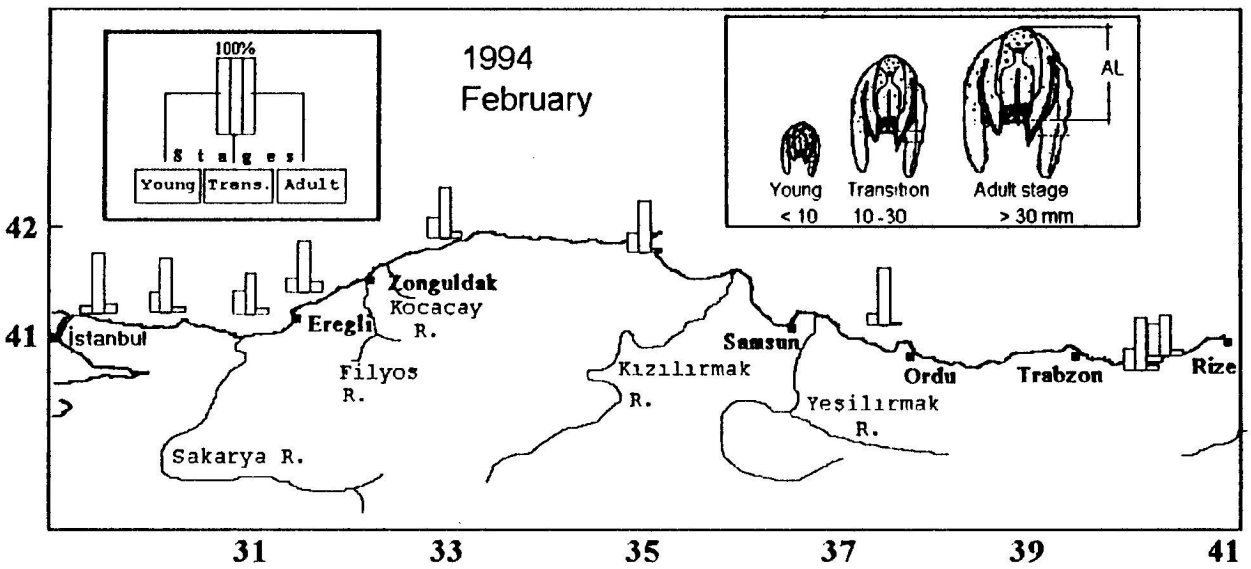
A preliminary study on biometry and size composition of *Mnemiopsis leidyi* (Ctenophora:Lobata) in the Black Sea in space and time (1992-1994)

Erhan Mutlu

Institute of Marine Sciences
Middle East Technical University
P.O. Box. 28, Tr 33731, Erdemli
Icel, Turkey



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Erhan Mutlu
Institute of Marine Sciences
Middle East Technical University
P.O.Box 28, TR33731 Erdemli, Icel,
Turkey

Key words: The Black Sea, Ctenophore, *Mnemiopsis*, biometry, size

Abstract

Five cruises were carried out to monitor the distribution of *Mnemiopsis leidyi* in years January, 1992- April, 1994 in the Black Sea. From the measurements made on the individuals, length (oral-to-aboral length; AL: cm)-wet weight (W: g)-displacement volume (V: ml) relationships were significantly formulized with the following equations:

$V=0.926AL^{1.987}$; $W=0.886V-0.249$ and $W=0.927AL^{2.227}$.

Ratio of aboral to auricle and lobate lengths was 1:0.69:0.65 and auricle-to-lobate length ratio was 0.94. Largest individuals (aboral length) measured 7 cm in January-1992, 5.6 in July-1992, 6.6 in August-1993, 5.9 in February-1994 and 6 in April-1994. Larger individuals appeared in the coastal and open waters of the south-western part of the Black Sea. Base of the lobate comb-jelly was made up of young specimens (aboral length <10 mm) in high percentage (15-50% in April,1994 -August, 1993 and usually 30-50%) in all sampling time. Animals greater than 30 mm (adult specimens) rarely made up more than 12-13% of the total ctenophore density. From January to August, percent recruitment of younger individuals declined slightly within a period of January to April, then increased together with numerical occurrence of adult specimens in August, with the second outburst of *Mnemiopsis* in the Black Sea.

Introduction

The *Mnemiopsis leidyi* Agassiz, A., 1865, is an endemic gelatinous zooplankton of the north-western coast of Atlantic Ocean (MAYER, 1912). The first records about *Mnemiopsis* appearance in the Black Sea go back to the beginning of 1980s (ZAIKA and SERGEEVA, 1991; CADDY, 1993). The welcome of this non-native species to the Black Sea had been speculated on view concerning with the release of ballast water from ocean-crossing vessel. Biomass development of the *Mnemiopsis* in the Black Sea started in 1987 when it occupied only bays and coastal waters. During the summer of 1988 *Mnemiopsis* were introduced also with open areas of the Sea, and in the autumn its biomass reached a considerable amount as much as of 1.5 kg/m^2 (SHUSHKINA and VINOGRADOV, 1991). In 1989 and 1990 the biomass of *Mnemiopsis* grew so considerably that total value for the whole Sea attained 8 x 10^8 (VINOGRADOV, 1990) to 1 x 10^9 (ANON, 1994) metric tons of wet weight in August-September. In several coastal areas its density reached 10-12 kg m^{-2} (ANON, 1994). In 1991 its biomass decreased and declined 4-6 folds gradually on a comparison of statistic in 1989. In 1992 and 1993 the biomass of *Mnemiopsis* remained at same level (100 and 91 million metric tons) (MUTLU, et al 1994) as becoming in autumn-1991.

During the first appearance, *Mnemiopsis* was strictly associated to the upper mixed layer over the thermocline (VINOGRADOV, 1990), therefore, its assemblages were often found immediately under the surface. The young animals were definitely confined to the layer above the thermocline. Presuming as whether to attain the prey (*Calanus*) in the deep water, the large-size ctenophore individuals went down to lower layer of thermocline as occurred in autumn 1989 (SHUSHKINA and MUSAYEVA, 1990). The spring observations of 1991 showed the regular penetrations of large

quantities of ctenophores beyond the thermocline down to the upper boundary of picnocline (BOGDANOVA and KONSOULOV, 1993). At controversy case against previous vertical distribution, only a few individuals were encountered in the surface layer in the summer of 1991 and 1992. The whole population inhabited the thermocline layer, sometimes fetched down to the boundary of picnocline to feed on copepod.

Population size structure shows differences within year. In the starting of population development in the beginning of spring-summer, mostly adult animals appeared. The size of these individuals varied from 20-55 mm aboral length. At that time juveniles and larvae usually disappeared. Percent proportion of juveniles (less than 5 mm) to adults was about 10%. At the end of summer and in autumn the base of ctenophore population was made up of small and middle size (5-15 mm) animals, big ctenophore was very rare at this time. The maximum size did not exceed 70-80 mm aboral length (VOLOVIK et al, 1993). Young ctenophores were predominant in nearshore waters, particularly on the north-western shelf; intermediate-size and large animals concentrated in the depth fall area in convergence waters along the outer margin of the Main Black Sea Current (VOLOVIK et al., 1993). The largest individuals were 75 mm long and 40 mm wide in the waters of the central circulations (VINOGRADOV et al., 1992). Empirical relationship between lobate length (l, mm) and live weight (W;g) of *Mnemiopsis leidyi*, was formulated with the equation of $W=2.36l^{2.35}$ for the Black Sea (VINOGRADOV et al, 1989). The carbon content was slightly higher (0.16%) for small individuals than for large individuals (0.10%) and averaged 0.12% of live weight.

Mnemiopsis sp. hatch out of their egg envelope as cydippid larvae about 24 h after being spawned at 22 to 23 °C (MARTINDALE, 1987). Individuals have reached 10 mm length in 5 days and complete the first stage (precociously reproductive young). The transition to

the lobate stages begins at around 5.0 mm (oral-aboral length) and is complete around 15 mm. Individuals of *Mnemiopsis* have attained a size in excess of 90 mm in the laboratory (REEVE et al. 1978). Adult begins to reproduce at 30 5 mm, at an age of 13 to 17 days, depending on growth rates (BAKER and REEVE, 1974).

Size composition and structure of *Mnemiopsis leidyi* was one of guidelines offered at the meeting on the scientific aspects of marine pollution for the Black Sea (ANON, 1994). This study represented the detailed biometry and size composition of *Mnemiopsis leidyi* in the Black Sea in years 1992-1994.

Study Area

All over the world, the Black Sea (423 000 km^2) is one of the large basins having the permanent halocline (80-200 m) and a deep basin with steep slopes in the order of 4-6°. A major shelf area exists only in its north-western region, comprising 27% of the total area of the Black Sea. The surface area of continental shelf in the southern part of the Black Sea is very less regarding to the northern, especially north-western shelf. Circulation of surface water consists mainly of two cyclonic gyres steered by the rim current (Fig. 1). Additionally, there are several mesoscale anticyclonic eddies. The layer of hydrogen sulfide occurs below the halocline. The salinity in the layer from surface to halocline is between 18 and 18.5 in the central Black Sea, 18 and 17.5 over the continental shelf, but drops below 16 in nearshore areas of the western Black Sea. In the open sea in summer the temperatures above the thermocline vary between 23-25 °C, with a maximum of 27 °C, the winter temperatures vary between 5-7 °C while it falls to 2 °C in winter in the north-western shelf area (OGUZ et al., 1993, 1994 and SUR et al., 1994).

Material and methods

Five cruises were conducted in the Turkish Black Sea in January-1992, July-1992, August-1993, January/February, 1994 and April/May-1994 to observe the size composition, hence, spatial distribution of *Mnemiopsis* stages. The surveys were carried out with RV Bilim. Samples were collected with the vertical hauls using Hensen egg net from 55 stations in January-1992, 45 in July 1992, 36 in August 1993, 9 in January/February-1994 and 42 in April/May-1994. The investigated areas of the first four cruises located in the Turkish Exclusive Economic Zone whereas the last occupied additionally the Bulgarian and Romanian zones. Table 1 gives the overall outline of individual sampling within the seasons.

Table 1. Data collection scheme for the cruises.

Net type and mesh size	Hensen 0.3 mm				
Net opening diameter	70 cm				
Hauling speed	1 m s^{-1}				
Depth recording	Angle and wire length				
Sampling depth offshore by total depth >100 m	Anoxic layer-->surface				
Sampling depth inshore by total depth <100 m	2 m above bottom -->surface				
Sampling time	Jan-92	Jul-92	Aug-93	Feb-94	Apr-94
Number of stations for size composition	55	45	36	9	42
Investigated area	TEEZ	TEEZ	TEEZ	TEEZ	T&OEEZ

TEEZ: Turkish Exclusive Economic Zone
T&OEEZ:Exclusive Economic Zone of Turkey and other reperian countries

Regional classification are as follows: inshore areas (<200 m), offshore areas (>200 m), western Black Sea (west of 35 °E), eastern Black Sea (east of 35 °E) and Turkish Exclusive Economic Zone (TEEZ; underneath 43 °N in the western Black Sea).

The haul depth was confined to the upper layer of anoxic zone.

which coincided well with the depth of sigma (theta)=16.2 in the Black Sea (TUGRUL et al ., 1992; OGUZ et al, 1993). In the coastal areas (<100 m depth), net was hauled from depth 2 m above bottom to surface. After numerating and weighing the specimens of *Mnemiopsis*, individuals were sized in the unit of millimeter and settling volumes (ml) were measured in the fine graded cylinders onboard. Four types of length from each individual were measured. These are aboral length, lobate length, auricle length and body width (Fig. 2). In addition to the cruises listed above, another length measurements experiment were made on individuals in the laboratory in Trabzon*. This was used for the establishment of functional relationship between lengths, settling volume and live weight.

Regarding to the apparent biometric changes, individuals <10 mm (aboral length) are defined as a young/juveniles which have a little capability of spawning, 10-30 mm as transition/lobate stage and > 30 mm as real reproductive adult individual (BAKER and REEVE, 1974).

For statistical treatment of morphological and biometric measurements SYSTAT package software was utilized. Prior to the calculation of length and weight-volume relationship via curve-linear regression, raw data was log transformed (base 10) (SOKAL and ROHLF, 1981). No transformation is required for the regression of weight on displacement volume and one length to to length measurements (e.g. lobate length, auricle length, aboral length Fig.2).

Results

Functional equations of the relationships between some biometric variables (aboral length, lobate length, auricle length and body

* Tarım ve Köy İşleri Bakanlığı Yomra Su Ürünleri Araştırma Enstitüsü (Ministry of Agriculture and Rural Affairs-Yomra Aquatic Resources Research Institute)

width: cm; Fig. 2) to wet weight (g) and settling volume (ml) of *Mnemiopsis leidyi* living in the Black Sea were given in Table 2. Individual displacement volume and live weight were fitted to length measurements with the multiplicative model of regression analysis whereas by applying linear regression better concordance for relations between lengths mentioned above was obtained. All relationships were found to be highly significant at a level of $P<0.001$ (Table 2). Following are the equations which summarize the relationship between biometric measurements of *Mnemiopsis leidyi* from the Black Sea. Relationships between all the measurements in a matrix form is given in Figure 3.

Table 2. Functional approximation of length-wet weight-settling volume relationship (Wet weight W, g; settling volume V,ml; aboral length AL, cm; lobate length LL, cm; auricle length ArL, cm; and body width BW, cm).

Empirical equations	Correlation coefficient	Sample size (n)	Probability level (P)
$V=0.926*AL^{1.987}$	0.94	450	0.00000
$V=0.460ArL^{2.054}$	0.93	450	0.00000
$V=0.292LL^{1.867}$	0.94	450	0.00000
$W=0.886*V-0.249$	0.98	49	0.00000
$W=0.393LL^{2.163}$	0.97	213	0.00000
$W=0.334BW^{3.237}$	0.97	92	0.00000
$W=0.927AL^{2.227}$	0.95	214	0.00000
$W=0.460ArL^{2.471}$	0.96	92	0.00000
$AL=0.596*LL+0.205$	0.97	215	0.00000
$AL=0.357*BW-0.866$	0.90	94	0.00000
$AL=0.883*ArL-0.149$	0.98	94	0.00000

Mean ratios between the biometric parameters for all size and for the separated stages in a matrix form were shown in Table 3-4. respectively. Ratio of aboral to auricle and lobate lengths was 1:0.69:0.65 and auricle-to-lobate length ratio was 0.94 (Table 3).

Table 3. Matrix of length-volume-weight ratio of the *Mnemiopsis leidyi*.

	ArL	LL	BW	*W*	V
AL	·0.69	0.65	0.88	0.23	0.11
ArL		0.94	1.27	0.34	0.16
LL			1.36	0.36	0.17
BW				0.27	0.13
W					0.47
n	217	95	216	95	215

About three stages of *Mnemiopsis*, aboral-to-auricle length ratio increased with stages from young towards adult. Lobate length-to-body width ratio was less than 1 (Table 4) only at young stage as individual has not built-up the lobe, yet.

Table 4. Length-to-length ratio of *Mnemiopsis leidyi* into three stages.

	Young stage			**Lobate stage**			**Adult stage**		
	ArL	LL	BW	ArL	LL	BW	ArL	LL	BW
AL	0.67	0.49	0.46	0.74	0.55	0.62	0.76	0.46	0.77
ArL		0.73	0.69		0.74	0.85		0.61	1.01
LL			0.94			1.14			1.67
n	144	144	144	216	216	216	101	101	101

The spatial and temporal size distributions of *Mnemiopsis leidyi* were as follows:

In January 1992, numerical occurrence of adult (> 30 mm oral-aboral length) to young specimens (< 10 mm) was apparently higher in the west regarding to the distribution in east (Figure 6). Animals greater than 30 mm made up less than 15% of the total lobate-ctenophore density (Figure 4). Transistory lobate-stage (10-30 mm) constituted half of the population. 30-35% of the

population in January-1992 was composed of animals less than 10 mm long. Young individuals were higher in the coastal waters of the eastern part of the Black Sea, where coastal waters run between the rim current and the coast in the east (Figures 6 and 1). In coast of the south western Black Sea, particularly area between Bosphorus and Sakarya eddies, transitory and adult *Mnemiopsis* were predominant. *Mnemiopsis* appeared to be smaller with a mean value of the body length of 1.65 cm in the eastern areas compared with that (2.72 cm) of the western part of the Black Sea (Table 5) as minimum, mean and maximum values of aboral length was found to decrease gradually from west towards the east (Figure 6). While minimum, mean and maximum aboral length of *Mnemiopsis leidyi* was siginficantly much higher eastern (1.64, 2.72 and 5.26 cm, respectively) than the western area (0.67, 1.65 and 4.47 cm) of the Black Sea (Table 5) no significant differences were found between inshore and offshore areas. Maximum length differred significantly between inshore and offshore areas of the western part of the Sea whereas mean length was significantly different between the inshore and offshore areas of the eastern part of the Black Sea (Table 5). As shown in size-frequency distribution (Figure 5), the median and mean values of the distribution were characterized with 1.34 cm and 2.16 cm in January 1992, respectively.

In July 1992, adult specimens were so predominant that young individuals seems to be disappeared completely in the western escarpment of the Turkish Black Sea. The eastern basin at which the surface water warmed up to 23-25 $^{\circ}$C was full of young and transitory lobate individuals (Figure 7). Animals greater than 30 mm made up approximately 5% of the population (Figure 4). Adult specimens (>30 mm length) were often observed in the central areas of the western main gyre near rim current. In the western part, young individuals were found to be dominant only at two stations in the east of Bosphorus (Figures 7 and 1) where the

warmer water of the Mediterranean Sea undergo the water mass to the Black Sea. Overall, significant differences in minimum and mean lengths occurred between western (2.87 cm) and eastern (1.57 cm) areas while the distribution of mean length for *Mnemiopsis* appeared to be more stable between inshore and offshore areas (Table 5). The minimum length averaged were larger either western (2.27 cm) than the eastern areas (0.67 cm) or inshore (2.27 cm) than offshore (1.54 cm) areas. In July 1992, the distribution of mean length from west to east displayed the same fluctuation decreasing gradually compared with that of January 1992. By July 1992, mean and median aboral lengths of *Mnemiopsis* for the entire Sea were found to attain the higher values of 2.38 cm and 1.39 cm than those found in January 1992, respectively. The size-frequency distribution was figured out by a unimodal gaussian-distributed length (Figure 5).

One year later (August-1993), synoptic size structure was as similar as that in the previous year of summer. Organisms larger than 30 mm length constituted of around 15% of the population (Figure 4). In western half of the Turkish Black Sea, adult individuals concentrated mostly in the peripheral longshore waters between the coastline and main gyres and were dispersed throughout the route of rim current (Figures 8 and 1). Adult individual were distinguished with a second distinct size class from the remaining stages (Figure 5). In late summer, the saplings had joined the population whilst a 2-3% increment in adult stage was observed due to the growing up of transistory lobate stage (Figure 4). The size-frequency distribution was figured out by a bimodal gaussian-distributed length (Figure 5). In size-frequency distribution of *Mnemiopsis*, a second cohort was separated with a second size class mode. This may also suggest that at this time new and older generation was observed together in the Sea. In this time, median value was at least to indicate the evidence of new generation compared with the annual median.

Minimum and mean aboral lengths of *Mnemiopsis leidyi* were significantly higher western area (2.27 and 2.87 cm) than eastern area (1.12 and 1.83 cm, respectively). Only in the eastern area was the minimum aboral length of *Mnemiopsis* significantly higher for offshore waters (Table 5).

In February-1994, about 7-8% of the population was constituted of individuals larger than 30 mm. Specimens of 10-30 mm length attained a maximum contribution (about 65-70%) among other stages (Figure 4). There are two modes of size classes (< 35 mm and >40 mm aboral length) of *Mnemiopsis leidyi* (Figure 5). Here, individuals greater than 40 mm length were defined adult specimens which were about to die of advanced age. However, the greatest aboral length (9 cm) was found only in this season. Cohort II was found not to distinguish exactly from the first cohort in February 1994 compared with that in August 1993. Median and mean value of aboral length averaged over only nine stations were 1.41 cm and 1.77 cm. Comparison on size statistics either between eastern and western or between inshore and offshore might be biased. Because, on the one hand measurements for the *Mnemiopsis* was made only at the nine stations in this cruise. On the other hand *Mnemiopsis* growth is very rapid and the time lag of 10 days between the collections of east-west would not be comparable (Figure 9).

May-1994 was a period of minimum numerical occurrence (less than 15%) of young individuals constituted the population. Organisms larger than 30 mm length made up more than 15% of the population. As seen in Figures 10, adult specimens of *Mnemiopsis* was appeared to be more numerous in inshore and nearshore waters of the Turkish Black Sea where there are comparatively warmer waters associated with high river discharge. Adult specimens were at rare to almost disappear in the Bulgarian, Romanian and Ukranian

EEZ. These zones might provide favorable condition for the organisms to reproduce. New individuals might be either circulated from Turkish coast to other open waters of the Black Sea with the rim current and the main western and eastern gyres or trapped the main western gyre after the reproduction on the northwestern shelf of the Black Sea. Overall, the distribution of *Mnemiopsis* stages seemed to follow the incoming new generation. As young individual grew up, their abundance decraesed while transition stage increased. Hence, adult stages increased. During this period, the median length is 1.89 cm and is close to the value of the mean of 2.20 cm. Size-frequency changed from the gaussian distribution to the normal distribution (Figure 5). This cruise comprised only the whole western part of the Black Sea. Mean length was found to increase gradually from Bulgarian, Romanian and Ukranian EEZ (1.65 cm) to Turkish EEZ (2.37 cm) (Table 5). Aboral length averaged over the offshore (2.33 cm) was greater than inshore (1.81 cm). Significant differences in mean length of *Mnemiopsis leidyi* were found either between inshore and offshore areas or between Turkish EEZ and Bulgarian, Romanian and Ukranian EEZ (Table 5).

The overall results of size composition of *Mnemiopsis leidyi* in year 1992-1994 are given in Table 5. Aboral length did not exceed 7 cm. Largest individuals (aboral length) measured 7 cm in January-1992, 5.6 cm in July-1992, 6.6 cm in August-1993, 5.9 cm in February-1994 and 6 cm in April-1994. Larger individuals appeared in the coastal water of the south-western part of Turkish Exclusive Economic Zone. Smaller length measurements (1.5-2 cm) were often observed in winter seasons (January-1992 and February-1994). Length grew slightly in a period of spring (2.20 cm in April-1994) to summer 2.38 in July-1992 and it attained 2.88 cm in August-1993) (Table 5).

Major size of the lobate comb-jelly was made up of the saplings (oral-to-aboral length <10 mm) in high percentage (15-50% April, 1994-August,1993 and usually 30-50%) in all sampling time (Figure 4). Animals greater than 30 mm rarely made up more than 12-13% of the total ctenophore density. Aboral length frequency distributions in the sampling time were shown in Figure 5. However, two distinct modes of length class correspond to individuals hatched in late winter (January-1992 and February-1994) and late summer (August-1993; Figure 5). From January to August, numerical occurrence of the younger individuals declined slightly within a period of January to April, then increased with numerical occurrence of the adult specimens in August, due to a second outburst of *Mnemiopsis* in the Black Sea (Figure 4). Contribution of transitory lobate-stage to the stock was not associated with the young and adult specimens. In the population, while quantity of adult and precociously reproductive individuals increased, numerical occurrence of nonreproductive (transistory) lobate-stage decreased. Seasonality for the generation of *Mnemiopsis leidyi* resulted mainly from the spawning in the winter and early summer. Percent number of newly hatched individuals was minimum in later spring (April-1993). Young individuals have a increasing trend with the frequency of occurrence from the west to east whereas real adult specimens are predominant in southwestern part of the Black Sea.

Size structure of *Mnemiopsis leidyi* in the Black Sea showed marked seasonal fluctuation. On comparison for the mean length in years 1992-1994, lower length measurements (1.5-2 cm) were often observed in winter seasons (January-1992 and February-1994). Length grew slightly in a period of spring (2.20 cm in May-1994) to summer 2.38 in July-1992 and it attained 2.88 cm in August-1993) (Table 5). In a period of January to August occurrunce of the *Mnemiopsis* young stages suggested that it might

spawn continuously, but least in April. Overall, numerical occurrence of young specimens increased in Winter, then declined in April and rose up again in late summer, in contrast to the distribution of other stages (Figure 4).

Discussion

In the Black Sea, *Mnemiopsis leidyi* has a dynamic structure in size distribution in time since it reaches adult stage within 17-20 days (BAKER and REEVE, 1974). In this study, comparison samples have represented the instantaneous size composition of the *Mnemiopsis* at the locations. Besides fast growth of this animal, additionally, transportation of specimens with water circulation and much time (at least 20 days) required for finishing the cruise, have removed the opportunity to compare the simultaneous size distribution of *Mnemiopsis leidyi* in the Black Sea.

Biometric relationships of the organisms change depending on the growth rate, hence, time, place and availability of food in the media. In this study, empirical equations (in various metric units) derived were as follows:

W (g) vs. L (cm)	W (mg) vs. L (mm)	W (g) vs. L (mm)
$W=0.927AL^{2.227}$	$W=5.501AL^{2.227}$	$W=0.005501AL^{2.227}$
$W=0.393LL^{2.163}$	$W=2.658LL^{2.163}$	$W=0.002658LL^{2.163}$

The live weight of *Mnemiopsis* was determined from the size (mm)-weight (mg) equation $W=2.36LL^{2.35}$ for the Black Sea (VINOGRADOV et al, 1989). The equation found for the same species redefined as *Mnemiopsis mccradyi* was $W=0.001LL^{2.36}$ where live weight is gramme and lobate length is millimeter (ZAIKA and SERGEEVA, 1990). The equations, biometric conversion for the *Mnemiopsis leidyi* from Narragansett Bay, KREMER and NIXON (1976)

derived are as follows:

$W\ (g)=0.009LL^{1.872}$
$W\ (g)=0.01\ AL^{1.98}$

UYSAL and MUTLU (1993) who recorded first appearance of *Mnemiopsis leidyi* in Mersin Bay, Turkish coast of the Mediterranean Sea, have established the relationship between length (cm)-weight (g) with the following equations:

$W=0.27762LL^{2.16839}$
$W=0.599ArL^{2.10223}$
$W=0.87147AL^{1.98569}$

In this study, average wet weight of *Mnemiopsis leidyi* can be approximated in terms of displacement volume via the relationship:

W (g)=0.886*V (ml)-0.249

while KREMER and NIXON (1976) derived the equation of W (g)=1.017*V (ml)-0.122 and in the Mediterranean Sea UYSAL and MUTLU (1993) found the following functional regression of the wet-weight relating to settling volume (ml); W (g)=0.981138*V (ml)-0.944635. This equation may be erroneous because of the equation found for the same species inhabiting the salted regions of the Mediterranean.

Ratio of aboral to auricle and lobate lengths was 1:0.69:0.65 and auricle-to-lobate length ratio was 0.94 (Table 3). The AL/LL ratio calculated is about 0.65, ZAIKA and SERGEEVA (1990) found the same ratio (0.6) for the *Mnemiopsis mccradyi*, synonymous with *Mnemiopsis leidyi*, of the Black Sea.

Regarding to three stages of *Mnemiopsis*, aboral-to-auricle length ratio has increased at each stage. Lobate length-to-body width ratio was less than 1 only at young stage which was devoid of

lobe, but delicate with tentacles as becoming in cydippid larvae.

In years 1992-1994, only one individual has a aboral length of 9 cm (14.8 cm total=lobate length: February-1994) in the offshore water of Ordu in the Black Sea. Aboral length did not generally exceed 7 cm (11.5 cm lobate length). Largest individuals (aboral length) measured 7 cm in January-1992, 5.6 cm in July-1992, 6.6 cm in August-1993, 5.9 cm in February-1994 and 6 cm in April-1994. Larger individuals were predominant in the prevailing area of western gyre of the Black Sea. Large ctenophores over 45 mm, sometimes as long as 10-13 cm were dominant in the waters of the central circulation (VINOGRADOV et al, 1992). The largest individuals collected in late September of 1988 were about 75 mm long and 40 mm wide (VINOGRADOV et al, 1989). Comparison on the mean length in years 1992-1994, smaller length measurements (1.5-2 cm) were often observed in winter seasons (January-1992 and February-1994). Mean length increased slightly in a period of spring (2.20 cm in April-1994) to summer (2.38 in July-1992) and it attained 2.88 cm in August-1993). base of the lobate comb-jelly was composed mostly of young specimens (15-50% April, 1994-August,1993 and usually 30-50%). Animals greater than 30 mm rarely made up more than 12-13% of the total ctenophore density. Seasonal observation (VINOGRADOV et al., 1992) in the Gelendzhik area showed that young (<10 mm) occurred in the plankton practically throughout the year, with the lowest abundance recorded in late March-April and a sharp peak in July-August. Seasonality for the generation of *Mnemiopsis leidyi* resulted mainly from the spawning in the winter and early summer. Minimum recruitment of newly hatched individuals was in later spring (April-1993) when mean biomass of this animal was about 0.15 g per square meter for the entire Sea (MUTLU et al., 1994). In the Azov Sea, size structure of the population differ within period of a year. When population development starts (in the beginning

of summer), mostly adult animals are predominant. Their size is 20-55 mm. Juveniles and larvae constituted of less than 10% of the population. Between end of summer and late autumn, the base-population was made up of small and middle size individuals (5-15 mm) whereas larger specimens were rare at this time (VOLOVIK et al., 1993).

Young individuals have a increasing trend with the frequency of occurrence from west to east whereas real adult specimens appeared in tremendous amount in southwestern part of the Black Sea. Such distribution suggested that major spawning area of the *Mnemiopsis* were in the eastern part, which warmed up more than western escarpment of the Black Sea. For fine size distribution of the *Mnemiopsis*, time-series study in the field is considered at every 15-20 day interval which corresponds to time from birth of the organism to beginning of adult stage in future.

Acknowledgement

This study is part of a Ph.D. thesis supervised by Prof. Ferit BINGEL, entitled "Biomass estimation of gelatinous zooplankton in the Black Sea: net sampling and acoustic application". This study was funded by the Turkish Scientific and Technical Research Council (TUBITAK), and by the Scientific Affairs Division of NATO within the framework of Science for Stability Programme. I would like to extend my sincere thanks to Prof. Umit UNLUATA, the Director of the IMS, for his encouragement and to crew of R/V "Bilim" and to my fellow students for their support.

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List of Figures

Fig. 1. General circulation of the surface water of the Black Sea (redrawn from OGUZ et al., 1993). The bold line denotes the rim current. Gray area: shelf area with depth <200 m.

Fig. 2. Morphometric measurements performed on the individuals. (Aboral length, AL; lobate length, LL; auricle length, ArL; and body width, BW).

Fig. 3. Matrix of existing relationship among biological parameters of *Mnemiopsis leidyi*. (Wet weight W, g; settling volume V,ml; aboral length AL, cm; lobate length LL, cm; auricle length ArL, cm; and body width BW, cm).

Fig. 4. Seasonal changes in stage composition of *Mnemiopsis leidyi*.

Fig. 5. Length distribution of *Mnemiopsis leidyi* in the Black Sea in years 1992-1994.

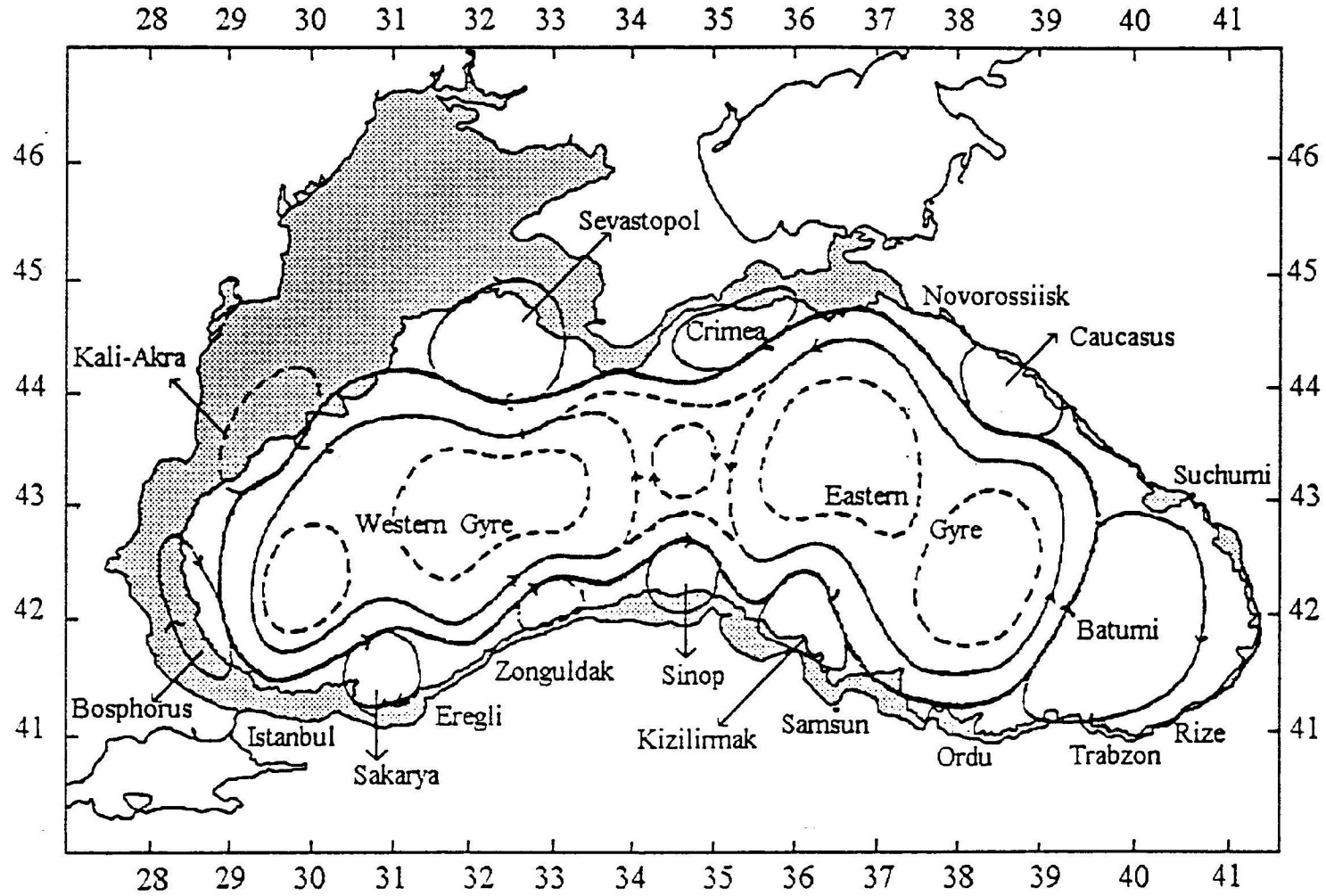
Fig. 6. Spatial distribution of three stages of *Mnemiopsis leidyi* in January-1992. Young stage (< 10 mm aboral length), transition lobata stage (10-30 mm) and adult stage (> 30 mm).

Fig. 7. Spatial distribution of three stages of *Mnemiopsis leidyi* in July-1992. Young stage (< 10 mm aboral length), transition lobata stage (10-30 mm) and adult stage (> 30 mm).

Fig. 8. Spatial distribution of three stages of *Mnemiopsis leidyi* in August-1993. Young stage (< 10 mm aboral length), transition lobata stage (10-30 mm) and adult stage (> 30 mm).

Fig. 9. Spatial distribution of three stages of *Mnemiopsis leidyi* in February-1994. Young stage (< 10 mm aboral length), transition lobata stage (10-30 mm) and adult stage (> 30 mm).

Fig. 10. Spatial distribution of three stages of *Mnemiopsis leidyi* in April-1994. Young stage (< 10 mm aboral length), transition lobata stage (10-30 mm) and adult stage (> 30 mm).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Crimea
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Kali-Akra
Suchumi
Eastern
Gyre
Western Gyre
Batumi
Zonguldak
Sinop
Bosphorus
Eregli
Istanbul
Kizilirmak
Samsun
Rize
Ordu
Trabzon
Sakarya

Fig.1.

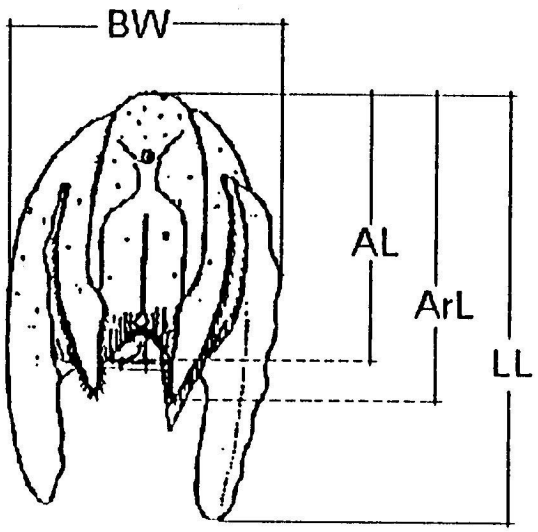


Fig. 2.

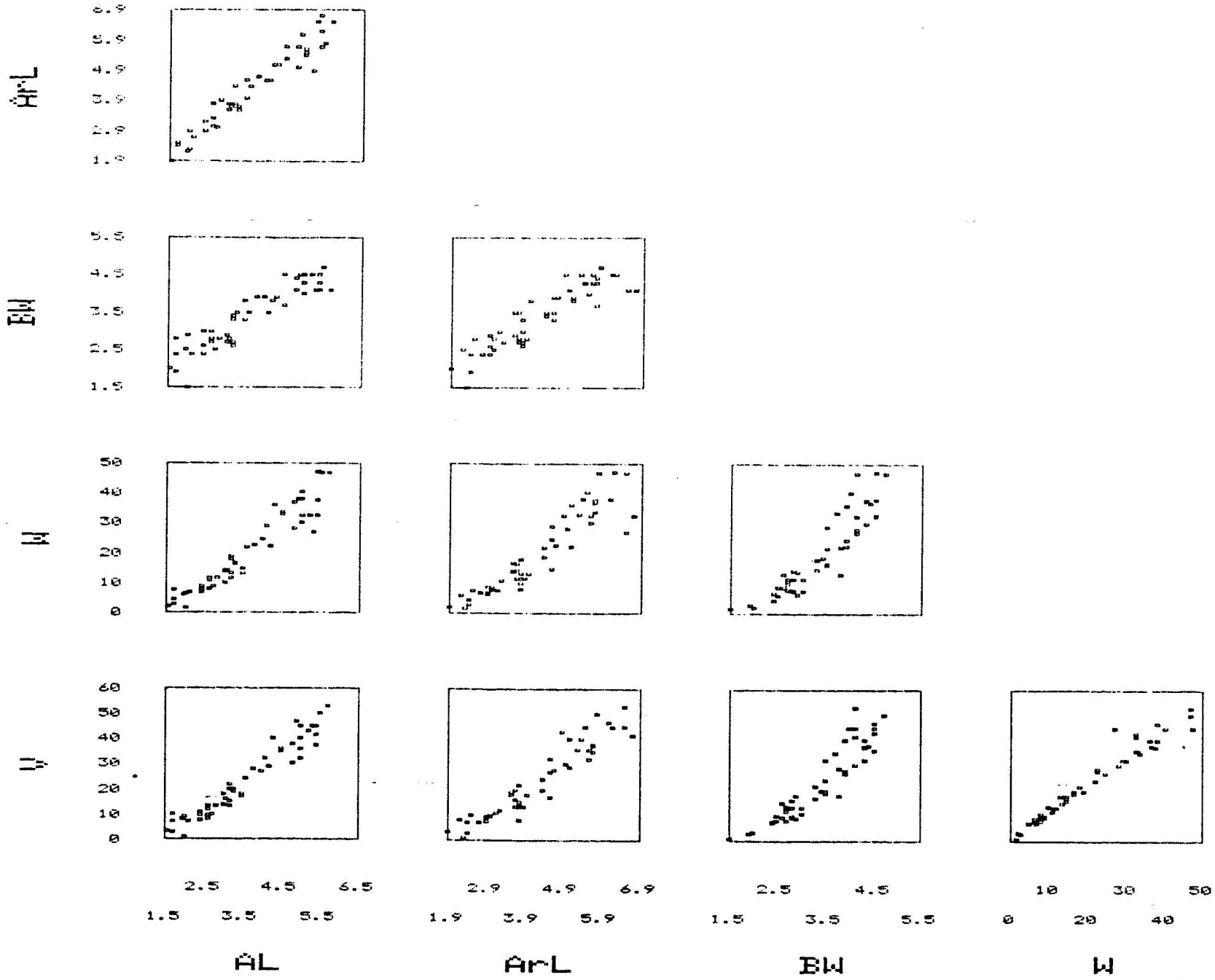


Fig. 3.

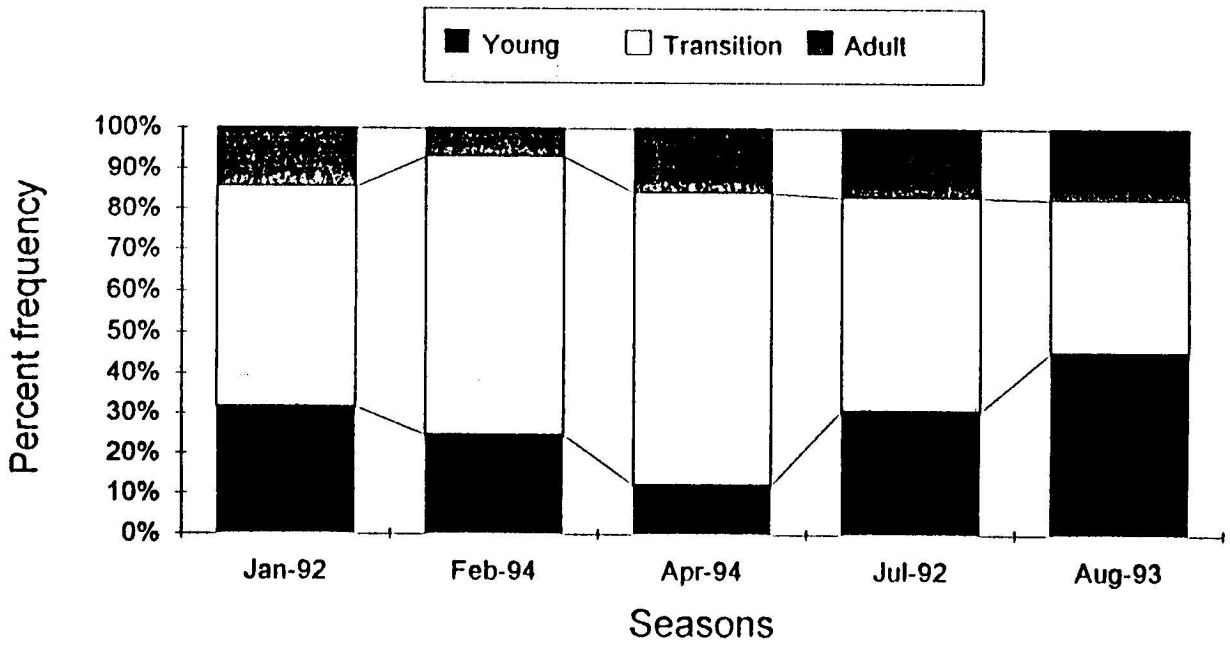
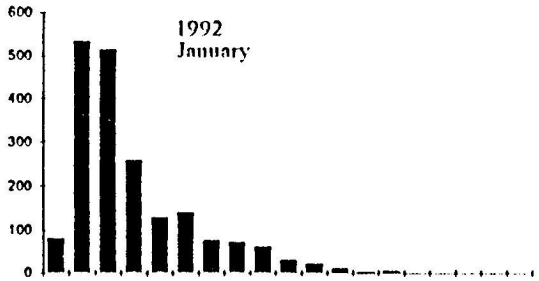
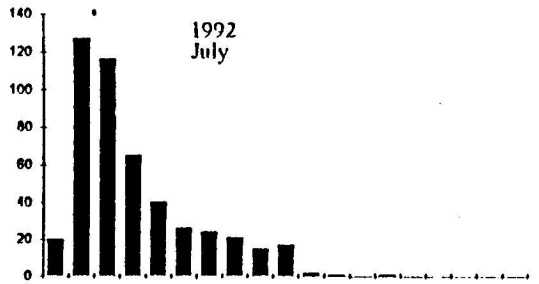

Young
Transition
Adult
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent frequency
Jan-92
Feb-94
Apr-94
Jul-92
Aug-93
Seasons

Fig. 4


1992
January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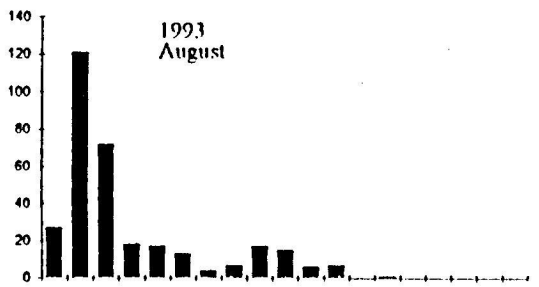
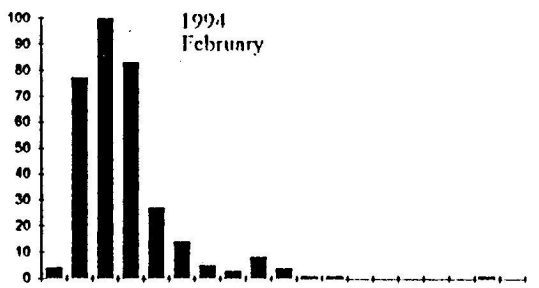

1993
August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February

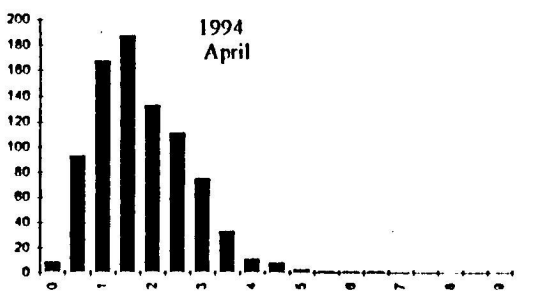
1994
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Fig. 5.

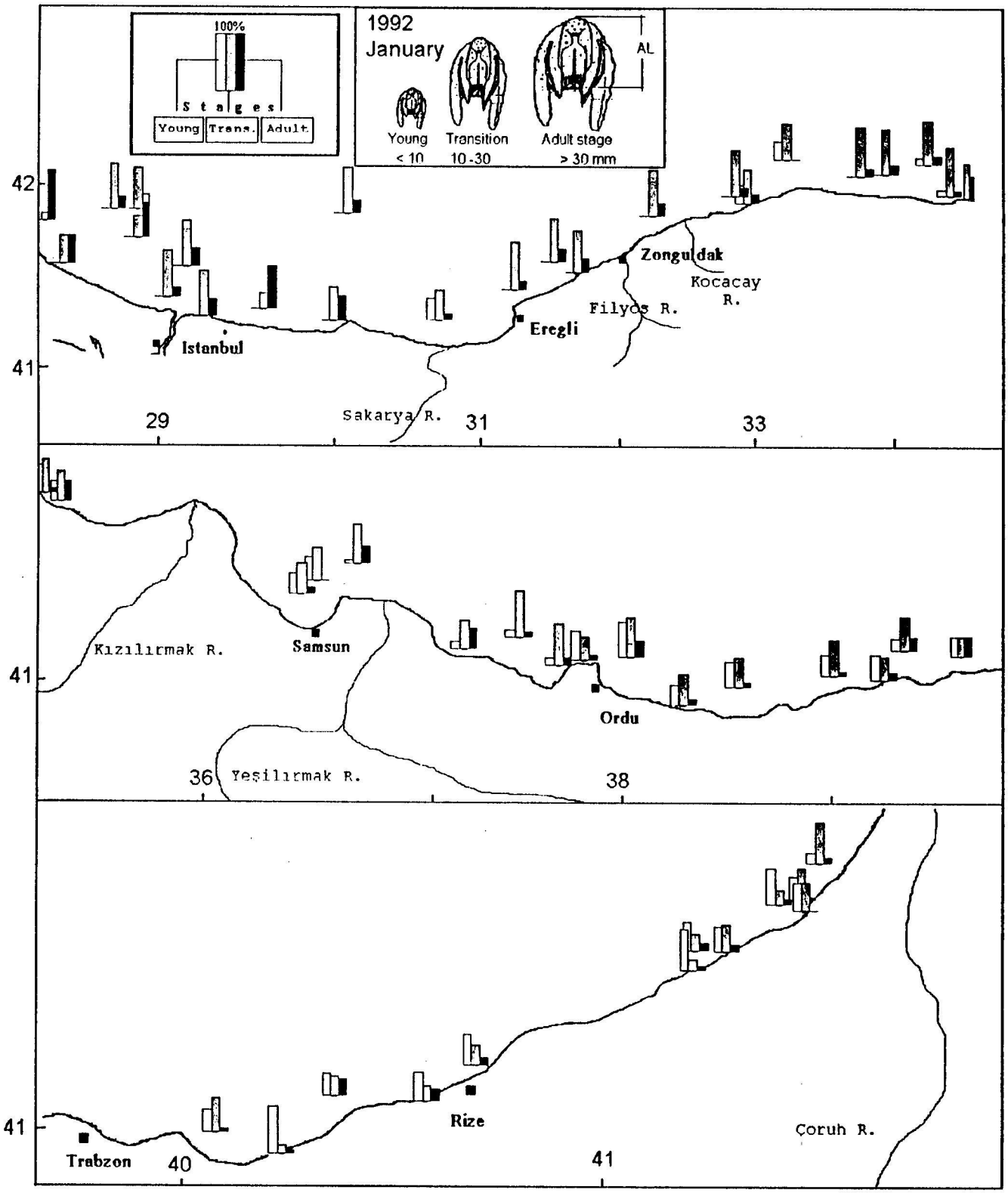

Figure 6: Spatial distribution of three stages of *Mnemiopsis leidyi* in January 1992. Young stage (< 10 mm aboral length), transition lobate stage (10-30 mm) and adult stage (> 30 mm).

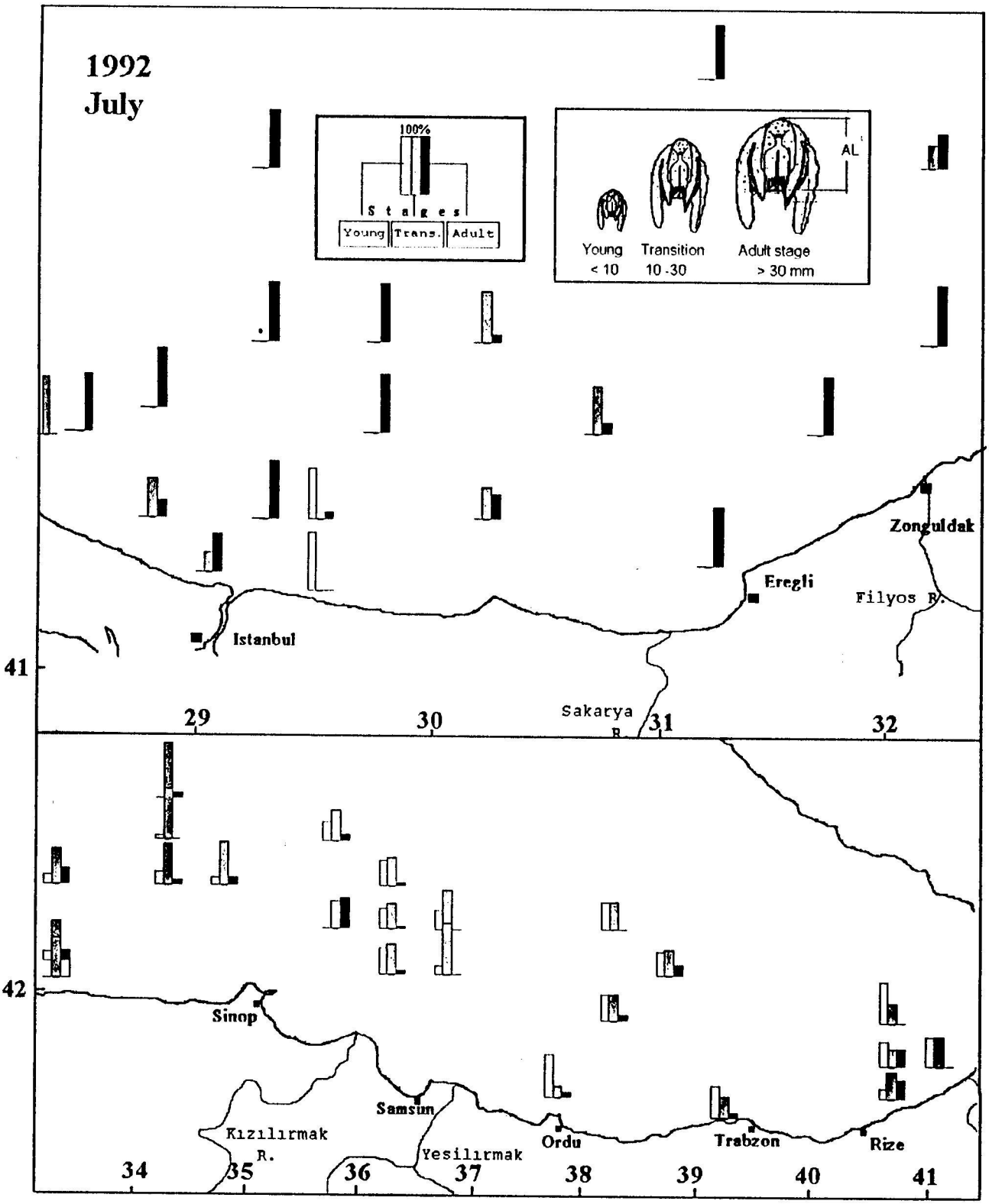

Figure 7: Spatial distribution of three stages of *Mnemiopsis leidyi* in July 1992. Young stage (< 10 mm aboral length), transition lobate stage (10-30 mm) and adult stage (> 30 mm).

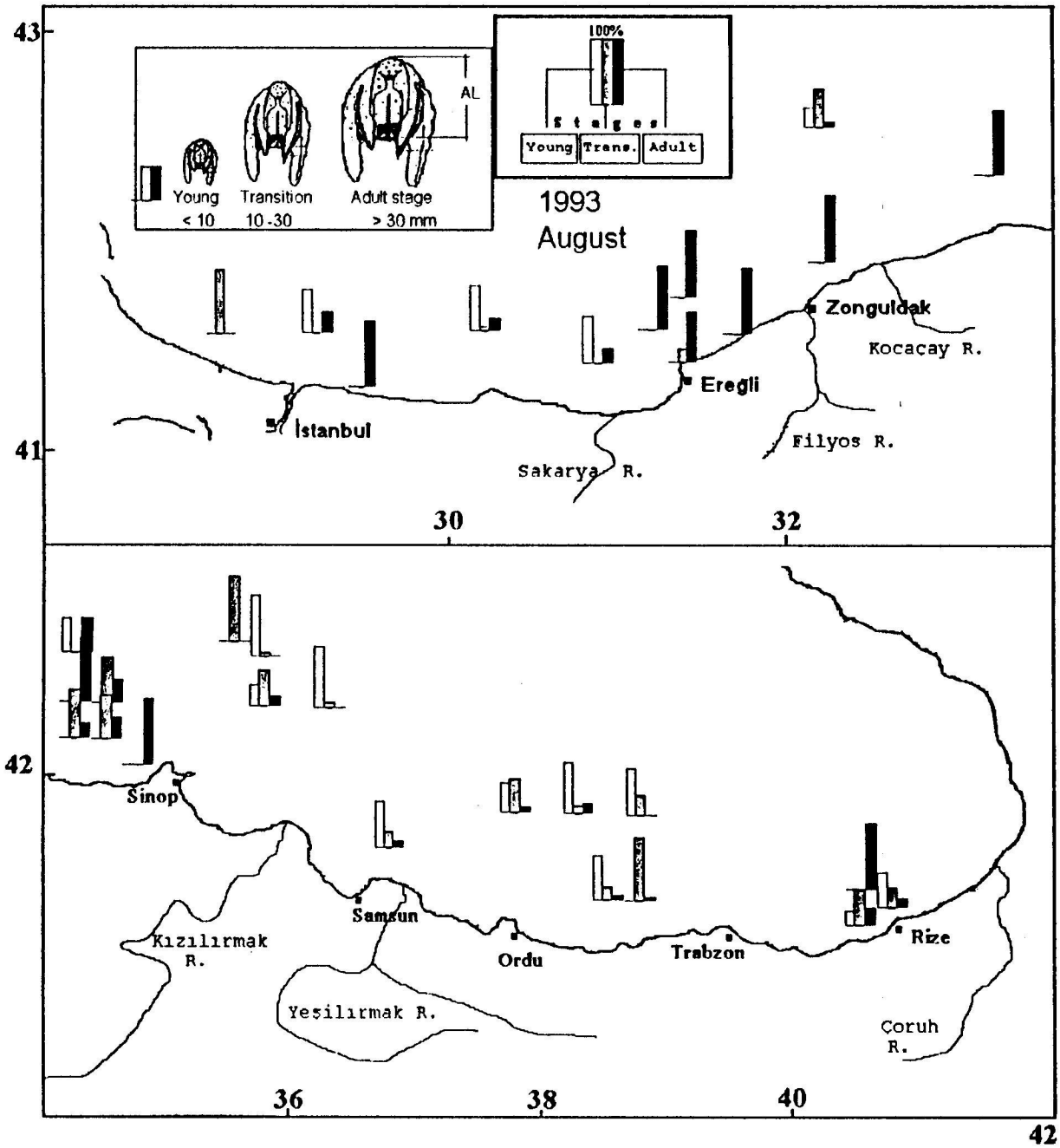

Figure 48: Spatial distribution of three stages of *Mnemiopsis leidyi* in August 1993. Young stage (< 10 mm aboral length), transition lobate stage (10-30 mm) and adult stage (> 30 mm).

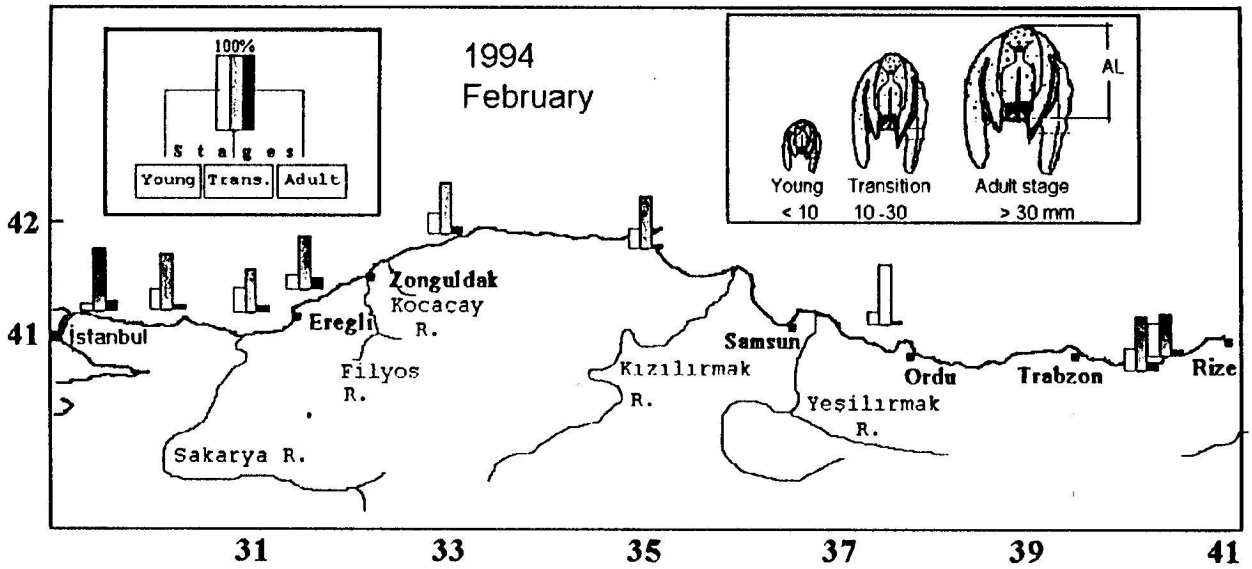

Figure 67: Spatial distribution of three stages of *Mnemiopsis leidyi* in February 1994. Young stage (< 10 mm aboral length), transition lobate stage (10-30 mm) and adult stage (> 30 mm).

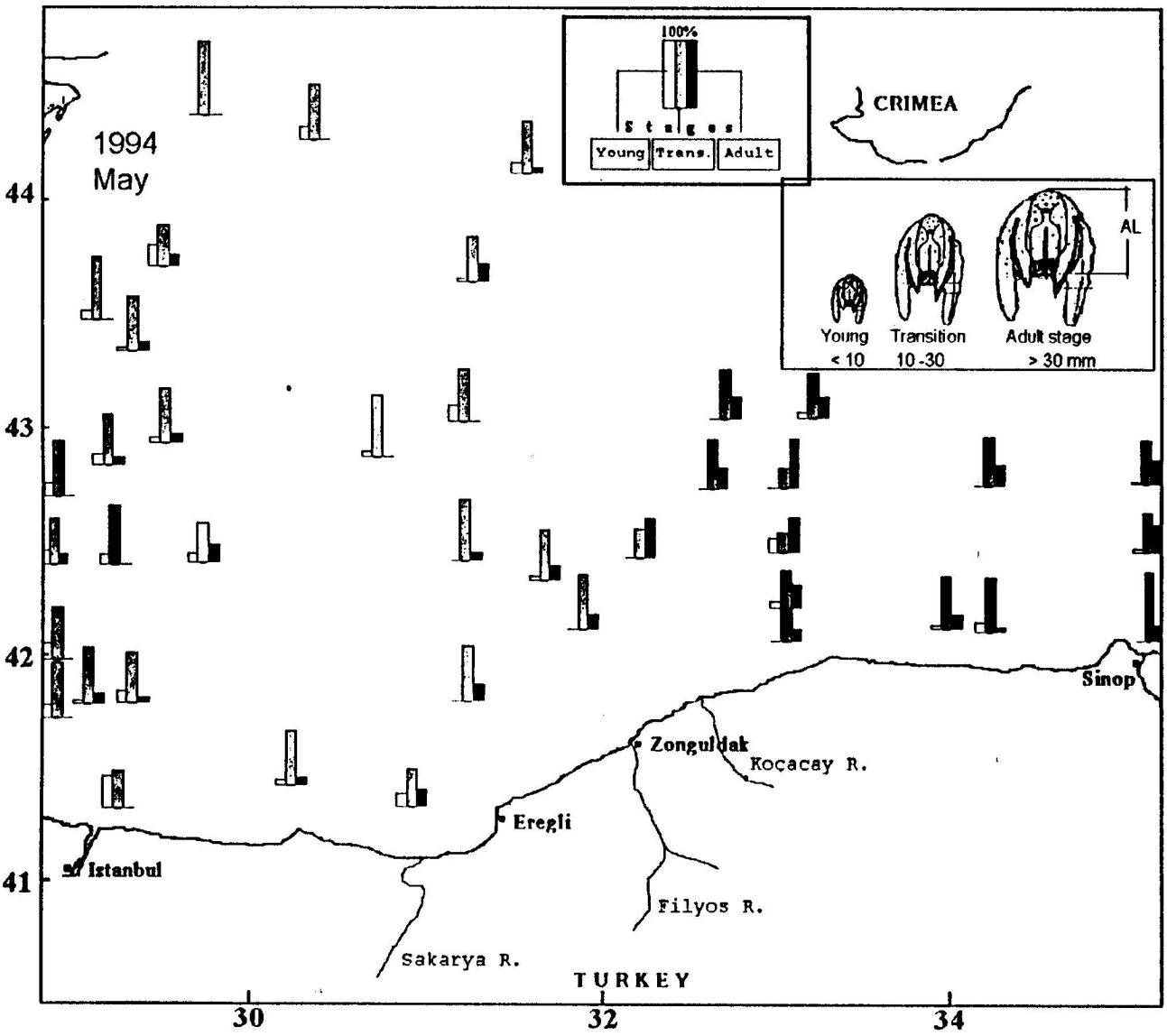

Figure 10: Spatial distribution of three stages of *Mnemiopsis leidyi* in May 1994. Young stage (< 10 mm aboral length), transition lobate stage (10-30 mm) and adult stage (> 30 mm).

Table 2.

Empirical equations	Correlation coefficient	Sample size (n)	Probability level (P)
$V=0.926*AL^{1.987}$	0.94	450	0.00000
$V=0.460ArL^{2.054}$	0.93	450	0.00000
$V=0.292LL^{1.867}$	0.94	450	0.00000
$W=0.886*V-0.249$	0.98	49	0.00000
$W=0.393LL^{2.163}$	0.97	213	0.00000
$W=0.334BW^{3.237}$	0.97	92	0.00000
$W=0.927AL^{2.227}$	0.95	214	0.00000
$W=0.460ArL^{2.471}$	0.96	92	0.00000
$AL=0.596*LL+0.205$	0.97	215	0.00000
$AL=0.357*BW-0.866$	0.90	94	0.00000
$AL=0.883*ArL-0.149$	0.98	94	0.00000

Table 3.

	ArL	LL	BW	*W*	V
AL	0.69	0.65	0.88	0.23	0.11
ArL		0.94	1.27	0.34	0.16
LL			1.36	0.36	0.17
BW				0.27	0.13
W					0.47
n	217	95	216	95	215

Table 4.

	Young stage			**Lobate stage**			**Adult stage**		
	ArL	LL	BW	ArL	LL	BW	ArL	LL	BW
AL	0.67	0.49	0.46	0.74	0.55	0.62	0.76	0.46	0.77
ArL		0.73	0.69		0.74	0.85		0.61	1.01
LL			0.94			1.14			1.67
n	144	144	144	216	216	216	101	101	101

Table 5. Overall results of size composition of Mnemiopsis leidyi in years 1992-1994.

	WEST			EAST			BLACK SEA		
	Inshore	Offshore	Total	Inshore	Offshore	Total	Inshore	Offshore	Total
Jan-92									
Minimum length (cm)	1.69±0.15	1.46±0.15	**1.64±0.12**	0.65±0.04	0.69±0.06	**0.67±0.04**	1.25±0.12	0.89±0.10	1.13±0.09
Mean length (cm)	2.81±0.18	2.43±0.16	**2.72±0.15**	**1.48±0.10**	**1.84±0.11**	**1.65±0.08**	2.25±0.15	1.98±0.11	2.16±0.11
Maximum length (cm)	**5.45±0.19**	**4.63±0.30**	**5.26±0.17**	4.27±0.34	4.70±0.25	**4.47±0.22**	4.94±0.20	4.66±0.20	4.85±0.15
Mean number of specimens (ind/m2)	57±4	57±4	**57±3**	**95±7**	**154±8**	**123±5**	**73±4**	**127±7**	92±4
Number of station	20	6	26	15	14	29	36	19	55
Jul-92									
Minimum length (cm)	**2.27±0.45**	2.28±0.31	**2.27±0.25**	±	0.67±0.07	**0.67±0.07**	2.27±0.45	1.54±0.21	1.67±0.20
Mean length (cm)	2.59±0.47	2.98±0.24	**2.87±0.22**	±	1.57±0.14	**1.57±0.14**	2.59±0.47	2.33±0.19	2.38±0.17
Maximum l.(cm)	3.35±0.49	4.28±0.21	4.01±0.21	±	3.74±0.31	3.74±0.31	3.35±0.49	4.03±0.18	3.91±0.18
Mean number of specimens (ind/m2)	11±1	21±2	**18±2**	±	46±3	**46±3**	11±1	**33±2**	29±2
Number of station	8	20	28	0	17	17	8	37	45
Aug-93									
Minimum length (cm)	3.11±0.67	2.64±0.45	**2.79±0.37**	2.30±err	1.03±0.43	**1.12±0.40**	**3.01±0.59**	**1.95±0.34**	2.19±0.30
Mean length (cm)	3.69±0.56	3.39±0.35	**3.48±0.29**	2.40±err	1.78±0.40	**1.83±0.37**	3.53±0.51	2.70±0.30	2.88±0.26
Maximum length (cm)	4.48±0.55	4.66±0.26	4.60±0.24	2.50±err	4.04±0.48	3.92±0.46	4.23±0.54	4.39±0.25	4.36±0.23
Mean number of specimens (ind/m2)	7±1	9±1	**8±1**	5±err	55±4	**51±4**	**7±1**	**28±3**	24±2
Number of station	7	16	23	1	12	13	8	28	36
Feb-94									
Minimum length (cm)	0.90±0.10	0.63±0.18	0.74±0.12	0.60±0.12	0.50±err	0.58±0.09	0.72±0.10	0.60±0.13	0.67±0.08
Mean length (cm)	1.81±0.13	1.89±0.20	1.85±0.12	1.60±0.06	1.82±err	1.65±0.07	1.68±0.07	1.87±0.14	1.77±0.08
Maximum length (cm)	4.50±0.00	5.20±0.35	4.92±0.26	4.23±0.49	9.00±err	5.43±1.24	**4.34±0.28**	**6.15±0.98**	5.14±0.53
Mean number of specimens (ind/m2)	73±4	70±10	70±5	96±11	169±err	114±11	87±7	95±12	90±6
Number of station	2	3	5	3	1	4	5	4	9
	Turkish EEZ			Bulgarian, Romanian, Ukranian EEZ			BLACK SEA		
Apr-94	Inshore	Offshore	Total	Inshore	Offshore	Total	Inshore	Offshore	Total
Minimum length (cm)	0.77±0.11	1.16±0.11	1.11±0.10	0.99±0.19	0.75±0.13	0.67±0.04	0.91±0.13	1.08±0.10	1.04±0.08
Mean length (cm)	**1.78±0.25**	**2.37±0.09**	**2.29±0.09**	**1.83±0.08**	**2.17±0.10**	**1.65±0.08**	**1.81±0.10**	**2.33±0.08**	2.20±0.07
Maximum length (cm)	3.48±0.68	4.08±0.21	4.00±0.20	3.57±0.69	3.88±0.30	4.47±0.22	3.54±0.48	4.04±0.20	3.91±0.18
Mean number of specimens (ind/m2)	49±3	49±2	**49±2**	58±8	54±4	**123±5**	55±5	50±2	52±2
Number of station	4	25	29	7	6	29	11	19	42