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Influence of seasonal and spatial seagrass vegetation (Plantae, Zosteraceae) on fish assemblages in southern Geoje Island, Korea

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Abstract

Seagrass beds are vital marine ecosystems that provide habitat and resources for diverse fish communities. This study evaluated the effects of spatial and seasonal seagrass vegetation on fish assemblages inhabiting seagrass (*Zostera marina* Linnaeus, 1753) beds around Myeongsa (typically a sandy shore) and Daepo (denser seagrass beds) in the southern coastal region of Geoje Island. Fish samples were collected monthly from September 2009 to November 2010 using a beach seine and push net. A total of 51 fish species (42 species at Myeongsa and 36 species at Daepo) from 31 families were identified across both study sites. The two study sites exhibited distinct seagrass vegetation patterns, with denser seagrass at Daepo and relatively sparse seagrass at Myeongsa. At Myeongsa, *Takifugu niphobles* (Jordan et Snyder, 1901), *Aulichthys japonicus* Brevoort, 1862, and *Syngnathus schlegeli* Kaup, 1856 were the most dominant species (in terms of frequency of occurrence). In contrast, Daepo was dominated by *Rudarius ercodes* Jordan et Fowler, 1902, *Hexagrammos agrammus* (Temminck et Schlegel, 1843), and *Paracentropogon rubripinnis* (Temminck et Schlegel, 1843), highlighting habitat-specific differences between fish assemblages and common fish species. Fish species richness, abundance, and diversity varied substantially depending on habitat type and season. Myeongsa, which was dominated by *Takifugu niphobles*, had the highest fish abundance, whereas Daepo exhibited a more balanced and diverse species composition. Non-metric multidimensional scaling analysis further demonstrated that habitat and season significantly influenced fish assemblage structure, with seasonal variations in abundance correlating with changes in seagrass biomass and temperature. Our findings provide baseline data for the conservation and management of seagrass-associated fish communities in Korea and contribute to broader efforts to sustain biodiversity within coastal habitats.

Keywords

abundance, fish assemblage, Geoje Island, seagrass vegetation, *Zostera marina*

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Introduction

Seagrass promotes high species variety, abundance, and biomass and provides a protective habitat for the early life stages of marine fish and shellfish (Hemminga and Duarte 2000; Morrison et al. 2014). Seagrass also enhances the flow of energy within the habitat and strengthens ecological interactions among species, thereby maintaining biodiversity and ecosystem stability (Parrish 1989; Duffy 2006). The most prevalent seagrass species around the Korean Peninsula is *Zostera marina* Linnaeus, 1753 (also referred to as eelgrass), which is found in vast meadows along the South Korean coast (Green and Short 2003). *Zostera marina* beds are found in shallow coastal waters and estuaries of Korea, where the water depth is often less than 5 m, and the height varies from 30 to 210 cm (Lee et al. 2000; Green and Short 2003). Several studies have documented variations in fish assemblages across different seagrass habitats in South Korea. For example, studies on fish species composition in Jeju Island (Go and Cho 1997), Geoje Island (Kim and Gwak 2006), Gamak and Yeoja Bays (Kim et al. 2009), Namhae Island (Park and Kwak 2018), and Tongyeong (Kim et al. 2023) have reported differences in species composition influenced by vegetation structure and habitat conditions.

Eelgrass meadows and seaweed farms are among the most productive marine ecosystems and act as ecosystem engineers by stabilizing sediments, preventing bottom erosion, providing nutrients, and storing carbon (Bos et al. 2007; Mcleod et al. 2011; O'Brien et al. 2018; Gintowt et al. 2025). Similar to the sheltering functions of terrestrial forests for land-dwelling fauna, seagrass- and seaweed-dominated underwater forests serve as critical habitats that provide feeding, breeding, and nursery grounds for a diverse assemblage of fish and invertebrates, including numerous taxa of significant economic value (Nelson 1981; Guidetti and Bussotti 2000; Kim et al. 2012b; Park and Kwak 2019; Wang et al. 2023). Juveniles of demersal and coastal species often exhibit a strong habitat affinity for these structurally complex seagrass beds, reflecting the trade-off between foraging efficiency and predator avoidance (Boström and Bonsdorff 1997; Lefcheck et al. 2019). In contrast, sparsely vegetated or fragmented habitats support lower fish densities and higher proportions of transient or predatory species that exploit open areas for prey capture (Hovel and Lipcius 2002; Horinouchi et al. 2009). The spatial arrangement of seagrass beds, particularly patch size, edge length, and adjacency to unvegetated sediments or macroalgal mats, further modulates assemblage composition, emphasizing the importance of seasonal heterogeneity in structuring coastal fish communities (Boström et al. 2011; Staveley et al. 2017). Seagrass meadows act as ecologically dynamic mosaics, where fish species distributions reflect fine-scale differences in seagrass structural attributes and landscape contexts.

The study area, which is located in the coastal waters of Geoje Island, is influenced by the Tsushima Warm Current, a branch of the Kuroshio Current. In addition, substantial nutrient input from adjacent landmasses enhances primary productivity, thereby creating favorable environmental conditions for the distribution of both resident and migratory fish species (Cha 1999; Lie and Cho 2002). Several studies on seagrass fish assemblages and the trophic relationships among seagrass-associated fish species have been conducted around Geoje Island and the adjacent coastal areas of southern Korea (Huh and Kwak 1997; Kwak et al. 2005; Lee et al. 2010; Choi et al. 2018; Park et al. 2018). However, most previous studies have not evaluated how habitat structures and seagrass vegetation influence the configuration of assemblage structures or how seagrass microhabitat preferences differ among fish groups. Relatively few studies have evaluated differences in seagrass fish assemblage structures regarding the extent of seagrass vegetation and temporal habitat utilization in the southern coastal waters of Korea (Kwak et al. 2018; Park and Kwak 2018).

In this study, we observed the species composition and monthly fluctuations of fish inhabiting *Zostera marina* meadows in Myeongsa and Daepo on the southern coast of Geoje Island. Specifically, we aimed to:

- Determine the species composition and dominance of fish,
- investigate seasonal variations in species composition and their temporal patterns,
- examine the environmental factors influencing seasonal fluctuations in fish communities, and
- evaluate the ecological importance of seagrass beds as habitats supporting fish populations.

Through these objectives, this study sought to enhance our understanding of the ecological functions of *Zostera* meadows as key coastal ecosystems. These findings provide valuable baseline data for the conservation and management of seagrass-associated fish communities in Korea and contribute to broader efforts to sustain biodiversity within coastal habitats.

Methods

Study area. The study area is located in the southeastern part of the Korean Peninsula. Two study sites, Myeongsa and Daepo, within the southern coastal region of Geoje Island, where seagrass (*Zostera marina*) is prevalent, were selected (Fig. 1). *Zostera marina* is the dominant seagrass species widely distributed along the coastal areas of the Korean Peninsula and is also the predominant seagrass species at the study sites (Lee et al. 2002; Park et al. 2025). *Zostera marina* was found at both locations, exhibiting denser seagrass at Daepo and relatively sparse

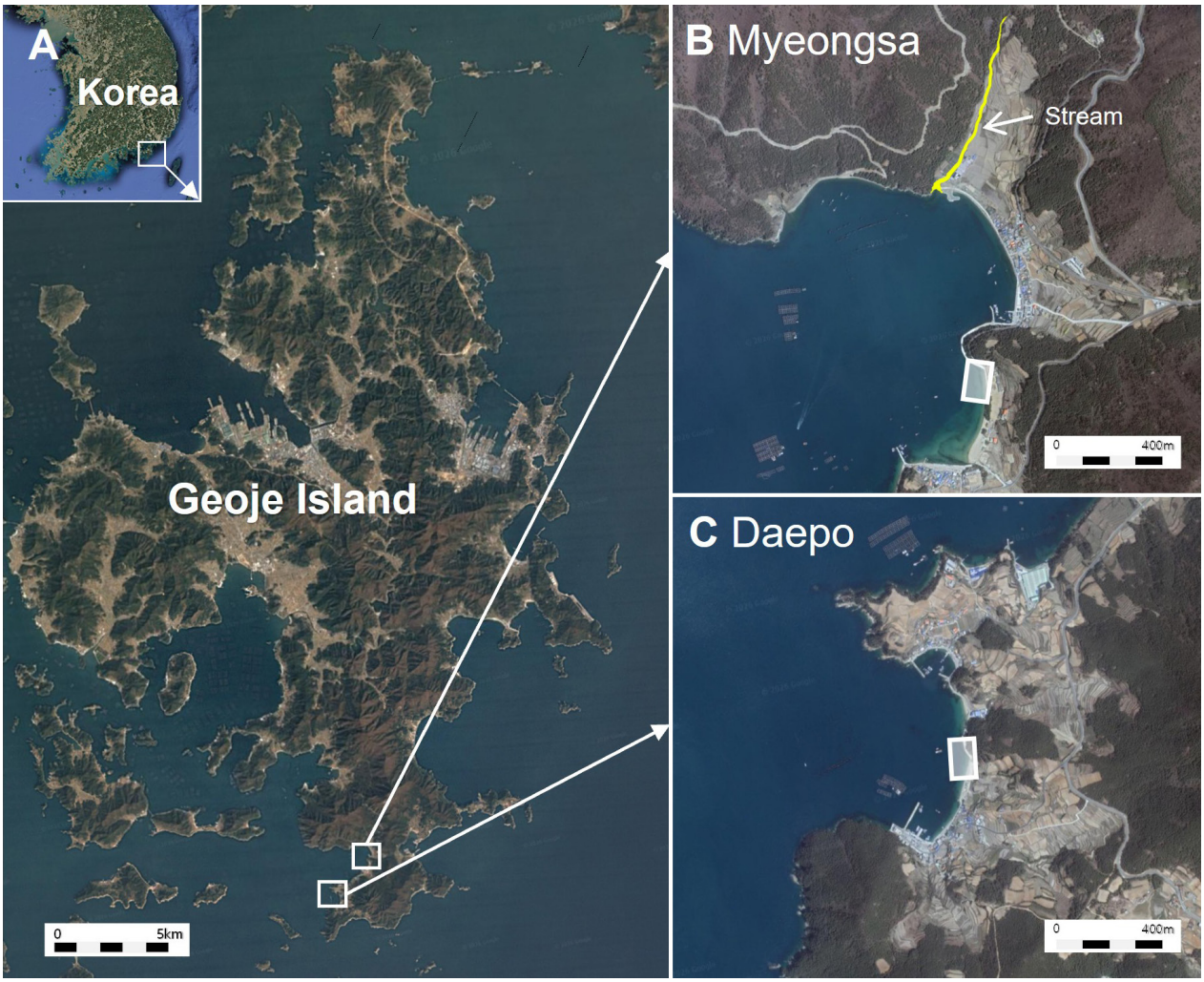

Figure 1. Location of study areas on Geoje Island. (**A**) Southern Geoje Island, Republic of Korea; (**B**) Myeongsa; (**C**) Daepo. Samples were collected within boxed areas at each site.

seagrass at Myeongsa (Fig. 2). The substrate at Myeongsa was mainly composed of sandy bottoms, whereas Daepo had a mixed gravel and sandy substrate (Fig. 2). In addition, the Myeongsa area was influenced by freshwater inflows from the north, whereas the Daepo region showed no evidence of freshwater input from adjacent areas (Fig. 1).

Sampling. Fish samples were collected monthly from September 2009 to November 2010, except during October 2009 at Daepo due to coastal road reclamation construction and during August 2010 due to high tourist activity at both sites. A beach seine (5 m long and 1.5 m high) and push net (2 m long and 1.8 m high) with a 5 mm mesh size for both fishing gears were used for collection. Five hauls were carried out during daytime low tides in the neap tide period at every survey session, roughly 20 m from the shoreline; each haul was 50 m long with a total sampled area of 250 m^2 for the beach seine and 20 m long with a total area of 100 m^2 for the push net. Data for fish abundance comparisons were reported as the number of individuals per square meter (m^2) (Lee 2001). Immediately after capture, the specimens were fixed in 10% formalin prepared with seawater for subsequent analyses. In the laboratory, specimens were identified according to Kim et al. (2005) and Nakabo (2013), counted, and their standard length (SL) (±0.1 cm) and the fish biomass (total wet weight, W_T) (± 0.1 g) were measured using a measuring board and an electronic balance (MR2001, Mettler Toledo, Switzerland). All scientific names and taxonomic classifications were checked with reference to FishBase (Froese and Pauly 2025).

Surface (~0.5 m) water temperature and salinity were monitored monthly for each sampling instance using an Orion 3-Star (Thermo Fisher Scientific, USA). Seagrass biomass was determined by extracting all plant matter within a 0.1 m^2 area. After being dried for 24 h at 80°C, plant samples were weighed to the nearest gram (MR2001, Mettler Toledo, Switzerland). Seagrass biomass was calculated as dry weight (W_D) per square meter [$gDW \cdot m^{-2}$] (Kwak and Klumpp 2004).

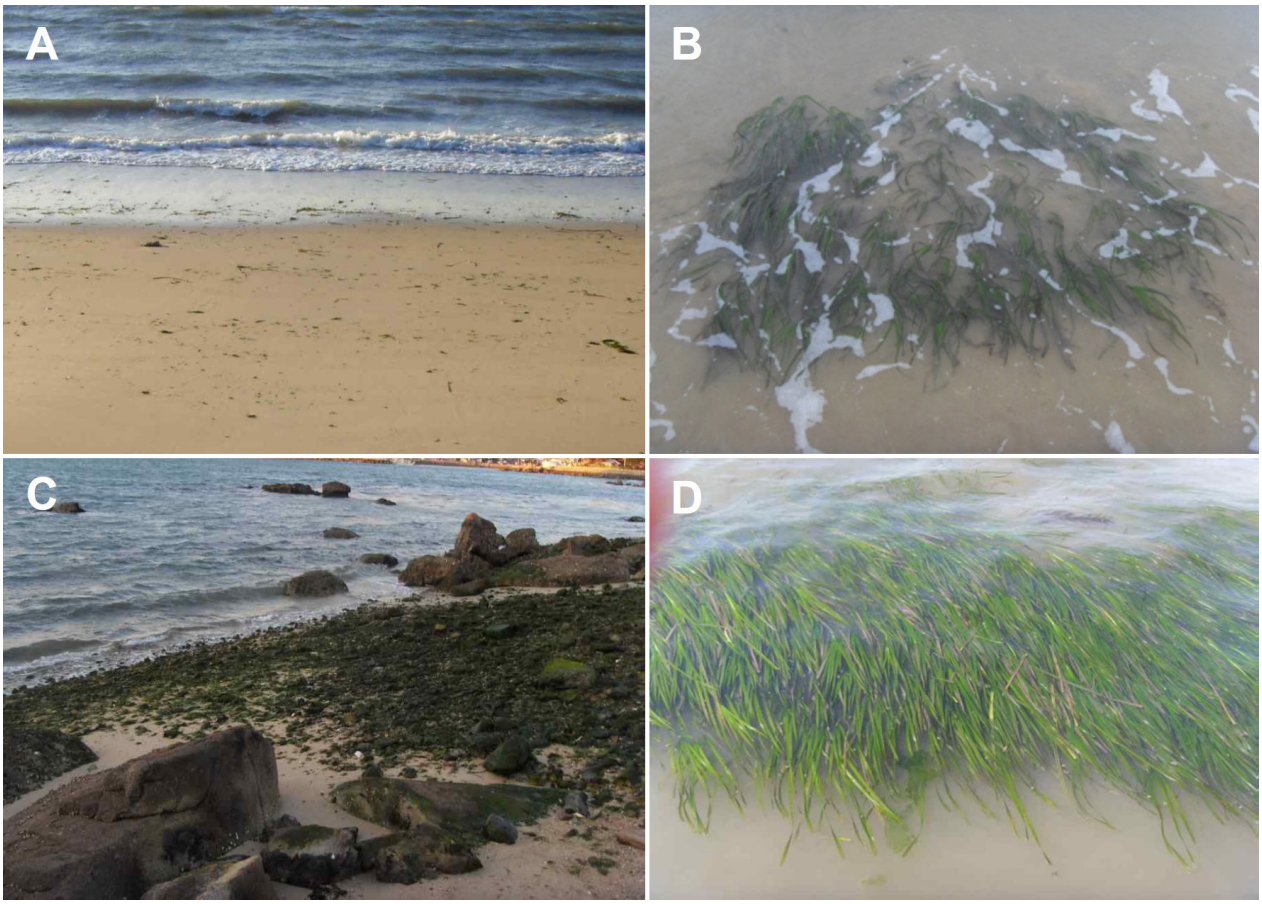

Figure 2. Environmental conditions of Myeongsa **(A–B)** and Daepo **(C–D)**.

Data analysis. To characterize the fish community structure, the Shannon–Wiener diversity index (*H'*) (Shannon and Weaver 1949) was calculated. Multivariate analyses based on fish abundance data were used to analyze spatial and seasonal differences in fish assemblage structures. Abundance data were log-transformed ([$\log_{10}(x + 1)$]), and a Bray–Curtis similarity matrix was constructed to calculate assemblage similarity. The Bray–Curtis technique is suitable for use in assemblage datasets, where maintaining relative abundance and species composition is crucial (Anderson et al. 2011). Permutational multivariate analysis of variance (PERMANOVA) was conducted to examine abundance trends by study site and season. The four seasons were classified as winter (December–February), spring (March–May), summer (June–August), and autumn (September–November). The matrix was visualized using non-metric multidimensional scaling (NMDS). 2D stress in NMDS refers to the measure of data distortion in the ordination. Stress values < 0.10 indicate a good ordination with minimal risk of misinterpretation, whereas stress values < 0.20 indicate an acceptable but potentially less reliable ordination. The commonly accepted threshold for stress values is 0.2 and ideally 0.1, beyond which the visualization may be considered unacceptable (Quinn and Keough 2002). The relative contributions of species to the observed differences were assessed using correlation coefficients, and species that met specific criteria were plotted. Individual species with correlations higher than 0.6 were plotted on the NMDS ordination for additional visualization of the results. Multivariate statistical analyses were performed using PRIMER v7 with the PERMANOVA+ module (Anderson et al. 2008; Clarke and Gorley 2015).

Results

Environmental variables. Water temperatures at Myeongsa ranged from 5.8 to 28°C, whereas those at Daepo ranged from 5.9 to 27.9°C (Fig. 3). At both study sites, the highest temperature was recorded in July and the lowest in December and January. Salinity levels ranged from 25.9‰ to 26.8‰ at both sites, with no significant monthly or spatial variations observed. Seagrass biomass ranged from 52.8 to 282.1 gDW · m^{-2} at Myeongsa and from 108.6 to 378.0 gDW · m^{-2} at Daepo. At both sites, seagrass biomass peaked in April at Daepo and May at Myeongsa, declined substantially after July, and remained at low levels between November and December (Fig. 3). The average seagrass biomass at Daepo was higher than at Myeongsa (212.4 vs. 152.5 gDW · m^{-2}).

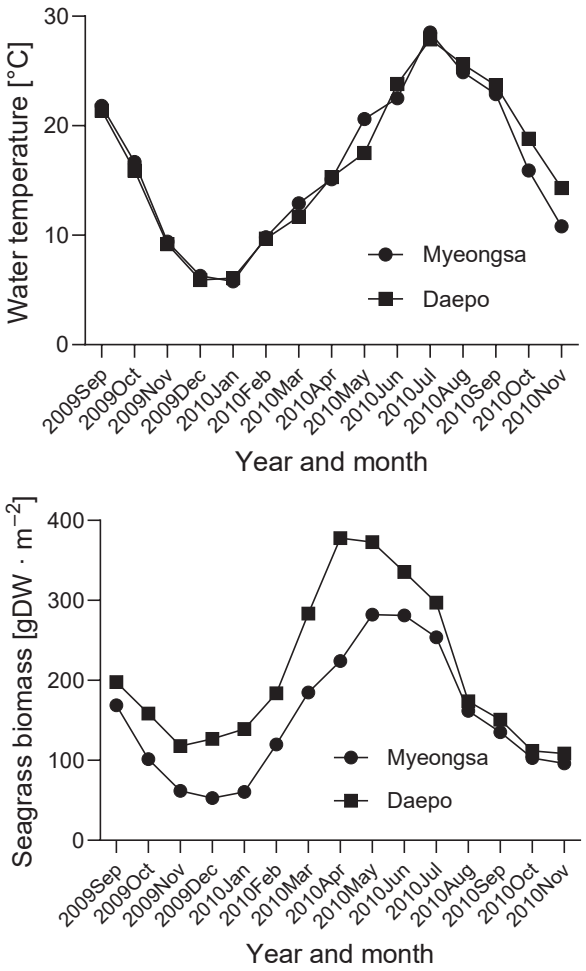

Figure 3. Monthly variations in water temperature and seagrass biomass at Myeongsa and Daepo, southern Geoje Island, Korea.

Fish species composition. During the study period, a total of 51 species (42 species at Myeongsa and 36 species at Daepo) belonging to 31 families were collected, with a total density of 3019 ind · m^{-2} (Table 1). In terms of species richness (number of species), the highest number of species was recorded in Gobiidae (eight species), followed by Cottidae (five species), and Hemiramphidae, Sebastidae, and Syngnathidae (three species each). At Myeongsa, greater species richness and fish abundance were observed than at Daepo, whereas Daepo had a higher total biomass than Myeongsa (8145.67 vs. 6414.18 g). The most frequently occurring species at Myeongsa were *Takifugu niphobles* (Jordan et Snyder, 1901), *Aulichthys japonicus* Brevoort, 1862, and *Syngnathus schlegeli* Kaup, 1856, whereas *Rudarius ercodes* Jordan et Fowler, 1902, *Hexagrammos agrammus* (Temminck et Schlegel, 1843), and *Paracentropogon rubripinnis* (Temminck et Schlegel, 1843) were most frequent at Daepo, each showing a frequency of occurrence greater than 60% (Table 1). In terms of relative abundance, *T. niphobles* (34.3%), *A. japonicus* (31.9%), and *Neoditrema ransonnetii* Steindachner, 1883 (7.1%) were the dominant fish species at Myeongsa, whereas *R. ercodes* (38.4%), *P. rubripinnis* (13.1%), and *H. agrammus* (9.1%) were abundant at Daepo.

Spatio-temporal changes in species richness, abundance, biomass, and diversity. Mean species richness (number of species), abundance, biomass, and diversity differed by research area and time (Fig. 4). The highest species richness was observed in October 2009 at Myeongsa and in September 2010 at Daepo.

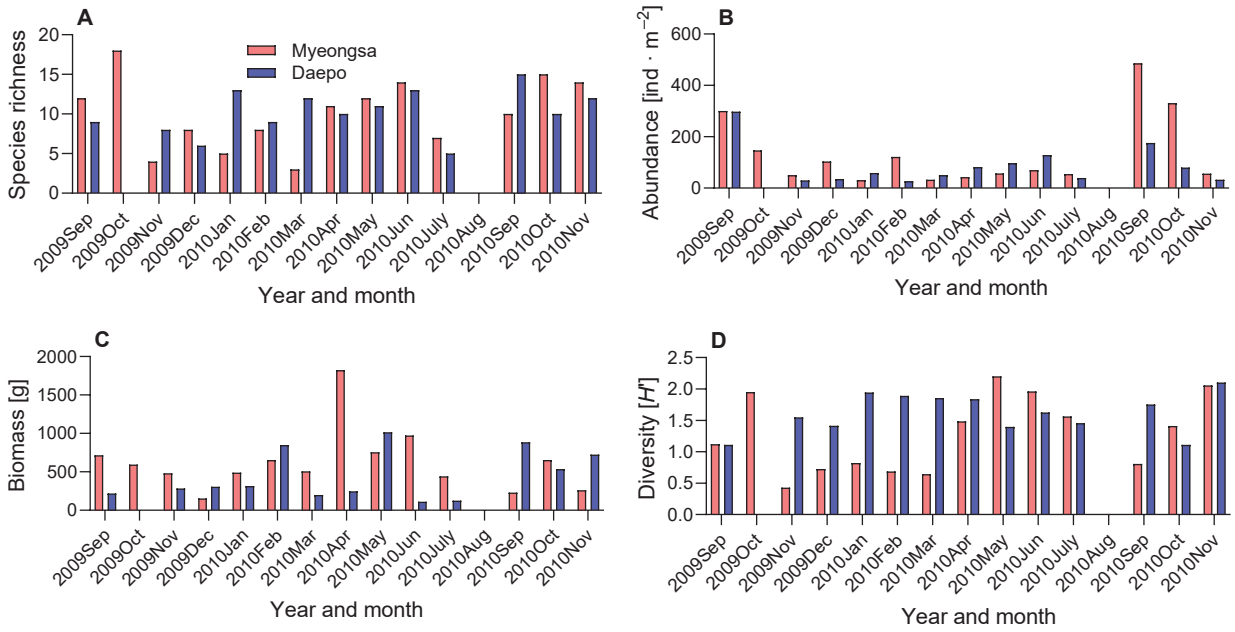

Figure 4. Monthly variations in species richness **(A)**, abundance **(B)**, biomass **(C)**, and diversity **(D)** at Myeongsa and Daepo in the southern Geoje Island of Korea.

Table 1. List of fish species recorded at two sites in the southern Geoje Island of Korea with basic characteristics, frequency of occurrence (FO), abundance (N_T), and fish biomass (W_T). N_T (W_T) indicates total number (weight) of individuals collected over the 14-months sampling period at Myeongsa and the 13-month sampling period at Daepo.

Family	Scientific name	Sampling site					
		Myeongsa			Daepo		
		FO [%]	N_T [ind · m^{-2}]	W_T [g]	FO [%]	N_T [ind · m^{-2}]	W_T [g]
Blenniidae	*Petroscirtes breviceps*	21.4	14	37.81	23.1	12	19.84
Callionymidae	*Callionymus curvicornis*	14.3	3	55.63			
Chaenopsidae	*Neoclinus bryope*				7.7	1	0.36
Cottidae	*Furcina osimae*				15.4	2	6.98
	Gymnocanthus herzensteini				7.7	1	10.1
	Porocottus leptosomus				15.4	2	7.36
	Pseudoblennius cottoides	14.3	5	25.05	53.8	16	153.72
	Pseudoblennius percoides	21.4	9	149.42	53.8	8	132.62
Cyclopteridae	*Eumicrotremus pacificus*				7.7	1	0.55
Cynoglossidae	*Paraplagusia japonica*	14.3	2	16.84			
Embiotocidae	*Ditrema temminckii*	50.0	84	1577.01	30.8	26	152.14
	Neoditrema ransonnetii	28.6	133	398.67			
Girellidae	*Girella punctata*	14.3	3	25.42	7.7	4	14.39
Gobiidae	*Acanthogobius flavimanus*	35.7	11	96.14	7.7	3	85.81
	Chaenogobius annularis	7.1	1	0.89	7.7	1	1.75
	Chaenogobius gulosus	14.3	19	3.25	7.7	1	0.64
	Favonigobius gymnauchen	50.0	57	62.36	15.4	4	8.03
	Gymnogobius heptacanthus	35.7	42	10.68	23.1	92	17.03
	Pterogobius elapoides	7.1	1	10.23			
	Pterogobius zonoleucus	21.4	12	10.08	7.7	3	0.82
	Sagamia geneionema	14.3	6	38.13	15.4	3	17.73
Hemiramphidae	*Hyporhamphus sajori*	7.1	1	26			
Hexagrammidae	*Hexagrammos agrammus*	64.3	44	627.06	**84.6**	103	3574.88
	Hexagrammos otakii				7.7	1	89.87
Hypoptychidae	*Aulichthys japonicus*	**71.4**	601	519.73	30.8	7	19.45
Labridae	*Halichoeres tenuispinis*				7.7	1	12.6
Monacanthidae	*Rudarius ercodes*	35.7	25	40.07	**100.0**	436	814.8
	Stephanolepis cirrhifer				38.5	11	74.77
Mugilidae	*Mugil cephalus*	14.3	7	52.41			
Mullidae	*Upeneus japonicus*	7.1	1	3.76			
Neozoarcidae	*Zoarchias uchidai*	7.1	1	1.41	38.5	16	321.23
Pholidae	*Pholis crassispina*	7.1	1	0.45			
	Pholis nebulosa	28.6	5	41.54	23.1	6	61.38
Platycephalidae	*Platycephalus indicus*	14.3	2	23.66			
Pleuronectidae	*Pseudopleuronectes yokohamae*	14.3	3	33.66			
Sebastidae	*Sebastes inermis*	14.3	12	83.97	38.5	12	56.89
	Sebastes longispinis				7.7	1	41.02
	Sebastes schlegelii	14.3	2	87.68	46.2	43	692.82
Siganidae	*Siganus fuscescens*	21.4	18	45.5	15.4	27	20.32
Sillaginidae	*Sillago japonica*	28.6	37	26.76	7.7	17	6.86
Sphyraenidae	*Sphyraena pinguis*	7.1	3	3.27			
Stichaeidae	*Dictyosoma burgeri*	7.1	1	0.21	7.7	1	10.92
Syngnathidae	*Hippocampus kuda*	7.1	1	0.15			
	Syngnathus schlegeli	**57.1**	38	100.87	**76.9**	74	152.74
	Urocampus nanus	35.7	6	5.49	30.8	11	2.47
Synodontidae	*Trachinocephalus myops*	7.1	1	0.58			
Terapontidae	*Rhynchopelates oxyrhynchus*	21.4	5	5.95			
Tetraodontidae	*Takifugu niphobles*	**100.0**	646	1978.44	46.2	33	524.06
	Takifugu pardalis	21.4	3	41.05	30.8	5	78.7
Tetrarogidae	*Paracentropogon rubripinnis*	21.4	18	146.32	**76.9**	149	960.02
Triglidae	*Lepidotrigla guentheri*	7.1	1	0.58			
	Total		**1885**	**6414.18**		**1134**	**8145.67**
	Number of species		**42**			**36**	

The fish biomass is the total wet weight, W_T. The highest occurrence values for each site were distinguished in bold font.

Overall, species richness was greater at Daepo than at Myeongsa during the colder months, whereas during the warmer months, it was greater at Myeongsa. Abundance peaked in September at both study sites and was lower during the colder months (between November 2009 and April 2010). At Myeongsa, total biomass was highest in April 2010 and lowest in December 2009, whereas at Daepo, it was highest in May 2010 and lowest in June 2010. The greatest diversity was observed in May 2010 and November 2010 at Myeongsa and Daepo, respectively, whereas it was lowest in November 2009 and October 2010 at Myeongsa and Daepo, respectively.

Temporal changes in abundance of dominant species. The relative abundances of the dominant species varied by site and season (Fig. 5). *Takifugu niphobles* dominated Myeongsa between September 2009 and March 2010, whereas *H. agrammus* (April 2010), *A. japonicus* (September and October 2010), and *Ditrema temminckii* Bleeker, 1853 (November 2010) were the most abundant fish species during the other months (Fig. 5). At Daepo, *R. ercodes* and *P. rubripinnis* were abundant during the warmer months, whereas *H. agrammus* and *Syngnathus schlegeli* Kaup, 1856 tended to be more abundant during the colder months (Fig. 5).

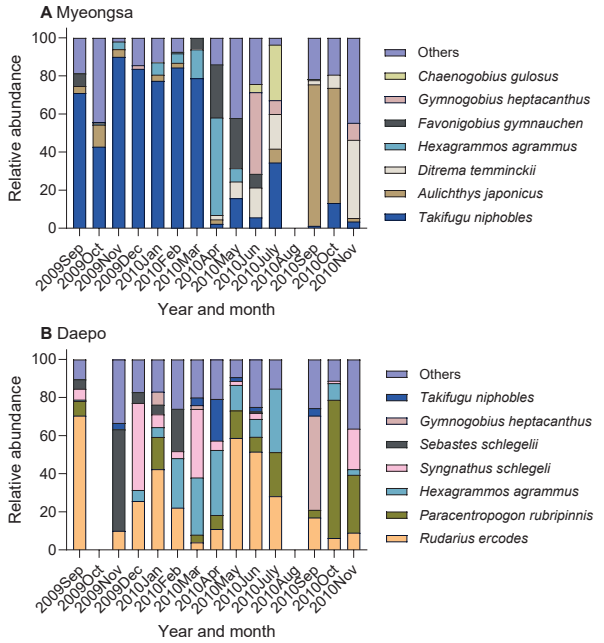

Figure 5. Monthly variations in dominant fish species and their relative abundance (%) at Myeongsa and Daepo in the southern Geoje Island of Korea.

Fish assemblage structure. Two-way PERMANOVA revealed that fish assemblages were significantly associated with site (pseudo-F = 7.991, $P < 0.05$) and season (pseudo-F = 2.019, $P < 0.05$); however, the two-way interaction was not significant (pseudo-F = 1.301, $P > 0.05$). NMDS showed clear variation in fish assemblages between the two sites (Fig. 6). The 2D stress in NMDS was 0.2, indicating an acceptable threshold for fitting ordination. Samples from Myeongsa and Daepo revealed distinct clustering patterns, with the former located on the right side and the latter on the left side of the plot (Fig. 6). Monthly data per location also revealed a different pattern in NMDS, with samples collected during the warmer months tending to be located in the lower area of the plot and those collected during the colder months located on the upper side of the plot (Fig. 6). Two fish species (*R. ercodes* and *P. rubripinnis*) characterized the fish assemblages at Daepo, whereas *T. niphobles*, *Gymnogobius heptacanthus* (Hilgendorf, 1879), and *Pterogobius zonoleucus* Jordan et Snyder, 1901 characterized the fish assemblages at Myeongsa.

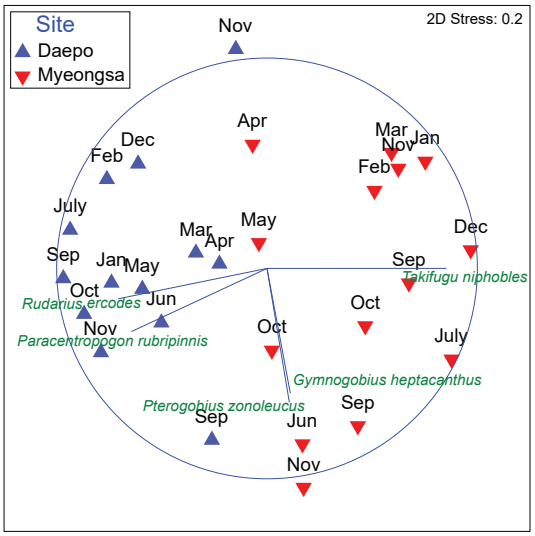

Figure 6. NMDS ordination of fish assemblages constructed from Bray–Curtis similarity matrices of the two study sites.

Discussion

Seagrass beds serve as critical nursery habitats that support juvenile growth and enhance fish recruitment (Nakamura and Sano 2004). Among the 51 collected fish species, the most common species were *T. niphobles*, *A. japonicus*, and *N. ransonnetii* at Myeongsa and *R. ercodes*, *P. rubripinnis*, and *H. agrammus* at Daepo. *Hexagrammos agrammus*, *G. heptacanthus*, and *S. schlegeli* were relatively abundant in both habitats. Most species collected in the presently reported study were small specimens or juveniles. Previous studies on seagrass fish assemblages on Geoje Island, including Myeongsa and Gujora, reported that the dominant species were similar to those observed at Myeongsa in this study, particularly small-sized species such as *T. niphobles* and *Favonigobius gymnauchen* (Bleeker, 1860) (see Lee et al. 2011a; Kim et al. 2012a). These areas share sandy shore habitats, which may explain this species overlap (Table 2). In contrast, seagrass-rich environments, including Jeogu (Lee et al. 2011b), Jisepo Bay (Kim and Gwak 2006), and Geoje Bay (Lee et al. 2010), showed dominance of *R. ercodes*

Table 2. Comparison of species composition of fishes collected in seagrass beds of Myeongsa Beach and Daepo Port with those obtained from the adjacent coastal waters of Geoje Island.

Site	Sampling period	Sampling gear	Mesh size [mm]	Environmental condition	Number of species	Three dominant species			Source
Myeongsa	Sep. 2009–Nov. 2010	Beach seine, push net	5	Sandy shore	42	*Takifugu niphobles*	*Aulichthys japonicus*	*Neoditrema ransonnetii*	Presently reported study
Daepo	Sep. 2009–Nov. 2010	Beach seine, push net	5	Seagrass bed	36	*Rudarius ercodes*	*Paracentropogon rubripinnis*	*Hexagrammos agrammus*	Presently reported study
Myeongsa	Aug. 2009–Jul. 2010	Beam trawl	2.5	Sandy shore	38	*Favonigobius gymnauchen*	*Takifugu niphobles*	*Paracentropogon rubripinnis*	Kim et al. 2012a
Jeogu	Aug. 2009–Jul. 2010	Surf net	2	Seagrass bed	38	*Chaenogobius annularis*	*Gymnogobius heptacanthus*	*Rudarius ercodes*	Lee et al. 2011b
Jisepo Bay	Mar. 2005–Feb. 2006	Surf net	2	Seagrass bed	34	*Rudarius ercodes*	*Ditrema temminckii*	*Syngnathus schlegeli*	Kim and Gwak 2006
Gujora	Mar. 2005–Feb. 2006	Beam trawl	2.5	Sandy shore	20	*Favonigobius gymnauchen*	*Trachinocephalus myops*	*Pseudoblennius percoides*	Lee et al. 2011a
Geoje Bay	Jun. 2006–May 2007	Surf net	2	Seagrass bed	26	*Acentrogobius pflaumii*	*Aulichthys japonicus*	*Gymnogobius heptacanthus*	Lee et al. 2010

and *G. heptacanthus*, which resembled the species composition at Daepo (Table 2). This suggests that habitat structure strongly influences assemblage composition, with sandy shores favoring small benthopelagic fish, whereas denser seagrass beds support higher species richness and adult–juvenile recruitment. Similar results were observed by Nagelkerken and van der Velde (2004) and Nakamura and Sano (2004), who reported that seagrass beds are important nursery habitats for larger fish species.

Multivariate analysis revealed significant differences in the fish assemblage structures between Myeongsa and Daepo. These differences were primarily driven by the higher abundance of *T. niphobles* and *A. japonicus* at Myeongsa and that of *R. ercodes* and *P. rubripinnis* at Daepo. Seagrass structural complexity, particularly shoot density and canopy height, strongly influences fish community composition (Ruesink et al. 2019). Dense and fine seagrass supports deeper-bodied fish (laterally compressed), which can maneuver easily between blades and use the vegetation for shelter and feeding, whereas sparse or patchy seagrass favors streamlined, fast-swimming species that rely on open spaces for movement and foraging (Heck and Orth 1980; Horinouchi 2007; Reis-Júnior et al. 2023). In addition, the sandy habitat at Myeongsa supported species adapted to open substrates, whereas the mixed sand–gravel substrate at Daepo provided shelter for species associated with more structured environments. In this study, *T. niphobles* and *A. japonicus*, which possess a more streamlined body form, were more abundant at Myeongsa. In contrast, *R. ercodes* and *P. rubripinnis*, characterized by relatively laterally compressed bodies, preferred to inhabit denser meadows, such as those at Daepo. Moreover, the Myeongsa area was influenced by freshwater input from the northern region, which supported a higher abundance of euryhaline fish species such as *T. niphobles* (see Kato et al. 2010). Therefore, such differences in habitat preferences among fish species contribute to shaping distinct assemblage structures in seagrass meadows under varying environmental conditions.

Generally, seagrass biomass is strongly influenced by water temperature, which affects its distribution and abundance (Park and Kwak 2018). Both study regions exhibited a clear trend in which species richness and abundance declined as water temperature decreased and, conversely, increased with rising temperature. This pattern suggests that lower water temperatures may lead to a contraction in available habitats for fish and other marine organisms, resulting in reduced species abundance. These observations align with the findings of Ezenwaji et al. (2014), who reported a positive relationship between water temperature and fishery productivity within species' tolerable thermal limits. In addition, each fish species exhibited distinct seasonal occurrence patterns according to seasonal changes in seagrass density and water temperature. For example, the abundance of *T. niphobles* peaked from September to March, when seagrass biomass was relatively low, but declined during spring and summer as water temperature and seagrass biomass increased. Conversely, an increase in *H. agrammus* and *F. gymnauchen* in April suggests that these species prefer warmer conditions and higher seagrass biomass. This seasonal trend may be attributed to spawning migration, temperature-driven prey availability, or habitat structure (e.g., seagrass vegetation patterns), as observed in other temperate fish species (McDevitt-Irwin et al. 2016; Park and Kwak 2018; Zhang et al. 2024), possibly due to enhanced shelter, spawning, and foraging opportunities (Boström and Bonsdorff 1997; Plummer et al. 2013; Steinfurth et al. 2022). Overall, these results highlight the pivotal role of temperature in regulating seagrass ecosystem dynamics and the associated fish community structure.

Although the seagrass beds at Myeongsa and Daepo are located in close proximity, the taxonomic compositions of the fish assemblages exhibited notable differences between the sites. Even when identical species were present in both regions, their relative abundances varied substantially; some species dominated the community structure at one site but were represented by only a few

individuals at the other (Lee et al. 2002; Kim et al. 2009). This variation in species dominance indicates that local environmental factors such as water temperature, seagrass vegetation pattern, and substrate type may influence community composition and species distribution between the two regions (Koch 2001; Touchette 2007; Park and Kwak 2018). For example, although *A. japonicus*, *T. niphobles*, *R. ercodes*, and *P. rubripinnis* occurred at both sites, the relative abundance of the former two species was significantly higher at Myeongsa than at Daepo, whereas *R. ercodes* and *P. rubripinnis* were more abundant at Daepo. Notably, *H. agrammus*, which was abundant in both areas, appeared to possess a broad ecological tolerance that allowed it to thrive under varying environmental conditions. The persistence and dominance of this species across both sites suggest that it may play an important ecological role within these seagrass ecosystems, acting as a key component of the local fish assemblage (Kimura and Munehara 2010). Overall, the contrast between community structures at Myeongsa and Daepo highlights the significance of site-specific environmental conditions in shaping species distribution and dominance patterns within seagrass habitats.

Seagrass beds play a crucial role in supporting species that depend exclusively on seagrass habitats. However, global seagrass loss driven by climate change, declining water quality, and coastal development poses significant threats to local fisheries, potentially leading to reduced fish diversity and economic losses (Waycott et al. 2009). During the study period, we observed coastal reclamation activities for port expansion at Daepo and a heavy tourist presence during the summer season at Myeongsa. These activities likely affect seagrass health, with reclamation activities at Daepo altering water quality and sedimentation patterns and tourism at Myeongsa causing habitat disturbances. These effects emphasize the vulnerability of seagrass-dependent fish species to habitat degradation, a matter of global concern (Orth et al. 2006; Short et al. 2011). Therefore, implementing habitat protection, restoration initiatives, and sustainable fishery management is essential to mitigate these impacts and enhance the resilience of fish populations.

Conclusion

This study demonstrated distinct spatial and temporal patterns in seagrass-associated fish assemblages in Myeongsa and Daepo, reflecting the influence of site-specific environmental conditions and habitat characteristics on fish faunal structures. Despite similar temperature and salinity regimes, Daepo exhibited higher average seagrass biomass and total fish biomass, whereas Myeongsa supported greater species richness and abundance, particularly during the warmer months. In particular, certain dominant species (e.g., *T. niphobles* and *R. ercodes*) exhibited pronounced site-specific and temporal preferences. These findings highlight the sensitivity of seagrass-associated fish communities to local habitat conditions and seasonal dynamics. In addition, recent changes in coastal seagrass habitats around the Korean Peninsula, particularly along the southern coast, have been increasingly documented as a result of anthropogenic disturbances and ocean warming (Kim et al. 2024). Records from both current and past studies are therefore of considerable importance for assessing the extent of future environmental change. Maintaining seagrass meadow integrity through habitat protection and sustainable coastal management is essential for preserving fish diversity and supporting the ecological productivity of coastal ecosystems.

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