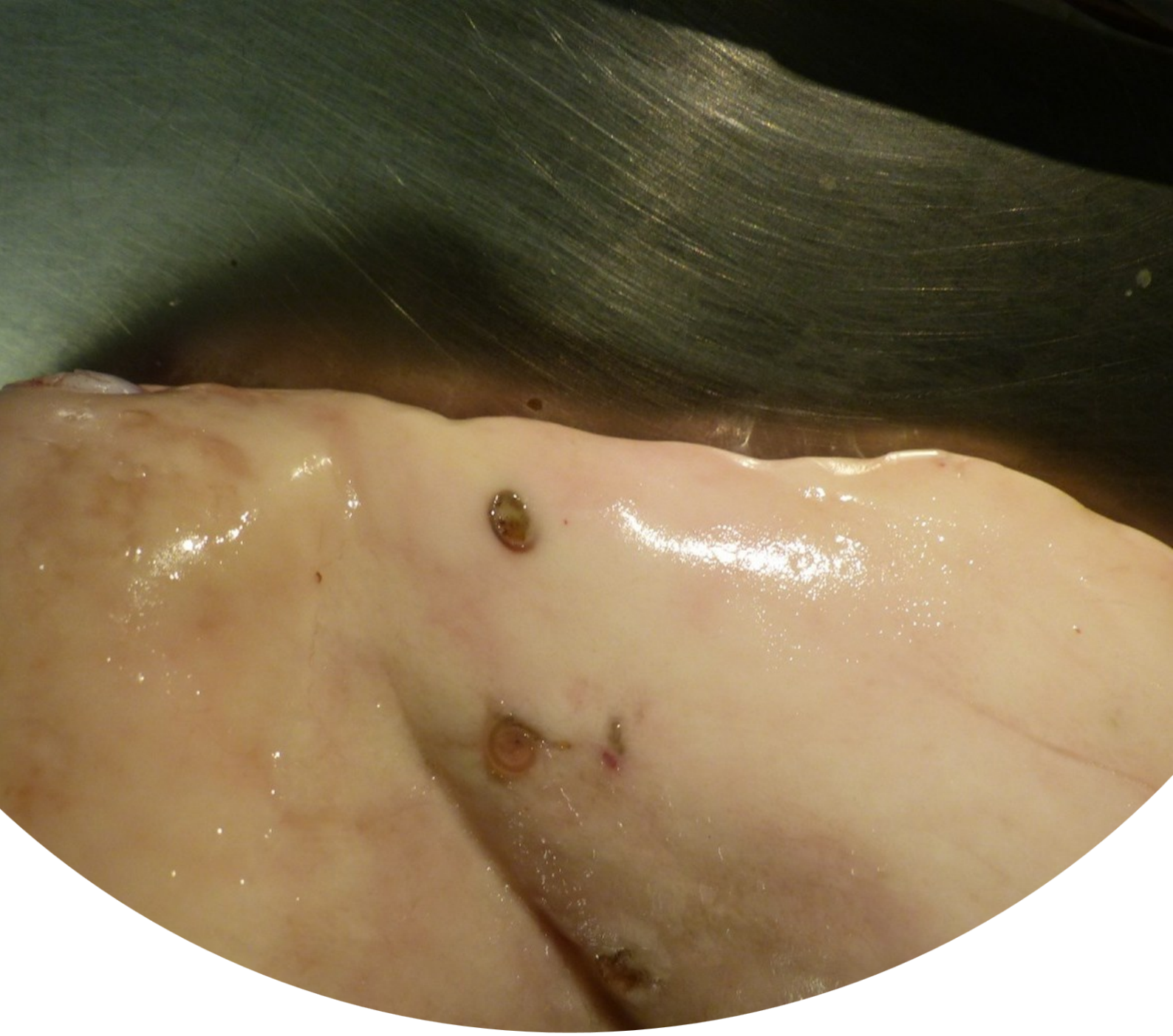

Natural resources and bioeconomy studies 95/2025

Report on scientific cod fishing and monitoring in 2024 in Åland, Finland

Jari Raitaniemi

Luke

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Abstract

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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 worm (*Contracaecum osculatum*). It has been hypothesized that 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 the cod. The final host of the liver worm is grey seal (*Halichoerus grypus*), and the worm is carried to cod via prey, smaller 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 especially in the Sea of Åland and the prey of the cod in the year 2024 were examined and presented together with the results from the years 2020, 2021, 2022, and 2023. The size of measured cod in 2024 varied from 30 to 110 cm (total length). Similarly, as in 2020–2023, the number of *Contracaecum osculatum* larvae on liver surface correlated with cod length. The Fulton's condition factor of the cod in all years was high (annual average 1.05–1.13 in Åland) and not in a statistically significant relation to the number of *Contracaecum* larvae per liver weight. The most common food items in all years were *Saduria* and clupeid fish. The samples from all years support the conclusion that when there is enough of food for the cod, the effects of *Contracaecum osculatum* infection on the condition and growth of cod are small or even insignificant. But in the southern Baltic Sea, starvation together with the occurrence of *Contracaecum osculatum* may cause the high mortality of cod reported in that area.

Keywords: *Gadus morhua*, Cod, *Contracaecum osculatum*, the Sea of Åland, Hangö, 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 (e.g. Vallin et al. 1999, Cardinale & Arrhenius 2000, Hjerne & Hansson 2001, Köster et al. 2001), and Council of the EU allowed no direct fisheries on the stock in 2020–2026. However, after a long break, it has since the 2010's been possible to catch cod in the waters especially south and west of Åland and southwestern coast of Finland (Figures 1, 2 and 3). The cod in these waters have been reported to be in good physical condition in contrast to the cod in the southern Baltic Sea.

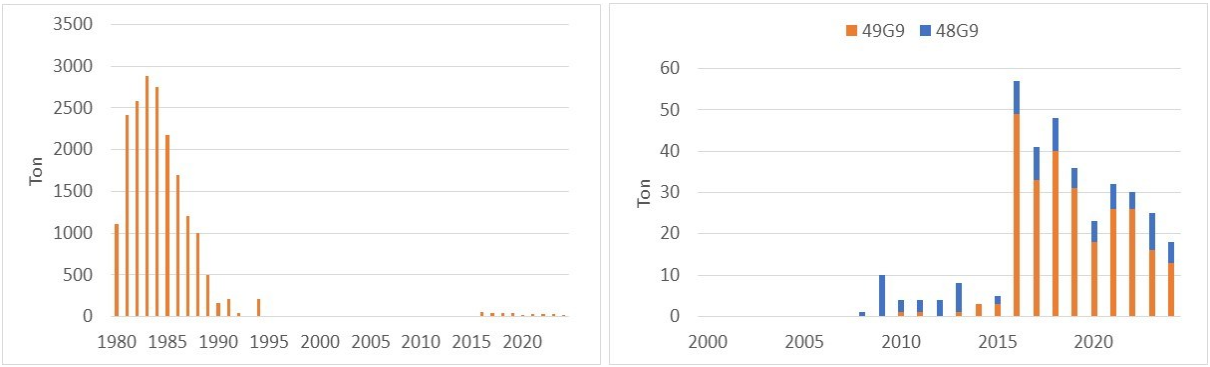

Figure 1. The landings of cod by Finland in ICES subdivision 29 (SD 29) in 1980–2024 (left) and in different scale in 2000–2024, the statistical squares 49G9 on the western side and 48G9 southwestern side of Åland Island being itemized (right) (Finnish

Figure 2. Catch effort (Fishing days x the number of gillnets with mesh size ≥ 120 mm (60 mm bar length), left above) and catch per unit effort (CPUE, right above) of cod fishery in statistical rectangles 49 and 58 (49G9 and 48G9, SD 29) in 2010–2023, and CPUE of cod from the logbooks of cod fishers in ICES subdivisions 29–32 with similar gillnets (below, kg/gillnet/day, Finnish fisheries statistics, daily records).

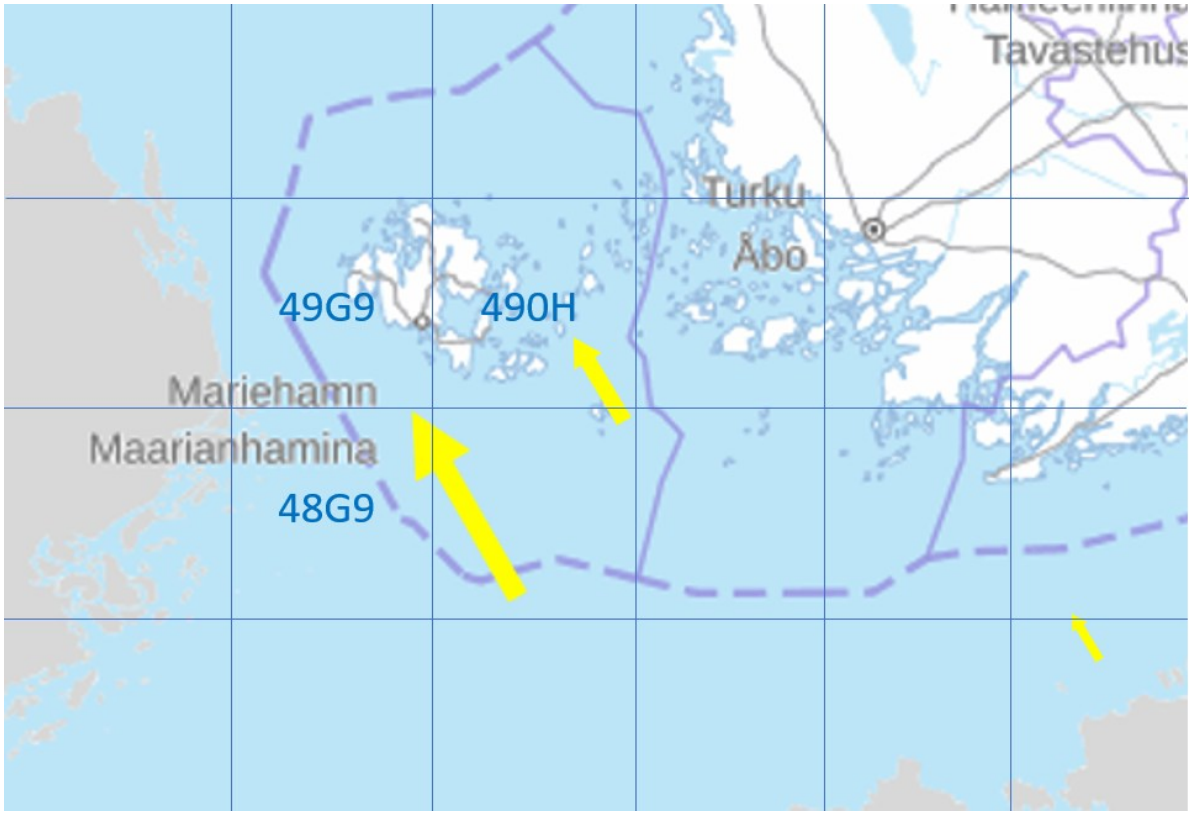

Figure 3. The fishing areas in the Åland Sea (within Finnish statistical squares 58, 49, and 50 i.e. ICES rectangles 48G9, 49G9, and 49H0) marked with the large and middle-sized yellow arrow and Hangö area marked with the smallest arrow. In addition, in 2024 some samples were taken from cod fishery in northern Åland in 2024. The map contains data from the National Land Survey of Finland, Background map series 02/2021.

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, Zuo et al. 2017, 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), which are a consequence of large anoxic bottom areas (Limburg et al. 2018), and possibly due to other reasons as well. The increase of cod otolith hypoxia proxies (Mn:Mg) has also been detected (Heimbrand et al. 2024).

According to Heimbrand et al. (2023), the cod caught from the Swedish half of Åland Sea in 2021 and 2022 had grown clearly faster and to larger sizes than those in the southern Baltic Sea. However, their growth was on average not as fast as that of the cod in the North Sea in the 1960s (Daan 1974).

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 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. 1988, Valtonen et al. 2012).

In the catch samples of cod in 2020–2023 in Åland, *Contracaecum* larvae were commonly found on the surfaces of the livers, especially those of large specimens, sometimes in very large numbers (Raitaniemi & Leskelä 2021, 2022, 2023, 2024). 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 and increasing in the adjacent waters (https://www.luke.fi/fi/luonnonvaratieto/tiedetta-ja-tietoa/merihylkeet, HELCOM 2023). Baltic International Trawl Surveys (BITS) do not cover this area, and thus there is a lack of knowledge about the stock size of cod in the Sea of Åland. The annual Baltic International Acoustic Survey (BIAS) passes these waters, and occasional cod of various sizes from fingerlings to larger specimens have been caught in the trawl.

This is the report of the fifth 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 examine the food of cod. These data are compared with earlier results and published results from elsewhere in and near the Baltic Sea. In addition, cod samples from one fisher in Hanko (Hangö) area at the southernmost coast of Finland have been examined similarly.

2. Material and methods

Samples were collected from scientific fishery, which was executed by commercial fishermen from March to December in 2020–2024 and regulated by fisheries authorities in Åland and the Finnish ministry of Agriculture and Forestry (Figure 3). In Åland, the samples of 2024 were collected from the same depression area to the south/southwest of the main island as in earlier years (deepest points 240 m or more) and in addition, from northern Åland. In 2023, samples had also been taken from Sottunga, which is to the southeast of the main island and where there is a small depression with depths mostly at 50–70 m (deepest point 87 m).

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 on the liver surface can be classified in five categories, which can be used to illustrate the number of larvae in the whole liver (Ryberg et al. 2021, 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). 141 specimens were examined from the year 2023, earlier 170, 125, 130, and 204 specimens had been examined similarly from the years 2020, 2021, 2022, and 2023, respectively.

In addition, samples from 10 specimens, which had been caught in 2024 from Hangö at the southernmost coast of Finland, were received for examination (though their individual measurement data still lacking). 32, 12, 18, and 9 specimens had been examined earlier in 2020, 2021, 2022, and 2023 respectively.

3. Results and discussion

In the measured cod specimens in 2020–2024 by an official of the government of Åland, most abundant individuals in the main fishing area in all five years were 60–70 cm of length with mean lengths of 64–68 cm. The mean length has had an increasing trend in the catches. In Sottunga, however, the cod in 2023 (n = 170) were smaller with mean length of 55 cm, and similarly among the 21 specimens from northern Åland in 2024, mean length was 52 cm. Some shift towards larger sizes can be seen in the length distributions (Figures 4 and 5). Fulton's condition factor has slightly varied from year to year (Figure 6). Although the numbers of examined specimens in Sottunga and northern Åland were small, condition factors in those areas were close to, or a bit higher than those in the Åland Sea.

Similarly, as in 2020–2023 (Raitaniemi & Leskelä 2021, 2022, 2023, 2024), in 2024 there tended to be more *Contracaecum* on liver surfaces of cod specimens the longer they were (Figures 7 and 8). The number of larvae (on liver surface) per liver weight did not correlate with cod length, which was also seen in the samples from earlier years.

As in Sottunga in 2023, in the northern Åland in 2024 the number of Contracaecum larvae on cod liver surfaces was smaller than in the Åland Sea depression area. In northern Åland, only in the samples from the length group 50–59 cm, there were enough of specimens to compare this. This suggests that the effect of the *Contracaecum* larvae on cod condition is small or negligible, as the above-mentioned condition factors in the same length groups were so similar in these areas. On the other hand, other local factors may affect the condition, as well.

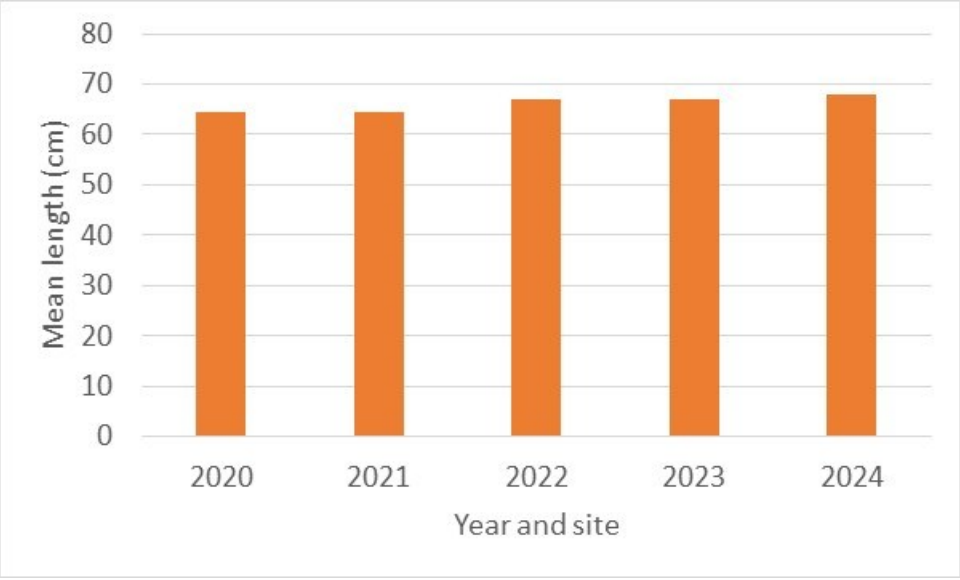

Figure 4. The mean length of cod caught from the depression area south/southwest of Åland main island in 2020–2024.

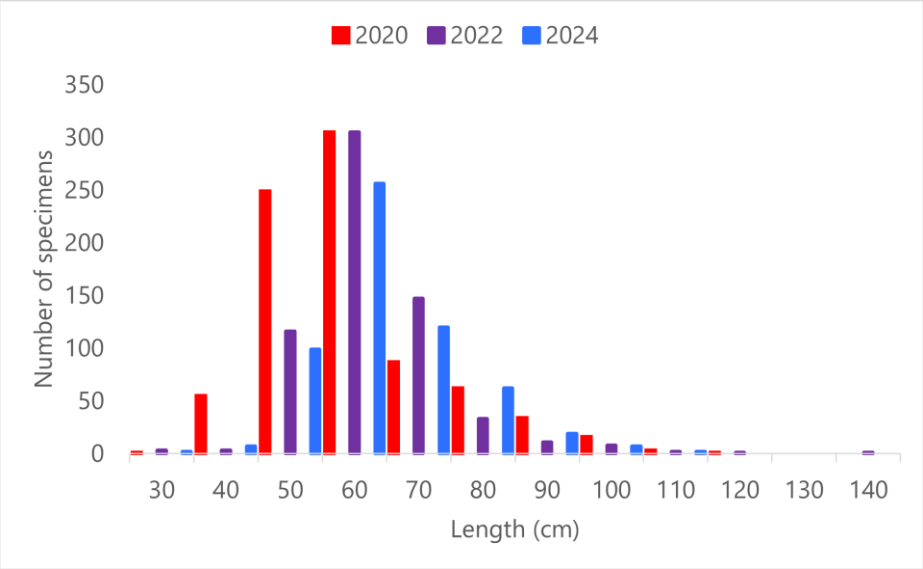

Figure 5. Length distribution of cod measured by an official from government of Åland in 2020 (n = 813), 2022 (n = 630), and 2024 (n = 574 at the depression to the south/southwest of Åland island). Lengths rounded down to the closest ten.

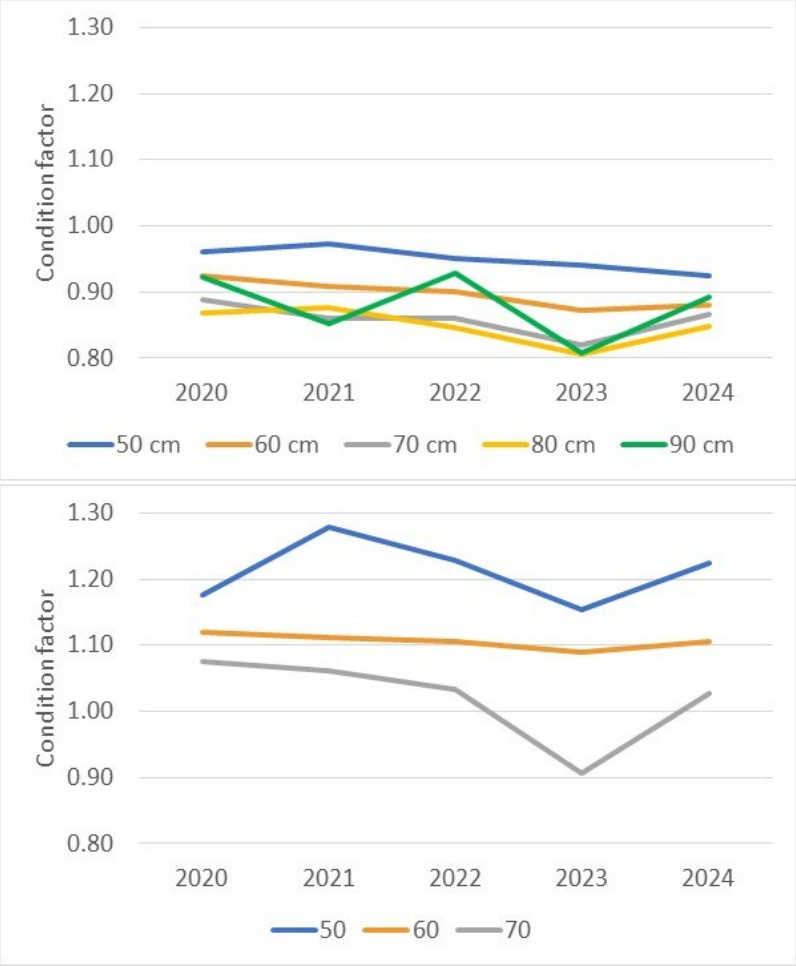

Figure 6. Mean Fulton's condition factor in 10 cm length groups (50–59 cm, 60–69 cm,…) from specimens with gutted weight (above, minimum number in length group 11 specimens) and individually sampled specimens with total weight (below, minimum number in length group 24 specimens) from the Åland Sea in 2020–2024.

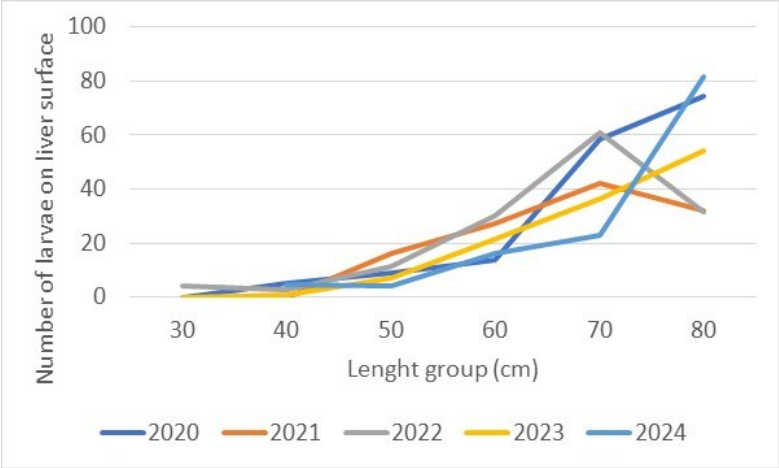

Figure 7. The mean number of Contracaecum larvae on liver surface of cod in different length groups (e.g. 50 cm length group includes specimens of 50–59 cm).

Figure 8. 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).

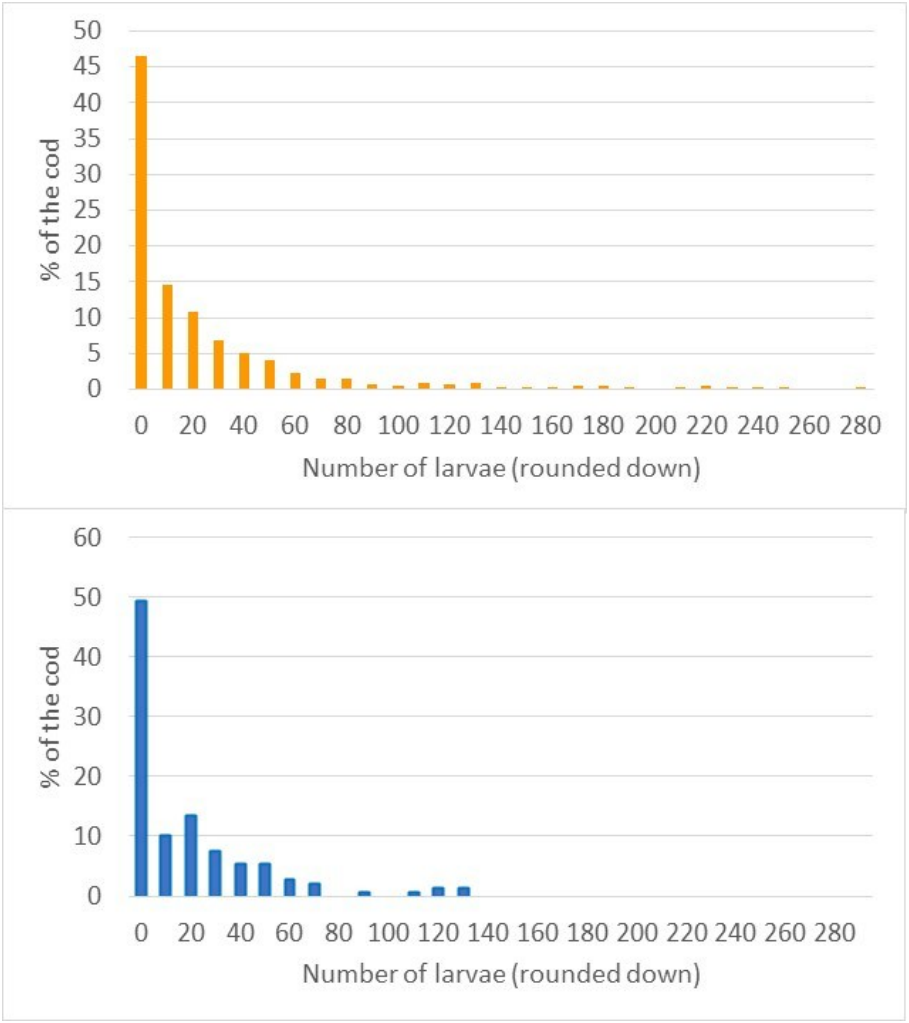

Figure 9. The distribution of the abundance of Contracaecum larvae on the liver surfaces of cod in the Åland Sea samples in 2020–2024 (above, N = 709) and in 2024 (below, N = 126). The number of larvae is rounded down to nearest 10.

In a large part of the livers sampled from the cod, the abundance of *Contracaecum* larvae has been relatively small (Figure 9), and so it was in 2024 (Figure 9 below). No parasites were found on the surfaces of 15%, 7%, 9%, 15%, and 6% of the livers in 2020, 2021, 2022, 2023, and 2024 respectively. In Sottunga in 2023, 58% and in the northern Åland in 2024, no parasites were observed in 64% of the sampled cod. Considering that Sokolova et al. (2018) were describing the abundances of all *Contracaecum* larvae in the livers of cod in Skagerrak, Kattegat and the most western Baltic Sea areas, the larvae have been abundant in the Åland Sea samples when compared with those areas.

Like in the previous years in the Åland Sea, in 2024 the condition of the cod was not found to be in a statistically significant relation with the number of *Contracaecum* larvae or the number of *Contracaecum* larvae / liver weight, however, the result of correlation test was closer to significance in 2023 ($n = 149$, $r = -0.148$, $P < 0.1$; $n = 149$, $r = -0.162$, $P < 0.1$, respectively). This was possibly in connection with the decreased condition of the larger specimens in 2023 (Figure 6, below). Thus in 2023, the relationship was similar as in the study of Sagebakken & Bergström (2019) from the Åland Sea in 2019. In the southern Baltic Sea, the body condition of infected cod was lower than that of those free of parasites and declined with the intensity of infection (Horbowy et al. 2016, Podolska et al. 2024).

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 numbers of larvae on liver surfaces in the Åland Sea in 2020–2023 have been larger than the whole number of larvae in the livers of cod counted by Ryberg et al. (2021) even from SD 25, i.e. the area with highest infection rate. When compared with the cod from the ten areas examined by Sokolova et al. (2018), the mean condition of the cod in Åland, 1.05–1.13 in 2020–2024, reminds of those in Skagerrak, The Sound, and Kattegat, where the cod had the highest condition factors.

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. Furthermore, Heimbrand et al. (2023) showed that cod in the western Åland Sea grow clearly faster than in the southern Baltic Sea. This was 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 growth of cod take place together with fast growth of the liver. Hence, large numbers of worms do not essentially increase the number of larvae per liver weight 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 all years (Figures 10 and 11). In the Åland Sea, *Saduria entomon* was the most common prey along with fish (Table 2). Mysids were also commonly found; in some specimens from 2022 and 2023, more than a hundred mysids could be counted in a stomach (Figure 10, below). In the cod stomachs from Sottunga in 2023 and northern Åland in 2024, no mysids were found, but in the latter a shrimp among a few unidentifiable fish in the same stomach was observed. *Saduria* was detected in only one stomach from northern Åland. Herring and fourhorn sculpin were the identified fish species in the samples from northern Åland. Among fishes in the Åland Sea, herring has been the most common in all years, and sprat remains (*Sprattus sprattus*) have also been possibly detected among clupeids with smaller backbone. The otoliths of clupeids have often been already melted or disappeared. Fourhorn sculpin was again the most common of the family Cottidae. Herring and fourhorn sculpin were probably the most common among the unidentified species, as well. In 2024, eelpout (*Zoarches viviparus*) was recognized, too.

In Hangö, *Saduria* has similarly been the most found prey, and eelpout has been the most common fish along with herring. The appearance of several three-spined sticklebacks in 2020 and blue mussels in 2023 in addition to abundant eelpouts, may suggest that the cod in the catches from Hangö have been foraging in shallower water than those caught from the Åland Sea. In BIAS survey catches, three-spined sticklebacks have usually been more abundant in the Åland Sea than in Hangö area, and they have been observed in relatively shallow water, i.e. below 30 (–40) metre's depth (SUOMU database, Natural Resources Institute Finland).

Saduria were the most common food item in the stomachs of specimens that were sampled in March–August in 2020, 2021, and 2023 (in 10–15 specimens each month). Clupeids were most found in the samples from 2020 and 2021 in November–December and in 2023 and 2024 in May, as well. In 2022, similar differences between seasons could not be seen. 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), although e.g. the largest cod in 2024 weighing over 14 kg had only *Saduria* in its stomach. *Saduria* were also the most common among the smaller size groups of cod. 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 (BIAS) in the northern parts of ICES subdivision 29, herring and sprat have been found very abundant in recent years.

Table 2. The number of stomachs, in which different prey were observed in the years 2020–2024 in the Åland Sea.

Prey	Observations				
	2020	2021	2022	2023	2024
Number of the specimens of cod	170	125	131	148	141
Saduria entomon	75	72	79	74	81
Mysidae	32	39	37	34	28
Clupeid fish, mostly herring	34	28	15	12	20
Cottidae, mostly *Myoxocephalus sp* .	11	6	10	3	16
Other and unrecognized fish	25	25	21	47	28
Empty stomachs	34	18	20	27	22

Table 3. The length of those cod specimens that were found to have eaten different types of prey in 2020–2024 in the Åland Sea.

Prey	Length of cod
Saduria entomon	mostly in specimens < 90 cm
Mysidae	in specimens < 80 cm
Clupeid fish	mostly in specimens 50–80 cm
Cottidae, mostly *Myoxocephalus* sp.	mostly in specimens ≥ 60 cm
Other and unrecognized fish	in specimens ≥ 50 cm

Figure 10. Examples of stomach contents: Herring, eelpout and some Saduria remains, too (above); mysid and Saduria remains (below, photograph Pia Lindberg-Lumme).

Figure 11. 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

The number of *Contracaecum osculatum* larvae on liver surface correlated with cod length. The Fulton's condition factor of the cod in all years was high (annual average 1.05–1.13 in Åland) and not in a statistically significant relation to the number of *Contracaecum* larvae per liver weight. The most common food items in all years were *Saduria* and clupeid fish. The samples from all years support the conclusion that when there is enough of food for the cod, the effects of *Contracaecum osculatum* infection on the condition and growth of cod are small or even insignificant. But in the southern Baltic Sea, starvation together with the occurrence of *Contracaecum osculatum* may cause the high mortality of cod reported in that area.

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