Invasive ctenophore *Mnemiopsis leidyi* in Danish waters - assessment of abundance and predation impact

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The native habitats of the invasive lobate ctenophore *Mnemiopsis leidyi* are coastal waters along the Atlantic coast of North and South America.

*Bolinopsis infundibulum* & *Mnemiopsis leidyi*

*Mnemiopsis leidyi* is closely related to *Bolinopsis infundibulum* found in Danish waters; but its oral lobes terminate near the apical sense organ (statocyst).
**Mnemiopsis leidyi**  
- life stages

**Fig. 1.** Life stages of the ctenophore *Mnemiopsis leidyi*: (A) cydippid larva, 0.3 cm, (B) transitional stage between cydippid and lobate form, 1.0 cm, and (C) lobate form, 3.0 cm total length.
Cydippid: tentacular stage

About 5 mm tentaculate stage *Mnemiopsis leidyi* with 2 long tentacles

The tentacles with long side branches are about 6-7 times longer than the body.

Prey organisms are captured by the sticky tentacles.
Lobate stage

Two capture mechanisms result in a wide range of prey:
(A) Collision of swimming prey such as copepods with inner surfaces of the oral lobes (ambush predator)
(B) Fluid motions created by the beating of cilia lining the 4 auricles bring veliger larvae, nauplii and fish eggs in contact with capturing tentilae
Food uptake

Ambush capture by *Mnemiopsis leidyi*: copepods are captured by the oral lobes (fixed by sticky colloblasts or mucus)

Costello et al. (1999)
Mnemiopsis – capture of copepod

- and an unsuccessful attempt

Costello (pers. comm.)
Mnemiopsis leidyi is a simultaneous hermaphrodite and possibly capable of self fertilization

The ctenophore may begin to produce eggs about 2 weeks after its hatching when it is 26 mm in length. During the 10 following days it may produce up to 12,000 eggs.

Large specimens, more than 10 cm length, can produce more than 5,000 eggs per day (Shiganova, unpublished)

![Graph showing the relationship between total body length and eggs production for Mnemiopsis](graph.png)
Mnemiopsis leidyi in the Black Sea

In the early 1980s, Mnemiopsis leidyi was unintentionally brought to the Black Sea in ballast water of cargo ships and exhibited mass occurrences that peaked in 1989 and coincided with the breakdown of the pelagic fisheries in the Black Sea.

*Mnemiopsis leidyi* is a voracious zooplanktivore, and a catastrophic decrease in zooplankton inevitably influenced the stocks of planktivorous fishes (sprat, anchovy, horse-mackerel). The catch of those fishes in 1991 was less than 1/5 of that in 1988.

The collapse of fishing was probably caused by a combination of over-fishing, food competition from the ctenophore, and predation of *Mnemiopsis leidyi* on fish eggs and larvae.
Breakdown of the pelagic fisheries in the Black Sea

Merlangus merlangus = whiting (hvilling)
Sprattus sprattus = sprat (brisling)
Engraulis e. ponticus = anchovy (ansjos)
Trachurus e. ponticus = horse-mackerel (makrel)

Shiganova et al. (2001)
Later, in the years after 1982, the invasive ctenophore spread into the Azov, Marmara, Aegean, and Caspian Seas where similar effects were observed.

During the late summer of 2006, blooms of *Mnemiopsis leidyi* were observed along the coast of The Netherlands, presumably, it came to the Dutch coast in ballast water. Subsequent expansion of *Mnemiopsis leidyi* into neighbouring waters is of major concern.

In February-March 2007, *Mnemiopsis leidyi* was observed for the first time in Danish waters.
During the late summer of 2006, blooms of *Mnemiopsis leidyi* were observed along the coast of The Netherlands. Presumably, it came in ballast water. Subsequent expansion of *M. leidyi* into neighbouring waters and far into the Baltic Sea took place from late summer 2006 to spring 2007.

Faasse & Bayha (2006)
Public observations of *Mnemiopsis leidyi* along the German Baltic Sea coast, from Wismar Bay to the east coast of Rügen Island, during autumn 2006 and winter 2006/07

Kube et al. (2007)

Appeal to the public to report observations of jellies
The first *Mnemiopsis leidyi* was observed in the inlet to Kerteminde Fjord on 16 March 2007.
"Summer vacation studies”
Limfjorden July 2007

In the period 20-27 July 2007 *Mnemiopsis leidyi* was observed at:
Fursund, Glyngøre, Struer, Lemvig, Sundsøre, Thisted, Feggesund, Løgstør
Limfjorden - July 2007

Mass occurrence of Mnemiopsis in Fursund (Branden) 20 July 2007
"Public survey" summer of 2007

- No national Danish monitoring programme follow the development

- Therefore, the Marine Biological Research Centre (SDU) in co-operation with the Zoological Museum (KU) made a press release in July to call on the public to watch for *Mnemiopsis* and report observations (email & photo) to follow the invasion of the new ctenophore

- 175 reports from the public made it possible to follow the distribution of *Mnemiopsis* during the summer of 2007

Observations of *Mnemiopsis* in 2007

Limfjorden August-September 2007
Jellyfish-cruises with ”LIMGRIM”

Locations in Limfjorden where *Mnemiopsis leidyi* were collected on two cruises, 7-8 August and 11-12 September 2007

A = Nissum Bredning, B = Venø Bugt, C = Kås Bredning, D = Sallingsund, E = Thisted Bredning, F = Feggesund, G = Løgstør Bredning, H = Junget Øre, I = Skive Fjord
Estimation of predation impact exerted by *Mnemiopsis leidyi*

Individuel filtration rate: \( \text{Find} \ (l/day) = 2.64V \)  
where \( V \) (body volume, ml) = 0.0226\( L \)(oral-aboral length, mm) \(^{1.72} \)  

Volume-specific population filtration rate: \( \text{Fpop} \ (m^3/day) = \text{Find} \times D/1000 \)  
where \( D \) = population density (ind./m\(^3\))

Half-life time of zooplankton: \( t_{1/2} = \ln2/\text{Fpop} \)

Example: a 50 mm long \( (V = 18.9 \text{ ml}) \) *Mnemiopsis* filters \( \text{Find} = 18.9 \text{ litres per day} \); if \( D = 30 \text{ ind./m3} \) then \( \text{Fpop} = 1.5 \text{ m3/d} \), and \( t_{1/2} = 0.46 \text{ d} \ (12 \text{ hours}) \)
Table 1. *M. leidyi* collected during two cruises in Limfjorden in 2007, 8 locations on 7-8 August, and 5 locations on 11-12 September, respectively (see Fig. 1). D = mean (±SD) population density based on 3 hauls; L = mean (±SD, n = 50) body length; estimated individual body volume (cf. equation 4); B = D × V = specific bio-volume of ctenophores; F_{ind} = individual clearance rate; F_{pop} = population clearance rate; t_{1/2} = estimated half-life time.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Position</th>
<th>D</th>
<th>L</th>
<th>V</th>
<th>B</th>
<th>F_{ind}</th>
<th>F_{pop}</th>
<th>t_{1/2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-8 August 2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Nissum</td>
<td>56°36.05N</td>
<td>34 ± 12</td>
<td>12 ± 3</td>
<td>1.62</td>
<td>55</td>
<td>4.3</td>
<td>0.145</td>
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<tr>
<td>B</td>
<td>Bredning</td>
<td>56°31.39N</td>
<td>35 ± 8</td>
<td>8 ± 2</td>
<td>0.81</td>
<td>28</td>
<td>2.1</td>
<td>0.074</td>
</tr>
<tr>
<td>D</td>
<td>Veno Bugt</td>
<td>56°46.62N</td>
<td>35 ± 4</td>
<td>15 ± 1</td>
<td>2.37</td>
<td>83</td>
<td>6.2</td>
<td>0.219</td>
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<tr>
<td>E</td>
<td>Sallingsund</td>
<td>56°55.20N</td>
<td>208 ± 18</td>
<td>6 ± 2</td>
<td>0.49</td>
<td>102</td>
<td>1.3</td>
<td>0.269</td>
</tr>
<tr>
<td>F</td>
<td>Thisted</td>
<td>56°58.51N</td>
<td>18 ± 10</td>
<td>15 ± 0</td>
<td>2.4</td>
<td>43</td>
<td>6.3</td>
<td>0.114</td>
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<tr>
<td>G</td>
<td>Bredning</td>
<td>56°57.15N</td>
<td>54 ± 10</td>
<td>14 ± 3</td>
<td>2.1</td>
<td>113</td>
<td>5.5</td>
<td>0.299</td>
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<tr>
<td>H</td>
<td>Logstar</td>
<td>56°47.00N</td>
<td>230 ± 51</td>
<td>9 ± 1</td>
<td>0.99</td>
<td>228</td>
<td>2.6</td>
<td>0.601</td>
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<tr>
<td>I</td>
<td>Junget Øre</td>
<td>56°37.25N</td>
<td>867 ± 121</td>
<td>5 ± 0</td>
<td>0.36</td>
<td>312</td>
<td>1.0</td>
<td>0.824</td>
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<td>II</td>
<td>Skive Fjord</td>
<td>56°39.40N</td>
<td>52 ± 8</td>
<td>5 ± 2</td>
<td>0.35</td>
<td>18</td>
<td>0.9</td>
<td>0.048</td>
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<tr>
<td>C</td>
<td>Kås Bredning</td>
<td>56°55.20N</td>
<td>262 ± 34</td>
<td>8 ± 2</td>
<td>0.81</td>
<td>212</td>
<td>2.1</td>
<td>0.560</td>
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<tr>
<td>E</td>
<td>Thisted</td>
<td>56°57.15N</td>
<td>454 ± 175</td>
<td>7 ± 3</td>
<td>0.66</td>
<td>300</td>
<td>1.7</td>
<td>0.791</td>
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<tr>
<td>G</td>
<td>Logstar</td>
<td>56°47.00N</td>
<td>33 ± 15</td>
<td>9 ± 1</td>
<td>0.92</td>
<td>30</td>
<td>2.4</td>
<td>0.080</td>
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<tr>
<td>H</td>
<td>Junget Øre</td>
<td>56°39.40N</td>
<td>52 ± 8</td>
<td>5 ± 2</td>
<td>0.35</td>
<td>18</td>
<td>0.9</td>
<td>0.048</td>
</tr>
</tbody>
</table>

Population bio-volumes in Skive Fjord, Løgstør Bredning and Thisted Bredning were high 312, 113 and 102 ml jellies per m3 water, respectively, in August 2007.

Population densities were high, more than 800 ind. per m3 in Skive Fjord in August 2007, whereas body length of ctenophores was small, 5-15 mm.

In the Black Sea the greatest mean bio-volume was 184 ml per m3 in the autumn of 1989 when the zooplankton and fish stocks collapsed.

Half-life times of zooplankton (copepods) were very short (< 1 day) at certain locations, and relatively short (mean 4.4 days) at most other locations in the Limfjord in August-September 2007.

Mnemiopsis leidyi in the Bornholm Basin May 2007

*Mnemiopsis leidyi* in northern Baltic Sea: Gulf of Finland, Åland and Bothnian Seas, August-September 2007

Mnemiopsis leidyi in the central Baltic Sea - November 2007

Vertical distribution of *Mnemiopsis leidyi* on 3 stations (A,B,C) in the Bornholm Basin. The highest densities occurred at 40 to 60 m around the halocline.

Monitoring of *Mnemiopsis leidyi* during winter and spring of 2008 – a ticking bomb?
Temperatures 1975-2006

30 years measurement of temperature indicates increasing temperatures of the waters around Fyn: +2.3 °C of surface water, +1 °C of bottom water

Source: Harley Bundgaard Madsen, Environmental Centre Odense, Denmark
Mnemiopsis leidyi has survived the mild winter 2007/08 – although predated by Beroe cucumis naturally occurring in Danish waters.
Beroe cucumis with Mnemiopsis leidyi in the gut
Kerteminde harbour, 5 February 2008
**Mnemiopsis in late 2007 and early 2008**

**Limfjorden**
- 11 December 2007: 0.1 to 4.0 ind./m³ (5 mm long)
- 30 April 2008: no *Mnemiopsis* but many *Aurelia aurita*

**Great Belt**
- Density decreased from 57 to 0.8 ind./100 m³ from 4 February to 31 March 2008; but not observed in April and May 2008
Horsens Fjord - 21 May 2008

Large 7-10 cm long *Mnemiopsis*
"Public survey" - summer of 2008

Still no national Danish monitoring programme follow the development

Therefore, the Marine Biological Research Centre (SDU) in co-operation with the Zoological Museum (KU) made a press release in July 2008 to call on the public to watch for Mnemiopsis and report observations (email & photo) to follow the invasion of the new ctenophore

So far, 100 reports from the public has made it possible to follow the distribution of Mnemiopsis

During the summer and early autumn of 2008 Mnemiopsis leidyi has been observed in most inner Danish waters, but no quantitative studies have been made
By the end of August 2008, 100 people had reported on observations of *Mnemiopsis leidyi* on about 150 localities. Only few *Mnemiopsis leidyi* were observed in June and July, but mass occurrences have been reported in an increasing number during August.

Thank you!

THE END