The occurrence of medusae in the southern Baltic and their importance in the ecosystem, with special emphasis on *Aurelia aurita*

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Aurelia aurita
Jellyfish
Medusae
Biomass
Baltic Sea

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Abstract

The material for the study was collected in 1983–1991 in the Polish fisheries zone by means of a bongo net. Long-term studies reveal that during the year, the first *Aurelia aurita* medusae appear in the southern Baltic in July and may occur until January of the following year. The period of their mass occurrence was limited to four months (August–November). The mean biomass for that period was 800 $cm^3 1000 m^{-3}$. Medusae of another species, *Cyanea capilata*, occurred irregularly throughout the year but in much smaller numbers. Calculations made for the southern Baltic show that during their mass occurrence, the *Aurelia aurita* medusae consume on average 4.3% of the mesozooplankton production. This means that in general they have relatively little influence on mesozooplankton as predators and on fish as competitors for food. It should be noted, however, that there are periods and places, in which their abundance is several times higher than average. In such situations the pressure of medusae on the mesozooplankton is much greater.

1. Introduction

Aurelia aurita medusae play an important role in the pelagic trophic chain of inshore waters from 70° N to 40° S. They are also an important ecological factor influencing the stocks of commercial fish. These medusae are known to occur in large numbers; by feeding on mesozooplankton and fish larvae they have a direct (as competitors) and indirect impact (as predators) on the abundance of planktivorous fish (Möller, 1980a,b; Bailey and Batty, 1984; Shushkina and Musayeva, 1983).

A. aurita occur in the southern Baltic in large numbers in the summer months, so their role in the ecosystem may be expected to be the greatest at that time. However, the literature on the biology and ecology of this species in Polish Baltic waters is very scanty. The studies conducted so far have dealt only with the life cycle of *A. aurita* in the Hel Peninsula area (Bogucki, 1933) and anomalies in their body structure (Żak, 1971). There are no papers describing their occurrence and biomass or determining their importance in the circulation of matter in the southern Baltic ecosystem. That is why these problems were chosen for the subject of the present paper. The observations made during oceanographic research cruises in 1983–1991 were used as materials for this study, which made it possible to determine the time and place of occurrence and the biomass of *A. aurita* and another, much less important medusa species – *Cyanea capilata*, in the Polish fisheries zone in the Baltic. On the basis of the estimated biomass and bioenergetic indices taken from the literature an attempt was also made to evaluate the pressure of medusae as predators on mesozooplankton.

2. Material and method

The material for determining the biomass of medusae (Tab. 1) was collected by the Sea Fisheries Institute (SFI) in the Polish fisheries zone in the Baltic in 1983–1991 (with the exception of 1984). Medusae were collected with a bongo net with an inlet diameter of a single net equal to 60 cm and mesh diameter of 500 μm; the vessel speed was about 3 knots. Double oblique hauls were made from the surface to a depth of about 5 m above the bottom and back to the surface. The amount of water filtered was measured with a flow-meter. The total volume of whole medusae and their remains was determined by a displacement method using a measuring cylinder.

The biomass of the medusae was calculated on the assumption that their body density was equal to 1 g cm^{-3}. Calculations of the food requirements of medusae were based on the estimated biomass and food balance proposed by Schneider (1989).

3. Results

3.1. Occurrence and biomass (biovolume) of medusae

In 1983–1991 two species of medusae were found to occur in the Polish fisheries zone in the Baltic: *Aurelia aurita* (L.) on a regular basis and *Cyanea capilata* (L.) from time to time. Ephyrae of these species were not observed.

Table 1. List of research cruises and occurrence of medusae

Year	Period	Area	Number of stations	Species
1983	August–September	PSR	41 – Aug 64 – Sept	medusae
1985	November	PSR east part	26	medusae
1986	April–May	transect	12	no medusae
	August	transect	8	*A. aurita*, *C. capilata*
	October	transect	13	medusae
	November	transect east part	4	medusae
1987	January	BG	6	no medusae
	February (2 cruises)	BG	2 × 6	no medusae
	March	BG	6	no medusae
	April (3 cruises)	BG	3 × 6	no medusae
	May (2 cruises)	BG	2 × 6	no medusae
	June	BG	2	medusae
	July (2 cruises)	BG	2 × 6	*A. aurita*
	August	PSR	93	*A. aurita*, *C. capilata*
	September (2 cruises)	BG	2 × 6	*A. aurita*
	October (2 cruises)	BG	2 × 6	*A. aurita*, *C. capilata*
	November	BG	6	no medusae
	December (2 cruises)	BG	2 × 6	*A. aurita*
1988	January	BG	6	*A. aurita*
	February	transect	16	*C. capilata*
	April	transect	17	no medusae
	May	PSRs	25	no medusae
	June	PSR	39	no medusae
	July	PSRs	22	*A. aurita*, *C. capilata*
	August–September	PSR	49 – Aug 2 – Sept	*A. aurita*, *C. capilata*
	November	PSRs	4	*A. aurita*

Table 1. (continued)

Year	Period	Area	Number of stations	Species
1989	March	PSR	43	no medusae
	May	PSRs	22	no medusae
	August	PSRs	4	*A. aurita*
	October	PSRs	20	*A. aurita*
1990	March	transect	4	no medusae
	June	PSRs	19	no medusae
	October	PSRs	20	*A. aurita*
1991	March	PSR	39	*C. capilata*
	June	PSR	41	*C. capilata*
	August	PSR	42	*A. aurita*

Notation used in table:

PSR – Polish fisheries zone – full grid of stations,
PSRs – Polish fisheries zone – shortened version of station grid,
transect – series of deep-water stations running through the Gdańsk Deep, Słupsk Furrow and Bornholm Deep,
BG – Gdańsk Basin,
medusae – undifferentiated species.

During the eight years of the study, *A. aurita* medusae were observed from July to January, but they occurred in large numbers only between August and November. Changes in their distribution patterns are shown in Figs. 1–7 (charts arranged according to season). In August the distribution of medusae was the most uneven (Figs. 1–3): their largest numbers were observed in the in-shore zone, in the western part of the study area, and in the Gulf of Gdańsk, but at the same time, no medusae were found at many open sea stations. The maximum biovolume during the entire study period was recored in August 1991 in the Pomeranian Bay — 23 329 cm^3 1000 m^{-3}, the mean for this month being 1494.33 cm^3 1000 m^{-3}.

In a later period (late August and early September, and October), the distribution of medusae in the entire zone was more uniform (Figs. 4–6). In November the medusae were smaller in number and were found to have disappeared from many stations (Fig. 7).

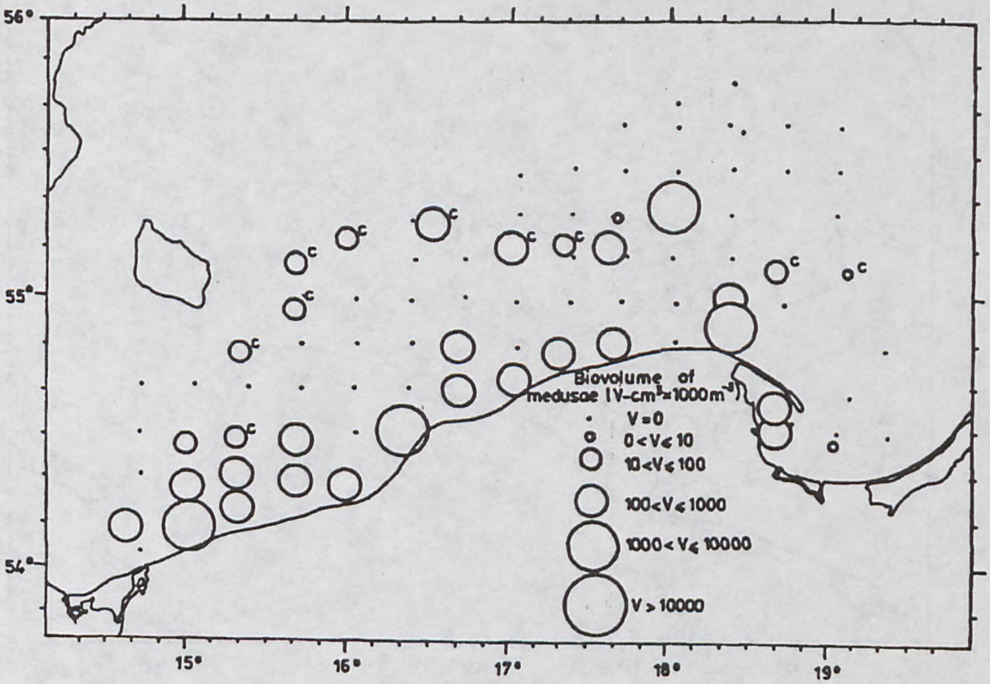

Fig. 1. Distribution of medusae in the Polish fisheries zone of the Baltic in August 1987. Symbol (c) denotes the presence of *Cyanea capilata* medusae

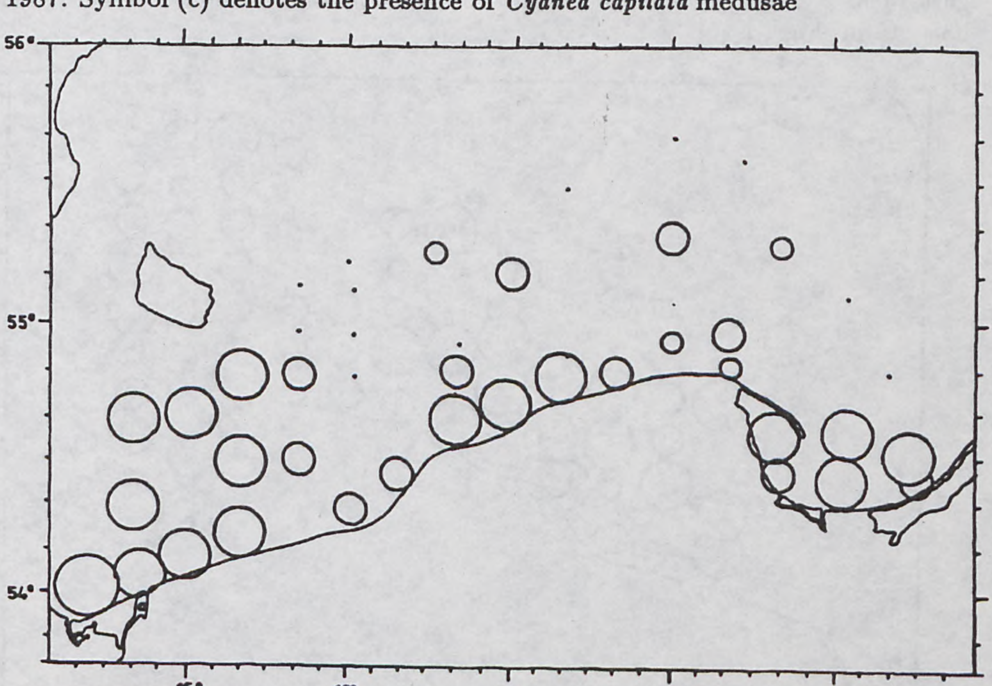

Fig. 2. Distribution of medusae in the Polish fisheries zone of the Baltic in August 1991. Symbols as in Fig. 1

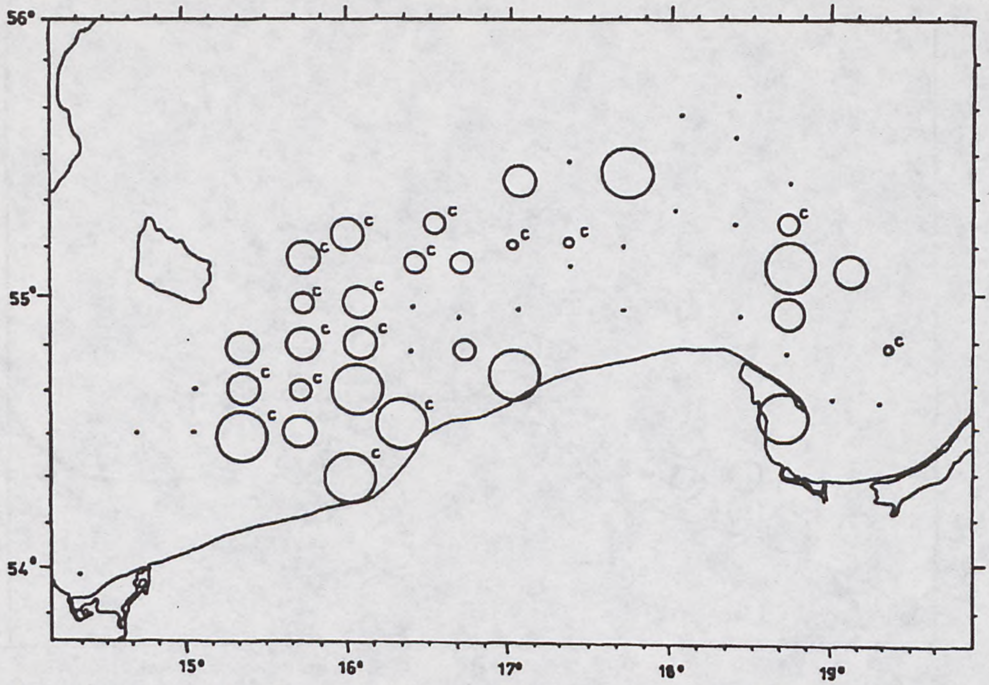

Fig. 3. Distribution of medusae in the Polish fisheries zone of the Baltic in August 1988. Symbol (c) denotes the presence of *Cyanea capilata* medusae. Symbols as in Fig. 1

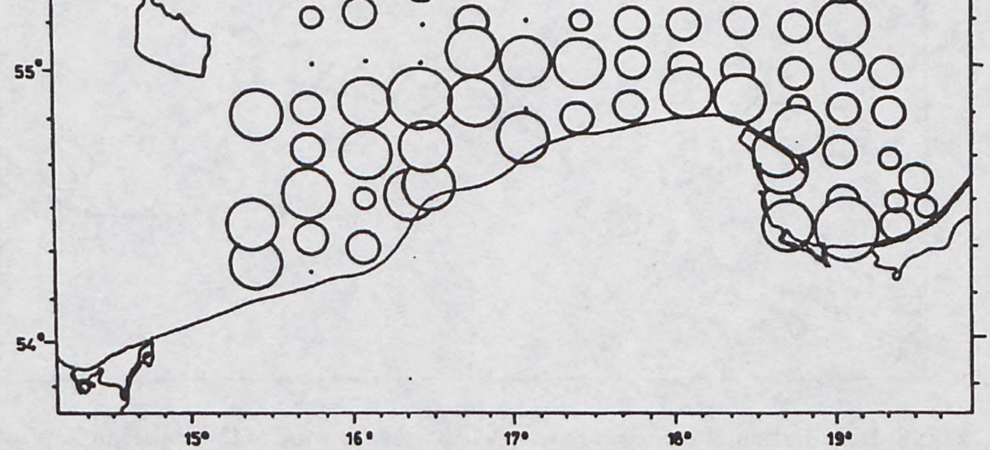

Fig. 4. Distribution of medusae in the Polish fisheries zone of the Baltic in late August and early September 1983. Symbols as in Fig. 1

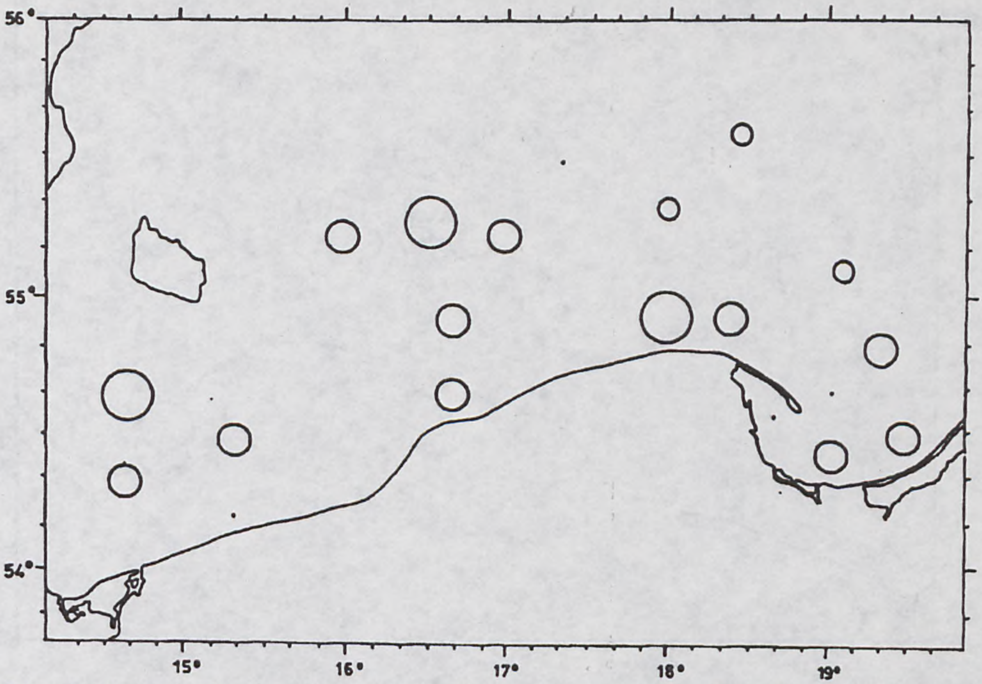

Fig. 5. Distribution of medusae in the Polish fisheries zone of the Baltic in October 1989. Symbols as in Fig. 1

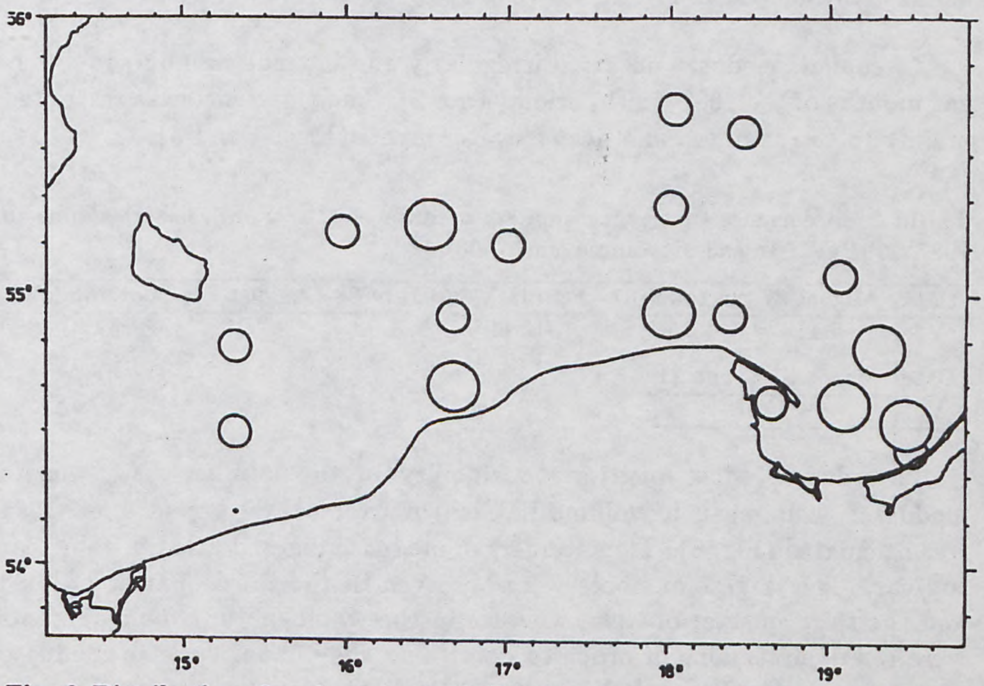

Fig. 6. Distribution of medusae in the Polish fisheries zone of the Baltic in October 1990. Symbols as in Fig. 1

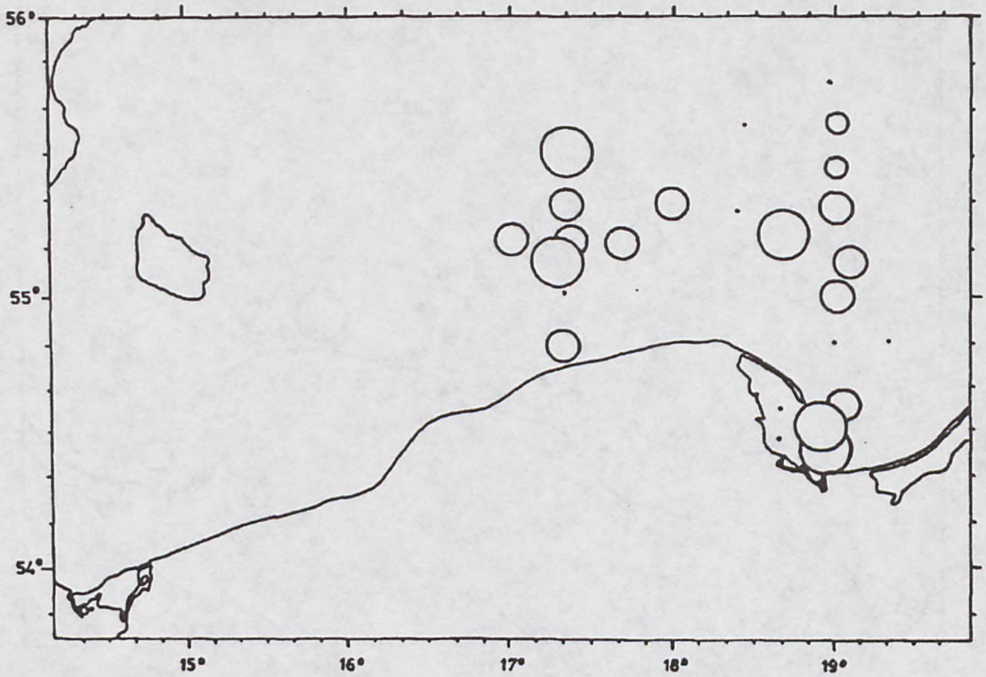

Fig. 7. Distribution of medusae in the Polish fisheries zone of the Baltic in November 1985. Symbols as in Fig. 1

C. capilata medusae occurred irregularly and in small numbers in different months of the 1987–1991 period (Tab. 2). Their presence was restricted mainly to the open sea and deeper water layers (Figs. 1 and 3).

Table 2. Occurrence of *Cyanea capilata* medusae in the Polish fisheries zone in 1987–1991 (V_c – mean biovolume, $cm^3\,1000\,m^{-3}$)

Date	August 87	October 87	February 88	July 88	August 88	September 88
V_c	5.41	6.10	12.89	4.92	57.16	31.37

Date	March 91	June 91
V_c	+	+

In order to show long-term variability in the number of *A. aurita* medusae, their mean biovolume in each quarter of the period 1983–1991 was calculated (Fig. 8). The numbers of medusae differed greatly from year to year. The largest numbers were observed in the third quarter of 1983 and the third quarter of 1991, whereas in the whole of 1987 their numbers were relatively small. In order to determine the annual cycle of medusae occurrence in the Polish Baltic zone, their mean biovolume in each month was calculated (Fig. 9).

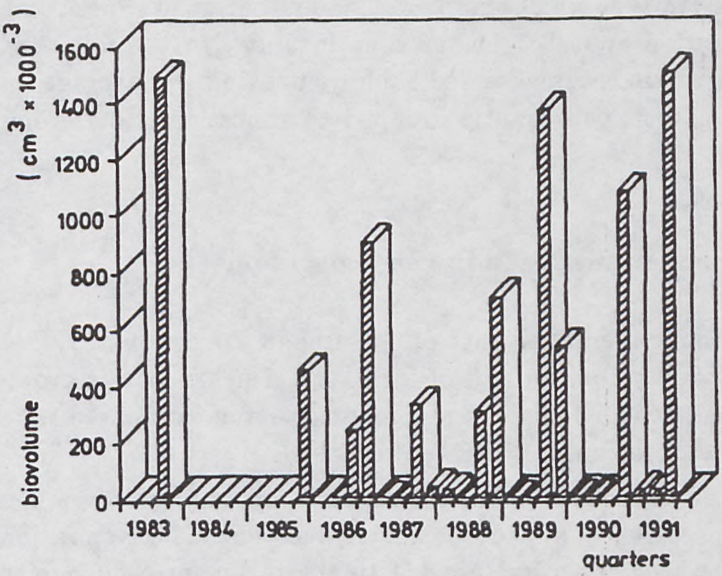

Fig. 8. Mean biovolume of *Aurelia aurita* medusae in particular quarters in the period 1983–1991. Empty spaces indicate lack of data

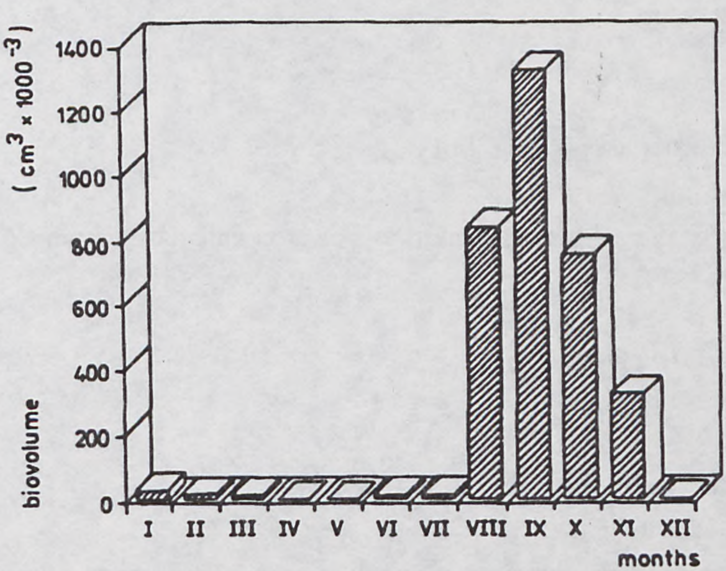

Fig. 9. Annual changes in biovolume of *Aurelia aurita* medusae (mean values from 1983–1991)

It appears from our data that between January and June medusae from the previous season were scarce – *C. capilata* occurred only sporadically and *A. aurita* was present in very small numbers. The first *A. aurita* specimens from the new generation appeared in our zone in July. In the following months the number of medusae increased rapidly, peaking, on average, in September. Their numbers subsequntly dropped to almost zero in December.

3.2. The importance of medusae in the ecosystem

In order to determine the importance of medusae in the southern Baltic ecosystem, the cost of metabolism and of food requirements in this group of animals were calculated. The figures obtained were then compared with the production of mesozooplankton their potential food.

Calculations based on the food balance were made for August–November, the season of mass occurrence of medusae during the year. The respiration of single specimens whose size corresponded to the mean for each month was calculated by means of a formula (Schneider, 1989) determined on the basis of a study of 18 individuals of *A. aurita* in the Baltic at a temperature range of 13°–18°C:

$$R = 0.103\, W_p^{0.94}, \tag{1}$$

where

R – respiration of a single specimen [$\mathrm{ml\,O_2\,d^{-1}}$] and

W_p – its wet weight [g].

Carbon catabolism by the medusae population was next calculated from the formula

$$R^* = 0.455 mg\, \mathrm{C}/ml\, \mathrm{O_2}\, R\, B_m / W_p, \tag{2}$$

where

R* – carbon catabolism by the population [$\mathrm{mg\,C\,m^{-3}\,d^{-1}}$],

B_m – biomass of medusae [$\mathrm{g\,m^{-3}}$].

It was assumed that the consumption of 1 ml O_2 corresponds to the consumption of 0.455 mg of organic carbon, with $RQ = 0.85$ (Schneider, 1989). The results of the calculations are presented in Tab. 3.

Table 3. Mean weight, biomass, and cost of metabolism of medusae during their mass occurrence in the southern Baltic

Month	W_p [g]	B_m [g 1000 m^{-3}]	R [ml O_2 d^{-1}]	R* [mg C m^{-3} d^{-1}]
August	40.44	837.24	3.34	0.031
September	71.99	1321.71	5.67	0.047
October	88.18	755.70	6.94	0.027
November	30.50	320.85	2.56	0.012

W_p – mean weight of a single specimen,
B_m – biomass of medusae,
R – respiration of a single specimen,
R* – carbon catabolism of the entire medusae population.

For calculating the production and assimilation of the medusae population, a net production efficiency coefficient $K_2 = 0.25$ was used (Humphreys, 1979). The food assimilation efficiency coefficient $U^{-1} = 0.8$ was used to calculate food consumption by the medusae population (Schneider, 1989). The food balance of medusae in the season of their mass occurrence is shown in Tab. 4.

Table 4. Food balance of the *A. aurita* population in the southern Baltic in the season of their mass occurrence (August–November). Calculated on the basis of mean biomass values from 1983–1991. All values given in mg C m^{-3} season $^{-1}$

Consumption	5.95
Assimilation	4.76
Production	1.19
Respiration	3.57

For comparative reasaons, mesozooplankton production ($P_{mes.}$) in August–November was calculated from

$$P_{mes.} = B_{mes.}\,(P/B)_{mes.}, \tag{3}$$

where
$B_{mes.}$ – mesozooplankton biomass,
$(P/B)_{mes.}$ – production intensity.
The mean mesozooplankton biomass for two-month periods in 1982–1988 (August–September and October–November) was used in the calculations (Wolska-Pyś and Ciszewska, 1991). On the basis of the studies by Ciszewski and Witek (1977) conduced on the dominant Baltic copepods *Pseudocalanus elongatus* and *Acartia bifilosa*, it was assumed that the average daily mesozooplankton production intensity between August and November was

$(P/B)_{mes.} = 0.05$. The biomass and production of mesozooplankton was then converted into organic carbon, assuming that 1 mg w.w. contains 0.064 mg C (Vinogradov and Shushkina, 1987). The results are set out in Tab. 5.

Table 5. Mean biomass ($B_{mes.}$) and daily production ($P_{mes.}$) of mesozooplankton in the southern Baltic during the mass occurrence of medusae. Calculated on the basis of the papers by Wolska-Pyś and Ciszewska (1991) and Ciszewski and Witek (1977)

Season	$B_{mes.}$ [mg C m^{-3}]	$P_{mes.}$ [mg C m^{-3} d^{-1}]
August–September	30	1.5
October–November	15	0.75

The mesozooplankton production between August and November was estimated at 137.25 mg C m^{-3} $season^{-1}$ It appears from the above calculations that between August and November the average food requirement of medusae is equal to 4.3% of the mesozooplankton production.

4. Discussion

Aurelia aurita medusae appear in the southern Baltic in July and perish in November. Single specimens may be encountered as late as January or even February of the following year (Mańkowski, 1950). However, the period of their mass occurrence is limited to four months (July–November). From the moment of their appearance, their biomass increases rapidly. This is the result not only of an increase in numbers but also of the growth of individual specimens. Once their numbers have attained a maximum in September, they decrease until December, when there are hardly any left. The reason for the reduction in the number of medusae is the morphological degradation of their bodies as well as increased mortality of the entire population following reproduction (Möller, 1980a)

In other areas, medusae occur at different periods. For instance, off the coast of Germany small medusae appear as early as April (Möller, 1980a), and off the coast of Sweden – in May (Hernroth and Gröndahl, 1983). In both those areas they occur until November. In the Black Sea the presence of two generations during the year has been observed: a winter one – developing for six months (from December to May) and a spring one – developing for five months (April–Agust) (Mironov, 1967).

The reason for the later appearance and shorter occurrence of medusae in Polish Baltic waters cannot be explained until the reproduction site of this species is known. So far, no exhaustive studies of this problem have been carried out. On the basis of the phytoplankton composition studies conducted so far, in the Gulf of Gdańsk and in the southern Baltic as well as on the basis of our own observations made in 1990–1991, one can only attempt to formulate certain hypotheses.

During detailed zooplankton studies in the Gdańsk Basin in 1987, the presence of considerable numbers of *A. aurita* planulae was observed in autumn (Krajewska-Sołtys, personal communication). However, despite a search carried out in the Gulf of Gdańsk in the spring of 1991 on stones, algae, and shells of *Mytilus edulis*, no polyps of *A. aurita* were found (authors' own observations). Ephyrae of *A. aurita* have only very rarely been found in Polish waters. Single ephyrae have been encountered between May and July in the vicinity of Gdynia and the Hel Peninsula, close to harbour constructions (Mańkowski, 1948, 1950: authors' own observations). The presence of ephyrae was not observed in the plankton of open waters during the numerous studies carried out in 1978–1991 (Wiktor *et al.*, 1982; Wiktor and Żmijewska, 1985; present paper). The first appearance of larger numbers of medusae was observed in the western part of the Polish fisheries zone *e.g.* in July 1988 near the Bornholm Deep). At the beginning of the period of mass occurrence, the largest numbers were also noted in the western part of the Polish fisheries zone and in the in-shore zone, in which there were strong easterly currents (Łomniewski *et al.*, 1975). The above observations suggest that reproduction of *A. aurita* may occur in Polish waters, but most likely it takes place locally and only a small fraction of the medusae appearing in very large numbers in August is born off the Polish coast. It is possible that in the 1950s, the reproduction of *A. aurita* in Polish waters was of greater importance than at present (cf. Mańkowski, 1959). It seems, however, that the vast majority of the medusae living in Polish waters are transported by surface currents from the western Baltic. The reason for the poor reproduction of this species may be the absence of a suitably hard bottom for the development of polyps. Low salinity may also be a factor. Thus, migration may be the reason why *A. aurita* medusae appear later in the southern Baltic and remain there for a shorter time.

The sparse numbers of *Cyanea capilata* medusae occurring sporadically in the southern Baltic are also immigrants, having reached this area by a slightly different route from *A. aurita.* These medusae occur primarily in the near-bottom layer, along an axis of the Baltic running through the deepest parts of the Bornholm Deep and Słupsk Furrow, and also the Gotland Deep, of which the Gdańsk Deep is the southern part. This clearly indicates their appearance together with more saline waters flowing in from the North Sea.

The biomass of the *A. aurita* medusae in the southern Baltic is lower than that observed in other European seas, including the western part of the Baltic Sea (Tab. 6). For example, in Kiel Bay, known to be a site of reproduction of *A. aurita* (Möller, 1980c), or in the Danish Straits, mean concentrations many times exceed the mean value observed in our waters. The decrease in the number of medusae when moving from the western Baltic to the east seems to confirm the hypothesis about their migrations.

In comparison with other regions, the medusae biomass is small, so their share in the energy flow of the southern Baltic ecosystem is lower than that in the western Baltic or the Black Sea. Assuming that primary production in the Baltic equals 100–200 $g\,C\,m^{-2}$ annually (Renk, 1990), *A. aurita* consumes only 0.1–0.2% of this value for respiration. The moderate food requirements of medusae, on average constituting 4.3% of the mesozooplankton production in the season from August to November, cannot significantly influence its biomass.

Table 6. Biomass of medusae in various areas of the world ocean

Area	Biomass [$g\,m^{-3}$]	Season, year and source
North Sea	0.06	August–September 1978
Kattegat	1.97	Möller (1980c)
Kiel Bight	15.83	
Southern Baltic	1.44	
Baltic proper	0.62	
Polish Baltic zone	1.08	August–September 1983–1991, this paper
Black Sea	25.00	August–September 1978 Shushkina and Musayeva (1983)
Elefsis Bay (Saronikos Gulf, Greece)	1.45	May 1981–1985 Panyotidis *et al.* (1988)
Western part of the Dutch Wadden Sea	9.92	May 1981–1982 Van der Veer and Orthuysen (1985)

In the Black Sea and Kiel Bay, where numbers of medusae are very high (Tab. 6), their influence on mesozooplankton is very great. It has been calculated, for instance, that in the Black Sea *A. aurita* annually consumes about 30% of the production of nonpredatory crustaceans (Shushkina and Musayeva, 1983). In Kiel Bay *A. aurita* medusae consume about 30% of the daily zooplankton production during the period of the biomass increase, and about 13% of its production in summer, when the biomass remains at a stable level (Schneider, 1989). In those ecosystems the *A. aurita* medusae belong to the most important factors regulating zooplankton biomass. Within the entire southern Baltic ecosystem, *A. aurita* does not play such an important role. It is worth remembering, however, that the distribution of medusae in our waters is not uniform and periodically, especially in the inshore zone, their biomass is high; at such times, their impact on other elements of the community will be considerably greater.

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