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Spatiotemporal distribution, abundance, and species–environment relationships of Scyphozoa (Cnidaria) species in Hisarönü, Marmaris, and Fethiye bays (Muğla, Turkey)

Nurçin GÜLŞAHİN*, Ahmet Nuri TARKAN, Ali Serhan TARKAN
Department of Basic Sciences, Faculty of Fisheries, Muğla Sıtkı Koçman University, Muğla, Turkey

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Abstract: This study was undertaken monthly between September 2011 and October 2012 at 10 stations in Hisarönü, Marmaris, and Fethiye bays of Muğla Province with the aim of examining spatiotemporal patterns of distribution, abundances, and environmental associations of Scyphozoa species. Temperature, salinity, dissolved oxygen, and chlorophyll-a values were measured both on the surface and at a depth of 20 m. Scyphozoa species were sampled by observation and counting from a boat and by diving. Mean temperatures of the sampling stations were between 20.08 and 21.26 °C. Salinity and chlorophyll-a concentrations showed typical Mediterranean features in the bays. Three Scyphozoa species, *Aurelia aurita* (Linnaeus, 1758), *Cotylorhiza tuberculata* (Macri, 1778), and *Cassiopea andromeda* Forskål, 1775, were determined in the sampling sites. *C. tuberculata* was observed at only one station in Fethiye Bay in August while *A. aurita* was found at two stations in Fethiye Bay. It showed a bloom in February with abundance of 152 ind./100 m^3 at the Fethiye 3 station. Distribution of *C. andromeda*, which was distributed extensively in the study area, was determined only by scuba diving. This species was observed from April to December with high abundances. Maximum abundances of *C. andromeda* were 64 ind./100 m^2 (August) in Hisarönü Bay, 71 ind./100 m^2 (August) in Marmaris Bay, and 64 ind./100 m^2 (June) in Fethiye Bay. Significant relationships were detected between environmental variables and Scyphozoa species. *C. andromeda* was positively and significantly correlated with temperature and negatively with dissolved oxygen, while *A. aurita* was insignificantly and positively associated with dissolved oxygen and negatively with temperature.

Key words: Scyphozoa, *Aurelia aurita*, *Cotylorhiza tuberculata*, *Cassiopea andromeda*, temperature, redundancy analysis

1. Introduction

Scyphozoa species, as one of gelatinous zooplankton groups, have become important components of plankton, especially in summer months. In recent years, these species are of interest as predators in marine ecosystems due to their effects on lower trophic levels (Purcell, 1992, 1997; Schneider and Behrends, 1994; Martinussen and Båmstedt, 1995; Omori et al., 1995; Pagès et al., 1996) because the eggs and larvae of commercial fish species are consumed by these organisms (Moller, 1984; Purcell, 1985, 1989; Arai, 1988; Purcell and Arai, 2001). In the last decades, numerous cases of jellyfish blooms and new records of invasive species have been documented (Galil, 1990; Galil and Spanier, 1990; Lotan, 1994; Mutlu et al., 1994; Mutlu 1996, 1999, 2001; Kıdeyş and Gücü, 1995; Kıdeyş et al., 2000; Kıdeyş and Romanova, 2001; Doyle et al., 2007; Abed-Navandi and Kikinger, 2007; Turan et al., 2011). These studies suggest that climatic changes and anthropogenic effects such as global warming, eutrophication, overfishing, and increase of hard substrates (dams, harbors, artificial reefs, etc.) cause jellyfish blooms (Unoki and Kishino, 1977; Mills, 1995; CIESM, 2001; Pagès, 2001; Purcell et al., 2001, 2007; Daskalov, 2002; Parsons and Lalli, 2002; Uye and Ueta, 2004; Purcell, 2005; Tatsuki, 2005; Holst and Jarms, 2007; Uye, 2008). In spite of the high ecological importance and well-known human disturbance of these species, there has been no study conducted on them in Muğla Province, which is considered as one of the most important tourism areas of Turkey. The aim of this study is therefore to study spatiotemporal patterns of distribution, abundances, and environmental associations of Scyphozoa species in Hisarönü, Marmaris, and Fethiye bays, which are located in Muğla Province.

2. Materials and methods

The study was performed between September 2011 and October 2012 at a total of 10 different stations (Figure 1) in Hisarönü, Marmaris, and Fethiye bays, Muğla. Temperature, salinity, and dissolved oxygen (DO) were

* Correspondence: ngulsahin@mu.edu.tr

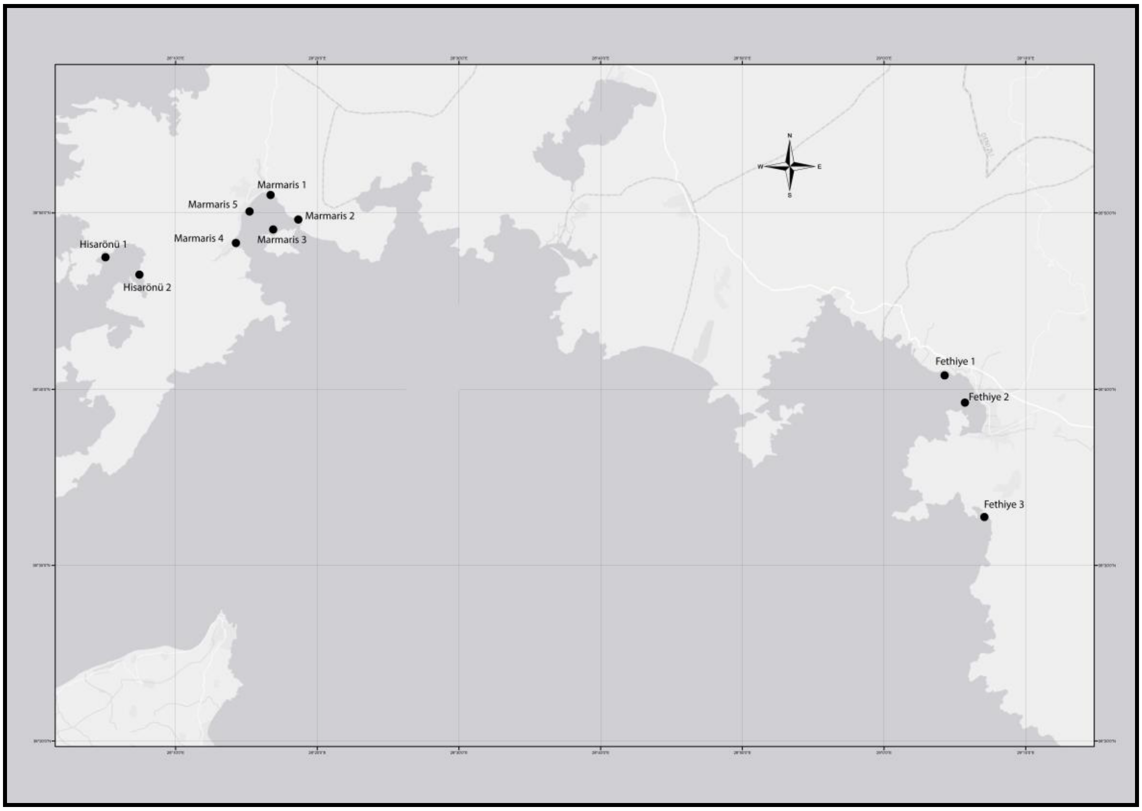

Figure 1. Sampling stations on the coast of Muğla.

measured with a YSI 556 Multiprobe System at the surface and at a depth of 20 m. Chlorophyll-a (Chl-a) values were determined by spectrophotometric method according to Parsons and Strickland (1963).

Scyphozoa species were sampled by transect method. Observations were carried out from both sides of a boat (2 m transect width off each side and 2 m depth) while the boat drove at the lowest speed. Medusae were counted along direct lines whose lengths were measured from the multiplication of speed of boat and time. Data were additionally converted to numbers of individuals per 100 m^3. Only *C. andromeda*, which lives upside-down on the sea floor, was counted by scuba diving. A quadrat method was used in the diving (Figure 2). Individuals were counted in quadrats of 10 m^2 (5 m × 2 m) and the counts were averaged and calculated to numbers of individuals per 100 m^2.

$$A = \frac{[N1 + N2 + N3 + N4 + \ldots]}{n}$$

A = Abundance (individual/100 m^2)
N = Total number of individuals in a quadrat
n = Number of quadrats

Associations between jellyfish taxa and the environment were evaluated with a linear model of ordination instead of unimodal since preliminary detrended correspondence analysis (DCA) indicated a short gradient length on the biological data (SD = gradient length < 2) (Ter Braak and Šmilauer, 2002). There were six measured environmental variables and Chl-a for 10 stations and 14 months, where environmental variables were displayed by their weights in an ordination diagram. The biological data in redundancy analysis (RDA) were log(x+1)-transformed to downweight large values. To guard against interpretation of spurious axes, the statistical significance of the first and all the ordination axes was tested by Monte Carlo permutation test (999 unrestricted permutations). The CANOCO 4.5 software package for Windows was used to perform DCA and RDA analyses.

3. Results

Mean, minimum, and maximum temperature; salinity; and DO values of the stations are presented in Table 1 (for the surface) and Table 2 (for 20 m). On the surface, the minimum temperature was measured at the Marmaris 5 station in February 2012, while the maximum temperature was 29.76 °C at the Fethiye 3 station in August 2012. At the depth of 20 m, the minimum temperature was measured at the Hisarönü 2 station (February 2012) and the maximum temperature was found at the Marmaris 3 and Marmaris

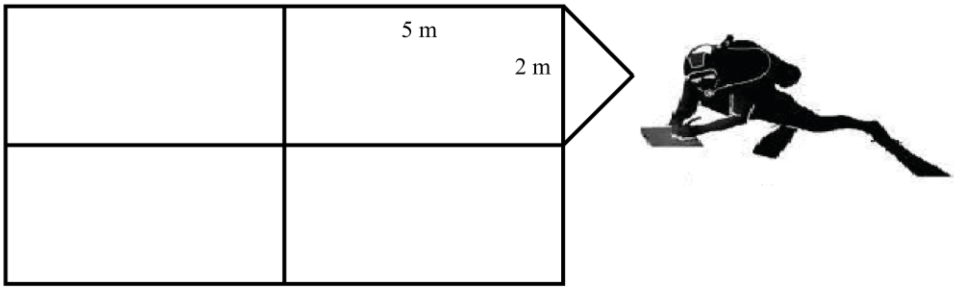

Figure 2. Diagram of quadrat method of counting *C. andromeda*.

Table 1. Mean ± SD, minimum, and maximum values of temperature and the salinity and DO of the stations on the surfaces of Hisarönü, Marmaris, and Fethiye bays in Muğla.

Surface	Temperature (°C)			Salinity (‰)			DO (mg/L)			Chlorophyll-a (µg/L)		
Stations	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD
Hisarönü 1	14.4	27.8	20.08 ± 4.35	36.88	39.26	38.14 ± 0.74	6.50	8.20	7.52 ± 0.89	0.007	0.103	0.028 ± 0.026
Hisarönü 2	15.2	27.2	21.03 ± 4.77	36.58	39.00	37.91 ± 0.57	6.30	8.30	7.52 ± 0.93	0.008	0.045	0.020 ± 0.014
Marmaris 1	14.32	27.16	21.10 ± 4.82	36.4	39.87	38.62 ± 1.15	4.59	8.12	6.53 ± 1.10	0.016	0.118	0.064 ± 0.037
Marmaris 2	14.4	26.72	21.03 ± 4.83	38.05	39.84	39.14 ± 0.55	5.03	8.14	6.80 ± 0.96	0.01	0.061	0.03 ± 0.016
Marmaris 3	14.5	27.00	21.12 ± 4.67	38.21	39.81	39.07 ± 0.42	4.97	8.26	6.58 ± 1.06	0.012	0.203	0.043 ± 0.05
Marmaris 4	14.72	26.04	20.64 ± 4.57	38.16	39.79	39.10 ± 0.45	5.24	8.83	6.94 ± 1.06	0.013	0.168	0.068 ± 0.044
Marmaris 5	14.30	26.74	21.22 ± 4.83	38.17	39.80	38.99 ± 0.53	5.31	8.47	6.85 ± 0.98	0.008	0.098	0.04 ± 0.027
Fethiye 1	16.88	27.00	21.15 ± 3.43	35.43	39.03	37.12 ± 1.22	7.05	9.71	8.16 ± 0.81	0.005	0.059	0.028 ± 0.016
Fethiye 2	17.03	28.02	21.26 ± 3.86	35.36	39.31	37.69 ± 1.10	7.42	9.44	8.26 ± 0.63	0.013	0.076	0.033 ± 0.016
Fethiye 3	15.78	29.76	21.18 ± 4.45	35.57	38.81	37.49 ± 1.01	7.03	9.25	8.17 ± 0.76	0.008	0.104	0.03 ± 0.026

Table 2. Mean ± SD, minimum, and maximum values of temperature and the salinity and DO of the stations at a depth of 20 m of Hisarönü, Marmaris, and Fethiye bays in Muğla.

	Temperature (°C)			Salinity (‰)			DO (mg/L)			Chlorophyll-a (µg/L)		
Stations	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
Hisarönü 1	14.60	24.23	19.01 ± 3.73	37.91	39.77	38.87 ± 0.63	6.00	8.44	7.05 ± 0.81	0.012	0.098	0.034 ± 0.024
Hisarönü 2	14.06	24.18	18.49 ± 3.60	36.15	38.73	37.73 ± 0.73	5.49	8.23	6.82 ± 0.85	0.01	0.06	0.026 ± 0.016
Marmaris 1	14.14	24.81	19.34 ± 3.91	37.12	39.84	38.72 ± 0.87	5.16	8.01	6.43 ± 0.95	0.022	0.163	0.075 ± 0.046
Marmaris 2	14.70	24.18	19.05 ± 3.56	37.15	39.73	38.93 ± 0.77	4.94	7.91	6.75 ± 0.93	0.015	0.077	0.037 ± 0.02
Marmaris 3	14.55	25.96	19.79 ± 4.07	37.14	39.83	38.95 ± 0.72	4.71	8.05	6.69 ± 0.99	0.016	0.169	0.049 ± 0.043
Marmaris 4	14.96	25.96	19.97 ± 4.25	37.01	39.86	39.05 ± 0.76	4.6	8.55	6.69 ± 1.15	0.018	0.203	0.064 ± 0.046
Marmaris 5	15.04	24.61	20.22 ± 3.64	37.65	39.75	39.02 ± 0.71	4.96	8.32	6.44 ± 0.95	0.027	0.084	0.047 ± 0.018
Fethiye 1	15.02	25.00	19.27 ± 3.47	37.00	38.72	37.99 ± 0.65	6.85	9.10	7.90 ± 0.71	0.013	0.059	0.031 ± 0.015
Fethiye 2	15.09	25.63	19.56 ± 3.59	36.43	39.54	38.18 ± 0.99	7.15	8.89	7.84 ± 0.50	0.011	0.059	0.031 ± 0.015
Fethiye 3	15.34	24.68	19.15 ± 3.45	37.00	38.95	38.20 ± 0.59	4.96	8.43	6.70 ± 1.09	0.012	0.089	0.035 ± 0.023

4 stations (September 2011). Mean temperatures of all stations on the surface changed between 20.08 °C and 21.26 °C. For the depth of 20 m, the values varied between 18.49 °C and 20.22 °C. DO values decreased below 5 mg/L in summer months at the Marmaris Bay stations. Salinity of the sampling area was between 35.36‰ (Fethiye 2) and 39.87‰ (Marmaris 1) on the surface, while it was 36.15‰ (Hisarönü 2) and 39.86‰ (Marmaris 4) at a depth of 20 m.

Chl-a concentrations showed typical Mediterranean Chl-a features; maximum values did not exceed 0.203 µg/L. Chl-a values decreased down to 0.01 µg/L in winter months. In Hisarönü Bay, Chl-a values started to increase from March and April 2012 on, and they showed two peaks in May and September 2012. At the Marmaris 1 station, which is near the harbor, Chl-a was relatively higher. In the Fethiye stations, Chl-a began to increase in April 2012 and peaked in May 2012. A second peak was observed in July and August 2012. At a depth of 20 m, Chl-a values were high in September and October 2012 at the Hisarönü stations, and a first peak was observed in May 2012 in both stations. In Marmaris Bay, Chl-a values of the Marmaris 1 and Marmaris 4 stations were relatively higher than those of the other stations at 20 m. At the Marmaris stations, the first peak was observed in May 2012, but the second peak was in July 2012 at the Marmaris 2 and Marmaris 5 stations, in September 2012 at the Marmaris 1 and Marmaris 3 stations, and in October 2012 at the Marmaris 4 station. At 20 m, Chl-a showed two peaks in July and September 2012 at the Fethiye 1 and 3 stations, and in August and October 2012 at the Fethiye 2 station.

C. andromeda was the only scyphozoan species in Hisarönü Bay. This species was observed from April 2012 to December 2012 in the bay. Maximum abundance of this species was determined in August 2012 (64 ind./100 m^2) at the first station in Hisarönü Bay (Hisarönü 1), and in May (45 ind./100 m^2) at the second station (Hisarönü 2) (Table 3). *C. andromeda* was also the only scyphozoan species in Marmaris Bay, except for *Rhopilema nomadica* (Gülşahin and Tarkan, 2011) observed from April to November in the bay. Abundances of *C. andromeda* at the Marmaris stations are given in Table 3. Maximum abundance of the species was 71 ind./100 m^2 in August 2012 at the Marmaris 1 station. In May and June 2012, high abundance values were observed at the Marmaris 2 station (Table 3).

A. aurita, *C. tuberculata*, and *C. andromeda* were all observed in Fethiye Bay. *C. tuberculata* was found at the Fethiye 2 station only in August 2012 (22 ind./100 m^3). *C. andromeda* was only determined at the Fethiye 1 station and it was observed from May to November. Maximum abundance of *C. andromeda* was found in August (37 ind./100 m^2) at the Fethiye 1 station. *A. aurita* was detected at the Fethiye 2 station in September 2011 and in July 2012, and at the Fethiye 3 station in February 2012 and March 2012. In February 2012, *A. aurita* showed a bloom with 152 ind./100 m^3 abundance. Monthly abundances of *C. andromeda* at the Fethiye stations are presented in Table 3.

Table 3. Monthly abundances of *C. andromeda* at the Hisarönü Bay, Marmaris Bay, and Fethiye Bay stations (ind./100 m^2).

	Hisarönü 1	Hisarönü 2	Marmaris 1	Marmaris 2	Marmaris 3	Marmaris 4	Marmaris 5	Fethiye 1	Fethiye 2	Fethiye 3
Sep 2011	0	25	14	27	11	28	7	17	18	7
Oct 2011	11	0	24	0	5	4	0	8	13	3
Nov 2011	1	0	0	0	0	0	0	0	0	0
Dec 2011	0	0	0	0	0	0	0	0	0	0
Jan 2012	0	0	0	0	0	0	0	0	0	0
Feb 2012	0	0	0	0	0	0	0	0	0	0
Mar 2012	0	0	0	0	0	0	0	0	0	0
Apr 2012	0	14	0	0	4	0	5	0	0	0
May 2012	28	45	5	63	3	18	23	11	31	0
Jun 2012	20	7	22	60	38	23	13	11	34	64
Jul 2012	36	12	46	36	16	27	25	18	30	17
Aug 2012	64	23	71	31	27	21	7	37	1	9
Sep 2012	31	16	24	18	17	14	17	13	12	12
Oct 2012	16	2	16	0	4	6	2	5	12	1
Mean ± SD	14.79 ± 19.32	10.29 ± 13.44	15.86 ± 21.03	16.79 ± 23.1	8.93 ± 11.73	10.07 ± 11.21	7.07 ± 21.03	8.57 ± 10.57	10.79 ± 12.92	8.07 ± 16.99

RDA revealed statistically significant relations between environmental variables measured and Scyphozoa species (Table 4). The first two eigenvalues of RDA illustrated 36% of the cumulative variance of species data. The species–environmental correlation of the first axis was high (0.66). The environmental variables explained 36.6% of the total variance in species data. The Monte Carlo permutation test was significant on the first axis (F-ratio = 72.966, P-value = 0.001) and all axes (F-ratio = 9.467, P-value = 0.001) (Table 4).

The first RDA axis explained 35.8% of variation in the Scyphozoa variables and 98% of variation in jellyfish–environment relations (Table 4). On the first RDA-axis, DO on the surface and at a depth of 20 m had the highest scores, and salinity and Chl-a at 20 m had the lowest scores (Figure 3).

All species had negative scores on the first RDA axis, except *A. aurita*, which had positive score on that axis. The second RDA axis explained 36.6% of the variation in the species variables and 99% of the variation between the jellyfish and environmental variables (Table 4). The other species had high positive scores, except for *C. andromeda*, which had low scores on this axis (Figure 3).

C. andromeda was positively and significantly correlated with surface temperature (r = 0.48, P < 0.01) and temperature at a depth of 20 m (r = 0.37, P < 0.05), while it showed negative and significant correlations with DO on the surface (r = –0.42, P < 0.01) and at a depth of 20 m (r = –0.39, P < 0.05). Indeed, *C. andromeda* was closely related to summer months and stations in Hisarönü Bay (Figure 3). Albeit insignificantly, *A. aurita* was positively associated with DO on the surface (r = 0.14, P > 0.05) and at a depth of 20 m (r = 0.11, P > 0.05), and negatively with temperature on the surface (r = 0.05, P > 0.05) and at a depth of 20 m (r = 0.06, P > 0.05).

4. Discussion

Mean temperatures of surface water varied between 20.08 °C and 21.26 °C in Hisarönü, Marmaris, and Fethiye bays. At a depth of 20 m, mean temperatures were measured

Table 4. Results of RDA for Scyphozoa species and biotic and environmental variables. T: Temperature; S: salinity; DO: dissolved oxygen; Chl-a: chlorophyll-a; T(20m): temperature at a depth of 20 m; S(20m): salinity at a depth of 20 m; DO(20m): dissolved oxygen at a depth of 20 m; Chl-a(20m): chlorophyll-a at a depth of 20 m.

Axes	1	2	All
Scyphozoa species			
A. aurita	0.0536	–0.2221	
C. andromeda	–0.6586	–0.0029	
C. tuberculata	–0.0530	–0.1665	
Environmental factors			
T	–0.8771	–0.2297	
S	–0.3218	0.0138	
DO	0.7684	–0.5417	
Chl-a	–0.2558	0.2452	
T(20m)	–0.6491	–0.3007	
S(20m)	–0.2709	–0.2574	
DO(20m)	0.1199	–0.4918	
Chl-a(20m)	–0.2943	0.2733	
Eigenvalues	0.358	0.008	
Species–environment correlations	0.660	0.241	
Cumulative percentage variance of species data	35.8	36.6	
Cumulative percentage variance of species-environment relation	97.7	99.9	
F-ratio	72.966		0.0010
P-value	9.467		0.0010

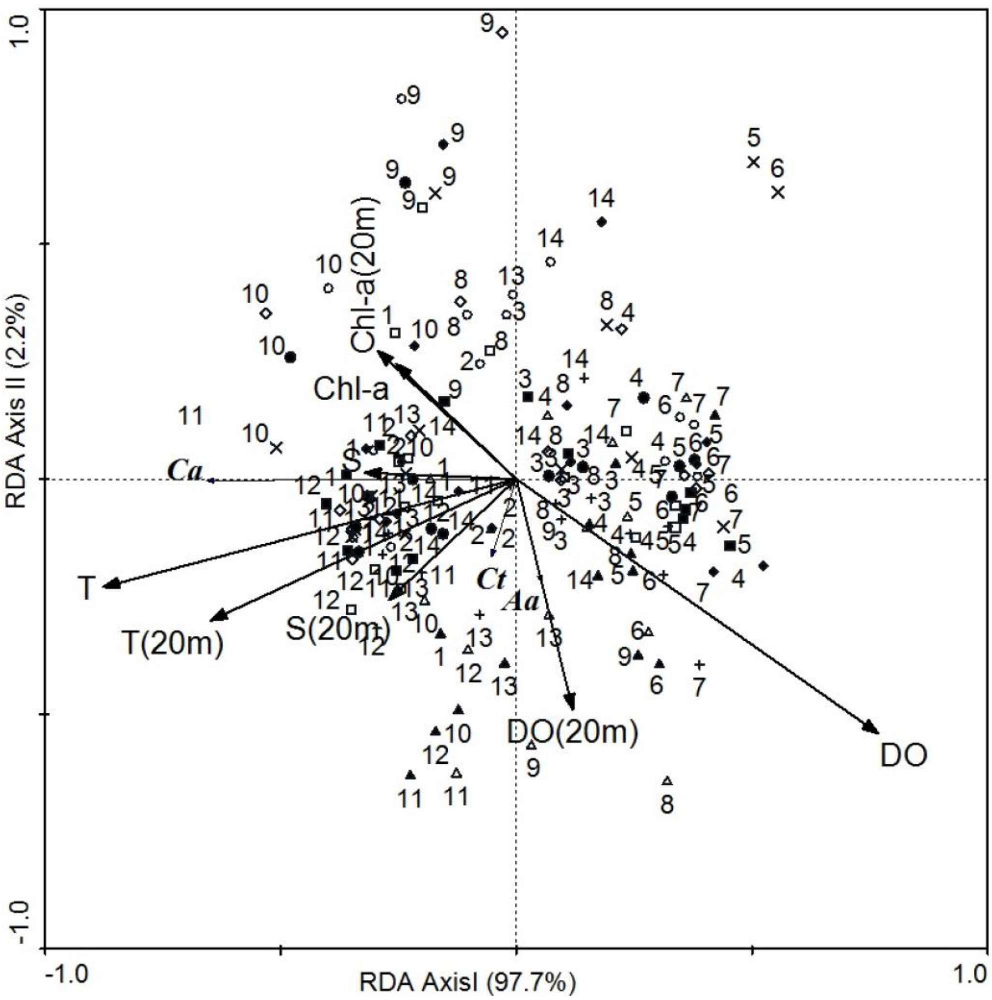

Figure 3. RDA ordination plot for Scyphozoa species, environmental parameters, sampling months, and stations. Sampling stations in RDA plot indicated with □: Hisarönü 1; ■: Hisarönü 2; ○: Marmaris 1; ●: Marmaris 2; ◇: Marmaris 3; ◆: Marmaris 4; ×: Marmaris 5; ∆: Fethiye 1; △: Fethiye 2; ▲: Fethiye 3. Scyphozoa species indicated by the following abbreviations: *Aa*: *Aurelia aurita*; *Ct*: *Cotylorhiza tuberculata*; *Ca*: *Cassiopea andromeda*. Sampling months in RDA plot indicated with: 1: September 2011; 2: October 2011; 3: November 2011; 4: December 2011; 5: January 2012; 6: February 2012; 7: March 2012; 8: April 2012; 9: May 2012; 10: June 2012; 11: July 2012; 12: August 2012; 13: September 2012; 14: October 2012. See Table 4 for abbreviations of environmental variables.

between 18.49 and 20.22 °C in the bays. Beyter (2012) determined that mean surface water temperature was 18–19 °C in spring, 24–25 °C in summer, 20–21 °C in autumn, and 17 °C in winter in Hisarönü Bay. In the present study, we found similar temperatures: 18 °C in spring, 25 °C in summer, 23 °C in autumn, and 15 °C in winter.

Salinity increased up to 39.87‰ on the surface and 39.86‰ at 20 m in the study area, which shows typical Mediterranean characteristics. DO values decreased down to 4.6 mg/L in May and June 2012 at the Marmaris Bay stations. Similarly, according to Tarkan et al. (2013), the DO values of the bay declined below 5 mg/L between June and September 2011. This reduction can be related to intensive tourism activities, weak water circulation, and the increase of the water temperature (e.g., Tarkan et al. 2013).

Increasing abundances of Scyphozoa species observed in the all studied bays in the spring months can be attributed to the increase of Chl-a in the same months. This pattern was more intense in the relatively smaller bays. During the study period, *A. aurita*, *C. tuberculata*, and *C. andromeda* were determined in all the sampled bays. Notably, *C. andromeda* was found to be highly abundant in spring, summer, and autumn months. *C. tuberculata* was observed only at the Fethiye 2 station in August.

A. aurita was observed in high density in Fethiye Bay. In particular, in February it showed a bloom where the surface water temperature was 16.63 °C. *A. aurita*, as a eurythermal and euryhaline species, did not show variations in seasonal distribution in Fethiye Bay. On Swedish coasts, strobilation of *A. aurita* polyps occurred in autumn when zooplankton abundance and biomass peaked (Hernroth and Gröndahl, 1983). It was also reported that abundance and biomass of *A. aurita* were maximum in late spring and summer (Lucas, 2001; Mutlu, 2001; Purcell, 2005). Purcell (2005) and Toyokawa et al. (2000) determined that small individuals together with big ones (>20 cm) were observed in April, so medusae live in winter months, as well. This can explain the high abundance of *A. aurita* (152 ind./100 m^3) found in February at the Fethiye 3 station. According to Lucas and Lawes (1998) and Hansson (1997), the optimum temperature for *A. aurita* is between 9 and 19 °C. Çardak et al. (2011) noted that the optimal living conditions of *A. aurita* occur in winter in Antalya Bay. Therefore, one of the reasons for low abundances of this species and observing it only at certain stations would be the high temperature values measured in the study areas. The temperature was measured to increase to 29.76 °C at the surface and 25.96 °C at a depth of 20 m in the present study. Indeed, species–environmental relations showed a negative correlation between temperature and this species, although it was not significant (Figure 3). However, the high level of DO in winter may be the reason for the presence of *A. aurita* in these months, which was supported by a positive correlation between DO and this species (Figure 3). As this species is highly tolerant to environmental factors (e.g., Gülşahin, 2013), insignificant relevancy with measured environmental factors can be expected; however, our analyses showed, albeit nonsignificantly, some preference to DO and avoidance of higher temperature (Figure 3).

Distribution of *C. andromeda* could be determined by only scuba diving. *C. andromeda*, which is the first Lessepsian scyphozoan species reported from the Mediterranean Sea (Keller, 1888), lives upside-down on the sandy and muddy bottom of the sea floor and swims only for feeding and defense. *C. andromeda* was collected in the Suez Canal in 1886 (Galil et al., 1990) and soon after from Cyprus (Maas, 1903). It was first recorded from Turkey in Göcek, Fethiye, by Bilecenoğlu (2002). After that, six individuals of the species were reported from İskenderun Bay (Çevik et al., 2006). In the Ölüdeniz Lagoon, Fethiye, mean abundances of *C. andromeda* were determined as 9.44 ind./100 m^2 in August, 8.89 ind./100 m^2 in October, 8.22 ind./100 m^2 in January, and 10.56 ind./100 m^2 in May (Özgür and Öztürk, 2008). According to our observations, mean abundances of the species in Fethiye Bay were 17 ind./100 m^2 in August, 7 ind./100 m^2 in October, and 14 ind./100 m^2 in May. No individual was found in January. At the Fethiye 3 station, which is located outside of the lagoon, abundances were 9 ind./100 m^2 in August and 2 ind./100 m^2 in October. Özgür and Öztürk (2008) noted that the surface temperature of the lagoon was 29.9 °C in August. This suggests that winter temperatures of the Muğla coasts were not suitable for this species, but in the lagoon, temperatures were higher than in the open sea, so *C. andromeda* was observed in winter months in the Ölüdeniz Lagoon. The temperature relevance of this species was apparent from the RDA plot and associated analyses (Table 4; Figure 3). On the other hand, spring water goes out from the bottom of the lagoon. This water creates a current move from the lagoon to the Mediterranean Sea. The salinity of the lagoon also decreases because of the spring water and another current occurs from the open sea with high salinity to the lagoon (http://www.mugla.bel.tr/). Hence, it can be suggested that Scyphozoa species drift between the lagoon and the open sea with the effects of the currents.

In the last two decades, studies of gelatinous organisms have increased, but they are still not at a sufficient level, probably due to the difficulties in sampling. Sudden occurrences and blooms of scyphozoans increase the interest in these species. For instance, *C. tuberculata* could only be found at one station in Fethiye Bay in the present study. Therefore, its environmental relations could be very weakly explained (Figure 3; Table 4). However, this species showed blooms in Gökova Bay in 2011 and 2012 (Gülşahin, 2013). It therefore warrants further research as to why *C. andromeda* did not show any blooms in Hisarönü and Marmaris bays.

The main conclusion of the present study is that Hisarönü, Marmaris, and Fethiye bays are located on the migration pathways of the Scyphozoa species. Alien species, which are arriving with the currents, increase their numbers owing to the coastal structures of the study area, consisting of many small bays, and the warmer climate of the area facilitates scyphozoan species' entry into these bays. Our observations in the present study confirmed that *C. andromeda* was successfully established on the Muğla coasts. The results of the present study suggest that the environment and physical structure of the bays of the Muğla coasts provide suitable habitats, especially for Lessepsian scyphozoans, with the exception of *A. aurita*, for which winter temperatures are more convenient despite the species' wide environmental tolerance. Further studies are encouraged to explore and monitor Scyphozoa species in the Muğla region, which is considered as very important touristic area and biodiversity reserve.

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References

Arai MN (1997). A Functional Biology of Scyphozoa. London, UK: Chapman and Hall.

Beyter T (2012). Gökova ve Hisarönü Körfezleri fiziksel oşinografisi. MSc, Muğla Sıtkı Koçman University, Muğla, Turkey (in Turkish).

Çardak M, Özbek EÖ, Kebapçıoğlu T (2011). The winter aggregation of *A. aurita* (Linnaeus, 1758) in the Gulf of Antalya, Levantine Coast of Turkey, Eastern Mediterranean. In: Turan C, Öztürk B, editors. Proceedings of the First National Workshop on Jellyfish and Other Gelatinous Species in Turkish Marine Waters, 20–21 May 2011, Bodrum, Muğla, Turkey. İstanbul, Turkey: Turkish Marine Research Foundation, pp. 50–52.

Çevik C, Erkol IL, Toklu B (2006). A new record of an alien jellyfish from the Levantine coast of Turkey – *Cassiopea andromeda* (Forsskal, 1775) (Cnidaria: Scyphozoa: Rhizostomea). Aquat Inv 1: 196–197.

Gülşahin N, Tarkan AN (2011). The first confirmed record of the alien jellyfish *Rhopilema nomadica* Galil, 1990 from the southern Aegean coast of Turkey. Aq Inv 6: 95-97.

Gülşahin N (2013). Muğla neritik bölgesi Scyphozoa (Cnidaria) ve Ctenophora türlerinin bolluk, dağılım ve biyomas özellikleri. PhD, Muğla Sıtkı Koçman University, Muğla, Turkey (in Turkish).

Hansson LJ (1997). Effect of temperature on growth rate of *Aurelia aurita* (Cnidaria, Scyphozoa) from Gullmarsfjorden, Sweden. Mar Ecol Prog Ser, 161: 145–153.

Hernroth L, Gröndahl F (1983). On the biology of *Aurelia aurita* (L.) 1. Release and growth of *Aurelia aurita* (L.) ephyrae in the Gullmar Fjord, western Sweden, 1982–83. Ophelia 22: 189–199.

Huntley ME, Hobson LA (1987). Medusa predation and plankton dynamics in a temperate fjord, British Columbia. J Fish Res Bd Can 34: 73–82.

Keller C (1888). Die Wanderung der marinen Thierweltim Suezcanal. Zool Anz 11: 359–364, 389–395 (in German).

Lotan A, Fine M, Benhillel R (1994). Synchronization of the life cycle and dispersal pattern of the tropical invader scyphomedusan *Rhopilema nomadica* is temperature dependent. Mar Ecol Prog Ser 109: 59–65.

Lucas CH (2001). Reproduction and life history strategies of the common jellyfish, *Aurelia aurita*, in relation to its ambient environment. Hydrobiologia 451: 229–246.

Lucas CH, Lawes S (1998). Sexual reproduction of the scyphomedusa *Aurelia aurita* in relation to temperature and variable food supply. Mar Biol 131: 629–638.

Martinussen MB, Båmstedt U (1995). Diet, estimated daily food ration and predation impact by the scyphozoan jellyfishes *Aurelia aurita* and *Cyanea capillata*. In: Skjoldal HR, Hopkins C, Erikstad KE, Leinaas HP, editors. Ecology of Fjords and Coastal Waters. Amsterdam, the Netherlands: Elsevier, pp. 127–145.

Moller H (1984). Reduction of a larval herring population by jellyfish predator. Science 224: 621–622.

Mutlu E (2001). Distribution and abundance of moon jellyfish (*Aurelia aurita*) and its zooplankton food in the Black Sea. Mar Biol 138: 329–339.

Mutlu E, Bingel F, Gücü AC, Melnikov VV, Niermann U, Ostr NA, Zaika VE (1994). Distribution of the new invader *Mnemiopsis* sp. and the resident *Aurelia aurita* and *Pleurobranchia pileus* population in the Black Sea in the years 1991-1993. ICES J Mar Sci 51: 407–421.

Nadeem MS, Imran SMK, Mahmood T, Kayani AR, Shah SI (2012). A comparative study of the diets of barn owl (*Tyto alba*) and spotted owlet (*Athene brama*) inhabiting Ahmadpur East, Southern Punjab, Pakistan. Anim Biol 62: 13–28.

Omori M, Ishii H, Fujinaga A (1995). Life history strategy of *Aurelia aurita* (Cnidaria, Scyphomedusae) and its impact on the zooplankton community of Tokyo Bay. ICES J Mar Sci 52: 597–603.

Özgür E, Öztürk B (2008). A population of the alien jellyfish, *Cassiopea andromeda* in the Ölüdeniz Lagoon, Turkey. Aquat Inv 3: 423–428.

Pagès F, White MG, Rodhouse PG (1996). Abundance of gelatinous carnivores in the nekton community of the Antarctic Polar Frontal Zone in summer 1994. Mar Ecol Prog Ser 141: 139–147.

Purcell JE (1985). Predation on fish eggs and larvae by pelagic cnidarians and ctenophores. Bull Mar Sci 37: 739–755.

Purcell JE (1989). Predation of fish larvae and eggs by the hydromedusa *Aequorea victoria* at a herring spawning ground in British Columbia. Canadian J Fish Aquat Sci 46: 1415–1427.

Purcell JE (1992). Effects of predation by the scyphomedusan *Chrysaora quinquecirrha* on zooplankton populations in Chesapeake Bay, USA. Mar Ecol Prog Ser 87: 65–76.

Purcell JE (1997). Pelagic cnidarians and ctenophores as predators: selective predation, feeding rates and effects on prey populations. Ann Inst Oceanogr Paris 73: 125–137.

Purcell JE (2005). Climate effects on formation of jellyfish and ctenophore blooms: a review. J Mar Biol Assoc UK 85: 461–476.

Purcell JE, Arai MN (2001). Interactions of pelagic cnidarians and ctenophores with fish: a review. Hydrobiologia 451: 27–44.

Schneider G, Behrends G (1994). Population dynamics and the trophic role of *Aurelia aurita* medusae in the Kiel Bight/western Baltic. ICES J Mar Sci 51: 359–367.

Tarkan AN, Özdemir N, Çoker T, Önsoy MB, Ercan MD, Gülşahin N, Öntaş C, Sunar MC, Yapıcı S, Ağdamar S (2013). Marmaris Körfezi Su Kalitesi ve Biyolojik Araştırma Sonuç Raporu. Marmaris, Turkey: Marmaris Çevreciler Derneği (in Turkish).

Ter Braak CJ, Šmilauer P (2002). CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (Version 4.5). Ithaca NY, USA: Microcomputer Power.

Toyokawa M, Furota T, Terazaki M (2000). Life history and seasonal abundance of *Aurelia aurita* medusae in Tokyo Bay, Japan. Plankton Biol Ecol 47: 48–58.

Unoki S, Kishino M (1977). Average ocean condition and water exchange in Tokyo Bay. Tech Rep Phys Oceanogr Lab Inst Phys Chem Res 1: 1–89 (in Japanese).

Uye S (2008). Blooms of the giant jellyfish *Nemopilema nomurai*: a threat to the fisheries sustainability of the East Asian Marginal Seas. Plank Benth Res 3 (Suppl.): 125–131.

Uye S, Ueta U (2004). Recent increase of jellyfish populations and their nuisance to fisheries in the Inland Sea of Japan. Bull Jpn Soc Fish Oceanogr 68: 9–19 (in Japanese with English abstract).