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Diel Variability in the Bottom-Trawl Catch Rates of Sparid Fishes in İzmir Bay (Central-Eastern Aegean Sea)

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Abstract

Time of day may affect the availability, distribution and behaviour of many fishes, at least in the depths that the light penetrates. Changes in the activity and position of the demersal fish as a response to the changing light levels during a diel (24 h) cycle may affect their catchability or vulnerability to the bottom trawl. Diel variability in the bottom-trawl catch rates of five sparid fish species, namely *Boops boops, Diplodus annularis, Diplodus vulgaris, Pagellus acarne* and *Pagellus erythrinus*, were investigated during seven experimental bottom-trawl surveys conducted within the same locality in İzmir Bay. All trawl haulings were performed using the same operation and sampling procedure and carried out for each seasonal survey at different periods day, including the morning, noon, afternoon, dusk, early-night, midnight, late-night and dawn. Percentage contribution by weight of the sparid fishes to the total catch varied according to the sampling season between 23-79%. Catch rates of the sparid fishes usually did not show significant diel periodicity except *D. vulgaris*. Daylight catch rates of *D. vulgaris* were significantly higher than twilight and night periods (Daylight>Twilight>Night). Information on diel variations obtained in this study could be fundamental in understanding the distribution dynamics of the five sparid fishes and developing future management approaches.

Keywords:
24 h cycle, time of day, diel periodicity, Sparidae, bottom-trawl
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Introduction

Bottom-trawl surveys are used worldwide to estimate the biomass of demersal fish species (Francis & Williams, 1995; Petrakis et al., 2001). The efficiency of trawl surveys depends on many factors such as the set-up and operating protocol of the net, the ability of the gear to catch the available fish, and the behaviour of the target fish species towards the gear and environmental variables (Godø, 1994; Francis & Williams, 1995). The periods of a day with different light intensities is one

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of the important environmental factors affecting trawl efficiency (Helfman, 1993; Gaertner et al., 1999; Carpentieri et al., 2005). Changes in the activity and position of the demersal fish as a response to the changing light levels during a 24 h cycle may affect their catchability or vulnerability to the bottom-trawl (Parsley et al.,1989; Michalsen et al., 1996; Korsbekke & Nakken, 1999; Petrakis et al., 2001; Aly Yousif, 2003; Vasconcellos et al., 2011). While the higher visibility during daylight hours increased the probability of the fish avoiding the trawl, low visibility in the dark may inhibit the detection of gear by the fish. Therefore, capture efficiencies may be quite variable for some species by the periods of a diel cycle (Nash & Santos, 1998; Petrakis et al., 2001; Adlerstein & Ehrich, 2003; Carpentieri et al., 2005; Yule et al., 2008; Vasconcelloset al., 2011). Consequently, a thorough understanding of how the feeding, schooling, moving and resting behaviours of a species change during a diel (24 h) period is essential to give more precise and unbiased fish biomass indices with the data obtained from scientific surveys (Godø, 1994; Casey & Myers, 1998; Nash & Santos,1998).

Bottom trawling fleets predominate in many Mediterranean fisheries, being responsible for a high share of total catches and, in many cases, yielding the highest earnings among all the fishing sub-sectors (Tudela, 2004). In the Mediterranean Sea, investigations on the demersal fish assemblages primarily focused on the seasonal and/or depth-related changes (Relini et al., 1999; Ungaro et al., 1999; Kallianotis et al., 2000; Labropoulou & Papaconstantinou, 2000; Colloca et al., 2003; Gaertner et al., 2005). However, the majority of the bottom-trawl data have been collected by diurnal surveys, and information on the composition and distribution pattern of demersal fish assemblages in the dark period is very limited. Accordingly, few studies have considered the diel variations in catch rates of demersal fish in the Mediterranean Sea.

In the Mediterranean demersal fish fauna, the Sparidae family compose one of the most abundant taxa represented by 12 genera, and 25 species usually inhabit coastal areas down to 250 m. (Sbragaglia et al., 2018; Froese & Pauly, 2019; Kara & Quignard, 2019). While the young individuals are more abundant in shallow waters in small aggregation or schools on various habitats such as sandy or muddy bottoms and seagrass beds, the adults of some sparids may be solitary and spread in deeper environments (Sala & Ballesteros, 1997; Relini et al., 1999; Froese & Pauly, 2019; Parenti, 2019). Some sparid fishes are highly appreciated as seafood and commercially important for fisheries and aquaculture in many areas worldwide (Pavlidis & Mylonas, 2011). Sparids constitute the target of small-scale fishing and are caught mainly with trammel nets, gill nets and longlines. They are also caught in large quantities by seine nets and trawl nets (Fischer et al., 1987; Froese & Pauly, 2019).

Karataş et al. (2021) reported that 25 sparid species live in the Turkish Seas. The annual catch amount of 15 of them are collected and published every year by the Turkish Statistical Institute. These sparids are *Boops boops*, *Dentex dentex*, *Dentex gibbosus*, *Dentex macrophthalmus*, *Diplodus annularis*, *Diplodus puntazzo*, *Diplodus vulgaris*, *Lithognathus mormyrus*, *Oblada melanura*, *Pagellus erythrinus*, *Pagrus pagrus*, *Sarpa salpa*, *Sparus aurata*, *Spondyliosoma cantharus* and *Spicara maena*, respectively. Over the last decade, the average production of sparid fishes was 5704 tonnes (minimum 4580 tonnes in 2015 and a maximum of 8253 tonnes in 2010). Their share varied between 1.3-2.8 % of the total annual production of marine capture fisheries in Turkey (TurkStat, 2010-2019).

Sparid fishes are also an important component of demersal fish fauna in İzmir Bay (Tosunoğlu et al., 1997; Ünlüoğlu et al., 2017). They were chosen in the present study because they are usually dominant in the bottom trawl catches and have a high probability of being caught regularly throughout the sampling period in İzmir Bay. This study aims to provide information on how the bottom-trawl catch rates of sparid fishes vary over a 24 h cycle by considering the daylight, night and twilight periods and whether the sampling seasons affect diel variability in the catch rates.

Materials and Method

Fish samples were collected by bottom-trawl during seven experimental seasonal surveys conducted in İzmir Bay (the central-eastern Aegean Sea). Each survey covers a 24 h cycle and a total of 8 trawl samplings, which were performed at the different periods of a day: morning, noon, afternoon, dusk, early-night (between dusk and midnight), midnight, late-night (between midnight and dawn) and dawn. Altogether, 56 bottom trawl operations were carried out by *R/V K. Piri* Reis on 8-9 February 2007 (winter), 29-30 March 2007 (spring), 27-28 July 2007 (summer), 31 January-1 February 2008 (winter), 14-15 May 2008 (spring), 5-6 August 2008 (summer) and 1-2 November 2008 (autumn). All trawl samplings were towed with a constant speed of 2.5 knots at the same location between 50 and 60 m depth (Figure 1).

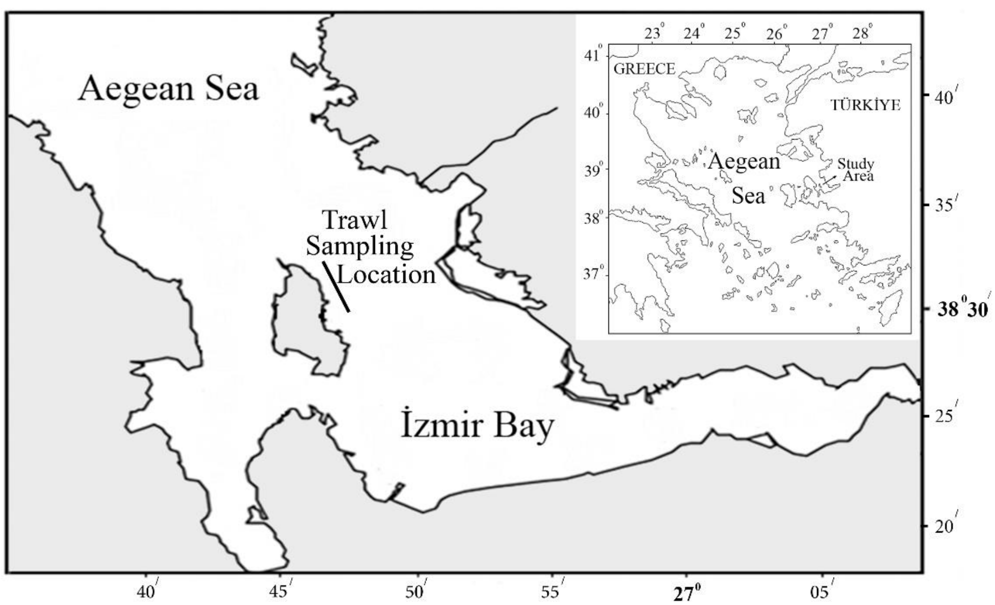

Figure 1. Location of bottom trawl samplings (the straight line highlights the trawl sampling area).

A catch monitoring system (SCANMAR) was used during each trawl operation. Thus, catching efficiency and the duration of each trawl operation were calculated more accurately. However, the duration of the trawl hauls varied between 15-20 minutes, mostly around 20 minutes. The same trawl net and operation protocol was used throughout the sampling study. The trawl cod-end was 22 mm in mesh size (knot-to-knot).

After each trawl operation, the catch was separated by species. Each species was counted and weighted with 2 g accuracy using a special balance designed for the sea (MAREL). Then, the number and weight data were converted to 1 h towing duration and analyzed separately to assess whether there was a variation in the catch rate of the species at the different periods of a 24-hour cycle.

In order to evaluate the data statistically, the trawl samples were grouped as the daylight (samplings between dawn and dusk), night (samplings between dusk and dawn) and twilight (samplings at dusk and dawn) for each sampling season. One-way ANOVA was used to analyze whether species catch rates (weight kg-h) varied significantly among the periods of the day. Prior to ANOVA, the catch rates were checked for normality using the Shapiro-Wilk test and the homogeneity of variances with Levene's test (Sokal & Rohlf, 2012). If the catch rate data did not fit the normal distribution and the variances were not homogeneous, log(e) transformation was applied. If there was a significant difference according to the ANOVA, Tukey's honestly significant difference (HSD) test was run for pairwise comparisons among the periods of the day. Besides, a two-way ANOVA was used to determine whether there was an interaction between sampling seasons and periods of the day for catch rates. Sampling seasons and the periods of the day were modelled as fixed effects: seasons with seven levels (winter07, spring07, summer07, winter08, spring08, summer08, autumn08), day periods with three levels (daylight, night and twilight). Statistical analyses were performed by using SPSS 24 for windows with a significance level set at 0.05.

Results

Sparid fishes caught in the study area throughout the bottom-trawl surveys were: *B. boops, D. annularis, D. vulgaris, P. acarne, Pagellus bogaraveo, P. erythrinus, D. maroccanus, S. aurata* and *S. maena*. According to the sampling surveys, the overall percentages in the total catch mostly varied between 35-45% (Figure 2). A tremendous amount of capture of *D. annularis* (a total of 18 576 specimens with a total weight of 839.5 kg) in spring 2008 caused the highest contribution of the sparid fishes (79%) to the total catch by weight, while the lowest share was 23% in summer 2008 (Figure 2). The catch rates of *B. boops*, *D. annularis* and *P. erythrinus* were significantly different between the sampling surveys (One-way ANOVA, $P<0.05$). Catch rates of the *B. boops* in spring 2008 and autumn 2008 were higher than the remaining surveys (Tukey HSD test, $p<0.05$). Similarly, the catch rates of the *D. annularis* in winter 2007 and spring 2008 and the catch rates of *P. erythrinus* in summer samplings were significantly higher than the other surveys (Tukey HSD test, $p<0.05$). On the contrary, no significant differences were found between the sampling surveys for *D. vulgaris* and *P. acarne* (One-way ANOVA, $P>0.05$). The other sparids in the study area, *P. bogaraveo, D. maroccanus, S. aurata* and *S. maena* were rarely caught in a few sampling seasons and omitted from further analysis due to their insufficient data. *D. maroccanus* were caught in spring 2007 at noon (2 specimens weighing 0.05 kg) and in spring 2008 at dawn (3 specimens weighing 0.1 kg). Similarly, *S. aurata* were caught in winter 2007 at midnight (14 specimens weighing 3.6 kg), in spring 2008 at noon and in the afternoon (6 specimens weighing 0.7 kg at noon and 3 specimens weighing 0.3 kg in the afternoon), and in autumn 2008 at noon (3 specimens weighing 0.5 kg). *P. bogaraveo* were also caught in low number and biomass in summer 2007, winter 2008 and summer 2008, usually at noon and afternoon periods; however, that species were captured relatively in large amounts at each period of a day in autumn 2008.

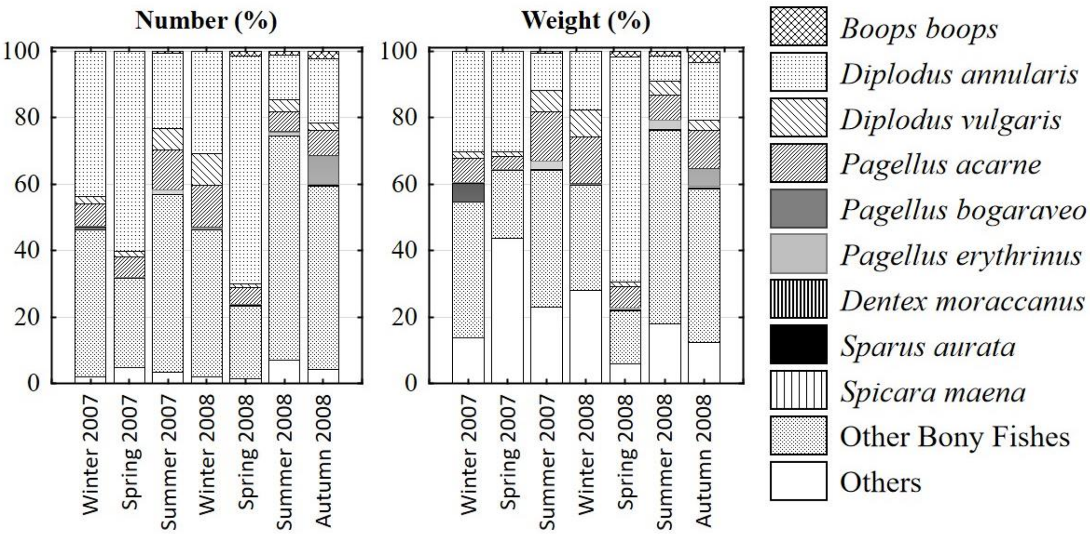

Figure 2. Percentage contribution of sparid fishes according to the sampling surveys in the study area (Others represents cartilaginous fishes and invertebrates).

Among the sparid fishes, *B. boops* were caught in a few trawl samplings (at dawn, morning and noon) with a very low catch rate in winter 2007 and winter 2008 (Figure 3). In spring 2007, the maximum catch rates were observed at noon and late-night, coinciding with each other. Catch rates decreased almost by half, with a similar trend in the afternoon and dawn periods. Only a few B. *boops* were caught at dusk and in the morning, while no specimen was captured at early-night and midnight (Figure 3). A distinctive distribution pattern was observed in spring 2008. The catch rates of *B. boops* were the highest at dusk, followed by a lesser catch at early-night. The catch rates were low at noon, afternoon, midnight and morning periods, while no *B. boops* specimen was captured at late-night and dawn. In the summer samplings, the catch rates of *B. boops* showed a slightly similar trend, and the highest catch rates were at late-night. Finally, in autumn 2008, the lowest catch rate was at noon, and it increased by fluctuations in the following periods. The catch rate reached its maximum at late-night and sharply decreased at dawn (Figure 3). Throughout the study, the average catch rates during the dark period (mean weight and SD: 3.27±3.39 kg) were higher than the catch rates of daylight (1.07±1.14 kg) and twilight (2.23±2.71 kg), but no significant difference was found between the periods of the day (One-way ANOVA, $p>0.05$).

D. annularis was the most abundant sparid species almost in each trawl sampling with various catch rates. While the maximum catch was observed at early-night, the minimum catch rates were at midnight and late-night during winter 2007. The catch of *D. annularis* increased at dawn, and the species were caught in identical quantities during the daylight period (Figure 4). In winter 2008, the catch rates were very low, showing similarity in general, but a slight increase was determined at early-night. In spring 2007, catch rates fluctuated while the highest catch was at midnight and the lowest catch rates were at noon, dusk and morning. In spring 2008, the highest catch of *D. annularis* was at noon, and then the catch rates decreased by more than half of this amount, and small fluctuations occurred at the remaining periods (Figure 4). In the summer surveys, low catch rates were recorded in most of the trawl samplings. The catch rates increased remarkably at the early-night period in summer 2007 and increased slightly at late-night in summer

2008. In autumn 2008, the afternoon and dusk catch rates were lower than in the other periods, while the highest catch was found at noon (Figure 4). Although the catch rates showed fluctuations in some diel cycles, the difference observed between the day periods was insignificant (One-way ANOVA, $p>0.05$). Average catch rates were 34.76 ± 44.18 kg during daylight, 36.41±37.90 kg during the night and 29.14±33.11 kg during twilight.

Catch rates of *D. vulgaris* showed diel variations according to the sampling surveys (Figure 5). Remarkably, a diel pattern was determined for *D. vulgaris* since the highest catch rates were always obtained during the daylight (One-way ANOVA, $p<0.05$) either in the morning (winter 2008, spring 2008, autumn 2008) or in the afternoon (winter 2007, summer 2007-2008) (Figure 5). Average catch rates during daylight (6.79±6.19 kg) were significantly higher than the night (1.60±1.50 kg) and twilight (1.95±2.09 kg) periods (Tukey HSD test, $p<0.05$). There was no significant difference between the night and twilight (Tukey HSD test, $p>0.05$).

Catch rates of *P. acarne* also varied by the periods of the day for each sampling survey like the other sparid fishes evaluated in the present study (Figure 6). In winter 2007, a few *P. acarne* specimens were captured at noon and midnight. The maximum catch rate for this survey was observed at dusk and fluctuated in the remaining periods. In winter 2008, the catch rates were low except for the morning (Figure 6). Maximum catch rates were at noon in the spring surveys, and only a few *P. acarne* were caught at afternoon, dusk, early-night and morning periods in spring 2007. In summer 2008, the catch rate at early-night was higher than the other periods, while the lowest catch rates were at late night, dawn, morning and noon. The highest catch of *P. acarne* was observed in the morning in autumn 2008, and relatively small amounts were caught at the other periods of the day except for noon. Even though the average catch rates during the daylight (13.44±11.98 kg) were higher than the catch rates of the night (8.38±6.65 kg) and twilight (7.01±7.06 kg), no significant difference was detected between the periods of the day (One-way ANOVA, $p>0.05$).

P. erythrinus is the last sparid species evaluated in the present study. Only a few *P. erythrinus* were caught in winter 2007, 2008 and spring 2007. Similar catch rates were observed in all periods of the diel cycle in spring 2008 except for morning (Figure 7). In summer 2007, the highest catch rate was determined at early-night, and relatively high catch rates were recorded at noon, afternoon and dusk. The lowest catch rates were at late-night and dawn during this survey. In summer 2008, even though the maximum catch rate in terms of weight was found at midnight, the number of specimens caught was very low, indicating that the sizes of *P. erythrinus* individuals at this period were larger than all other individuals captured during the study. Catch rates were low at noon, late-night and morning in summer 2008. In Autumn 2008, the catch rates were similar in the dark period, while no *P. erythrinus* specimen was captured at afternoon and dusk. Throughout the study, the catch rates of *P. erythrinus* fluctuated in diel cycles, but no significant difference was found between the periods of the day (One-way ANOVA, $p>0.05$). Average catch rates were 1.57±1.19 kg during the daylight, 1.61±1.73 kg during the night and 1.08±1.18 kg during the twilight.

Even though the seasonal or diel variations were found to be significantly effective on the catch rates of some sparid fishes by the One-way ANOVA, no significant interaction was detected between the periods of the day and sampling seasons by the Two-way ANOVA (Table 1). Since the data were inadequate to run a Two-way ANOVA for *B. boops* and *P. erythrinus* in winter 2007, 2008 and spring 2007 surveys, the analysis was performed by excluding those data. However, the seasonal effect was found nonsignificant for *P. erythrinus* by two-way ANOVA, while it was significant by the one-way ANOVA.

Table 1. Results of two-way ANOVA for comparisons of the catch rate (by weight) of sparid fish species

	Effect	df	MS	F	p
B. boops	Period of Day	2	2.240	2.238	0.141
	Season	3	5.122	5.118	**0.012**
	Period of Day*Season	6	0.630	0.630	0.705
D. annularis	Period of Day	2	0.846	2.136	0.133
	Season	6	10.512	26.554	**0.000**
	Period of Day*Season	12	0.493	1.244	0.294
D. vulgaris	Period of Day	2	8.017	6.618	**0.004**
	Season	6	1.601	1.322	0.278
	Period of Day*Season	12	1.803	1.488	0.183
P. acarne	Period of Day	2	1.719	1.509	0.236
	Season	6	2.446	2.146	0.074
	Period of Day*Season	12	1.025	0.900	0.557
P. erythrinus	Period of Day	2	1.174	1.197	0.326
	Season	3	0.884	0.902	0.461
	Period of Day*Season	6	0.613	0.625	0.708

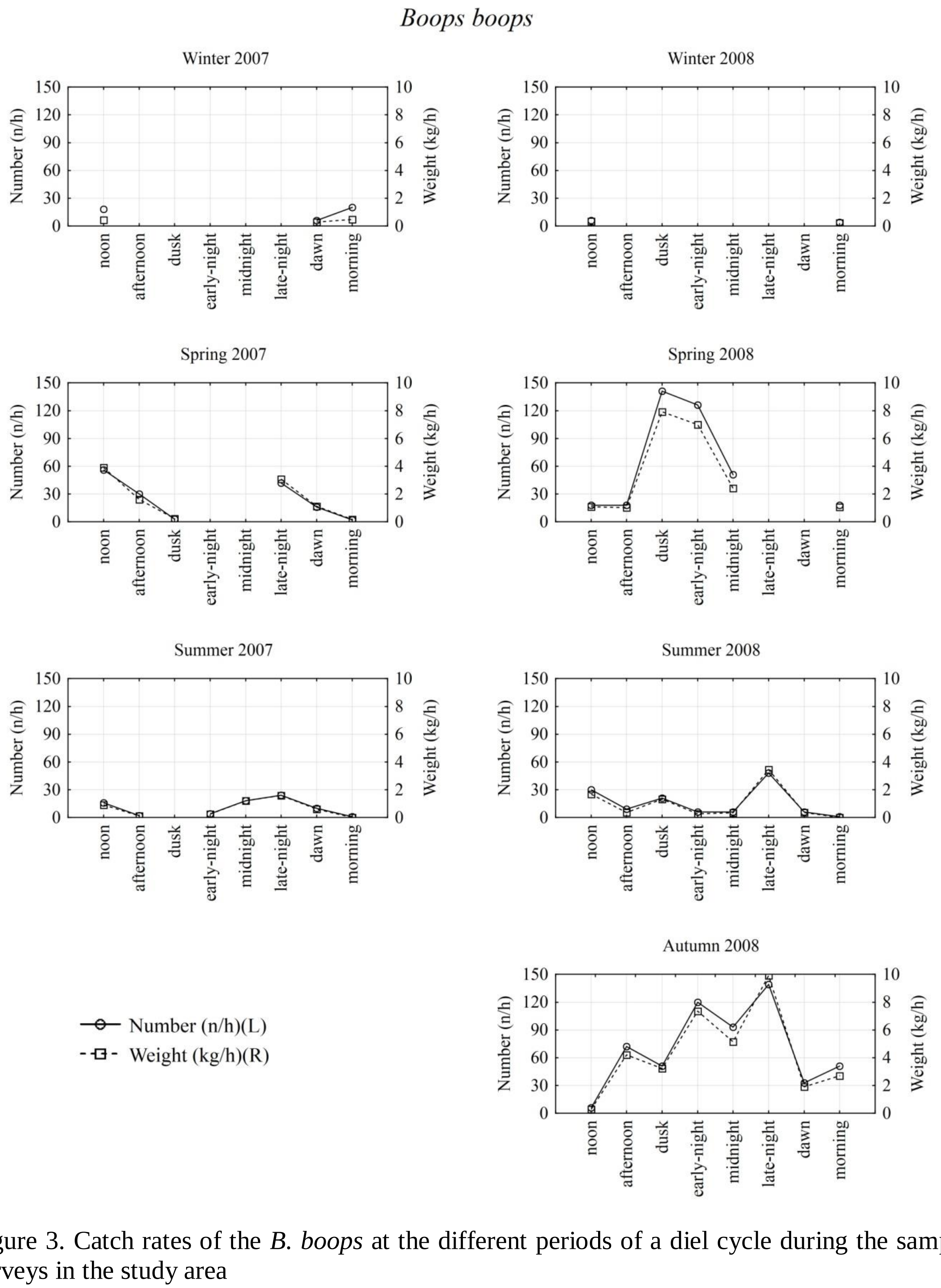

Figure 3. Catch rates of the *B. boops* at the different periods of a diel cycle during the sampling surveys in the study area

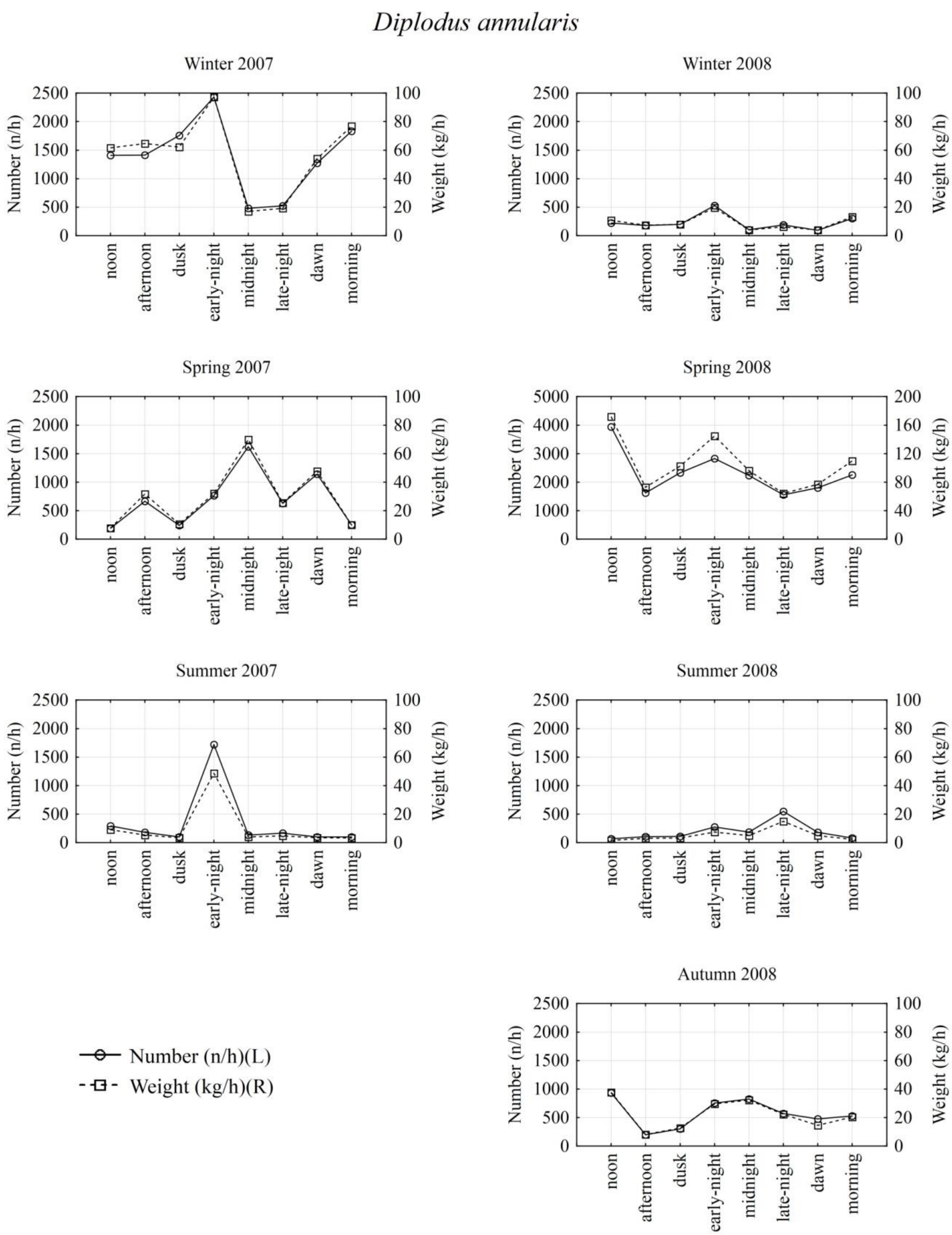

Figure 4. Catch rates of the *D. annularis* at the different periods of a diel cycle during the sampling surveys in the study area.

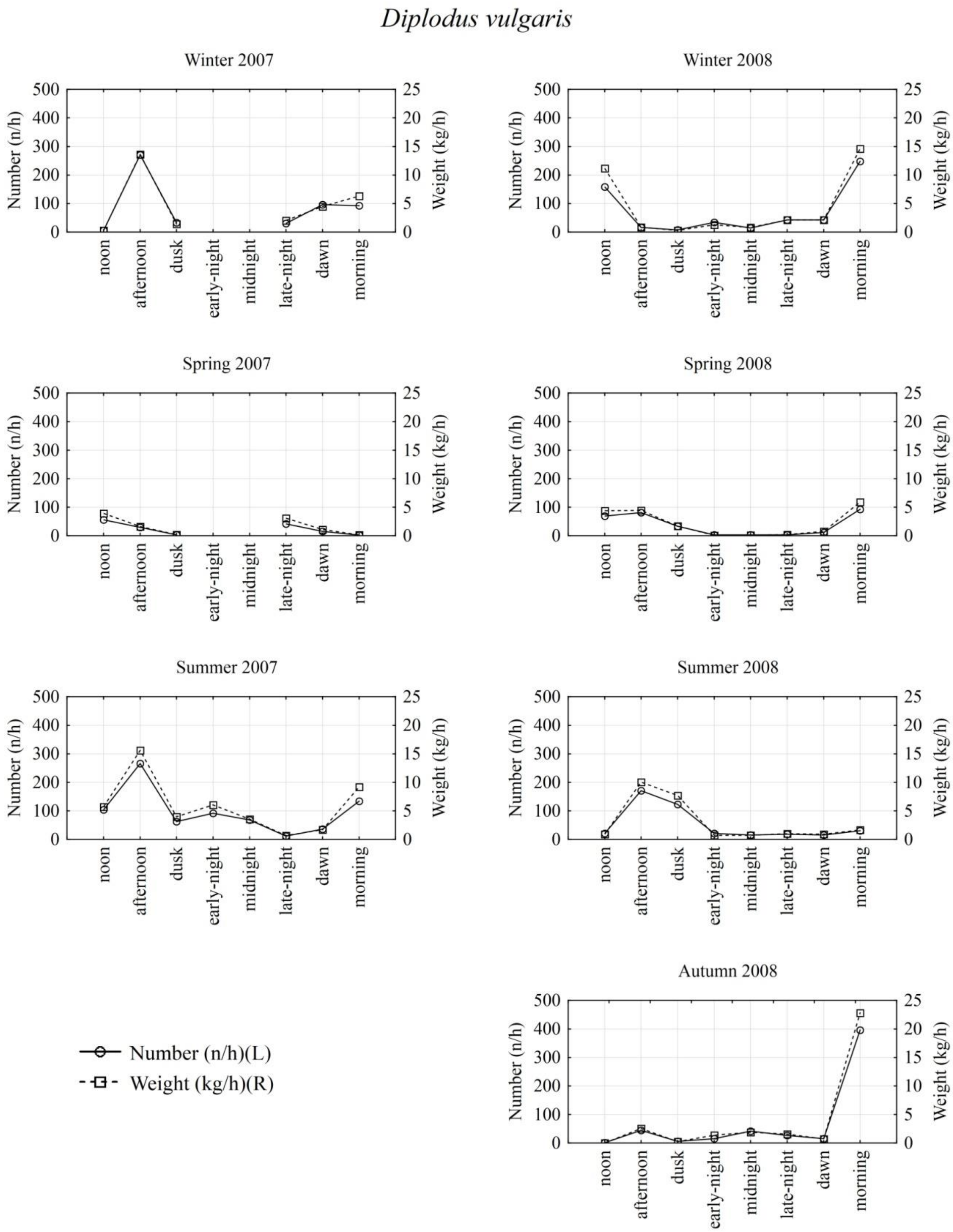

Figure 5. Catch rates of the *D. vulgaris* at the different periods of a diel cycle during the sampling surveys in the study area.

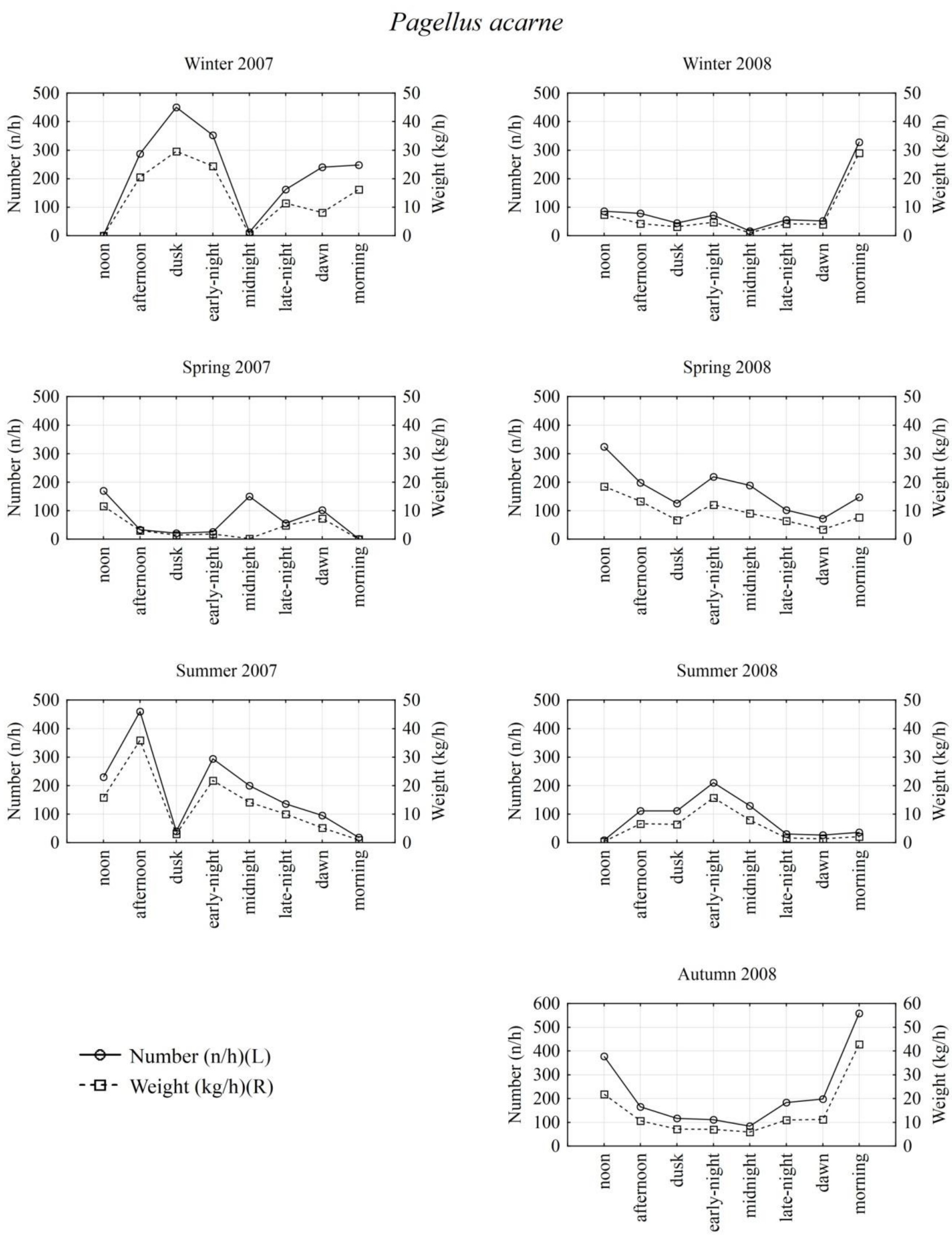

Figure 6. Catch rates of the *P. acarne* at the different periods of a diel cycle during the sampling surveys in the study area.

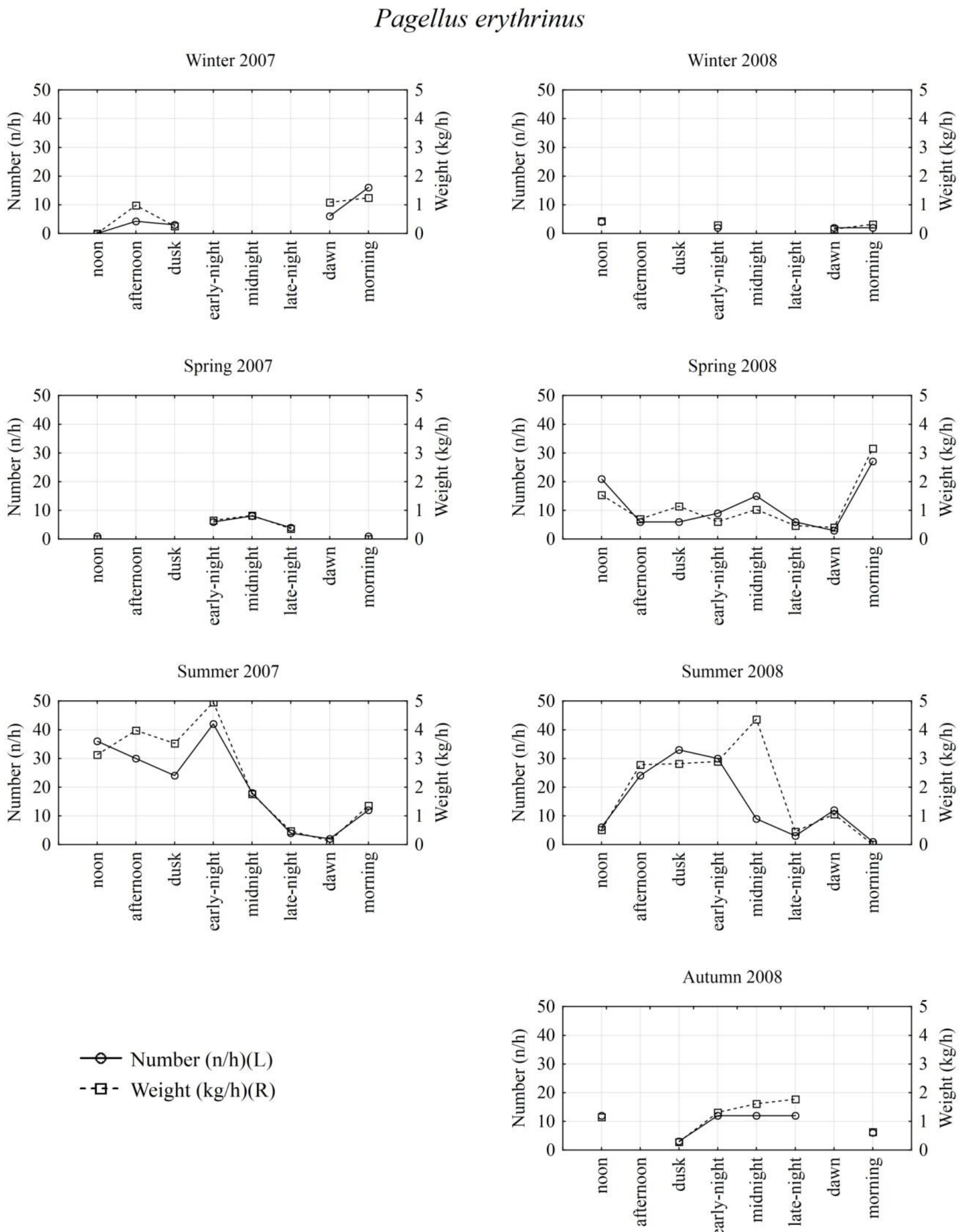

Figure 7. Catch rates of the *P. erythrinus* at the different periods of a diel cycle during the sampling surveys in the study area.

Discussion

Catch rates of the sparid fish in the sampling area in İzmir Bay were generally fluctuated during 24 h cycles by the species, sometimes with high catch rates in daylight time, sometimes in twilight or night time, but with a different distribution pattern for each sampling survey. Variations in the catch rates during 24 h cycle usually did not reflect an expected species-specific diel periodicity except *D. vulgaris*. Average daylight catch rates of *D. vulgaris* were significantly higher than in twilight and night periods throughout the study (Daylight>Twilight>Night). Kara & Quignard (2019) stated that *D. vulgaris* is the most gregarious seabream and is rarely found alone. The temporal distribution shows a nycthemeral pattern, with more frequent detections during the daylight, regardless of the season (Kara & Quignard, 2019). Similarly, no interaction was found between the sampling season and the time of day in the present study. Dulcic et al. 2004, observed in their research that beach seine catch rates of D. *vulgaris* showed in general diurnal pattern while *D. annularis* was nocturnal. Although they caught the *D. annularis* at very close rates between day and night, they noted it as primarily nocturnal. In the present study, average catch rates of *D. annularis* during the night were slightly higher than in daylight and twilight, respectively. These results could be related to the variation in feeding sheltering behaviours and predator avoidance of individuals of different sizes (Azzuro et al., 2007).On the other hand, Witkowski et al. 2016 pointed out that the diel activity rhythm of *D.vulgaris* is still under discussion. According to their visual observations by the video monitoring system, there is no discernible rhythmicity of the abundances of *D. vulgaris* due to highly variable detections.

In the present study, although there was no significant difference between the catch rates by the sampling periods of a day, the distribution pattern of the average catch rates of *P. acarne* (Daylight>Twilight>Night) during the 24 h cycle was similar to those of *D. vulgaris*. Otherwise, diel variations in the catch rates of the remaining two sparids, *P. erythrinus* and *B. boops,* showed a different pattern. Average catch rates of both species were higher at dark than in the other periods (*P. erythrinus*: Night>Daylight>Twilight, *B. boops*: Night>Twilight>Daylight). Pipitone et al. 1997 observed that the catches of *P. erythrinus* did not show any important diel variation. The higher catch rates in the dark can be because those species may be closer to the bottom, form more extensive shoals (herding behaviour), and become more vulnerable to the trawl. Almost identical discussions have been made by various researchers for different species (Nash & Santos, 1998; Petrakis et al., 2001; Carpentieri et al., 2005; Azzuro et al., 2007; etc.).

Few studies in the Mediterranean Sea have considered the relationships between fish abundance/catch rate and light intensity (Cartes et al., 1993; Pipitone et al., 1997; Relini et al., 1997; Dulcic et al., 2004; Carpentieri et al., 2005; Witkowski et al. 2016). These studies, furthermore, have focused their attention on a few commercial species (i.e., *M. merluccius* or *Aristeus antennatus*) or the structure and composition of nektobenthic assemblages. The present study is the first detailed research examining the variations in the bottom-trawl catch rates of sparid fish over 24 h for the Turkish coastal area and the Mediterranean Sea. There are many methods to collect data during a diel period, such as acoustic, telemetry, tag-recapture experiments, visual observations and sampling with various fishing techniques. Although bottom trawling is one of the effective methods to collect data for determining catch indices relating to the population density of demersal fishes, the essential requirement is to produce more reliable and unbiased results (Godø, 1994; Casey & Myers, 1998; Nash & Santos,1998; Petrakis et al., 2001). Using the same trawl gear, vessel and sampling methodology under the same environmental conditions can be a solution to reduce the bias due to sampling (Petrakis et al., 2001). In this context, the data collected with a standard methodology in the present study is relatively reliable. Nevertheless, the results were interpreted with caution because many factors affect the efficiency of the trawl operation. One of the critical factors is the trawling duration, and prolonged duration or more frequent trawl sampling will allow more reliable and precise data for each species' distribution and catch rates. Since the trawling duration was almost the same throughout the study, the errors that may arise from the trawling duration can be assumed to be minimum.

Bottom-trawl samplings carried out only in a single depth is the most critical weakness of the present research. Performing trawl samplings at different depth layers during 24 h cycle would provide more detailed information about the horizontal distributions and movements of the sparid fishes. This gap needs to be filled by future studies and will provide complementary information.

In conclusion, investigating the distribution pattern and behavioural ecology of demersal marine organisms during a diel cycle is complex. Information on diel variations obtained in this study could be fundamental in understanding the distribution dynamics of the sparid fishes and developing future management approaches.

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Author Contributions

The author contribution is equal for the preparation research in the manuscript.

Conflict of Interest

The author declares that he has no conflict of interest

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