Marine Research
of the National Academy of Marine Research
ISSN: 2709-6629 (Vol.2 Iss.2)
GPN: 2011200033

DOI: http://dx.doi.org/10.29677/MR.202212_2(2).0002
2022, 2(2), 24-41

Seasonal Variations in the Trawling Marine Organism Community at the Changyun Rise off Central Western Taiwan from Spring to Autumn 2020

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ABSTRACT

This study investigated the macrobenthic fauna in the sandy-bottom sublittoral area off the Changhua coastline, central western Taiwan, before the planned construction of offshore wind turbines. We used a local commercial demersal otter trawling boat to conduct a spring–autumn survey with simultaneous measurement of hydrographic parameters and water sampling for water quality analysis at the tentative wind farm fields at inshore (15–25-m depth) and offshore (40–50-m depth) sites. Three surveys were performed in March, July, and September 2020, and the water parameters complied with standard Grade A seawater quality. In total, 92 marine macrobenthic species were identified, including 33 families and 62 fish species, 3 families and 8 species of shrimps, 6 families and 10 species of crabs, 6 families and 9 species of cephalopods, and 3 others. Among them, 40 sandy dwelling fish species constituted 65% of the total number of species, whereas only 15 reef-sandy, 5 reef, and 2 pelagic residential fish species were identified, constituting 24%, 8%, and 3%, respectively, of the total number of fish species. The top 8 dominant components in descending order were all sand-inhabiting species: *Equulites rivulatus*, *Loliolus beka, E. absconditus, Plotosus lineatus, Upeneus japonicus, Parapenaeopsis sinica, P. hardwickii*, and *Trachinocephalus myops*, constituting 77.2% of the relative abundance and 12.0% of the relative biomass. The macrobenthic fauna were categorized into two groups: dry and wet seasonal groups. *Loliolus beka, P. hardwickii, Pennahia pawak,* and *Trichiurus japonicus* were the major members of the dry season group, and *Arius arius, T. myops, Lagocephalus lunaris*, and *Uroteuthis chinensis* were members of the wet season group. Four local residents, namely *T. myops, U. japonicus,* and *P. hardwickii,* as well as *A. arius* (ranked the second highest in biomass), were identified and suggested as potential marine ecological indicators of the Changyun Rise.

Keywords: baseline, seasonal variation, *Trachinocephalus myops, Upeneus japonicus, Arius arius, Parapenaeiopsis hardwickii.*

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Received 27 September 2022, Accepted 22 October 2022.

1 INTRODUCTION

An increasing number of offshore wind farms (OWFs) are being constructed worldwide in this century to produce clean renewable energy. In 2012, the Taiwanese government initiated the exploitation of renewable energy with a plan to construct one thousand wind turbines at the Changyun Rise (CYR), which is located in central western Taiwan off the mouth of the Zhuoshui (Choshui) River and lies west–eastward across the Taiwan Strait. Because of limited available technology and high building costs, OWFs are constructed in shallow coastal water (Stenberg et al., 2015). The rise has a water depth of 40–50 m, which is 20–30-m shallower than the depths of other parts of the Taiwan Strait (Jan et al., 2002). Owing to its potential wind power, the rise ranks third among the world's potential wind farm fields. Therefore, the CYR was selected as the optimal site for OWF development.

The construction of OWFs in the CYR began in 2018 and progressed in depth since inception. In 2016, two anemometer towers, namely the Fuhai Offshore Met Mast and the Taipower Met Mast, were constructed by the Fuhai and Taipower companies, respectively, each with a foundation of approximately 10^4 m^2 at a depth of 20 m in the nearshore area off the coast of Changhua, central western Taiwan. Because the establishment of wind turbines constructed in shallow sandy marine habitats necessitates the construction of hard turbine stands, the sandy seabed can be transformed by anchoring artificial reefs (Stenberg et al., 2015). Stakeholders such as local fishermen, developers, and government managers should investigate the influence of such transformation of a tropical–subtropical sandy seabed on marine biodiversity, local fisheries, and the health of the local marine ecosystem.

OWFs have been developed at high latitudes in the North Sea. Studies have investigated the influence of OWFs on the benthic infauna and epifauna communities in Europe (Vattenfall, 2006; Lindeboom et al., 2011). Most new communities were established in close proximity to the individual turbine foundations and their scour protection, whereas no differences were observed in fish communities in the sandy areas between turbines (Stenberg et al., 2015). Moreover, OWF constructions had a long-term influence on several high-latitude fish species; for example, the abundance of sand eel increased after OWF development in sandy habitats (van Deurs et al., 2012). Gobiid species (Wilhelmsson et al., 2006), gadoids such as cod *Gadus morhua* (Winter et al., 2010; Reubens et al., 2013a, 2013b, 2014a), and pouting *Trisopterus luscus* (Reubens et al., 2011, 2013b) are attracted to the underwater structures of OWFs. Reubens et al. (2011, 2014b) reported that pouting and cod fish species at OWFs construction predominantly preyed on amphipods *Jassa hermani* and porcelain crabs *Pisidia longicornis*. Moreover, fishes are attracted to OWFs with specific/certain types of underwater structures (e.g., wrecks, oil rigs, and artificial reefs), and they forage for associated fauna (Fabi et al., 2006; Langhamer and Wilhelmsson, 2009).

Few studies have reported on OWFs in tropical–subtropical areas such as the Taiwan Strait. For a systematic assessment, a baseline dataset is first established for analyzing the influence of OWFs development. Baseline surveys were conducted in 2020 before the first stage of development in the area. The first two wind turbines were constructed by the Taipower Company in September 2020. In June 2021, 19 wind turbines were set up in the nearshore wind farm area. In this study, macrobenthic organisms were collected through appropriate local trawl fishing from spring to autumn 2020, and their preferred seabeds and possible habitat utilization were identified before the construction.

Marine Research of the National Academy of Marine Research
DOI: 10.29677/MR.202212_2(2).0002

2 RESEARCH METHODS

Three sampling cruises were conducted in this study. The cruises represented the spring (March 18), summer (July 24), and autumn (September 15) seasons of 2020. Sampling was not conducted for the winter season because of the funding constraints and unfavorable conditions for fishing due to the severe northeastern monsoon. To determine the potential influence on the marine biota in the CYR, particularly fishing resources, commercial trawl fishing was conducted at inshore (FS20; 20–30-m water depth, *ca*. 24°02'N, 120°16'E) and offshore (FS40; 40–50-m water depth, *ca.* 24°06'N, 120°00'E) sites off the coast of Changhua, central western Taiwan (Figure 1). The sites are located in the northern estuary of the Zhuoshui (Choshui) River that received sediment outflow from the river during the sampling period. The water temperature was affected by the warm Kuroshio Branch Water and South China Sea Surface Water during spring and summer and by the China Coastal Water during winter (Jan et al., 2002, 2006).

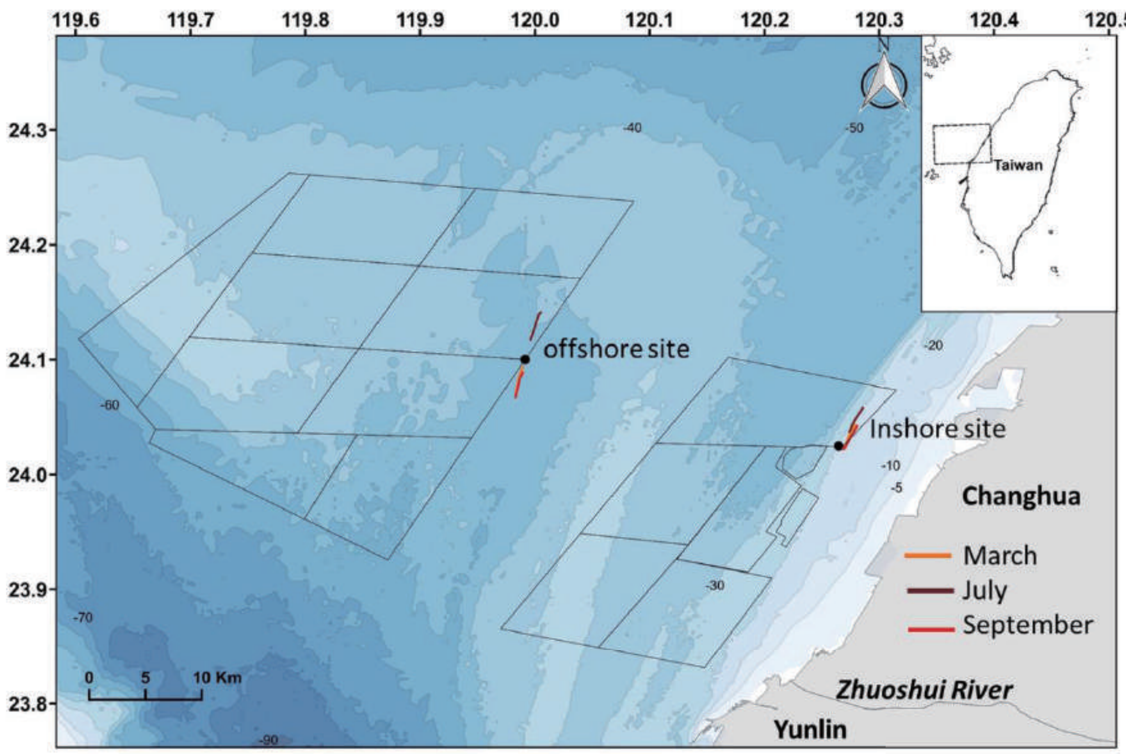

Figure 1. Map indicating the inshore and offshore sites and transects of the three sampling cruises in the study. Black frame: planned wind farm area; red frame: Taipower Company (TPC) Changhua Demonstration wind farm area.

The surveys were conducted in the daytime using a local commercial otter trawl (width = 8 m, body length = 70 m, body mesh = 7 cm, and cod end mesh = 4 cm) operating at a water depth of between 15–25 m and 40–50 m, approximately 9 km and 42 km off the coastline at the inshore and offshore sites, respectively. The trawling routines are summarized in Table 1. At each site, 20 min of trawling was conducted, and water sampling and hydrological measurements were performed in situ. The trawling samples of fish, shrimp, crab, and squids were sorted and kept on ice for further identification in the laboratory. Hydrological parameters, such as surface water temperature, salinity, dissolved oxygen, pH, and transparency, were measured in situ using a thermometer, conductivity meter (YSI-EC300), dissolved oxygen meter (YSI pro ODO), pH meter (HACH sensION+ pH1), and Secchi disk, respectively. Bottom water temperature, salinity, and water depth were measured using a conductivity–temperature–depth measuring system (OCEAN SEVEN 305*Plus* CTD).

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Table 1. Sampling site and track of the trawling route off the coast of Changhua, central western Taiwan on the three seasonal cruises in 2020.

Season (date)	Site (code)	Water depth (m)	Cast net point	Haul net point
Spring (Mar. 18, 2020)	Inshore (FS20)	18	N24°02.840, E120°16.960	N24°04.057, E120°17.430
	Offshore (FS40)	45	N24°06.460, E119°59.982	N24°05.101, E119°59.647
Summer (Jul. 24, 2020)	Inshore (FS20)	19	N24°03.699, E120°17.164	N24°04.951, E120°17.824
	Offshore (FS40)	42	N24°07.916, E120°00.329	N24°09.343, E120°00.806
Autumn (Sep. 15, 2020)	Inshore (FS20)	17	N24°02.789, E120°16.873	N24°04.003, E120°17.553
	Offshore (FS40)	45	N24°06.181, E119°59.990	N24°04.877, E119°59.644

Water samples were transported to the laboratory to analyze the concentrations of nitrite, nitrate, phosphate, silicate, ammonia, biochemical oxygen demand (BOD_5), chlorophyll-a, and suspended solid concentration according to methods reported by Meng et al. (2008). Biological samples were identified to the lowest level of taxonomic hierarchy possible according to the approaches of Chen et al. (2019), Froese and Pauly (2021), and Shao (2021) for fish, Yu and Chan (1986) and Li et al. (2017) for shrimp, Dai and Yang (1991) for crab, Lu and Chung (2017) for cephalopods, and Okutani (2017) for mollusks. The total weight (to 0.01 g) and total length, carapace length, and mantle length (to 1 mm) of fish, crustaceans, and cephalopods were measured, respectively. Each organism was counted and weighed to estimate its abundance (ind./10^4 m^2) and biomass (g/10^4 m^2) by dividing the trawled area (in hectare, 10^4 m^2), calculated by multiplying the trawling distance with the width of the trawl mouth opening (8 m), as reported by Chen et al. (2021). Based on the assumption that all collected animals are uniformly and evenly distributed in the water columns trawled, the potential overestimation or underestimation of the abundance and biomass datasets due to the schooling nature of the fish was not accounted for in this study.

Log-transformed abundance data (i.e., log[X + 1]) of the top 25 benthic organisms, comprising more than 80% of the relative abundance, were selected to construct a Bray–Curtis resemblance matrix of haul-specific taxon data and were used in multivariate analyses. Using the constructed resemblance matrix, hierarchical clustering of the haul-specific taxon data was performed based on group-average linking. Furthermore, nonmetric multidimensional scaling (nMDS) ordination was performed using the Bray–Curtis resemblance matrix to visualize the patterns of the taxon composition over months as well as at the inshore and offshore sites. The aforementioned multivariate analyses were performed using PRIMER v6 (Clarke and Gorley, 2006).

3 RESULTS

The hydrological parameters of the three sampling cruises are displayed in Table 2. The water temperatures ranged from 23.7°C to 31.5°C, which were mostly consistent between surface and bottom layers for each

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DOI: 10.29677/MR.202212_2(2).0002

sampling site but varied with sampling times and seasons. The mean ± standard deviation of the water temperature was higher during summer (30.0°C ± 1.6°C) than during spring (24.0°C ± 0.2°C) and autumn (24.0°C ± 0.2°C). Salinity ranged from 33.67–34.56 psu, and it was slightly lower at the inshore site during summer (33.67–33.90 psu) than during other seasons (34.30–34.56 psu). Dissolved oxygen concentration (DO) and pH were relatively stable, ranging within 6.39–7.15 mg/L and 8.14–8.19, respectively. The concentrations of chlorophyll-a, all nutrients, and biochemical oxygen demand (BOD_5) differed among seasons and were generally higher during summer than during spring and autumn. The concentration of nitrate (NO_3^--N) was drastically higher during summer (0.696 ± 0.201 mg/L) than during spring (0.025 ± 0.001 mg/L) and autumn (0.015 ± 0.002 mg/L); BOD_5 was higher during summer (2.42 ± 1.43 mg/L) than during autumn (1.46 ± 0.20 mg/L) and spring (1.15 ± 0.11 mg/L). Turbidity and the concentration of suspended solids exhibited similar patterns, which were higher at inshore sites than at offshore sites during each season and were higher during summer than during spring and autumn. By contrast, transparency was higher at offshore sites than at inshore sites. In general, the hydrological parameters at most sampling sites complied with Grade A seawater quality (>5.0 mg/L for DO, within 7.7–8.5 for pH, and <0.3 mg/L for NO_3^--N, and <2.0 mg/L for BOD_5), except those of NO_3^--N and BOD_5 during summer (Table 2).

Table 2. Hydrological parameters of water temperature, salinity, dissolved oxygen concentration (DO), pH, chlorophyll-α, ammonia (NH_3-N), nitrate (NO_3^--N), nitrite (NO_2^--N), phosphate (PO_4^{3-}-P), silicate (SiO_2-Si), biochemical oxygen demand (BOD_5), turbidity, suspended solid concentration (SS), and transparency of the surface (S) and bottom (B) layers off the Changhua coast, central western Taiwan observed on the three seasonal cruises in 2020.

Season (date)	Site (code)	Layer	Sampling time	Temp. (°C)	Salinity (psu)	DO conc. (mg/l)	pH	Chl.-α (mg/l)	NH_3-N (mg/l)	NO_3^--N (mg/l)	NO_2^--N (mg/l)	PO_4^{3-}-P (mg/l)	SiO_2-Si (mg/l)	BOD_5 (mg/l)	Turbidity (ntu)	SS conc. (mg/l)	Transparency (m)
Spring (Mar. 18, 2020)	Inshore (FS20)	S	12:49	24.1	34.34	7.03	8.17	0.23	0.006	0.024	0.002	0.003	0.037	1.20	1.77	10.3	4.5
		B	12:57	23.7	34.30	7.15	8.19	0.40	0.020	0.026	0.003	0.003	0.027	1.04	1.91	8.8	-
	Offshore (FS40)	S	09:02	24.0	34.33	6.82	8.14	0.22	0.012	0.025	0.001	0.003	0.037	1.08	1.24	6.3	5.3
		B	09:16	24.2	34.32	6.88	8.16	0.23	0.009	0.025	0.001	0.005	0.040	1.28	0.91	8.2	-
	Mean		-	24.0	34.32	6.97	8.17	0.27	0.012	0.025	0.002	0.003	0.035	1.15	1.46	8.4	4.9
	SD		-	0.2	0.02	0.15	0.02	0.09	0.006	0.001	0.001	0.001	0.006	0.11	0.47	1.7	0.6
Summer (Jul. 24, 2020)	Inshore (FS20)	S	10:45	31.5	33.67	6.57	8.18	0.43	0.020	0.970	0.001	0.003	0.039	0.89	3.08	10.0	1.8
		B	10:50	31.2	33.90	6.40	8.17	0.26	0.025	0.489	0.001	0.005	0.042	2.15	4.03	17.9	-
	Offshore (FS40)	S	06:53	28.6	34.56	6.57	8.17	<0.11	0.021	0.644	<0.001	0.003	0.085	2.29	1.41	6.9	3.8
		B	07:05	28.6	34.55	6.51	8.16	<0.11	0.020	0.679	<0.001	0.003	0.074	4.34	1.50	10.9	-
	Mean		-	30.0	34.17	6.51	8.17	-	0.021	0.696	-	0.004	0.060	2.42	2.51	11.4	2.8
	SD		-	1.6	0.45	0.08	0.01	-	0.002	0.201	-	0.001	0.023	1.43	1.27	4.6	1.4
Autumn (Sep. 15, 2020)	Inshore (FS20)	S	15:04	24.1	34.42	6.79	8.17	0.40	0.006	0.017	<0.001	<0.003	0.044	1.73	1.47	9.1	3.0
		B	15:13	23.7	34.42	6.56	8.17	0.45	0.004	0.015	<0.001	<0.003	0.039	1.24	1.55	9.1	-
	Offshore (FS40)	S	12:09	24.0	34.46	6.39	8.16	<0.11	0.006	0.012	<0.001	<0.003	0.047	1.42	0.41	6.6	13.0
		B	12:20	24.2	34.46	6.43	8.16	<0.11	0.010	0.014	<0.001	<0.003	0.044	1.44	0.67	7.7	-
	Mean		-	24.0	34.44	6.54	8.17	-	0.007	0.015	-	-	0.044	1.46	1.03	8.1	8.0
	SD		-	0.2	0.02	0.18	0.01	-	0.003	0.002	-	-	0.003	0.20	0.57	1.2	7.1

DOI: 10.29677/MR.202212_2(2).0002

In total, 3,026 organisms and 92 macrobenthic species were collected. The detailed classifications of each group were as follows: 33 families, 50 genera, and 62 species of fish; 6 families, 7 genera, and 9 species of cephalopods; 3 families, 6 genera, and 8 species of shrimps; 6 families, 7 genera, and 10 species of crabs; and 3 families, 3 genera, and 3 species of other invertebrates (see Appendix 1). More species were collected in July (37 families, 48 genera, and 66 species) than were collected in March (24 families, 30 genera, and 34 species) and in September (28 families, 37 genera, and 43 species). Only 8 species belonging to 6 families, 6 genera, and 6 species of fish (i.e., *Neotrygon kuhlii, Arius arius, Trachinocephalus myops, Upeneus japonicus, Cynoglossus bilineatus*, and *Inegocia japonica*) as well as 1 family, 2 genera, and 2 species of shrimps (i.e., *Metapenaeopsis barbata* and *Parapenaeopsis hardwickii*) were noted in all three surveys (Appendix 1, Table 3).

Table 3. Abundance, biomass and relative abundance (R%) of the top 25 benthos collected off the Changhua coast, central western Taiwan observed on the three seasonal cruises in 2020. SD, standard deviation.

	Abundance (ind./10^4m^2)						Biomass (g/10^4m^2)					
	Spring	Summer	Autumn	Mean	SD	R%	Spring	Summer	Autumn	Mean	SD	R%
Fish												
Dasyatis zugei	0.2	4.9	0.0	1.7	2.8	0.7	72.6	971.3	0.0	348.0	541.0	6.2
Alepes djedaba	0.0	6.5	2.2	2.9	3.3	1.2	0.0	379.0	118.3	165.8	193.9	3.0
Arius arius	4.3	3.6	0.7	2.9	1.9	1.2	1,025.1	649.0	332.1	668.7	346.9	12.0
Engyprosopon grandisquama	0.0	2.0	3.2	1.7	1.6	0.7	0.0	6.5	16.4	7.6	8.3	0.1
Ephippus orbis	0.0	0.4	3.2	1.2	1.7	0.5	0.0	33.0	135.7	56.2	70.8	1.0
Equulites absconditus	1.5	0.0	86.7	29.4	49.6	12.2	21.9	0.0	291.3	104.4	162.2	1.9
Equulites rivulatus	0.0	162.9	8.5	57.1	91.7	23.7	0.0	101.2	5.1	35.4	57.0	0.6
Lagocephalus lunaris	0.0	8.3	2.7	3.7	4.2	1.5	0.0	1,452.2	666.5	706.2	726.9	12.7
Liachirus melanospilos	0.0	0.0	3.4	1.1	2.0	0.5	0.0	0.0	74.7	24.9	43.1	0.4
Ostorhinchus kiensis	0.0	0.0	4.5	1.5	2.6	0.6	0.0	0.0	2.5	0.8	1.4	0.0
Pennahia pawak	5.5	0.0	0.0	1.8	3.2	0.8	226.7	0.0	0.0	75.6	130.9	1.4
Photopectoralis bindus	0.0	0.0	11.1	3.7	6.4	1.5	0.0	0.0	13.4	4.5	7.7	0.1
Plotosus lineatus	0.0	62.1	0.0	20.7	35.9	8.6	0.0	729.8	0.0	243.3	421.4	4.4
Saurida elongata	0.0	1.9	6.1	2.7	3.1	1.1	0.0	108.9	231.3	113.4	115.7	2.0

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	Abundance (ind./10^{4}m^2)						Biomass (g/10^{4}m^2)					
	Spring	**Summer**	**Autumn**	**Mean**	**SD**	**R%**	**Spring**	**Summer**	**Autumn**	**Mean**	**SD**	**R%**
Terapon theraps	5.5	5.8	0.0	3.8	3.3	1.6	748.3	1,023.2	0.0	590.5	529.5	10.6
Trachinocephalus myops	0.8	7.6	7.4	5.3	3.9	2.2	7.9	52.8	111.0	57.2	51.7	1.0
Trichiurus japonicus	5.5	0.0	0.0	1.8	3.2	0.8	207.4	0.0	0.0	69.1	119.7	1.2
Upeneus japonicus	0.8	19.7	30.9	17.1	15.2	7.1	13.8	207.5	35.0	85.4	106.2	1.5
Shrimp												
Metapenaeopsis barbata	0.3	5.1	0.7	2.0	2.7	0.8	1.6	12.6	1.6	5.3	6.4	0.1
Metapenaeus ensis	0.0	6.2	0.0	2.1	3.6	0.9	0.0	8.1	0.0	2.7	4.7	0.0
Parapenaeopsis hardwickii	35.4	0.4	1.7	12.5	19.8	5.2	101.5	0.7	3.1	35.1	57.5	0.6
Parapenaeopsis sinica	1.7	34.7	0.0	12.1	19.6	5.0	4.6	47.2	0.0	17.3	26.0	0.3
Crab												
Calappa philargius	0.0	1.6	2.7	1.4	1.4	0.6	0.0	209.6	233.1	147.6	128.3	2.6
Cephalopoda												
Loliolus beka	95.8	0.0	0.0	31.9	55.3	13.2	267.1	0.0	0.0	89.0	154.2	1.6
Uroteuthis chinensis	0.0	8.1	1.7	3.3	4.3	1.4	0.0	209.6	52.2	87.3	109.1	1.6
Others	10.5	24.4	12.4	15.8	7.5	6.5	2,447.4	1,597.2	1,448.7	1,831.1	538.9	32.9
Total	167.7	366.4	190.0	241.4	108.9	100.0	5,145.9	7,799.5	3,772.0	5,572.5	2,047.4	100.0

A total of 55 sandy and related dwelling fishes, constituting 88.7% of the total fish species, were identified, and only 5 reef dwellers and 2 pelagic fishes were identified, constituting 8.1% and 3.2%, respectively, of the total fish species. In addition to the fish species, 30 species of invertebrates were regarded as sandy dwellers that constituted 93.4% of the macro benthos of sandy sea floor organisms (Appendix 1).

The top 25 benthos were identified in terms of abundance (constituting 93.5% of the relative abundance and 66.7% of the relative biomass; Table 3). The top 8 species in terms of abundance were different from the top 8 species in terms of biomass. In descending order, the top 8 most abundant species were *Equulites rivulatus, Loliolus beka, E. absconditus, Plotosus lineatus, U. japonicus, P. sinica, P. hardwickii, and T. myops*, which constituted 77.2% of the relative abundance and 12.0% of the relative biomass, whereas the top 8 species in terms of biomass were *Lagocephalus lunaris, A. arius, Terapon theraps, Dasyatis zugei, P. lineatus, Alepes djedaba, Calappa philargius,* and *Saurida elongate,* which constituted 16.5% of the relative abundance and 54.2% of the relative biomass (Table 3). Among the 8 dominant species in terms of abundance and biomass, *T. myops, U. japonicus, P. hardwickii,* and A. *arius* were caught in three samplings, whereas the others were caught only in one or two samplings. Species caught that were either large in number or had large biomass were thus identified as dominant. For example, the March dominants were *L. beka* and *P. hardwickii* in terms of abundance and *A. arius* in terms of biomass. Similarly, the July dominants were *E. rivulatus, P. lineatus,* and *P. sinica* in terms of abundance and *L. lunaris, T. theraps,* and *D. zugei* in terms of biomass. Finally, the September dominants were *E. absconditus* and *U. japonicus* in terms of abundance and *L. lunaris, A. arius,* and *E. absconditus* in terms of biomass (Table 3).

As illustrated in Figure 2A, the clades identified for the benthic assemblages at the study sites were categorized into two groups: dry season group and wet season group; however, the benthic assemblages demonstrated no significant differences in clades between the inshore and offshore sites. Furthermore, the results from the nMDS ordination indicated that *L. beka, P. hardwickii, Pennahia pawak,* and *Trichiurus japonicus* were the major members of the dry season group, and *A. arius, T. myops, L. lunaris*, and *U. chinensis* were members of the wet season group (Figure 2B).

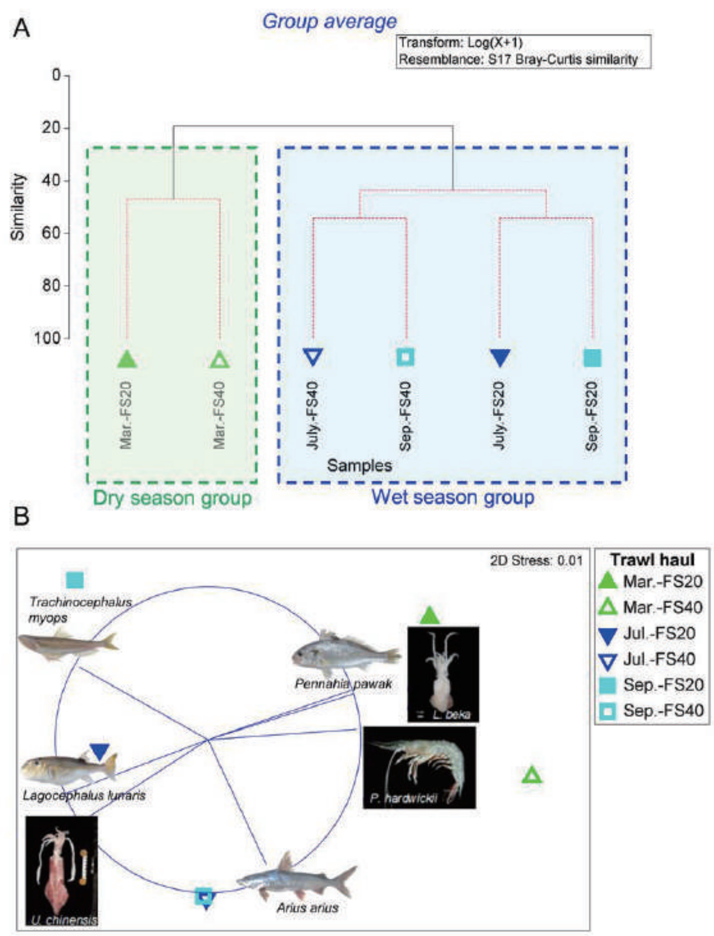

Figure 2. Plots of (A) cluster and (B) nonmetric multidimensional scaling (nMDS) ordination of haul-specific abundance (ind./104m2) data constructed using the top 25 benthos according to month and site in this study. The overlay blue lines on the nMDS graph indicate the species with Pearson correlations greater than 0.9. FS20: inshore site; FS40: offshore site.

The size of the top 8 most abundant species was mostly smaller than 100 mm in terms of the total length for fish, 50 mm in terms of the mantle length for squid, and 20 mm in terms of the carapace length for shrimp. The most dominant species was *E. rivulatus*, which was caught only in July and September. In July, 683 *E. rivulatus* samples were caught with a total length ranging from 22 to 64 mm, with two peak modes within the size ranges of 34–36 mm and 48–50 mm. In September, a smaller number and size range of the species were caught, with no significant peak mode (Figure 3A). The second dominant species was *L. beka,* a small nearshore squid, caught only in March in great abundance (n = 377); its mantle length ranged from 9 to 72 mm, with two peak modes within the size ranges of 18–21 mm and 48–51 mm (Figure 3B). The third dominant species was *E. absconditus,* which was caught only in March and September. In September, they were caught in great abundance (n = 353), with sizes ranging from 33 to 106 mm and two peak modes within the size ranges of 42–45 mm and 66–69 mm. In March, a considerably smaller number of the species was caught with a larger size range (81–106 mm) but with no significant peak mode (Figure 3C). The fourth dominant species in terms of abundance was *P. lineatus*, which was caught in July in large numbers (n = 279) and with the size ranges of 87–144 mm and two peak modes within the size ranges of 105–108 mm and 126–129 mm (Figure 3D). The fifth dominant species was *U. japonicus* in the samples of all three months. In July and September, they were caught in larger numbers (n = 88 and n = 124, respectively), but with significantly different size ranges (30–140 mm in July and 35–70 mm in September). Three small modes were identified within the size ranges of 80–85 mm, 105–110 mm, and 120–125 mm in the *U. japonicus* sample in July, and a remarkable peak mode was determined within the size range of 40–45 mm in September. In March, only three large *U. japonicus* samples (80–120 mm) were caught (Figure 3E). The sixth dominant species in terms of abundance was *P. hardwickii,* a commercial sword shrimp, caught in all three sampling months, with great abundance (n = 145) in March. In March, their carapace size range was 8–34 mm, with three peak modes within the size ranges of 10–12 mm, 16–18 mm, and 26–28 mm. In July and September, a smaller number and smaller size of the species were caught with no notable peak mode (Figure 3F). The seventh dominant species was *P. sinica*, a commercial sword shrimp, caught in March and July. In July, they were caught in abundance (n = 156) with a carapace length ranging from 8 to 24 mm and a remarkable peak mode within the size range 14–16 mm. In March, a smaller number of the species with both small and large sizes was caught, with no significant peak mode (Figure 3G). The eighth dominant species was *T. myops*, which was caught in all three sampling months. In July and September, they were caught in greater abundance (n = 32 and n = 30, respectively), but with peak modes within different size ranges: 90–100 mm in July and 110–110 mm in September (Figure 3H).

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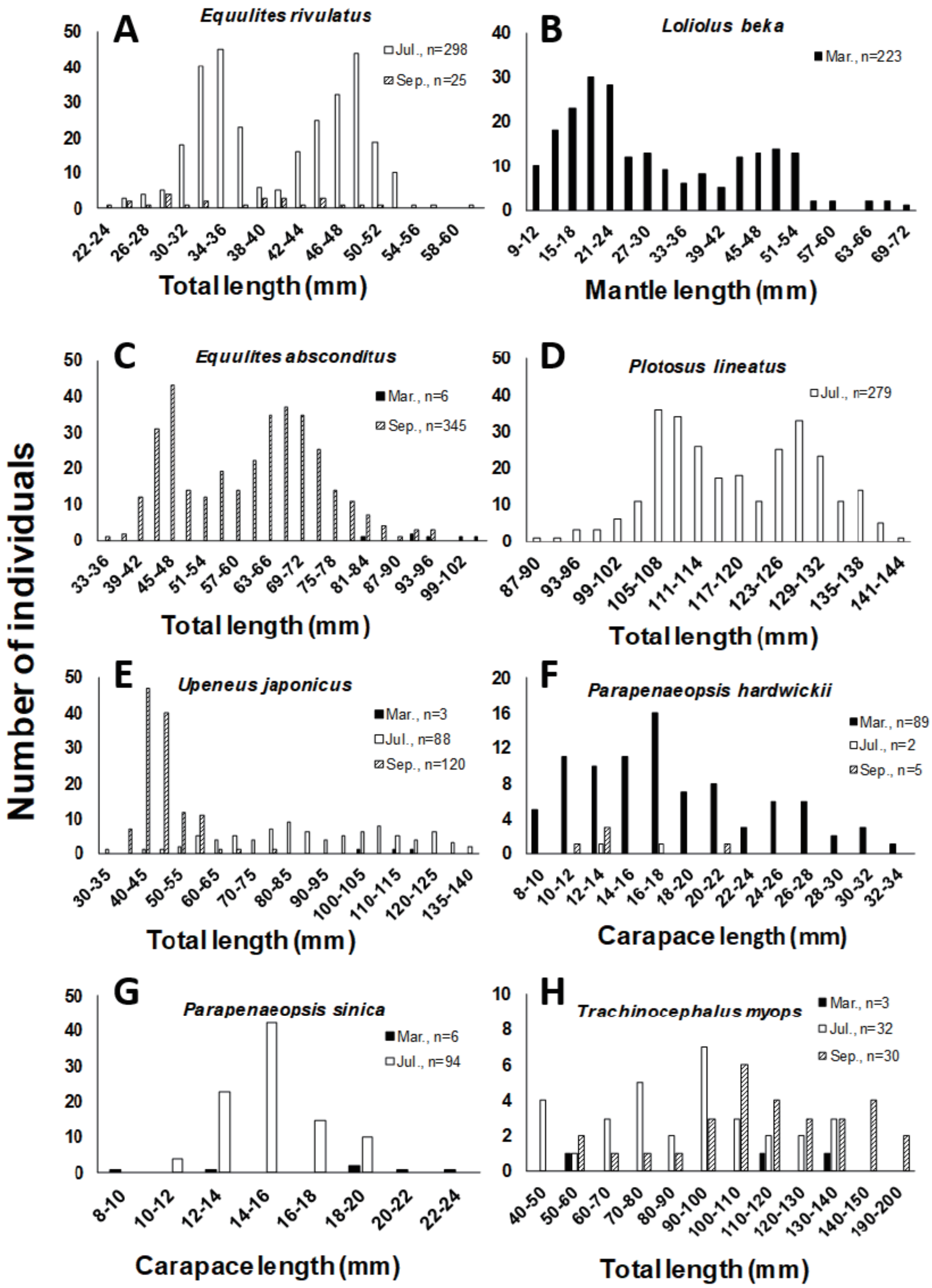

Figure 3. Monthly length frequency distribution of the top 8 dominants (A) *Equulites rivulatus,* (B) *Loliolus beka,* (C) *Equulites absconditus,* (D) *Plotosus lineatus,* (E) *Upeneus japonicus,* (F) *Parapenaeopsis hardwickii,* (G) *Parapenaeopsis sinica,* and (H) *Trachinocephalus myops* measured on the three seasonal cruises on March 18, July 24, and September 15, 2020 off the coast of Changhua, central western Taiwan.

Marine Research of the National Academy of Marine Research
DOI: 10.29677/MR.202212_2(2).0002

4 DISCUSSION

The tentative OWF area was situated at the CYR within 9–42 km off the coastline of Changhua, central western Taiwan, in the tropical–subtropical climate zone. This coastal region is rich in soft-bottom habitats, mainly in the Zhuoshui (Choshui) River, which contributes an annual mean discharge of 33.86 m^3/s with a recorded maximum sediment of 1,330 ppm (Water Resources Agency Ministry of Economic Affairs, 2022). These sediment deposits formed the CYR, which is rich in soft-bottom habitats inhabited by various tropical–subtropical marine sandy dwelling organisms. Therefore, we identified mostly (93.4%) sandy and related dwelling marine benthos and only 2.2% pelagic and 5.4% reef living marine fishes in this study.

A total of 33 families and 62 species of fish were identified, constituting 1% (0.98%) of the 631 coastal fish species (Shao et al., 2012) identified in the coastal waters of Taiwan. Among the fish families, Synodontidae, Carangidae, and Leiognathidae each included five species, constituting 17%, 9%, and 21%, respectively, of the fish families in Taiwan's coastal waters (Shao et al., 2012). Our results indicated that the fishes were mostly typical sandy dwellers. Among the 62 fish species identified in this study, 64.5% were soft-bottom shallow-water (<50 m depth) marine benthic fishes (e.g., *A. arius, E. rivulatus, E. absconditus, U. japonicus, T. theraps,* and *L. lunaris*; Chen et al., 2020, 2022), 24% of the species live on reefs and sand combined substrates (e.g., *T. myops, O. kiensis,* and *Decapterus maruadsi*), 8.1% live on hard substrates, such as coral reefs (e.g., *P. linearus* and *A. djedaba*), and 3.2% are pelagic fishes, such as *Sardinella gibbosa* (Appendix 1).

Introducing large amounts of pile-supporting materials during the construction of wind turbines can transform the sandy sea floor into a rocky foundation, thereby forming more small caves and microhabitats suitable for reef dwellers. For example, the edible crab species *Cancer pagurus* and the cod species *Gadus morhua* were caught in abundance near the monopiles' foundations in an OWF in the Netherlands (Egmond aan Zee) during spring and summer 5 years after the farm was established and began operations (van Hal et al., 2017). *Cancer pagurus* colonized the monopiles with scour protection and used them as nursery grounds, causing an increase of 27% in the local crab stock in the German Bight, North Sea (Krone et al., 2017). Such transformation of ecosystems can be observed during scientifically baseline research, including monitoring and experimental scientific studies throughout the development period, and using the baseline data reported in the present study. We expected that with the construction of an increasing number of wind turbines, the population of reef-related marine organisms would increase in the CYR wind farm area, thereby increasing marine biodiversity.

We categorized the benthic organisms into dry and wet season groups with significantly different dominant species, reflecting the temporal variations in the CYR benthic marine organism community. Penaeid shrimps and loliginid squids were the dominant species during the dry season, whereas fishes such as leiognathids, plotosids, and mullids dominated the wet season.

According to the appearance and abundance of organisms collected, the benthos was categorized into local residents and seasonal aggregators. The four local residents were the fish species *T. myops, U. japonicus*, and *A. arius* and the shrimp *P. hardwickii.* Large numbers of the young (aged 0+ years) and 1- and 2-year-old subadult *T. myops* were caught at the CYR (Yang et al., 2013). *Upeneus japonicus* (red mullet) also utilized the CYR to complete its life cycle; its size peak mode ranged within 40–55 mm in September after the mature adults were caught at the CYR in July, which was its spawning period. *Arius arius* (engraved catfish) was approximately 200 g in weight at an age of approximately 3 years, likely attributable to its large size (Balamurgugan et al., 2013); therefore, we assumed that it fed and spawned at the coastal CYR and off the Zhuoshui River estuary. *Parapenaeopsis hardwickii,* a 1-year short living and high-priced middle-sized shrimp, may aggregate to spawn in March and nurse, feed, and grow from summer to autumn at the CYR (Song et al., 2009).

DOI: 10.29677/MR.202212_2(2).0002

The other five dominants were identified as seasonal aggregators that came to the CYR in a particular month for spawning, nursing, or feeding. The March aggregator was *L. beka,* a small nearshore squid aged less than 6 months and is similar to *L. noctiluica* (Ceriola and Jackosn, 2010) and *L. plei* (Jackson and Forsythe, 2002). It was caught at the 20-m nearshore site of the CYR with two notable small ML size modes and one large ML size mode, indicating that it may reside in the coastal area throughout its lifespan during spring and summer. The July aggregators included the fish species *E. rivulatus,* ponyfish, slipmouth or sliverbelly, and *P. lineatus,* striped eel catfish, and the shrimp *P. sinica.* Based on the two modes, *E. rivulatus* and *P. lineatus* were caught in July and assumed to mature with a size of 100 mm; it utilized the CYR as a nursing and feeding ground during the juvenile and subadult life stages (Vijayakumaran, 1998; Acharya and Naik, 2015). *Parapenaeopsis sinica* had a small size, indicating that it used the CYR as a nursing ground. The September aggregator was *E. absconditus,* and similar to *E. rivulatus,* it aggregated at the CYR for nursing and feeding after possible spawning in March. The arrival and departure of these seasonal aggregators indicated possible prey–predator relationships among them, which can be used to explore life cycles through more frequent samplings in the future.

Trachinocephalus myops, snakefish or bluntnose lizardfish or painted lizardfish, was one of the top predators caught in large numbers at the CYR. It inhabited the tropical muddy bottoms of the bays and the coastal water and sandy bottoms of reef slopes up to 200 m, as well as in estuaries. As a carnivore, it has a diet constituting 50% fish, 44% crustaceans, and 6% mollusks, as identified in the Gulf of Guinea, Sao Tome Island, west of Africa between 1°42'N and the equator. Among them, fish diets constitute 31% dragonets (Callionymidae), 15% flatheads (Platycephalidae), 13% lizardfishes (Synodontidae), 8% goatfishes (Mullidae), 5% silverbellies (Leiognathidae), and 32% others, whereas crustacean diets constitute *Metapenaeopsis stidulans,* velvet shrimp (62%), and crab and shrimp remains (21%) (Kizhakudan and Gomathy, 2007). Accordingly, the top 1, 3, 5, 7, and 8 dominants were all the preferred diet of *T. myops* and supported it to thrive at the CYR. Therefore, we suggested that the four local residents that completed their life cycles at the CYR, namely the fishes *T. myops, U. japonicus,* and *A. arius* and the shrimp *P. hardwickii,* are potential ecological indicators after

5 CONCLUSIONS

To the best of our knowledge, this is the first report on the macrobenthic community collected by a local otter trawler from spring to autumn 2020. The list of species, abundance, and biomass can be used as the baseline data before the construction of wind turbines in the coming decade. The abundance of eight dominant species exhibited significant temporal variations, and the species were categorized into dry and wet seasonal groups. Among the eight dominants, *T. myops, U. japonicus,* and *P. hardwickii,* and *A. arius* (ranked the second highest in biomass) were identified as local species and are potential marine ecological indicators for the CYR.

ACKNOWLEDGEMENTS

The survey was conducted by the local otter trawling boat (Yong-Shen no. 6, CT3-5732). Messrs. Shi-Hao Huang and Shi-Hong Huang, who were the captain and crew operating the fishing boat for the field sampling survey, were highly appreciated. Messrs. Hsuan-Yao Hsu, Zhi-Ren Tong, as well as many graduate and undergraduate part-time students helped with the field surveys and laboratory work throughout the study. This research was supported by funding from the National Academy of Marine Research under Grant No. NAMR-109-014.

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Appendix 1. Number, weight, habitat type, life stage, and trophic level of the benthos determined on the three seasonal cruises in 2020 off the Changhua coast, central western Taiwan. Habitat type: D = demersal, Pn = neritic pelagic, RA = reef associated, and BP = benthic pelagic according to the Fish Database of Taiwan (Froese & Pauly, 2021); S = sandy, SR = sandy and reef, P = pelagic, and R = reef; life stage: A = adult, SA = subadult, and J = juvenile; trophic level according to the Fish Database of Taiwan (Shao, 2021).

		Spring	Summer	Autumn	Total number	Total weight (g)	Habitat type	Life stage	Trophic level*
Chondrichthyes									
Triakidae	*Mustelus griseus*	1			1	1,520.2	D, S	A	3.5
Rhynchobatidae	*Rhynchobatus immaculatus*	1			1	4,550	Pn, S	SA	3.5
Dasyatidae	*Dasyatis acutirostra*	1			1	161	D, S	A	3.7
	Dasyatis bennettii	1		1	2	1,014.4	D, S	SA	4.5
	Dasyatis zugei	1	22		23	4,664.7	D, S	A	3.5
	Neotrygon kuhlii	1	2	2	5	2,725.9	RA, SR	J, SA, A	3.3
Actinopterygii									
Clupeidae	*Sardinella gibbosa*		6		6	311.8	Pn, P	A	2.9
Plotosidae	*Plotosus lineatus*		279		279	3,276.6	RA, R	SA, A	3.6
Ariidae	*Arius arius*	18	16	3	37	8,538.2	D, S	A	3.5
	Arius maculatus			1	1	410.9	D, S	A	3.4
Synodontidae	*Saurida elongata*		8	25	33	1,402.2	D, S	J, SA, A	4.4
	Saurida undosquamis		4		4	24.6	RA, S	J, SA	4.5
	Saurida wanieso		2		2	3.3	D, S	J	4.0
	Synodontoidei sp.	1			1	0.2	D, S	J	-
	Trachinocephalus myops	3	32	30	65	701.9	RA, SR	J, SA, A	4.4
Syngnathidae	*Hippocampus kuda*		1	1	2	16.2	RA, SR	SA	3.6
Scorpaenidae	*Apistus carinatus*		4		4	4.7	D, S	SA	3.5
Platycephalidae	*Inegocia japonica*	1	1	1	3	162	D, S	A, SA	3.7
	Sorsogona tuberculata			1	1	9.6	D, S	A	3.6
	Suggrundus meerdervoortii		4		4	84.4	D, S	A, SA	3.7
Acropomatidae	*Acropoma japonicum*	3			3	11.1	BP, S	J, SA	3.3
Apogonidae	Apogonidae spp.		2		2	0.5	RA, SR	J	-
	Ostorhinchus fasciatus	1			1	0.5	RA, SR	J, SA	3.6
	Ostorhinchus kiensis			18	18	10.2	RA, SR	J, SA	3.4
Carangidae	*Alectis ciliaris*		2		2	258.3	RA, P	J, SA	4.0
	Alepes djedaba		27	9	36	2055	RA, R	A	3.3
	Decapterus maruadsi	2	6		8	1,018.1	RA, SR	A	3.4
	Parastromateus niger	3			3	604.9	RA, S	SA, A	2.9
	Trachurus japonicus		1		1	1.6	Pn, R	J	3.4
Leiognathidae	*Equulites absconditus*	6		353	359	1,270.6	Pn, S	J, SA, A	3.3
	Equulites rivulatus		683	34	717	449.5	D, S	J, SA	3.2
	Leiognathidae sp.			1	1	0.6	D, S	J	-
	Photopectoralis bindus			45	45	54.5	D, S	J, SA	2.9
	Secutor ruconius	3		2	5	23.4	D, S	A	2.7
Lutjanidae	Lutjanidae sp.			5	5	2.6	RA, SR	J	-
Gerreidae	*Gerres filamentosus*		1		1	126.6	D, SR	A	3.3
Haemulidae	*Plectorhinchus pictus*		2		2	83.2	RA, R	J, SA	3.9
	Pomadasys kaakan	1		4	5	1,586.4	RA, SR	SA	3.5

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		Spring	Summer	Autumn	Total number	Total weight (g)	Habitat type	Life stage	Trophic level*
Nemipteridae	*Nemipterus peronii*			2	2	161.8	D, S	SA, A	3.7
Sparidae	*Evynnis cardinalis*	1	1		2	115.4	RA, S	A	3.3
Sciaenidae	*Pennahia macrocephalus*	3			3	34.8	D, S	J, SA	4.1
	Pennahia pawak	22			22	913.7	BP, S	SA, A	3.3
Mullidae	*Upeneus japonicus*	3	88	124	215	1,112.3	RA, S	J, SA, A	3.6
Terapontidae	*Terapon jarbua*		2		2	219.6	D, SR	A	3.9
	Terapon theraps	23	26		49	7,715	RA, S	A	3.5
Ephippidae	*Ephippus orbis*		2	13	15	700.4	RA, S	SA, A	4.0
Siganidae	*Siganus fuscescens*		3		3	368.4	RA, SR	A	2.0
Trichiuridae	*Trichiurus japonicus*	23			23	868.2	BP, S	A	4.4
Scombridae	*Scomberomorus commerson*		2		2	177.3	Pn, SR	SA	4.5
Stromateidae	*Pampus argenteus*			1	1	1,002.9	BP, S	A	3.3
Paralichthyidae	*Pseudorhombus arsius*		1		1	34.5	D, S	A	4.2
	Tarphops oligolepis		2	5	7	19.4	D, S	A	3.3
Bothidae	*Bothus pantherinus*		1		1	0.6	RA, SR	J	3.5
	Engyprosopon grandisquama		9	13	22	95.1	RA, S	SA, A	3.1
Soleidae	*Liachirus melanospilos*			14	14	304	D, S	SA, A	3.4
Cynoglossidae	*Cynoglossus bilineatus*	1	7	2	10	1,429.2	D, S	SA, A	3.5
	Paraplagusia blochii			1	1	50.3	D, S	A	3.4
Tetraodontidae	*Lagocephalus gloveri*	1			1	61.4	D, S	SA	3.4
	Lagocephalus lunaris		35	11	46	8,969.3	D, S	SA, A	3.7
	Lagocephalus sceleratus		6		6	161.7	RA, R	SA	3.7
	Lagocephalus spadiceus		3		3	636.1	D, S	A	3.7
Diodontidae	*Diodon holocanthus*		1		1	134.5	RA, SR	A	3.9
Cephalopoda									
Enoploteuthidae	*Abralia multihamata*	7			7	7.5			
Loliginidae	*Loliolus beka*	377			377	1,088.6			
	Loliolus uyii		1		1	2.6			
	Uroteuthis chinensis		36	7	43	1,132.6			
Octopodidae	*Amphioctopus aegina*		1		1	12.2			
Sepiadariidae	*Sepiadarium kochii*		2		2	4.7			
Sepiidae	*Sepia aculeata*			3	3	381.8			
	Sepia lycidas		12		12	925			
Sepiolidae	*Euprymna berryi*	1	1		2	11.3			
Malacostraca									
Albuneidae	*Albunea occulta*		1	1	2	14.8		-	
Calappidae	*Calappa philargius*		7	11	18	1,838.3		A, SA, J	
Diogenidae	Diogenidae sp.		4		4	72.8		-	
Dorippidae	*Paradorippe granulata*	1			1	2.5		A	
Parthenopidae	*Ceratocarcinus trilobatus*			1	1	0.4		-	
Pasiphaeidae	*Leptochela gracilis*	6			6	1.1			
Penaeidae	*Metapenaeopsis barbata*	1	23	3	27	69.5			
	Metapenaeopsis dalei			1	1	0.5			
	Metapenaeus ensis		28		28	36.4			

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		Spring	Summer	Autumn	Total number	Total weight (g)	Habitat type	Life stage	Trophic level*
	Parapenaeopsis hardwickii	145	2	7	154	425.6			
	Parapenaeopsis sinica	7	156		163	231.4			
	Trachysalambria curvirostris	1			1	1.3			
Portunidae	*Charybdis natator*			1	1	235		A	
	Portunus argentatus		2	2	4	8.9		A, SA	
	Portunus haanii		5	1	6	109.6		A	
	Portunus pelagicus		1	1	2	378.7		A	
	Portunus sanguinolentus			6	6	653.7		A	
Squillidae	*Lophosquilla costata*		2		2	2.6			
Gastropoda									
Arcidae	*Anadara antiquata*			1	1	2.1			
Arminidae	Arminidae sp.		1	2	3	7.7			
Anthozoa									
Hormathiidae	*Calliactis polypus*		6		6	6.2		-	
Total		671	1,585	770	3,026	70,091.6			

**The trophic level of an organism denotes the position it occupies in a food web and increases with the progression of the chain. The trophic level is 1 for primary producers, 2 for herbivores, 3 or higher for carnivores, and 4 or 5 for apex predators.*

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