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Gelatinous zooplankton – a potential threat to the ecosystem of the Puck Bay (the southern Baltic Sea, Poland)

Zooplankton galaretowaty – potencjalne zagrożenie dla ekosystemu Zatoki Puckiej (Bałtyk Południowy, Polska)

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Abstract: Gelatinous zooplankton is a group of organisms, which in recent decades has become one of the most important elements to shape the marine ecosystem. Their growing numbers and spreading to the new marine regions, in combination with the high feeding rate, causes significant changes in the flow of energy in the food webs.

The only regularly-occurring gelatinous zooplankton species in the Puck Bay area is scyphozoan *Aurelia aurita*, most abundant in the summer and fall seasons. As shown in Barz and Hirche's (2005), Möller's (1980a), Schneider's (1989), and Schneider and Behrends' (1994) studies, the abundance of jellyfish in Bornholm Basin and Kiel Bight was several times lower than that in Puck Bay. Nevertheless, the authors of these studies concluded that the population of *A. aurita* can significantly reduce mesozooplankton and fish resources by preying on their larvae and eggs. Taking this into account, it is possible that the impact of *A. aurita* medusae on the Puck Bay ecosystem is even higher than in other parts of the Baltic Sea. Verification of this thesis requires detailed investigation; the scope of which should include investigation of: *A. aurita* food selectivity and long-term mesozooplankton, and *A. aurita* medusae abundance.

The aim of this study, based on the few data in the literature, is to estimate if the gelatinous zooplankton is also an important element of the marine ecosystem the Puck Bay

Keywords: Gelatinous zooplankton, the Puck Bay, *Aurelia aurita,* mesozooplankton

Streszczenie: Zooplankton galaretowaty to grupa organizmów, która w ostatnich dekadach stała się jednym z najważniejszych elementów kształtujących ekosystemy morskie. Ich rosnąca liczebność i rozprzestrzenianie się na nowe akweny w połączeniu z wysokim tempem żerowania, powodują istotne zmiany w przepływie energii w sieciach troficznych. Celem pracy była próba zbadania, na podstawie nielicznych danych literaturowych i własnych danych niepublikowanych, czy zooplankton galaretowaty jest również istotnym elementem ekosystemu Zatoki Puckiej. Jedynym regularnie występującym w tym akwenie gatunkiem z tej grupy zwierząt jest *Aurelia aurita*, która w miesiącach lata i jesieni występuje w wysokiej liczebności (Olenycz – dane niepublikowane). W przypadku Basenu Bornholmskiego i Zatoki Kilońskiej stwierdzono (Möller 1980a, Schneider 1989, Schneider and Behrends 1994, Barz and Hirche 2005), że liczebność meduz była około kilkukrotnie mniejsza niż w przypadku Zatoki Puckiej. Tym niemniej autorzy tych badań uznali, że populacja tego gatunku może znacząco redukować zasoby mezozooplanktonu i ryb, poprzez żerowanie na ich larwach i ikrze. Potencjalnie więc, wpływ meduz *A. aurita* Zatoki Puckiej jest większy niż w przypadku innych rejonów Bałtyku. Jednak aby potwierdzić tę tezę należy przeprowadzić kompleksowe badania, które swym zakresem objęłyby długoterminowe analizy wybiórczości pokarmowej meduz *A. aurita* oraz zmian liczebności mezozooplanktonu i meduz *A. aurita*.

Słowa kluczowe: Zooplankton galaretowaty, Zatoka Pucka, *Aurelia aurita*, mezozooplankton

Introduction

Gelatinous zooplankton is the common name given to several planktonic groups of marine and brackish water animals: scyphozoan (Scyphozoa) and hydrozoan (Hydrozoa) medusae, ctenophores (Ctenophora), siphonophores (Siphonophora), thaliaceans (Thaliacea), and chaetognaths (Chaetognatha), (Haddock 2004, Condon *et al.* 2012). These organisms exhibit morphological (delicate, transparent, or translucent body) and ecological (planktonic lifestyle) similarity; however they do not exhibit close taxonomic and phylogenetic relationships (Haddock 2004).

Since the beginning of the 1980s, gelatinous zooplankton has become a subject of interest to both scientists and users of marine areas. The reason for this were sudden outbreaks (seasonal or non-seasonal exceptional abundances of gelatinous zooplankton) of these organisms, which resulted in significant changes in marine ecosystems (CIESM 2001, Purcell *et al.* 2010).

Gelatinous zooplankton outbreaks are often linked with global warming, which can be particularly important in temperate zones because it can lengthen the growing season of phytoplankton. Combined with eutrophication, it can trigger a rapid increase in the abundance of phytoplankton, which in turn leads to an increase in the abundance of mesozooplankton (Brodeur *et al.* 1999, Brierley *et al.* 2001, Mills 2001, Lynam *et al.* 2004, Attrill *et al.* 2007). Ample food resources promotes an intensive development of gelatinous zooplankton, manifested in its high numbers. Another cause for gelatinous zooplankton outbreaks is overfishing (Daskalov 2002, Lynam *et al.* 2011). Depleting of planktivorous fish stocks leaves more mesozooplankton for jellyfish and ctenophores to be consumed. In the following years, even with reduction or cessation of fishing limits, the fish population cannot rebuild because their place in the food web has already become occupied by gelatinous zooplankton.

Apart from an environmental impact, outbreaks of gelatinous zooplankton may adversely affect various human activities in marine areas. The largest negative impact is most probably on the fishing industry. High densities of jellyfish can clog fishing nets, and thus reduce their catching effectiveness (Omori and Kitamura 2004, Uye 2008). Competition with fish for food resources may reduce stocks of commercially exploited planktivorous species (Palmieri *et al.* 2013). Another cause for fishery decline is preying on fish larvae and eggs by gelatinous zooplankton (Palmieri *et al.* 2013). The most famous example is the outbreak of comb jelly *Mnemiopsis leidyi* in the Black Sea in the early 1980s, which led to the depletion of commercial fish stocks and the collapse of the Black Sea fisheries. The presence of gelatinous zooplankton in coastal waters and their decomposing remains on beaches in tourist resorts can decrease tourist traffic and therefore cause financial losses (Brotz and Pauly 2012). In recent years, there were cases reported when high numbers of gelatinous zooplankton led to the clogging of power plant cooling systems intakes, which resulted in their shutdown and temporary power outages (Purcell *et al.* 2007, www1 and www2).

Gelatinous zooplankton in Puck Bay and other marine regions of the Baltic Sea

In Puck Bay, gelatinous zooplankton is represented almost exclusively by the scyphozoan jellyfish *Aurelia aurita* (the moon jellyfish). *A. aurita* (several cryptic species – Dawson and Jacobs 2001) has a worldwide distribution between 70°N and 40°S latitude (Kramp 1961). Its broad geographical distribution, from temperate to tropical regions, is due to its wide tolerance of environmental conditions (Malej *et al.* 2007). Populations of *A. aurita* are found in both cold water fjords of the northern Scandinavia and saltwater Jellyfish Lake (Palau) with a temperature of 31°C throughout the year. A wide range of tolerance to salinity allows *A. aurita* to inhabit the Gulf Elefis (Greece) with a salinity of 38 PSU and brackish waters of the Black Sea and the Baltic Sea, where it is absent only in nearly freshwater in the Gulf of Bothnia (Janas and Witek 1993, Olesen *et al.* 1994, Lucas 2001). The largest populations of *A. aurita* are found in shallow bays, fjords, and estuaries with prevailing stable hydrodynamic conditions where moon jellyfish find suitable conditions for reproduction and development (Olesen *et al.* 1994, Lucas 1996 and 2001). Horizontal distribution of *A. aurita* medusae is highly influenced by wind-induced surface currents and the availability of food resources. Its populations are therefore patchy, for instance medusae occur in high densities in a relatively small area, while there are absences in other parts of the same geographical region (Möller 1980a, Mutlu and Bingel 1995).

Data show that *A. aurita* populations grow in many of the world's coastal ecosystems. A fourfold increase in *A. aurita* biomass has been noted in the Black Sea from the late 1970s to the first half of the 1990s (Mutlu 2001) - such an enormous expansion has been explained by the heightened primary production caused by water temperature rise. A positive correlation between *A. aurita* population growth and the increase in primary production was also drawn in other regions of the world (Omori *et al.* 1995, Arai 2001, Mutlu 2001, Shoji *et al.* 2005).

In the case of Puck Bay there is lack of quantitative data describing the long-term population dynamics of *A. aurita*. Quantitative data relating to a short one-year period were provided by Janas and Witek (1993). Unfortunately, the authors described *A. aurita* population by biomass estimated from the volume of captured medusae. This makes the data difficult to compare to results from other studies, in which the population was described as the abundance expressed in the number of medusae per cubic meter of water. The first data describing *A. aurita* abundance in Puck Bay were derived from studies conducted by Olenycz in 2006 (Olenycz 2007 and unpublished data). They show that *A. aurita* medusae occur in Puck Bay from the beginning of June and reach maximum abundance in August and September. Their numbers diminish in October

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and November, with only single individuals occurring until the second half of December (Fig. 1).

Another scyphozoan, *Cyanea capillata*, sporadically appears in the waters of Puck Bay during the winter season - usually from December to March. Encounters of more than one individual are rare (M. Olenycz - own observations, P. Bałazy – oral communication). *C. capillata* medusae are most probably carried with sea currents from the western part of the Baltic Sea (Żmudziński 1990).

Another rarely observed gelatinous zooplankton species in Puck Bay is ctenophore *Pleurobrachia* (Schneider 1987, Żmudziński 1990). It inhabits deep parts of the southern Baltic Sea and appears in Puck Bay only occasionally, carried by sea currents (Wiktor 1990, Żmudziński 1990).

In October and November 2007, ctenophore *Mnemiopsis leidyi*, native to coastal waters of the western Atlantic (Ivanov *et al.* 2000, Janas and Zgrundo 2007), appeared in Puck Bay. *M. leidyi* can quickly colonize water bodies, in which it was not previously observed, thanks to its broad tolerance to a wide range of water salinity and temperature. For this reason it is considered as one of the most threatening invasive marine species (GESAMP 1997).

A good example of *M. leidyi* rapid colonization is the Black Sea. When it appeared in 1982 its average biomass was 225 g·m^{-3}, however it increased greatly in subsequent years reaching a maximum in 1991 of 11000-12000 g·m^{-3} (Vinogradov *et al.* 1989, Zaika and Sergeeva 1990). In later years, the population of *M. leidyi* started to decreased, however since 1994 it has started to grow again (GESAMP 1997). Such fluctuations in population size were observed in subsequent years (Vladymyrov *et al.* 2011). After the colonization of the Black Sea, *M. leidyi* spread its geographical distribution on the Caspian Sea, the Sea of Azov, the Sea of Marmara, and the Mediterranean Sea (Boero *et al.* 2009, Galil *et al.* 2009, Fuentes *et al.* 2009 and 2010).

Although *M. leidyi* has a broad salinity tolerance, a salinity below 10 PSU is not sufficient for the survival of its larvae. Distribution of this ctenophore in the Baltic Sea is therefore narrowed exclusively to the western part and the Danish Straits (Jaspers *et al.* 2011). With this, the appearance of *M. leidyi* in Puck Bay in the future is expected to be occasional.

Estimation of gelatinous zooplankton impact on the ecosystem of Puck Bay

Feeding on the mesozooplankton

Taking into account previously given evidence provided in the literature, we can assume that the only gelatinous zooplankton species that may affect the ecosystem of Puck Bay is *A. aurita*. As previously mentioned, the most important ecological impact of gelatinous zooplankton is associated with its feeding on mesozooplankton stocks. Research has shown that in the Baltic Sea *A. aurita* feeds mainly on adult stages of two mesozooplankton groups: cladocerans and copepods,

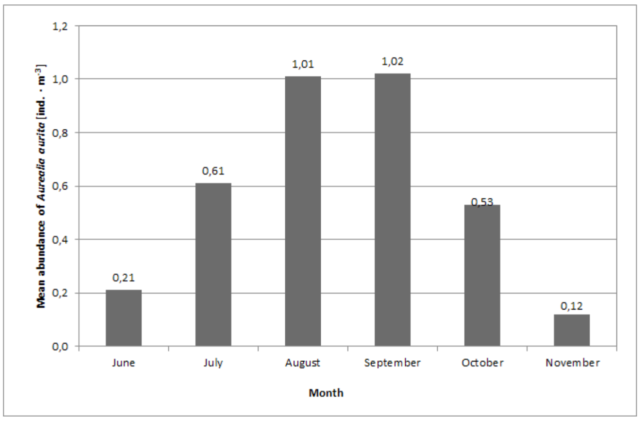

Fig. 1. Mean abundance (ind.·m^{-3}) of *Aurelia aurita* medusae in Puck Bay (the southern Baltic Sea, Poland) from June to November 2006 (Olenycz – unpublished data).

and to a lesser extent, on pelagic larvae of mussels and snails, and fish eggs and larvae (Möller 1980 a and b, Möller 1984, Schneider 1989, Margoński and Horbowa 1995, Olesen 1995, Graham and Kroutil 2001, Hansson 2006). The small-sized mesozooplankton, for example rotifers and copepods larvae, is not jellyfish primary food resource (ibidem). Below an analysis of seasonal changes in abundance of copepods and cladocerans is based on the most recent data from 1999-2000, published by Mudrak (2004).

Copepods are present in the mesozooplankton of Puck Bay throughout the year. Their numbers are highest in July and August (approximately 30000 ind.·m^{-3} in 2000), and the lowest in February (1333 ind.·m^{-3} in 2000), when the water temperature reaches minimum values. Genus *Acartia* (consisting of *A. bifilosa*, *A. tonsa*, and *A. longiremis*) is the species that has the highest and most frequent rate of appearance throughout the whole year. In October, November, June, and July, its contribution diminishes in favour of *Temora longicornis*. Less frequently observed copepod species are *Centropages hamatus*, *Pseudocalanus elongatus*, and *Eurytemora* sp.

Cladocerans are the second major group of the mesozooplankton community. These mostly thermophilic organisms appear in May (approximately 4 ind.·m^{-3} in 2000) and disappear in November (approximately 5 ind.·m^{-3} in 2000). They reach their highest abundance in August, when they peak rapidly (to 49 633 ind.·m^{-3} in 2000). In August, cladocerans have the largest percentage share in the whole mesozooplankton community of Puck Bay, mostly due to a very high abundance of *Bosmina coregoni maritima*. In the remaining months the most abundant cladoceran is *Pleopis polyphaemoides*. Less frequently noted cladocerans are *Podon intermedius* and *Evadne nordmanni* appearing in small numbers in July and August.

Data characterizing *A. aurita* feeding rate on mesozooplankton were derived mostly from laboratory experiments (i.e. Møller and Riisgård 2007, Hosia *et al.* 2012). Their biggest drawback is the impossibility of restoring natural environmental conditions in ex-situ experiments. More accurate data are derived from analysing the field-caught mesozooplankton and *A. aurita* gut content, collected in the same place and time which allow to obtain qualitative and quantitative data on jellyfish feeding rates and their food selectivity.

When it comes to the Baltic Sea, the only studies of this type were carried out and published by Barz and Hirche (2005) in the area of Bornholm Basin, in the period from July to October 2002. Results of the mesozooplankton composition and abundance, and jellyfish gut content analysis calculated with the average digestion time (Purcell 2003), allowed estimations of potential predation effect of the *A. aurita* medusae on the mesozooplankton community. Gut content analysis showed that jellyfish prey primarily on cladocerans (79.8%), among which dominated the species *Bosmina coregoni maritima* (62.8%). Copepods made up 16.0% of the gut content and *Temora longicornis* was the most abundant prey item (9.3%). Bivalve larvae made up only 4.1% of the food consumed by the jellyfish, however in late August that share was much higher (21.0%). The authors estimated that the population *A. aurita* in Bornholm Basin can graze up to 0.27% of daily copepod production and 2.15% of daily cladoceran production. Taking into account the small number of medusae (0,01-0,18 ind.·m^{-3}), the authors estimated *A. aurita* does not regulate the zooplankton community in Bornholm Basin, and fish larvae did not suffer from competition with, and predation by, the jellyfish.

A. aurita feeding rate and its potential impact on the mesozooplankton community were also investigated in Kiel Bight by several research projects (Möller 1980a, Schneider 1989, Schneider and Behrends 1994). Results show that *A. aurita* medusae abundance ranged from 0.03 to 0.33 ind.·m^{-3}, which is at least twice more than in Bornholm Basin. No quantitative data on the mesozooplankton volumes were presented in the cited publications, however it is expected that it was at least similar to the values characterizing the open waters of Bornholm Basin. The authors suggest that *A. aurita* can have a major impact on the ecosystem of Kiel Bight by regulating the abundance of the mesozooplankton community. This was later confirmed by Schneider and Behrends (1998), who summarized the data of the jellyfish and mesozooplankton abundance and showed, in contrast to Barz and Hirche (2005), that medusae feeding can substantially reduce cladoceran and copepod stocks.

The abundance of *A. aurita* medusae in Puck Bay was investigated in 2006. Results showed that it was at least ten times higher than in Bornholm Basin and Kiel Bight (Fig. 2). Assuming that the feeding rate of jellyfish is the same in Puck Bay as in Bornholm Basin, its population could have much greater impact on the food web of the basin than in case of Bornholm Basin and Kiel Bight. However, the confirmation of this thesis requires a detailed investigation. At the moment, it is only possible to compare the abundance of *A. aurita* and its food resources, for instance cladocerans and copepods obtained for the two water bodies: Bornholm Basin (Barz and Hirche 2005) and Puck Bay (data derived from: Mudrak 2004, Olenycz 2007, and author's unpublished data).

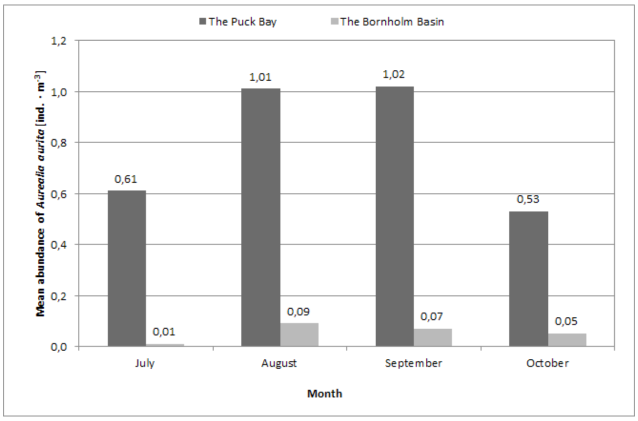

Fig. 2. Comparison of mean abundance (ind. · m^{-3}) of *Aurelia aurita* in Puck Bay in year 2006 and in Bornholm Basin in year 2002.

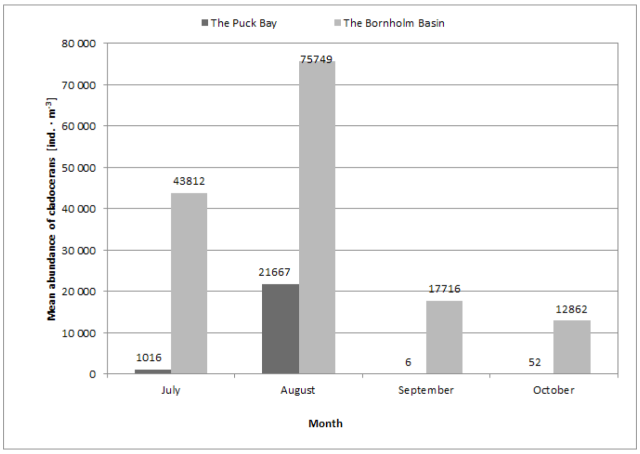

Fig. 3. Comparison of mean abundance (ind.·m^{-3}) of cladocerans in Puck Bay in the years 1999-2001 and in the Bornholm Basin in year 2002.

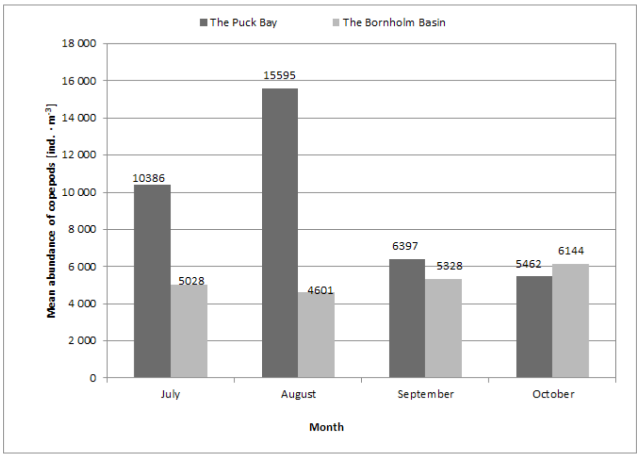

Fig. 4. Comparison of mean abundance (ind.·m^{-3}) of copepods in Puck Bay in the years 1999-2001 and in the Bornholm Basin in year 2002.

A higher abundance of medusae in Puck Bay is most likely the result of *A. aurita* finding more suitable conditions in this

Tab. I. Fish species of Puck Bay, which populations can be impacted by *Aurelia aurita* medusae and the scope of the impact.

LP.	FISH SPECIES (LATIN NAME)	POTENTIAL PREYING OF A. AURITA MEDUSAE ON FISH EGGS	POTENTIAL PREYING OF A. AURITA MEDUSAE ON FISH LARVAE	COMPETITION FOR COMMON FOOD RESOURCES
1.	roach (*Rutilus rutilus*)*	-	+	+
2.	bream (*Abramis brama*)*	-	+	+
3.	sticklebacks (Gasterosteidae)	-	-	+
4.	herring (*Clupea harengus*)**	-	+	+
5.	sprat (*Sprattus sprattus*)**	+	+	+
6.	eelpout (*Zoarces viviparus*)	-	-	+
7.	the lesser sand eel (*Ammodytes tobianus*)	-	-	+
8.	the great sand eel (*Hyperoplus lanceolatus*)	-	-	+
9.	straightnose pipefish (*Nerophis ophidion*)	-	+	+
10.	broadnosed pipefish (*Syngnathus typhle*)	-	+	+

importance to fisheries: * - low, ** - high

Tab. II. Salinity tolerance of gelatinous zooplankton species noted in Puck Bay determined on the basis of literature data.

GELATINOUS ZOOPLANKTON SPECIES	SALINITY TOLERANCE RANGE [PSU]	SALINITY ABOVE WHICH THE HIGHEST ABUNDANCES WERE OBSERVED [PSU]	LITERATURE
Aurelia aurita	2-35	>5	Kramp 1961, Möller 1980 a and b, Schneider and Behrends 1994, Schneider 1989, Janas and Witek 1993, Lucas 2001, Olenycz 2007,
Cyanea capillata	5-34	>15	Båmstedt et al. 1994, Purcell 2003, Holst and Jarms 2010, Purcell et al. 2010
Pleurobrachia pileus	2-35	>12	Arai 1973, Yip 1984, Schneider 1987, Mutlu and Bingel 1995
Mnemiopsis leidyi	4-38	>10	GESAMP 1997, Ivanov et al. 2000, Fuentes et al. 2009 and 2010, Hansson 2006, Javidpour et al. 2009

semi-enclosed basin, in large sheltered by land. The hydrodynamic conditions are much more stable than those in the open waters of Bornholm Basin and provide more favourable conditions to the development of the *A. aurita* population.

Copepods and cladocerans communities of Puck Bay, in the months of *A. aurita* medusae high abundance, were characterized on the basis of data provided by Mudrak (2004). While cladocerans were significantly more abundant in Bornholm Basin in all months (Fig. 3), the volume of copepods in Puck Bay in July and August was significantly higher when compared with Bornholm Basin - twice and three times higher, respectively. In September and October it declined and their abundance was similar in both basins (Fig. 4).

Barz and Hirche (2005) found that cladoceran *Bosmina coregoni maritima*, which occurred in the highest abundance of all species of mesozooplankton (up to 94% of cladoceran standing stock), was the most frequently consumed by *A. aurita* medusae in all months of investigations. Medusae also preyed upon cladocerans of genus *Podon* and copepod *Temora longicornis*, which is also an important component of mesozooplankton of Puck Bay (Mudrak 2004). Considering the much higher abundance of *A. aurita* medusae in Puck Bay it is possible that grazing medusae can significantly reduce cladoceran stock through intensive feeding on *B. coregoni maritima*. Verification of this thesis requires detailed investigation, however it is possible that *A. aurita* in much greater extent shapes the marine food web of Puck Bay than of Bornholm Basin and Kiel Bight.

Although the evidence that the abundance of *A. aurita* medusae in Puck Bay can be higher than in other regions of the Baltic Sea, no visible consequences for the ecosystem were noticed so far. It is possible that the population of *A. aurita* has not exceeded the carrying capacity of the environment, and for this reason non-drastic changes in the structure of the food web occur. However, it is also possible that the impact on the ecosystem already exists but it is "hidden" due to a lack of data describing the correlation between the abundance of mesozooplankton species and jellyfish mass occurrence. Seasonal and annual changes in the mesozooplankton stock are explained solely as a result of changing physico-chemical conditions of the area of water.

Competing with fish on common food resources and preying on their larvae and eggs

An additional difficulty in the identification of "if" and "in what amount" *A. aurita* can alter the marine ecosystem of Puck Bay

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is the fact that mesozooplankton and jellyfish are not the subject of interest of marine area users. However, mesozooplankton is the main prey for several fish species caught in Puck Bay and for fish larvae. Thus, jellyfish grazing on mesozooplankton can reduce its availability to fish and therefore reduce the size of commercial fish standing stocks. It is also unknown to what extent *A. aurita* medusae can affect fish stocks by preying on their larvae and eggs. Table I provides the list of the most common fish species of Puck Bay, size populations of which can be regulated by *A. aurita* medusae.

Taking into account all factors listed in Table I, *A. aurita*, can exert the greatest impact on populations of sprat and herring and, to a lesser extent, bream and roach, which are found in small quantities in Puck Bay. Results of studies conducted in other regions of the Baltic Sea indicate that *A. aurita* can significantly reduce fish stocks, feeding on the eggs and larvae (Möller 1980b, Bailey 1984, Bailey and Batty 1984, Titelman and Hansson 2006). Although studies have not shown that moon jellyfish were actively "looking" for this type of food (Titelman and Hansson 2006), due to the small ability of fish larvae to evade predators and its complete lack of fish eggs, they are an easy prey for medusae, especially at high densities (Purcell and Arai 2001). As calculated by Möller (1980b) in Kiel Bight, *A. aurita* can reduce from 2.6 to 4.4% of herring larvae stock. It should be noted that the abundance of *A. aurita* medusae was 0.03 ind.·m^{-3}, which is several times lower than in Puck Bay in 2006 (Fig. 1). This may indicate that *A. aurita* could have major impact on fish standing stock in this basin. Verification of this only theoretical consideration requires performing a detailed investigation.

Prediction of changes in community structure of gelatinous zooplankton in Puck Bay

Growth of gelatinous zooplankton species populations and appearance of new species in Puck Bay is limited by two environmental factors: water salinity and temperature. All species found in Puck Bay are both eurythermal and euryhaline, however the latter has a decisive influence on the distribution being a form of a natural barrier to its spread. As shown in Table II, all species can tolerate a broad range of salinity values, however their populations are only abundant above a certain salinity level.

Aurelia aurita is the only species found in large quantities in salinities below 10 PSU. It is clear that no other species can develop stable population in Puck Bay with a salinity range of 7.3-7.6 PSU (Nowacki 1993). The water salinity is probably somewhat below the minimum needed for these species to carry out successful breeding. It is unlikely that the salinity of Puck Bay will change significantly in the near future, and thus *A. aurita* will remain as the only abundant gelatinous zooplankton species in that basin.

Water temperature of Puck Bay varies within the range of 1 to 21°C, depending on the season and weather conditions (Cyberski 1993), and *A. aurita* tolerates values in the range of 0 to 31°C (Hernroth and Grondahl 1983). Therefore this environmental factor does not limit the population dynamics of this scyphozoan. However, increase of water temperature can affect the size of *A. aurita* population. Global warming can indirectly increase the abundance of mesozooplankton in the effect, and this could lead to an increase in *A. aurita* population.

Conclusions

Of the four species of gelatinous zooplankton found in Puck Bay, only one *Aurelia aurita* is abundant and may play an important role in the food web of this marine ecosystem. Literature data show that in the other regions of the Baltic Sea moon jellyfish is an important component of the pelagic communities and are at a much lower abundance than that found in Puck Bay, can significantly reduce the mesozooplankton and certain fish species stocks by preying on their larvae and the eggs, and by competing for common food resources. Verification of this thesis requires detailed investigation that should be carried out in the following areas: (1) *A. aurita* feeding selectivity and feeding rate; (2) long-term changes in the abundance of mesozooplankton, fish larvae and eggs, which were determined prey items for *A. aurita* medusae. Gathering this data will allow the relationship between the abundance of moon jellyfish and the abundance of mesozooplankton and fish to be examined.

At this point, due to lack of data, it is not possible to estimate the carrying capacity of the environment for this species. It is recommended that the institutions responsible for environmental monitoring include gelatinous zooplankton in their monitoring programs. Filling the gaps in the knowledge of this very likely important part of the marine ecosystem of Puck Bay will allow more accurate forecasting of changes in the marine ecosystem

References:

[1] Arai, M. N. (1973). Behaviour of the planktonic coelenterates, ***Sarsia tubulosa***, ***Phialidium gregarium*** and ***Pleurobrachia pileus*** in salinity discontinuity layers. Journal of the Fisheries Research Board of Canada, 30 (8), 1105-1110.

[2] Arai, M. N. (2001). Pelagic coelenterates and eutrophication: a review. Hydrobiologia, 451, 69-87.

[3] Attrill, M. J., Wright, J., Edwards, M. (2007). Climate-related increases in jellyfish frequency suggest a more gelatinous future for the North Sea. Limnological Oceanography, 52 (1), 480-485.

[4] Bailey, K. M. (1984). Comparison of laboratory rates of predation on five species of marine fish larvae by three planktonic invertebrates – effects of larval size on vulnerability. Marine Biology, 79, 303-309.

[5] Bailey, K. M., Batty, R. S. (1984). Laboratory study of predation by ***Aurelia aurita*** on larvae of cod, flounder, plaice and herring – development and vulnerability to capture. Marine Biology, 83, 287-291.

[6] Båmstedt, U, Martinussen, M. B., Matsakis, S. (1994). Trophodynamics of the two scyphozoan jellyfishes, ***Aurelia aurita*** and ***Cyanea capillata***, in western Norway. ICES Journal of Marine Science, 51 (4), 369-382.

[7] Barz, K., Hirche, H.-J. (2005). Seasonal development of scyphozoan medusae and the predatory impact of ***Aurelia aurita*** on the zooplankton community in the Bornholm Basin (central Baltic Sea). Marine Biology, 147 (2), 465-476.

[8] Boero, F., Putti, M., Trainito, E., Prontera, E., Piraino, S., Shiganova, T. A. (2009). First records of ***Mnemiopsis leidyi*** (Ctenophora) from the Ligurian, Thyrrhenian and Ionian Seas (Western Mediterranean) and first record of ***Phyllorhiza punctata*** (Cnidaria) from the Western Mediterranean. Aquatic Invasions, 4 (4), 675-680.

[9] Brierley, A. S., Axelsen, B. E., Buecher, E., Sparks, C. A. J., Boyer, H., Gibbons, M. J. (2001). Acoustic observations of jellyfish in the Namibian Benguela. Marine Ecology Progress Series, 210, 55-66.

[10] Brodeur, R. D., Mills, C. E., Overland, J. E., Walters, G. E., Schumacher, J. D. (1999). Evidence for a substantial increase in gelatinous zooplankton in the Bering Sea, with possible links to climate change. Fisheries Oceanography, 8, 296-306.

[11] Brotz, L., Pauly, D. (2012). Jellyfish populations in the Mediterranean Sea. Acta Adriatica, 53, 211-230.

[12] CIESM (2001). Gelatinous zooplankton outbreaks: theory and practise. CIESM Workshop Series, 14, Monaco.

[13] Condon, R. H., Graham, W. M., Duarte, C. M., Pitt, K. A., Lucas, C. H., Haddock, S. H. D., Sutherland, K. R., Robinson, K. L., Dawson, M. N., Decker, M. B., Mills, C. E., Purcell, J. E., Malej, A., Mianzan, H., Uye, S., Gelcich, S., Madin, L. P. (2012). Questioning the Rise of Gelatinous Zooplankton in the World's Oceans. BioScience, 62, 160-169.

[14] Cyberski, J. (1993). Hydrologia. In: K. Korzeniewski, Zatoka Pucka (40-71). Institute of Oceanography of the University of Gdańsk. Gdynia.

[15] Daskalov, G. M. (2002). Overfishing drives a trophic cascade in the Black Sea. Marine Ecology Progress Series, 225, 53-63.

[16] Dawson, M. N, Jacobs, D. K. (2001). Molecular evidence for cryptic species of Aurelia aurita (Cnidaria, Scyphozoa). The Biological Bulletin, 200, 92-96.

[17] Fuentes, V. L., Angel, D. L., Bayha, K. M., Atienza, D., Edelist, D., Bordehore, C., Gili, J. M., Purcell, J. E. (2010). Blooms of the invasive ctenophore, ***Mnemiopsis leidyi***, span the Mediterranean Sea in 2009. Hydrobiologia, 645 (1), 23-37.

[18] Fuentes, V. L., Atienza, D., Gili, J. M., Purcell, J. E. (2009). First records of ***Mnemiopsis leidyi*** A. Agassiz 1865 off the NW Mediterranean coast of Spain. Aquatic Invasions, 4 (4), 671-674.

[19] Galil, B., Kress, N., Shiganova, T. A. (2009). First record of ***Mnemiopsis leidyi*** A. Agassiz, 1865 (Ctenophora; Lobata; Mnemiidae) off the Mediterranean coast of Israel. Aquatic Invasions, 4 (1), 357-360.

[20] GESAMP (1997). Opportunistic settlers and the problem of the ctenophore ***Mnemiopsis leidyi*** invasion in the Black Sea. Reports and Studies, GESAMP, 58, London.

[21] Graham, W. M., Kroutil, R. M. (2001). Size-based prey selectivity and dietary shifts in the jellyfish, ***Aurelia aurita***. Journal of Plankton Research, 23, 67-74.

[22] Haddock, S. H. D. (2004). A golden age of gelata: past and future research on planktonic ctenophores and cnidarians. Hydrobiologia, 530/531, 549-556.

[23] Hansson, H. G. (2006). Ctenophores of the Baltic and adjacent Seas – the invader ***Mnemiopsis*** is here! Aquatic Invasions, 1 (4), 295-298.

[24] Hernroth, L., Grondahl, F. (1983). On the biology of ***Aurelia Aurita***. Ophelia, 22(2), 189-199.

[25] Holst, S., Jarms, G. (2010). Effects of low salinity on settlement and strobilation of Scyphozoa (Cnidaria): Is the lion's mane ***Cyanea capillata*** (L.) able to reproduce in the brackish Baltic Sea? Hydrobiologia, 645, 53-68.

[26] Hosia, A., Granhag, L., Katajisto, T., Lehtiniemi, M. (2012). Experimental feeding rates of gelatinous predators ***Aurelia aurita*** and ***Mnemiopsis leidyi*** at low northern Baltic Sea salinity. Boreal Environmental Research, 17, 473-483.

[27] Ivanov, V. P., Kamakin, A. M., Ushivtzev, V. B., Shiganova, T., Zhukova, O., Aladin, N., Wilson, S. I., Harbison, G. R., Dumont, H. J. (2000). Invasion of the Caspian Sea by the comb jellyfish ***Mnemiopsis leidyi*** (Ctenophora). Biological Invasions, 2, 255-258.

[28] Janas, U., Witek, Z. (1993). The occurrence of medusae in the southern Baltic Sea and their importance in the ecosystem, with special emphasis on ***Aurelia aurita***. Oceanologia, 34, 69-84.

[29] Janas, U., Zgrundo, A. (2007). First records of ***Mnemiopsis leidyi*** A. Agassiz, 1865 in the Gulf of Gdansk (southern Baltic Sea). Aquatic Invasions, 2 (4), 450-454.

[30] Jaspers, C., Møller, L. F., Kiørboe, T. (2011). Salinity gradient of the Baltic Sea limits the reproduction and population expansion of the newly invaded comb jelly ***Mnemiopsis leidyi***. PLoS ONE, 6 (8), 1-6.

[31] Javidpour, J., Molinero, J. C., Peschutter, J., Sommer, U. (2009). Seasonal changes and population dynamics of the ctenophore ***Mnemiopsis leidyi*** after its first year of invasion in the Kiel Fjord, Western Baltic Sea. Biological Invasions, 11 (4), 873-882.

[32] Kramp, P. L. (1961). Synopsis of the medusae of the world. Journal of the Marine Biological Association of the United Kingdom, Cambridge At The University Press.

[33] Lucas, C. H. (1996). Population dynamics of the scyphomedusa ***Aurelia aurita*** (L.) from an isolated brackish lake, with particular reference to sexual reproduction. Journal of Plankton Research, 18, 987-1007.

[34] Lucas, C. H. (2001). Reproduction and life history strategies of the common jellyfish, ***Aurelia aurita***, in relation to its ambient environment. Hydrobiologia, 451, 229-246.

[35] Lynam, C. P., Hay, S. J., Brierley, A. S. (2004). Interannual variability in abundance of North Sea jellyfish and links to the North Atlantic Oscillation. Limnological Oceanography, 49, 637-643.

[36] Lynam, C. P., Lilley, M., Bastian, T., Doyle, T., Beggs, S. Hays, G. (2011). Have jellyfish in the Irish Sea benefited from climate change and overfishing? Global Change Biology, 17, 767-782.

[37] Malej, A., Turk, V., Lučić, D., Benović, A. (2007). Direct and indirect trophic interactions of ***Aurelia*** sp. (Scyphozoa) in a stratified marine environment (Mljet Lakes, Adriatic Sea). Marine Biology, 151, 827–841.

[38] Margoński, P., Horbowa, K. (1995). Vertical distribution of cod eggs and medusae in the Bornholm basin. Scientific Papers Presented at the Polish-Swedish Symposium on Baltic Cod., MIR, Gdynia (Poland). Medd Haviskelab Lysekil, 327, 7-17.

[39] Mills, C. E. (2001). Jellyfish blooms: Are populations increasing globally in response to changing ocean conditions? Hydrobiologia, 451, 55-68.

[40] Møller, F. L, Riisgård, H. U. (2007). Population dynamics, growth and predation impact of the common jellyfish ***Aurelia aurita*** and two hydromedusae, ***Sarsia tubulosa*** and ***Aequorea vitrina***, in Limfjorden (Denmark). Marine Ecology Progress Series, 346, 153-165.

[41] Möller, H. (1980a). Population dynamics of ***Aurelia aurita*** medusae in Kiel Bight, Germany (FRG). Marine Biology, 60, 123-128.

[42] Möller, H. (1980b). Scyphomedusae as predators and food competitors of larval fish. Journal of Marine Research, 28, 90-100.

[43] Möller, H. (1984). Data on the biology of jellyfish and youngfish in Kiel Bight. Verlag H. Moeller, Kiel (FRG).

[44] Mudrak, S. (2004). Krótko- i długoterminowa zmienność zooplanktonu wód przybrzeżnych Bałtyku na przykładzie Zatoki Gdańskiej. Ph.D. thesis. Institute of Oceanography of the University of Gdańsk. Gdynia.

[45] Mutlu, E. (2001). Distribution of gelatinous macrozooplankton and ecosystem change in the Black Sea. CIESM Workshop Series, 14, 75-80.

[46] Mutlu, E., Bingel, F. (1995). Distribution and abundance of ctenophores, and their zooplankton food in the Black Sea. I. ***Pleurobrachia pileus***. Marine Biology, 135, 589-601.

[47] Nowacki, J. (1993). Temperatura, zasolenie i gęstość wody. In: K. Korzeniewski, Zatoka Pucka (79-112). Institute of Oceanography of the University of Gdańsk. Gdynia.

[48] Olenycz, M. (2007). Wybrane elementy biologii i ekologii ***Aurelia aurita*** (Scyphozoa, Cnidaria) z Zatoki Gdańskiej. M.Sc. thesis. Institute of Oceanography of the University of Gdańsk. Gdynia.

[49] Olesen, N. J. (1995). Clearance potential of jellyfish ***Aurelia aurita***, and predation impact on zooplankton in a shallow cove. Marine Ecology Progress Series, 124, 63-72.

[50] Olesen, N. J., Frandsen, K., Riisgård, H. U. (1994). Population dynamics, growth and energetics of jellyfish ***Aurelia aurita*** in a shallow fjord. Marine Ecology Progress Series, 105, 9-18.

[51] Omori, M., Ishii, H., Fujinaga, A. (1995). Life history strategy of ***Aurelia aurita*** (Cnidaria, Scyphomedusae) and its impact on the zooplankton community of Tokyo Bay. ICES Journal of Marine Science, 52, 597-603.

[52] Omori, M., Kitamura, M. (2004). Taxonomic review of three Japanese species of edible jellyfish (Schyphozoa: Rhizostomeae). Plankton Biology and Ecology, 51, 36-51.

[53] Palmieri, M. G., Barausse, A., Luisetti, T., Turner, K. (2013). Jellyfish blooms in the Northern Adriatic Sea: Fishermen's perceptions and economic impacts on fisheries. Fisheries Research, 155, 51-58.

[54] Purcell, J. E. (2003). Predation on zooplankton by large jellyfish, ***Aurelia labiata***, ***Cyanea capillata*** and ***Aequorea aequorea***, in Prince William Sound, Alaska. Marine Ecology Progress Series, 246, 137-152.

[55] Purcell, J. E., Angel, D., Dror, L. (2010). Jellyfish blooms: New problems and solutions. Developments in Hydrobiology, 212, Springer Netherlands.

[56] Purcell, J. E., Arai, M. N. (2001). Interactions of pelagic cnidarians and ctenophores with fish: a review. Hydrobiologia, 451, 27-44.

[57] Purcell, J. E., Uye, S. Lo, W. T. (2007). Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review. Marine Ecology Progress Series, 350, 153-174.

[58] Schneider, G. (1987). Role of advection in the distribution and abundance of ***Pleurobrachia pileus*** in Kiel Bight. Marine Ecology Progress Series, 41, 99-102.

[59] Schneider, G. (1989). Estimation of food demands of ***Aurelia aurita*** medusae populations in the Kiel Bight/western Baltic. Ophelia, 31, 17-27.

[60] Schneider, G., Behrends, G. (1994). Population dynamics and the trophic role of ***Aurelia aurita*** in the Kiel Bight and western Baltic. ICES Journal of Marine Sciences, 51, 359-367.

[61] Schneider, G., Behrends, G. (1998). Top-down control in a neritic plankton system by ***Aurelia aurita*** medusae - a summary. Ophelia, 48, 71-82.

[62] Shoji, J., Masuda, R., Yamashita, Y., Tanaka, M. (2005). Effect of low dissolved oxygen concentrations on behaviour and predation rates on fish larvae by moon jellyfish ***Aurelia aurita*** and by a juvenile piscivore, Spanish mackerel ***Scomberomorus niphonius***. Marine Biology, 147, 863-868.

[63] Titelman, J., Hansson, L. J. (2006). Feeding rates of the jellyfish ***Aurelia aurita*** on fish larvae. Marine Biology, 149, 297-306.

[64] Uye, S. (2008). Blooms of the giant jellyfish ***Nemopilema nomurai***: a threat to the fisheries sustainability of the East Asian Marginal Seas. Plankton Benthos Research, 3, 125-131.

[65] Vinogradov, M. E., Shushkina, E. I., Sorokin, P. Y. (1989). A newly acclimated species in the Black Sea: the ctenophore ***Mnemiopsis leidyi*** (Ctenophora: Lobata). Oceanology, 29 (2), 220-224.

[66] Vladymyrov, V., Kideys, A. E., Myroshnychenko, V., Slipetsky, D., Shiganova, T., Abolmasova, G., Bingel, F., Tezcan, D., Ak, Y., Anninsky, B., Bat, L., Finenko, G., Gorbunov, V., Isinibilir, M., Kamburska, L., Mihneva, V., Ozdemir, Z. B., Romanova, Z., Sergeyeva, O., Stefanova, K., Xalvashi, M. 2011. A basin-wide Black Sea ***Mnemiopsis leidyi*** database. Aquatic Invasions, 6, 115-122.

[67] Wiktor, K. (1990). Zooplankton. In: A. Majewski, Zatoka Gdańska (380-401). Wydawnictwo Geologiczne, Warszawa.

[68] www 1. http://www.theguardian.com/world/2013/oct/01/jellyfish-clog-swedish-nuclear-reactor-shutdown

[69] www 2. http://www.nbcnews.com/id/43591474/ns/world_news-weird_news/t/jellyfish-clog-uk-nuclear-plant-force-shutdown/#.UzFj2M7DCpU

[70] Yip, S. Y. (1984). The feeding of ***Pleurobrachia pileus*** Mueller (Ctenophora) from Galaway Bay. Proceedings of the Royal Irish Academy, 84, 109-122.

[71] Zaika, V. E., Sergeyeva, N. G. (1990). Morphology and development of ***Mnemiopsis mccradyi*** (Ctenophora, Lobata) in the Black Sea. Hydrobiological Journal, 26, 1-6.

[72] Żmudziński, L. (1990). Świat Zwierzęcy Bałtyku. Wydawnictwa Szkolne i Pedagogiczne.

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