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Report on scientific cod fishing and monitoring in 2020 in Åland, Finland

Jari Raitaniemi and Ari Leskelä

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Jari Raitaniemi, ORCID ID, https://orcid.org/0000-0002-7720-1447

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Summary

Authors: Jari Raitaniemi and Ari Leskelä

Natural Research Institute Finland, (Luke), Latokartanonkaari 9, FI-00790 Helsinki, Finland

At present, Eastern Baltic cod in the southern Baltic Sea grows slowly, shows low condition factor and is heavily infected by the larvae of liver worms. It is hypothesized, that either the heavy infection by liver worms, lack of suitable food due to lack of oxygen in the deep bottoms of the Baltic Sea or both together cause severe problems for cod. The final host of the liver worm is grey seal (*Halichoerus grypus*), and this parasite is carried to cod via prey, smaller pelagic fish. There is a small-scale cod fishery in the Finnish waters in the Sea of Åland, where cod are large sized and in good condition. Grey seals are abundant in these waters.

In this study, the occurrence of *Contracaecum* larvae in the livers of cod in the Sea of Åland and the food of the cod were examined. The size of measured cod varied from 30 to 120 cm. The number of *Contracaecum osculatum* larvae correlated with cod length, but the number of larvae per liver weight did not. The condition factor of the cod was higher (1.115) and the specimens were larger than compared with recent findings from the southern Baltic Sea. More importantly, the condition of the cod was not found to be in relation to the number of *Contracaecum* larvae on the liver surface nor the number of larvae per liver weight. The most common food items were *Saduria* and clupeid fish. It looks probable that when there is enough food for the cod, the effects of *Contracaecum osculatum* infection on the condition and growth of cod are small or even insignificant.

Keywords: *Gadus morhua*, Cod, *Contracaecum osculatum*, the Sea of Åland, liver worm, the Baltic Sea

Contents

1. Introduction

Major declines of the eastern Baltic cod (*Gadus morhua*) (hereafter referred to as Baltic cod) stock have been reported (Vallin et al., 1999; Cardinale & Arrhenius, 2000; Hjerne & Hansson, 2001; Köster et al., 2001), and EU commission allowed no direct fisheries on the stock in 2020. However, in recent years and after a long break, it has been possible to catch cod in the waters south and west of Åland and southwestern coast of Finland (Figures 1 and 2). The cod in these waters have been reported to be in good physical condition in contrast to the cod in the southern Baltic Sea. The reasons for this have not been known.

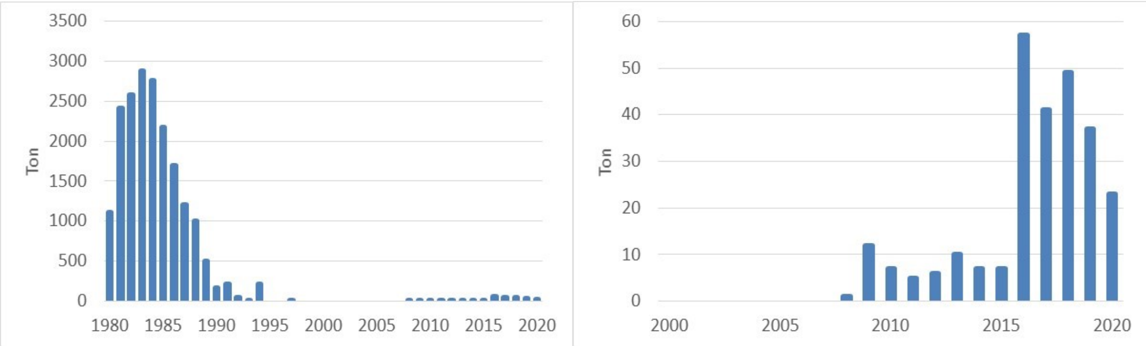

Figure 1. The landings of cod by Finland in ICES subdivision 29 (SD 29) in 1980–2020 (left) and in different scale in 2000–2020 (right) (Finnish fisheries statistics, * still preliminary estimate of landings in 2020).

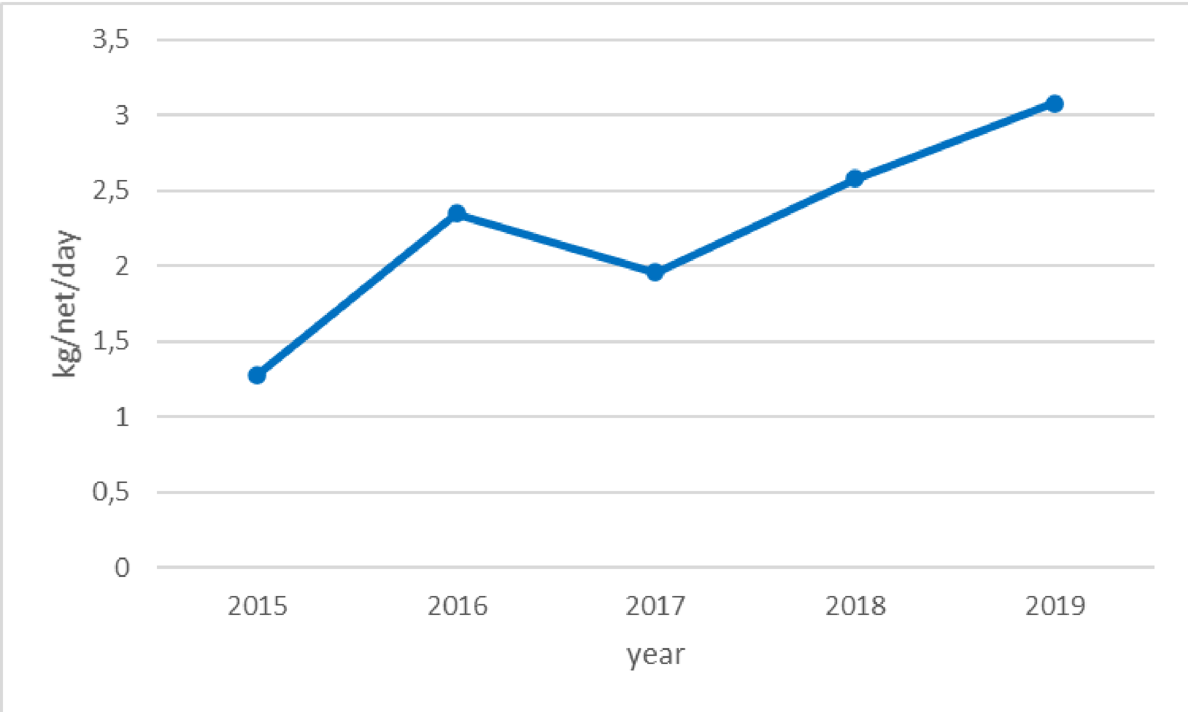

Figure 2. Catch per unit effort (CPUE) of cod fishery with gillnets of 120 mm mesh size (60 mm stretched mesh) in statistical rectangles 49 and 58 in 2015–2019 (Finnish fisheries statistics, daily records).

Eastern Baltic cod in the southern Baltic Sea, i.e. in its most important distribution area, is heavily infected by the larvae of liver worms (*Contracaecum osculatum*; Zuo et al. 2016, Sokolova et al. 2018, Mohamed et al. 2020, Ryberg et al. 2020). The condition factor and growth of the eastern Baltic cod is at present very low (e.g. Sokolova et al. 2018), probably due to both liver worms and lack of suitable food (Neuenfeldt et al. 2020) that is a consequence of large anoxic bottom areas (Limburg et al. 2018), and possibly due to other reasons as well. The final host of the liver worm is grey seal (*Halichoerus grypus*), and this parasite is carried to the cod via its prey, probably mostly smaller pelagic fish. The abundance of the parasite infections in the Baltic Sea has increased together with the number of grey seals. However, in the 1970's, when the Baltic grey seal population was significantly smaller than at present (e.g. Galatius et al. 2020), *Contracaecum osculatum* was found in the livers of several fish species in the Finnish Archipelago Sea: most commonly in cod, but also in salmon (*Salmo salar*), fourhorn sculpin (*Myoxocephalus quadricornis*), herring (*Clupea harengus*), and burbot (*Lota lota*). In the Bothnian Bay, *C. osculatum* was also found in smelt (*Osmerus eperlanus*) and shorthorn sculpin (*Myoxocephalus scorpius*) (Valtonen et al. 2012).

There is little data on how severe the *Contracaecum* infections are in cod in the Finnish waters south of Åland, although there is a cod fishery, and based on Baltic seal counts, grey seals are abundant in the adjacent waters. ICES trawl survey does not cover this area, and thus there is a lack of knowledge about the stock size of cod in the Sea of Åland.

This is the report of the first year in the sampling and monitoring program to collect data and gather information of the cod in Åland waters. Scientific cod fishing and monitoring has been implemented as a co-operation by local fishermen, the Government of Åland and Natural Resources Institute Finland (Luke). The main aim of the program is to collect data on cod length, weight, and condition in the catch, determine abundance and prevalence of liver worm infection and the food of cod. These data are compared with published results from elsewhere in and near the Baltic Sea.

In addition, an effort to get more information on the abundance and status of the cod in the Sea of Åland will take place. The data collected during the monitoring will be used here, and it will also be examined, if the statistics from commercial fisheries (fishing effort, catches) from earlier years, as well, can be used to get information on cod abundance on index level. To get as thorough figure as possible, the monitoring took place from 1st March to 31st December 2020.

Accordingly, this study of the first year of the scientific program aims to identify i) the level and prevalence of liver worm infections in the Baltic cod in the Ålands Sea. The liver worms ii) effect on the Baltic cod status will be measured and the food availability and preference of cod will be investigated.

2. Material and methods

Samples were collected from scientific fishery, which was executed by commercial fishermen from 1st March to 31st December 2020 and regulated by fisheries authorities in Åland (Figure 3).

Figure 3. The fishing area (within Finnish statistical squares 58 and 49 i.e. ICES rectangles G948 and G949) marked with a yellow arrow (contains data from the National Land Survey of Finland, Background map series 02/2021).

1) From each fishing trip, the fishermen delivered the usual log-book data together with the number of caught cod.

2) Monthly, an official from the Government of Åland, measured individual length and weight of 25 randomly selected cod from at least one fishing trip. When needed, cod from two or more trips per fisherman were measured.

3) In addition, an official from the Government of Åland took liver and stomach samples and otoliths from 5 of the 25 randomly selected cod (point 2 above). The liver and stomach of each specimen were frozen for later examination.

In laboratory, the specimens of *Contracaecum*-larvae were counted from the surface of each liver. The numbers were classified in five categories used earlier in Denmark and Sweden (Table 1).

Table 1. Liver worm Contracaecum osculatum abundance classification (Unknown 2018).

Category	Number of worms
0	0
I	1–10
II	11–20
III	21–30
IV	< 30

The contents of each stomach were weighed and examined to recognize the species of prey and to estimate the degree of digestion (scale of 3 categories).

3. Results and discussion

The lengths of, altogether 813 cod specimens, were measured by an official of the government of Åland. Most abundant individuals were 50–70 cm of length (average 64.5 cm), but there were also very large specimens with length above 120 cm (Figure 4). Fulton's condition factor of these specimens (gutted weight) was on average 0.935 (Figure 5). The condition factor was stable with no trends between different length classes (Figure 6).

The number of *Contracaecum* larvae was counted on the surface of 170 cod livers in total. In these cod specimens with data on total weight (mean condition 1.115), condition decreased with increasing length (Figure 6). The number of *Contracaecum* larvae on their livers (Figure 7) correlated with cod length (average 64.3 cm), which was also found by Sagebakken et al. (2019), but there was no correlation between the number of larvae per liver weight and cod length (Figure 8).

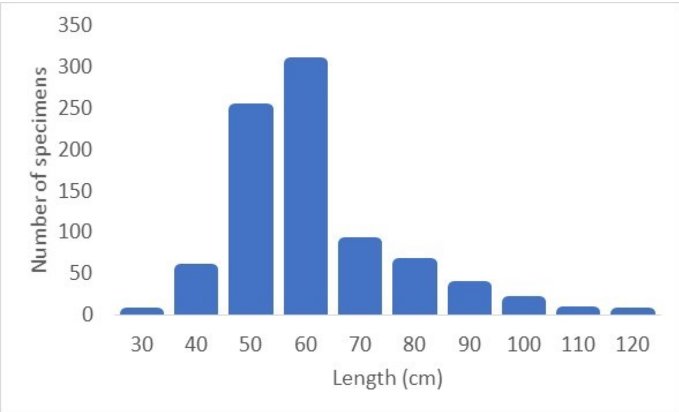

Figure 4. Length distribution of cod measured by an official from government of Åland (n = 813). Lengths rounded down to the closest tenth.

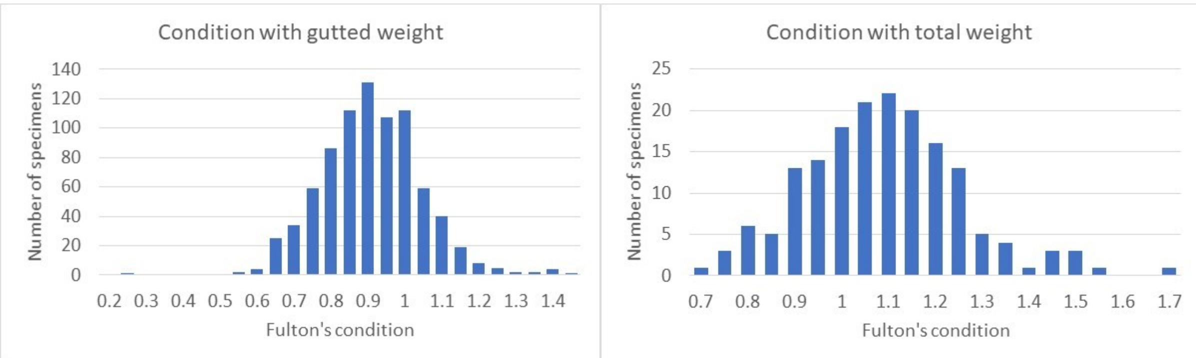

Figure 5. The distribution of condition factor in the measured and weighed specimens (left: gutted weight, n = 813) and sampled specimens (right: total weight, n = 170).

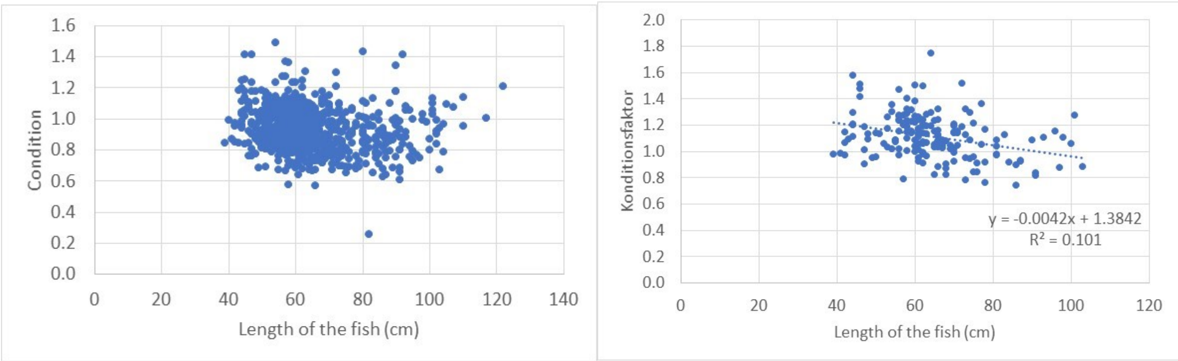

Figure 6. The condition (Fulton's condition factor) of the measured 813 specimens of cod (left, gutted weight) and the sampled 170 specimens (right, total weight; $r = 0.318$, $p < 0.001$).

Figure 7. A liver with no findings of *Contracaecum* larvae (above), a few specimens on the liver surface (below left), large number of larvae on the liver surface (below right).

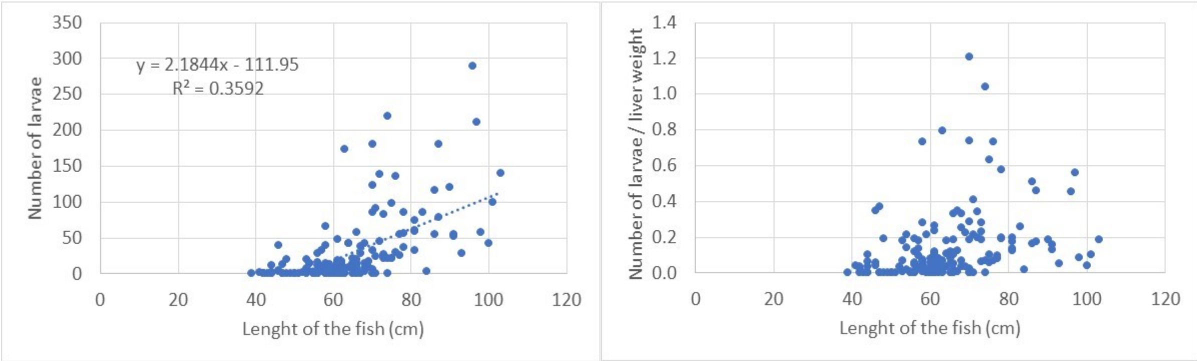

Figure 8. The number of *Contracaecum osculatum* larvae counted on cod liver surfaces (left), number of larvae / liver weight (right) and the total lengths of the cod specimens.

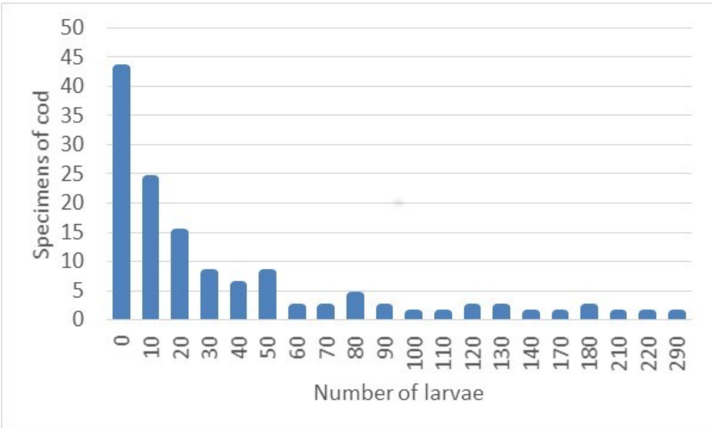

Figure 9. The distribution of the abundance of *Contracaecum* larvae on the liver surfaces of cod (n = 170, the number of larvae is rounded down to the closest tenth).

In a large part of the livers sampled from cod, the abundance of *Contracaecum* larvae was relatively small (Figure 9, no parasites were found in 15% of the livers), smaller than found in several southern Baltic Sea areas, but larger than in Skagerrak, Kattegat and the most western Baltic Sea areas (Figure 10). It resembled the findings from south of Gotland, i.e. the closest area to our study by Sokolova et al. (2018).

The condition of the cod was not found to be in relation to the number of *Contracaecum* larvae (Figure 11), contradictory to what was observed in cod from the southern Baltic Sea by Horbowy et al. (2016) and Sagebakken & Bergström (2019). The absolute numbers of observed larvae on liver surface gave a similar view on the relationship with condition factor as the use of the five categories used in Denmark and Sweden. Although, the categorywith the most infected group (> 30 larvae) includes individuals with relatively small numbers of larvae, and a number of specimens had clearly larger numbers of larvae on their livers (Figure 11). When compared with the cod from the ten areas examined by Sokolova et al. (2018), the mean condition of the cod in Åland, 1.12, reminded of those in Skagerrak, The Sound, and Kattegat, where the cod had the highest condition factors (1.04–1.13). These differed clearly from those in eastern and western Bornholm Basin, Arkona Basin, and south of Gotland (0.82–0.91). The mean total length (65 cm) and weight (3 227 g) of the examined cod in the Åland Sea were higher than in any of the areas studied by Sokolova et al (2018) or Ryberg et al. (2020).

The fact that the number of larvae per liver weight had no relationship with cod condition (Figure 12) shows that the situation in Åland Sea is different from the area east of Bornholm in the southern Baltic Sea, where Ryberg et al. (2020) found that condition factor decreased with increasing infection density with *Contracaecum osculatum*.

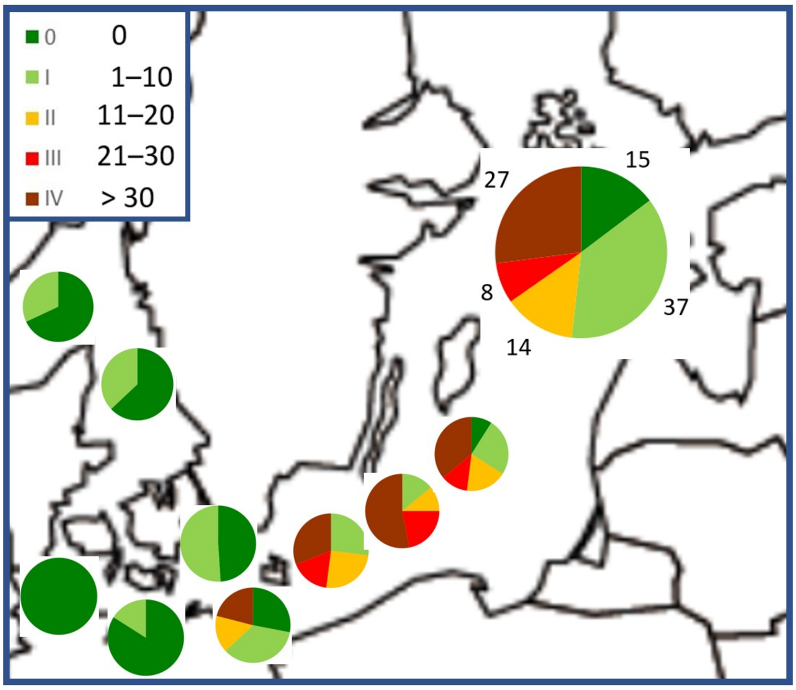

Figure 10. The abundance of *Contracaecum* larvae in the livers of the sampled cod in Åland (n = 170; the largest pie chart south of Åland with percentages) and corresponding abundances by Sokolova et al. (2018) in Skagerrak, Kattegat, the Sound, Kiel Bight, Mecklenburg Bay, Arkona Basin, Western Bornholm Basin, Eastern Bornholm Basin and south of Gotland.

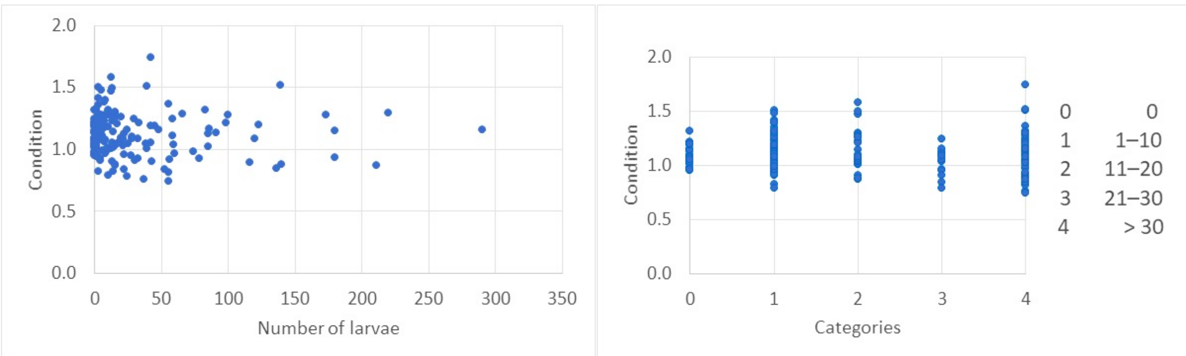

Figure 11. The condition of the cod (Fultons's condition value) in relation to the number of *Contracaecum* larvae on liver surface (left) and four categories of larval abundance (right).

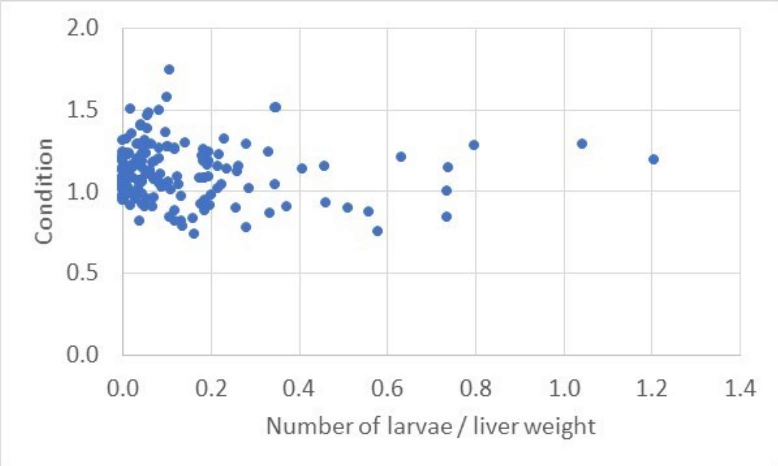

Figure 12. The condition of the cod (Fultons's condition value) in relation to an index of infection density with *Contracaecum* larvae (worms on liver surface/liver weight (g)).

Although growth data (from the analysis of sampled cod otoliths) were not yet available for this report, the high condition and large body sizes of the cod in the Åland Sea indicate good growth rates. These results suggest that the poor condition and high mortality of cod in the southern Baltic Sea are due to the combination of starvation and the occurrence of *Contracaecum osculatum*(e.g. Ryberg et al. 2020). In the Åland Sea, the good condition and probably fast growth of cod take place together with good growth of the liver. Hence, large numbers of worms do not increase the number of larvae per liver weight (Figure 8) and, thus, have little effect on the growth and condition of the cod.

In cod stomachs (Figure 13), *Saduria entomon* was the most common prey along with fish (Table 2). Mysids were also commonly found. Among fishes, herring was the most common, and the remains of sprat (*Sprattus sprattus*) were also possibly detected among clupeids with smaller backbone. Fourhorn sculpin was the most common of the family Cottidae, but also shorthorn sculpin was identified. These were probably the most common groups among the unidentified species, as well. Eelpout (*Zoarches viviparus*), cod (indicating cannibalism), and snakeblenny (*Lumpenus lampretaeformis*) were recognized, too.

Saduria were the most common food item in the stomachs of specimens that were sampled in March–July (in 10–13 specimens each month). Clupeids were most found in the samples in November–December (in 8 specimens in each month). Fish were an important prey throughout the year (in 6–8 specimens in 5–6 months of the year).

As expectable, mysids were found in the stomachs of the smallest and sculpins in those of the largest cod (Table 3). In the work of Zuo et al. (2016), *Saduria entomon* were not found to have *Contracaecum* infections, but 11.6% of examined sprat were infected with *C. osculatum*. This explained why cod started to have *Contracaecum* infections at larger sizes than 30 cm length, as small cod prey mostly on invertebrates and larger specimens on invertebrates and fish. In the acoustic surveys of Natural Research Institute Finland (ICES subdivision 29), herring and sprat have been found very abundant in this area in recent years.

Table 2. The number of stomachs (n=170), in which different prey were observed.

Prey	Observations
Saduria entomon	75
Mysidae	32
Clupeid fish	35
Cottidae, mostly *Myoxocephalus* sp.	11
Other and unrecognized fish	28
Empty stomachs	35

Table 3. The length of those cod specimens that were found to have eaten different types of prey.

Prey	Length of cod
Saduria entomon	in specimens < 90 cm
Mysidae	in specimens < 70 cm
Clupeid fish	in specimens 50–80 cm
Cottidae, mostly *Myoxocephalus* sp.	in specimens ≥ 70 cm
Other and unrecognized fish	in specimens ≥ 50 cm

Figure 13. Examples of stomach contents: Fish backbones and *Saduria* (above left), mainly *Saduria* (above right), *Saduria* and several fish backbones (middle), clupeid remains (below).

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Natural Resources Institute Finland
Latokartanonkaari 9
FI-00790 Helsinki, Finland
tel. +358 29 532 6000