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Spatial and Temporal Characteristics of Demersal Assemblages in Sığacık Bay, Central Aegean Sea, Turkey

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Abstract: This study aimed to determine the spatial and temporal variation of species diversity and CPUE in trawl fisheries in the Central Aegean Sea (Sığacık Bay). The study also aimed to evaluate changes in some biometric parameters (mean and frequency of length) depending on the season and depth for three important commercial species (*Parapenaeus longirostris, Nephrops norvegicus* and *Illex coindetii*). Monthly trawl samplings were carried out in three depth strata (0-200; 201-400 and 401-600 m) between May 2008 - April 2009. A total of 111 species were identified including 74 Osteichthyes, 13 Chondrichthyes, 18 Cephalopods and 6 Crustaceans. The highest species diversity and catch per unit effort (CPUE) values were obtained at 201-400 m strata. Among these, Osteichthyes had the highest frequency and CPUE values in all strata and seasons. Summer was the season with the highest CPUE in all groups followed by a decrease until winter due to openning of trawl fisheries in the Autumn. The mean carapace length of *P. longirostris*, the target species in Sığacık Bay trawl fisheries, increased with depth and this species was more abundant at the 201-400 m strata.

Key words: Species Diversity, CPUE, Fish, Cephalopoda, Crustacea, Sığacık Bay

Sığacık Körfezi'nde (Orta Ege Denizi, Türkiye) Demersal Toplulukların Mekansal ve Zamansal Özellikleri

Özet: Bu çalışma, Orta Ege Denizi'nde (Sığacık Körfezi) trol balıkçılığında tür çeşitliliği ve CPUE'nin mekansal ve zamansal değişimini belirlemeyi amaçlamıştır. Çalışmada ayrıca üç önemli ticari tür (*Parapenaeus longirostris, Nephrops norvegicus* ve *Illex coindetii*) için mevsime ve derinliğe bağlı olarak bazı biyometrik parametrelerin (ortalama boy ve boy frekansı) değişiminin değerlendirilmesi de amaçlanmıştır. Aylık trol örneklemeleri Mayıs 2008 ile Nisan 2009 tarihleri arasında 3 derinlik katmanında (0-200; 201-400 ve 401-600 m) gerçekleştirilmiştir. 74'ü Osteichthyes, 13'ü Chondrichthyes, 18'i Cephalopoda ve 6'sı Crustacea grubunda olmak üzere toplam 111 tür tespit edilmiştir. En yüksek tür çeşitliliği ve birim çaba başına av miktarı (CPUE) değerleri 201-400 m derinlik katmanında elde edilmiştir. Gruplar arasında, tüm katmanlarda ve mevsimlerde en yüksek frekans ve CPUE değerlerine Osteichthyes grubu sahiptir. Yaz mevsimi, tüm gruplarda CPUE'nin en yüksek olduğu mevsimdir ve sonrasında sonbaharda başlayan balıkçılığın etkisiyle değerler kışa kadar düşmüştür. Sığacık Körfezi trol balıkçılığında hedef tür olan *P. longirostris*'in ortalama karapaks boyu derinlikle birlikte artmış ve bu tür 201-400 m derinlik katmanında daha bol bulunmuştur.

Anahtar kelimeler: Tür Çeşitliliği, CPUE, Balık, Cephalopoda, Crustacea, Sığacık Körfezi

Introduction

Demersal resources have an important place in the Aegean Sea fisheries which provides 15% of the total capture fishery in Turkey (TURKSTAT, 2021) and 90% of these resources were caught by trawl fisheries (Kınacıgil and İlkyaz, 1997). There are 786 registered trawlers in Turkey and 55 of these trawlers are registered in the coastal ports of the Aegean Sea (TURKSTAT, 2021). Sığacık Bay located in the Central Aegean Sea is considered one of the most efficient trawling zones in the Aegean Sea. The national waters of Sığacık Bay at depths of 100-400 m are fished extensively by trawlers. According to the regulations, trawl operations in the Sığacık Bay are allowed between September and March in national waters and between July 15 and September 15 in international waters (BSGM, 2008-2020). Deep water rose shrimp (*Parapenaeus longirostris*) dominates the catch composition in the trawl fisheries in the Sığacık Bay (Soykan et al. 2016). Furthermore, in the Central Aegean Sea trawl fisheries, of the 83 species caught in addition to target species *P. longirostris*, 34 species have commercial value. *Nephrops norvegicus* in the Crustacea group, *Illex coindetii* in the Cephalopoda group, *Trachurus mediterraneus*, *Merluccius merluccius* and *Lophius sp*. in the Osteichthyes group are other most captured commercial species (Soykan et al. 2016).

Catch in numbers or weight represents the removal of biomass and individuals from the ecosystem, and it is the fundamental impact that fishing has on fish populations. Also, catch per unit of effort (CPUE) is often used as an index of stock abundance (De Graaf et al. 2015). For sustainable fisheries, the effects of trawl fisheries on diversity and abundance of demersal resources should be defined by determining the spatial and temporal variation of the catch. Therefore, this study aimed to determine the variation of species diversity and CPUE in trawl fisheries in four seasons (including banned season) and three strata (0-200; 201-400, and 401-600 m). The study also aimed to determine changes in some biometric parameters (mean and frequency of length) depending on the season and depth for *P. longirostris, N. norvegicus and I. coindetii*).

Materials and Methods

This study was carried out by obtaining the legal permission (Date: 05.05.2008, Number: 1164 34587) from the Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture.

Study areas and sampling

The study was conducted between May 2008 and April 2009 in Sığacık Bay located on the Central Aegean Sea (Figure 1). Monthly samplings were obtained from 0-200, 201-400, and 401-600 m strata with a commercial demersal trawler (F/V Hapuloğlu - 27 m LOA). The duration of each haul was 1 hour at 2.5 knots. Trawling was carried out during daylight hours i.e. from dawn to dusk. A conventional bottom trawl with a circumference of 1100 meshes and a codend of 44 mm mesh size was used in all operations. Further information on the characteristics of the gear is available in Aydın and Tosunoğlu (2009).

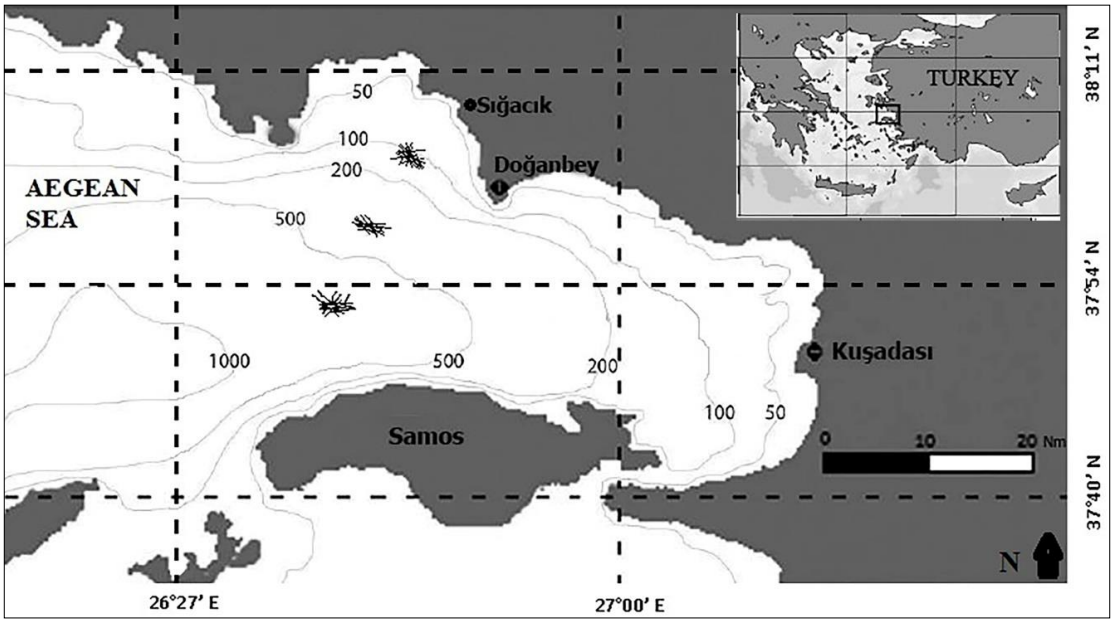

Figure 1. Study area and trawl hauls (lines)

After each haul, catches were landed on the deck. All species were defined according to Whitehead et al. (1984) and Fischer et al. (1987) and separated into four main species groups (Osteichthyes, Chondrichthyes, Cephalopoda, Crustacea). Numbers and weights of all species were recorded. Doubtful species were preserved for subsequent identification in the laboratory. Scientific names for each species were checked with the FishBase (Froese and Pauly, 2021).

The carapace length (CL) and mantle length (ML) were measured in millimeter precision on deck for some important commercial species (CL for *P. longirostris* and *N. norvegicus*; ML for *I. coindetii*).

Data analysis

The number of species (*S*), the total number of individuals (*N*), "Shannon-Wiener" Index (H′), Evenness Function (*J′*) and maximum species diversity (H_{max}) were calculated using PRIMER for each strata and all.

"Shannon-Wiener" Index (*H′*) was used to calculate species diversity in all strata (Shannon and Weaver, 1949; Pielou, 1975).

$$\mathrm{H}' = -\sum_{i=1}^{f}(pi * \ln pi)$$

H′; species diversity, *pi*; ratio of *i* species to total number of species, *f*; total number of species.

Evenness Function (*J′*) was used to state the distribution of the species numbers (Pielou, 1969).

$$J' = \frac{\mathrm{H}'}{\mathrm{H}_{\max}}$$

H′; species diversity, H_{max}; maximum species diversity.

Percentage frequency values of the four main species groups were calculated for all strata and seasons. Catch per Unit Effort (CPUE) of four main species groups were calculated as seasonal and strata using the following formula of Phiri and Shirakihara (1999).

$$CPUE = \frac{\sum Ci/N\text{ç}}{\sum t/N\text{ç}}$$

Ci: catch amount per operation (kg); t: hauling time (hour); Nç: number of operations.

Percentage frequency values of *P. longirostris*, *N. norvegicus* and *I. coindetii* were calculated for all strata and seasons. Season-dependent length distributions were determined for these three species. Strata-dependent length distribution was also determined for *P. longirostris.*

The differences of CPUE values according to depth and season and four species groups were analyzed. The differences of CL values in seasons and strata for *P. longirostris* and in seasons for *N. norvegicus* were analyzed. Data were evaluated using SPSS Statistics 22.0 (IBM Corp., Armonk, New York, USA) statistical package program. Number of units (*n*), mean ± standard deviation ($\bar{x} \pm ss$), and Median (*Q1-Q3*) values were given as descriptive statistics. The data were log-transformed prior to the analysis. The Shapiro Wilk test and Q-Q graphs were used to evaluate normal distribution of the data and Kruskal-Wallis analysis was used for non-normally distributed variables. The assumption of the homogeneity of variance was tested by Levene's test for normally distributed data. One-way analysis of variance (ANOVA) was applied for comparisons of groups with homogeneous variance, and the Welch test was applied to non-homogeneous groups. If there was a difference between the groups in these tests, post *hoc* multiple comparison tests were applied to find the groups that differed. Games Howell test was used for normally distributed variables and the Dunn-Bonferroni test was used for non-normally distributed variables as a post *hoc* multiple comparison test. A p value of <0.05 was considered statistically significant.

Results

Spatial and temporal distribution

Thirty six hauls were made and a total of 111 species were identified in four main groups (74 of Osteichthyes, 13 of Chondrichthyes, 18 of Cephalopoda, and 6 of Crustacea) (Table 1).

When the spatial distribution of the captured species is examined; in the 0-200 m strata, 74 species were found (51 Osteichthyes, 7 Chondrichthyes, 14 Cephalopoda, and 2 Crustacea) (Table 1). In addition to *P. longirostris*, which is dominant in terms of abundance, the incidence of *Macroramphosus scolopax*, *Citharus linguatula*, *Scyliorhinus canicula*, *M. merluccius* was also high. Most of the Chondrichthyes and Cephalopoda caught in this zone belonged to *S. canicula* and *I. coindetii*. (Table 1).

In the 201-400 m strata, 77 species were identified (47 Osteichthyes, 9 Chondrichthyes, 17 Cephalopoda, and 4 Crustacea) (Table 1). *P. longirostris* still predominated in terms of abundance (Table 1). *Gadiculus argenteus* and *M. merluccius* were dominant Osteichthyes species (Table 1). Most of the Chondrichthyes and Cephalopoda caught in this zone belonged to *S. canicula*, *Sepietta sp*. and *I. coindetii*.

Table 1. List and number of captured species according to depth strata.

Species	Total	0-200	201-400	401-600
Osteichthyes				
Antonogadus megalokynodon	2	1		1
Argentina syphyraena	728	71	656	1
Argylopelecus hemigymus	7		7	
Arnoglosus rueppelli	11	1	5	5
Arnoglossus thori	11	11		
Arnoglosus laterna	602	577	24	1
Blennius ocellaris	1	1		
Boops boops	626	236	390	
Caelorhynchus caelorhynchus	2006		830	1176
Callionymus spp	5	5		
Capros aper	853	313	531	9
Cephola macrophalma	25	24	1	
Chlorophthalmus agassizi	2057	1	1939	117
Citharus linguatula	3468	3439	26	3
Conger conger	43	36	4	3
Deldentosteus quadrimaculatus	2	2		
Dentex macrophthalmus	107	107		
Diaphus spp.	39		1	38
Echiodon dentatus	1			1
Engraulis encrasicholus	48	48		
Epigonus constanciae	67		40	27
Eutrigla gurnardus	175	175		
Gadidae	1			1
Gadiculus argenteus	24614	3	24604	7
Gaidropsaurus biscayensis	1		1	
Glossanodon leioglosus	387	347	39	1
Gnathophis mystax	3	2		1
Helicolenus dactylopterus	408		79	329
Hoploptethus mediterraneus	1703		264	1439
Hymrnocephalus italicus	2857	4	1707	1146
Lampanycthus sp	18		2	16
Lepidopus caudatus	238	113	121	4
Lepidorhombus boscii	179	1	109	69
Lepidorhombus whiffiagonis	121		121	
Lepidotrigla cavillone	1474	1456	18	
Lesueurigobius friseii	30	29	1	
Lesueurigobius sueurii	5	5		
Lophius spp	3458	3145	199	114
Macropramphosus sp.	3877	3677	195	5
Maurolicus muellei	1		1	
Merluccius merluccius	6004	3115	2821	68
Micromesistius potassou	100		44	56
Molva dipterygia	8		1	7
Molva macrophthalma	11		3	8
Mullus barbatus	827	826	1	
Mullus surmuletus	37	33	4	
Myctophidae	68		18	50
Nettastoma melanurum	3			3
Nezumia sp.	1444		3	1441
Nezumia sclerorhynchus	176			176
Ophidion barbatum	2	2		
Pagellus acarne	1		1	
Pagellus bogaraveo	181	10	92	79
Pagellus erythrinus	1	1		
Peristedion cataphractum	275	2	272	1
Phycis blennoides	2477		1441	1036
Scomber scombrus	2	2		

Table 1 continued.

Species	Total	0-200	201-400	401-600
Osteichthyes				
Scorpeana notata	2	2		
Serranus cabrilla	10	10		
Serranus hepatus	167	165	2	
Stomias boa	10			10
Spicara (flexuosa) maena	37	37		
Spicara smaris	8	6	2	
Spicara spp	45	45		
Sudis hyaline	1			1
Symphodus nigrescens	5	2	2	1
Trachinus draco	11	11		
Trachurus trachurus	1361	1287	73	1
Trigla lucerna	1	1		
Trigla lyra	66	38	25	3
Trigloporus lastoviza	7	6	1	
Trisopterus minitus	1	1		
Uranoscopus scaber	29	29		
Zeus faber	44	38	6	
Chondrichthyes				
Chimera monostrosa	113		1	112
Dasyatis lichia	1			1
Dasyatis pastinaca	1	1		
Etmopterus spinax	286		62	224
Galeus melastomus	603		149	454
Oxynotus centrina	1		1	
Raja asterias	1		1	
Raja clavata	74	19	53	2
Raja oxyrinchus	22	3	17	2
Torpedo marmorata	3	3		
Scyliorhinus canicula	3644	1830	1790	24
Squallus blainville	80	3	71	6
Mustelus mustelus	1	1		
Cephalopoda				
Sepietta sp.	1196	269	870	57
Rossia macrosoma	145	7	122	16
Neorossia caroli	143		4	139
Sepia officinalis	52	52		
Sepia orbignyana	557	454	103	
Sepia elegans	993	900	93	
Abralia verany	27	6	16	5
Todarodes sagittatus	66	23	3	40
Loligo forbesi	5		5	
Loligo vulgaris	11	10	1	
Illex coindetii	1458	975	435	48
Alloteuthis media	1094	869	225	
Octopus vulgaris	29	26	2	1
Octopus salutii	4		3	1
Eledone moschata	204	188	16	
Eledone cirrhosa	95	16	70	9
Pteroctopus tetracirrhus	22		9	13
Scaeurgus unicirrhus	6	4	1	1
Crustacea				
Aristeomorpha foliacea	2		2	
Nephrops norvegicus	359		136	223
Parapenaeus longirostris	46841	13836	30288	2717
Plesionika martia	2844			2844
Plesionika heterocarpus	14074		14074	
Squilla mantis	4	3		1

A total of 63 species (40 Osteichthyes, 8 Chondrichthyes, 11 Cephalopoda, and 4 Crustacea) (Table 1) were caught in the 401-600 m strata. The dominant species in this deepest strata were as follows: *Plesionika martia*, *P. longirostris*, *Hoploptethus mediterraneus*, species of *Nezumia*, *Hymrnocephalus italicus*, *Phycis blennoides*. Most of the Chondrichthyes and Cephalopoda caught in this zone belonged to *Galeus melastomus* and *Neorossia caroli*.

Species diversity was calculated for Shannon-Wiener (*H'*), Evenness Function (*J'*), and maximum species diversity (H_{max}) as 2.563, 0.544, and 4.710, respectively. The highest values were obtained at 401-600 m strata for *H'* (with 2.526) and *J'* (with 0.610) and at 201-400 m strata for H_{max} (with 4.344) (Table 2).

Table 2. Species diversity values in total and 3 different strata (*H'*: Shannon-Wiener; *J'*: Evenness Function; H_{max}: Maximum species diversity; *S*: Total species; *N*: Number of individuals)

	Total	**0-200 m**	**201-400 m**	**401-600 m**
H'	2.563	2.430	1.893	2.526
J'	0.544	0.565	0.436	0.610
$\boldsymbol{H_{max}}$	4.710	4.304	4.344	4.143
S	111	74	77	63
N	138.668	38.951	85.327	14.390

The spatial variation of the distribution of the main groups is given in Figure 2. While the frequencies of Osteichthyes in total catch increase with increasing depth (43%, 48%, 65%, respectively), in Chondrichthyes (29%, 20%, 17%, respectively) and in the Cephalopoda (20%, 11%, 10%, respectively) a decrease was observed. However, in Crustacea, which prefer 201-400 m (21%), no change was observed in distribution depending on the depth and they showed a distribution of 8% at 0-200 m and 401-600 m strata (Figure 2).

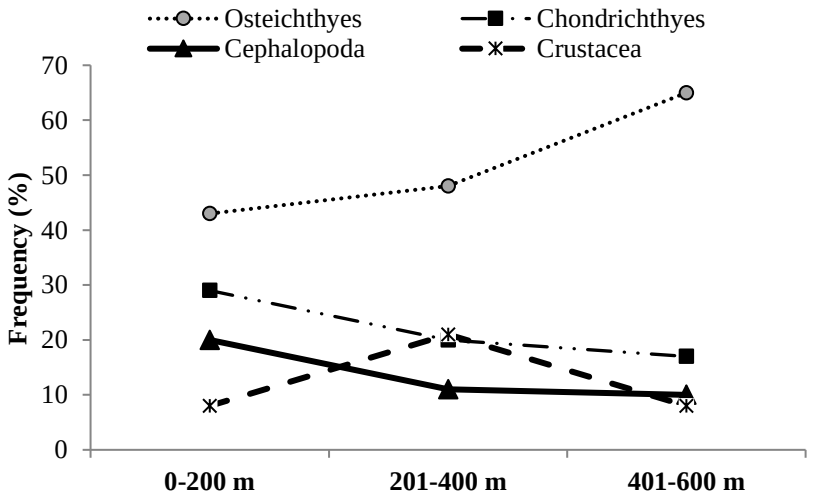

Figure 2. Spatial variations in frequency of four main groups

The distribution of the main groups according to the seasons is presented in Figure 3. Osteichthyes, the main group in all seasons had a frequency of 48% in the spring and summer, and 50% and 64% in the autumn and winter, respectively. Frequencies of Chondrichthyes from spring to winter were 27%, 29%, 15%, and 16%, respectively. The frequency, which was low in the spring (6%) and summer (8%) in the Cephalopoda group, increased to 25% in the autumn and decreased again to 12% in the winter. In the Crustacea group, the frequency, which was 20% in the spring, decreased towards the winter with values of 15%, 10%, and 8%, respectively (Figure 3).

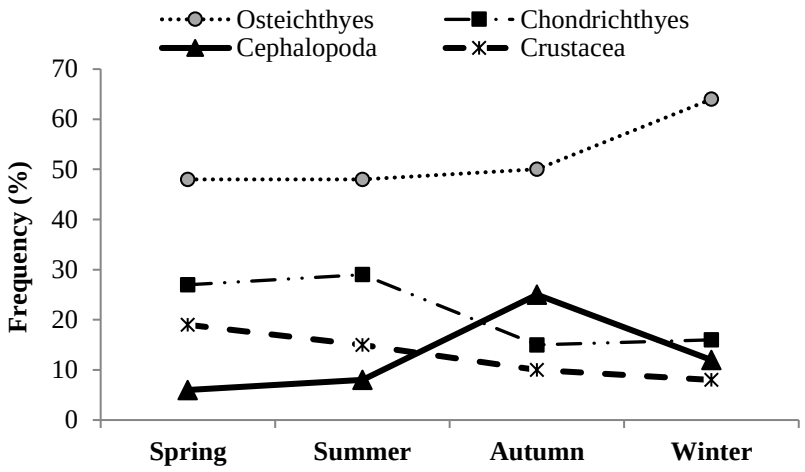

Figure 3. Seasonal variations in frequency of four main groups

Mean CPUE (kg/h) values of four main groups and all catches according to season and strata were presented in Table 3. The highest CPUE values of all catches were obtained in summer (83.79 ± 17.57 kg/h) and at 201-400 m strata (67.51 ± 38.93 kg/h). Among the main groups, Osteichthyes had the highest CPUE values in all seasons and strata.

Summer was the season with the highest CPUE in all groups and after that, the values decreased until winter. The highest values for Chondrichthyes and Cephalopoda were obtained at 0-200 m strata and a decrease was observed depending on the depth. On the other hand, Osteichthyes and Crustacea had the highest values at 201-400 m strata (Table 3).

Table 3. CPUE (kg/h) values (mean ± standart deviation) of main groups and all catches according to season and strata.

Season/Strata	*n*	Osteichtyes	Chondrichtyes	Cephalopoda	Crustacea	Total
Spring	9	22.46 ± 15.35	12.45 ± 14.05	2.89 ± 2.47	8.83 ± 10.58	46.62 ± 31.66
Summer	9	40.43 ± 12.65	24.23 ± 11.00	6.87 ± 4.13	12.26 ± 9.64	83.79 ± 17.57
Autumn	9	37.27 ± 25.78	10.89 ± 10.74	6.50 ± 4.26	7.57 ± 5.72	62.23 ± 38.49
Winter	9	20.43 ± 11.52	5.31 ± 4.54	4.04 ± 4.30	2.72 ± 2.30	32.49 ± 16.22
0-200 m	12	25.88 ± 12.57	17.26 ± 17.71	9.26 ± 3.19	4.64 ± 5.28	57.04 ± 29.46
201-400 m	12	34.33 ± 24.30	14.54 ± 8.65	3.66 ± 3.05	14.98 ± 9.97	67.51 ± 38.93
401-600 m	12	29.40 ± 18.26	7.86 ± 6.80	2.28 ± 1.84	3.91 ± 2.00	44.30 ± 27.05
Total	36	30.15 ± 18.77	13.22 ± 12.36	5.07 ± 4.07	7.84 ± 8.22	56.28 ± 32.74

Statistical results of CPUE (kg/h) comparisons in groups, seasons, and strata were presented in Table 4. It was determined that the Osteichthyes had a statistically higher CPUE value than those of the other groups. The summer season had a statistically higher CPUE value than the spring and winter seasons according to Welch test results. There was no statistical difference between CPUE values according to strata as a result of the Games Howell test (Table 4).

The spatial and seasonal variations in biological parameters of some commercial species

Parapenaeus longirostris

A total of 46616 *P. longirostris* individuals were measured, 29.5% of which were at 0-200 m, 64.7% at 201-400 m, and 5.8% at 401-600 m strata (Figure 4). The mean CL of the species was calculated as 22.2 ± 3.71 mm CL at 201-400 m and 25.2 ± 5.18 mm CL at 401-600 m strata. Strata was a factor affecting CL of the species and the CL increased depending on the depth (p=0.000) (Table 5). The minimum, maximum and mean CL of 46 616 specimens were, 7 mm, 41 mm and 36.3 ± 9.9 mm, respectively. The seasonal distribution of the samples was 31.5% in spring, 34.9% in summer, 24.7% in autumn and 8.9% in winter. The average seasonal carapace length were 32.5 ± 10.1, 38.5 ± 9.6, 35.2 ± 8.3 and 36.7 ± 10.8 for spring, summer, autumn and winter, respectively (Figure 5). The CL of the species was statistically higher in summer than in other seasons (p=0.000) (Table 5).

Table 4. Statistical results of CPUE (kg/h) comparisons in groups, seasons, and strata (CPUE values are given as *Median (Quartile$_1$-Quartile$_3$)* for non-parametric tests (Dunn-Bonferroni test), and as mean ± standard deviation for parametric tests (one-way analysis of variance-ANOVA and Games Howell test))

Group	**Osteichthyes** 28253 (15107-42071)^a	**Chondrichthyes** 11380 (2990-21972)^b	**Cephalopoda** 4178 (1304-9176)^c	**Crustacea** 4273 (1924-12313)^{bc}	p = 0.000
Season	**Spring** 46.62 ± 31.66^a	**Summer** 83.79 ± 17.57^b	**Autumn** 62.23 ± 38.49^{abc}	**Winter** 32.49 ± 16.22^{ac}	p < 0.05 F = 5.698
Strata	**0-200 m** 57.04 ± 29.46^a	**201-400 m** 67.51 ± 38.93 ^{a}	**401-600 m** 44.30 ± 27.05 ^{a}		p > 0.05 F = 1.561

The superscripts *a, b, c* indicate the difference between groups. There is no difference in groups with the same letters.

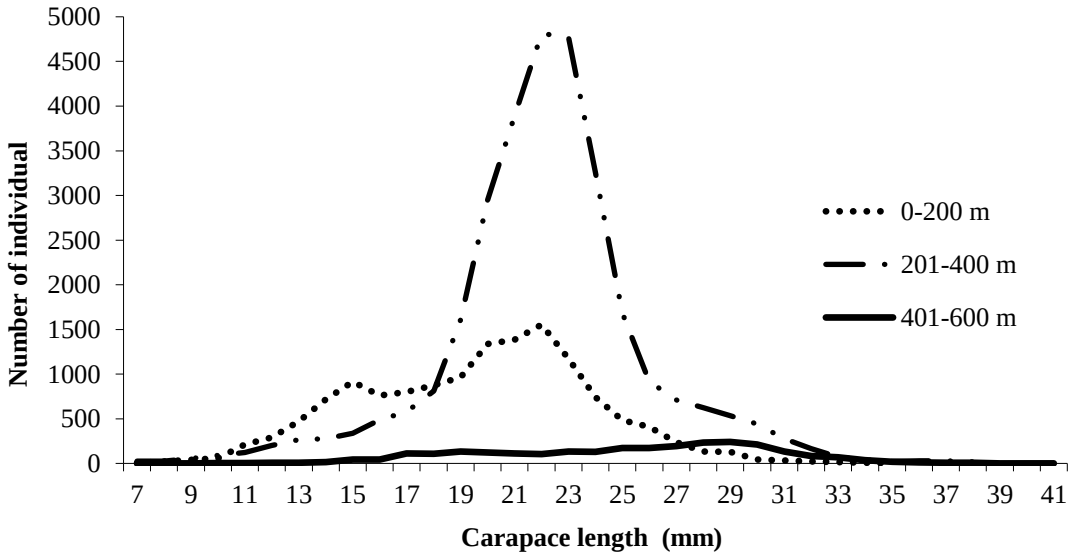

Figure 4. Strata-dependent carapace length distribution of *Parapenaeus longirostris*

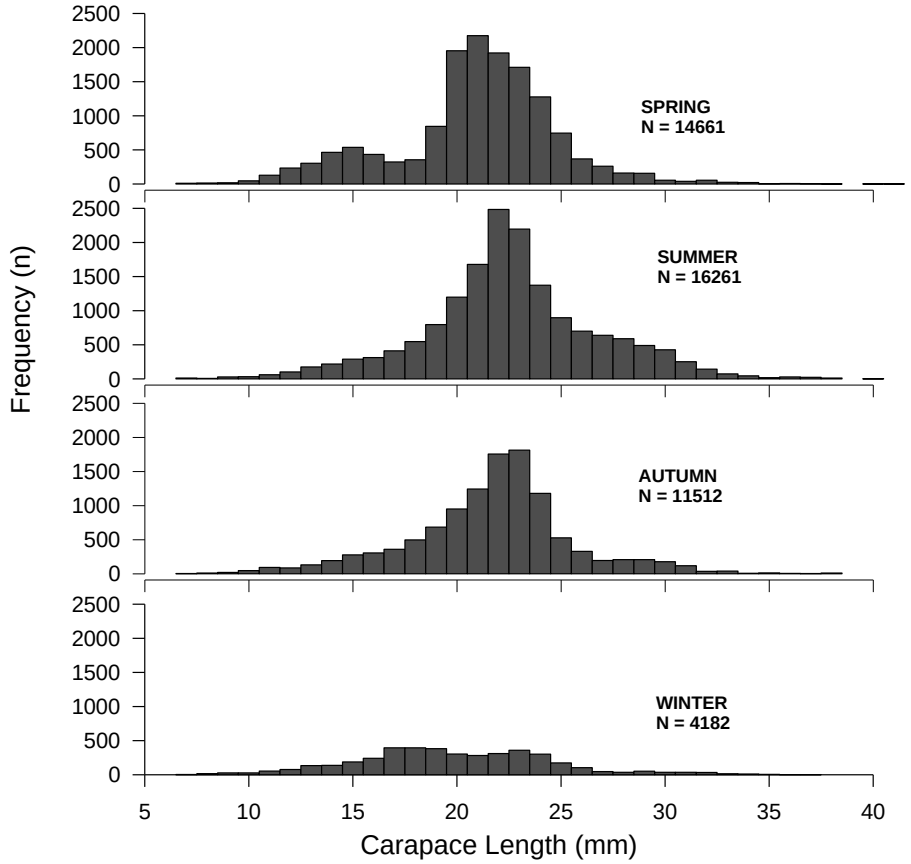

Figure 5. Season-dependent carapace length distribution of *Parapenaeus longirostris*

Nephrops norvegicus

The minimum, maximum and mean CL of 278 specimens were 14 mm, 66 mm and 36.4 ± 10.0 mm, respectively. The seasonal distribution of the samples was 15.7% in spring, 33.7% in summer, 22.2% in autumn, and 28.4% in winter (Figure 6). The mean seasonal carapace length were 32.5 ± 10.1, 38.5 ± 9.6, 35.2 ± 8.3, and 36.7 ± 10.8 for spring, summer, autumn and winter, respectively. A significant difference in the carapace length was found between Spring and Summer (p=0.007) (Table 5).

Table 5. Statistical results of carapace length (CL) comparisons in seasons and strata for *P. longirostris* and *N. norvegicus* (CL values are given as *Median (Quartile$_1$-Quartile$_3$)* for non-parametric post-*hoc* test (Dunn-Bonferroni test))

Season (*P. longirostris*)	**Spring** 21.7 (18.1-25.0)^a	**Summer** 22.6 (18.7-27.4)^b	**Autumn** 22.1 (18.9-24.5)^a	**Winter** 21.4 (18.33-24.3)^a	p = 0.000
Strata (*P. longirostris*)	**0-200 m** 19.7 (16.2-22.4)^a	**201-400 m** 20.9 (17.7-24.5)^b	**401-600 m** 22.4 (19.6-24.7)^c		p = 0.000
Season (*N. norvegicus*)	**Spring** 32.9 (26.4-37.2)^a	**Summer** 39.3 (30.3-44.7)^b	**Autumn** 31.9 (29.3-40.8)^{ab}	**Winter** 34.3 (29.1-44.9)^{ab}	p = 0.007

The superscripts *a, b, c* indicate the difference between groups. There is no difference in groups with the same letters.

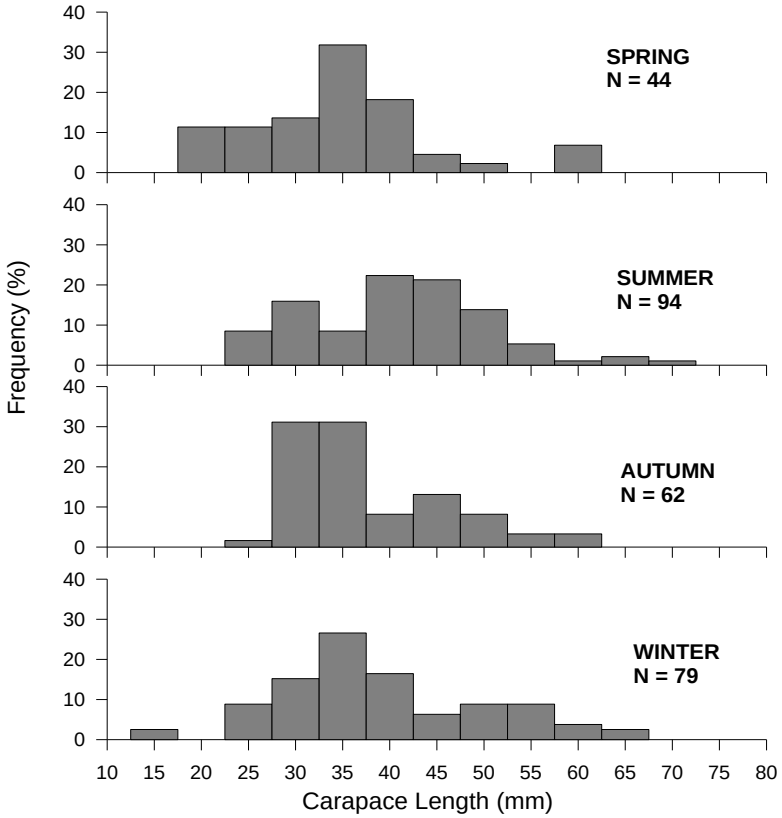

Figure 6. Season-dependent carapace length distribution of *Nephrops norvegicus*

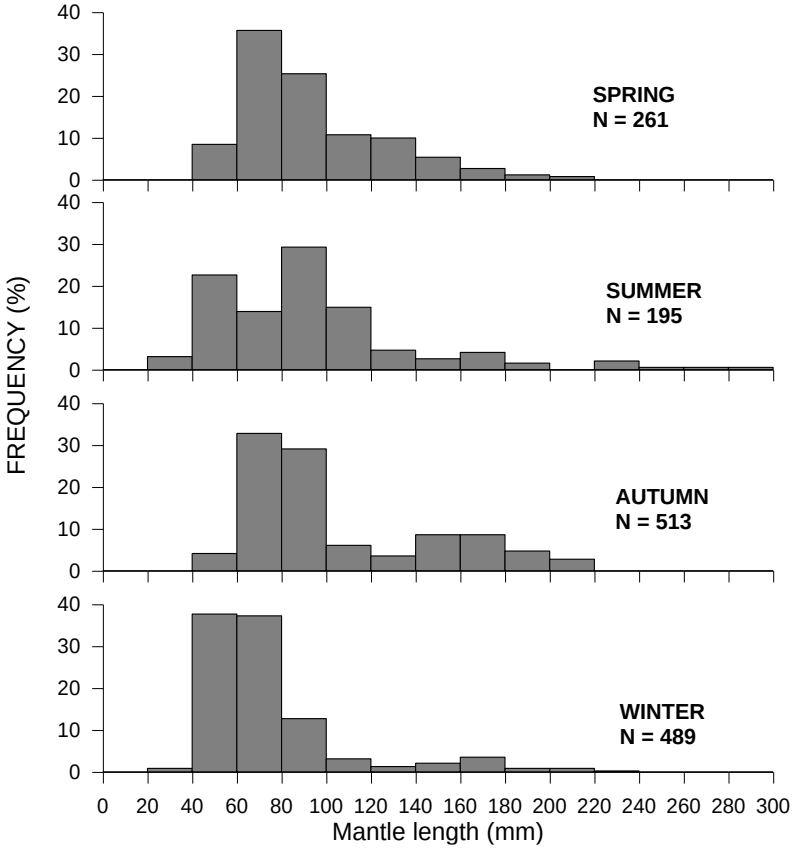

Figure 7. Season-dependent mantle length distribution of *Illex coindetii*

Illex coindetii

The minimum, maximum and mean ML of 1 458 specimens were 25 mm, 278 mm and 80.56 ± 39.17 mm, respectively. The seasonal distribution of the samples was 17.9% in spring, 13.4% in summer, 35.2% in autumn and 33.5% in winter. The mean seasonal mantle length were 83.7 ± 32.2, 83.9 ± 46.9, 94.1 ± 41.6, and 65.7 ± 31.1 for spring, summer, autumn and winter, respectively (Figure 7). The mean mantle length (ML) of the species increased depending on the depth. The smallest mean length was obtained in all months except August and January in the 0-200 m strata (Figure 8).

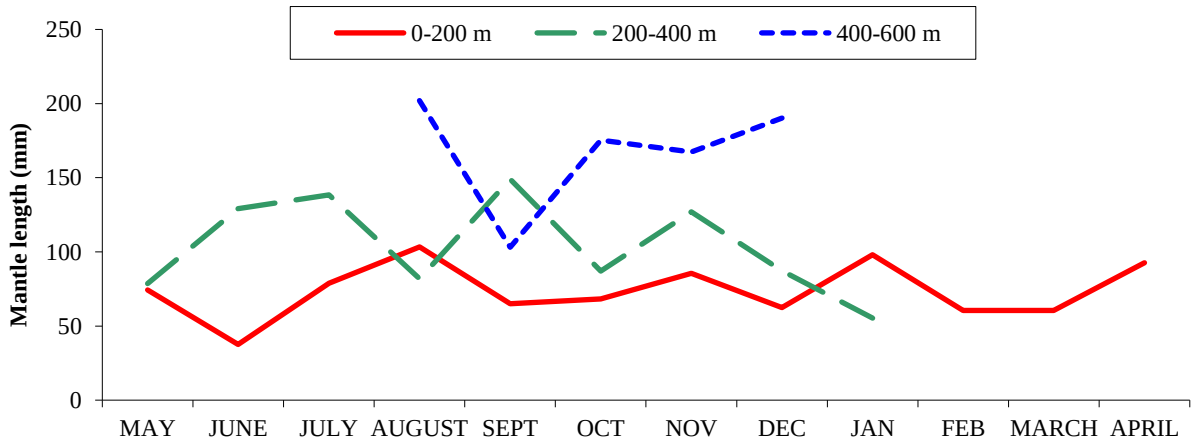

Figure 8. Monthly and spatial variations of mean mantle lengths of *Illex coindetii*

Discussion

In this study, a total of 111 species were defined, mostly in the Osteichthyes group (74 species) in the Central Aegean trawl fisheries. The Osteichthyes also had the highest frequency at all depths and seasons and had a statistically higher CPUE value than those of the other groups. The predominance of teleost fish (49 species) among a total of 60 species was also reported by Özaydın et al (2014) in the Çandarlı Bay (Aegean Sea). Similarly, Daban et al (2021) reported 61 species of teleost fish from a total of 73 species caught from the Sea of Marmara. In other studies, numbers of teleost species were reported as 49 (Eryılmaz, 2001) and 43 (Altuğ et al., 2011) in the Southwestern part of the Sea of Marmara. The total number of fish species reported in other studies from the Mediterranean coasts of Turkey, were higher than that reported in the present study. A total of 147 demersal fish species (Osteichthyes and Chondrichthyes) were reported in the shelf (10-200 m) of Antalya Gulf (De Meo et al., 2018).

In this study, some species were found less frequently than in other studies carried out in the same region. Soykan et al (2016) reported that discards accounted for 33.2% of the total catch biomass, with the majority represented by *Lampanyctus crocodilus* with 97 kg total weight. Although our study carried out in the same season, only 18 individuals of *Lampanyctus sp*. were captured. This difference may be due to season and depth intervals between the two studies. In a previous study that examined the trawl fisheries, operations carried out between 90 -297 m during open seasons (autumn, winter and spring) (Soykan et al 2016). Whereas in this study, trawl operations were carried out in all seasons including the closed season in summer covering a wider depth range (up to 600 m).

Species diversity in Sığacık Bay was average according to the Shannon-Wiener index, which can be maximum 5. It was determined that the Evenness Function values were higher than 0.5 at depth stratas of 0-200 m and 401-600 m, but lower than 0.5 at depths of 201-400 m. The value of the Evenness Function was close to zero when the species accumulated in certain families and was close to 1 when species were equally distributed among all families. Accordingly, it was found that the species were limited to certain families at depths of 201-400 m in Sığacık Bay.

The highest values in species diversity (H':2.526) and Evenness Function (J':0.610) were obtained at the 401-600 m strata. Trawl fishing in Sığacık Bay is generally carried out at the 201-400 m strata by targeting *P. longirostris*. The 401-600 m strata further from the coast is less exploited due to high fuel consumption and therefore considered as unprofitable. This may explain higher species diversity in this strata.

The summer season had the highest CPUE in all groups followed by decreased values until the winter season. The summer season also had a statistically higher CPUE value than that of the spring and winter seasons. The summer period coincides with the seasonal trawl ban in the region. Lower CPUE values

in the winter may be due to opening of trawl fisheries in the Autumn.

CPUE values with regard to total catch did not differ significantly among strata. CPUE values in terms of taxa indicated that, the highest CPUE values were obtained at 0-200 m strata for Chondrichthyes and Cephalopoda and a decrease was observed depending on the depth. *O. vulgaris*, *S. officinalis* and *E. moschata* which are found in shallower waters and have relatively larger sizes than other species, played an important role in the depth-dependent CPUE decrease.

On the other hand, Osteichthyes and Crustacea had the highest CPUE values at 201-400 m strata. In addition, share of Crustacea in the total catch was higher at 201-400 m. This may be due to the presence of *P. longirostris* at 201-400 m, which is the dominant crustacaean species and the target species of trawl fisheries in the region. In this study, *P. longirostris* was also the dominant species at 0-200 m and 201-400 m strata and it was determined that this species reached the highest values in number at 201-400 m strata. This depth preference of the species was also reported by other studies conducted in the Aegean Sea (Politou et al., 1998; Tserpes et al., 1999; Kara ve Gurbet, 1999; Sbrana et al 2019).

Water temperature has an effect on the depth-dependent spatial distribution of *P. longirostris*. Bombace (1972) suggested that the distribution of *P. longirostris* is associated with 14 °C water of Atlantic origin and in many studies carried out in the Mediterranean and the Sea of Marmara, it was reported that this species showed a dense distribution around 14 ºC temperatures. (Dall et al., 1990; Yüksek et al., 2000; Nouar, 2001; Ungaro and Gramolini, 2004; Artüz, 2005; Ungaro and Gramolini, 2006). It has been reported that the water temperature stabilizes at 14-15 ºC after 200 m in the Aegean Sea (Miller et al., 1970; Zaitsev and Öztürk, 2001). Our findings support earlier findings that the abundance of this species at depths of 201-400 m is related to the water temperature.

The carapace length (CL) of *P. longirostris* increased depending on the depth. Similarly, in many studies, it has been stated that the length of the species increased depending on the depth (Froglia, 1982; Spedicato et al., 1996; Campos et al., 2002; Kapiris et al., 2002; Zengin et al., 2004; Guijarro and Massuti, 2006; Manaşırlı, 2008). Sobrino et al. (2005) defined the relationship between the length and the bathymetric distribution of the deep-water rose shrimp in the Atlantic and Mediterranean waters of Europe and stated that following dispersal stage in shallow waters, this species moves to deep waters; juveniles usually settle around 100 m and large individuals are always found at a depth of more than 350 m.

Unlike the deep-water rose shrimp, *N. norvegicus* showed no particular trend in bathymetric distribution (Sbrana et al, 2019). Considering the seasonal variation of the length distributions of the other 2 species examined in this study, there was no seasonal variation (except between Spring and Summer) in the carapace lengths of *N. norvegicus*. On the other hand, larger individuals of *I. coindetii* were observed in the summer. D'Onghia et al (1991) reported that a decrease in the number of individuals with maximum length may be observed towards the winter months, as they die after spawning. In addition, the fishing pressure, which started in the autumn and gradually increased, was also effective. Depth-dependent length stratification was not observed in *I. coindetii* from the summer months to the end of winter. It is thought that the species migrated to shallower waters as the waters cooled.

In summary, in the present study the spatial and temporal variations in species diversity, CPUE and biological parameters of some commercial species targeted by trawl fisheries in the Central Aegean Sea with emphasis on *P. longirostris*, *N. norvegicus* and *I. coindetii* were determined in. For successful fisheries management, further studies are required.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

Z. Tosunoğlu and O. Özaydın planned and designed the research. All authors collected and analysed the data. All authors contributed to writing of the manuscript.

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