North-Western Journal of Zoology
P-ISSN: 1584-9074, E-ISSN: 1843-5629

Vol. 5, No. 2, 2009, pp.225-241
Article No.: 051119

Distribution and population dynamics of *Aurelia aurita* (Cnidaria; Scyphozoa) in the southern Black Sea

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Abstract. The distribution, abundance, biomass and population dynamics of the jelly fish, *Aurelia aurita* were determined during 2001-2003 in the southern Black Sea (Sinop Region). *Aurelia aurita* was collected by hand net from inshore and with vertical and with horizontal net hauls from offshore. Volume (wet weight) to length (disc diameter) relation was calculated to be WW= 0.1988 $L^{2.4406}$ (R= 0.9525, N= 1162) during October 2001-December 2003 in handling samples; WW= 0.2773 $L^{2.1282}$ (R= 0.9351, N= 351) during May 2002-December 2003 in vertical and horizontal net hauls, respectively. In March 2003, maximal abundance and biomass of *Aurelia aurita* were 20 ind.m^{-2} and 2130 ml.m^{-2} at station A, respectively. In horizontal tows, maximum abundance and biomass was found in November 2003 (10.63 ind.100m^{-3}) at station A and in April 2003 (291 ml.100m^{-3}) at station C. Abundance and biomass of *A. aurita* was detected to increase in autumn and from early to late spring. The highest biomass of *A. aurita* was observed in March, July and December of 2002 and March and April of 2003. Biomass and abundance was not found to be significantly different between stations A, B and C at Sinop region in the southern Black Sea (p>0.05). Difference of the size and weight relationships was not found among different months in 2002 and 2003 in shallow and hauls sampling (p>0.05). In survey, the difference in diameter groups was found significant (p<0.05) among months of 2002 and 2003.

Key words: Jellyfish, *Aurelia aurita*, Black Sea, distribution, population dynamics.

Introduction

Moon jellyfish *Aurelia aurita* has been reported from a variety of coastal and shelf sea marine environments (Dawson & Jacobs 2001, Schroth et al. 2002). Several reports indicate considerable ecological as well as commercial impacts of medusae on coastal regions. Jellyfish may be a major limiting factor for the population growth in copepods and larval fish. They may impede fishing activities, power plant cooling, and local tourism (Möller 1980).

Aurelia aurita is very common in the mixed layer down to the subthermocline region in the Black Sea. Small animals are mostly found above the thermocline, while larger individuals up to 40 cm are found just below it (Mutlu 1999, Kideys & Romanova 2001). The biomass of *A. aurita* fluctuates seasonally. The biomass of *Aurelia* reaches a maximum during spring and at the end of summer and beginning of autumn (Shuskina & Musayeva 1990). In the enclosed, brackish Black Sea the number and biomass of *A. aurita* underwent changes by several orders of magnitude in recent decades. From low levels reported for the 1940s and 1950s, the total biomass of *Aurelia* has increased with intensifying eutrophication of the Black Sea and reached to 1 million tons wet weight (wwt) in the early 1960s (Shuskina & Musayeva 1983, Caddy & Griffiths 1990). The population size of *Aurelia* exploded in the late 1970s, making a peak at a total wwt of 300-500 million tons in 1980s. The peak biomass is equivalent to about 1.5 kg wwt of *Aurelia* m^{-2} (Mutlu et al. 1994, Kovalev & Piontkovski 1998). Following the population bloom of the invading comb jelly, *Memiopsis leidyi*, in 1988/89, biomass of *Aurelia* was reduced. After the decrease of *Mnemiopsis* in summer 1990 the biomass of *Aurelia* increased again and since summer 1991 the biomass of both species has remained at the same level (Mutlu et al. 1994, Shiganova 1997) however with the competition in favor of *M.leidy*i. Shiganova et al. (1998) found a significant negative correlation (n=14, r=–0.80, p=0.005) between the amount of *M. leidyi* and the biomass of *A. aurita*, indicating a potential for an intense competition between these species.

Aurelia and *Mnemiopsis* inhabit the same layer above and around the thermocline and compete for the same planktonic food. Since *Mnemiopsis* has a faster generation time and a higher production rate than *Aurelia* it was presumably successful in depressing *Aurelia* in the first years (Kideys 1994).

Although studies are scarce concerning *Aurelia aurita* at the Turkish coasts of Black Sea, Tunçer (1990), Mutlu et al. (1994), Mutlu & Bingel (1999), Mutlu (2001), Mutlu (2007), Kideys & Romanova (2001) and Ünal (2002) have reported on spatial distribution, abundance and biomass, diameter distribution and morphometry of this species. In order to contribute to these studies, we aimed to determine the monthly variations of abundance-biomass values, wet weight-length relationships, diameter distributions and also development and reproduction times of *A. aurita* populations at Sinop coast where effective currents (anti-cyclonic eddy) are seen and important fishing activities take place.

Materials and Methods

Samples of *Aurelia aurita* were collected from the shallow waters of the southern Black Sea (Sinop region) in October - November 2001, March - June 2002 and during 2003 (except November 2003) using hand nets (mouth diameter 25 cm and 0.5-1 mm mesh size) (Table 1).

Hand sampling was conducted at monthly intervals to estimate volume (wet weight) to length (disc diameter) relation. Sampled medusae were transferred into a 5 l plastic bucket and rapidly transported to the laboratory for morphometric measurements.

Abundance, biomass and volume (wet weight) to length (disc diameter) relation of *Aurelia aurita* were determined from both vertical and horizontal hauls. The sampling was carried out during cruises of R/V "Arastırma I". All samples were obtained monthly and during daytime. The abundance and biomass of *A. aurita* was studied by collecting plankton nets (50 cm diameter mouth opening and 500 μm mesh size for horizontal hauls; 50 cm diameter mouth opening and 210 μm mesh size for vertical hauls). Samples were collected monthly from three stations between May 2002-December 2003 (except June 2002 and August 2003) in the coastal zone of Sinop (max. depth of Station A: 25 m, max. depth of Station B: 50 m, max. depth of Station C: 65 m) (Fig. 1).

Horizontal tows were utilized by towing the net for 15 minutes at a vessel speed of 3 miles h^{-1}. Vertical samples were obtained by standard plankton net

Table 1. Sampling dates and haul types of sampling stations (H.S: Handling Sample, H: Horizontal, V: Vertical).

Sampling Date	Stations			
	H.S.	**A**	**B**	**C**
13 October 2001	+	-	-	-
22 November 2001	+	-	-	-
05 March 2002	+	-	-	-
25 April 2002	+	-	-	-
01 May 2002	+	-	V,H	V,H
02 July 2002	+	-	V,H	-
06 August 2002	-	-	V,H	-
26 September 2002	-	-	V,H	-
23 October 2002	-	-	V,H	-
26 November 2002	-	H	V,H	V,H
26 December 2002	-	H	V,H	V,H
21 January 2003	+	H	V,H	V,H
25 February 2003	+	H	V,H	V,H
27 March 2003	+	H	V,H	V,H
30 April 2003	+	H	V,H	V,H
13 May 2003	+	H	V,H	V,H
26 June 2003	+	H	V,H	V,H
31 July 2003	+	H	V,H	V,H
11 September 2003	+	H	V,H	V,H
23 October 2003	+	H	V,H	V,H
26 November 2003	-	H	V,H	V,H
26 December 2003	+	H	V,H	V,H

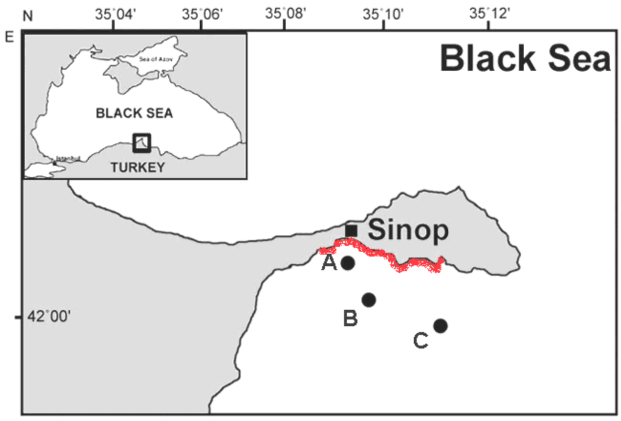

Figure 1. Sampling stations at Sinop region in the southern Black Sea (**A:** 42° 01' 15" N- 35° 09' 00"E, **B:** 42° 00' 21" N- 35° 09' 32"E, **C:** 41° 59' 27" N- 35° 10' 12"E).

at each station vertically from bottom to surface.

At the end of each haul, nets were exteriorly washed and their cod end contents were washed through a 2 mm sieve to retain the gelatinous organisms. Mean abundance and biomass values were calculated from data obtained from vertical and horizontal hauls (Station B and Station C) and horizontal hauls (Station A) at three stations.

Disc diameters of specimens were measured to the nearest millimeter and individual displacement volumes (ml) were determined in finely graded cylinders for each sampling periods. Monthly length-frequency distributions were categorized into 2 cm length classes.

Sea water temperatures (10 m) were measured using a YSI 6600 profiler. Spearman rank correlation was applied in order to test for relationships between temperature and abundance-biomass of *Aurelia aurita*. Volume (wet weight) to length (disc diameter) relationship at each station was tested using ANCOVA and abundance-biomass to months relation was tested using Kruskal-Wallis (ANOVA) non-parametric variance analyses, employing MINITAP 13.0 package.

Results

The following analysis of the size composition of *A. aurita* in southern Black Sea does not include ephyrae and planulae larvae (<1 cm) which could not be measured. The disc diameters of a total of 1513 jellyfish were measured between 2001 and 2003.

Handling sample data

We demonstrated that wet weight of the jellyfish could be estimated by exploring the association between disc diameter and wet weight. Non-linear, quadratic functions revealed significant relationships between disc diameter and wet weight of *Aurelia aurita*. Volume (wet weight) to length (disc diameter) relationship of *A. aurita* was estimated to be $WW= 0.1904\ L^{2.451}$ (R= 0.9585, N= 721) and $WW= 0.2234\ L^{2.4009}$ (R= 0.9341, N= 441) in October 2001-June 2002 and January 2003-December 2003 in handling samples, respectively (Fig.2). The strong regression between disc diameter and wet weight is applicable to the total sample (Fig.2). In the first period, length and weight relationship was found to be stronger compared to the second period. The difference may have resulted from lesser food (zooplankton) and smaller individual sample size.

The relationship between size and weight of medusae was measured during each sampling. ANOVA was applied for homogeneity of slopes and no difference was detected ($p > 0.05$). No difference was also found in terms of size and weight relations among different months during 2001-2002 (Table 2a). However in 2003, the intercepts of slopes were considerably different and size-weight relationship showed a variation among months ($p<0.001$, Table 2b).

Hauls sample data

A total of 351 individuals were counted during the sampling period. Figure 3 combines data from different years to give disc diameter and wet weight of *Aurelia aurita*. Average diameter (cm) and average wet weight (ml) of *A. aurita* are shown in Tables 3 and 4. In 2002, small disc diameters presented an increase in July, August, September and October. Maximum average wet weight was noted in May 2002 (Table 3).

In 2003 surveys, high weight and diameter values were detected in February 2003 and March 2003, followed by lower average disc diameters and weight in late spring and early summer. However, larger

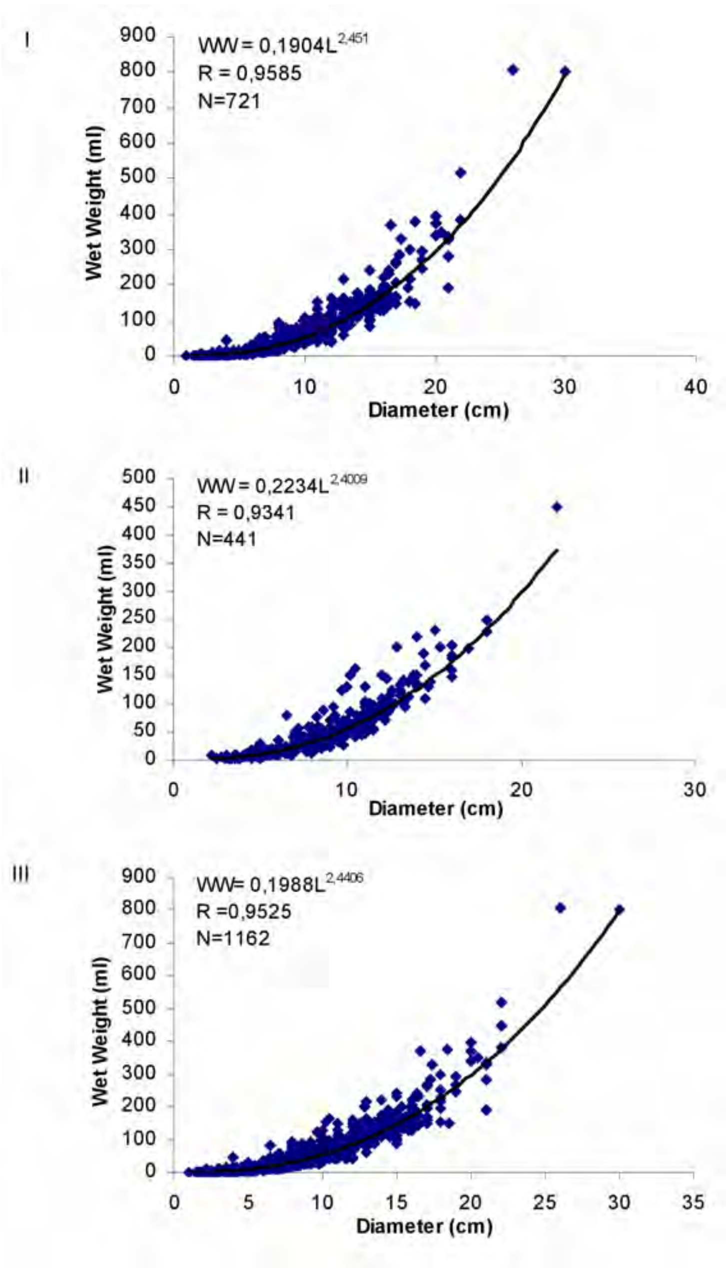

Figure 2. *Aurelia aurita* diameter to wet weight relationship at Sinop region. Handling samples (I: 2001-2002, II: 2003, III: 2001-2003).

Table 2. ANCOVA test to evaluate differences among intercepts on the relationship between 2001-2002 and 2003 (a) 2001-2002, (b) 2003.

(a)

Source of Variation	DF	MS	F	P
Size	1	3202977	1989.22	< 0.001
Month	9	6051	3.76	0.002
Error	714	1610		

(b)

Source of Variation	DF	MS	F	P
Size	1	637839	1374.14	< 0.001
Month	9	2909	6,27	< 0.001
Error	430	464		

Table 3. *Aurelia aurita* average diameter (cm) and average wet weight (ml) (X±SE) at Sinop region during 2002.

Months	Diameter (cm)	Weight (ml)	Individual (n)
May	6.44 ± 0.60	21.26 ± 4.50	23
July	3.74 ± 0.25	6.54 ± 1.17	25
August	2.43 ± 0.45	3.09 ± 0.70	4
September	3.13 ± 0.57	1.81 ± 0.70	3
October	3.35 ± 0.40	3.33 ± 0.76	10
November	4.62 ± 0.43	10.20 ± 3.08	46
December	4.60 ± 0.37	9.92 ± 1.71	45
Mean	**4.58 ± 0.21**	**10.38 ± 1.30**	**∑=156**

individuals were observed in winter. *Aurelia aurita* was observed to present with small disc diameters in May, September and October 2003 (Table 4) when dominance of small individuals were seen in the coastal zone.

The average wet weight increased during late winter and early spring indicating that small individuals (new generation) dominated in spring and autumn. Mean disc diameter increased during summer and winter. Average weight and maximum diameters differed between 2002 and 2003 (Table 3, 4). We consider that the variations in sea water temperature led to changes in timing of ephyrae release and in growth rate resulting in a wide size range of medusae occurring in the water column at the same time.

Volume (wet weight) to length (disc diameter) relationship of *Aurelia aurita* was calculated to be $WW= 0.428\ L^{1.840}$ ($R= 0.9121$, $N= 156$) and $WW= 0.1614\ L^{2.4394}$ ($R= 0.9661$, N= 195) in 2002 and 2003, respectively (Fig.3). Exponent b increased while the coefficient a declined from 2002 to 2003. It is obvious from Figure 3 that a strong relationship exists between wet weight and diameter of *A. aurita*.

We applied the test of homogeneity of slopes and differences between slopes and they were not found to be statistically significant (ANOVA, $p > 0.05$). The resulting slopes and Y-intercepts were examined by an analysis of covariance (ANCOVA). No difference was found for the size and weight relationships among different months during 2002 and 2003 (Table 5a, b).

Size composition of Aurelia aurita in hauls sampling

Aurelia aurita appeared in the water column throughout the year but exhibited seasonal dynamics. Size composition demonstrated a wide diameter range during late winter and spring (Fig 4.).

The difference in diameter groups was found to be significant ($p<0.05$) among the months of 2002 and 2003. The difference of diameter composition was found to be significant on a monthly basis, except September in 2002. A significant difference was detected in February, March and April 2003 (ANOVA, $p<0.05$). Diameter frequency showed a wide range in May 2002, January 2003, April 2003 and September 2003. The diameter differences were found to be significant in late winter and spring of 2002 and 2003.

Abundance and biomass of Aurelia aurita

Vertical Distribution

Maximal abundance and biomass of *Aurelia aurita* were found to be 20- ind.m^{-2} and 2130 ml.m^{-2} in March 2003 at the station B, respectively. A higher abundance was detected in July 2002 (20 ind.m^{-2}) and September 2003 (17.5 ind.m^{-2}). In spring, large numbers of small medusae (<50 mm) were observed.

Table 4. *Aurelia aurita* average diameter (cm) and average wet weight (ml) (X±SE) at Sinop region during 2003.

Months	Diameter (cm)	Weight (ml)	Individual (n)
January	6.84 ± 0.61	20.52 ± 4.97	21
February	11.38 ± 2.93	106.38 ± 50.56	8
March	11.13 ± 2.93	106.50 ± 50.42	8
April	9.51 ± 1.04	81.21 ± 18.76	29
May	3.75 ± 0.25	2.25 ± 0.75	2
June	5.78 ± 0.63	15.52 ± 3.69	26
July	5.70 ± 0.84	14.64 ± 6.39	7
September	4.85 ± 0.44	12.92 ± 3.28	31
October	3.98 ± 0.42	5.78 ± 1.42	9
November	5.13 ± 0.33	11.76 ± 2.34	48
December	6.58 ± 1.00	14.67 ± 4.08	6
Mean	**6.51 ± 0.31**	**31.31 ± 4.6**	**∑=195**

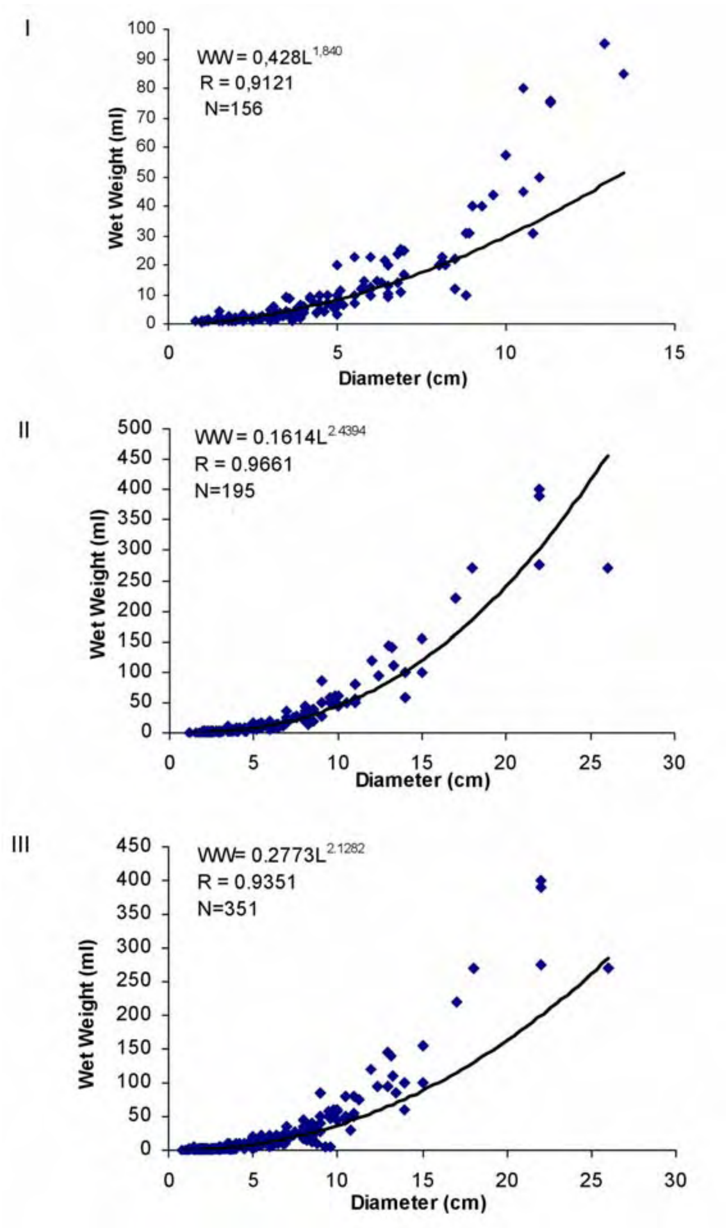

Figure 3. *Aurelia aurita* diameter to wet weight relationship at Sinop region. Vertical and horizontal hauls (I: 2002, II: 2003, III: 2002-2003).

Table 5. ANCOVA test to evaluate differences among intercepts on the relationship between 2002 and 2003 (a: 2002, b: 2003).

(a)

Source of Variation	DF	MS	F	P
Size	1	27984.4	397.39	< 0.001
Month	6	26.4	0.38	0.894
Error	148	70.4		

(b)

Source of Variation	DF	MS	F	P
Size	1	469831	591.61	< 0.001
Month	10	1434	1.81	0.062
Error	183	794		

The highest biomass of *A. aurita* was observed in December 2002 (320 ml.m^{-2}) and February 2003 (255 ml.m^{-2}). Average biomass of *Aurelia* was not constant throughout the period of 2003 and was similar to that in 2002 (Fig.5).

Plankton sampling was not conducted regularly in 2002. Maximum biomass of *Aurelia aurita* at station C was determined to be 376 ml.m^{-2} and 215 ml.m^{-2} in May 2002 and April 2003, respectively. A high abundance of 15 ind.m^{-2} was found in September. An abundance increase occurred at both stations during spring and autumn (Fig.5). The inshore biomass of *A. aurita* was generally higher. Seasonal distribution of *A. aurita* was not correlated with temperature in st.B (p>0.05). The biomass and abundance of *A. aurita* wasn't significantly different between stations B and C (p>0.05).

Horizontal Distribution

Horizontal tows were carried out at three stations. Maximal abundance was detected in November 2002 and 2003 (7.69 ind.100 m^{-3} and 10.63 ind.100 m^{-3}), while maximum biomass was observed in February (175.9 ml.100 m^{-3}) and November 2003 (163.12 ml.100 m^{-3}) at station A. The highest values at station C occurred in May 2002 (137.5 ml.100 m^{-3}) and April 2003 (291 ml.100 m^{-3}). Abundance and biomass were determined to increase in December 2002 and February 2003.

Maximal abundance and biomass of *Aurelia aurita* at station B was noted in December 2002 as 8.44 ind.100 m^{-3} and 94.9 ml.100 m^{-3}. Biomass made a decline in July 2002, June 2003 and December 2003 (Fig.6). Inshore horizontal distribution of *Aurelia* was observed to be a little higher. In horizontal tows biomass and abundance values were not significantly correlated with temperature (p>0.05). The difference among disc diameters of *A. aurita* obtained in vertical and horizontal tows were significant on a monthly basis (p<0.05). In addition, abundance and biomass were not noticeably different among stations (p>0.05). However, difference in sampling stations was significant depending on vertical and horizontal tows (p<0.05). *A. aurita* showed a higher vertical distribution.

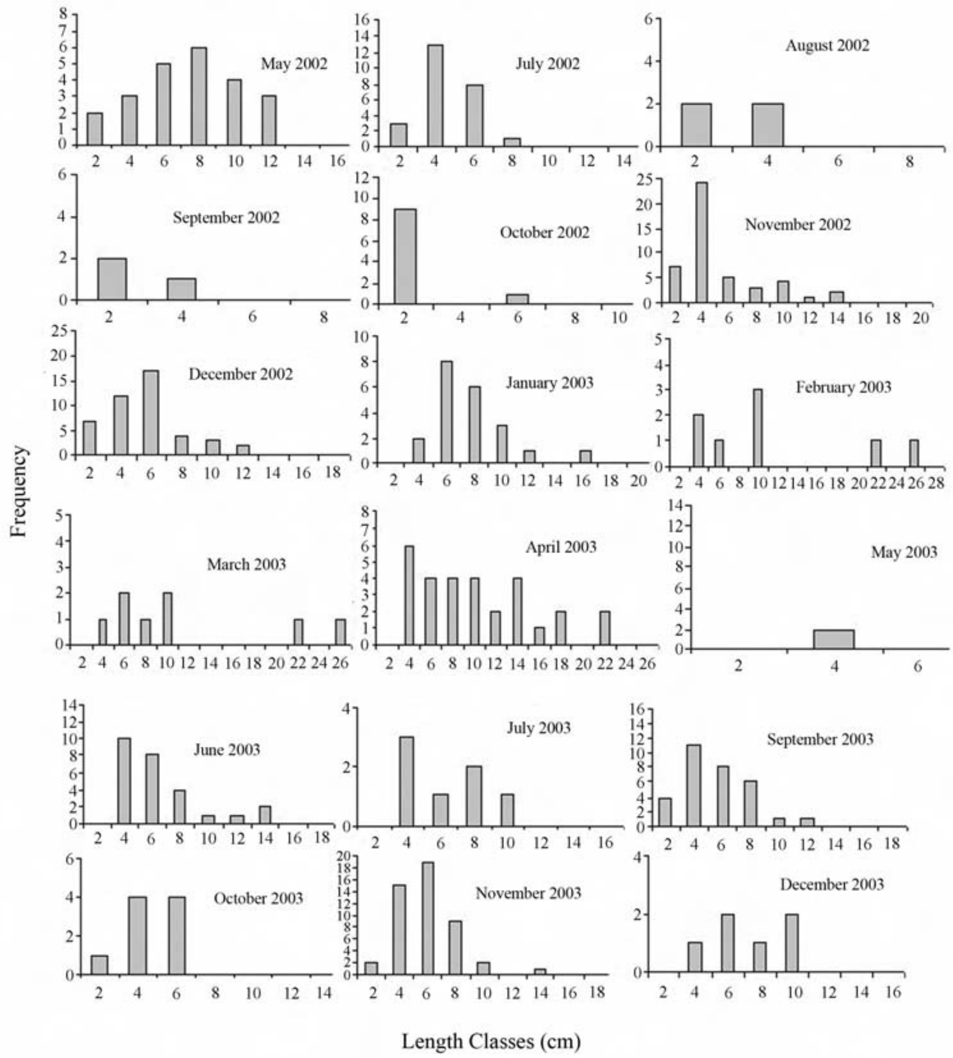

Figure 4. *Aurelia aurita* size composition at Sinop Bay between May 2002 - December 2003 in hauls sampling.

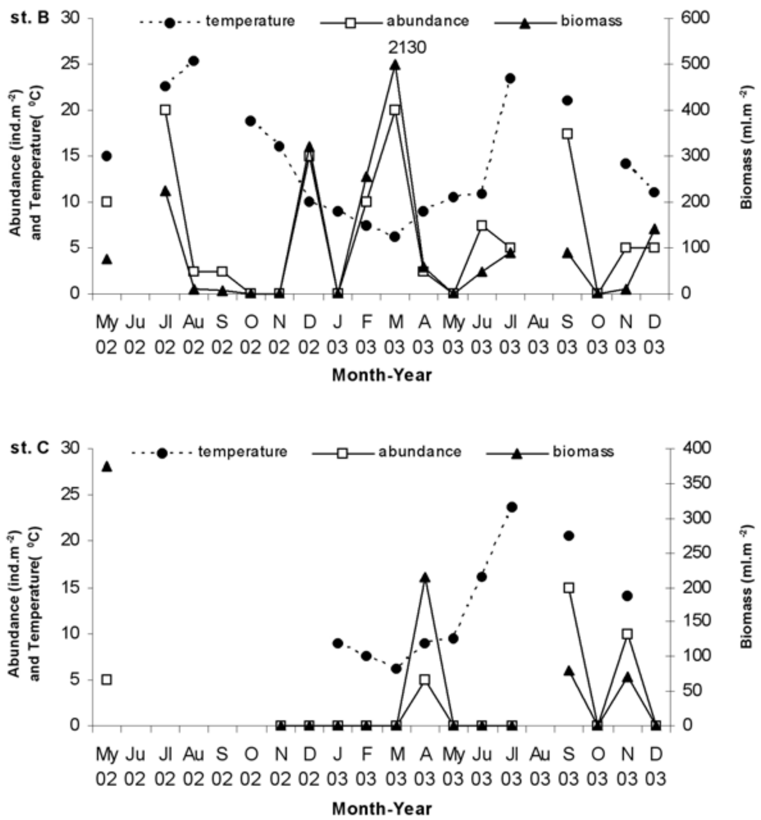

Figure 5. *Aurelia aurita* vertical abundance (ind. m^{-2}) and biomass ($ml.m^{-2}$) values at Sinop region.

Discussion

Aurelia aurita has been shown to be an important predator on smaller species of several other fish larvae (Kideys et al. 2000, Niermann 2004). *A. aurita* consumed three times more fish egg and larva compared to *Mnemiopsis leidyi* as detected in stomach content analyzes (Mutlu 2001). Although there is no proof, *A. aurita* seems particularly abundant in eutrophicated regions (Caddy & Griffiths 1990). *A. aurita* is characteristic of the Black Sea pelagic fauna (Zenkevitch 1963), and its population has recently increased substantially.

Understanding the temporal variation and life history of *Aurelia aurita* is of importance if we are to predict present and future role of it in Black Sea ecosystem (Purcell 2005, Lynam et al. 2005). This study aimed to follow variation of jellyfish *A. aurita* in southern Black sea. To this aim, we

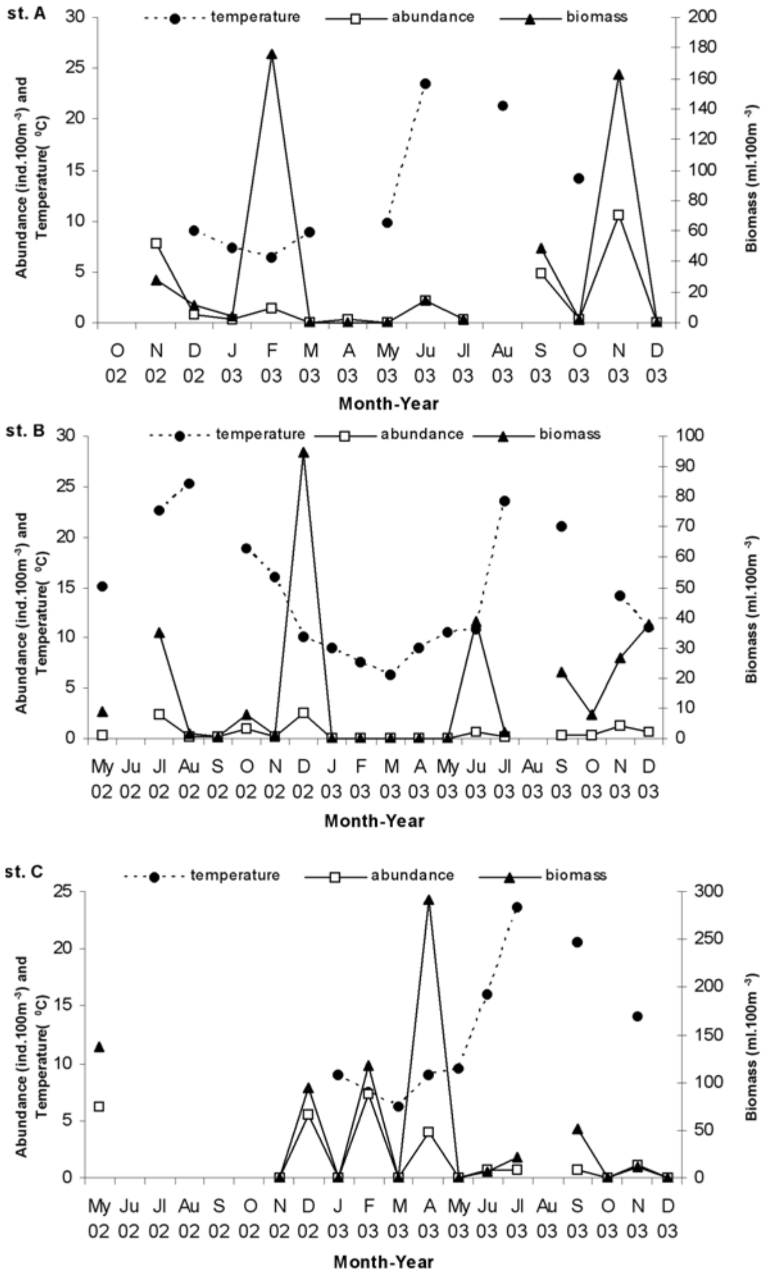

Figure 6. *Aurelia aurita* horizontal abundance (ind. 100m[-3]) and biomass (ml.100m[-3]) values at Sinop region.

explored size composition and seasonality of jellyfish *A. aurita* in the Sinop region, the southern Black Sea. First, we tested if the size of *A. aurita* showed timely and monthly variation. Second, we attempted to determine the population level of *A. aurita* during 2002-2003.

A maximum diameter of 42 cm has been found in western Baltic and Black Sea (Ishii & Bamstedt 1998) whereas in northwestern Black Sea the maximum diameter was measured to be 17 cm (Weisse & Gomoiu 2000). Mean diameter of *Aurelia aurita* in the Black Sea didn't exceed 10 cm and the maximum diameter was 28 cm in January 1992, 23 cm in August 1993, 30.5 cm in May and 43 cm in March 1995. Individuals with a diameter <10 cm were determined to make up 25% of the population in March 1995 whereas in August 1993 the percentage of small individuals declined to a minimum level of 1% (Mutlu 2001). In our research, the largest and smallest diameters were measured as 26 cm (in March 2003 and February 2003) and 1.2 cm (in May 2002) respectively. Smaller individuals (disc diameter ≤2 cm) dominated in late spring. Individuals with a diameter <10 cm represented 80% of population and individuals of 4 cm were dominant in September 2002 (24%) and September 2003 (14%). Disc diameter of *A. aurita* in the Sinop region was lower compared to the Baltic Sea and higher than those found in the northwestern Black Sea.

In open waters, the disc diameter ranges from 20 - 30 cm, although the more abundant medusae from semi-enclosed areas reach peak diameters of 4-10 cm (Ishii & Bamstedt 1998). In this study *Aurelia aurita* was observed to be larger in offshore waters during summer. We considered the water temperature and food supply to have influence on this result.

Inshore-offshore differences had little effect on this seasonal variation since individuals sampled at shelf stations dominated at all times. The seasonal variation of the volume to length power function is of importance if the biomass is not calculated directly as displacement volume (this study), but indirectly derived from size measurements. Kovalev & Piontkovski (1998) have suggested an association between diameter and weight as $Wwt = 0.0028\ L^{2.19}$ in order to calculate the biomass of *Aurelia* in the Black Sea. Weisse & Gomoiu (2000) estimated this relationship to be $W= 0.08\ L^{2.71}$ for northwestern Black Sea. In our study, correlation coefficients for diameter-weight of *A. aurita* were high (R = 0.9525 in n= 1162) and relation of diameter and weight was estimated as $Ww=0.1988\ L^{2.4406}$ in 2001-2003 handling sampling (inshore) whereas for offshore waters it was $W= 0.2773L^{2.1282}$ (R= 0.935, n= 351). In our results, condition factor was found to be good. Using equations, we were able to estimate the wet weight of this jellyfish, based on disc diameter alone.

Surveys were carried out in two subsequent years and abundance of *Aurelia aurita* showed great seasonal and annual fluctuations. Distribution of *Aurelia* was highly patchy during our investigation. Data of *A. aurita* were explored over broad temporal and spatial scales. *Aurelia aurita* populations fluctuate throughout the year. In the present study, biomass of *A. aurita* was demonstrated to rise in spring and autumn which we attributed to reproduction, thereby adding to the biomass during this period. Similarly, in other regions of the Black Sea, the maximum biomass values of *A. aurita* were observed in spring and autumn (Shushkina & Musaeva 1990, Mutlu 2001). In the western Black Sea, the biomass and abundance of *A. aurita* showed an increase in early spring (March 1995) and a peak in late summer (August 1993) (Mutlu 2001).

A high abundance of *Aurelia aurita* was seen in the Sinop coast especially in late spring, early summer and autumn. Small individuals of *A. aurita* increased in spring and summer probably due to the acceleration in sexual cycle of the organisms at the coast during those periods indicating the release of *A. aurita* ephyrae in coastal areas beginning with warming in sea water. Vinogradov et al. (1992) found similar results in their study. We detected that *A. aurita* occurred with the lowest abundance in winter although biomass was high in several months. Larger individuals observed in winter samplings which helps account for the higher biomass discovered in these periods. Shushkina & Musaeva (1983) showed mass mortality in winter generation and consequently a decrease in the biomass during mid-summer. Peak of zooplankton resulted in growth of the gelatinous population in spring. In this study, *A. aurita* was observed to increase in December of 2002 and February, April, September and November of 2003. Concordantly, Bat et al. (2005) reported a peak of zooplankton in Sinop region during the same time periods. Available and suitable prey to medusae has effect on reproduction, growth and population of *Aurelia.* Mutlu (2001) reported that an increase in water temperature resulted in a peak of zooplankton biomass and consequently in *A. aurita* from late spring (May 1994) to late summer (August 1993). Similarly, Shiganova (1998) showed an increase in the biomass from April to August in western Black Sea.

During our study, maximum average abundance and biomass was 7.6 ind.m^{-2} and 96.9 g ww m^{-2}, respectively. A high abundance and biomass was recorded in May - July 2002 and March - April - September 2003. Mutlu et al. (1994) reported a mean wwt of *Aurelia* ranging from 146 to 280 g m^{-2} at inshore and 41 to 260 g m^{-2} at offshore stations in the western Black Sea for June 1991, July 1992 and August 1993. The biomass of *Aurelia aurita* was about four times lower during 1991-1992 than the stock estimates of 400 million tons for the whole Black Sea during 1978-1988 (Gomoiu 1981). The reduction in the biomass of *A. aurita* during 1989-1993 was not so severe that levels fell to those of the 1950's and early 1960's, when the total wet weight was about 30 million tons for the whole Black Sea (Shushkina & Musayeva 1983). In the central part of the Black Sea, *Aurelia* biomass was found to range from 69 to 1449 g m^{-2} during 1990-1995 (Kovalev & Piontkovski 1998). Weisse & Gomoiu (2000) calculated mean values of 132–179 g wwt m^{-2} which fall into this range. Shiganova (1997) estimated somewhat higher values for the whole Black Sea for the period 1993 to 1996.

Vinogradov et al. (1989), Mutlu et al. (1994), Kideys & Romanova (2001) and Shiganova et al. (2004) reported *Aurelia aurita* to compete with *Mnemiopsis leidyi.* This jellyfish and comb jelly inhabit the same layer above and around the thermocline and compete for the same planktonic food. Tropical *M. leidyi* has been more successful than *A. aurita* leading to a decrease in abundance in the Black Sea since 1988 (Shiganova et al. 2001, Kideys et al. 2005). Mean abundance and biomass of *M.*

leidyi and *A. aurita* was compared for Sinop waters. Bat et al. (2005) and Birinci-Özdemir (2005) reported the population levels of *M. leidyi* in 2002-2004. In our study, summer biomass of *A. aurita* was generally found to be lower, whereas abundance of *M. leidyi* was higher in July and August accounting for the poor biomass of *A. aurita* in summer. Only in July 2002 biomass of jellyfish was higher due to the big size of individuals. It was observed that the boost in abundance of *M. leidyi* caused a reduction in *A. aurita* biomass in August 2002 (12.5 n.m^{-2}) and September (15 n.m^{-2}). Mean abundance of *M. leidyi* made a peak of 86.25 n.m^{-2} in July 2003 as the mean value of *A. aurita* decreased to 2.5 n.m^{-2}. Mean abundance of *M. leidyi* declined in September 2003 (20 n.m^{-2}) whereas *A. aurita* demonstrated a slight rise (10.8 n. m^{-2}). Ünal (2002) reported that *A. aurita* did not seem to follow a seasonal pattern, displaying two distinguishable peaks in early January (20 n.m^{-2}) and late July (36 n.m^{-2}) at inshore, and a single remarkable peak in late April (36 n.m^{-2}) at the offshore waters of southern Black Sea in 1999. The maximum biomass was more profound in late July (753 g.m^{-2}) and late April (950 g.m^{-2}). We examined recent data and our findings suggested no pronounced increase in the population of *A. aurita*. In addition, the population of *A. aurita* was found to have been approximately balanced in Sinop coast at the southern Black Sea. We also observed that *A. aurita* showed a seasonal variation, however with no statistically significant correlation with temperature. In calm shallow waters, a rise was seen for *A. aurita* biomass following stormy and windy air conditions.

Conclusion

Different periods can be defined in the evolution of the Black Sea ecosystem during the last few decades. Each of these periods was characterized by development of certain species of gelatinous macroplankton. *Aurelia aurita* was dominant in gelatinous plankton until 1987 when the Black Sea basin was conquered by ctenophore *Mnemiopsis leidyi*. The invasion of *M. leidyi* in the Black Sea prevailed in gelatinous macrozooplankton until the invasion of another carnivorous ctenophore *Beroe ovata*, considered to be a specialized predator, feeding on *M. leidyi*. Each period of the ctenophores population explosions was characterized by significant changes in the structure of plankton communities in the pelagic ecosystem of the Black Sea which effected fish productivity. This was first caused by *Aurelia*, then by *Mnemiopsis* and finally by *Beroe*.

Therefore, the significance of indirect trophic relations and direct feeding interactions among the gelatinous zooplankton in the Black Sea has important consequences for the energy flow along the food web. This might well be so and requires further investigation.

Aurelia aurita peaked in spring and late autumn. Biomass was high while abundance was low in summer. *A. aurita* reproduction increased in the spring, the maximum biomass occurring in March and April. Maximum size was noted in May 2002 (from handling sample) and March 2003 (hauls sample).

Acknowledgements. This study was supported by T.C. Basbakanlik DPT (T.R. Prime Minister State Planning

Organization), Project Number 2002 KI20500 (TAP-S013). We would like to thank Prof. Dr. Ensar Başpınar and Assoc. Prof. Dr. Erhan Mutlu for comments on statistical analysis. Suggestions from three anonymous reviewers are greatly appreciated.

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Submitted: 08 May 2008
/ Accepted: 11 January 2009

Published Online: 01 April 2009