Digestion Rate in relation to temperature on *Mnemiopsis leydi* (Agassiz, 1865)

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**Introduction**

*Mnemiopsis leidyi* is a comb jelly that is related to jellyfish, with a length up to 100mm. It originates from Western Atlantic coastal waters and estuaries and was accidentally introduced into the Black Sea in the early 1980s, where it showed an explosive population growth (Vinogradov et al. 1989). Also, it has been accidentally introduced into the Sea of Marmara (Shiganova 1993), the Mediterranean (Kideys and Niermann 1993), Caspian (Ivanov et al. 2000), and Baltic Sea (Kube et al. 2007).

*M. leidyi* lives in the photic region and can be found from the littoral zone to the pelagic (GESAMP 1997). They are able to live in oxygen poor waters and are not significantly harmed by water pollution. In addition, this organism thrives in brackish water that has a high concentration of organic material suspended in it (Ginn et. al 2001). This species may occur in temperatures from 0 and 32 °C, and salinities between 2 and 38 °C, *M. leidyi* mainly lives above the thermocline (from 0 to 15-20 m) during the warm season and, as most ctenophores, is annual and does not survive Black Sea winters if water temperatures decrease below 4° C (Purcell et al. 2001).

Introduced species are known to cause severe ecological alterations in the invaded habitats such as changes of the habitat structure, food web composition and species diversity (Diederich et al. 2005). *Mnemiopsis leidyi* feed at high rates on zooplankton, fish eggs, ichthyoplankton and fish larvae (Purcell et al, 2001). The pelagic ecosystem of the Black Sea was degraded, manifested as sharply decreased biodiversity, abundance, and biomass of the main components of the pelagic ecosystem-zooplankton (Dumont, 1998). Fish stocks in the Black Sea and Sea of Azov have suffered due to predation on eggs and larval stages of food supplies (Shiganova et al. 2004). Effects on the ecosystem in the Caspian Sea were faster and stronger than in the Black Sea. In 2001, repercussions were felt at all trophic levels, including that of the top predator, the Caspian seal (Dumont 1998). *M. leidyi* is a voracious zooplanktivore (Purcell and Decker 2005), and a catastrophic decrease in zooplankton inevitably influenced the stocks of planktivorous fishes (sprat, anchovy, and horse-mackerel). The catch of those fishes in 1991 was less than one-fifth of that in 1988 (Shushkina et al. 2000). In late summer of 2007, at
Limfjorden, Denmark, the population densities of *Mnemiopsis leidyi* were high, up to more than 800 individuals m\(^{-3}\) in the innermost part, but body lengths were small, 5 to 15 mm (Hans *et al*, 2007). The bio-volumes were very high, between 100 and 300 ml m\(^{-3}\), in the central parts of Limfjorden and were even higher than those from the Black Sea, where the highest mean bio-volume was about 184 ml m\(^{-3}\) in the autumn of 1989 when the zooplankton and fish stocks collapsed (Hans *et al*, 2007).

Species with high digestion rate will consequently have a competitive advantage by being able to use the food resources more efficiently than slow-digesting species, and the information on temperature effects is essential when using data on digestion rate (Martinussen & Båmstedt, 2001). The objective of this report was to study the different temperature effect for the digestion rate of *Mnemiopsis leidyi*. 
Materials and methods

Predator and Prey

*Mnemiopsis leidyi*, used for the experiment, was collected from the sea at 0-5 m depth near Kristineberg, with 20 mm or bigger size, between September and October, 2008. These samples were acclimated to laboratory conditions in filtered sea water inside a transparent bucket during approximately 24 hours, before the experiments were conducted.

*Acartia tonsa*, a calanoid marine copepod, was used as prey in the experiments. These samples were obtained from a culture (≥ 200 µm mesh size filter)

Digestion time at different temperatures

These experiments were made at two different temperature levels, 14.7 ± 0.6 °C in the first experiment and 18.9 ± 1.5 °C in the second experiment was at.

*M. leidyi* (n=5 for each experiment) and *Acartia tonsa* (n= 100 approximately for each experiment), with 11 replicates in the first experiment and 5 replicates for the second experiment. They were put in filtered sea water inside a transparent bucket, for at least 10 minutes in each experiment.

Thereafter, the number of prey inside the gut of every comb jelly was determined using a microscope Leica Wild M3Z. Digestion was monitored and noted down when digestion was finished. After that, predators size was measured. In order to follow digestion progress the predators were examined under microscope every tenth or fifth (in the end) minute until digestion was completed.

Temperature was recorded for every experiment.

A prey sample was taken and preserved with lugol, with the aim of measuring prey size later, using microscope Leica Wild M10.
Results

Temperature in experiment

Two experiments with two different temperatures. The first experiment was at 14.7 ± 0.6 °C and the second experiment was at 18.9 ± 1.5 °C

Size of prey

The length of *Acartia tonsa* for the first experiment (at 14.7 °C) was 726 ± 64 µm (n=30) and in the second experiment (at 18.9 °C) was 663.5 ± 295 µm (n=30)

Size of predator

The length of *Mnemiopsis leidyi* for the first experiment was 40.9 ± 5.8 mm (n=25) and for the second experiment was 32.3 ± 9.0 mm (n=55, each experiment comprising 5 individuals)
Time of digestion at different temperatures

Experiment at 14.7 °C

1 to 10 prey in gut

<table>
<thead>
<tr>
<th>Size Mnemiopsis (mm)</th>
<th>Time (min)</th>
<th>n total</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>31-40</td>
<td>198.3 ± 95.9</td>
<td>9</td>
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<tr>
<td>41 o more</td>
<td>180.1 ± 43.6</td>
<td>7</td>
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11 or more prey in gut

<table>
<thead>
<tr>
<th>Size Mnemiopsis (mm)</th>
<th>Time (min)</th>
<th>n total</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>31-40</td>
<td>149 ± 84.7</td>
<td>5</td>
</tr>
<tr>
<td>41 o more</td>
<td>186.7 ± 52.6</td>
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Experiment at 18.9 °C

1 to 10 prey in gut

<table>
<thead>
<tr>
<th>Size Mnemiopsis (mm)</th>
<th>Time (min)</th>
<th>n total</th>
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</thead>
<tbody>
<tr>
<td>20-30</td>
<td>60.6 ± 29.6</td>
<td>17</td>
</tr>
<tr>
<td>31-40</td>
<td>72.7 ± 30.5</td>
<td>13</td>
</tr>
<tr>
<td>41 o more</td>
<td>64.8 ± 19.6</td>
<td>5</td>
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11 or more prey in gut

<table>
<thead>
<tr>
<th>Size Mnemiopsis (mm)</th>
<th>Time (min)</th>
<th>n total</th>
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</thead>
<tbody>
<tr>
<td>20-30</td>
<td>110.4 ± 57.5</td>
<td>9</td>
</tr>
<tr>
<td>31-40</td>
<td>127.9 ± 58.9</td>
<td>11</td>
</tr>
<tr>
<td>41 o more</td>
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Conclusions

In the first experiment (at 14.7 °C), were not made experiments with of *Mnemiopsis leidyi* smaller than 30 cm.

The results show that at this temperature, time of digestion is longest for individuals with smaller size, in experiments with 1 to 10 preys in the gut. However, the situation is different for experiments with 11 or more prey in the gut, because the time of digestion is longer when the size of *M. leidyi* is larger than to 41 mm.

In the experiments at 18.9 °C, a smaller number of preys in the gut are also less time for the digestion. This is not so clear for experiments at 14.7 °C.

The shorter digestion time was averaging 60.7 minutes, in ctenophores with sizes between 20 and 30 mm (with 1 to 10 preys in gut). Meanwhile those with larger sizes take longer to digest the food (11 or more prey in gut).

From these experiments, one may conclude that the temperature is very important when considering the digestion in *Mnemiopsis leidyi*, because the digestion time was strongly temperature dependent, as a higher temperature shortened digestion time.
Discussion

The West Atlantic ctenophore *Mnemiopsis leidyi* is well known for its great invasive capacity and its significant ecological impact on zooplankton communities across its native, as well as invaded, distribution range (Kube et al., 2007).

Knowledge of the digestion rate of an organism is necessary for understanding the trophic transfer of energy and material in a quantitative way. Also, digestion rates are important in assessing the impact of the organism on the ecosystem.

Reports on digestion time of gelatinous zooplankton are described by many authors (Martinussen & Båamstedt, 2001, Appendix 1). The digestion time was found to decrease with increasing food concentration and size of predator, and to increase with increasing size and number of prey (Martinussen & Båmstedt, 2001). However, from this experiment it is not clear that the digestion time in big predators is longer than in small predators, because individuals 30 mm or less in length, sometimes, are slower to digest the food.

Literature data for the same species at different temperatures conclude that digestion time was strongly temperature dependent. This report indicates that *Mnemiopsis leidyi* have a very variable digestion rate with the respect to temperature.

The recommendation for future work is to have similar laboratory, because in this experiment there are only 11 replicates for the first experiment (14.7 °C) and 5 replicate in the second experiment (18.9 °C). Also, the size of *Acartia tonsa* present in the second experiment is very different compared to first experiment, (presents a large standard deviation), and this can influence the results.
References


