Iranian Journal of Fisheries Sciences 22(1) 1-12 2023
DOI: 10.22092/ijfs.2023.128571

Research Article

Feeding habits of juvenile Parrotfish, *Oplegnathus fasciatus* (Temminck and Schlegel, 1844), in the coastal waters of Gijang, Korea

Kang D.Y.[1]; Seong G.C.[1]; Kim D.G.[1]; Jin S.[1]; Shin Y.J.[2]; Baeck G.W.[1*]

Received: September 2022 Accepted: December 2022

Abstract

The juvenile *Oplegnathus fasciatus* were collected off the Gijang, Korea coast. A total of 203 juvenile *O. fasciatus* were examined, and the range of total length (TL) was 7.9-31.0 mm. The most important prey component of *O. fasciatus* was Copepods, with 75.0% in IRI (index of relative importance) index. Among Copepods, *Paracalanus parvus* s.l. in the Calanoida was the most significant dietary component. Cladocera was the second important prey component. Pisces, Amphipoda, Decapoda, and the other preys accounted for less than 1.8% of the diet by IRI index. The feeding strategy showed that *O. fasciatus* held a specialist niche with a considerable individual specialization. The result of analysis in ontogenetic changes was significantly exhibited among size classes. The proportion of Copepods decreased as increasing in body size, whereas the consumption of Cladocera, Pisces, Amphipoda, and Decapoda increased gradually. As body size increased, both the mean numbers of prey per gut (mN/Gut) and the mean volume of prey per gut (mV/Gut) constantly increased.

Keywords: Parrotfish, *Oplegnathus fasciatus*, Feeding habits, Juvenile fish, Juvenile feeding

1-Department of Marine Biology & Aquaculture, Institute of Marine Industry, College of Marine Science, Gyeongsang National University, Tongyeong, Korea
2-Resources Enhancement Division, Korea Fisheries Resources Agency, Busan, Korea
*Corresponding author's Email: gwbaeck@gnu.ac.kr

Introduction

The parrotfish, *Oplegnathus fasciatus*, belongs to the order Perciforms and the family Oplegnathidae which lives mainly around reefs off the coastal areas of Korea, Japan, and China (MIFFAF, 2010). *O. fasciatus* juveniles are benthic and live under seaweed. Adults mainly eat shellfish, sea urchins and spawn eggs singly on the sand between April and July (Kim *et al*., 2005; Nelson, 2006; Shimada *et al*., 2009). In Korea, *O. fasciatus* is considered a luxury seafood with a high market value. It is usually cultured in sea cages, or its fry is released into the sea for restocking purposes (Hwang *et al*., 2005).

In Korea, research on *O. fasciatus* has focused on aquaculture to increase resources, while more research on the natural ecology of *O. fasciatus* is insufficient. Although fish spawn many eggs, the population are declining because of the effects of habitat conditions, such as food and water temperature (May, 1974). Thus, the population is determined early in life. Since the feeding activities of larvae and juvenile fish are closely related to population growth, it is essential to identify the diets of larvae and juvenile fish, to understand their early life history and ecology (Lasker *et al*., 1970; Heath, 1992).

Fish ecology studies such as feeding habits are essential for understanding the ecological niche and functional aspects of the marine ecosystem (Baeck *et al*., 2011), and understanding the impact of marine organisms according to changes in the environment. In particular, the early stage of fish and zooplankton communities are affected by environmental factors such as water temperature, dissolved oxygen, and food organisms (Moon *et al*., 2006). Therefore, the continuous accumulation of data with larval and juvenile fish studies can be used as essential data to understand the biological clusters in the habitat. Also, studying the predators that feed on them can be used to understand the fluctuations and characteristics of the marine environment.

Therefore, this study analyzed the prey of *O. fasciatus* juveniles on the Gijang coast of Korea, identifying main prey items, feeding strategy, and changes in prey items by size group and providing ecological data for the efficient management of juvenile *O. fasciatus* resources.

Materials and methods

The juvenile *O. fasciatus* were collected with the RN80 Net (net mouth 0.8 m, mesh size 330 μm) from the surface during the summer of 2018 (June-August) off the coast of Gijang, Korea (35˚ 25’ E, 35˚ 26’ E, 129˚ 25’ N) (Fig. 1). The collected juvenile *O. fasciatus* were fixed to 70% alcohol, and then the total length of each object was measured up to 0.1 mm. After that, the entire digestive tract was separated using an anatomical needle under a Leica DMIL LED microscope (Leica, Solms, Germany). The contents of the digestive tract were analyzed after removing debris using 70% lactic acid.

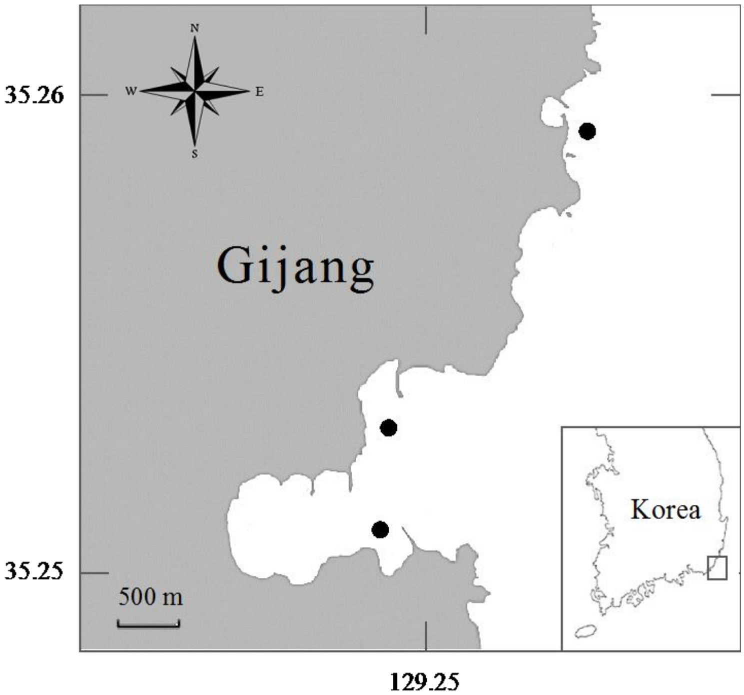

Figure 1: Location of sampling sites in the coastal waters of Gijang, Korea, from June to August 2018 (●).

The digestive tract contents were identified to the lowest possible species level. In the case of Copepods, taxonomic features such as the fifth thorax, posterior body, and tactile were closely observed with illustrated books (Okiyama, 1988; Yamaji, 1966; Soh, 2010).

Prey items were counted by type, measured size (width and length), and volume calculated by referring to the volume calculation formula of Takatsu *et al*. (2007).

The prey item was quantified based on the frequency of occurrence (F, %), numerical percentage (N, %), and volume percentage (V, %) of each prey item, which was calculated using the following equations:

$\% F = A_i / N \times 100$

$\% N = N_i / N_{total} \times 100$

$\% V = V_i / V_{total} \times 100$

Where A_i is the number of fish prey on species i, N is the total number of fish examined (excluding individuals with empty digestive tract), and N_i (V_i) is the number (volume) of prey. Then the index of relative importance (IRI) was calculated for each prey type, as follows (Pinkas *et al*., 1971):

$IRI = (\%N + \%V) \times \%F$

And expressed as a percentage (IRI, %):

$\%IRI = IRI_i / IRI_{total} \times 100$

The juvenile *O. fasciatus* level of specialization was then directly assessed using the percent prey specific abundance (P_i, %) versus frequency of occurrence (F, %) diagram described by Amundsen *et al*. (1996). Percent prey specific abundance (P_i, %) was measured using the following equations:

$$P_i = (\sum S_i \div \sum S_{ti}) \times 100$$

In which P_i is equal to the prey-specific abundance of prey i, S_i is the total weight of prey i from all digestive tracts, and S_{ti} is the total prey weight of all digestive tracts containing prey i. Empty digestive tracts and unidentified material were excluded from the calculations, which would bias the results.

Size-related dietary changes were examined by dividing the specimens into three size classes: <20.0 mm, 20.0-25.0 mm, ≥25.0 mm. The mean number of prey items per gut (mN/Gut) and mean volume of prey items per gut (mV/Gut) were used to characterize size-related changes in the diet via one-way analysis of variance (Analysis of variance, One-way ANOVA). All statistical tests were conducted using SPSS 11.0 for Windows; statistical differences were determined based on a significance level of 0.05.

Results

A total of 203 juvenile *O. fasciatus* were collected, and the TL ranged from 7.9 to 31.0 mm, with an average of 19.7 mm (Fig. 2). Especially the 21.0-22.0 mm group was the most dominant, accounting for 16.3%.

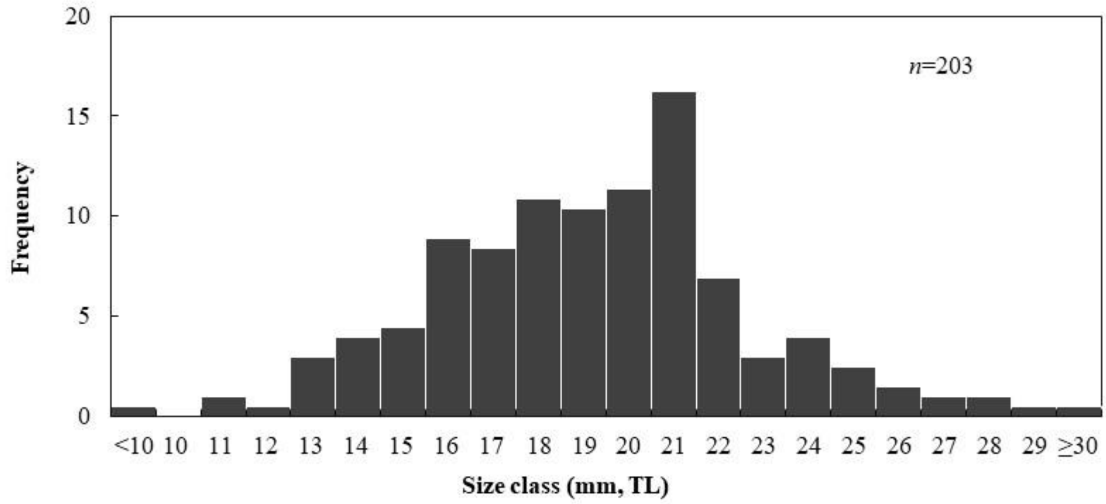

Figure 2: Size distribution of juvenile *Oplegnathus fasciatus* in the coastal waters of Gijang, Korea.

Among 203 individuals, one had an empty digestive tract, and the rate of the empty digestive tract was 0.5%. Table 1 analyzes the contents of the digestive tracts of 202 individuals, where prey items were found. Copepods was the most important prey item for juvenile *O. fasciatus*, comprising 99.0% in terms of prey occurrence, 59.6% in terms of prey number, 68.1% of the prey volume, and 75.0% of the index of relative importance. Among them, Calanoida was the dominant taxon, making up 91.1% of the occurrences, 31.7% of the number, and 54.5% of the volume.

[DOR: 20.1001.1.15622916.2023.22.1.1.4]

Table 1: Composition of the gut contents of juvenile *Oplegnathus fasciatus* by frequency of occurrence (F, %), number (N, %), volume (V, %), and index of relative importance (IRI, %).

Prey organism		F, %	N, %	V, %	IRI	IRI, %
Amphipoda		**25.7**	**1.0**	**10.2**	**287.4**	**1.7**
	Caprellidae	2.5	0.1	0.2		
	Caprella acutifrons	0.5	+	0.1		
	Caprella sp.	2.0	+	0.1		
	Gammaridae	23.3	0.9	9.9		
	Allorchestes sp.	1.0	+	0.1		
	Eurystheus sp.	0.5	+	+		
	Jassa falcata	1.5	+	1.0		
	Liljeborgia sp.	0.5	+	+		
	Melita denatata	0.5	+	+		
	Pseudocrangonyx yezonis	13.9	0.5	5.5		
	Vibilia viatrix	11.4	0.3	3.4		
	Hyperiidae	1.0	+	+		
	Hyperia latissima	0.5	+	+		
	Hyperiidae	0.5	+	+		
	Unidentified Amphipoda	2.0	+	+		
Decapoda		**40.6**	**1.7**	**5.3**	**284.6**	**1.7**
	Brachyura	23.3	0.8	0.7		
	Brachyura zoea	23.3	0.8	0.7		
	Macrura	20.3	0.6	2.9		
	Lucifer chacei	1.5	+	1.0		
	Macurura mysis	18.8	0.5	1.9		
	Mysidacea	10.9	0.4	1.7		
Copepoda		**99.0**	**59.6**	**68.1**	**12,636.1**	**75.0**
	Calanoida	91.1	31.7	54.5		
	Calanopia sp.	0.5	+	0.6		
	Calanus sinicus	5.9	0.8	2.4		
	Calocalanus pavo	1.0	0.1	+		
	Calocalanus sp.	0.5	+	+		
	Canthocamptus sp.	13.9	0.5	0.4		
	Centropages abdominalis	0.5	+	+		
	Labidocera kroyeri	0.5	+	0.4		
	Labidocera pavo	36.1	5.2	7.0		
	Labidocera sp.	23.3	2.7	4.0		
	Paracalanus parvus s.l.	75.2	18.0	27.4		
	Temora discaudata	27.7	2.7	9.5		
	Temora tubinata	19.3	1.8	2.7		
	Cyclopoida	91.6	24.5	12.5		
	Corycaeus anglius	82.7	11.9	5.2		
	Halicyclops pumilus	1.0	+	+		
	Oncaea venusta	75.2	12.6	7.3		
	Harpacticoida	32.2	1.4	0.8		
	Apolethon sp.	10.4	0.7	0.4		
	Euterpina acutifrons	2.0	0.1	+		
	Harpacticoidae	2.0	+	0.1		
	Leptocaris brevicornis	6.4	0.2	0.1		
	Neotachidius sp.	1.0	+	+		
	Phyllognathopus sp.	10.4	0.3	0.1		
	Tigriopus sp.	3.5	0.2	0.1		
	Unidentified Nauplius	16.8	1.3	+		
	Unidentified Copepodite	1.5	+	+		
	Unidentified Copepods	3.5	0.6	0.2		

[DOR: 20.1001.1.15622916.2023.22.1.1.4]

Table 1 (continued):

Prey organism		F, %	N, %	V, %	IRI	IRI, %
Cladocera		**93.1**	**29.8**	**3.8**	**3,125.2**	**18.6**
	Evadne tergestina	93.1	29.8	3.8		
Cumacea		**1.5**	+	**0.1**	**0.2**	+
Anthozoa		**0.5**	+	+	+	+
Bivalvia		**28.7**	**1.0**	+	**29.1**	**0.2**
Chaetognatha		**4.0**	**0.1**	**1.0**	**4.2**	+
	Sagitta sp.	4.0	0.1	1.0		
Gastropoda		**40.1**	**1.8**	**0.5**	**91.5**	**0.5**
	Creseis sp.	3.0	0.1	+		
	Sorbeoconcha	39.6	1.8	0.4		
Monogenea		**0.5**	**0.1**	+	+	+
Ostracoda		**41.6**	**1.7**	+	**72.4**	**0.4**
Pisces		**22.8**	**2.6**	**10.9**	**308.3**	**1.8**
	Thamnaconus modestus	0.5	+	7.1		
	Unidentified Pisces eggs	22.8	2.6	3.8		
Tintinnid		**1.0**	+	+	+	+
Radiolaria		**4.5**	**0.4**	+	**1.8**	+
	Drymosphaera sp.	4.5	0.4	+		
Rhizopoda		**1.0**	+	+	+	+
	Globigerinidae	1.0	+	+		
Diatom		**4.5**	**0.1**	+	**0.5**	+
Seaweeds		**2.5**	**0.1**	+	**0.2**	+
Plastic		**0.5**	+	+	+	+
	Total		100.0	100.0	16,841.8	100.0

Paracalanus parvus s.l. (Chihara and Murano, 1997) from Calanoida was the most significant dietary component, constituting 75.2% of the occurrences, 18.0% of the number, and 27.4% of the volume.

Evadne tergestina from Cladocera was the second largest prey item, constituting 93.1% of the occurrences, 29.8% of the number, 3.8% of the volume, and 18.6% of index of relative importance in the diet. Pisces, Amphipoda, Decapoda, and the other preys accounted for less than 1.8% of the diet by the IRI index.

The relative importance of the juvenile *O. fasciatus* prey items is shown in Figure 3 (A), where each is the percentage of prey-specific abundance (P_i, %) over frequency of occurrence (F, %). The feeding strategy plot showed that *O. fasciatus* held a specialist niche with a considerable individual specialization. Copepods was the most important prey item, thus having a 68.1% of % prey-specific abundance value and 99.0% frequency of occurrence value. Other groups of prey located towards the lower axis of the diagram in regions were considered rare or unimportant prey items. These results indicated their specialization for Copepods with a wide niche gradient. Focused on the taxon of Copepods was analyzed; additionally, the result is shown in Figure 3 (B). Calanoida from Copepods was the most important prey item, with an 80.6% of prey-specific abundance value and 91.1% frequency of occurrence. Cyclopoida and

[DOR: 20.1001.1.15622916.2023.22.1.1.4]

Harpacticoida were non-importance prey items located towards the lower axis.

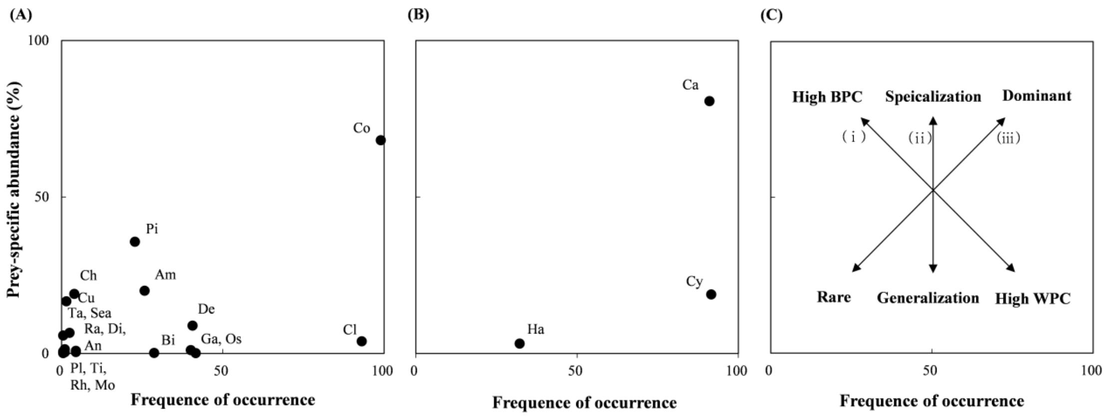

Figure 3: (A) Graphical representation of feeding pattern of juvenile *Oplegnathus fasciatus* (Am, Amphipoda; An, Anthozoa; Bi, Bivalvia; Ch, Chaetognatha; Cl, Cladocera; Co, Copepods; Cu, Cumacea; De, Decapoda; Di, Diatom; Ga, Gastropoda; Mo, Monogenean; Os, Ostracoda; Pi, Pisces; Pl, Plastic; Ra, Radiolaria; Rh, Rhizopoda; Sea, Seaweed; Ta, Tanaidacea; Ti, Tintinnid). (B) Graphical representation of feeding pattern of juvenile for dominant prey item (Copepods) (Ca, Calanoida; Cy, Cyclopoida; Ha, Harpacticoida). (C) Explanatory diagram for interpretation of niche width contribution (axis ⅰ, within phenotypic component (WPC) or between phenotypic component (BPC)) of the study population, feeding strategy (axis ⅱ), and prey importance (axis ⅲ).

It was analyzed into three sizes to determine the changes in the composition of prey items by the growth of the juvenile *O. fasciatus* (Fig. 4; <20.0 mm, 20.0-25.0 mm, ≥25.0 mm). In the size class of <20.0 mm, Copepods, and Cladocera represented 83.2% and 15.6%, respectively, based on the IRI index. Additionally, Pisces, Amphipods, and Decapods accounted for only 0.2%, 0.1%, and 0.3% of the diet by IRI, respectively. In the size class of 20.0-25.0 mm, the proportion of Copepods decreased to 71.4%, while Cladocera, Pisces, Amphipods, and Decapods increased slightly. In the size class of ≥ 25.0 mm, the proportion of Copepods consistently decreased to 56.8% of IRI. Cladocera also decreased somewhat to 16.8%. However, Pisces, Amphipods, and Decapods consistently increased, accounting for 17.1%, 5.6%, and 2.0% of IRI, respectively. Thus, juvenile *O. fasciatus* tends to decrease the feeding of Copepods, while the feeding of others increases as the size classes increase.

The mean number of prey items per gut (mN/Gut, one-way ANOVA, $p<0.05$) and mean volume of prey items per gut (mV/Gut, one-way ANOVA, $p<0.05$) of *O. fasciatus* juvenile were significantly increased with size classes (Fig. 5).

[DOR: 20.1001.1.15622916.2023.22.1.1.4]

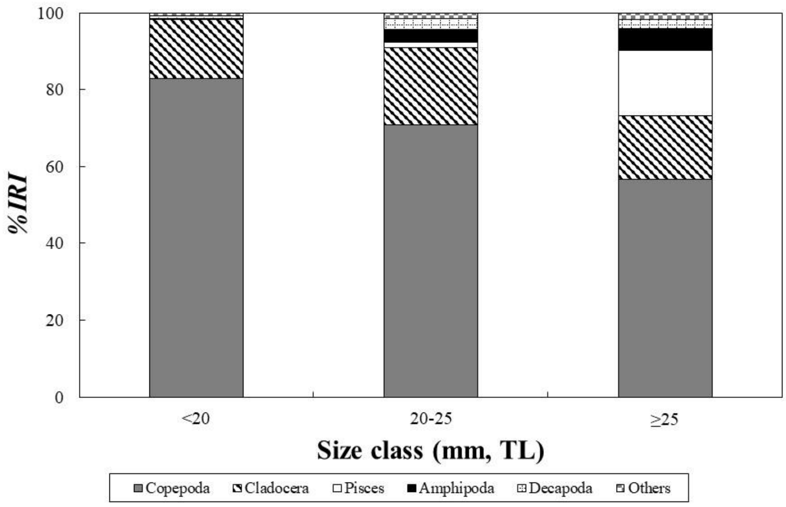

Figure 4: Ontogenetic changes in composition of prey items based on the index of relative importance (IRI, %) of juvenile *Oplegnathus fasciatus* among different size classes (<20.0 mm; 20.0-25.0 mm; ≥25.0 mm). TL, Total length.

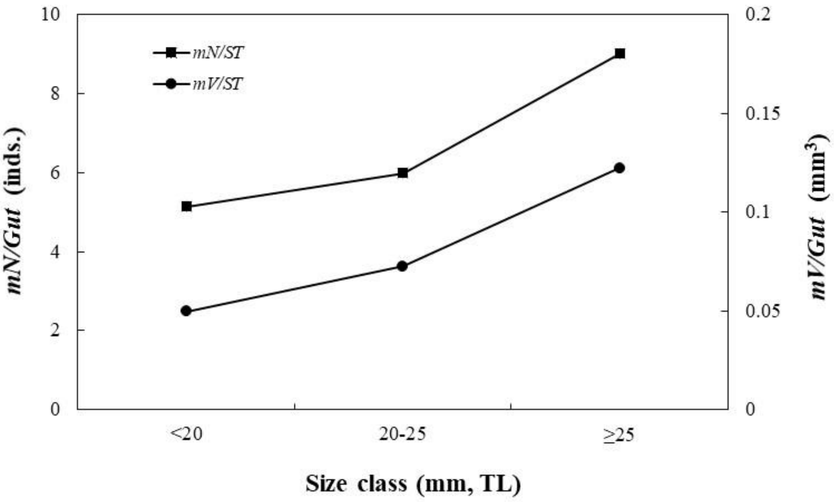

Figure 5: Variation of the mean number of prey per gut (mN/Gut, individuals/gut) and mean volume of prey per gut (mV/Gut, mm^3/gut) of juvenile *Oplegnathus fasciatus* among size classes (<20.0 mm; 20.0-25.0 mm; ≥25.0 mm). TL, Total length.

Discussion

The study area of this study was conducted in the inner bay of the coast, and a semi-enclosed reef area, which is rich in nutrients as various organic and inorganic substances originating from land are introduced. In particular, typhoons and floods are frequent in summer. Thus, the influx of nutrients from the land increases and various plankton live there, creating a suitable environment for fish spawning and breeding grounds (Kwon *et al*., 2013). Therefore, the study area is a suitable environment for *O. fasciatus* spawning and growing, which mainly inhabits coastal reefs and spawns in late spring-early summer.

The rate of the empty digestive tract in this study was 0.5%, which was lower than Clupeiformes, which showed an average rate of about 40%. Perciformes have a curved digestive tract, making it difficult to excrete or vomit food during the sampling or fixing process (Cha and Park, 2001; Yoo and Jeong, 2016).

In this study, juvenile *O. fasciatus* mainly ate Copepods showed a similar result to a previous study performed in the Goto Islands of Japan (Hasegawa *et al*., 2016). Most larvae and juvenile fish absorbed the egg yolk after hatching and fed on Copepods as they grew (Hunter, 1981). This is because larvae and juvenile fish with poor swimming ability and not fully developed digestive organs can easily eat small Copepods with minimal efforts (Huh and Kwak, 1997). Furthermore, near the seaweed where juvenile *O. fasciatus* lives, zooplankton is abundant since phytoplankton has relatively dominant. Therefore, the juvenile *O. fasciatus* also appeared to be opportunistic predators, mainly eating Copepods, which is abundant along the coast.

Among Copepods in the prey items, *O. fasciatus* ate *P. parvus* s.l. from Calanoid the most. *P. parvus* s.l. is a small species with a size of less than 1 mm. It mainly inhabits inner bays and appears in high density throughout the year in the South Sea of Korea and the southern part of the East Sea (Moon *et al*., 2010). In summer, as the water temperature rises, their productivity increase and they multiply rapidly in large numbers. In addition, *O. fasciatus* ate a lot of *E. tergestina*, which belongs to Cladocera. *E. tergestina* feeds on phytoplankton in coastal waters and shows a negative correlation with dissolved oxygen because it proliferates in large numbers in a short period through parthenogenetic reproduction in eutrophic habitat environments (Longhurst and seilbert, 1972; Moon *et al*., 2006). The study area is semi-enclosed, and there is a lot of freshwater inflow due to high precipitation in summer. Therefore, eutrophication occurs because of the many nutrients influx from the land. In this study, since *O. fasciatus* were collected in summer, it is expected that *O. fasciatus* lived where *P. parvus* s.l. and *E. tergestina* proliferated. Therefore, it is judged that *O. fasciatus* ate the prey items that were easy to feed and appeared abundantly in the habitat when they lived in hiding under the seaweed.

Feeding strategy plots of the diet composition based on prey biomass showed that *O. fasciatus* was a specialized predator that heavily relied on Copepods. Especially, *P. parvus* s.l. from Calanoida was the main prey item. Because *P. parvus* s.l. is smaller than other Copepods, it is easy for small mouth-width juvenile or larvae fish to eat (Moon *et al*., 2010). Dietary analysis is critical to assessing feeding strategy (Amundsen *et al*., 1996) and dietary breadth or niche width of predatory fish (Schoener, 1971). Pianka (1988) has reported that specialist predators have narrow dietary niches, while generalist predators consume many prey items. Based on such results, identifying the functional role of a predator within an ecosystem is ultimately needed. Therefore, analysis of dietary compositions showed that *O. fasciatus* occupied a specialist niche at the

[DOR: 20.1001.1.15622916.2023.22.1.1.4]

population level but a high specialization on Copepods at the individual level.

As a result of analyzing the change in the prey composition by size class, juvenile O. fasciatus did not consistently dominate certain types of prey as the size class increased. As the size of *O. fasciatus* increases, the consumption rate of Copepods decreases, while the rates of other prey items increase gradually. As they grew, juvenile *O. fasciatus* fed on prey hiding under floating algae; their habitat depth deepened, and their ability to catch prey increased, allowing them to eat a variety of prey (Cho *et al*., 2002).

The mN/Gut and mV/Gut of juvenile *O. fasciatus* by size classes significantly tended to increase. Fish generally have three main trends: 1) Both the mean number and volume of prey per gut increase; 2) the mean number increases, but the mean volume decreases; 3) the mean number decreases, but the mean volume increases (Kim *et al*., 2017). In this study, both mN/Gut and mV/Gut of juvenile *O. fasciatus* increased significantly with size class feeding strategy. *O. fasciatus* improve nutritional efficiency due to the development of mouth size and digestive organs due to growth.

Acknowledgements

The English in this document has been checked by at least two professional editors, both native speakers of English.

References

Amundsen, P.A., Gabler, H.M. and Staldvik, F.J., 1996. A new approach to graphical analysis of feeding strategy from stomach contents data modification of Costello (1990) method. *Journal of Fish Biology*, 48, 607-614. DOI: 10.1006/jfbi.1996.0060

Baeck, G.W., Huh, S.H., Choi, H.C. and Park, J.M., 2011. Feeding habits of the redbanded searobin *Lepidotrigla guentheri* in the coastal waters off Gori, Korea. *Korean Journal of Fisheries and Aquatic Sciences*, 44, 372–377. DOI: 10.5657/KFAS.2011.0372

Cha, S.S. and Park, K.J., 2001. Feeding selectivity of post larvae of white croaker (*Argyrosomus argentatus*) in Kwangyang Bay, Korea. *Korean Journal of Fisheries and Aquatic Sciences*, 34, 27–31.

Chihara, M. and Murano, M., 1997. An illustrated guide to marine plankton Japan, Tokai University Press, Tokyo, Japan. 1270 P.

Cho, S.H., Myoung, J.G., Kim, J.M., Lee, J.H. and Park, Y.J., 2002. Study on the young yellowtail, *Seriola quinqueradiata* (Carangidae, Perciformes) from drifting seaweeds in the coast of Tongyeong, Korea. *Korean Journal of Fisheries and Aquatic Sciences*, 35, 583–588.

Hasegawa, T., Manda, A., Takatsuki, N., Kawabata, Y., Nishihara, G.N., Fujita, S., Kawabe, R., Yamada, M., Kinoshita, T., Yamawaki, N., Morii, Y. and Sakakura, Y., 2016. Feeding habit of juvenile fishes associated with drifting seaweeds in the East China Sea with reference to oceanographic parameters. *Aquaculture Science*, 64, 157–171.

Heath, M.R., 1992. Field investigations of the early life stages of marine fish. *Advances in Marine Biology*, 28, 1–174. DOI: 10.1016/s0065-2881(08)60039-5

Huh, S.H. and Kwak, S.N., 1997. Feeding habits of *Pholis nebulosa*. *Korean journal of Ichthyology*, 9, 22–29.

Hunter, J.R., 1981. Feeding ecology and predation of marine fish larvae. In: Marine fish larvae: morphology, ecology, and relation to fisheries. R. Lasker (edi.). Seattle, *Washington Sea Grant Program*, 343–355.

Hwang, H.K., Lee, J.U., Yang, S.G., Kim, S.C. and Kim, K.M., 2005. Water temperature and food on growth and survival of parrot fish larvae, *Oplegnathus fasciatus*. *Aquaculture*, 18, 13–18. DOI: 10.1016/0044-8486(79)90096-6

Kim, I.S., Choi, Y., Lee, C.L., Lee, Y.J., Kim, B.J. and Kim, J.H., 2005. Illustrated book of Korean fishes. *Kyo-Hak Publishing*, Seoul, Korea. 615 P.

Kim, H.J., Jeong, J.M., Park, J.H. and Baeck, G.W., 2017. Feeding habits of larval *Clupea pallasii* in the Eastern Jinhae Bay, Korea. *Journal of the Korean Society of Fisheries and Ocean Technology*, 53, 107–113. DOI: 10.3796/KSFT.2017.53.1.107

Kwon, J.N., Park, Y.C. and Eom, K.H., 2013. The Characteristic of Long Term Variation of the Water Quality from Hansan-Geoje bay, Korea. *Journal of the Korean Society for Marine Environment & Energy*,16, 189–201.

Lasker, R., Feder, H., Theilacker, G. and May, R., 1970. Feeding, growth, and survival of *Engraulis mordax* larvae reared in the laboratory. *Marine Biology*, 5, 345–353. DOI: 10.1007/BF00346901

Longhurst, A.R. and Seilbert, D.L.R., 1972. Oceanic distribution of Evadne in the eastern Pacific (Cladocera). *Crustaceana*, 22, 239-248. DOI: 10.1163/156854072X00525

May, R.C., 1974. Larval mortality in marine fishes and the critical period concept. In: The early life history of fish. J.H.S. Blaxter (edi.). *Springer*, Berlin, Heidelberg. 19 P.

MIFFAF (The Ministry for Food, Agriculture, Forestry and Fisheries)., 2010. Studies on the development of marine ranching program 2009 in the East, West and Jeju coast of Korea. 1269 P.

Moon, S.Y., Yoon, H.S., Soh, H.Y. and Choi, S.D., 2006. Environmental Factors and Variation Characteristics of Zooplankton Communities in Gamak Bay. *Ocean and Polar Research*, 28, 79–94. DOI: 10.4217/OPR.2006.28.2.079

Moon, S.Y., Oh, H.J. and Soh, H.Y., 2010. Seasonal variation of zooplankton communities in the southern coastal waters of Korea. *Ocean and Polar Research*, 32, 411–426. DOI: 10.4217/OPR.2010.32.4.411

Nelson, J.S., 2006. Fishes of the world, 4th ed. John. *Wiley and Sons*, New York. 601 P.

Okiyama, M., 1988. An atlas of the early stage fishes in Japan. Tokai University Press, Japan. 1154 P.

Pinkas, L., Oliphant, M.S. and Iverson, I.L.K., 1971. Food habits of albacore, bluefin tuna and bonito in California waters. *Fishery Bulletin*, 152, 1–105.

Pianka, E.R., 1988. Evolutionary Ecology, 4th ed. *Harper Collins*, NewYork, USA. 468 P.

Schoener, T.W., 1971. Theory of feeding strategies. *Annual Review of Ecology, Evolution, and Systematics*, 2, 369–404. DOI: 10.1146/annurev.es.02.110171.002101

Shimada, Y., Nokubi, K., Yamamoto, S., Murata, O. and Kumai, H., 2009. Reproduction between *Oplegnathus fasciatus* and *O. punctatus*, and fertility of their interspecies. *Fisheries Science*, 75, 521–523.

Soh, H.Y., 2010. Invertebrate Fauna of Korea, Marine Planktonic Copepoda. *National Institute of Biological Resources*, Korea. 171 P.

Takatsu, T., Suzuki, Y., Shimizu, A., Imura, K., Hiraoka, Y. and Shiga, N., 2007. Feeding habits of stone flounder *Platichthys bicoloratus* larvae in Mutsu Bay, Japan. *Fisheries Science*, 73, 142–155.

Yamaji, I., 1966. Illustrations of the marine plankton of Japan. *Hoikusha*, Japan. 971 P.

Yoo, J.T. and Jeong, J.M., 2016. Gut Composition of Postlarval and Juvenile Anchovy *Engraulis japonicus* in the Coastal Waters of Yeosu, Korea. *Korean Journal of Fisheries and Aquatic Sciences*, 49, 642–647. DOI: 10.5657/KFAS.2016.0642