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Original Research

Heavy Metal (Hg, Cd, Zn) Concentrations and Condition of Eelpout (*Zoarces viviparus* L.), around Baltic Sea

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Abstract:

In total, 145 adult (<15 cm) eelpouts from various parts of the Baltic Sea were analyzed: Brunskär (Archipelago Sea) Tvärminne (Finnish Western Gulf of Finland), Bays of Kunda and Muuga (Estonian Gulf of Finland), Bay of Matsalu (Western Estonian coast), Roja (Latvian Gulf of Riga), Laboe and Schwentine river-mouth (German Kieler Förde). Concentrations of Hg were higher in muscle tissue than in liver, but for Cd and Zn the opposite was the case. The highest mean values for Hg were obtained from eelpouts from Schwentine river-mouth (Kieler Förde), for Cd from eelpouts from the Bay of Muuga, and for Zn from eelpouts from the Bay of Kunda. Statistically significant negative correlations have been calculated between the condition factor (CF) and Hg for eelpouts from Brunskär (Archipelago Sea), Tvärminne (Gulf of Finland) and Schwentine (Kieler Förde), between CF and Cd for eelpouts from Brunskär, Tvärminne, and between CF and Zn for eelpouts from Brunskär, Tvärminne and Kunda, respectively, indicating sub-lethal influences on the condition of the fishes by the metals in question.With the exception of a few liver samples from Finnish (Tvärminne) and Estonian (Muuga) costal waters the safety level for metals in fish as food in the European Union were not exceeded.

Keywords: Heavy metals (Hg, Cd, Zn), condition factor (CF), eelpout (*Zoarces viviparus* L.), Baltic Sea (Archipelago Sea, Gulf of Finland, Gulf of Riga, Kieler Förde).

Introduction

The decline and re-establishment of various populations of eelpout (*Zoarces viviparus* L.) in Finnish, Estonian, and Latvian coastal waters, has recently been summarized [1-4]. With the exception of an extensive study from the Gulf of Riga [5] and some preliminary data from Tvärminne [6], data regarding concentrations of harmful substances (heavy metals), from eelpouts in the Baltic Sea, previous to their decline, are lacking. This might seen astonishing, given the recommendations of the Baltic Marine Environment Protection Commission (HELCOM) to use eelpouts, or viviparous blennies, for environmental monitoring in the Baltic Sea [7] due to the great suitability of this stationary species [8] to reflect environmental pollution [9-12]. Additionally, the few reports made after the re-establishment of the eelpout populations around the Baltic Sea are rather scarce and incomplete [3-4, 13-20].

Thus the aim of this study is;

a) to present actual results regarding heavy metal concentrations in eelpouts from various parts of the Baltic Sea; the Archipelago Sea, Gulf of Finland, Gulf of Riga and the Kieler Förde,

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b) to determine significant conformities or distinctions between the sampling areas,
c) to study possible correlations between the levels of metal contamination and the condition of the investigated fish.

Material and Methods

Sampling was concentrated in the season after spawning (autumn) but prior to birth (January-February), e.g. the period when food intake is active, and the gonads (testes and ovaries) are still developing.

The eelpouts were caught by either trap net fishing (Archipelago Sea, Gulf of Riga, Kieler Förde) or by gillnets and trawling (Gulf of Finland, both sides) Fig. 1.

All fish were measured (total length cm; TL), and weighed (total weight g; TW) fresh prior to frozen storage (-18°C), and further investigations. In the laboratory interior organs (liver, bile, spleen, gonads, alimentary canal, and kidneys) were removed from the nearly thawed fish, after which carefully cut portions of muscle tissue from the left dorsal part of the fish were weighed prior to preparation for analysis. Observations on severe malformations, visible diseases, macroscopic parasites, and food organisms completed the examinations.

The calculated mean length (TL), weight (TW), condition factor (CF), and number of investigated fish (N) from the various sampling stations are presented in Table 1. The CF was calculated for all the fish according to the formula: $CF = 100 \times TW / (TL)^3$ [21]. As the eelpouts were not aged the material was divided into three size groups; 1= 15–19.9 TL, 2 = 20–25.9 TL, and 3 > 26 TL.

Mercury (Hg) was analyzed according to the cold vapor atomic spectro-photometric method (CVAAS) [22] using the Coleman Mercury Analyzer System (MAS-50B). The results of the mercury analysis are all expressed in $mg \cdot kg^{-1}$, fresh weight (f wt).

Cadmium (Cd), and zink (Zn), were both analyzed according to atomic absorption spectrometry (AAS) using the Varian SpectrAA-400 with acetylene flame (FAAS) for Zn, and equipped with a graphite furnace GTA-96 (ETAAS) for Cd [4].

The results for Cd and Zn are primarily given in $mg \cdot kg^{-1}$, dry weight (d wt), but for comparisons the means also were transformed into $mg \cdot kg^{-1}$ f wt using calculated conversion factors (0.20 for muscle tissue, and 0.35 for liver).

All samples were analyzed in duplicate, and accuracy was assessed using blanks (5 per each sequence of 40 samples), and reference materials; CRM-422 cod muscle [23], for which the certified value compared to the obtained were; Hg = 0.559, SD 0.016 and 0.55, SD 0.035 (= recovery 93.4% and relative error ± 6.4%), Cd = 0.017, SD 0.002 and 0.018, SD 0.003 (= recovery 105.9% and relative error ±1.2%), and Zn = 19.6, SD 0.5 and 20.8, SD 1.5 (= recovery 106.1% and relative error ±7.2%), $mg \cdot kg^{-1}$ f wt, respectively.

The homogeneity of the eelpout material was tested from each locality separately by the Shapiro-Wilk (W)/ rankit plot test for normality, by the Pearson (P-test) or Spearman rank (Sr-test) tests for correlations, and by the two-sample (ts-test) t-test or the Wilcoxon rank (Wrs-test) sum test for differences between the sexes (♂♂ ♀♀), sampling stations, and size groups [1-3], respectively.

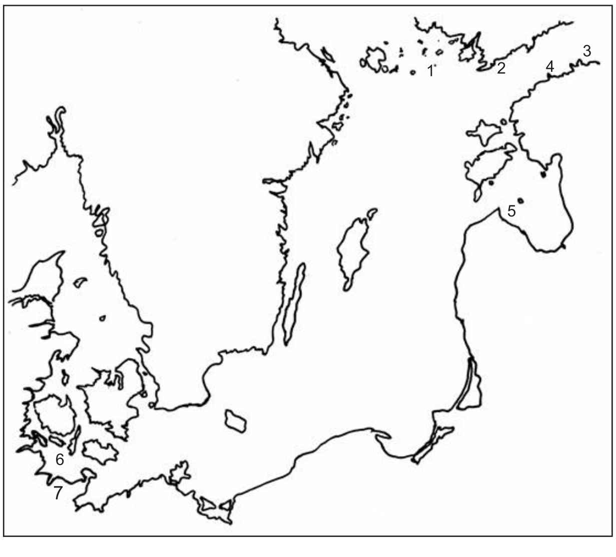

Fig. 1 Sampling stations in the Baltic Sea; 1 = Brunskär (Archipelago Sea), 2 = Tvärminne, 3 = Kunda, 4 = Muuga (Gulf of Finland), 5 = Roja (Gulf of Riga), 6 = Laboe, 7 = Schwentine (Kieler Förde).

Results

The calculated means of TL, TW, and CF for the whole studied eelpout material (N = 145) are presented in Table 1. The corresponding mean values of the concentrations of Hg, Cd and Zn in muscle tissue (M), liver (L), including the ratio M/L for the metals are presented in Tables 2-4.

Table 1. Means and standard deviations (SD) for total length, cm (TL), total weight (g) (TW), condition factor (CF), of eelpouts from Brunskär (Archipelago Sea), Tvärminne, Kunda, Muuga (Gulf of Finland), Roja (Gulf of Riga), Laboe, Schwentine (Kieler Förde), Baltic Sea.

LOCALITY	TL (SD)	TW (SD)	CF (SD)	N
Brunskär	21.0 (2.2)	35.0 (13.1)	0.37 (0.06)	25
Tvärminne	19.4 (2.6)	30.3 (11.5)	0.40 (0.05)	36
Kunda	19.2 (1.9)	29.8 (10.3)	0.40 (0.04)	15
Muuga	21.7 (2.3)	44.9 (15.1)	0.43 (0.05)	15
Roja	20.7 (2.4)	40.1 (17.6)	0.43 (0.05)	12
Laboe	27.8 (3.7)	106.2 (44.3)	0.48 (0.05)	21
Schwentine	25.6 (4.0)	94.1 (39.4)	0.49 (0.08)	21

According to the calculated means of TL, the eelpouts from Brunskär, Tvärminne, Kunda, Muuga and Roja, mainly are included in size group 2, meanwhile the eelpouts from the Kieler Förde partly also are included in size group 3.

Statistically significant differences for TL between the sexes were found only for the eelpouts from Brunskär (p = 0.0222, ts-test), and Schwentine (p = 0.0117, Wrs-test), with females being bigger than males.

For CF the differences between some of the sampling stations are distinct and considerable. Thus the eelpouts may be divided into two separate groups, a low value CF group, consisting of the samples from Brunskär, Tvärminne, Kunda, Muuga, Roja, and a high value CF group, consisting of both samples from the Kieler Förde (Laboe and Schwentine).

Statistically significant differences between the sexes were calculated for CF for the eelpouts from Brunskär (p = 0.0130, Wrs-test), Tvärminne (p = 0.0066, ts-test), and Muuga (p = 0.0223, ts-test).

Mercury (Hg)

The results for Hg are presented in Table 2.

The main decreasing order of Hg in the eelpouts from all sampling stations was HgM – HgL. Only in a few cases were the values for HgL higher than HgM (eg. 2 of 25 at Brunskär, 2 of 36 at Tvärminne, none at Kunda and Muuga, 1 of 12 at Roja, 1 of 21 at Laboe, and 4 of 21 at Schwentine). In several cases the concentrations of Hg in both muscle tissue and liver were higher in male fishes than females, but without statistical significance.

The highest values for HgM and HgL were calculated for the eelpouts from Schwentine, for which the ratio HgM/HgL was the lowest, in contrast to the high value for CF.

Statistically significant negative correlations were calculated between CF and HgM (Schwentine; r = – 0.52, p = 0.0213, P-test), CF and HgL (Tvärminne; r = – 0.63, p = 0.004, Sr-test, Schwentine; r = – 0.64, p = 0.0078, P-test).

Cadmium (Cd)

The results for Cd are presented in Table 3.

The decreasing order of Cd in the eelpouts from all sampling stations was CdL – CdM.

The highest mean values for CdL were calculated for the eelpouts from Muuga, Kunda, Brunskär, and the lowest for the eelpouts from the Kieler Förde (both sampling stations).

A statistically significant negative correlation was calculated between CF and CdM for the sample from Brunskär (r = – 0.61, p = 0.0069, Sr-test).

Statistically significant differences between the sexes were calculated only for CdL of the eelpouts from Roja (p = 0.0455 Wrs-test), male fishes having higher concentrations than female fishes.

The highest mean values for CdM were calculated for the eelpouts sampled from Tvärminne and Kunda, respectively, and the two lowest means for the eelpouts from both sampling stations at the Kieler Förde.

Zinc (Zn)

The results for Zn are presented in Table 4.

At all sampling stations the decreasing order of Zn in the eelpouts was ZnL – ZnM. The highest mean values of ZnL were calculated for the eelpouts from Kunda and Muuga, and the lowest from Roja. The highest mean values of ZnM were likewise calculated for the eelpouts from Kunda and Muuga, but the lowest mean values of ZnM were calculated for the eelpouts from Schwentine and Tvärminne.

Statistically significant differences between the sexes were calculated only for the samples from Tvärminne (ZnM p = 0.0019, ZnL p = 0.0016), males from Tvärminne having higher values for ZnM than females.

Statistically significant negative correlations were calculated between CF and ZnM for the samples from Brunskär (r = – 0.54, p = 0.0238, Sr-test), Tvärminne (r = – 0.50, p = 0.0112, Pearson), Kunda (r = – 0.54, p = 0.048, Sr-test), and a close to significant correlation for the sample from Roja (r = – 0.51).

Table 2. Condititon factor (CF) and concentrations of mercury (Hg) in mg.kg^{-1} f wt (fresh weight) in muscle tissue (HgM), liver (HgL), and the ratio of HgM/HgL of eelpouts (*Zoarces viviparus* L.) from Brunskär (Archipelago Sea), Tvärminne, Kunda, Muuga (Gulf of Finland), Roja (Gulf of Riga), Laboe, Schwentine (Kieler Förde), Baltic Sea.

LOCALITY	CF (SD)	HgM (SD)	HgL (SD)	HgM/HgL	N
Brunskär	0.37 (0.06)	0.09 (0.03)	0.05 (0.02)	2.1	25
Tvärminne	0.40 (0.05)	0.06 (0.03)	0.03 (0.02)	2.2	36
Kunda	0.40 (0.03)	0.10 (0.03)	0.05 (0.01)	1.8	15
Muuga	0.43 (0.05)	0.09 (0.03)	0.05 (0.01)	1.7	15
Roja	0.43 (0.05)	0.04 (0.02)	0.02 (0.01)	2.1	12
Laboe	0.48 (0.05)	0.07 (0.03)	0.04 (0.02)	1.8	21
Schwentine	0.49 (0.08)	0.11 (0.05)	0.09 (0.05)	1.5	21

Table 3. Condition factors (CF) and concentrations of cadmium (Cd) in mg.kg^{-1} d wt (dry weight) in muscle tissue (CdM), liver (CdL), and the ratio of CdM/CdL of eelpouts (*Zoarces viviparus* L.) from Brunskär (Archipelago Sea), Tvärminne, Kunda, Muuga (Gulf of Finland), Roja (Gulf of Riga), Laboe, Schwentine (Kieler Förde), Baltic Sea.

LOCALITY	CF (SD)	CdM (SD)	CdL (SD)	CdM/CdL	N
Brunskär	0.37 (0.06)	0.04 (0.06)	1.14 (1.62)	0.04	25
Tvärminne	0.40 (0.05)	0.05 (0.09)	0.47 (0.52)	0.20	36
Kunda	0.40 (0.03)	0.05 (0.03)	1.46 (0.38)	0.04	15
Muuga	0.43 (0.05)	0.03 (0.02)	2.09 (0.65)	0.01	15
Roja	0.43 (0.05)	0.01 (0.01)	0.26 (0.06)	0.05	12
Laboe	0.48 (0.05)	0.02 (0.04)	0.18 (0.14)	0.16	21
Schwentine	0.49 (0.08)	0.02 (0.02)	0.14 (0.07)	0.17	21

Table 4. Condition factors (CF) and concentrations of zink (Zn) in mg.kg^{-1} d wt (dry weight) in muscle tissue (ZnM), liver (ZnL), and the ratio ZnM/ZnL of eelpouts (*Zoarces viviparus* L.) from Brunskär (Archipelago Sea), Tvärminne, Kunda, Muuga (Gulf of Finland), Roja (Gulf of Riga), Laboe, Schwentine (Kieler Förde), Baltic Sea.

LOCALITY	CF (SD)	ZnM (SD)	ZnL (SD)	ZnM/ZnL	N
Brunskär	0.37 (0.06)	73 (19)	90 (32)	0.88	25
Tvärminne	0.40 (0.05)	48 (11)	99 (31)	0.49	36
Kunda	0.40 (0.04)	101 (32)	148 (21)	0.72	15
Muuga	0.43 (0.05)	96 (26)	145 (30)	0.66	15
Roja	0.43 (0.05)	56 (12)	62 (23)	0.99	12
Laboe	0.48 (0.05)	55 (12)	94 (20)	0.62	21
Schwentine	0.49 (0.08)	47 (7)	69 (19)	0.75	21

Fresh Weight

When calculated to fresh weight the range of the obtained mean values are: for Cd; CdM 0.002 – 0.01, CdL 0.049 – 0.732 (Table 3.), for Zn; ZnM 9.4 – 20.2, ZnL 24.7 – 51.8 mg·kg^{-1} f wt (Table 4).

Food Items of Eelpout

Remains of mussels, e.g. shells of *Mytilus edulis* L. and *Macoma balthica* L., were observed more frequently than remains of crustaceans, e.g. *Monoporeia-Pontoporeia* spp, *Saduria entomon* L., in the alimentary canals of the eelpouts from Brunskär, Tvärminne, Kunda, and Muuga compared to the findings from Roja. Remains of the crustacean *Mysis* sp, undeterminated ostracods, and copepods were, however, frequently observed at all sampling stations in the Gulf of Finland. Polychaets, as *Nereis* sp, were regularly observed at both stations in the Kieler Förde.

Fishes (small eelpouts and gobies *Gobius* sp), and fish eggs (mainly of *Clupea* sp) were consumed frequently by the eelpouts from the sampling stations in the Archipelago Sea and the Gulf of Finland.

The corresponding metal concentrations in some food organisms of eelpout from various parts of the Baltic Sea (Tvärminne, Kunda, Muuga, Tallinn Bay, Roja, Mesgars, Laboe and inner parts of the Kieler Förde) are presented in Table 5.

The data for the mussels *Mytilus* and *Macoma* origin from analyzes made of only the soft tissue, meanwhile the crustacean *Saduria* and the teleost *Gobius*, are both analyzed "in toto." As for the eelpouts (Table 2), only the values for Hg are in f wt, all other values are presented in d wt.

Diseases and Parasites

Malformed livers with tumors were observed in eelpouts from Tvärminne (30%), Schwentine (17%), and Roja (9%). Cysts of the microsporide *Glugea anomala* (MONIETZ 1887) were observed in the liver of eelpouts from Tvärminne (20%), Laboe (10.5%), and Schwentine (10%).

The eelpout nematode *Hysteriothylacium aduncum* (RUDOLPHI, 1802) was only occassionally observed in the intestines of the eelpouts from Laboe (5%), Kunda (6%), Brunskär (9%), Tvärminne (16%), Roja (18%). Additionally the nematode *Cucullanus* sp was observed in the intestines of eelpouts only from the Kieler Förde; Schwentine (9%) and Laboe (5%).

Discussion

The homogeneity of the studied material may be questioned as the calculated means of TL for the eelpout samples from Brunskär, Tvärminne, Kunda, Muuga, and Roja correspond to the means for Baltic populations of eelpouts of age groups 5–7, but the means of both samples from the Kieler Förde (Laboe and Schwentine) mainly correspond to the mean TL of age group 8 [36, M. Vetemaa pers. comm. 25.2.1997, E. Urtans pers. comm. 15.10.1998]. On the other hand, of the condition factor (CF), and the metals (Hg, Cd, Zn) observed, the concentrations of HgM (Schwentine), CdL, ZnL (Tvärminne) correlate positively at high significance level with TL, indicating increase by age, as shown for Hg for other species already since the 1960s [32-33], and for eelpouts in the 1980s [9-10].

Additionally, statistically significant differences between the sexes regarding TL were calculated only for the samples from Brunskär and Schwentine (females being larger than the males), whereas the studied eelpout material, with the distinction of the concentrations of Hg, is regarded otherwise comparable.

Hg

The statistically significant negative correlations between HgM and CF (Schwentine), and HgL and CF (Tvärminne, Schwentine), require more attention in future studies, as equivalent correlations have also been previously calculated for several other fish species from Finnish, Estonian, and German coastal waters [16, 20, 34]. The percentage of explained variation in the concentration of Hg, however, ranged between 20 and 40%. The correlation was negative for all other sampling stations, although weak and not always significant.

The statistically significant positive correlations between HgM and HgL (Brunskär, Tvärminne, Laboe and Schwentine) mainly reflect the distribution of Hg within the fish. The low mean values of the ratio HgM/HgL for the eelpouts sampled from Schwentine, however, do not support this assumption, as they merely indicate an equalization of Hg between muscle tissue and liver.

Along with the positive correlations of Hg between the studied muscle tissues and livers, the ratio HgM/HgL, therefore, mainly describes the equal distribution of Hg within the fish.

Cd

The high mean values of CdL and CdM (Muuga, Kunda, Brunskär, Tvärminne), compared to the low values from the Kieler Förde (both sampling stations), indicate a contamination of Cd in the eelpouts from the former group of sampling stations. This perception may, with the exception of Tvärminne, partly be supported by the low mean values of the ratio CdM/CdL for the eelpouts from Muuga, Kunda, Brunskär, and Roja, in contrast to the higher values for the eelpouts from the Kieler Förde (both sampling stations), as they depend on the higher concentrations of Cd in the liver where, besides in the kidneys, Cd mainly is concentrated in fish [35].

The corresponding high mean value of CdL, and the high mean value for the ratio CdM/CdL (Tvärminne), may indicate an acute contamination of Cd in the eelpouts from Tvärminne, in contrast to the otherwise more heav-

Table 5. Mean concentrations of Hg mg.kg^{-1} (**f wt**), Cd, Zn mg.kg^{-1} (d wt) recorded from various food organisms (*Mytilus edulis*, *Macoma balthica*, *Saduria entomon*, *Gobius* sp) of eelpout (*Zoarces viviparus*) from various parts of the Baltic Sea (Tvärminne, Kunda, Muuga, Tallinn, Mesgars, Roja, Laboe, Kieler Bucht and Kieler Förde).

Locus	Hg	Cd	Zn	Source
Mytilus				
Tvärminne	0.03	0.98	90	[24]
Muuga Bay	0.10	4.05		[25]
Roja		1.23	33	[5]
Laboe	1.9*	2.7	690	[26]
Kieler Förde	1.5*	3.2	906	[26]
Macoma				
Tvärminne	0.06	0.64	620	[24]
Kunda Bay		0.91	397	[25]
Tallinn Bay	0.08	2.0*		[27]
Mersgars **		1.42	44	[5]
Kieler Bucht		1.0		[28]
Saduria				
Tvärminne	0.05	0.93	450	[24]
Estonian coast	0.03			[29]
Kunda		1.5*	100*	[30]
Roja		1.23	34	[5]
Gobius sp				
Tvärminne	0.03	0.16	125	[16]

* recalculated [26] or estimated [27, 30] from original data.

** Mersgars, south of Roja, Gulf of Riga.

ily Cd-contaminated (CdL) eelpouts from Muuga and Kunda. This paradox may be explained by the differences of contamination between these sampling stations. Since the late 1950:s the whole area of Tvärminne has been influenced by a continuous discharge of Cd (besides several other metals, as e.g. Fe, Mn, Zn, Cu, Pb, Ni etc), by a neighbouring iron- and steelfactory at Koverhar [24, 36], which may be observed also from both surface sediments and the benthic invertebrate fauna (Table 5.), but at Muuga a new port for the Estonian capital, Tallinn, has been under construction only since the 1990s [37]. Meanwhile, there are no known sources for discharges of Cd, or any other metals, at Brunskär or Kunda.

The low mean values of CF for the eelpouts from Brunskär, Tvärminne, Kunda, and Muuga, thus may be partly explained by the higher mean values of CdL and CdM, in case the factor actually reflects the health condition of the fish. Sub-lethal effects of Cd, e.g. growth reduction, reproduction inhibition, etc., are pronounced at lower salinities [38], which is true for Brunskär, Tvärminne, Kunda, and Muuga, in contrast to the more saline environment of the Kieler Förde. For the statistically significant negative correlations between CF vs. CdM (Brunskär and the total material, respectively), the percentage of explained variance in the concentration of Cd ranged between 5 and 16% respectively.

The positive significant correlations between CdM and CdL (Muuga), may indicate an even distribution of Cd in the fish (as for Hg).

Zn

As for Cd, the highest mean values for ZnM and ZnL were both calculated for the eelpouts from Kunda and Muuga, indicating a contamination of Zn, compared to the eelpouts from the other sampling stations. This assumption is supported by the findings from the benthic invertebrate fauna of the corresponding sampling stations (Table 5).

Significant negative correlations between CF and ZnM were calculated for the eelpouts from Brunskär, Tvärminne, and Kunda, (and close to significant at Roja), indicating some relationship between Zn and CF. A similar correlation was, however, not obtained for the eelpouts from the Kieler Förde, for which the mean of CF values were notably high and the concentration of Zn in all organs and tissues among the lowest calculated. The percentage of explained variance in the concentration of ZnM vs., CF ranged between 25 and 29% for the samples from Brunskär and Tvärminne. For total material the range is 8–10%.

Significant positive correlations between ZnM and ZnL were found only for the eelpouts from Tvärminne, indicating a balanced distribution of Zn in the fishes, as for Hg and Cd. The concentrations of ZnL in all cases exceeded the concentrations of ZnM, in contrast to the opposite statement regarding eelpouts from Darsser Ort (Southern Baltic Sea), and the Bays of Meldorf and Jade (North Sea), respectively [14].

Tough not significant for the whole studied material, neither for all sampling stations separately, the concentrations of some metals, (as CdL at Roja, ZnM at Tvärminne) were significantly higher in male fishes than females. Bearing in mind the significant differences between the sexes for CF at Brunskär, Tvärminne and Muuga, female fish having higher values than males, there may be some sexual related differences in metal affection, as stressed previously [39].

The obtained mean concentrations of Hg of all investigated eelpouts in both muscle tissue and liver exceeded the level of 0.03 $mg \cdot kg^{-1}$ f wt, considered as "background level" for Baltic Sea fish [40].

For Cd the accepted "natural" level" for marine fish is 0.00x $mg \cdot kg^{-1}$ f.wt, but in muscle tissue of Baltic fish it is considered even as high as < 0.02 $mg \cdot kg^{-1}$ f wt [40], which corresponds to < 0.10 $mg \cdot kg^{-1}$ d wt for muscle tissue, a level that was not found in any of the eelpouts investigated. Instead the high mean values of CdL of the eelpouts from Muuga, Kunda, and Tvärminne (corresponding to 0.73 – 0.17 $mg \cdot kg^{-1}$ f wt) indicate contamination of the environment in contrast to the lower values for the eelpouts from Laboe, and Schwentine (0.06 – 0.05 $mg \cdot kg^{-1}$ f wt).

Compared to the preliminary values from Tvärminne in the 1970-1980s; CdM ca 0.14 and CdL ca 2.2 $mg \cdot kg^{-1}$ d wt [6], the obtained present values are considerably lower.

For Cd the obtained results from Roja were of the same order of magnitude as previously (1977-80) presented results [5], but for Zn the present values were considerably higher than a decade earlier [5]. Some corresponding figures for Cd and Zn are also reported for eelpouts from the Polish coast of the southern Baltic Sea; CdM; 0.01-0.20, CdL; 0.01-0.29, ZnM; 14, ZnL; 30, $mg \cdot kg^{-1}$ f wt [13], indicating concentrations of about the same order of magnitude as for eelpouts from the Gulf of Riga.

In eelpouts sampled from the southern coastal waters of the Baltic Sea; Bay of Puck concentrations of HgM obtained were 0.05 $mg \cdot kg^{-1}$ [41], from Darsser Ort the concentrations of HgM were estimated at 0.04 $mg \cdot kg^{-1}$ Hg f wt [14], and from the main inlets to the Baltic Sea; Skagerrak and Öresund the concentrations of HgM ranged between 0.04 to 0.13 $mg \cdot kg^{-1}$ f wt, of CdL between 0.01 to 0.06, and of ZnL between 15 to 30 $mg \cdot kg^{-1}$ f wt, respectively [42], indicating considerably lower concentrations of both Cd and Zn, compared to the results obtained from eelpouts of the northern parts of the Baltic Sea.

Outside the Baltic Sea concentrations of HgM in eelpouts have been recorded from coastal waters in Germany; Meldorf Bay estimated to ca 0.11 and Jade Bay ca 0.09 $mg \cdot kg^{-1}$ f wt, respectively [14]. In the Northerlands; Wadden Sea and the Ems estuary 0.02-0.05 [9], and in Scotland; Firth of Forth 0.07 [10], and Firth of Clyde; 0.05-0.13 $mg \cdot kg^{-1}$ f wt [43] respectively, i.e. they all are of the same order of magnitude, as are the values for eelpouts from various northern parts of the Baltic Sea.

Mussels (e.g. *Mytilus* spp, and *Macoma* spp), are well-known to accumulate heavy metals from their environment [44-45]. And as the digesting tract is the main gate of entrance for heavy metals in fish [46] (and as most of the metal contaminants in the fish origin from the food organisms of the fish [47]), data on metal concentrations of the surrounding waters are regarded as less important than data regarding concentrations of these elements in the corresponding surface bottom sediments and especially in the benthic invertebrate fauna.

From the sampling stations in question actual data are, however, scarce and incomplete, but in the vicinity of Brunskär, in the Archipelago Sea, some recent surface sediment data are available e.g. Cd; 0.2–0.5, Zn; 210–275 mg·kg^{-1} d wt [48]. At Tvärminne corresponding data are Hg; 0.06 [49], Cd; 0.20-1.05, Zn; 100-200 mg·kg^{-1} d wt [24], corresponding well with the combined recent data for surface sediments of the whole Gulf of Finland [50]. In the environment of Tvärminne, these metals mainly originate from the iron- and steel factory at Koverhar [20, 36-37]. Corresponding recent data from surface sediments of the Gulf of Riga are Hg; 0.05-0.16, Cd; 0.21-1.11, Zn; 44-196 mg·kg^{-1} d wt [51], i.e. of the same order of magnitude for Hg, and Cd as from Tvärminne, in contrast to the considerably lower concentrations of Zn. Recent actual data are not known neither from Kunda and Muuga, nor the Kieler Förde. Corresponding figures, however, for the Bight of Kiel (Kieler Bucht), origin from the 1970s [52], outside the Kieler Förde regarding Cd and Zn of the same order of magnitude as are the present figures for Tvärminne.

The metal concentrations in the food organisms of the eelpouts from Tvärminne, Kunda and Muuga correspond well to the concentrations of the eelpouts from the same areas, in glaring contrast to the findings from the Kieler Förde, for which area food organisms of the actual eelpouts were not systematically determined. As only a few remains of mainly polychaets (*Nereis* sp) were identified here in contrast to the clearly dominating mussels (*M. balthica* and *M. edulis*) and small fishes (mainly *Gobius* sp) in the food of eelpouts from Tvärminne [3], only an assumption of the importance of these organisms can be made. If the food of the eelpouts in the Kieler Förde consists of mainly polychaets (e.g. *Nereis* sp, which is known for a weaker bioaccumulation of heavy metals than *Mytilus* sp [53]), then this contradictory situation may be explained in the same terms as for flounder (*Platichthys flesus* L.) from Tvärminne vs. the Kieler Förde [34], leading to the conclusion that mussels are not of the same importance as food for the fish in the Kieler Förde as they are for the same species around the Åland Islands, the Archipelago Sea and the Gulf of Finland. Thus the concentrations of heavy metals are lower in eelpout (and flounder) from the Firth of Kieler Förde compared to the northern parts of the Baltic Sea. This assumption may additionally partly be supported by the fact that the uptake of Cd in fish is increased by decreased salinity conditions [54], as is the situation in the Gulf of Finland compared to the Kieler Förde.

Conclusions

Consequently, eelpouts are not reliable bio-indicator organisms for environmental monitoring regarding heavy metals in situations of comparisons between areas where both food habits of the fishes and the conditions of salinity in the environment differ remarkably. Instead, the stationary eelpouts reflect the environmental state of their local environment, as they intensively concentrate the harmful substances of their food organisms.

The obtained differences between the sampling stations regarding both malformed livers with tumors and parasitic infestations showed no correlations to the condition factors. Instead, the observed differences regarding the food organisms of the eelpouts may contribute to explain the parasitic infestations, meanwhile the explanation for the prevalence of the liver tumors remains open.

As the distinctions between the two value groups; low metal concentrations and high CF vs. high metal concentrations and low CF, are not related to size (age), they instead may be related to the sampling sites and contribute to a description of the state of condition of the corresponding eelpouts.

Whether the condition factor, CF, actually may be useful in indicating sub-lethal effects of harmful substances upon fishes or not, remains unsolved. Specific additional studies are needed.

The concentrations of the two toxic metals, mercury and cadmium, in the edible parts (e.g. muscle tissue) of the investigated eelpouts did not exceed the stipulated safety levels for fish as human food, according to regulations by government officials, in the European Union (including Finland, Estonia, Latvia, and Germany); 0.5 mg·kg^{-1} f wt for mercury and 0.05 mg·kg^{-1} f wt for cadmium [55].

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