The potential direct and indirect effects of grey seal on Baltic cod

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Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
The potential direct and indirect effects of grey seal on Baltic cod

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¹: DTU Aqua, 2: KU-SUND, 3: AU, 4: Thünen Institute 5: SLU, 6: KU

During the past few decades, the Baltic grey seal (Halichoerus grypus grypus) population size has increased significantly. The grey seal is a top predator known to consume a wide range of fish species depending on prey availability, geographical area and season. Grey seal is also final host to the nematode parasite Contracaecum osculatum (commonly referred to as cod liver worm), to which cod (Gadus morhua) is one of several transport hosts. Here we present data on the spatial occurrence of C. osculatum in cod livers in 321 fish sampled from Skagerrak to south of Gotland. Prevalence of infection was high (90-100%) in the three most eastern areas, decreasing towards the west and northwestward. Abundance of infection (number of parasites per infected fish) was likewise highest in the most eastern areas, mean abundances varying from 27 to 40 parasites. Preliminary analysis suggests that the nutritional status of the fish (evaluated by protein, water, oil and energy content of fish and liver) is affected when the parasite load is high. Several countries have now initiated visual registrations of C. osculatum in cod livers during monitoring surveys. We evaluate the applicability and pitfalls of these routine registrations of liver worm. At present also the direct – through consumption – effect of grey seals on cod in the central and western Baltic is unknown. To investigate this, 820 scats were collected at Måkläppen, Tat, Rødsand, and Utklippan. Two methods were used to assess the prey composition – molecular analysis and otolith analysis of scats. The DNA analysis suggests that cod, garfish, herring, sprat, flatfishes and sandeel comprise a major part of the grey seal diet when estimated as frequency of occurrence. Cod was likewise found to be the most frequently occurring species in the otolith analysis, followed by flatfishes, sandeel, unidentified codfishes (Gadidae), herring and whiting. However, in terms of biomass, cod comprised 83% of the total consumption by grey seals – more than ten times the amount of flatfishes (8%) as the second most abundant prey. In total, grey seals in the south Central and Western Baltic had an annual consumption per individual of 1370 kg cod. This high proportion of cod in the diet of grey seals in the central and western Baltic calls for further assessments of the impact of the seals on the Baltic cod stock.
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Jane W. Behrens
Cod liver worm (*Contracaecum osculatum*) lifecycle

Illustration by Kurt Buchmann, copyright International Wildlife Association, from Haarder et al 2014
central to many metabolic processes
storage site for energy
responsible for enzyme production relating to digestion and lipid uptake

?? May liver worm affect the nutritional status of the fish??
Spatial occurrence of liver worm in cod

Percentage of cod infected with liver worm

(35-50cm, Q4 2016/17, n=321)

Adapted from Sokolova et al 2018
doi.org/10.3354/meps12773
Spatial occurrence of liver worm in cod

Adapted from Sokolova et al 2018
doi.org/10.3354/meps12773
Is nutritional status affected by liver worm?

35-50cm

Q4 2017 (n=34)
Q4 2018 (n=10)
Is cod nutritional status affected by liver worm?

Fish protein content

Fish water content

Fish energy content

No change in oil content of the fish
Is cod nutritional status affected by liver worm?

Liver oil content

Liver protein content

Liver water content

Infection rate (number of worms/gram liver)

Oil content of the liver (g/kg) vs. Infection rate

Protein content of the liver (g/kg) vs. Infection rate

Water content of the liver (%) vs. Infection rate

p < 0.001
Visual registrations of liver worms on surveys

<table>
<thead>
<tr>
<th>Category</th>
<th># of parasites</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1-10</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
</tr>
<tr>
<td>3</td>
<td>&gt;20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Institute/country</th>
<th>Registrations initiated</th>
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<tbody>
<tr>
<td>Poland</td>
<td>2013</td>
</tr>
<tr>
<td>Thünen</td>
<td>2015</td>
</tr>
<tr>
<td>DTU Aqua</td>
<td>2017</td>
</tr>
<tr>
<td>IHF Hamburg</td>
<td>2017</td>
</tr>
<tr>
<td>Estonia</td>
<td>2018</td>
</tr>
<tr>
<td>GEOMAR</td>
<td>2018</td>
</tr>
<tr>
<td>Latvia</td>
<td>2018</td>
</tr>
<tr>
<td>SLU</td>
<td>2018 (test)</td>
</tr>
</tbody>
</table>

Photo Bastian Huwer
How (im)precisely do we predict total number of worms from categories?

475 livers sampled from SD22, 24 and 25 and assigned a category

Subsequently total number of worms in the liver counted

<table>
<thead>
<tr>
<th>Category</th>
<th># of parasites</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<tr>
<td>1</td>
<td>1-10</td>
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<tr>
<td>2</td>
<td>11-20</td>
</tr>
<tr>
<td>3</td>
<td>&gt;20</td>
</tr>
</tbody>
</table>
How (im)precisely do we predict total number of worms from categories?

<table>
<thead>
<tr>
<th>Category</th>
<th># of parasites</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
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<tr>
<td>1</td>
<td>1-10</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
</tr>
<tr>
<td>3</td>
<td>&gt;20</td>
</tr>
</tbody>
</table>

**SD22**
Mecklenburg/Kiel

**SD24**
Arkona

**SD25**
Bornholm Basin
## Collection sites for investigations of seal consumption

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>Maj</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Okt</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
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<tbody>
<tr>
<td>MÅK 2014</td>
<td>16</td>
<td>32</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>16</td>
<td>76</td>
<td></td>
<td></td>
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<tr>
<td>MÅK 2015</td>
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<tr>
<td>MÅK 2016</td>
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<td>30</td>
<td>32</td>
<td>16</td>
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<tr>
<td>TAT 2015</td>
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<td>19</td>
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<tr>
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<td>9</td>
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<tr>
<td>RØD 2017</td>
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<td>21</td>
<td>6</td>
<td>76</td>
<td>24</td>
<td>159</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>UTK 2016</td>
<td>4</td>
<td>29</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>39</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>UTK 2017</td>
<td>17</td>
<td>17</td>
<td>24</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>70</td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>38</td>
<td>18</td>
<td>76</td>
<td>161</td>
<td>218</td>
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<td>117</td>
<td>11</td>
<td>67</td>
<td>46</td>
<td>0</td>
<td>820</td>
</tr>
</tbody>
</table>

**Collaborative project SLU, KU, DTU**
Seal scats for DNA and otoliths
## Family | Species | Common name | FO<sub>DNA</sub> | FO<sub>Otoliths</sub>
--- | --- | --- | --- | ---
Gadidae | Gadus morhua | Atlantic cod | 64.83 | 65.60
Belonidae | Belone belone | Garfish | 38.62 | 10.55
Clupeidae | Clupea harengus | Atlantic herring | 37.24 | 4.13
Clupeidae | Sprattus sprattus | European sprat | 33.79 | 21.10
Pleuronectidae | Pleuronectes/Platichthys | Flatfishes | 18.62 | 21.10
Ammodytidae | Hyperolus lanceolatus | Great sand eel | 11.03 | 
Zoarcidae | Zoarces viviparus | Viviparous eelpout | 7.59 | 
Lotidae | Enchelyopus cimbrius | Fourbeard rockling | 5.52 | 10.09
Gadidae | Merlangius merlangus | Whiting | 4.14 | 
Cyclopteridae | Cyclopterus lumpus | Lumpsucker | 3.45 | 
Ammodytidae | Ammodytes tobianus | Lesser sand eel | 3.45 | 
Scophthalmidae | Scophthalmus rhombus | Brill | 2.07 | 
Anguillidae | Anguilla anguilla | European eel | 2.07 | 
Salmonidae | Salmo salar | Atlantic salmon | 2.07 | 
Salmonidae | Salmo trutta | Brown trout | 1.38 | 
Gasterosteidae | Gasterosteus aculeatus | Three-spined stickleback | 1.38 | 
Gobiidae | Pomatoschistus minutus | Sand goby | 1.38 | 
Gadidae | Pollachius virens | Saithe | 0.69 | 
Gobiidae | Neogobius melanostomus | Round goby | 0.69 | 
Esocidae | Esox lucius | Northern Pike | 0.69 | 
Percidae | Perca fluviatilis | European Perch | 0.69 | 
Gobiidae | Gobiusculus flavescens | Two-spotted goby | 0.69 | 
Gobiidae | Gobius niger | Black goby | 0.69 | 
Ammodytidae | Hyperolus/Ammodytes | Sandeel | 13.76 | 
Gadidae | Gadus/Merlangius | Cod or whiting | 12.84 | 
Clupeidae | Clupea/Sprattus | Herring or sprat | 7.34 | 
Gobiidae | Gobius/Neogobius | Goby | 5.05 | 
Pleuronectidae | Limanda limanda | Common dab | 1.83 |
**Weight proportions and consumed biomass**

![Bar chart showing weight proportions of grey seal prey species](image)

<table>
<thead>
<tr>
<th>Prey species</th>
<th>Daily consumption (kg)</th>
<th>Annual consumption per seal (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod</td>
<td>3.8</td>
<td>1370</td>
</tr>
<tr>
<td>Flatfish</td>
<td>0.4</td>
<td>134</td>
</tr>
<tr>
<td>Goby</td>
<td>0.1</td>
<td>51</td>
</tr>
<tr>
<td>Herring</td>
<td>0.1</td>
<td>28</td>
</tr>
<tr>
<td>Sandeel</td>
<td>0.1</td>
<td>25</td>
</tr>
<tr>
<td>Clupeidae</td>
<td>0.03</td>
<td>14</td>
</tr>
<tr>
<td>Whiting</td>
<td>0.03</td>
<td>10</td>
</tr>
<tr>
<td>Sprat</td>
<td>0.02</td>
<td>6</td>
</tr>
<tr>
<td>Dab</td>
<td>0.01</td>
<td>3</td>
</tr>
<tr>
<td>Cod/Whiting</td>
<td>0.004</td>
<td>2</td>
</tr>
</tbody>
</table>
Contributors

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Kurt Buchmann, Per Kania – KU SUND
Uwe krumme - Thünen Institute
Morten Tange Olsen – KU
Anders Galatius - AU
Karl Lundström - SLU

Funding

European Maritime and Fisheries Fund
The Danish Fisheries Agency
Horizon 2020
BONUS