Natural resources and bioeconomy studies 87/2022

Report on scientific cod fishing and monitoring in 2021 in Åland, Finland

Jari Raitaniemi and Ari Leskelä

Luke
NATURAL RESOURCES
INSTITUTE FINLAND

Natural resources and bioeconomy studies 87/2022

Report on scientific cod fishing and monitoring in 2021 in Åland, Finland

Jari Raitaniemi and Ari Leskelä

Natural Resources Institute Finland, Helsinki 2022

Recommended citation:

Raitaniemi, J. & Leskelä, A. 2022. Report on scientific cod fishing and monitoring in 2021 in Åland, Finland. Natural resources and bioeconomy studies 87/2022. Natural Resources Institute Finland. Helsinki. 18 p.

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

ISBN 978-952-380-529-3 (Print)
ISBN 978-952-380-530-9 (Online)
ISSN 2342-7647 (Print)
ISSN 2342-7639 (Online)
URN http://urn.fi/URN:ISBN:978-952-380-530-9

Authors: Jari Raitaniemi and Ari Leskelä
Publisher: Natural Resources Institute Finland (Luke), Helsinki 2022
Year of publication: 2022
Cover photo: Patrik Lundin 2022, a cod weighing 29,55 kg gutted weigh
Printing house and publishing sales: PunaMusta Oy, http://luke.omapumu/com/fi

Summary

Jari Raitaniemi and Ari Leskelä

Natural Resources Institute Finland, (Luke), Latokartanonkaari 9, 00790 Helsinki

At present, Eastern Baltic cod (*Gadus morhua*) in the southern Baltic Sea grows slowly, shows low condition factor and is heavily infected by the larvae of liver worms (*Contracaecum spp.)*. 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 in the year 2021 was examined and presented together with the results from the year 2020. The size of measured cod in 2021 varied from 40 to 105 cm. Similarly, as in 2020, the number of *Contracaecum osculatum* larvae on liver surface correlated with cod length, but the number of larvae per liver weight did not. The condition factor of the cod was still very high (1.14). More importantly and similarly as in the previous year, the condition of the cod was associated neither with the number of *Contracaecum* larvae on the liver surface nor the number of larvae per liver weight. The most common food items of cod were *Saduria* and clupeid fish. The samples from both years support the conclusion that when there is enough food for the cod, the association of *Contracaecum osculatum* infection and the condition or 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 nor in 2021. 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.

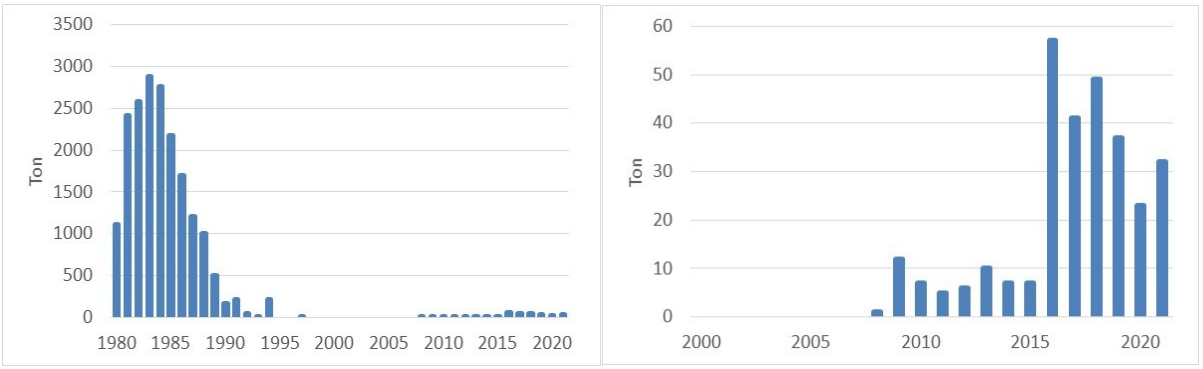

Figure 1. The landings of cod by Finland in ICES subdivision 29 (SD 29) in 1980–2021 (left) and in different scale in 2000–2021 (right) (Finnish fisheries statistics, still preliminary estimate of landings in 2021).

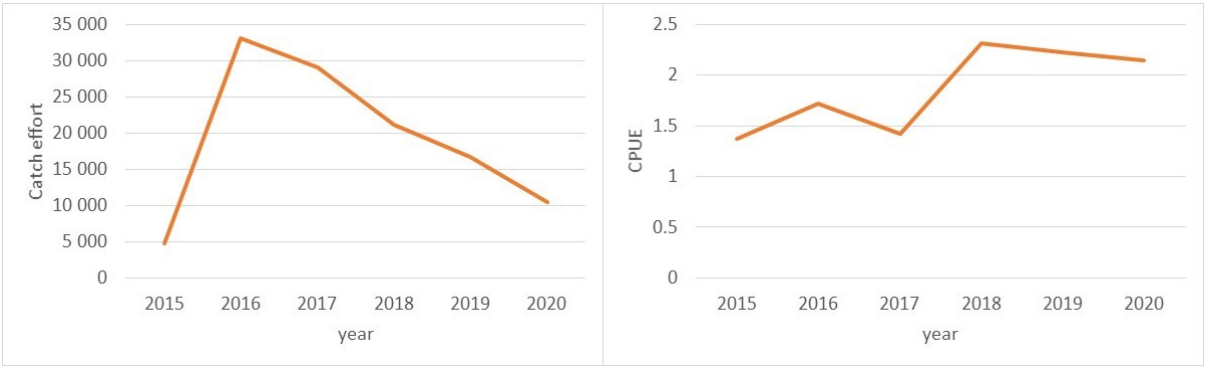

Figure 2. Catch effort (Fishing days x the number of gillnets with mesh size ≥ 120 mm (60 mm from knot to knot), left) and catch per unit effort (CPUE, right) of cod fishery in statistical rectangles 49 and 58 (49G9 and 48G9, SD 29) in 2015–2020 (Finnish fisheries statistics, daily records).

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 has been reported to be very low, e.g., according to Sokolova et al. (2018) Fulton's condition was 0.82–0.91, 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).

In the catch samples of cod in 2020 in Åland, *Contracaecum* larvae were commonly found on the surfaces of the livers, especially those of large specimens, sometimes in very large numbers. This was, however, not seen to affect the condition factor of the cod, which was on average higher than what has been recently found in the southern Baltic Sea (Sokolova et al. (2018)). 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 second 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 earlier results and published results from elsewhere in and near the Baltic Sea.

2. Material and methods

Samples were collected from scientific fishery, which was executed by commercial fishermen from 1st March to 31st December 2020 and from 10th March to 4th December 2021 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 48G9 and 49G9) 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 log-book data (at least daily documentation of important events in the management, operation, and navigation of a vessel) 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 (Rygerg et al. 2021).

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). In 2020, 170 specimens and in 2021, 125 specimens were examined in the laboratory.

In addition, 37 specimens caught from Hangö at the southernmost coast of Finland in 2020 and 2021 were examined similarly.

3. Results and discussion

In the measured 813 cod specimens in 2020 and 632 specimens in 2021 by an official of the government of Åland, most abundant individuals in both years were 50–70 cm of length (average 64.5 cm in 2020 and 64.6 cm in 2021). In 2021, there was less variation in the length distribution (Figure 4). Fulton's condition factor of these specimens (length / gutted weight ^3) was on average 0.935 in 2020 and 0.92 in 2021 (Figure 5). The average condition factor with total weight of the specimens that were sampled for further examinations was 1.12 in 2020 and 1.14 in 2021. The correlation between condition factor and cod length was practically zero in both years (Figure 6).

The number of *Contracaecum* larvae on the cod livers (Figure 7) correlated positively with cod length (average in 2020 64.3 cm and in 2021 65.4 cm), which was also found by Sagebakken et al. (2019). However, between the number of larvae (on liver surface) per liver weight and cod length, a correlation was found in 2020 but not in 2021 (Figure 8). Thus, the larvae often seem to have accumulated in the livers as the cod have been growing, but the good growth of the livers protect the cod from very high numbers of *Contracaecum* larvae per liver weight.

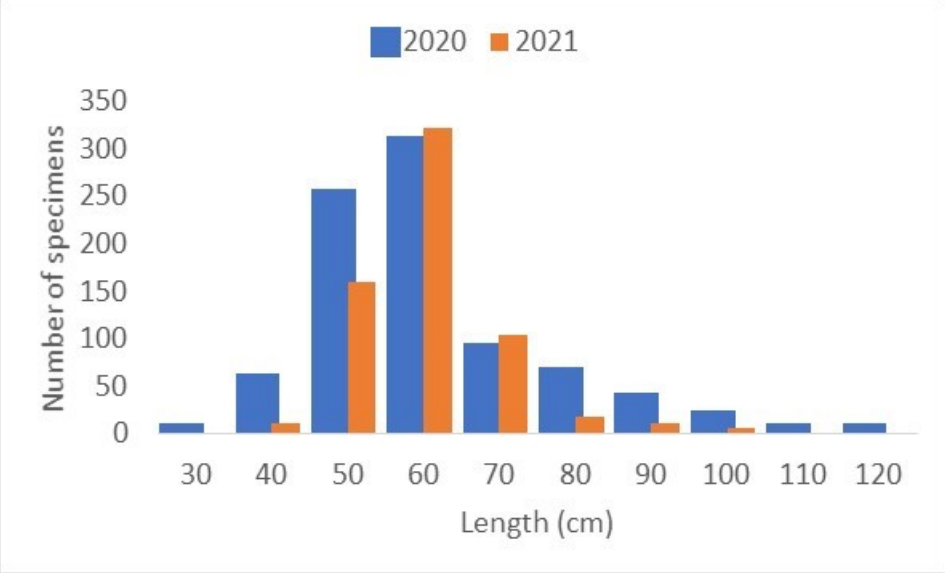

Figure 4. Length distribution of cod measured by an official from government of Åland in 2020 (n = 813) and 2021 (n = 632). Lengths rounded down to the closest tenth.

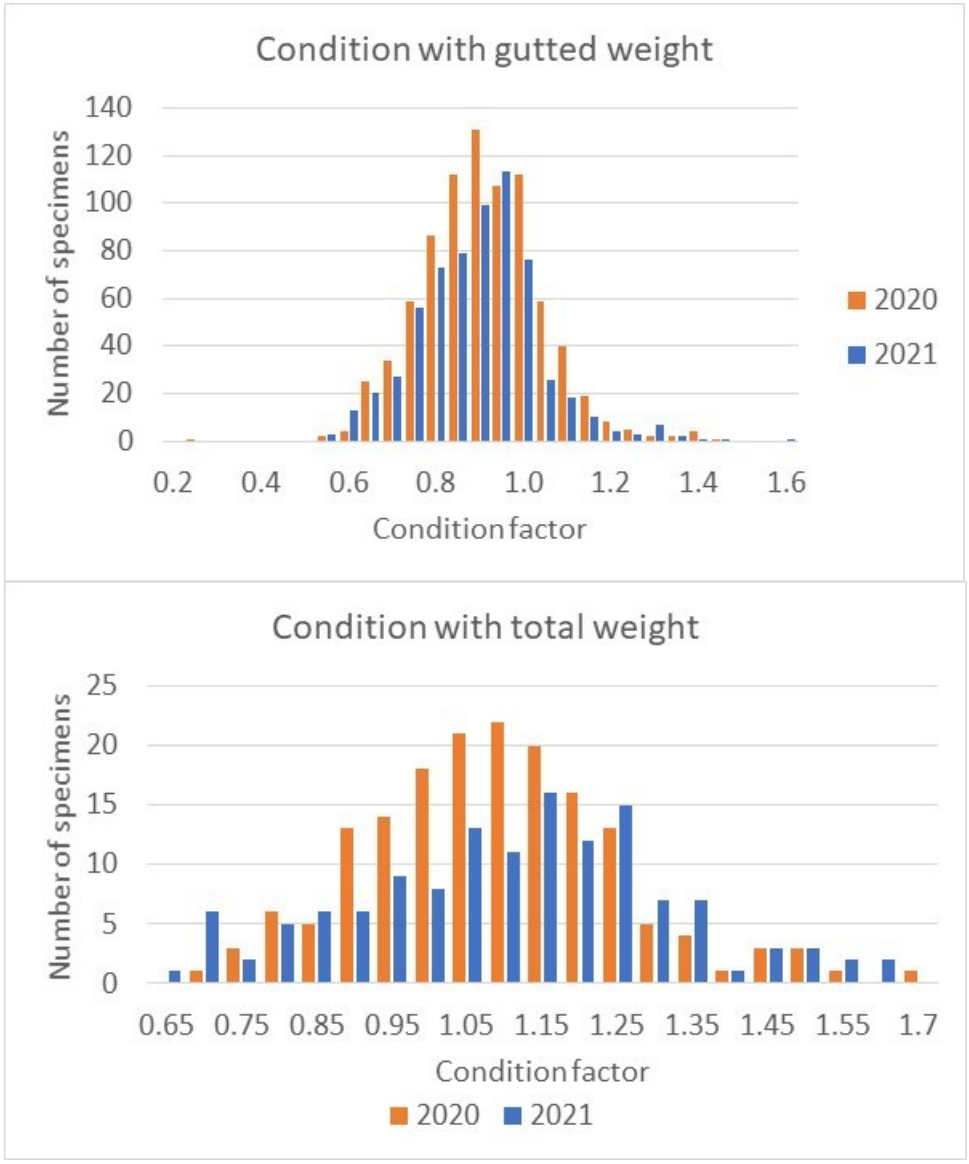

Figure 5. The distribution of condition factor in the measured and weighed specimens (above: gutted weight, n = 813 in 2020 and n = 632 in 2021) and sampled specimens (below: total weight, n = 170 in 2020 and n = 125 in 2021).

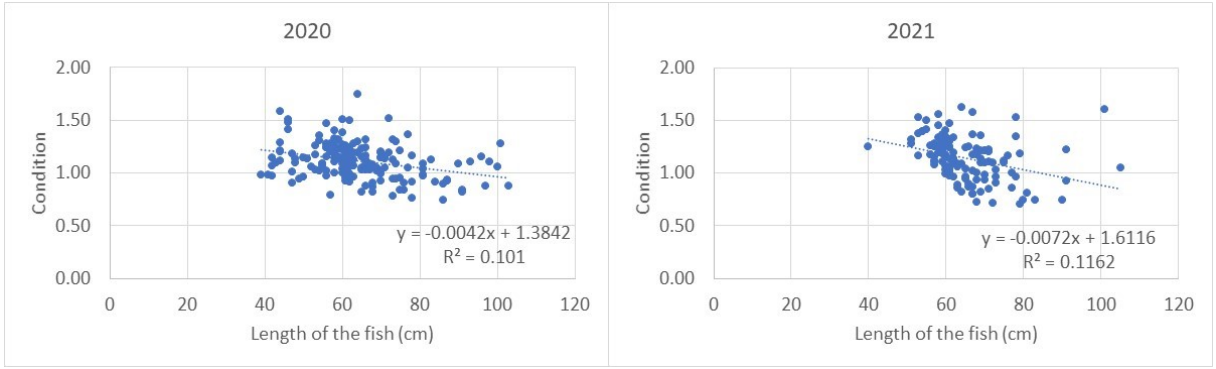

Figure 6. The relationship of condition (Fulton's condition factor) and total length of the 170 specimens sampled in 2020 (linear correlation, r = 0.318, P < 0.001) and 125 specimens sampled in 2021 (linear correlation, r = 0.341, p < 0.001).

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).

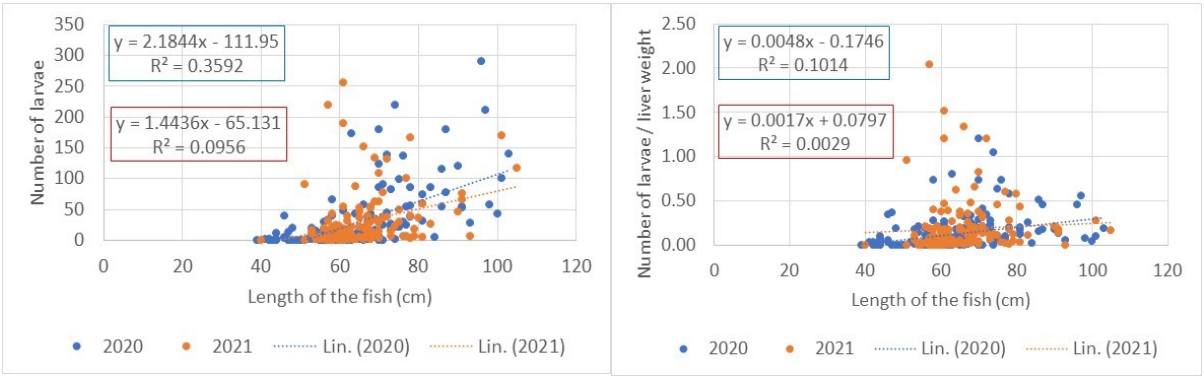

Figure 8. The number of *Contracaecum osculatum* larvae counted on cod liver surfaces and the total lengths of the cod specimens in 2020 (linear correlation, n = 170, r = 0.359, p < 0.001) and 2021 (n = 125, r = 0.309, p < 0.001) (left). The number of larvae / liver weight and the length of the cod in 2020 (linear correlation, n = 170, r = 0.318, p < 0.001) and 2021 (n = 125, r = 0.054, p> 0.05) (right).

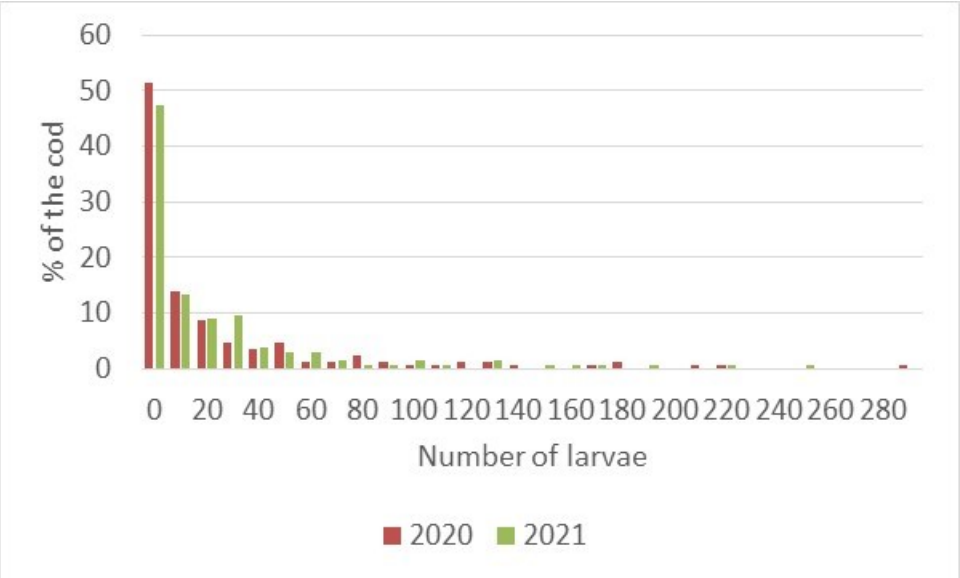

Figure 9. The distribution of the abundance of *Contracaecum* larvae in per cents on the liver surfaces of cod in 2020 and 2021 (the number of larvae is rounded down to the closest tenth).

In a large part of the livers sampled from the cod, the abundance of *Contracaecum* larvae was relatively small (Figure 9). No parasites were found in 15% of the livers in 2020 and 7% of the livers in 2021. Considering that Sokolova et al. (2018) were comparing the abundances of all *Contracaecum* larvae in the livers of cod in Skagerrak, Kattegat and the most western Baltic Sea areas, the larvae were abundant in the Åland Sea samples when compared with those areas.

The condition of the cod was not found to be in relation to the number of *Contracaecum* larvae (Figure 10), 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 of parasite load, presented by Ryberg et al. (2021). However, the category with the most infected group (> 30 larvae) includes not only individuals with relatively small numbers of larvae, but in addition, some specimens in both years had clearly larger numbers of larvae on the surfaces of their livers, between 200 and 300 (Figure 10), which is more than Ryberg et al. (2021) reported from SD 25 as the highest whole number of larvae in the livers of cod. 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 in the year 2020 and 1.13 in 2021, reminded of those in Skagerrak, The Sound, and Kattegat, where the cod had the highest condition factors (1.04–1.13). In Hangö at the southern coast of Finland, the mean condition of 37 specimens of cod examined in 2020 and 2021 was 1.01. These differed from those in the eastern and western Bornholm Basin, Arkona Basin, and south of Gotland (0.82–0.91). The mean total length (65 cm) and weight (3.28 kg) 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). In the sample from the 37 specimens from Hangö, the mean length was 55 cm and weight 1.7 kg.

The fact that the number of larvae per liver weight had no relationship with cod condition (Figure 11) 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*.

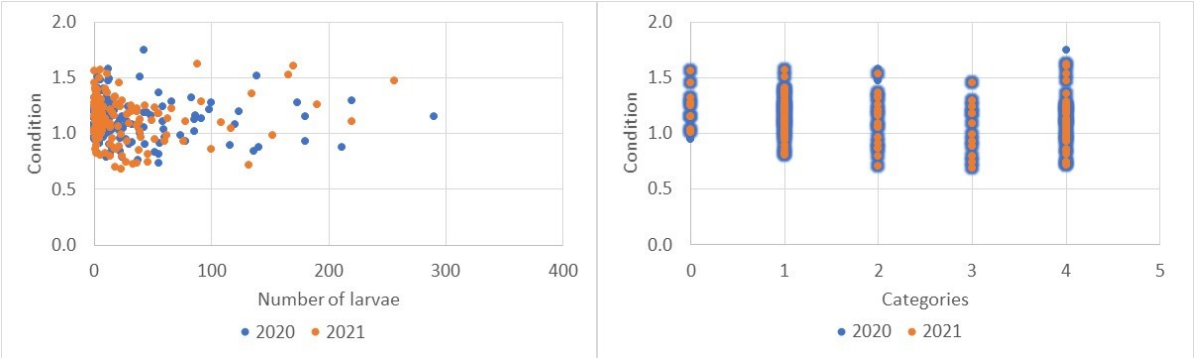

Figure 10. The condition of the cod (Fultons's condition value) in relation to the number of *Contracaecum* larvae on liver surface (left) and five categories of larval abundance (right).

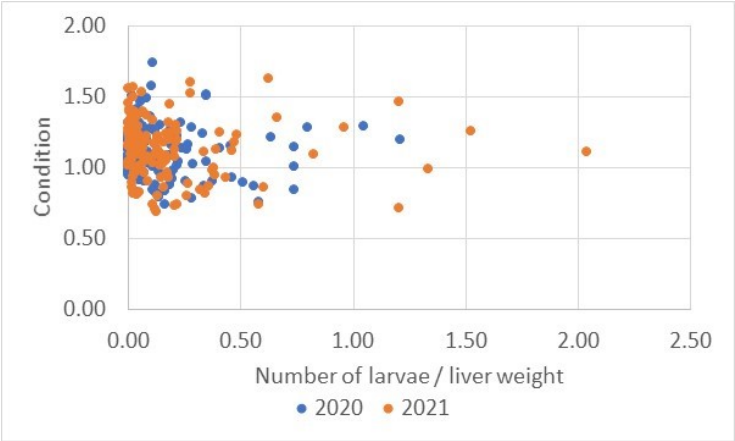

Figure 11. The condition of the cod (Fultons's condition value) in relation to an index of infection density with *Contracaecum* larvae (worms on liver surface/liver weight (g)).

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. This is also supported by a specimen caught in May 2022 with gutted weight of 29.55 kg (thus full weight was around 35 kg). 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.

The proportions of different prey groups in cod stomachs were very similar in both years (Figure 12). *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 both years (in 10–15 specimens each month). Clupeids were most found in the

samples from November–December (in 4–11 specimens in each month). Fish generally were an important prey throughout 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 the Natural Resources 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, in which different prey were observed in the years 2020 and 2021.

Prey	Observations	
	2020	2021
Number of the specimens of cod	170	125
Saduria entomon	75	72
Mysidae	32	39
Clupeid fish	35	28
Cottidae, mostly *Myoxocephalus sp.*	11	6
Other and unrecognized fish	28	25
Empty stomachs	35	12

Table 3. The length of those cod specimens that were found to have eaten different types of prey in the years 2020 and 2021.

Prey	Length of cod
Saduria entomon	all lengths
Mysidae	in specimens < 80 cm
Clupeid fish	mostly in specimens 50–80 cm
Cottidae, mostly *Myoxocephalus* sp.	in specimens ≥ 60 cm
Other and unrecognized fish	in specimens ≥ 50 cm

Figure 12. Examples of stomach contents: Fish backbones and *Saduria* (above left), mainly *Saduria* (above right), *Saduria* and several fish backbones (middle), clupeid remains (below).

4. Conclusions

On the contrary to the findings in the southern Baltic Sea, the cod in the Åland Sea were in good condition despite high numbers of *Contracaecum* in their livers. The larvae seem to accumulate with time into the livers of the cod in the Åland Sea as well as in the southern Baltic Sea, but the good growth of the cod in the Åland Sea and thus their livers, as well, protect the cod from very high numbers of *Contracaecum* larvae per liver weight. Thus, sufficient abundance of prey and good condition of the cod are probably the reasons why the effects of *Contracaecum* seem to be small or insignificant on the wellbeing of the cod in the Åland Sea.

Acknowledgements

We thank the Government of Åland for the funding of this study and its officials and the fishers who participated the sampling process. The Finnish ministry of Agriculture funded the examination of the cod samples from Hangö area.

References

Cardinale, M. & Arrhenius, F. 2000. The influence of stock structure and environmental conditions on the recruitment process of Baltic cod estimated using a Generalized Additive Model (GAM). Canadian Journal of Fisheries and Aquatic Sciences 57: 2402–2409.

Galatius, A., Teilmann, J., Dähne, M., Ahola, M., Westphal, L., Kyhn, L.A., Pawliczka, I., Olsen, M.T. & Dietz, R. 2020. Grey seal Halichoerus grypus recolonisation of the southern Baltic Sea, Danish Straits and Kattegat. Wildlife biology, URL: https://doi.org/10.2981/wlb.00711

Hjerne, O. & Hansson, S. 2001. Constant catch or constant harvest rate? The Baltic Sea cod (*Gadus morhua* L.) fishery as a modelling example. Fisheries Research 53: 57–70.

Horbowy, J., Podolska, M., Nadolna-Ałtyn, K. 2016. Increasing occurrence of anisakid nematodes in the liver of cod (*Gadus morhua*) from the Baltic Sea: Does infection affect the condition and mortality of fish? Fisheries Research 179: 98–103.

Köster, F.W., Hinrichsen, H.H., St. John, M.A., Schnack, D., MacKenzie, B.R., Tomkiewicz, J. & Plikshs, M. 2001. Developing Baltic cod recruitment models. II. Incorporation of environmental variability and species interaction. Canadian Journal of Fisheries and Aquatic Sciences 58: 1534–1556.

Limburg, K.E. & Casini, M. 2018. Effect of marine hypoxia on Baltic Sea cod Gadus morhua: evidence from otolith chemical proxies. Frontiers in Marine Science 5: 482.

Mohamed, A., Zuo, S., Karami, A.M., Marnis, H., Setyawan, A., Mehrdana, F., Kerkeby, C., Kania, P. & Buchmann, K. 2020. *Contracaecum osculatum* (sensu lato) infection of *Gadus morhua* in the Baltic Sea: inter- and intraspecific interactions. International journal of parasitology 50: 891–898.

Neuenfeldt, S., Bartolino, V., Orio, A., Andersen, K.H., Andersen, N.G., Niiranen, S. & Casini, M. 2020. Feeding and growth of Atlantic cod (*Gadus morhua* L.) in the eastern Baltic Sea under environmental change. ICES Journal of Marine Science, 77(2): 624–632.

Ryberg, M.P., Huwer, B., Nielsen, A., Dierking, J., Buchmann, K., Sokolova, M., Krumme, U. & Behrens, J.W. 2021. Parasite load of Atlantic cod *Gadus morhua* in the Baltic Sea assessed by the liver category method, and associations with infection density and critical condition. Fisheries management and ecology 29: 88–99. DOI: 10.1111/fme.12516

Ryberg, M.P., Skov, P.V., Vendramin, N., Buchmann, K., Nielsen, A. & Behrens, J.W. 2020. Physiological condition of Eastern Baltic cod, *Gadus morhua*, infected with the parasitic nematode *Contracaecum osculatum*. Conservation Physiology 8(1): 1–14. doi:10.1093/-conphys/coaa093.

Sagebakken, G. & Bergström, U. 2019. Rapport avseende undersökningar av *Contracaecum* sp. i torsk från Ålands hav. Statens veterinärmedicinska anstalt. Rapport 2019-10-07. Dnr 2019/764.

Sokolova, M., Buchmann, K., Huwer, B., Kania, P.W., Krumme, U., Galatius, A., Hemmer-Hansen, J. & Behrens, J.W. 2018. Spatial patterns in infection of cod *Gadus morhua* with the seal-associated liver worm *Contracaecum osculatum* from the Skagerrak to the central Baltic Sea. Marine Ecology Progress Series 606: 105–118.

Unknown 2018. Manual till visual vurdering af leverparasitter i torsk. Manualen er udviklet af Basti & Jane. Opdateret version fra September 2018.

Vallin, L., Nissling, A. & Westin, L. 1999. Potential factors influencing reproductive success of Baltic cod, *Gadus morhua*: a review. Ambio 28: 92–99.

Valtonen, T., Hakalahti-Siren, T., Karvonen, A. & Pulkkinen, K. (toim.). 2012. Suomen kalojen loiset. Gaudeamus. 978-952-495-237-8. 540 s.

Zuo, S., Huwer, B., Bahlool, Q., Al-Jubury, A., Christensen, N.D., Korbut, R., Kania, P. & Buchmann, K. 2016. Host size-dependent anisakid infection in Baltic cod *Gadus morhua* associated with differentia food preferences. Diseases of aquatic organisms 120: 69–75. doi: 10.3354/dao03002

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