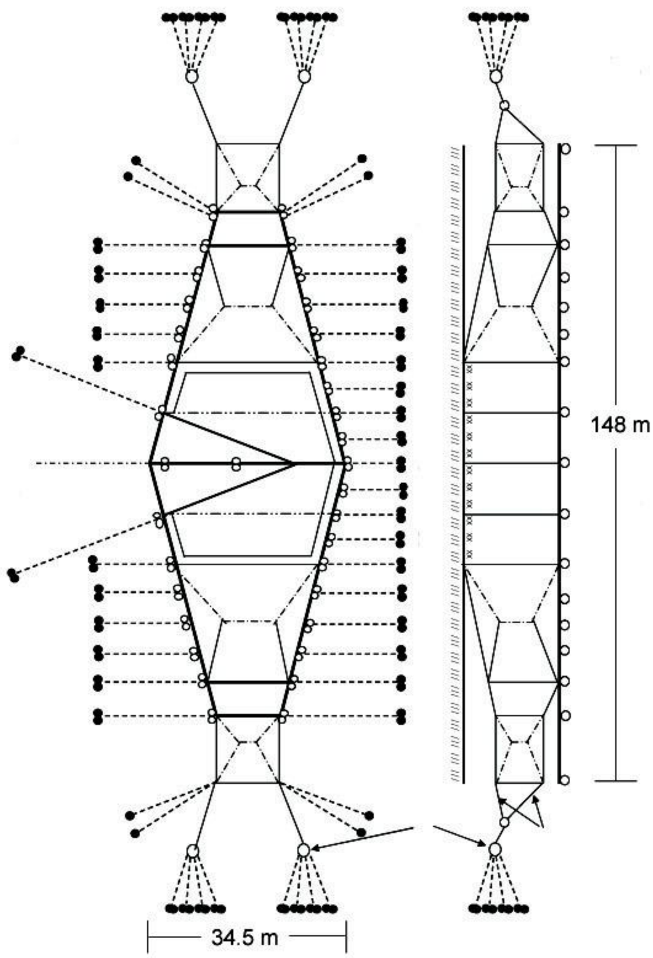
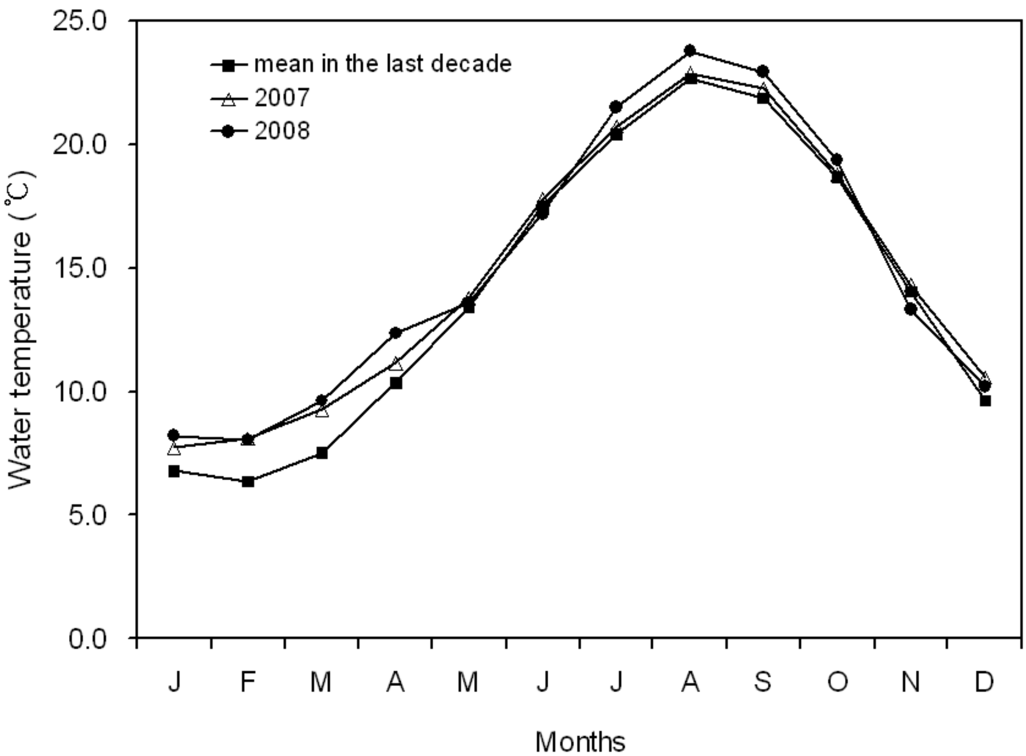
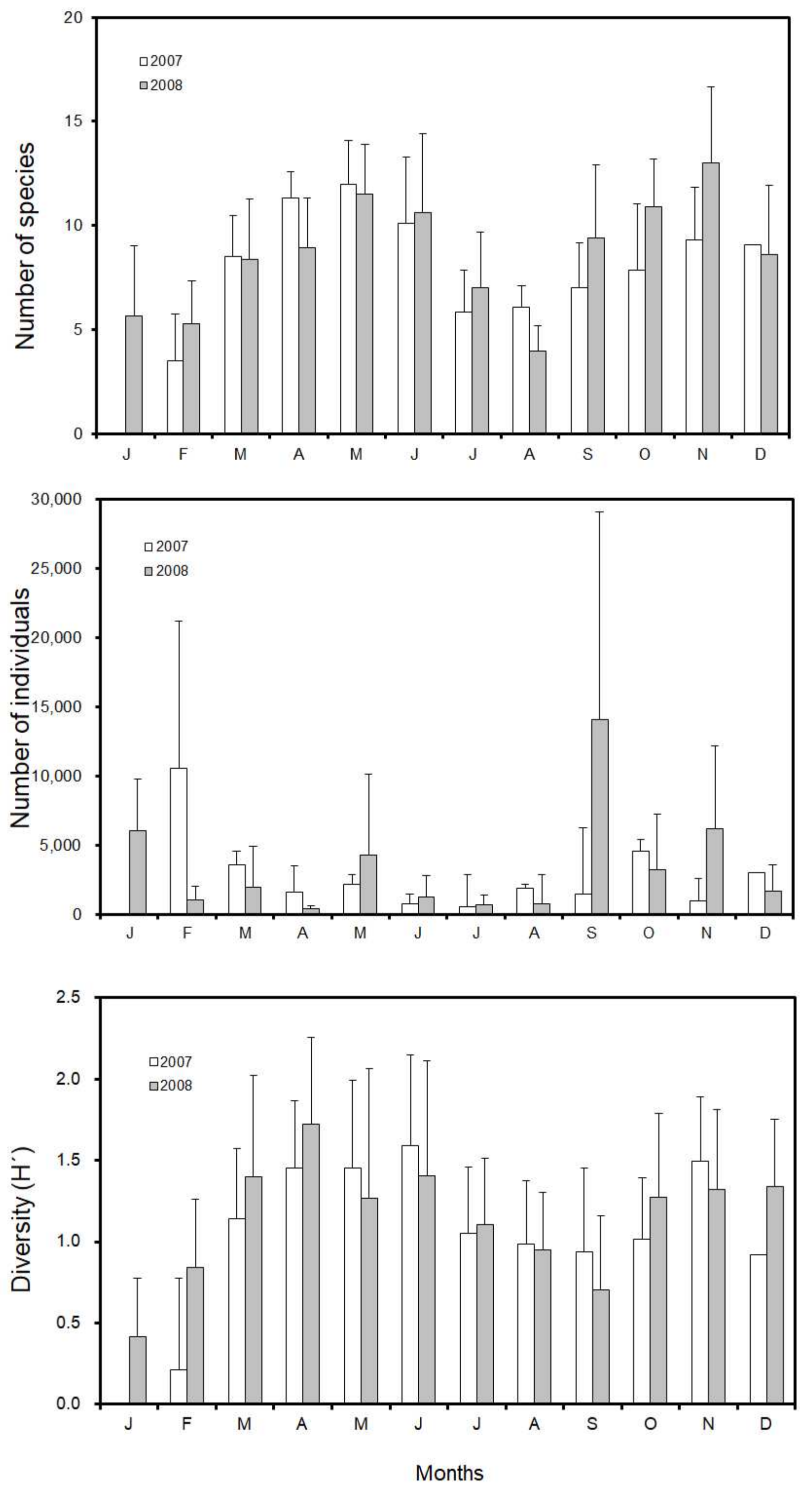


**Figure 3**



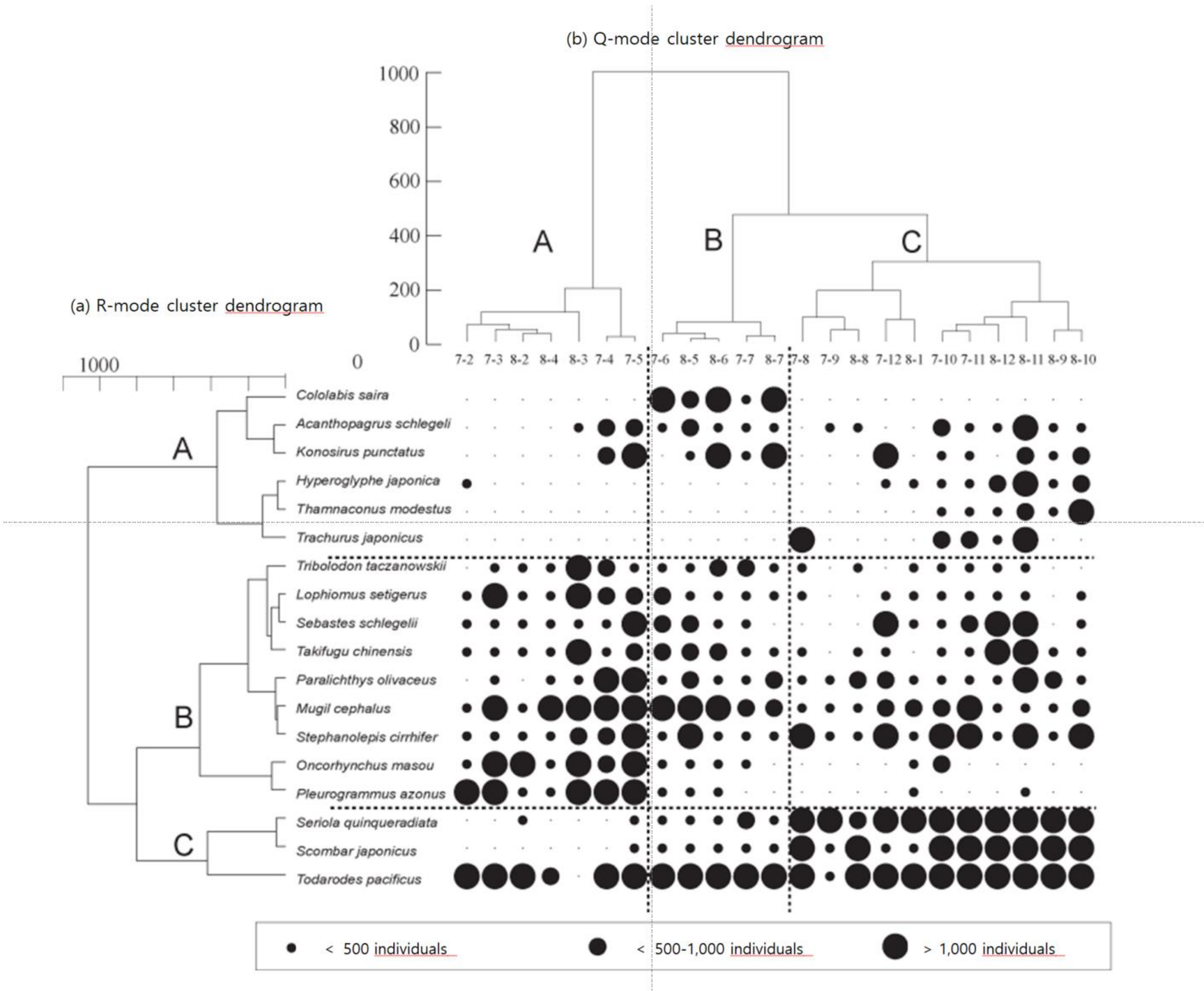
25.0
20.0
15.0
10.0
5.0
0.0
Water temperature (°C)
mean in the last decade
2007
2008
J
F
M
A
M
J
J
A
S
O
N
D
Months

**Figure 4**



Number of species
2007
2008
Number of individuals
Diversity (H´)
J F M A M J J A S O N D
Months

# Figure 5



(b) Q-mode cluster dendrogram
1000
800
600
400
200
0
A
B
C
7-2 7-3 8-2 8-4 8-3 7-4 7-5 7-6 8-5 8-6 7-7 8-7 7-8 7-9 8-8 7-12 8-1 7-10 7-11 8-12 8-11 8-9 8-10
(a) R-mode cluster dendrogram
1000
0
Cololabis saira
Acanthopagrus schlegeli
Konosirus punctatus
Hyperoglyphe japonica
Thamnaconus modestus
Trachurus japonicus
Tribolodon taczanowskii
Lophiomus setigerus
Sebastes schlegelii
Takifugu chinensis
Paralichthys olivaceus
Mugil cephalus
Stephanolepis cirrhifer
Oncorhynchus masou
Pleurogrammus azonus
Seriola quinqueradiata
Scombar japonicus
Todarodes pacificus
< 500 individuals
< 500-1,000 individuals
> 1,000 individuals

# Supplementary Files

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