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Short communication

Changes in distribution and lengths of *Mnemiopsis leidyi* in the central Baltic Sea between fall and spring

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Abstract

In March 2008, we conducted a survey to investigate the distribution and abundance of the invasive ctenophore *Mnemiopsis leidyi* in the Bornholm Basin after the winter period. Compared to the situation in November 2007 the centre of the distribution had shifted towards the deeper parts of the Basin where temperatures were higher than at the surface. Furthermore, we found a decrease in average size from 18.6 mm ± 7.6 SD in November to an average of 10.5 mm ± 4.9 SD in March, which may indicate the emergence of a new generation of *M. leidyi* between the two sampling dates.

Key words: *Mnemiopsis leidyi*, Ctenophora, invasive species, Baltic Sea, Bornholm Basin

Since the first observations of *Mnemiopsis leidyi* A. Agassiz 1865 in Northern Europe (Faasse and Bayha 2006; Hansson 2006; Javidpour et al. 2006; Oliveira 2007), several studies have described occurrences of this invasive lobate ctenophore in the Baltic, spanning from Kattegat to the Bothnian Sea (Haslob et al. 2007; Janas and Zgrundo 2007; Kube et al. 2007; Lehtiniemi et al. 2007; Tendal et al. 2007; Javidpour et al. 2009; Viitasalo et al. 2008). In November 2007, Huwer et al. (2008) investigated the horizontal and vertical distribution of *Mnemiopsis leidyi* in the central Baltic Sea. The studied area covered the Bornholm Basin, an important spawning ground for cod and sprat (Köster et al. 2005). Four months later, in March 2008, we conducted a survey in the same area to investigate if *M. leidyi* had survived the winter and how the distribution and abundances of this invasive species had changed during wintertime.

M. leidyi were sampled during a cruise with the Danish research vessel 'DANA' from March 1st to 17th 2008, on a station grid covering the Bornholm Basin. Additional sampling was conducted on a transect through the Arkona Basin consisting of 6 stations (Figure 1). To assess abundances and the horizontal distribution of *M. leidyi*, hauls with a Bongo net were taken on a total of 75 stations. The gear was equipped with two nets of different mesh size (335 µm and 500 µm) and with flowmeters to measure the volume of filtered water. Double oblique hauls from the surface to 2 meter above the seafloor were conducted at a towing speed of 3 knots.

Upon retrieval of the gear, specimens of *M. leidyi* were immediately sorted from the samples, counted and the body oral-aboral length of each individual was measured to the nearest 1.0 mm with a sliding caliper. All samples were analysed within 30 minutes after capture. Counts of *M. leidyi* were standardised to 1 m^2 surface area by accounting for the filtered water volume and the maximum depth of the tow.

A total of 208 and 261 specimens of *M. leidyi* were caught in the 335 µm and 500 µm net, respectively. There was no significant difference ($P = 0.634$) between the size ranges of specimens caught with the two different mesh sizes, as average lengths were 10.2 mm ± 4.6 SD and 10.7 mm ± 5.1 SD for the 335 µm and 500 µm net, respectively. Accordingly, samples from the two nets have been pooled in the further analysis.

For a comparison of length distributions of *M. leidyi* between fall and spring, length data from November 2007 were used. The sampling procedure for these data is described in Huwer et al. (2008).

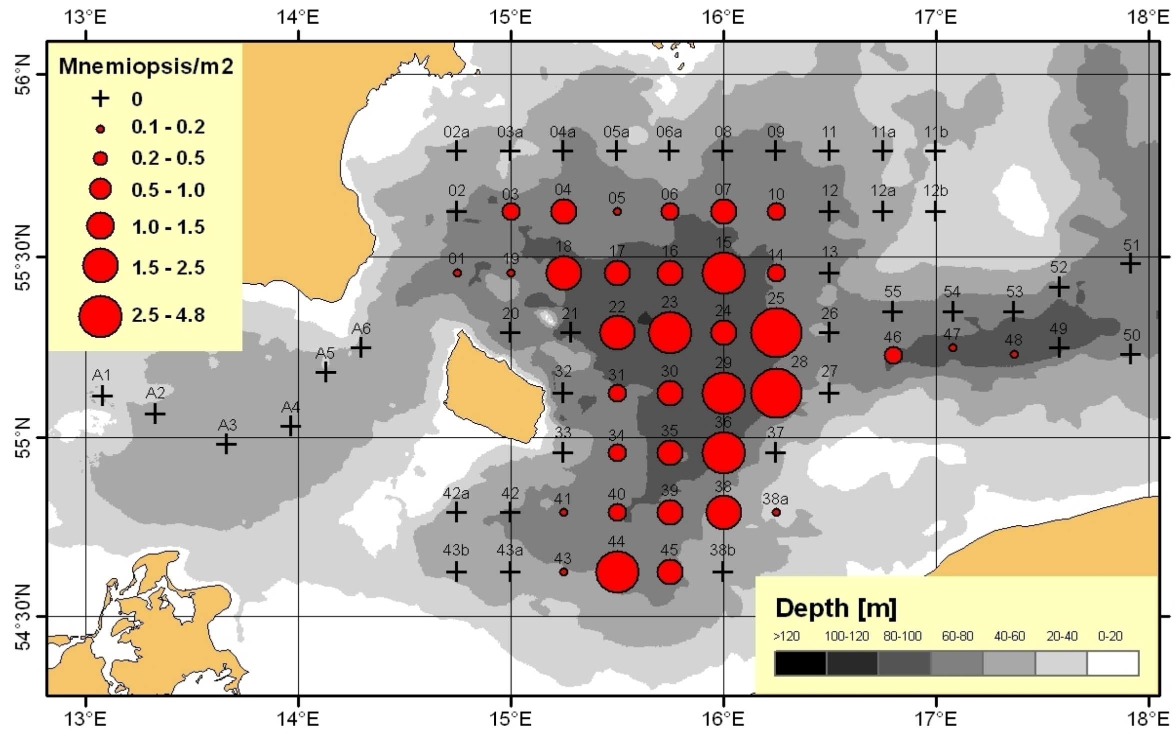

Figure 1. *Mnemiopsis leidyi.* Horizontal distribution and abundances (ind. m^{-2}) sampled with a Bongo net in March 2008. Station numbers are identical with the numbers in Annex 1.

Horizontal distribution and abundance

Low temperatures have been found to be a limiting factor for the distribution and growth of *M. leidyi* (Kremer 1994; Mutlu 1999; Purcell et al. 2001; Shiganova et al. 2001; Purcell and Decker 2005). Therefore, we were interested in investigating the abundance and distribution of *M. leidyi* in the central Baltic after the winter period.

Huwer et al. (2008) found *M. leidyi* to be present over large areas of the central Baltic Sea in November 2007. In the present study in March 2008 the species was again distributed over large parts of the area. However, in comparison to the situation in fall 2007, the centre of the distribution had shifted to the deeper central parts of the Bornholm Basin (Figure 1). During the present study in spring 2008, no ctenophores were found on the 18 stations with depths <50 meters. The abundances of *M. leidyi* increased with increasing depth and almost 90% of the specimens were registered on stations with depths >70 meter (Table 1).

A possible reason for this change may be colder winter temperatures above the halocline in the Bornholm Basin. Figure 2 shows temperature and salinity profiles from a station in the central Bornholm Basin (Station 23 in Figure 1 and Annex 1; 55.292°N, 15.750°E) in November 2007 and March 2008. The situation in March showed a well mixed surface layer with a temperature of 4°C, and higher temperatures of 6 to 8°C in the bottom layer below 50 m depth. In November no such distinct temperature difference was detected and the surface water was much warmer with temperatures of about 9.5°C. In contrast to temperature, salinity did not seem to have an influence on the change in distribution in the present study. The salinity profiles showed little differences between fall and spring due to the permanent halocline in the Bornholm Basin.

Kube et al. (2007) have shown that *M. leidyi* was able to survive the winter in the Baltic Sea. Even though abundances at a sampling station in the Bornholm Basin were generally low, they found a decrease in abundances from February to May.

Table 1. Abundances of *Mnemiopsis leidyi* at different depth strata in March 2008.

Depth	Stations (n)	*M. leidyi* (n)	*M. leidyi* (%)	Average *M. leidyi* m^{-2}
< 50 m	18	0	0%	0
50-59 m	12	18	3.8%	0.12±0.36
60-69 m	16	41	8.7%	0.19±0.44
70-79 m	17	178	38.0%	0.68±1.19
> 80 m	12	232	49.4%	1.37±0.98

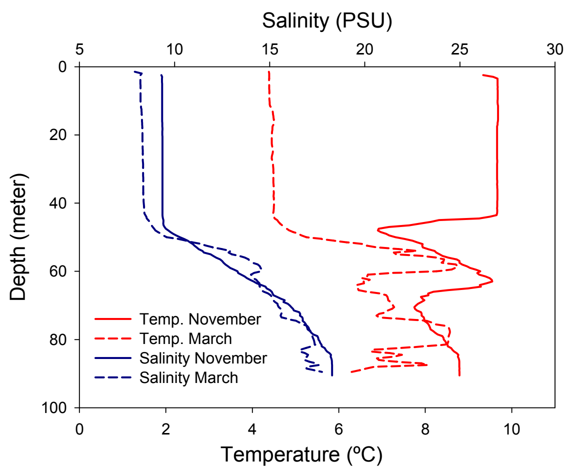

Figure 2. Temperature and salinity profiles in the central Bornholm Basin (station 23 in Figure 1 and Annex 1) in November 2007 and March 2008.

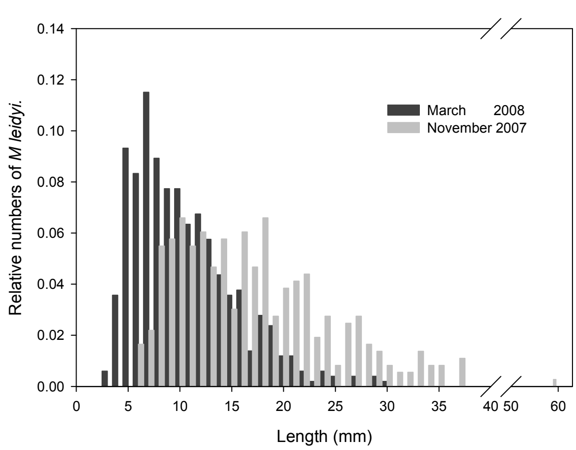

Figure 3. *Mnemiopsis leidyi*. Relative size distribution of ctenophores sampled in March 2008 (dark grey bars, n=469) and November 2007 (light grey bars, n=364; from Huwer et al. 2008).

Length distribution

Specimens of *M. leidyi* were significantly (P<0.001) larger in November 2007 than in March 2008. *M. leidyi* between 6-59 mm (average 18.6 mm ± 7.6 SD) and 3-27 mm (average 10.5 mm ± 4.9 SD) were caught in November 2007 and March 2008, respectively (Figure 3). Javidpour et al. (2009) investigated seasonal changes and population dynamics of *M. leidyi* in Kiel Fjord in the western Baltic Sea. Abundance peaks were observed in late summer-early autumn, which is in good correspondence to population dynamics in native habitats of *M. leidyi* (Kremer 1994). Javidpour et al. (2009) further describe seasonal shifts in the dominant size classes and conclude that peak reproduction in Kiel Fjord takes place in late summer and fall. However, their finding of a higher larvae: adult ratio from October 2006 to January 2007 may also indicate some reproduction in the winter period. In the present study, occurrence of smaller individuals in spring could be interpreted as the outcome of a new generation during fall or winter. This may indicate that successful reproduction and overwintering also occurs in the Bornholm Basin. However, because ctenophores can hardly be aged and are known to shrink at low food abundances (Reeve et al. 1989, Purcell et al. 2001), smaller size ranges in March could be due to starvation during wintertime. Another possible explanation for the shift in the length distribution may be passive transport of smaller individuals into the Bornholm Basin. A drift modeling study has shown that such a transport, e.g. from areas in the western Baltic, could be possible within few months (Postel et al. 2007).

The maximum abundance of *M. leidyi* in the Bornholm Basin in November 2007 was 8.92 ind. m^{-2}, with an average level of 1.58 ± 2.12 ind. m^{-2} (Huwer et al. 2008). In the present study four months later, abundances were lower with a maximum abundance of 4.83 ind. m^{-2}, and an average level of 0.43 ± 0.86 ind. m^{-2}.

However, even though abundances had decreased from fall to spring, *M. leidyi* has survived the second winter after its introduction to the central Baltic.

Conclusions

It can be concluded that *M. leidyi* was still present in the Bornholm Basin after the winter 2007/2008 and that the size distribution had shifted to smaller specimens, which may indicate the emergence of a new generation. Furthermore, there has been a shift in the horizontal distribution towards deeper parts of the Basin from fall to spring. Accordingly, *M. leidyi* may migrate from the colder surface layer to the warmer deep water during winter, while expanding its distribution to warmer upper layers and coastal areas during summer and fall. A similar temperature dependent vertical distribution was reported by Javidpour et al. (2008) for the *M. leidyi* population in Kiel Fjord. Other possible reasons for the changing distribution might be passive advection or differences in food availability. Thus, the present study provides further support for the hypothesis that *M. leidyi* uses the deep layers of the Bornholm Basin as over-wintering refuge (Kube et al. 2007; Huwer et al. 2008).

However, to obtain a better understanding of *M. leidyi* distribution and population dynamics in the central Baltic, a temporally explicit monitoring is highly advisable. *M. leidyi* is known to prey on fish eggs and larvae (Cowan and Houde 1993; Purcell and Arai 2001; Purcell et al. 2001) and to compete with fish for zooplankton prey. Therefore, the seasonal development of this invasive predatory species receives special interest in the light of spatio-temporal interactions with ichthyoplankton in the Bornholm Basin (Haslob et al. 2007; Huwer et al. 2008). This area is at present the most important spawning ground for Eastern Baltic cod, a fish stock already suffering from unfavorable environmental conditions and heavy exploitation (Köster et al. 2005).

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Annex 1. Station number, position, sampling date, depth and abundance of *Mnemiopsis leidyi* caught with 335 µm and 500 µm Bongo nets, respectively. The station numbers refer to Figure 1.

Station	Geographic coordinates		Date	Sampling depth (m)	Abundance (ind. m^{-2}) 335 µm	Abundance (ind. m^{-2}) 500 µm
	Latitude, °N	Longitude, °E				
A1	54.817	13.083	16.03.2008	0- 35	0.00	0.00
A2	55.067	13.333	16.03.2008	0- 41	0.00	0.00
A3	54.983	13.667	16.03.2008	0- 45	0.00	0.00
A4	55.033	13.967	16.03.2008	0- 46	0.00	0.00
A5	55.183	14.133	16.03.2008	0- 45	0.00	0.00
A6	55.250	14.300	16.03.2008	0- 45	0.00	0.00
1	55.458	14.750	13.03.2008	0- 69	0.12	0.12
2	55.625	14.750	06.03.2008	0- 66	0.00	0.00
02a	55.792	14.750	06.03.2008	0- 47	0.00	0.00
3	55.625	15.000	13.03.2008	0- 75	0.33	0.11
03a	55.792	15.000	06.03.2008	0- 37	0.00	0.00
4	55.625	15.250	12.03.2008	0- 76	0.50	1.49
04a	55.792	15.250	06.03.2008	0- 51	0.00	0.00
5	55.625	15.500	12.03.2008	0- 67	0.13	0.13
05a	55.792	15.500	06.03.2008	0- 59	0.00	0.00
6	55.625	15.750	12.03.2008	0- 70	0.42	0.00
06a	55.792	15.750	06.03.2008	0- 42	0.00	0.00
7	55.625	16.000	08.03.2008	0- 73	0.83	0.69
8	55.792	16.000	07.03.2008	0- 61	0.00	0.00
9	55.792	16.250	07.03.2008	0- 60	0.00	0.00
10	55.625	16.250	08.03.2008	0- 72	0.43	0.57
11	55.792	16.500	07.03.2008	0- 56	0.00	0.00
11a	55.792	16.750	07.03.2008	0- 47	0.00	0.00
11b	55.792	17.000	07.03.2008	0- 37	0.00	0.00
12	55.625	16.500	07.03.2008	0- 62	0.00	0.00
12a	55.625	16.750	07.03.2008	0- 44	0.00	0.00
12b	55.625	17.000	07.03.2008	0- 26	0.00	0.00
13	55.458	16.500	05.03.2008	0- 59	0.00	0.00

Annex 1 (continued).

Station	Geographic coordinates		Date	Sampling depth (m)	Abundance (ind. m^{-2}) 335 µm	Abundance (ind. m^{-2}) 500 µm
	Latitude, °N	Longitude, °E				
14	55.458	16.250	05.03.2008	0- 73	0.56	0.00
15	55.458	16.000	05.03.2008	0- 84	2.14	2.32
16	55.458	15.750	05.03.2008	0- 87	0.77	0.62
17	55.458	15.500	05.03.2008	0- 84	1.48	0.49
18	55.458	15.250	12.03.2008	0- 87	1.54	0.56
19	55.458	15.000	12.03.2008	0- 76	0.15	0.00
20	55.292	15.000	13.03.2008	0- 71	0.00	0.00
21	55.292	15.283	13.03.2008	0- 77	0.00	0.00
22	55.292	15.500	13.03.2008	0- 93	1.59	0.87
23	55.292	15.750	14.03.2008	0- 95	1.21	1.91
24	55.292	16.000	14.03.2008	0- 90	0.43	0.98
25	55.292	16.250	14.03.2008	0- 74	4.01	5.66
26	55.292	16.500	10.03.2008	0- 63	0.00	0.00
27	55.125	16.500	10.03.2008	0- 52	0.00	0.00
28	55.125	16.250	10.03.2008	0- 81	2.19	5.21
29	55.125	16.000	10.03.2008	0- 90	2.07	2.81
30	55.125	15.750	12.03.2008	0- 90	0.48	0.85
31	55.125	15.500	12.03.2008	0- 67	0.15	0.29
32	55.125	15.250	12.03.2008	0- 58	0.00	0.00
33	54.958	15.250	09.03.2008	0- 45	0.00	0.00
34	54.958	15.500	09.03.2008	0- 75	0.39	0.26
35	54.958	15.750	08.03.2008	0- 80	0.36	1.62
36	54.958	16.000	08.03.2008	0- 74	2.42	1.78
37	54.958	16.250	08.03.2008	0- 53	0.00	0.00
38	54.792	16.000	08.03.2008	0- 53	1.25	1.25
38a	54.792	16.250	08.03.2008	0- 50	0.00	0.20
38b	54.625	16.000	08.03.2008	0- 47	0.00	0.00
39	54.792	15.750	08.03.2008	0- 75	0.19	0.93
40	54.792	15.500	09.03.2008	0- 79	0.17	0.52
41	54.792	15.250	09.03.2008	0- 68	0.00	0.13
42	54.792	15.000	09.03.2008	0- 58	0.00	0.00
42a	54.792	14.750	09.03.2008	0- 46	0.00	0.00
43	54.625	15.250	10.03.2008	0- 58	0.16	0.00
43a	54.625	15.000	10.03.2008	0- 32	0.00	0.00
43b	54.625	14.750	09.03.2008	0- 47	0.00	0.00
44	54.625	15.500	09.03.2008	0- 65	1.44	2.02
45	54.625	15.750	09.03.2008	0- 60	0.50	0.84
46	55.230	16.800	04.03.2008	0- 75	0.34	0.34
47	55.250	17.080	04.03.2008	0- 80	0.00	0.36
48	55.233	17.367	04.03.2008	0- 66	0.00	0.33
49	55.250	17.583	05.03.2008	0- 63	0.00	0.00
50	55.233	17.917	05.03.2008	0- 58	0.00	0.00
51	55.483	17.917	05.03.2008	0- 66	0.00	0.00
52	55.417	17.583	04.03.2008	0- 76	0.00	0.00
53	55.350	17.367	04.03.2008	0- 70	0.00	0.00
54	55.350	17.083	04.03.2008	0- 66	0.00	0.00
55	55.350	16.800	04.03.2008	0- 63	0.00	0.00