Mar. Sci. Tech. Bull. (2022) 11(3): 361-368
e–ISSN: 2147–9666
info@masteb.com

dergipark.org.tr/en/pub/masteb
www.masteb.com
DOI: 10.33714/masteb.1159803

Marine Science and Technology Bulletin

RESEARCH ARTICLE

The seasonal fish diversity of Aliağa, a heavy industry zone on the Turkish coast of the Aegean Sea

Adnan Çağlar Oruç[1 *]

[1] *İzmir Katip Çelebi University, Faculty of Fisheries, İzmir, Türkiye*

ARTICLE INFO

Article History:
Received: 09.08.2022
Received in revised form: 22.09.2022
Accepted: 22.09.2022
Available online: 28.09.2022

Keywords:
Biodiversity
Fish
Industrialization
Visual census

ABSTRACT

The stress on the marine environment caused by industrialization in developing economies is indisputable. The Aliağa region, which has unique features such as being heavily influenced by industrialization and having different types of marine habitats was preferred as a monitoring point. By determining the current status of fish density and diversity, the focus was on obtaining data that could allow future comparisons. Without the seasonal variability, 39 fish species representing 14 families were identified, with two abundant families: ten species in both Sparidae and Labridae. The greatest fish diversity was recorded respectively in the spring, summer and autumn. Abundant species were *Boops boops* with 19.3%, *Chromis chromis* (17.4%), *Spicara smaris* (15.0%) and *Atherina boyeri* (12.5%) in total abundance. A total of 1.89 individuals/m^2 that weighed 20.43 g/m^2 were identified in the study period.

Please cite this paper as follows:

Oruç, A. Ç. (2022). The seasonal fish diversity of Aliağa, a heavy industry zone on the Turkish coast of the Aegean Sea. *Marine Science and Technology Bulletin*, *11*(3), 361-368. https://doi.org/10.33714/masteb.1159803

Introduction

Fishes are an essential component in marine ecosystems; however, at present, they are threatened by anthropogenic stressors (Pauly et al., 2002; Lotze et al., 2006). Fish biodiversity which represents an important indicator in determining ecosystem health (McField & Kramer, 2007), is an assessment of different fish species living in a particular area, and also provides numerous and valuable ecosystem goods and services (Worm et al., 2006; Beaumont et al., 2007; Halpern et al.,2012). The advantages of fish-based monitoring of the ecosystem health described in detail in Whitfield & Elliott (2002) are that; they are present in almost all aquatic ecosystems; have information about the extensive life history and environmental response; they are easy for species identification; harmless

* Corresponding author
E-mail address: acaglaroruc@gmail.com (A. Ç. Oruç)

sampling is available; various trophic levels that provide a long-term record of environmental stress.

Industrial activities play a significant role in the economies of the countries. Aliağa is one of the most important heavy industry zones in Turkey and has the only shipbreaking industry among OECD countries in the Mediterranean region. The negative effects of marine traffic and port activities on marine habitats are ship pollution and emissions, collisions and noise, grounding and anchoring damage, and transportation of non-indigenous species (Abdulla & Linden, 2008; Brynolf et al., 2016). Increasing industrial activities in Aliağa and the environmental effects of these activities make the region riskier.

Long-term data is required to determine the changes in marine ecosystems directly affected by intense industrial activities. This study aimed to determine the current status of fish biodiversity in a marine industrial zone and provide a comparison source for future research.

Material and Methods

The study was conducted at Nemrut Bay (38°45′53″N-26°54′20″E), located southwest of the Aliağa Port complex on the Aegean Sea coast of Turkey (Figure 1).

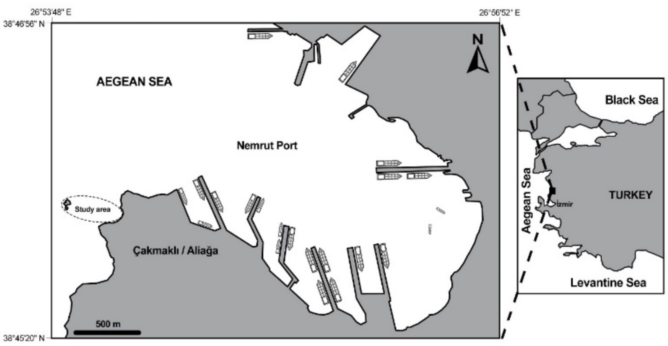

Figure 1. Study area

The non-destructive underwater visual census (UVCs) method (Harmelin-Vivien et al., 1985; Engin et al., 2018) was used following the 700 meters route marked on the map by two free divers both with experience in situ identification of fish species. UVCs were carried out in four seasons (December 2019-October 2020) and on a random date for each season between 9.00 a.m. and 11.00 a.m. The study was conducted on shallow waters between 0-10 meters in depth as they generally have high primary and secondary productivity levels maintaining the richest ichthyofauna (García-Rubies & Zabala, 1990). Two replications were performed (2 × 700 m in the same route) per season. Species, abundances, and size structure of fishes were recorded on a waterproof notepad. Divers simultaneously recorded their observations on the same route. The mean density data were used in the calculations to reduce the error rate that may arise from the divers.

Fish species richness and dominancy were evaluated using the Shannon-Weiner diversity index (H'), Margalef richness index (Dmg) and Pielou's evenness (J') index. Bray-Curtis similarity index, non-metric multidimensional scaling (nMDS), and similarity percentage (SIMPER) were performed using the Primer-E v7 package software to detect seasonal differences.

Results

A total of 10607 individuals (weighing 114.453 kg) of 39 species belonging to 14 families were observed in the study area. The most diverse families of the fish assemblage were Labridae and Sparidae, with 10 species each (Labridae 25.6%; Sparidae 25.6% of the total number of species). Blenniidae and Gobiidae were the other species-rich families, with 4 and 3 species (Table 1; Figure 2).

The highest fish density was found in spring (2.88 fish/m^2), and the highest biomass was found in autumn (28.2 g/m^2). The lowest density (0.5 fish/m^2) and biomass (11.75 g/m^2) were found in winter.

Based on the abundance, *Boops boops* (19.8%), *Spicara smaris* (16.1%) and *Atherina boyeri* (14.8%) were the most abundant species in the spring. In summer, *B. boops* (18.9%) and *Chromis chromis* (18.2%) were abundant fish species, followed by *A. boyeri* (14.6%) and *S. smaris* (13.7%). In autumn, similar to spring and summer, fish assemblage was dominated by *B. boops* (19.2%), *C. chromis* (17.3%), *S. smaris* (15.7%) and *A. boyeri* (13.4%). In winter, *C. chromis* (28%), *B. boops* (14.3%), *Oblada melanura* (12.9 %) and *S. smaris* (11.4%) were abundant fish species in the total number of the counted individual (Table 1).

Based on the seasonal variation of the biomass, *B. boops* (31.7%) was the most dominant fish species, followed by *O. melanura* (12.7%), *S. pilchardus* (7.3%) and *S. smaris* (6.9%) in spring (58.6% of the total biomass). During summer, *B. boops* (38.8%) was dominated the biomass and followed by *O. melanura* (17.2%), *S. pilchardus* (6.4%) and *S. smaris* (6.1%) which represented 68.5% of the total biomass. In autumn, similar to spring and summer fish assemblages dominated by *B. boops* (32.9%) and followed *O. melanura* (18.1%), *S. smaris* (7.0%) and *A. boyeri* (6.4%), both contributing with 64.4% of the total biomass. In winter, compatible with the other seasons, the fish biomass was mostly dominated by *B. boops* (29.7%) and *O. melanura* (14.4%), but differently, an increase in the dominance of *C. chromis* (9.2%) and *D. vulgaris* (8.7%) in biomass was detected (62% of the total biomass).

On the basis of the species richness, the highest number of species (38) was registered in spring, most of the species were belonging to Sparidae (10) and Labridae (9) families. In contrast, the lowest number of species (30) were registered in winter dominance with sparid fishes (9) and wrasses (8) again. A decrease was observed in the number of total recorded species after spring, and equal numbers were determined in summer (35) and autumn (35) (Table 1, Figure 2).

Table 1. The seasonal and annual abundance and biomass results of fish species

Family	Species	Spring		Summer		Autumn		Winter		Annual		IUCN Status
		Percentages (%) in										
		Abundance	*Biomass*	*Abundance*	*Biomass*	*Abundance*	*Biomass*	*Abundance*	*Biomass*	*Abundance*	*Biomass*	
Atherinidae	*A. boyeri*	12.40	6.42	14.63	5.26	13.48	6.44	0.00	0.00	12.54	5.13	LC
Blenniidae	*A. sphynx*	0.02	0.03	0.06	0.07	0.12	0.10	0.29	0.16	0.08	0.09	LC
	P. gattorugine	0.05	0.04	0.03	0.02	0.08	0.04	0.14	0.05	0.06	0.04	LC
	P. tentacularis	0.02	0.01	0.06	0.02	0.04	0.01	0.29	0.05	0.06	0.02	LC
	S. pavo	0.05	0.06	0.03	0.04	0.04	0.03	0.14	0.08	0.05	0.05	LC
Clupeidae	*S. pilchardus*	9.92	7.31	9.14	6.48	5.78	5.24	0.00	0.00	8.01	5.28	LC
Gobiidae	*G. geniporus*	0.12	0.07	0.12	0.03	0.12	0.02	0.43	0.05	0.14	0.04	LC
	G. niger	0.17	0.17	0.24	0.23	0.31	0.22	0.86	0.39	0.27	0.24	LC
	P. quagga	0.50	0.05	0.49	0.02	0.46	0.02	1.43	0.03	0.55	0.03	LC
Labridae	*C. julis*	1.12	1.91	1.62	1.80	1.85	1.97	4.02	2.76	1.64	2.02	LC
	L. viridis	0.10	0.06	0.21	0.10	0.31	0.15	0.14	0.05	0.19	0.10	VU
	S. cinereus	0.15	2.22	0.15	1.49	0.12	0.83	0.29	2.48	0.15	1.54	LC
	S. mediterraneus	0.02	0.01	0.09	0.02	0.15	0.03	0.00	0.00	0.08	0.02	LC
	S. melanocercus	0.30	0.40	0.34	0.22	0.23	0.21	0.86	0.50	0.33	0.29	LC
	S. ocellatus	0.02	0.01	0.06	0.03	0.12	0.09	0.14	0.07	0.07	0.06	LC
	S. roissali	0.12	0.04	0.18	0.08	0.15	0.05	0.00	0.00	0.14	0.05	LC
	S. rostratus	0.00	0.00	0.12	0.03	0.08	0.02	0.29	0.07	0.08	0.03	LC
	S. tinca	0.10	0.39	0.15	0.57	0.15	0.42	0.29	1.22	0.14	0.58	LC
	T. pavo	0.52	1.39	0.40	0.90	0.54	1.77	0.86	1.82	0.51	1.43	LC
Mugilidae	*C. labrosus*	0.30	2.16	0.00	0.00	0.15	0.99	0.00	0.00	0.15	0.76	LC
Mullidae	*M. surmuletus*	0.05	0.08	0.18	0.28	0.19	0.67	0.14	0.32	0.13	0.38	LC
Muraenidae	*M. helena*	0.05	6.07	0.00	0.00	0.00	0.00	0.00	0.00	0.02	1.16	LC
Pomacentridae	*C. chromis*	14.88	5.84	18.29	5.72	17.33	6.02	28.69	9.23	17.44	6.35	LC
Scaridae	*S. cretense*	0.30	0.76	0.24	0.53	0.35	0.55	0.86	2.55	0.33	0.87	LC
Serranidae	*E. costae*	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	DD
	S. scriba	0.22	0.52	0.30	0.61	0.31	0.90	0.86	1.63	0.31	0.84	LC
Sparidae	*B. boops*	19.84	31.77	19.81	38.88	19.25	32.92	14.35	29.77	19.33	34.15	LC
	D. annularis	0.45	1.35	0.70	1.38	1.00	1.89	2.87	5.63	0.82	2.16	LC
	D. puntazzo	0.05	0.15	0.12	0.29	0.12	0.31	0.14	0.25	0.09	0.27	LC
	D. sargus	0.30	1.04	0.40	1.16	0.65	1.79	2.15	5.79	0.54	2.02	LC
	D. vulgaris	0.94	4.02	1.37	4.43	1.96	4.65	5.74	8.77	1.64	5.05	LC
	L. mormyrus	0.22	0.44	0.18	0.17	0.19	0.13	0.00	0.00	0.19	0.19	LC
	O. melanura	10.42	12.71	9.14	17.29	10.40	18.10	12.91	14.50	10.18	16.29	LC
	S. salpa	9.92	4.37	7.16	5.18	8.09	6.29	8.61	4.32	8.53	5.29	LC
	S. aurata	0.07	0.60	0.12	0.48	0.00	0.00	0.14	0.27	0.08	0.31	LC
	S. smaris	16.12	6.89	13.72	6.15	15.79	7.10	11.48	7.16	14.99	6.76	LC
Torpedinidae	*T. marmorata*	0.02	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.12	LC
Tripterygiidae	*T. melanurus*	0.07	0.02	0.06	0.01	0.04	0.00	0.14	0.01	0.07	0.01	LC
	T. tripteronotum	0.02	0.01	0.06	0.01	0.08	0.01	0.43	0.03	0.08	0.01	LC
Number of species (n)		38		35		35		30		**39**		
TOTAL	**Abundance (n)**	4032		3281		2597		697		**10607**		
	Biomass (g)	21882.5		36595.9		39521.8		16452.8		**114453**		

Note: Based on IUCN status for Mediterranean Sea (2021) LC: Least Concern; NT: Near Threatened; VU: Vulnerable Population trends; DD: Data deficient.

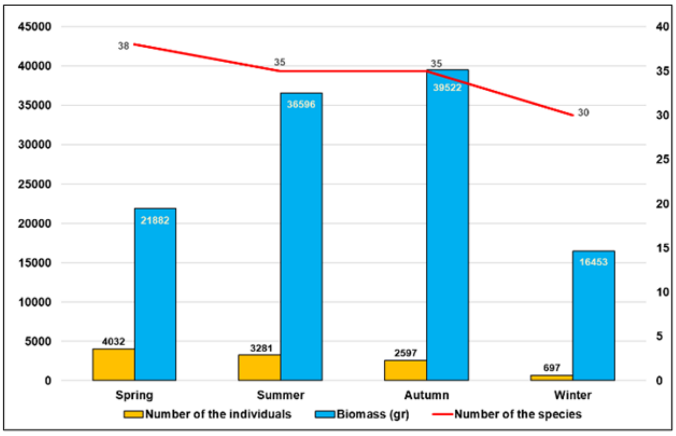

Figure 2. The number of species, individuals, and total biomass values are observed by season

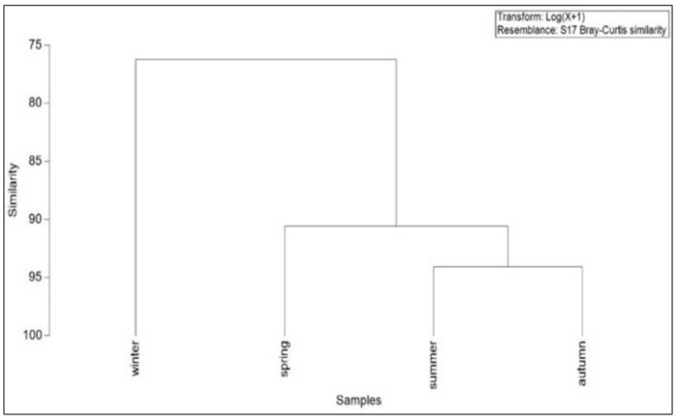

Figure 3. Bray-Curtis similarity dendrogram of the seasons

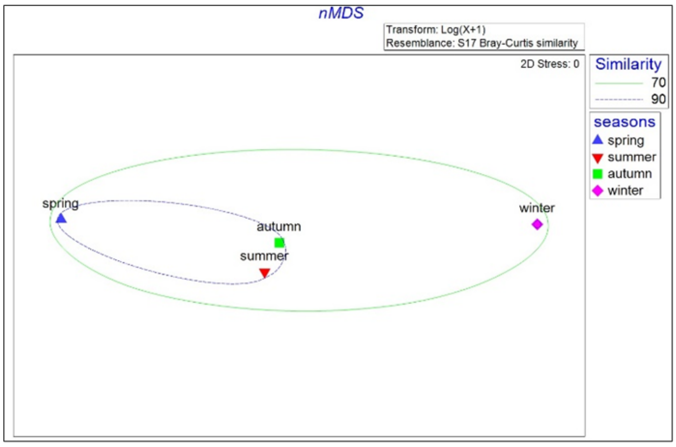

Figure 4. nMDS graph based on Bray-Curtis similarity

Based on Shannon-Wiener's diversity index (H'), the highest diversity was recorded in winter (2.31), and the lowest in spring (2.15). Species richness index Margalef's (d) had the highest value in spring (4.57) and the lowest in summer (4.2). The highest value of the Pielou's evenness (J') index was calculated in winter (0.68) and the lowest in spring (0.61) (Table 2). Comparisons of diversity indices did not reveal significant differences between seasons ($p<0.05$).

Bray-Curtis similarity analysis based on the counted number of individuals for the seasons were calculated ($p<0.05$), the maximum similarity between summer and autumn the minimum similarity between winter and summer-autumn (Figure 3). Non-metric multidimensional scaling (nMDS) based on Bray-Curtis similarities data showed approximately 90% similarity among the spring, summer, and autumn, however, the cold season (winter) was the least similar to others (70%) (Figure 4).

Discussion

The Mediterranean is the largest and deepest enclosed sea that occupies 0.8% of the surface area of the world's oceans (Bianchi & Morri, 2000; Psomadakis et al., 2012). Although it covers a small area, the Mediterranean Sea is a region of high biodiversity, with 7.5% marine fauna and 18% of the marine flora of the world's oceans (Fossi & Lauriano, 2008). However, the sensitive shallow and deep-sea habitats of the Mediterranean are under the influence of industrialization, such as a high volume of marine traffic and port activities (Abdulla & Linden, 2008).

Results of the Simper analysis based on seasonal abundance data of the species data showed that the maximum dissimilarity among the seasons was spring-winter (26.9%), and the minimum was summer-autumn (5.9%). The fish species that caused the difference between seasons are given in Table 3.

Table 2. Biodiversity indexes by seasons

Season	Total species (S)	Total individuals (N)	Margalef's index (d)	Pielou's evenness (J')	Shannon diversity index (H')
Spring	38	4032	4.57	0.61	2.15
Summer	35	3281	4.2	0.63	2.24
Autumn	35	2597	4.32	0.64	2.29
Winter	30	697	4.43	0.68	2.31

Table 3. Simper analysis results for fish species contributed to differences among the seasons

Spring vs. Summer		**Spring vs. Autumn**		**Summer vs. Autumn**	
Species	**DC%**	**Species**	**DC%**	**Species**	**DC%**
C. labrosus	15.2	*S. aurata*	7.08	*C. labrosus*	14.4
S. rostratus	9.54	*S. rostratus*	5.61	*S. aurata*	14.4
M. helena	6.51	*M. helena*	5.61	*S. pilchardus*	6.17
M. surmuletus	5.02	*S. pilchardus*	4.99	*S. mediterraneus*	4.82
S. cinereus	4.11	*C. labrosus*	4.88	*S. rostratus*	4.57
E. costae	4.11	*S. cinereus*	4.68	*P. tentacularis*	3.63
T. marmorata	4.11	*S. ocellatus*	4.36	*L. viridis*	3.63
Av. dissimilarity = 8.62		Av. dissimilarity = 10.21		Av. dissimilarity = 5.90	

Spring vs. Winter		**Summer vs. Winter**		**Autumn vs. Winter**	
Species	**DC%**	**Species**	**DC%**	**Species**	**DC%**
A. boyeri	14.34	*A. boyeri*	17.3	*A. boyeri*	17.42
S. pilchardus	13.83	*S. pilchardus*	15.99	*S. pilchardus*	14.91
C. labrosus	5.92	*S. roissali*	5.45	*L. mormyrus*	5.32
L. mormyrus	5.31	*L. mormyrus*	5.45	*S. smaris*	4.83
S. smaris	4.81	*B. boops*	5.22	*S. cinereus*	4.78
B. boops	4.78	*S. smaris*	4.81	*S. roissali*	4.78
S. salpa	4.34	*S. cinereus*	3.88	*C. labrosus*	4.78
Av. dissimilarity = 26.93		Av. dissimilarity = 22.54		Av. dissimilarity = 21.79	

Note: DC%= percentage contribution to total dissimilarity.

Because fishes are sensitive and mobile organisms, they respond more quickly to ecosystem changes than sessile organisms. Due to this reason, they are suitable indicators of ecosystem changes (Harrison & Whitfield, 2004; Breine et al., 2007; Martinho et al., 2015; Souza & Vianna, 2020). This study focused on fish diversity that was used as an indicator, and seasonal monitoring was carried out for one year using the UVC method.

Previous studies using the UVC method to investigate fish biodiversity on the eastern coast of the Aegean Sea were reviewed, focusing on a particular habitat (artificial habitats, reefs or islands) or fish group (cryptobenthics). In terms of fish biodiversity, in previous studies conducted on artificial habitats such as shipwrecks and sea-cage fish farms, and natural reefs, it has been stated that 27-40 fish species belong to 10-22 families (Gül et al., 2006, 2011; Lök et al., 2008; Akyol et al., 2019; Acarlı et al., 2020). In addition, in the other studies that focused on the cryptobenthic fishes, 19 species were stated by Dalyan et al. (2021), 23 species by Kesici & Dalyan (2020), and 33 gobiid species were stated from the northeastern Aegean by Engin et al. (2018). In the scope of this study, 39 species belonging to 14 families were observed in the natural habitat. In common with Lök et al. (2008), De Raedemaecker et al. (2010), Gül et al. (2011), Akyol et al. (2019) and Acarlı et al. (2020) the most diverse families were Sparidae and Labridae. This was interpreted as a usual case on the Mediterranean rocky shores (Harmelin, 1987; Ruitton et al., 2000). *B. boops* was the frequently dominant fish species from the family in this study (19.3% in total abundance; 34.1% in total biomass) which is similar to findings from previous studies focused on fish biodiversity in artificial habitats (Fernandez-Jover et al., 2008; Arechavala-Lopez et al., 2011; Šegvić Bubić et al., 2011; Acarlı et al., 2020). *B. boops* is abundant and widely distributed from the Eastern Atlantic to the Mediterranean and the Black Sea and inhabits all types of habitats (Bauchot & Hureau, 1986). In terms of total abundance (a) and biomass (b), the top species were *B. boops* (a:19.3%, b:34.1%), *C. chromis* (a:17.4%, b:6.3%), *S. smaris* (a:15%, b:6.7%), *A. boyeri* (a:12.5%, b:5.2%), *O. melanura* (a:10.2%, b:16.3%) and *S. salpa* (a:10.2%, b:5.3%). Gül et al. (2006), Ulaş et al. (2007), and Gül et al. (2011) stated similar results for artificial reefs in the Aegean Sea with this study.

The species richness and diversity indexes, Margalef's index (d) ranged from 4.20 (summer) to 4.57 (spring), and Shannon index from (H') 2.15 (spring) to 2.31 (winter). The highest Pielou's evenness (J') was calculated in winter (0.68) and the lowest in spring (0.61). The highest number of individuals and taxa counted in spring (4032;38), and the lowest was in winter (697;30) (Figure 2). Although the calculated biomass values for the summer and autumn seasons were close to each other, the highest biomass was in autumn with 35 species, and the lowest was in winter. In other studies, the seasons with the highest and lowest values were respectively stated as summer and autumn by Kalogirou et al. (2010), spring and summer by Acarlı et al. (2020), and also summer and autumn were stated as highest by Gül et al. (2006). Species distribution and abundance were associated with environmental factors in seasonal changes which typically increased during summer and decreased during winter (Jin & Tang, 1996). In spring and early summer, an increase in abundance with new additions to fish stocks, a decrease in abundance and species number in winter, but an increase in biomass were determined. Also, the simper analysis based on abundance calculated the highest average dissimilarity between spring and winter with 26.9%.

As a result of Simper analysis based on seasonal fish abundance data, the highest average uniqueness was calculated between spring and winter. Also, the simper analysis based on abundance show the maximum average dissimilarity between spring and winter with 26.9%.

The coastal marine area that conducted this study has a unique structure as it includes different habitats such as rocks, sand, seagrass, island slope and also being under the influence of marine traffic and port activities. It is known that the more heterogeneous habitats provide substrata for feeding, recruitment, and refuge from predators (Ruitton et al., 2000; Aburto-Oropeza & Balart, 2001; De Raedemaecker et al., 2010).

Conclusion

The importance of industrialization in the economies of countries is indisputable. However, determining the negative effects of industrialization on marine ecosystems is a global problem that needs long-term observations. Fish biodiversity represents an important indicator in determining ecosystem health. This study aimed to determine the current status of fish biodiversity in Aliağa which is an affected area by heavy industrial activities and marine traffic. Without the seasonal variability, a total of 10607 individuals (weighing 114.453 kg) of 39 species belonging to 14 families were observed in the study area. The most diverse families of the fish assemblage were Labridae and Sparidae, with 10 species each. The greatest fish diversity was recorded in the spring. In the fish-based monitoring studies on Turkish coasts, researchers have focused on artificial reefs or island ecosystems but coastal ecosystems especially those located in industrial areas have not been studied enough. Should be given due sensitivity to this type of marine ecosystem and more intensive, long-term periodical surveys should be carried out in these areas. Long-term data is required to determine anthropogenic activities' effects on marine ecosystems. For this purpose, the current status of a special region that needs continuous assessment of fish biodiversity was determined, and basic data were obtained to reveal the changes in the future.

Compliance With Ethical Standards

Conflict of Interest

The author declares that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

References

Abdulla, A., & Linden, O. (Eds.). (2008). *Maritime traffic effects on biodiversity in the Mediterranean Sea: Review of impacts, priority areas and mitigation measures*. IUCN Centre for Mediterranean Cooperation, Malaga, Spain.

Aburto-Oropeza, O., & Balart, E. F. (2001). Community structure of reef fish in several habitats of a rocky reef in the Gulf of California. *Marine Ecology*, *22*(4), 283-305. https://doi.org/10.1046/j.1439-0485.2001.01747.x

Acarlı, D., Kale, S., & Kocabaş, S. (2020). Biodiversity of TCSG-132 shipwreck artificial reef (Gökçeada, North Aegean Sea). *Acta Aquatica Turcica*, *16*(3), 313-329. https://doi.org/10.22392/actaquatr.677175

Akyol, O., Ceyhan, T., Düzbastılar, F. O., Özgül, A., & Şen, H. (2019). Wild fish diversity around the sea-cage fish farms in the Aegean Sea. *Ege Journal of Fisheries and Aquatic Sciences*, *36*(3), 271-283. https://doi.org/10.12714/egejfas.2019.36.3.08

Arechavala-Lopez, P., Sanchez-Jerez, P., Bayle-Sempere, J., Fernandez-Jover, D., Martinez-Rubio, L., Lopez-Jimenez, J. A., & Martinez-Lopez, F. J. (2011). Direct interaction between wild fish aggregations at fish farms and fisheries activity at fishing grounds: A case study with *Boops boops*. *Aquaculture Research*, *42*(7), 996-1010. https://doi.org/10.1111/j.1365-2109.2010.02683.x

Bauchot, M. L., & Hureau, J. C. (1986). Sparidae. In Whitehead, P. J. P., Bauchot, M. L., Hureau, J. C., Nielsen, J., & Tortonese, E. (Eds). *Fishes of the North-Eastern Atlantic and the Mediterranean Vol. II.* (pp. 883–907). UNESCO.

Beaumont, N. J., Austen, M. C., Atkins, J. P., Burdon, D., Degraer, S., Dentinho, T. P., Derous, S., Holm, P., Horton, T., Vanlerland, E., Marboe, A. H., Starkey, D. J., Townsend, M., & Zarzycki, T. (2007). Identification, definition and quantification of goods and services provided by marine biodiversity: implications for the ecosystem approach. *Marine Pollution Bulletin*, *54*(3), 253-265. https://doi.org/10.1016/j.marpolbul.2006.12.003

Bianchi, C. N., & Morri, C. (2000). Marine biodiversity of the Mediterranean Sea: Situation, problems and prospects for future research. *Marine Pollution Bulletin*, *40*(5), 367-376. https://doi.org/10.1016/S0025-326X(00)00027-8

Breine, J. J., Maes, J., Quataert, P., Van den Bergh, E., Simoens, I., Van Thuyne, G., & Belpaire, C. (2007). A fish-based assessment tool for the ecological quality of the brackish Schelde estuary in Flanders (Belgium). *Hydrobiologia*, *575*(1), 141-159. https://doi.org/10.1007/s10750-006-0357-z

Brynolf, S., Lindgren, J. F., Andersson, K., Wilewska-Bien, M., Baldi, F., Granhag, L., Johnson, H., Linne, P., Svensson, E., & Zetterdahl, M. (2016). Improving environmental performance in shipping. In *Shipping and the environment: Improving environmental performance in marine transportation* (pp. 399-418). Springer. https://doi.org/10.1007/978-3-662-49045-7_12

Dalyan, C., Kesici, N. B., & Yalgın, F. (2021). Preliminary study on cryptobenthic fish assemblages affected by the mucilage event in the northeastern Aegean Sea. *Journal of the Black Sea/Mediterranean Environment*, *27*(2), 202-213.

De Raedemaecker, F., Miliou, A., & Perkins, R. (2010). Fish community structure on littoral rocky shores in the Eastern Aegean Sea: Effects of exposure and substratum. *Estuarine, Coastal and Shelf Science*, *90*(1), 35-44. https://doi.org/10.1016/j.ecss.2010.08.007

Engin, S., Irmak, E., Seyhan, D., Akdemir, T., & Keskin, A. C. (2018). Gobiid fishes of the coastal zone of the Northeastern Aegean Sea. *Marine Biodiversity*, *48*(2), 1073-1084. https://doi.org/10.1007/s12526-016-0550-x

Fernandez-Jover, D., Sanchez-Jerez, P., Bayle-Sempere, J. T., Valle, C., & Dempster, T. (2008). Seasonal patterns and diets of wild fish assemblages associated with Mediterranean coastal fish farms. *ICES Journal of Marine Science*, *65*(7), 1153-1160. https://doi.org/10.1093/icesjms/fsn091

Fossi, M. C., & Lauriano, G. (2008). Impacts of shipping on the biodiversity of large marine vertebrates: persistent organic pollutants, sewage and debris. In Abdulla, A., & Linden, O. (Eds.), *Maritime traffic effects on biodiversity in the Mediterranean Sea: Review of impacts, priority areas and mitigation measures* (pp. 95-116). IUCN Centre for Mediterranean Cooperation.

García-Rubies, A. & Zabala, M. (1990). Effects of total fishing prohibition on the rocky fish assemblages of Medes Islands marine reserve (NW Mediterranean). *Scientia Marina*, *54*(4), 317-328.

Gül, B., Lök, A., Özgül, A., Ulaş, A., Düzbastilar, F. O., & Metin, C. (2011). Comparison of fish community structure on artificial reefs deployed at different depths on Turkish Aegean Sea coast. *Brazilian Journal of Oceanography*, *59*, 27-32.

Gül, B., Lök, Altan., Ulaş, A., & Düzbastılar, F. O. (2006). The investigation on fish composition at artificial reefs deployed on different substrates of Ürkmez Coast. *Ege Journal of Fisheries and Aquatic Sciences*, *23*(3), 431-434.

Halpern, B. S., Longo, C., Hardy, D., McLeod, K. L., Samhouri, J. F., Katona, S. K., Kleisner, K., Lester, S. E., O'Leary, J., Ranelletti, M., Rosenberg, A. A., Scarborough, C., Elizabeth Selig, E. R., Best, B. D., Brumbaugh, D. R., Chapin, F. S., Crowder, L. B., Daly, K. L., Doney, S. C., Elfes, C., Fogarty, M. J., Gaines, S. D., Jacobsen, K. I., Karrer, L.B., Leslie, H. M., Neeley, E., Pauly, D., Polasky, S., Ris, B., Martin, K., Stone, G. S., Sumaila, U. R., & Zeller, D. (2012). An index to assess the health and benefits of the global ocean. *Nature*, *488*(7413), 615-620. https://doi.org/10.1038/nature11397

Harmelin, J. G. (1987). Structure and variability of the ichthyofauna in a Mediterranean protected rocky area (National Park of Port-Cros, France). *Marine Ecology*, *8*(3), 263-284.

Harmelin-Vivien, M. L., Harmelin, J. G., Chauvet, C., Duval, C., Galzin, R., Lejeune, P., Barnabé, G., Blanc, F., Chevalier, R., Duclerc, J., & Lasserre, G. (1985). The underwater observation of fish communities and fish populations. Methods and problems *Revue d'Ecologie (France)*, *40*(4), 467-539.

Harrison, T. D., & Whitfield, A. K. (2004). A multi-metric fish index to assess the environmental condition of estuaries. *Journal of Fish Biology*, *65*(3), 683-710. https://doi.org/10.1111/j.0022-1112.2004.00477.x

Jin, X., & Tang, Q. (1996). Changes in fish species diversity and dominant species composition in the Yellow Sea. *Fisheries Research*, *26*(3-4), 337-352. https://doi.org/10.1016/01657836(95)00422-X

Kalogirou, S., Corsini-Foka, M., Sioulas, A., Wennhage, H., & Pihl, L. (2010). Diversity, structure and function of fish assemblages associated with *Posidonia oceanica* beds in an area of the eastern Mediterranean Sea and the role of non-indigenous species. *Journal of Fish Biology*, *77*(10), 2338-2357. https://doi.org/10.1111/j.1095-8649.2010.02817.x

Kesici, N. B., & Dalyan, C. (2020). Habitat Preferences and spatial distribution of the cryptobenthic fish assemblages around the Gökçeada Island (North Aegean Sea). *Journal of Ichthyology*, *60*(2), 263-271. https://doi.org/10.1134/S0032945220020083

Lök, A., Gül, B., Ulaş, A., Düzbastılar, F. O., & Metin, C. (2008). Diel variations on the fish assemblages at artificial reefs in two different environments of the Aegean Sea (Western Coast of Turkey). *Turkish Journal of Fisheries and Aquatic Sciences*, *8*(1), 79-085.

Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., Kidwell, S. M., Kirby, M. X., Peterson, C. H., & Jackson, J. B. C. (2006). Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science*, *312*(5781), 1806-1809. https://doi.org/10.1126/science.1128035

Martinho, F., Nyitrai, D., Crespo, D. & Pardal, M. A. (2015). Efficacy of single and multi-metric fish-based indices in tracking anthropogenic pressures in estuaries: An 8-year case study. *Marine Pollution Bulletin*, *101*(1), 153-162. https://doi.org/10.1016/j.marpolbul.2015.11.004

McField, M., & Kramer, P. (2007). Healthy reefs for healthy people: a guide to indicators of reef health and social well-being in the Mesoamerican Reef Region. *Smithsonian Institution, Washington, DC, EEUU, 208*.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., Watson, R., & Zeller, D. (2002). Towards sustainability in world fisheries. *Nature*, *418*(6898), 689-695. https://doi.org/10.1038/nature01017

Psomadakis, P. N., Giustino, S., & Vacchi, M. (2012). Mediterranean fish biodiversity: an updated inventory with focus on the Ligurian and Tyrrhenian seas. *Zootaxa*, *3263*(1), 1-46. https://doi.org/10.11646/zootaxa.3263.1.1

Ruitton, S., Francour, P., & Boudouresque, C. F. (2000). Relationships between algae, benthic herbivorous invertebrates and fishes in rocky sublittoral communities of a temperate sea (Mediterranean). *Estuarine, Coastal and Shelf Science*, *50*(2), 217-230. https://doi.org/10.1006/ecss.1999.0546

Šegvić Bubić, T., Grubišić, L., Tičina, V., & Katavić, I. (2011). Temporal and spatial variability of pelagic wild fish assemblages around Atlantic bluefin tuna *Thunnus thynnus* farms in the eastern Adriatic Sea. *Journal of Fish Biology*, *78*(1), 78-97. https://doi.org/10.1111/j.1095-8649.2010.02837.x

Souza, G. B. G., & Vianna, M. (2020). Fish-based indices for assessing ecological quality and biotic integrity in transitional waters: A systematic review. *Ecological Indicators*, *109*, 105665. https://doi.org/10.1016/j.ecolind.2019.105665

Ulaş, A., Düzbastılar, F. O., Lök, A., & Metin, C. (2007). A pre-study for determining of efficiency of fish sampling methods on artificial reefs. *Ege Journal of Fisheries and Aquatic Sciences*, *24*(3), 287-293.

Whitfield, A. K., & Elliott, M. (2002). Fishes as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future. *Journal of Fish Biology*, *61*, 229-250. https://doi.org/10.1111/j.1095-8649.2002.tb01773.x

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., Jackson, J. B. C., Lotze, H. K., Micheli, F., Palumbi, S. R., Sala, E., Selkoe, K. A., Stachowicz, J. J., & Watson, R. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science*, *314*(5800), 787-790. https://doi.org/10.1126/science.1132294