Meddelelser om Grønland

Zinc, cadmium, mercury and selenium in Greenland fish

Frank Riget, Rune Dietz and Poul Johansen

Bioscience

48 · 1997

Zinc, cadmium, mercury and selenium in Greenland fish

Frank Riget, Rune Dietz and Poul Johansen

MEDDELELSER OM GRØNLAND, BIOSCIENCE 48 · 1997

Meddelelser om Grønland

The series *Meddelelser om Grønland* was started in 1879 and has since then published results from all fields of research in Greenland. In 1979 it was split into three separate series:

Geoscience
Bioscience
Man & Society

The series should be registered as *Meddelelser om Grønland, Bioscience (Geoscience, Man & Society)* followed by the number of the paper. Example: *Meddr Grønland, Biosci. 1*, 1979.

The new series are issued by Kommissionen for Videnskabelige Undersøgelser i Grønland (The Commission for Scientific Research in Greenland).

Correspondence

All correspondence and manuscripts should be sent to:

The Secretary
Kommissionen for Videnskabelige Undersøgelser i Grønland
Danish Polar Center
Strandgade 100 H
DK-1401 Copenhagen K

Questions concerning subscription to all three series should be directed to the agent.

Agent

Geografforlaget, Fruerhøjvej 43, DK-5464 Brenderup. Tlf. +45 63 44 16 83. Fax: +45 63 44 16 97
e-mail:go@geografforlaget.dk

Meddelelser om Grønland, Bioscience

Meddelelser om Grønland, Bioscience invites papers that contribute significantly to studies of flora and fauna in Greenland and of ecological problems pertaining to all Greenland environments. Papers primarily concerned with other areas in the Arctic or Atlantic region may be accepted, if the work actually covers Greenland or is of direct importance to continued research in Greenland. Papers dealing with environmental problems and other borderline studies may be referred to any of the series *Geoscience, Bioscience,* or *Man & Society* according to emphasis and editorial policy.

Scientific editor – Zoology

G. Høpner Petersen, Zoological Museum, Universitetsparken 15, DK-2100 Copenhagen Ø. Telephone +45 35 32 10 82

Scientific editor – Botany

Gert Steen Mogensen, Botanical Museum, Gothersgade 130, DK-1123 Copenhagen K, Telephone +45 35 32 22 00

This volume is edited by G. Høpner Petersen

Instructions to authors. See page 3 of cover.

Accepted: August, 1997
ISSN 0106-1054
ISBN 87-90369-17-3

Contents

Zinc, cadmium, mercury and selenium in Greenland fish

FRANK RIGET, RUNE DIETZ AND POUL JOHANSEN

Riget F, Dietz R. & Johansen P. 1997. Zinc, cadmium and selinium in Greenland fish. – Meddelelser om Grønland, Bioscience 48, 29 pp. Copenhagen 1997.12.20.

Concentrations of zinc, cadmium, mercury and selenium in muscle, liver, kidney, spleen and bone in marine fish from Greenland are presented. Tissue differences are apparent for all elements. Except for mercury, higher concentrations are found in liver and kidney than in muscle. In general, the mercury concentration is positively correlated with fish length while selenium concentration shows a negative correlation. No such correlations are evident for cadmium and zinc. Significant differences in heavy metals levels are often found between geographic locations. Although there is tendency for higher concentrations of cadmium, mercury and selenium in fish from North West Greenland compared to fish from other areas of Greenland, the geographical variation is not consistent. The results indicate that high natural year to year variations in element levels (up to 3 times) occur in fish. Mercury and cadmium concentrations show relatively strong inter-organ correlations, whereas this is not the case for selenium and zinc. Zinc and cadmium show a high degree of association in all tissues.

Key words: Marine fish, Arctic, Greenland, heavy metals, Zn, Cd, Hg, Se.

Frank Riget, Rune Dietz and Poul Johansen, Department of Arctic Environment, National Environmental Research Institute, Tagensvej 135, 4th floor, DK-2200 Copenhagen N, Denmark

Introduction

Heavy metals in Greenland biota have mainly been reported for marine mammals and seabirds. However, the growing importance of fish as a human food source and an interest in understanding the accumulation of metals as well as other contaminants in higher trophic levels has extended the focus towards lower parts of the Arctic food chains. This article contributes data for a large number of fish species from West Greenland, and to a lesser extent East Greenland. The fish have been sampled in areas not influenced by point sources, and the levels may be regarded as baseline levels. The aim of this study is to present levels of selected elements (zinc, cadmium, mercury and selenium) and to provide information on species differences, size related differences, as well as year to year and geographical variation and trends.

The data presented in this article were collected by the Department of Arctic Environment (DAE) of National Environmental Research Institute (NERI) in connection with projects conducted since 1985. Zinc, cadmium and lead have been studied in a number of marine species to monitor the environmental impact of mining in Greenland since the early 1970'ies. The results of these studies have been published previously (Johansen *et al.* 1985; Johansen *et al.* 1991), mainly with the aim of discussing the accumulation of metals in marine organisms as result of pollution brought about by mining activities. In addition, a three year scientific programme was carried out at DAE between 1985 and 1988 to evaluate heavy metal levels in the Greenland marine environment as a whole. Results relating to levels in marine mammals and seabirds have been published (e.g. Nielsen & Dietz 1989, 1990; Dietz *et al.* 1990; Hansen *et al.* 1990; Paludan-Müller *et al.* 1993; Dietz *et al.* 1995). Baseline data on fish from Greenland waters are included in a review by Dietz *et al.* (1996) together with species from other trophic levels, however, a more detailed presentation and analysis of data is provided in the present study.

Materials and methods

In the data presentation in Appendix 1-4, a fish sample is represented by both locality and year of sampling. Figure 1 shows the localities mentioned in the text. In addition information is given on average fish size and sample size. Samples from 21 fish species from 10 different localities are included (Trivial and latin names are given in Appendix 1-4). Not all samples of fish have been analysed for the same elements. Most of the analyses were carried out

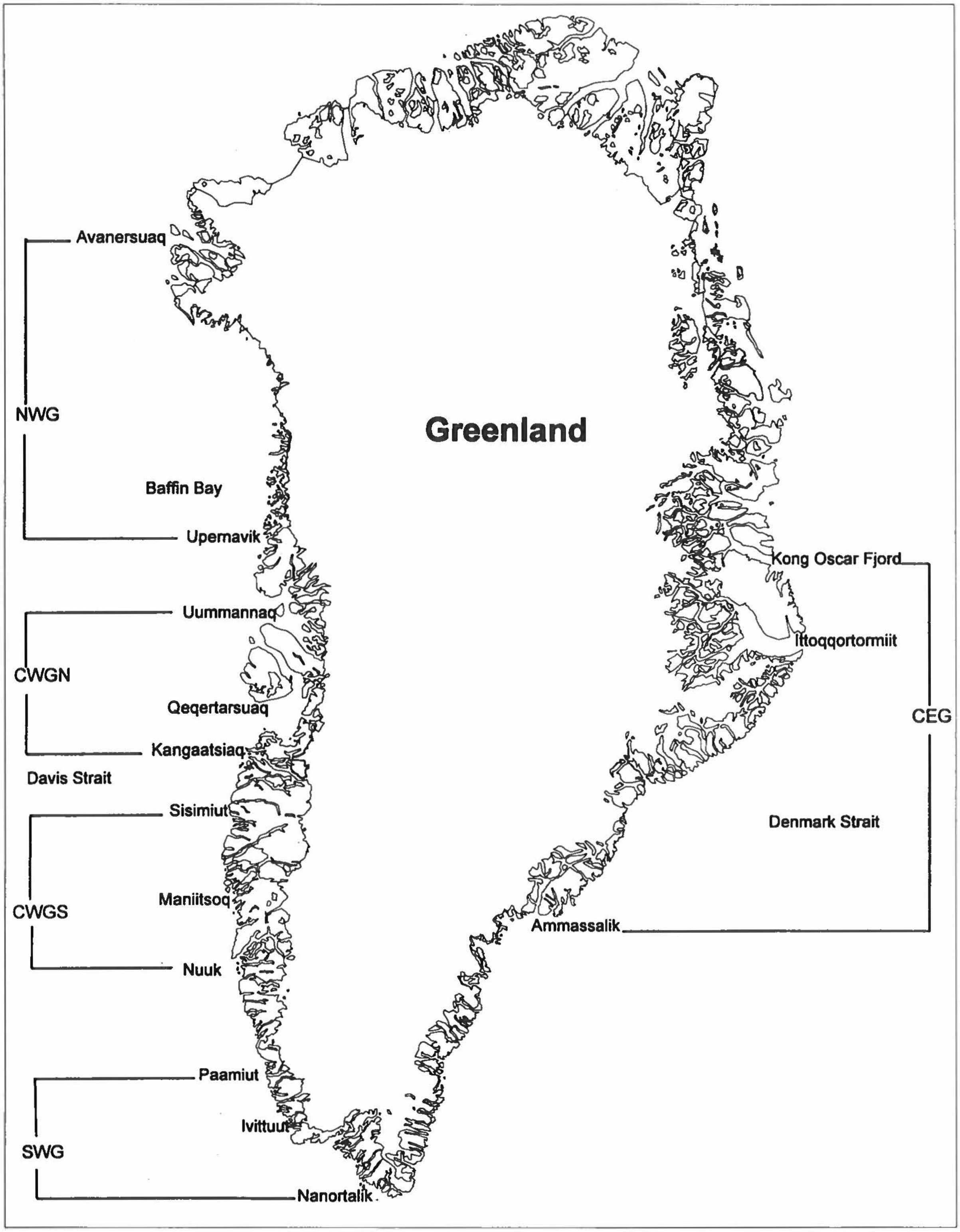

Fig. 1
Map of Greenland showing area definition used in the text. Abbreviations used as follows : North West Greenland (NWG), Central West Greenland northern part (CWGN), Central West Greenland southern part (CWGS), South West Greenland (SWG) and Central East Greenland (CEG).

on cadmium and zinc content. The number of tissues analysed also varied between samples. In most cases fish muscle and liver were analysed. In some cases kidney, bone and bile analyses were also carried out. A few analyses were performed on spleen. Capelin were analysed as whole fish. Tissues or hole fish were analysed individually, i.e. no pooling. Data were omitted where sample size was below 3 individuals.

In most cases sampling was carried out on board a research vessel using trawls, long lines or nets. Small individuals were registered and stored whole in polyethylene bags. Large individuals were dissected on board. Samples were stored in a deep-freezer shortly after sampling and dissection. During shipment from Greenland to storage in Copenhagen the samples were maintained at -20°C.

Before analysis tissue samples were lightly thawed. The surface tissue layer was cut away to minimize potential contamination and to avoid the inclusion of dehydrated tissue. Stainless steel scalpels, polyethylene gloves and polyethylene cutting boards were used.

Approximately 0.5 g of wet tissue was transferred to a tared teflon liner of a Berghof stainless seell bomb. After the addition of 4 ml of 65% HNO_3 (Merck Suprapur) the bombs were closed and incubated for four hours at 120°-150° C. After cooling, the digests were transferred to 50 ml screw-cap polyethylene bottles and the volume adjusted to approximately 26 ml using metal-free, deionized water (Millipore). For all further dilutions approximately 8% HNO_3 was used.

All zinc analyses were carried out by flame AAS (Perkin-Elmer 3030). Samples were screened for cadmium using the same technique, however the graphite furnace technique (Perkin-Elmer 3030 with Zeeman background correction) was used for final analyses of samples with < 2.5 µg cadmium/g. The latter technique was also used for selenium analyses. The mercury analyses were performed by hydride generation including the amalgam technique. One millilitre of the digest was transferred to the reaction vessel of a Perken Elmer MHS-20 mercury hydride generation system. Stannochloride solution was added, and the mercury vapor formed was purged by argon and collected on a gold net. Mercury was quantified by heating the gold net to 900° C and purging the mercury to quartz absorption cell replacing the burner in a Perkin Elmer 3030 flame AAS. Instrument settings, reaction times, and reagent concentrations were those recommended by the instrument manufacturer. Detection limits applying to the analytical procedures were, 0.015 µg/g for cadmium, 0.005 µg/g for mercury and 0.20 µg/g for selenium (wet weight basis). The detection limit is defined as the concentration calculated on the basis of 3 times the standard deviation of the blind value. None of the zinc analyses were below or close to the detection limit.

Analytical quality was regularly checked by repeating analyses and by the frequent use of various reference standards, especially Tort-1 (lobster hepatopancreas) supplied by the National Research Council Canada (Marine Analytical Chemistry Standards Program) and the dried tuna internal standard of the National Food Agency of Denmark. The laboratory participates in the international intercalibration exercises conducted by the International Council for the Exploration of the Sea (ICES) and by the Dept. of Fisheries & Oceans, Winnipeg, Canada.

All the results are reported as µg/g (ppm) wet weight. General recalculation factors from wet to dry weight basis for fish have been computed for comparative purposes as follows: muscle – 5.1, liver – 2.6, kidney – 5.4, bone – 3.1, spleen – 5.2 and bile – 32.

Although some data sets permitted the use of parametric tests (at least after logarithmic transformation) non-parametric tests have been used in order to standardize data treatment. Length dependency of element concentrations were analysed by Spearman rank correlation coefficients for each species, element and tissue combinations. Correlation studies were only carried out if sample size was equal or greater than 5 and only where at least 80% of the values were above detection limits. The sign test was used to test for surpluses of either positive or negative correlations. For $N<25$ a 2-tailed sign test was used, for $N>25$ the normal approximation of a bionomial distribution was used. Comparisons among geographical regions were based on the Kruskall-Wallis test. Calculations were carried out using the statistical software system SAS (SAS, 1990). For statistical analyses values below the detection limit were replaced by half the value of the detection limit.

Results and discussion

Element levels in Greenland marine fish

The analytical results in the present study are summarized in Appendices 1-4. Different statistics are presented in order to compare with results from other studies, where data has been presented differently.

Zinc

In muscle the mean zinc concentration ranges from 2.7 µg/g in silver rockling to 15 µg/g in twohorn sculpin. In liver the level is about four to five times higher, ranging from 14 µg/g in Arctic cod to 69 µg/g in Arctic staghorn sculpin (Fig. 2). In kidney the mean zinc concentration ranges from 19 µg/g in Greenland seasnail to 29 µg/g in Atlantic cod, and in spleen the level is similar, ranging from 14 µg/g in shorthorn sculpin to 30 µg/g in *Lycodes eudipleurostichus*. Zinc in bone is reported for spotted wolffish with levels ranging from 18 to 24 µg/g.

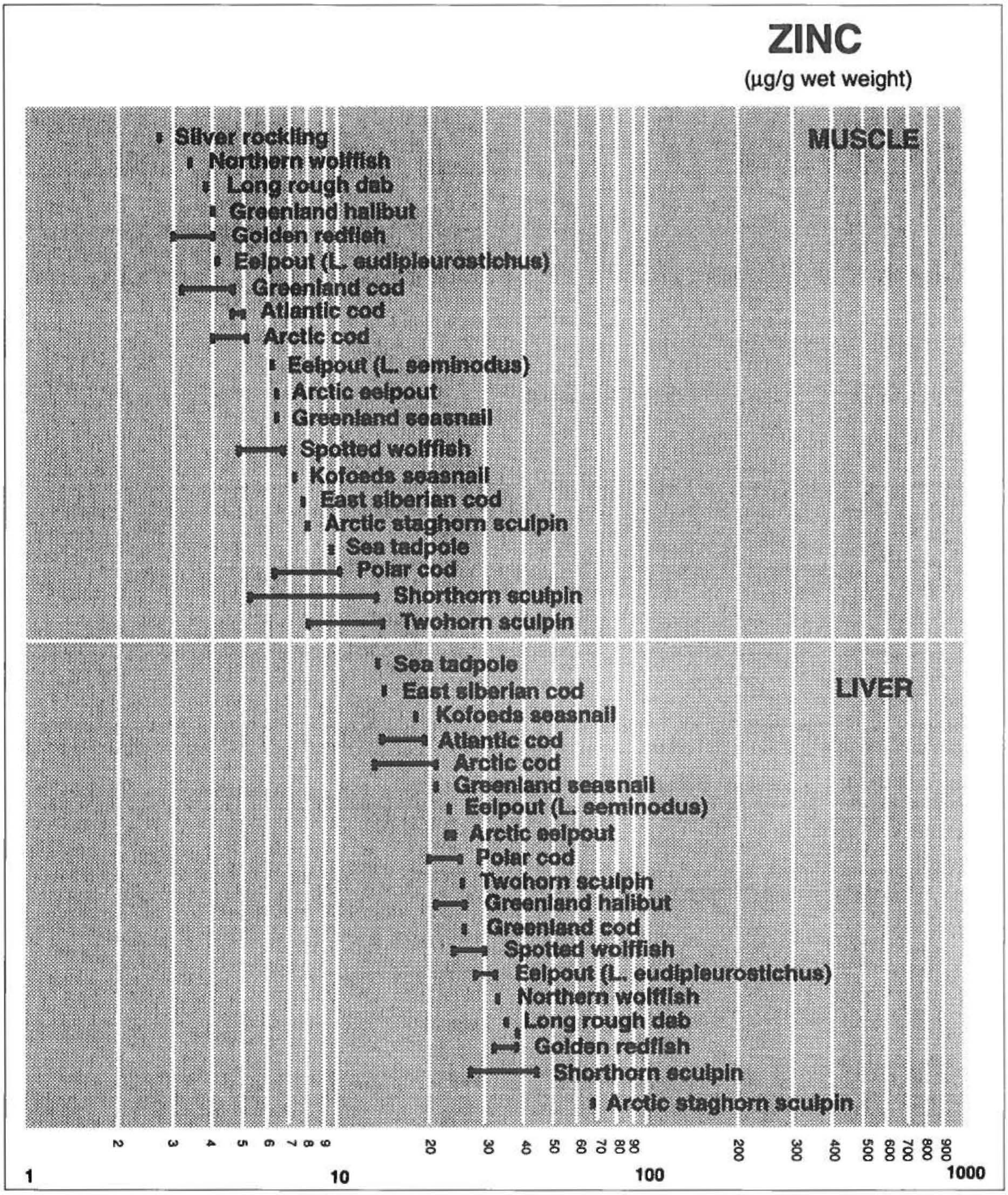

Fig. 2
Ranges of mean zinc in muscle and liver tissue of Greenland fish (µg/g wet weight).

Cadmium

In muscle the cadmium concentration for most fish species is below the detection limit (0.015 µg/g). The highest mean concentration (0.06 µg/g) was found in a sample of shorthorn sculpin. Levels above the detection limit in fish muscle, however, are considered questionable. It is worth noting, that for muscle results obtained from analytical laboratory dissections several months after collection, cad-

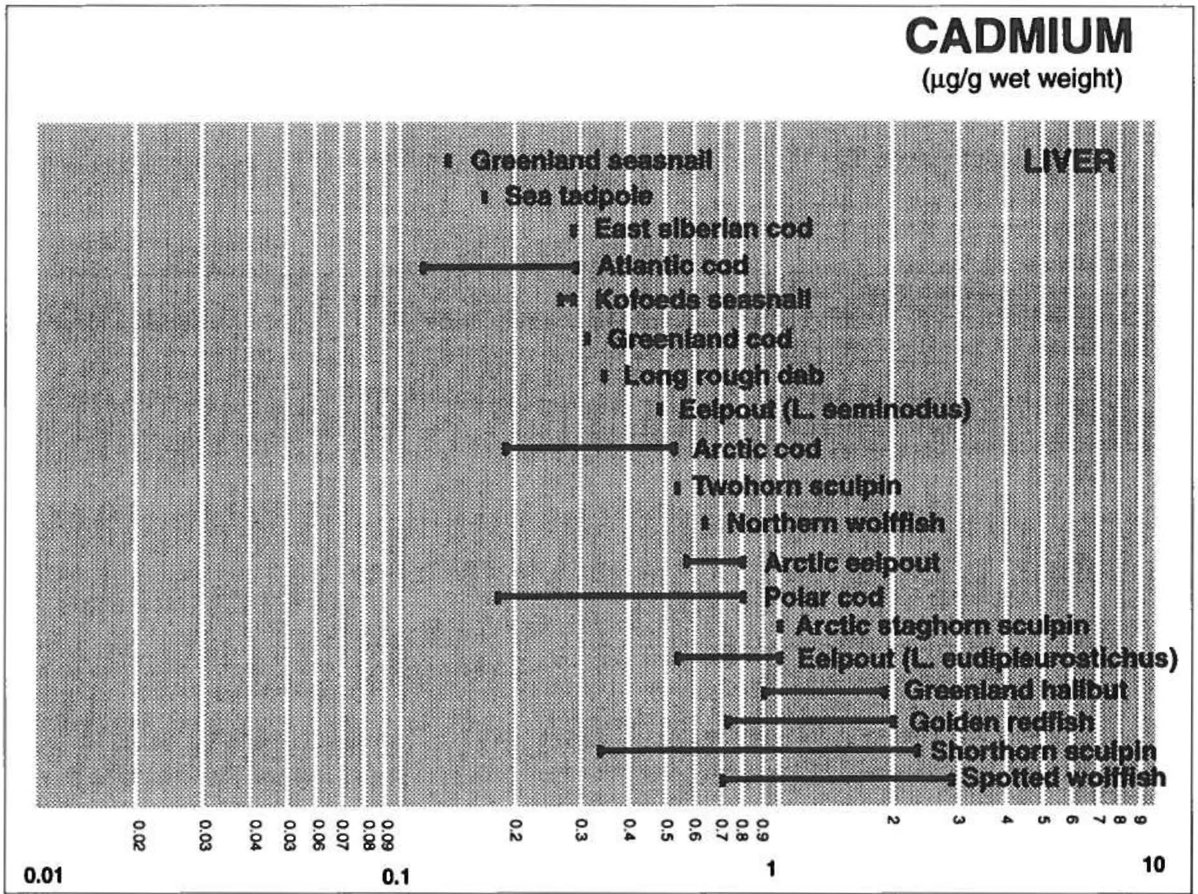

Fig. 3
Ranges of mean cadmium in liver tissue of Greenland fish (µg/g wet weight).

mium levels were below detection limits in fish species with large individuals and above in fish species with small individuals. A possible explanation for this is that in some cases it may not have been possible to take "clean" muscle subsamples for analyses from small individuals. In other words, muscle subsamples may have been contaminated with liquid from liver or kidney, where cadmium concentrations are much higher than in muscle.

Among tissues cadmium levels are highest in liver, with values ranging from 0.12 µg/g in Atlantic cod to 2.9 µg/g in spotted wolffish (Fig. 3). In kidney the mean cadmium concentration ranges from 0.03 µg/g in Greenland cod to 0.23 µg/g in Greenland seasnail. Similar levels are found in spleen, with values ranging from 0.02 µg/g in eelpout to 0.38 µg/g in shorthorn sculpin. The cadmium concentration in fish bone is below the detection limit (0.015 µg/g).

Mercury

Mean mercury concentrations in muscles range from below the detection limit (0.005 µg/g) in golden redfish to 0.28 µg/g in Arctic cod (Fig. 4). In liver the mercury concentration ranges from below the detection limit (0.005 µg/g) in polar cod to 0.08 µg/g in Arctic eelpout (Fig. 4). In kidney and spleen the levels are quite similar. Kidney levels range from 0.016 µg/g in Greenland halibut to 0.046 µg/g in Atlantic cod, and in spleen levels range from 0.012 µg/g in shorthorn sculpin to 0.056 µg/g in golden redfish.

Selenium

In muscle the selenium concentration ranges from below detection limit (0.2 µg/g) in many fish species to 1.0 µg/g in shorthorn sculpin. The level is higher in liver, ranging from 0.28 µg/g in Arctic cod to 2.8 µg/g in Greenland halibut (Fig. 5). In kidney the mean selenium concentration ranges from 0.77 µg/g in Greenland halibut to 5.2 µg/g in long rough dab, and in spleen from 1.5 µg/g in northern wolffish to 3.5 µg/g in east siberian cod.

Length dependence of element concentrations

The dependence of element concentrations in muscle, liver, kidney and bone to fish length (both sex combined)

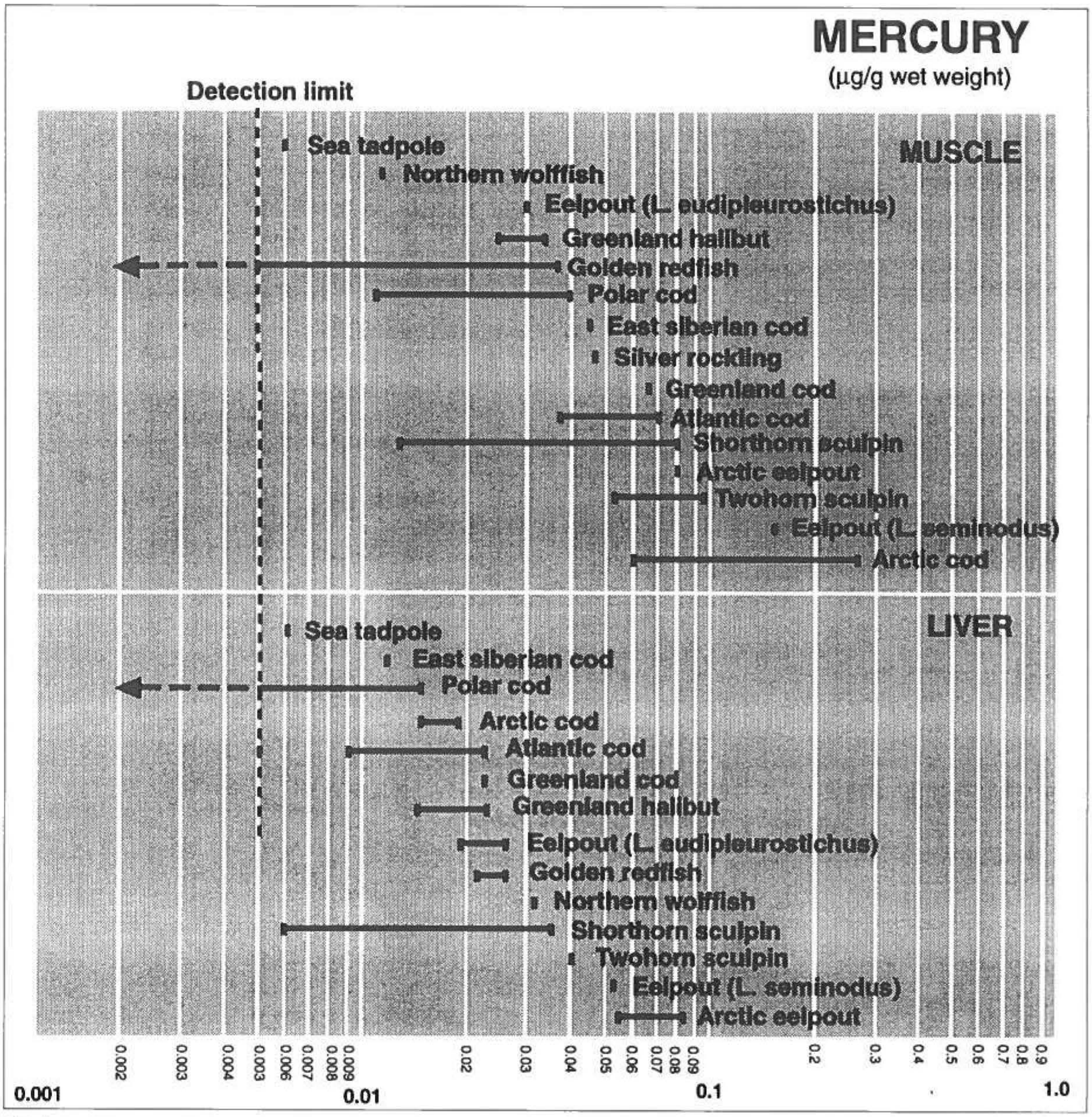

Fig. 4
Ranges of mean mercury in muscle and liver tissue of Greenland fish (µg/g wet weight).

was analysed by correlation studies. Fish length was used instead of age because methodologies of age determination have either not been developed or are not equally accurate for all fish species. Although weight was measured on all fish, this parameter was not used as it is known to show considerable seasonal variation. Spearman correlations between element concentrations and fish length were calculated for each fish sample. This resulted in a total of 54 correlation studies for zinc, 28 for cadmium, 27 for mercury and 12 for selenium. All of these differ from each other in tissue type, fish species and geographical location. Also sample size, length and concentration ranges involved differ between correlation analysis, which are essential for the power of correlation test to detect significant results. Furthermore, with a total of 121 correlation studies it is likely to find at least 6 to be significant (at 5% level) by chance. These conditions makes it difficult to interpret the outcome of the correlation analysis. Therefore, to deduce whether a general length dependency in element concentration exists, it has been tested whether a surplus of positive (or negative) correlations exists (Table 1).

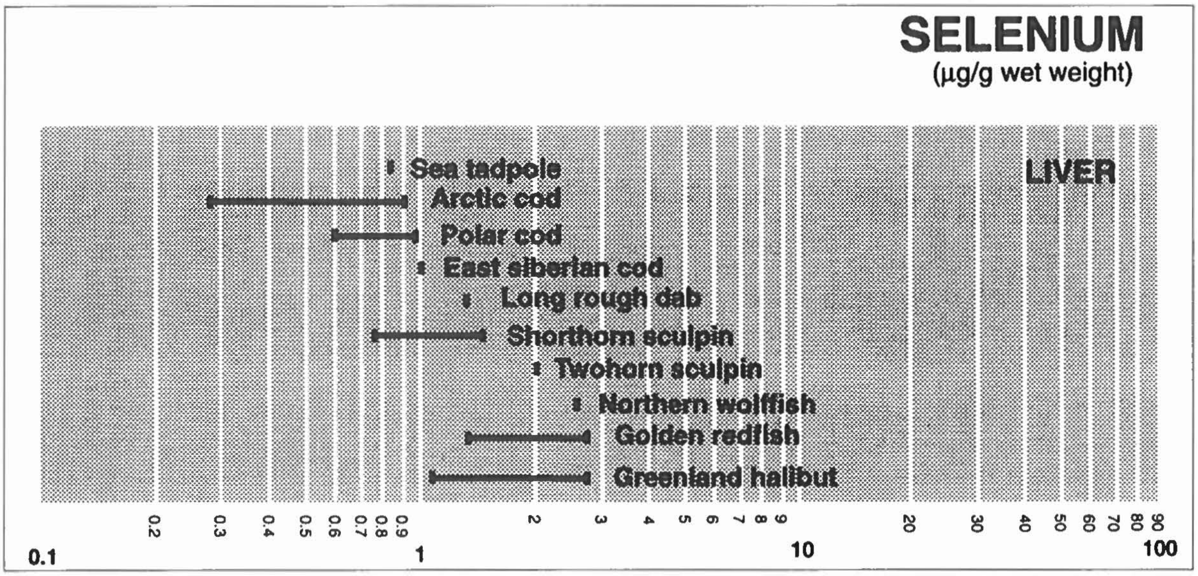

Fig. 5
Ranges of mean selenium in liver tissue of Greenland fish (µg/g wet weight).

For zinc, most correlation analyses were conducted for muscle and liver. In muscle both positive and negative correlations were found between zinc and length, but with a surplus of positive correlations (22 out of 30). An equal number of positive and negative correlations were found in liver. Zinc in bone also showed a surplus of positive correlations, but only a few of the correlations were significant.

To our knowledge only little information on the relationship between zinc concentration and fish size is available. Bohn & Fallis (1978) reported that zinc concentration and body weight of whole Arctic cod are significantly correlated, and that zinc in liver of shorthorn sculpin is correlated to body weight. Negative correlations have been reported by Hellou *et al.* (1992) in muscle and liver of Atlantic cod.

In other Arctic animals groups, including invertebrates, birds and marine mammals, zinc has been found to be independent of length and age parametres (e.g. Nielsen & Dietz 1989; Hansen *et al.* 1990; Paludan-Müller *et al.* 1993; Dietz *et al.* 1995; 1996).

No analyses could be carried out for cadmium in muscle as most values were below the detection limit. In liver and kidney the number of positive and negative correlations found were almost equal. Only one correlation was found to be significant. Based on these data, there does not appear to be any general correlation of cadmium concentration with fish size.

In the Arctic Monitoring and Assessment Programme (AMAP) carried out in 1994 to 1996, cadmium in livers of polar cod and shorthorn sculpin from four different areas in Greenland also showed no evidence of length dependency of cod (Riget *et al.* 1997b). Bohn & Fallis (1978), on the other hand, found a tendency for increasing concentrations in liver with size of shorthorn sculpin, whereas Hellou *et al.* (1992) found that cadmium concentrations in livers of Atlantic cod were negatively correlated with size. Stange *et al.* (1996) found no relationship between cadmium in liver and length of Atlantic cod, but a positive relationship in liver of redfish, and ex-

Table 1. Summary of 121 correlation analyses of element concentration and fish length. Spearman rank correlation has been used and only samples with 5 or more individuals were included. N gives the number of correlation studies. N+ and N- give the number of positive and negative correlations. N+5% and N-5% give the number of significant positive and negative correlations at the 5% level. Bold font indicate significant surplus of positive (or negative) correlations at the 5% level, tested by a twotailed sign test (where N>25 the normal approximation to the binomial distribution has been used).

Metal	Tissue	N	N_{+}	N_{-}	$N_{+5\%}$	$N_{-5\%}$
Zinc						
	Muscle	30	**22**	**8**	0	1
	Liver	14	7	7	1	2
	Kidney	2	0	2	0	0
	Bone	8	7	1	1	0
	All	54	**36**	**18**	2	3
Cadmium						
	Liver	21	10	11	1	0
	Kidney	7	4	3	0	0
	All	28	14	14	1	0
Mercury						
	Muscle	11	**11**	**0**	**5**	**0**
	Liver	11	8	3	3	0
	Kidney	5	**5**	**0**	0	0
	All	27	**24**	**3**	**8**	**0**
Selenium						
	Muscle	2	0	2	0	1
	Liver	8	**1**	**7**	0	1
	Kidney	2	2	0	0	0
	All	12	3	9	0	2

plained this with the relatively long life span of redfish. Several other studies reviewed by Phillips (1980) adds contradictory information of the accumulative pattern of cadmium. Factors such as differences in diet, migration, uptake and excretion rates may contribute to confuse any general pattern.

Cadmium concentrations are found to increase with size and age in other Arctic animal groups: e.g. blue mussels (Riget *et al.* 1996), shrimps (Dietz *et al.* 1996), seabirds (Nielsen & Dietz 1989; Riget *et al.* 1997b), seals (Dietz *et al.* 1996; Riget *et al.* 1997b), whales (Hansen *et al.* 1990; Paludan-Müller *et al.* 1993; Dietz *et al.* 1996) and polar bears (Dietz *et al.* 1995; 1996).

Fewer correlation analyses were carried out for mercury level and fish length than for zinc and cadmium. Nevertheless, there seems to be a more pronounced positive correlation evident for all tissues, strongest in muscle and kidney and weakest in liver (Table 1). None of the correlations in kidney were significant at the 5% level, whereas for liver and muscle, almost half were found to be significant.

In the AMAP study of mercury levels in liver of polar cod and shorthorn sculpin from Greenland, concentrations were generally found to increase with fish length (Riget *et al.* 1997b). Stange *et al.* (1996) also found a clear tendency for higher mercury levels in muscle tissue of Atlantic cod and redfish from the North Atlantic with increasing size and age. Increasing mercury concentrations with age have also been documented in species other than fish outside the Arctic (see reviews by e.g. Johnston (1976), Phillips (1980) and Law (1996)).

Mercury concentrations in soft tissues of blue mussels were not correlated with mussel length (Riget *et al.* 1996), and likewise no accumulation with age was evident in seabirds from Greenland (Nielsen & Dietz 1989; Riget *et al.* 1997b). However, in marine mammals from Greenland waters, mercury was found to accumulate with age in most animals examined (Born *et al.* 1981; Hansen *et al.* 1990; Paludan-Müller *et al.* 1993; Dietz *et al.* 1995; 1996; Riget *et al.* 1997b).

Only few correlations were available for selenium, of which most were negative (9 out of 12). In the AMAP study of selenium in livers of shorthorn sculpin from Greenland, both positive and negative correlations with fish length were found, while no evidence of length dependency was found in polar cod livers (Riget *et al.* 1997b). Stange *et al.* (1996) found decreasing selenium concentrations with increasing length in Atlantic cod liver tissue but no trend in livers of redfish.

Negative correlation with size has also been shown in blue mussels (Riget *et al.* 1996), while selenium concentration has been found to increase with age in seabird livers (Riget *et al.* 1997b). In marine mammals age accumulation is also primarily seen in livers (Hansen *et al.* 1990; Paludan-Müller *et al.* 1993; Dietz *et al.* 1995; 1996).

Table 2. Ratio of minimum and maximum mean metal concentrations for samples caught at the same place in different years.

Species	Sampling years	Tissue	Zinc	Cadmium
Capelin	1988-90, 1993	Whole		0.32
Spotted wolffish	1988-93	Muscle	0.70	
		Liver	0.83	0.44
		Bone	0.78	
Greenland cod	1989-93	Muscle	0.76	
Shorthorn sculpin	1988-93	Muscle	0.77	
		Liver	0.59	0.49
		Bone	0.78	

Geographical variation in element concentrations

In order to test geographical differences five main areas in Greenland were defined according to Fig. 1.

A certain sized fish in North West Greenland (NWG) will be older than a similar sized individual from South West Greenland (SWG). Therefore, if the uptake rate of an element is higher than the release rate, it would be expected that the level of that element would increase toward the north because growth rates decrease with decreasing temperature. However, other variable such as local differences in the geology, differences in food preferences, seasonal and year to year variation introduce variance to the expected pattern.

The year to year variability can be evaluated in a few occassions. From Uummannaq in Central West Greenland tissues from fish caught at the same place, but from different years, have been analysed for zinc and cadmium. The observed variations in metal levels are considered to represent natural year to year variation. Table 2 shows the ratio between the minimum and maximum mean concentrations for zinc and cadmium. The ratio for zinc ranges from 0.59 in liver of shorthorn sculpin to 0.83 in liver of spotted wolffish. For cadmium the ratio generally seems to be lower (variation higher) than for zinc, ranging from 0.32 in whole capelin to 0.49 in liver of shorthorn sculpin. The year to year variation found in fish from Greenland may be regarded as high. However, high unexplained year to year variations are often found in time trend studies of contaminants (Bignert *et al.* 1994; Nicholson & Fryer 1991). Such high year to year variations makes it difficult to compare metal levels between areas. Because of high natural variability observed differences in concentration levels between areas may be wrongly interpretated as geographical differences.

Zinc

Significant differences (at 5% level) in the level of zinc between areas are seen in 7 out of 18 cases (Table 3). However, when considering areas in decreasing order of concentrations in all fish species, no general pattern can be seen. Only when samples from NWG are included is it evident that levels of zinc are higher there. The lowest ra-

Table 3. Geographic comparison of metals by Kruskall-Wallis test. Areas are listed in order of decreasing concentrations. The numbers below the area codes indicate the relative percentage of the highest figure. Bold font indicates significant difference between areas (P<0.05). Area codes are according to Fig. 1. Only samples with more than 80% of values above the detection limit are included.

		Zinc	*Cadmium*	*Mercury*	*Selenium*
Atlantic cod	Muscle	CWGS 100, CEG 91, SWG 88		CWGS 100, CEG 61, SWG 8	
	Liver	SWG 100, CWGS 90, CEG 75	**SWG 100, CEG 46, CWGS 24**	CWGS 100, SWG 35, CEG 20	
Greenland cod	Muscle	CWGS 100, CWGN 81			
Polar cod	Muscle	**NWG 100, SWG 63, CEG 61**		**NWG 100, CEG 48, SWG 28**	**NWG 100, SWG 46, CEG 38**
	Liver	**NWG 100, CEG 82, SWG 55**	**NWG 100, CEG 97, SWG 23**	**NWG 100, CEG 46, SWG 21**	**CEG 100, NWG 96, SWG 67**
Arctic cod	Muscle	NWG 100, CEG 76		**NWG 100, CEG 96**	CEG 100, NWG 54
	Liver	CEG 100, NWG 63	**CEG 100, NWG 31**	**NWG 100, CEG 9**	**CEG 100, NWG 31**
L. eudipleurostichus	Liver	CEG 100, SWG 88	SWG 100, CEG 43		
	Spleen	CEG 100, SWG 82			
Golden redfish	Muscle	SWG 100, CWGS 72		**CWGS 100, SWG 14**	CWGS 100, SWG 68
	Liver	SWG 100, CWGS 87	SWG 100, CWGS 47	CWGS 100, SWG 76	**CWGS 100, SWG 49**
Twohorn sculpin	Muscle	**CEG 100, SWG 58**	**CEG 100, SWG 14**	CEG 100, SWG 59	
Shorthorn sculpin	Muscle	**NWG 100, CEG 100, SWG 90, CWGN 80, CWGS 67**		**SWG 100, NWG 66, CEG 63, CWGS 42**	**CEG 100, NWG 23**
	Liver	**NWG 100, CWGN 98, CWGS 92, CEG 87, SWG 80**	**NWG 100, SWG 83, CWGS 69, CEG 39, CWGN 35**	**SWG 100, CEG 44, NWG 37, CWGS 26**	**CEG 100, NWG 60**
	Kidney	NWG 100, SWG 95, CEG 92	CEG 100, NWG 87, SWG 50	SWG 100, CEG 82	
	Spleen	CEG 100, SWG 71	SWG 100, CEG 70	SWG 100, CEG 55	
Greenland halibut	Muscle	**CEG 100, CWGN 80**		CEG 100, CWGS 89	CEG 100, CWGS 39
	Liver	**CWGS 100, CEG 80**	**CWGS 100, CEG 31**	CWGS 100, CEG 52	**CWGS 100, CEG 41**
	Kidney		CWGS 100, CEG 59	**CWGS 100, CEG 60**	CEG 100, CWGS 100

tio of zinc levels between areas is 0.58 for muscle in two-horn sculpin. This is, however, of the same magnitude as the year to year variation found in fish species from Uummannaq (Table 2), which illustrates the difficulties in distinguishing between geographical and year to year variability. For fish species such as shorthorn sculpin and Greenland halibut, where significant differences between areas have been found, there were relatively large differences in mean length of the samples from the different areas, which may influence the geographical comparisons. Samples of shorthorn sculpin and Greenland halibut from Central East Greenland are generally composed of smaller fish than samples from the other areas, which may lead to a relative underestimation of the zinc concentration from this area.

Cadmium

Significant differences in the level of cadmium (at 5% level) between areas are seen in 6 out of 11 cases (Table 3). In some cases the difference between areas (up to 4 times for liver of polar cod) may indicate real geographical variability as they seem to be larger than the year to year differences observed in Uummannaq (Table 2), although different species are involved. However, there was no obvious systematic pattern in the geographical variation of cadmium concentrations.

In the AMAP study of cadmium in livers of polar cod, higher concentrations were found in North West Greenland than in East Greenland, and cadmium in shorthorn sculpin was also higher in North West Greenland than in other in areas of Greenland. However, these were only found to be significantly different from South West Greenland (Riget *et al.* 1997b).

Higher levels of cadmium have been documented for seabirds, ringed seals and polar bears in northern Greenland latitudes than further south (Nielsen & Dietz 1989; Dietz *et al.* 1996). However, no such systematic north – south trend was evident in the AMAP study of cadmium in livers of gulls and of seals from four areas of Greenland (Riget *et al.* 1997b).

Cadmium levels in biota have been shown to vary on a local geographical scale, which complicates comparisons on a regional scale. Local geographical differences have been found in cadmium levels in livers of shorthorn sculpin. The levels in samples from the open sea were 3 times higher than those from the inner regions of large fjords (Asmund *et al.* 1988). Similar observations have also been made for cadmium in seaweed (Riget *et al.* 1997a) and deep sea prawns (Johansen *et al.* 1991).

Mercury

Significant differences in levels of mercury between areas are seen in 8 out of total of 18 analyses. Geographical comparisons of mercury were generally based on smaller sampling sizes than for zinc and cadmium. Nevertheless, nearly 50% of the area comparisons are found to be significant. Furthermore, when looking at the relative concentrations in Table 3, relatively clear geographical differences in mercury concentrations are seen in several cases (up to a factor of 4). Unfortunately, no estimate of year to year variation is available for mercury. Mercury concentrations were shown to be positively correlated with fish length, which makes geographical comparisons more difficult for species with relatively large size differences between samples, such as is the case with Atlantic cod, shorthorn sculpin, Greenland halibut and golden redfish. As the overlaps in length range between some of the samples are small, and the number of fish in many of the samples are relatively low, no attempt was made to normalize mercury concentrations in relation to size. Among those fish species where length of the fish is not considered to influence the geographical comparisons (e.g. polar cod and Arctic cod) significant differences between areas are found. The highest mercury concentration was found in North West Greenland for both species. Comparisons were made with Central East Greenland for Arctic cod and with South West Greenland for polar cod. However, the concentrations of mercury were not highest in North West Greenland for shorthorn sculpin, even when similar approximate mean lengths were compared.

The AMAP study of mercury in livers of shorthorn sculpin from four areas of Greenland (Riget *et al.* 1997b) found that the highest concentrations occur in East Greenland and North West Greenland.

In seabirds, higher mercury concentrations were found in birds from North West and North East Greenland than in South Greenland (Nielsen & Dietz 1989; Dietz *et al.* 1996). However, in the AMAP study of mercury in livers of gulls from four areas of Greenland, no differences in levels were found (Riget *et al.* 1997b). In the same study mercury in livers of seals was also analysed. There was only weak tendency for higher mercury levels in older seals from East Greenland and North West Greenland than in the rest of Greenland.

Selenium

Significant differences in selenium levels (at 5% level) between areas are seen in most of the analyses (7 out of 11, Table 3). As for mercury, the sample sizes of the comparisons are generally much smaller than for zinc and cadmium. Selenium concentrations have been shown to be negatively correlated with size of the fish, which makes geographical comparisons difficult, as was the case with zinc and mercury. Fish length is expected to have an influence on comparisons, especially with golden redfish, shorthorn sculpin and Greenland halibut, where relative large differences in mean length of samples exist. Selenium concentrations in golden redfish are up to 2 times lower in the samples from South West Greenland than in the Central South West Greenland samples, even though the mean length of the samples from South West Greenland was smaller than the mean length of the samples from Central South West Greenland. For shorthorn sculpin, the selenium concentration is higher in the sample from Central East Greenland than in the sample from North West Greenland, which to some extent may be explained by the difference in mean length of the samples from the two areas. For Greenland halibut, liver samples from Central South West Greenland had a greater selenium concentration than samples from Central East Greenland, even though the mean length of fish from Central East Greenland was smaller than from Central South West Greenland. In the case of polar cod and Arctic cod, where no differences in mean length exist between the samples between areas, the selenium concentration in Central East Greenland seems to be higher than in North West Greenland. The only exception is in muscle of polar cod.

In the AMAP study Riget *et al.* (1997b) found higher selenium levels in liver of sculpins from North West Greenland than in sculpin from other areas of Greenland, however, no difference was seen in selenium levels in livers of polar cod from North West Greenland and East Greenland.

Dietz *et al.* (1996) reported higher selenium levels in fish, seabirds and marine mammals in northern latitutes of Greenland than in the southern. This difference was, however, not found in invertebrates from the same areas. Riget *et al.* (1997b) found a tendency for higher selenium levels in livers of gulls from North West Greenland than in other areas of Greenland, whereas no such tendency was seen in livers of seals from the same areas.

Inter-organ correlation of element concentrations

Inter-organ association of elements has been studied with correlation studies of each fish species where more than 4 observations were available and at least 80% of the values given were above the detection limit. To eliminate dependency on fish length, partial correlations were conducted. Only muscle, liver and kidney were included, as most data was available for these tissues. The number of observations for each correlation study varied, which had an effect on significance levels.

Concentrations in muscle, liver and kidney of zinc are positively correlated, except in the case of golden redfish (Table 4). For cadmium and mercury, the inter-organ correlations are much stronger than for zinc. For mercury, significant correlations are found even with small sample sizes. For selenium, most inter-organ correlations were negative. However, the only significant correlation, for muscle-liver in polar cod, was positive.

The relatively weak inter-organ correlations of zinc and selenium, and the strong inter-organ correlations of cadmium and mercury in Greenland fish were also evident in Greenland seabirds (Nielsen & Dietz 1989), belugas and narwhals (Hansen *et al.* 1990), and harbour porpoise from West Greenland (Paludan-Müller *et al.* 1993)

Table 4. The level of significance of partial correlation of elements between fish tissues where n ≧5. – and + indicate negative and positive correlation coefficient, respectively. The levels of significance indicated are : ** $p<0.01$, * $0.01<p<0.05$. Abbreviations used are M: Muscle, L: Liver, K: Kidney

Metal	Species	n	M v. L	n	M v. K	n	L v. K
	Shorthorn sculpin	172	+	71	+*	70	+
	Polar cod	62	+**				
	Spottet wolffish	35	+				
Zn	Arctic cod	14	+				
	Atlantic cod	11	+				
	Greenland cod	5	+	5	+	5	+
	Arctic staghorn sculpin	5	+	6	+	6	+
	Golden redfish	5	-	5	-	5	+
	Shorthorn sculpin	168	+**	71	+**	69	+**
	Polar cod	59	+**				
Cd	Arctic cod	11	-				
	Greenland cod					5	+
	Arctic staghorn sculpin					5	-
	Shorthorn sculpin	73	+**	16	+**	16	+**
	Polar cod	61	+**				
	Arctic cod	14	+				
Hg	Atlantic cod	11	+*				
	Greenland halibut	8	+	8	+	8	+
	Greenland cod	5	+**	5	+**	5	+**
	Golden redfish	5	+**	5	+	5	+
	Polar cod	62	+*				
	Arctic cod	11	-				
Se	Greenland halibut	8	-	8	-	8	-
	Golden redfish	5	-	5	-	5	-

Intra-organ association of element concentrations

Intra-organ associations of elements were studied by partial correlation studies of each fish species which had more than 4 observations and at least 80% of values above the detection limit (Table 5). The number of observations for each correlation study varied which had an influence on the level of significance. The number of observations in the correlation studies of zinc and cadmium in liver and muscle in particular are much higher than in other correlation studies.

Concentrations were all generally mutually correlated in liver, kidney and muscle. Only few negative correlations were found, and none were found to be significant at the 5% level. For each element combination, at least one significant correlation was found in both liver and muscle tissue. The only significant correlation in kidney was found between cadmium and mercury in Greenland cod. The most consistent association involves zinc and cadmium in liver and muscle tissue.

The association of zinc and cadmium in Greenland fish has been previously reported in liver and kidney tissues of Greenland seabirds (Nielsen & Dietz, 1989) and kidney of harbour porpoise (Paludan-Müller *et al.* 1993), belugas and narwhals (Hansen *et al.* 1990) and polar bears (Dietz *et al.* 1995).

Several studies involving liver tissue with high mercury and selenium concentrations from higher trophic levels show significant correlations between these two element, often with a molar ratio of 1:1. It has been argued that this relationship involves a detoxifying mechanism of mercury by selenium in the inert complex, mercury selinide. However, the mercury levels are generally low for Arctic fish, i.e. not high enough to induce such a detoxifying process.

Variations within the Arctic

Heavy metal concentrations in fish species from other areas in the Arctic are shown in Table 6. Only fish species and metals included in this study are shown. The zinc levels in fish from the Barents Sea and the Northeast Atlantic are similar or slightly lower than in Greenland. The

Table 5. Significance of association between elements. Pairwise partial correlation of element concentrations in muscle, liver and kidney of all species where n≥5. Symbols as in Table 4.

Species			Zn-Cd						Zn-Hg			
	n	M	n	L	n	K	n	M	n	L	n	K
Shorthorn sculpin	184	+	211	+**	71	+	75	+*	73	+	16	-
Spotted wolffish	79	+**										
Polar cod	66	+**	59	+**			65	+**	61	+**		
Twohorn sculpin	12	+**					12	+				
Arctic cod	11	+	14	+*			14	+	14	-		
Atlantic cod			6	+*			11	+	11	-		
Kofoed's seasnaill	8	+										
Greenland halibut			7	+					8	+		
L. polaris			7	+					7	+		
L. eudipleurostichus			6	+ .					6	+		
Greenland cod			5	+			5	+	5	+		
Arctic staghorn sculpin			5	+								
Golden redfish							5	-				
			Zn-Se						Cd-Hg			
	n	M	n	L	n	K	n	M	n	L	n	K
Shorthorn sculpin	31	-	32	+			75	+	69	+	16	+
Polar cod	66	+**	62	+**			65	+**	58	+**		
Twohorn sculpin	11	+					12	+				
Arctic cod	11	+	14	+**			11	-	14	-		
Atlantic cod			5	-					6	+		
Greenland halibut			8	+					7	-	8	+
L. polaris									7	+		
L. eudipleurostichus									6	+		
Greenland cod					5	+			5	+	5	+**
Golden redfish			5	+	5	+			5	+	5	+
			Cd-Se						Hg-Se			
	n	M	n	L	n	K	n	M	n	L	n	K
Shorthorn sculpin	31	+	29	-			30	+	31	-		
Polar cod	66	+**	59	+**			65	+**	61	+**		
Twohorn sculpin	11	+					11	+*				
Arctic cod	11	-	14	+*			11	+	14	-		
Atlantic cod									5	+		
Greenland halibut			7	+	8	+	8	+	8	-	8	+
Greenland cod					5	+					5	+
Golden redfish			5	+	5	-	5	-	5	+	5	+

Tabel 6. Zinc, cadmium, mercury and selenium in fish from the North Atlantic and the Arctic.

Species	Location	Year	Tissue	*N*	Sex	Age/size	Metals -µg/g Zinc	Cadmium	Mercury	Selenium	Reference
Arctic cod	Kugmallit Bay, Canada	1984	Liver	6	-	3 yrs	-	-	-	0.48±0.22	Muir et al., 1992 (1)
(Boreogadus saida)			Muscle	6	-	3 yrs	-	<0.05	0.02±0.01	0.42±0.06	
			Kidney	4	-	3 yrs	-	-	0.05	0.58±0.26	
	Grise Fjord, Canada	1983	Liver	6	-	-	-	1.14*/0.679	-	-	Macdonald & Sprague, 1988 (4)
	Resolute Bay, Canada	1984	Muscle	2	-	2-3 yrs	-	0.05	0.04±0.02	0.43±0.01	Muir et al., 1992 (1)
			Liver	2	-	2-3 yrs	-	-	-	0.58±0.4	
	Resolute Bay, Canada	1984	Gonads	2	-	2-3 yrs	-	-	-	0.8±0.04	
	Barrow Strait, Canada	1984	Liver	2	-	2 yrs	-	-	-	0.58±0.40	
			Muscle	2	-	2 yrs	-	<0.05	0.04±0.02	0.43±0.01	
	Cambridge Bay, Canada	1984	Muscle	1	-	-	-	0.05	0.02	0.33	
			Kidney	1	-	-	-	-	-	1.2	
	Arctic Bay, Canada	1983	Whole	50	-	7.0-16.8 cm	-	0.40*/0.53	-	-	Macdonald & Sprague, 1988 (4)
			Whole	47	-	-	-	0.62±0.22	-	-	
		1984	Liver	8	-	5 yrs	-	-	-	0.85±0.14(1)	Muir et al., 1992 (1)
			Muscle	8	-	5 yrs	-	<0.05	0.02±0.004	0.51±0.19	
			Kidney	6	-	5 yrs	-	-	-	0.91±0.32	
			Gonads	3	-	5 yrs	-	-	-	0.7	
	Pangnirtung, Canada	1984	Muscle	6	-	11-12 yrs	-	0.06	0.03±0.01	0.35±0.1	
			Liver	6	-	11-12 yrs	-	0.91±0.47	0.01±0.01	0.62±0.2	
			Kidney	6	-	11-12 yrs	-	-	0.05	0.81±0.19	
			Gonads	6	-	11-12 yrs	-	0.33±0.15	0.03±0.01	0.62±0.27	
	Cumberland Sound, Canada	1984	Liver	6	-	-	-	0.83±0.45	0.01±0.01	0.62±0.20	
			Muscle	6	-	-	-	<0.05	0.03±0.01	0.35±0.10	
	Jan Mayen, Norway	1994	Liver	25	M&F	12-18 cm	-	0.374	-	0.61	Stange et al., 1996 (1)
			Muscle	25	M&F	12-18 cm	-	0.013	0.02	-	
	Greenland Sea	1994	Liver	25	M&F	11-15 cm	-	0.394	-	0.70	
			Muscle	25	M&F	11-15 cm	-	0.0127	<0.01	-	
	Svalbard, Norway	1984	Liver	1	-	-	16	0.089	0.011	0.82	Carlberg & Bøler, 1985 (3)
			Muscle	1	-	-	11	0.014	0.025	0.38	
	Barents Sea	1992	Liver	25	M&F	16-19 cm	10.8±1.2	0.132±0.030	-	0.68±0.02	Maage et al., in press (1)
			Muscle	25	M&F	16-19 cm	7.7±3.6	0.0066±0.0029	0.01±0.00	-	
	Barents Sea	1993	Liver	25	M&F	15-19 cm	12.8±1.6	0.175±0.049	-	0.59±0.08	
			Muscle	25	M&F	15-19 cm	8.9±4.4	0.0034±0.0017	0.01±0.00	-	
Atlantic cod	Frobisher Bay, Canada	1976	Muscle	1	-	-		-	0.02	-	Hendzel, 1990; Unpublished (1)
(Gadus morhua)	Labrador, Canada	1990	Liver	12	F	64-75 cm	25	0.75	<0.05	1.1	Hellou et al., 1992 (3)
			Muscle	12	F	64-75 cm	19	<0.01	0.52	1.6	
	Newfoundland, Canada		Liver	10	F	43-108 cm	35	0.75	<0.05	2.3	
			Muscle	10	F	43-108 cm	19	0.03	0.44	1.7	
	Faroe Island	1994	Liver	25	M&F	46-59 cm	12.8	0.07	-	1.03	Stange et al., 1996 (1)
			Muscle	25	M&F	46-59 cm	4.8	0.0005	6.01	-	

Table 6. Zinc, cadmium, mercury and selenium in fish from the North Atlantic and the Arctic.

Species	Location	Year	Tissue	*N*	Sex	Age/size	Metals -µg/g				Reference
							Zinc	Cadmium	Mercury	Selenium	
	Norway	-	Muscle	2	-	-	-	0.01	-	-	Lande 1977 in Macdonald &
	Malvik, Norway	-	Muscle	4	-	-	-	0.02	-	-	Spraque 1988 (3)
	Halten Banken, Norway	1994	Liver	14	M&F	65-103 cm	9.6	0.15	-	0.35	Stange et al., 1996 (1)
			Muscle	12-14	M&F	65-103 cm	3.1	0.0002	0.08	-	
	Svalbard, Norway	1993	Liver	25	M&F	56-94 cm	14.8±7.0	0.168±0.098	-	0.79±0.40	Maage et al., in press (1)
			Muscle	25	M&F	56-94 cm	4.4±0.6	0.0024±0.0015	0.04±0.02	-	
	Barents Sea	1993	Liver	25	M&F	39-51 cm	12.1±2.5	0.056±0.038	-	0.69±0.19	
			Muscle	25	M&F	39-51 cm	3.9±0.4	0.0003±0.0002	0.01±0.01	-	
Greenland Cod	Cambridge Bay, Canada	1984	Liver	6	-	-	-	<0.05	0.04±0.02	1.14±0.21	Muir et al., 1992 (1)
(*Gadus ogac*)			Kidney	7	-	-	-	-	0.17	1.1±0.09	
			Muscle	7	-	-	-	<0.05	0.04±0.01	0.33±0.05	
			Gonads	7	-	-	-	0.03±0.01	0.02	0.88±0.2	
	Maquatua River, Canada	1987	Muscle	46	-	-	-	-	0.13±0.11	-	Whoriskey & Brown, 1988 (1)
	Hopedale, Canada	1978	Muscle	4	M	8.6 cm	-	-	0.1	-	Bruce et al., 1979 (1)
			Muscle	10	F	8.6 cm	-	-	0.15	-	
	Makkovik Bay, Canada	1978	Muscle	3	M	7.7 cm	-	-	0.11	-	
			Muscle	3	F	5.7 cm	-	-	0.05	-	
Redfish	Kap Farvel, Greenland	1994	Liver	25	M&F	32-35 cm	29.0	6.448	0.28	2.04	Stange et al., 1996 (1)
(*Sebastes sp.*)			Muscle	25	M&F	32-35 cm	3.0	0.0145	0.21	0.44	
	Denmark Strait, Greenland	1994	Liver	26	M&F	33-40 cm	25.0	12.101	0.49	4.87	
			Muscle	26	M&F	33-40 cm	2.6	0.0118	0.20	0.43	
	Iceland	1994	Liver	25	M&F	17-33 cm	30.6	0.553	0.02	1.35	
			Muscle	25	M&F	17-33 cm	4.0	0.0020	0.03	0.36	
	Faroe Island	1994	Liver	25	M&F	39-44 cm	27.0	3.721	0.26	1.71	
			Muscle	25	M&F	39-44 cm	3.0	0.0048	0.18	0.55	
	Halten Banken, Norway	1994	Liver	25	M6F	36-42 cm	24.0	0.807	0.07	1.98	
			Muscle	25	M&F	36-42 cm	2.7	0.0023	0.08	0.36	
Long rough dab	Iceland	1994	Liver	25	M&F	30-36 cm	39.9	0.268	-	1.24	Stange et al., 1996 (1)
(*Hippoglossoides*			Muscle	25	M&F	30-36 cm	3.6	0.0019	0.02	-	
platessoides)	Svalbard, Norway	1984	Liver	1	-	-	29	0.078	-	-	Carlberg & Bøler, 1985 (3)
			Muscle	1	-	-	6.2	<0.005	0.029	0.26	
		1993	Liver	25	M&F	27-36 cm	33.5±5.1	0.062±0.022	-	1.70±0.66	Maage et al., in press (1)
			Muscle	25	M&F	27-36 cm	6.0±0.6	0.0035±0.0004	0.02±0.01	-	
	Barents Sea	1992	Liver	25	M&F	24-28 cm	27.4±4.2	0.099±0.021	-	1.18±0.15	
			Muscle	25	M&F	24-28 cm	4.9±0.3	0.0018±0.0005	0.01±0.00	-	
		1993	Liver	25	M&F	19-30 cm	43.9±8.5	0.485±0.239	-	1.70±0.66	
			Muscle	25	M&F	19-30 cm	4.6±1.8	0.0015±0.0003	0.01±0.00	-	

(1)Wet weight, Arithmetic mean (2)Wet weight., Geometric mean (3)Dry weight, Arithmetic mean (4)Dry weight, Geometric mean ± Standard Deviation */ Relative Standard Deviation only comparable zinc data available from the Northwest Atlantic are in Atlantic cod from Labrador and Newfoundland, which show higher levels (a factor of 2).

Cadmium levels in livers of polar cod and Atlantic cod indicate a decreasing trend from the Canadian Northwest Atlantic, over West Greenlandic, to East Greenlandic waters and Northeast Atlantic to the Barents Sea. However, cadmium levels in livers of redfish from the Northeast Atlantic are higher than those found at West Greenlandic waters. Cadmium levels in livers of long rough dab are quite similar between the two areas.

Mercury levels in polar cod from Northwest Atlantic, Northeast Atlantic and the Barents Sea are similar. In Atlantic cod, the levels found at Labrador and Newfoundland, Canada, are higher than those found in Greenland, the Northeast Atlantic and the Barents Sea. Mercury levels in Greenland cod from the Canadian Northwest Atlantic are also higher than those found at West Greenland. In the case of redfish, it has been reported that levels in fish from the Northeast Atlantic are higher than those from West Greenlandic waters.

The observed selenium concentrations in fish from Greenland waters are comparable to values reported from the Canadian Northwest Atlantic, the Northeast Atlantic and the Barents Sea.

References

Asmund, G., Nielsen, P.B. & Johansen, P. 1988. Miljøundersøgelser ved Maarmorilik 1972-1987. Grønlands Miljøundersøgelser og Grønlands Geologiske Undersøgelser (English summary): 207 pp.

Bignert, A., Olsson, M. de Wit, C., Litzén, K., Rappe, C. & Reutergårdh, L. 1994. Biological variation – an important factor to consider in ecotoxicological studies based on environmental samples. Fresenius J. Anal. Chem. 348: 76-85.

Bohn, A. & Fallis, B.W. 1978. Metal concentrations (As, Cd, Cu, Pb and Zn) in shorthorn sculpin (*Myoxocephalus scorpius L.*) and Arctic char (*Salvelinus alpinus L.*), from the vicinity of Strathona Sound, Northwest Territories. Water Research 12: 659-663.

Born, E.W., Kraul, I. & Kristensen, T. 1981. Mercury, DDT and PCB in the Atlantic walrus (*Odobenus rosmarus rosmarus*) from the Thule District, North Greenland. Arctic, 34(3): 255-260.

Bruce, W.J., Spencer, K.D. & Arsenault, E. 1979. Mercury content data for Labrador fishes 1977-78. Fish. Mar. Serv. Data Rep. 142: 263 pp.

Carlberg, G.E. & Bøler, J.B. 1985. Determination of persistent pollutants in the Arctic. Centre of Industrial Research, Norway. Report 831101-1: 21 pp.

Dietz, R., Nielsen, C.O. , Hansen, M.M. & Hansen, C.T. 1990. Organic mercury in Greenland birds and mammals. Sci. Total Environ. 95: 41-51.

Dietz, R., Born, E. W., Hansen, C.T. & Nielsen, C.O. 1995. Zinc, cadmium, mercury, and selenium in polar bears (*Ursus maritimus*) from East Greenland, Polar Biol. 15: 175-185.

Dietz, R., Riget, F. & Johansen, P. 1996. Lead, cadmium, mercury and selenium in Greenland marine animals. Sci. Total Environ. 186: 67-93.

Hansen, C.T., Nielsen, C.O., Dietz, R. & Hansen, M.M. 1990. Zinc, cadmium, mercury and selenium in minke whales, belugas, and narwhals from West Greenland, Polar Biol. 10: 529-539.

Hellou, J., Warren, W.G., Payne, J.F., Belkhode, S. & Lobel, P. 1992. Heavy metals and other elements in three tissues of cod *Gadus morhua* from the northwest Atlantic. Mar. Pollut. Bull. 24: 452-458.

Hendzel, M. 1990. Canada. Department of Fisheries and Oceans (DFO) – Central and Arctic Region Inspection Branch, Winnipeg, Manitoba. Unpublished data.

Johansen, P., Hansen, M.M. & Asmund, G. 1985. Heavy metal pollution from mining in Greenland, in Proc. Mine Water Congress, Granada, Spain 1985: 685-693.

Johansen, P., Hansen, M.M., Asmund, G. & Nielsen, P.B. 1991. Marine Organisms as Indicators of Heavy Metal Pollution – Experience from 16 Years of Monitoring at a Lead Zink Mine in Greenland, Chem. and Ecol. 5: 35-55.

Johnston, R. 1976. Marine pollution. Academic Press, London: 729 pp.

Law, R. J. 1996. Metals in marine mammals. In: Beyer. N., Heinz, G. & Redmon-Norwood, A. W. (eds.). Environmental contaminants in wildlife. Interpreting tissue concentrations. Lewis Publishers, Inc., Boca Raton, USA: 357-376.

Maage, A., Stange, K. & Klungsøyr, J. in press. Trace elements in fish and sediments from the Barents Sea.

Macdonald, C.R. & Sprague, J.B. 1988. Cadmium in marine invertebrates and arctic cod in the Canadian Arctic. Distribution and ecological implications. Mar. Ecol. Prog. Ser. 47: 17-30.

Muir, D.C.G., Wagemann, R., Hargrave, B.T., Thomas, D.J., Peakall, D.B. & Norstrom, R.J. 1992. Arctic marine ecosystem contamination. Sci. Total. Environ. 122: 75-134.

Nicholson, M. & Fryer, R. 1991. The power of the ICES Cooperative Monitoring Programme to Detect Linear Trends and Incidents. In : Anon. Report of the Working Group on Statistical Aspects of Trend Monitoring. ICES Doc. CM 1991.

Nielsen , C.O. & Dietz, R. 1989. Heavy metals in Greenland seabirds, Meddr Grønland, Biosci. 29: 26 pp.

Nielsen, C.O. & Dietz, R. 1990. Distributional pattern of zinc, cadmium, mercury, and selenium in livers of hooded seal (*Cystophora cristata*), Biol. Trace Elem. Res. 24: 61-71.

Paludan-Müller, P., Agger, C.T., Dietz, R. & Kinze, C.C. 1993. Cadmium, mercury, selenium, copper and zinc in harbour porpoise (*Phocoena phocoena*) from West Greenland, Polar Biol. 13: 311-320.

Phillips, D.J.H. 1980. Quantitative aquatic biological indicators. Their use to monitor trace metals and organochlorine pollution. Pollution monitoring series. Applied Science Publishers Ltd, London: 488 pp.

Riget, F., Johansen, P. & Asmund, G. 1996. Influence of length on element concentrations in blue mussels (*Mytilus edulis*). Mar. Pollut. Bull. 32: 745-751.

Riget, F., Johansen, P. & Asmund, G. 1997a. Baseline levels and natural variability of elements in three seaweed species from West Greenland. Mar. Pollut. Bull. 34: 171-176.

Riget F., Dietz, R., Johansen, P. & Asmund, G. 1997b. Heavy Metals in the Greenland Marine Environment.

Section C, chapter 4.2, AMAP Greenland 1994-1996. Environmental Project No. 356. 788 pp.
SAS 1990. SAS Institute Inc.,Version 6, Fourth Edition, Cary, North Carolina.
Stange, K., Maage, A. & Klungsøyr, J. 1996. Contaminants in fish and sediments in the North Atlantic Ocean. NMR Report TemaNord 1996:522: 79 pp.
Whoriskey, F. G. & Brown, D. T. 1988. Mercury levels in lake herring (*Coregonus artedii*) and rock cod (*Gadus ogac*) from the Wemindji region of James Bay. Department of Renewable Resources, MacDonald Coolege of McGill University. Rapport à la direction Environment Hydro-Quebec: 78 pp.

Appendix 1. Zinc in fish from Greenland (µg/g wet weight).

Species	Municipality and year	Tissue	n	Length	A.mean	S.D.	Min.	Max.	G.mean	r.S.D.	Median
Capelin	Uummannaq 1988	Whole	40	15.5	14.16	1.697	9.11	18.73	14.06	1.13	13.94
(Mallotus villosus)	Uummannaq 1989	Whole	30	17.2	18.33	2.644	14.41	25.89	18.16	1.14	17.72
	Uummannaq 1990	Whole	49	17.7	15.71	3.122	10.69	25.88	15.43	1.21	15.07
	Uummannaq 1993	Whole	20	17.1	17.80	3.330	12.23	24.59	17.52	1.20	16.83
Atlantic cod	Nuuk 1986	Liver	5	87.6	17.53	3.712	15.05	24.04	17.26	1.21	15.88
(Gadus morhua)		Muscle	5	87.6	5.19	1.707	3.74	7.34	4.98	1.38	4.26
	Nanortalik 1985	Liver	3	59.3	19.48	3.223	15.77	21.57	19.29	1.19	21.11
		Kidney	3	59.3	32.25	17.855	20.80	52.82	29.40	1.67	23.13
		Muscle	3	59.3	4.59	0.587	4.09	5.24	4.57	1.13	4.46
	Ammassalik 1985	Liver	3	47.9	14.67	3.745	12.07	18.96	14.37	1.27	12.97
		Muscle	3	47.9	4.70	0.736	3.95	5.42	4.66	1.17	4.74
Greenland cod	Uummannaq 1988	Muscle	10	42.5	4.57	0.358	4.09	5.26	4.56	1.43	4.61
(Gadus ogac)	Uummannaq 1989	Muscle	10	47.9	4.33	0.543	3.81	5.49	4.30	1.72	4.12
	Uummannaq 1990	Muscle	10	51.5	3.95	0.546	3.43	5.12	3.92	1.73	3.86
	Uummannaq 1991	Muscle	16	54.6	4.06	0.654	3.01	5.07	4.01	1.92	3.93
	Uummannaq 1992	Muscle	10	51.5	3.49	0.614	2.07	4.14	3.43	1.85	3.56
	Uummannaq 1993	Muscle	10	52.5	3.49	0.442	2.65	4.30	3.47	1.56	3.44
	Nuuk 1985	Liver	5	51.4	26.18	4.999	21.97	34.29	25.83	1.20	24.78
		Kidney	5	51.4	19.71	3.568	15.43	24.69	19.45	1.20	19.24
		Muscle	5	51.4	4.96	1.926	3.62	8.27	4.71	1.40	4.35
		Spleen	4	52.3	21.25	3.519	17.70	24.84	21.03	1.18	21.23
Polar cod	Avanersuaq 1987	Liver	34	14.9	25.91	7.332	12.24	44.63	24.94	1.33	24.78
(Boreogadus saida)		Muscle	38	14.8	10.66	3.427	5.22	21.51	10.17	1.36	10.07
	Nanortalik 1985	Liver	22	12.6	14.20	2.058	11.09	19.73	14.07	1.15	13.89
		Muscle	22	12.6	6.68	0.781	5.57	8.74	6.64	1.12	6.63
	Ittoqqortoormiit 1985	Liver	3	14.5	20.10	0.865	19.24	20.97	20.09	1.04	20.10
		Muscle	3	14.5	6.14	0.635	5.72	6.87	6.12	1.11	5.83
	Kong Oscars Fjord 1985	Liver	3	14.5	22.60	8.053	13.46	28.66	21.47	1.50	25.67
		Muscle	3	14.5	6.68	1.661	5.40	8.56	6.55	1.27	6.09
Arctic cod	Upernavik 1987	Liver	11	21.0	14.22	3.986	9.16	21.82	13.72	1.32	13.90
(Arctogadus glacialis)		Muscle	11	21.0	5.42	1.928	3.19	9.39	5.14	1.40	4.82
	Ittoqqortoormiit 1985	Liver	3	20.7	22.53	7.022	14.43	26.87	21.68	1.42	26.29
		Muscle	3	20.7	4.12	1.281	2.74	5.28	3.97	1.40	4.33
Eastsiberian cod	Ammassalik 1985	Liver	3	35.9	17.12	9.258	6.84	24.80	14.96	1.99	19.72
(Arctogadus borisovi)		Muscle	3	35.9	8.05	2.742	6.07	11.18	7.77	1.38	6.90
		Spleen	3	35.9	19.03	1.298	18.14	20.52	19.00	1.07	18.43
Silver rockling	Ammassalik 1985	Muscle	3	21.6	2.77	0.892	1.75	3.39	2.66	1.44	3.18
(Onogadus argentatus)											
Northern wolffish	Nuuk 1985	Liver	3	100.7	33.14	4.146	28.54	36.59	32.96	1.14	34.29
(Anarhichas denticulatus)		Kidney	3	100.7	25.99	0.120	25.87	26.11	25.99	1.00	26.00
		Muscle	3	100.7	3.63	1.261	2.77	5.08	3.50	1.39	3.05
		Spleen	3	100.7	24.27	3.980	20.46	28.40	24.05	1.18	23.95
Spotted wolffish	Uummannaq 1988	Liver	16	79.0	27.91	3.406	22.84	34.69	27.72	1.13	27.53
(Anarhichas minor)		Muscle	9	80.8	5.31	1.253	4.15	8.43	5.20	1.23	5.18
		Bone	16	79.0	24.00	3.667	20.15	34.50	23.77	1.15	22.78
	Uummannaq 1989	Liver	20	75.3	28.79	4.348	21.38	38.17	28.49	1.16	28.48
		Muscle	10	75.2	7.01	2.073	4.26	11.59	6.76	1.33	7.02
		Bone	20	75.3	23.55	3.192	19.70	31.88	23.35	1.14	22.75
	Uummannaq 1990	Liver	18	74.9	28.12	4.053	20.39	34.57	27.84	1.16	28.95
		Muscle	7	70.4	5.60	1.177	4.29	7.84	5.50	1.22	5.82
		Bone	11	72.5	22.24	5.307	15.68	32.23	21.71	1.26	19.64
	Uummannaq 1991	Liver	16	69.8	30.35	2.706	24.74	34.95	30.23	1.10	30.37
		Muscle	6	68.3	4.88	0.689	3.98	5.84	4.84	1.15	5.01
		Bone	14	69.8	20.83	3.447	15.00	26.61	20.56	1.18	20.57
	Uummannaq 1992	Liver	9	79.2	26.87	2.878	21.64	30.53	26.73	1.12	26.97
		Muscle	7	73.7	5.19	0.807	4.26	6.69	5.14	1.16	5.23
		Bone	7	73.7	18.71	3.669	14.89	24.45	18.42	1.21	17.84
	Uummannaq 1993	Liver	16	79.2	25.09	4.601	18.95	34.50	24.71	1.20	24.69
		Muscle	5	77.1	5.04	0.959	4.13	6.49	4.97	1.20	4.98
		Bone	12	75.7	21.07	3.862	14.54	26.73	20.71	1.22	22.20

Eelpout	Nanortalik 1985	Liver	3	25.9	28.28	1.123	27.33	29.52	28.27	1.04	27.99
(Lycodes		Spleen	3	25.9	24.11	3.713	21.81	28.39	23.93	1.16	22.12
eudipleurostichus)	Ammassalik 1985	Liver	3	23.3	32.01	4.103	28.93	36.67	31.84	1.13	30.44
		Muscle	3	23.3	4.05	0.304	3.80	4.39	4.05	1.08	3.97
		Spleen	3	23.3	29.69	1.629	27.86	30.99	29.66	1.06	30.21
Eelpout	Ittoqqortoormiit 1985	Liver	3	38.4	22.90	1.754	21.66	24.91	22.86	1.08	22.14
(Lycodes seminudus)		Muscle	3	38.4	6.34	0.327	6.14	6.72	6.34	1.05	6.17
		Spleen	3	38.4	24.21	4.073	21.65	28.91	24.00	1.18	22.08
Arctic eelpout	Ittoqqortoormiit 1985	Liver	3	17.6	23.59	2.053	21.80	25.83	23.53	1.09	23.13
(Lycodes polaris)		Muscle	3	17.6	6.46	0.603	5.82	7.02	6.44	1.10	6.53
	Kong Oscars Fjord 1985	Liver	4	22.9	22.81	4.316	18.33	28.70	22.52	1.20	22.11
Golden redfish	Nuuk 1985	Liver	5	46.4	33.04	2.725	30.19	37.45	32.96	1.08	32.63
(Sebastes marinus)		Kidney	5	46.4	27.34	3.272	23.62	32.60	27.19	1.12	27.09
		Muscle	5	46.4	2.98	0.384	2.58	3.55	2.96	1.13	2.89
		Spleen	3	47.7	23.66	0.900	22.65	24.37	23.65	1.04	23.97
	Nanortalik 1985	Liver	3	23.6	37.92	1.676	36.37	39.70	37.90	1.05	37.70
		Muscle	3	23.6	4.13	1.369	3.31	5.71	3.99	1.36	3.37
Twohorn sculpin	Nanortalik 1985	Muscle	3	7.3	8.36	1.870	6.27	9.88	8.21	1.27	8.92
(Icelus bicornis)	Ammassalik 1985	Muscle	3	6.5	14.40	4.359	10.87	19.27	13.98	1.34	13.05
	Ittoqqortoormiit 1985	Liver	3	7.0	25.70	5.661	21.06	32.01	25.31	1.24	24.04
		Muscle	3	7.0	13.90	1.114	13.25	15.19	13.87	1.08	13.27
	Kong Oscars Fjord 1985	Muscle	3	7.0	14.87	2.202	12.39	16.59	14.76	1.17	15.64
Shorthorn sculpin	Avanersuaq 1987	Liver	24	26.7	33.38	5.639	22.55	43.98	32.91	1.19	34.31
(Myoxocephalus		Muscle	24	26.7	8.67	3.294	5.21	18.80	8.16	1.42	7.92
scorpius)	Upernavik 1985	Liver	10	28.2	41.50	7.055	33.47	56.79	41.00	1.17	40.88
		Kidney	10	28.2	23.32	4.532	18.95	34.32	22.98	1.19	22.60
		Muscle	10	28.2	14.28	4.196	9.56	21.85	13.77	1.32	12.27
	Uummannaq 1988	Liver	20	25.4	33.24	10.763	19.42	60.13	31.72	1.36	31.75
		Muscle	9	27.4	9.50	8.058	5.10	30.44	7.89	1.76	6.18
		Bone	20	25.4	25.41	10.298	14.40	54.02	23.84	1.42	22.24
	Uummannaq 1989	Liver	20	30.5	34.94	5.321	26.65	49.19	34.58	1.16	34.02
		Muscle	10	31.1	7.36	2.539	5.12	13.56	7.05	1.34	6.53
		Bone	20	30.5	27.18	6.645	16.04	45.32	26.46	1.27	25.60
	Uummannaq 1990	Liver	14	29.1	39.64	9.660	24.42	56.93	38.52	1.29	39.76
		Muscle	6	29.0	8.17	1.110	6.03	9.19	8.10	1.16	8.47
		Bone	10	29.0	27.18	4.108	19.02	33.39	26.88	1.18	27.38
	Uummannaq 1991	Liver	14	28.2	45.59	9.346	31.32	60.37	44.70	1.23	45.22
		Muscle	4	29.0	8.86	1.970	6.56	11.34	8.69	1.25	8.77
		Bone	10	26.4	29.93	4.037	25.04	37.57	29.70	1.14	28.52
	Uummannaq 1992	Liver	15	25.6	28.43	7.970	21.72	50.92	27.61	1.27	25.88
		Muscle	11	25.9	7.62	2.860	4.23	11.95	7.14	1.47	6.21
		Bone	12	24.6	25.91	10.436	13.72	49.15	24.22	1.46	22.99
	Uummannaq 1993	Liver	23	27.6	32.55	9.161	20.13	58.21	31.47	1.29	29.36
		Muscle	12	27.1	7.77	1.934	4.54	10.30	7.53	1.31	8.25
		Bone	18	26.8	21.94	6.673	11.71	35.79	20.99	1.36	21.05
	Maniitsoq 1987	Liver	18	26.8	32.17	10.282	17.02	62.41	30.86	1.33	29.97
		Muscle	18	26.8	5.32	1.101	3.92	7.95	5.22	1.22	4.93
	Nuuk 1987	Liver	3	12.0	40.97	9.223	35.57	51.62	40.33	1.24	35.72
		Muscle	3	12.0	11.52	2.766	8.47	13.86	11.28	1.29	12.23
	Nanortalik 1985	Liver	31	26.4	28.69	4.618	16.34	36.97	28.30	1.19	28.99
		Kidney	27	25.5	22.25	1.889	19.25	25.96	22.17	1.09	21.91
		Muscle	31	26.4	9.24	2.636	5.68	18.59	8.93	1.30	8.98
		Spleen	4	25.9	16.74	7.963	4.92	22.10	14.43	2.05	19.98
	Ammassalik 1985	Liver	25	26.9	30.89	7.251	20.43	53.16	30.16	1.24	30.11
		Kidney	25	27.2	20.75	3.456	14.98	33.98	20.51	1.16	20.13
		Muscle	26	27.3	9.41	2.891	5.75	16.40	9.04	1.33	8.47
		Spleen	3	27.6	23.06	2.639	21.49	26.11	22.97	1.12	21.59
	Ittoqqortoormiit 1985	Liver	3	9.2	31.03	6.876	23.76	37.43	30.50	1.26	31.89
		Muscle	3	9.2	13.44	2.126	11.05	15.12	13.32	1.18	14.15
	Kong Oscars Fjord 1985	Liver	14	16.8	32.02	5.958	24.29	46.20	31.54	1.19	31.79
		Kidney	8	18.9	23.64	2.379	20.53	27.58	23.54	1.11	23.86
		Muscle	14	16.8	11.30	3.119	6.09	16.82	10.87	1.34	11.25
		Spleen	12	18.1	23.69	5.618	17.57	38.05	23.17	1.24	22.07

Arctic staghorn	Upernavik 1985	Liver	5	20.0	72.61	26.322	43.68	109.15	68.79	1.45	72.26
sculpin		Kidney	6	19.8	19.26	2.464	15.09	21.76	19.12	1.14	19.86
(Gymnacanthus tricuspis)		Muscle	6	19.8	8.07	1.326	5.54	9.39	7.97	1.20	8.51
Kofoed's seasnail	Denmark Strait 1985	Liver	3	12.7	18.12	4.087	14.10	22.27	17.81	1.26	17.98
(Liparis fabricii)		Muscle	3	12.7	7.34	1.052	6.41	8.48	7.29	1.15	7.12
	Kong Oscars Fjord 1985	Liver	3	12.9	24.63	4.507	19.77	28.67	24.35	1.21	25.46
Greenland seasnail	Nanortalik 1985	Kidney	3	15.2	18.88	1.000	17.80	19.77	18.87	1.05	19.08
(Liparis tunicata)		Muscle	3	15.2	6.47	0.622	5.82	7.06	6.45	1.10	6.53
	Kong Oscars Fjord 1985	Liver	3	15.4	22.42	5.806	16.69	28.30	21.91	1.30	22.27
Sea tadpole	Nanortalik 1985	Liver	3	7.8	14.13	2.035	11.80	15.54	14.03	1.16	15.06
(Careproctus reinhardti)		Muscle	3	7.8	9.73	1.692	7.78	10.76	9.63	1.20	10.66
Greenland halibut	Nuuk 1985	Liver	5	71.4	26.02	4.048	22.20	32.60	25.78	1.16	24.50
(Reinhardtius	Ammassalik 1985	Liver	3	40.8	21.43	1.152	20.53	22.73	21.41	1.05	21.04
hippoglossoides)		Kidney	3	40.8	20.97	2.837	17.95	23.58	20.84	1.15	21.38
		Muscle	3	40.8	4.07	1.032	3.18	5.20	3.98	1.28	3.82
		Spleen	3	40.8	17.70	2.528	14.87	19.74	17.57	1.16	18.48
Long rough dab	Nanortalik 1985	Liver	3	22.9	35.73	7.717	31.06	44.64	35.22	1.23	31.50
(Hippoglossoides		Kidney	3	22.9	22.90	2.705	20.56	25.86	22.79	1.12	22.27
platessoides)		Muscle	3	22.9	3.80	0.385	3.55	4.24	3.78	1.10	3.60

Appendix 2. Cadmium in fish from Greenland (µg/g wet weight).

Species	Municipality and year	Tissue	n	Length	A.mean	S.D.	Min.	Max.	G.mean	r.S.D.	Median
Capelin	Uummannaq 1988	Whole	40	15.5	0.018	0.008	<0.015	0.039	0.016	1.69	0.018
(Mallotus villosus)	Uummannaq 1989	Whole	20	17.5	0.057	0.024	0.032	0.118	0.053	1.44	0.049
	Uummannaq 1990	Whole	49	17.7	0.037	0.012	0.017	0.068	0.035	1.39	0.035
	Uummannaq 1993	Whole	20	17.1	0.041	0.013	0.023	0.069	0.039	1.39	0.040
Atlantic cod	Nanortalik 1985	Liver	3	59.3	0.300	0.117	0.209	0.432	0.286	1.45	0.259
(Gadus morhua)		Kidney	3	59.3	0.128	0.033	0.092	0.156	0.125	1.31	0.137
		Muscle	3	59.3	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Ammassalik 1985	Liver	3	47.9	0.137	0.087	0.071	0.236	0.121	1.84	0.104
		Muscle	3	47.9	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
Greenland cod	Uummannaq 1989	Muscle	10	47.9	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
(Gadus ogac)	Uummannaq 1990	Muscle	10	51.5	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1991	Muscle	16	54.6	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1992	Muscle	10	51.5	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1993	Muscle	10	52.5	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Nuuk 1985	Liver	5	51.4	0.334	0.133	0.181	0.492	0.311	1.54	0.371
		Kidney	5	51.4	0.037	0.022	0.022	0.075	0.033	1.66	0.031
		Muscle	5	51.4	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Spleen	4	52.3	0.056	0.034	0.029	0.102	0.049	1.78	0.046
Polar cod	Avanersuaq 1987	Liver	34	14.9	0.908	0.525	0.310	2.950	0.802	1.63	0.790
(Boreogadus saida)		Muscle	38	14.8	0.058	0.070	<0.015	0.347	0.036	2.70	0.041
	Nanortalik 1985	Liver	22	12.6	0.212	0.152	<0.015	0.677	0.162	2.42	0.181
		Muscle	22	12.6	<0.015	0.005	<0.015	0.026	0.009	1.45	<0.015
	Ittoqqortoormiit 1985	Liver	3	14.5	0.394	0.222	0.223	0.644	0.356	1.72	0.315
		Muscle	3	14.5	0.020	0.021	<0.015	0.044	0.013	2.76	<0.015
	Kong Oscars Fjord 1985	Muscle	3	14.5	<0.015	0.005	<0.015	0.017	<0.015	1.56	0.015
Arctic cod	Upernavik 1987	Liver	11	21.0	0.214	0.127	0.134	0.567	0.192	1.54	0.167
(Arctogadus		Muscle	11	21.0	<0.015	0.003	<0.015	0.016	<0.015	1.26	<0.015
glacialis)	Illoqqortoormiut 1985	Liver	3	20.7	0.580	0.257	0.298	0.799	0.535	1.68	0.643
Eastsiberian cod	Ammassalik 1985	Liver	3	35.9	0.295	0.096	0.199	0.391	0.284	1.40	0.296
(Arctogadus		Muscle	3	35.9	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
borisovi)		Spleen	3	35.9	0.059	0.016	0.045	0.077	0.058	1.31	0.057
Silver rockling	Ammassalik 1985	Muscle	3	21.6	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
(Onogadus argentatus)											
Northern wolffish	Nuuk 1985	Liver	3	100.7	0.893	0.901	0.300	1.930	0.639	2.66	0.450
(Anarhichas		Kidney	3	100.7	0.085	0.052	0.025	0.120	0.069	2.41	0.110
denticulatus)		Muscle	3	100.7	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
Spotted wolffish	Uummannaq 1988	Liver	16	79.0	2.845	1.247	1.147	5.006	2.582	1.59	2.749
(Anarhichas minor)	Uummannaq 1989	Liver	20	75.3	2.000	1.200	0.654	4.505	1.687	1.83	1.613
		Muscle	10	75.2	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	20	75.3	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1990	Liver	18	74.9	2.787	2.291	0.709	8.846	2.117	2.12	1.952
		Muscle	8	70.9	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	14	75.1	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1991	Liver	16	69.8	2.578	1.134	0.706	5.268	2.330	1.63	2.554
		Muscle	12	72.5	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	16	71.5	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1992	Liver	9	79.2	2.730	2.483	0.234	8.563	1.842	2.82	2.073
		Muscle	8	72.6	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	10	75.8	<0.015	0.005	<0.015	0.019	<0.015	1.49	<0.015
	Uummannaq 1993	Liver	16	79.2	4.528	4.732	0.724	18.696	2.878	2.69	3.001
		Muscle	6	78.4	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	16	80.8	<0.015	0.002	<0.015	0.017	<0.015	1.22	<0.015
Eelpout	Nanortalik 1985	Liver	3	25.9	1.427	1.362	0.398	2.972	1.025	2.75	0.911
(Lycodes eudipleu		Spleen	3	25.9	0.082	0.035	0.052	0.120	0.077	1.52	0.074
-rostichus)	Ammassalik 1985	Liver	3	23.3	0.612	0.418	0.336	1.093	0.531	1.88	0.409
		Muscle	3	23.3	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Spleen	3	23.3	0.169	0.073	0.121	0.253	0.159	1.50	0.131

Eelpout	Ittoqqortoormiit 1985	Liver	3	38.4	0.494	0.169	0.342	0.676	0.475	1.41	0.464
(Lycodes seminudus)		Muscle	3	38.4	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Spleen	3	38.4	0.034	0.034	<0.015	0.073	0.023	3.12	0.022
Arctic eelpout	Ittoqqortoormiit 1985	Liver	3	17.6	0.584	0.166	0.480	0.776	0.570	1.31	0.497
(Lycodes polaris)		Muscle	3	17.6	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Kong Oscars Fjord 1985	Liver	4	22.9	0.813	0.208	0.669	1.120	0.796	1.26	0.732
Golden redfish	Nuuk 1985	Liver	5	46.4	0.960	0.944	0.393	2.638	0.730	2.12	0.600
(Sebastes marinus)		Kidney	5	46.4	0.125	0.092	0.056	0.282	0.104	1.92	0.096
		Muscle	5	46.4	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Spleen	3	47.7	0.061	0.037	0.029	0.101	0.053	1.87	0.053
	Nanortalik 1985	Liver	3	23.6	2.027	0.636	1.520	2.740	1.964	1.35	1.820
		Muscle	3	23.6	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
Twohorn sculpin	Nanortalik 1985	Muscle	3	7.3	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
(Icelus bicornis)	Ammassalik 1985	Muscle	3	6.5	0.044	0.036	0.017	0.085	0.035	2.25	0.029
	Ittoqqortoormiit 1985	Liver	3	7.0	0.584	0.244	0.414	0.863	0.553	1.48	0.473
		Muscle	3	7.0	0.041	0.011	0.032	0.054	0.040	1.31	0.038
	Kong Oscars Fjord 1985	Muscle	3	7.0	0.071	0.039	0.040	0.114	0.064	1.70	0.059
Shorthorn sculpin	Avanersuaq 1987	Liver	24	26.7	1.947	0.970	0.633	3.993	1.727	1.66	1.614
(Myoxocephalus		Muscle	24	26.7	0.099	0.126	<0.015	0.515	0.045	3.92	0.054
scorpius)	Upernavik 1985	Liver	10	28.2	2.519	1.112	1.501	5.057	2.340	1.48	2.227
		Kidney	10	28.2	0.181	0.219	0.055	0.786	0.127	2.17	0.101
		Muscle	10	28.2	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1988	Liver	20	25.4	0.628	0.996	0.090	4.491	0.350	2.63	0.232
	Uummannaq 1989	Liver	20	30.5	0.458	0.461	0.118	1.764	0.331	2.14	0.284
		Muscle	10	31.1	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	20	30.5	<0.015	0.013	<0.015	0.064	<0.015	1.76	<0.015
	Uummannaq 1990	Liver	14	29.1	0.863	1.266	0.097	5.108	0.523	2.54	0.438
		Muscle	8	26.7	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	12	28.5	<0.015	0.008	<0.015	0.034	<0.015	1.55	<0.015
	Uummannaq 1991	Liver	14	28.2	0.843	0.692	0.227	2.453	0.654	2.04	0.630
		Muscle	8	27.6	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	14	26.4	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1992	Liver	15	25.6	0.953	1.639	0.085	6.374	0.419	3.32	0.290
		Muscle	13	26.5	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	16	26.8	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1993	Liver	23	27.6	0.769	0.752	0.150	3.004	0.548	2.21	0.417
		Muscle	15	28.0	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
		Bone	23	27.9	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Maniitsoq 1987	Liver	18	26.8	1.675	1.947	0.240	8.420	1.131	2.34	1.035
		Muscle	18	26.8	<0.015	0.005	<0.015	0.030	<0.015	1.39	<0.015
	Nuuk 1987	Liver	3	12.0	0.977	0.233	0.710	1.140	0.956	1.30	1.080
		Muscle	3	12.0	0.066	0.023	0.040	0.085	0.063	1.49	0.074
	Nanortalik 1985	Liver	30	26.5	1.754	1.090	0.075	5.755	1.444	2.08	1.539
		Kidney	27	25.5	0.105	0.085	0.031	0.388	0.085	1.84	0.073
		Muscle	31	26.4	0.028	0.080	<0.015	0.444	<0.015	2.57	<0.015
		Spleen	3	27.3	0.418	0.203	0.202	0.605	0.379	1.76	0.446
	Ammassalik 1985	Liver	25	26.9	0.846	0.603	0.049	1.996	0.623	2.44	0.626
		Kidney	25	27.2	0.223	0.649	<0.015	3.321	0.081	3.19	0.095
		Muscle	26	27.3	<0.015	0.007	<0.015	0.041	<0.015	1.51	<0.015
	Ittoqqortoormiit 1985	Muscle	3	9.2	0.058	0.074	<0.015	0.143	0.029	4.43	0.023
	Kong Oscars Fjord 1985	Liver	14	16.8	0.764	0.731	0.050	2.548	0.478	3.12	0.503
		Kidney	8	18.9	0.167	0.129	0.049	0.475	0.139	1.86	0.135
		Muscle	14	16.8	<0.015	0.010	<0.015	0.037	<0.015	1.83	<0.015
		Spleen	12	18.1	0.322	0.195	0.088	0.768	0.266	1.98	0.300
Arctic staghorn	Upernavik 1985	Liver	5	20.0	1.145	0.582	0.632	2.011	1.035	1.65	0.986
sculpin *(Gymna-*		Kidney	6	19.8	0.120	0.026	0.073	0.149	0.118	1.28	0.124
canthus tricuspis)		Muscle	6	19.8	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
Kofoed's seasnail	Denmark Strait 1985	Liver	3	12.7	0.343	0.230	0.157	0.600	0.294	1.96	0.271
(Liparis fabricii)		Muscle	3	12.7	0.027	0.018	<0.015	0.041	0.022	2.53	0.034
	Kong Oscars Fjord 1985	Liver	3	12.9	0.334	0.221	0.102	0.542	0.270	2.39	0.358
Greenland seasnail	Nanortalik 1985	Kidney	3	15.2	0.237	0.063	0.167	0.286	0.231	1.33	0.258
(Liparis tunicata)		Muscle	3	15.2	0.016	0.015	<0.015	0.034	<0.015	2.39	<0.015
	Kong Oscars Fjord 1985	Liver	3	15.4	0.282	0.278	0.021	0.575	0.144	5.60	0.249

Sea tadpole	Nanortalik 1985	Liver	3	7.8	0.170	0.050	0.117	0.217	0.165	1.37	0.177
(Careproctus reinhardti)		Muscle	3	7.8	0.026	0.017	<0.015	0.042	0.021	2.47	0.028
Greenland halibut	Uummannaq 1989	Muscle	10	50.3	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
(Reinhardtius	Uummannaq 1990	Muscle	18	50.2	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
hippoglossoides)	Uummannaq 1991	Muscle	10	54.5	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Uummannaq 1993	Muscle	11	64.1	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Nuuk 1985	Liver	4	72.5	2.108	0.944	1.020	3.300	1.938	1.63	2.055
		Kidney	5	71.4	0.130	0.068	0.044	0.200	0.114	1.87	0.110
		Muscle	5	71.4	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
	Ammassalik 1985	Liver	3	40.8	0.918	0.283	0.701	1.238	0.891	1.34	0.814
		Kidney	3	40.8	0.076	0.090	<0.015	0.178	0.038	4.88	0.042
		Muscle	3	40.8	<0.015	.	<0.015	<0.015	<0.015	.	<0.015
Long rough dab	Nanortalik 1985	Liver	3	22.9	0.410	0.304	0.216	0.760	0.347	1.98	0.254
(Hippoglossoides		Kidney	3	22.9	0.049	0.040	0.024	0.095	0.039	2.15	0.027
platessoides)		Muscle	3	22.9	<0.015	.	<0.015	<0.015	<0.015	.	<0.015

Appendix 3. Mercury in fish from Greenland (µg/g wet weight).

Species	Municipality and year	Tissue	n	Length	A.mean	S.D.	Min.	Max.	G.mean	r.S.D.	Median
Atlantic cod	Nuuk 1986	Liver	5	87.6	0.047	0.061	0.008	0.147	0.022	3.90	0.009
(Gadus morhua)		Muscle	5	87.6	0.139	0.160	0.021	0.360	0.068	3.97	0.029
	Nanortalik 1985	Liver	3	59.3	0.016	0.004	0.012	0.020	0.016	1.31	0.017
		Kidney	3	59.3	0.046	0.008	0.038	0.055	0.046	1.20	0.046
		Muscle	3	59.3	0.038	0.009	0.031	0.048	0.038	1.25	0.035
	Ammassalik 1985	Liver	3	47.9	0.009	0.000	0.009	0.010	0.009	1.03	0.009
		Muscle	3	47.9	0.085	0.068	0.044	0.163	0.069	2.09	0.047
Greenland cod	Nuuk 1985	Liver	5	51.4	0.023	0.008	0.012	0.032	0.022	1.49	0.024
(Gadus ogac)		Kidney	5	51.4	0.031	0.023	0.014	0.070	0.025	1.94	0.018
		Muscle	5	51.4	0.071	0.030	0.034	0.112	0.066	1.57	0.064
		Spleen	4	52.3	0.037	0.005	0.032	0.045	0.037	1.15	0.036
Polar cod	Avanersuaq 1987	Liver	34	14.9	0.018	0.008	<0.005	0.042	0.016	1.72	0.017
(Boreogadus saida)		Muscle	38	14.8	0.041	0.011	0.022	0.066	0.039	1.31	0.039
	Nanortalik 1985	Liver	21	12.5	<0.005	0.002	<0.005	0.011	<0.005	1.00	<0.005
		Muscle	21	12.5	0.012	0.004	<0.005	0.018	0.011	1.70	0.012
	Ittoqqortoormiit 1985	Liver	3	14.5	0.008	0.002	0.006	0.009	0.008	1.27	0.008
		Muscle	3	14.5	0.020	0.014	0.011	0.036	0.018	1.87	0.013
	Kong Oscars Fjord 1985	Liver	3	14.5	0.010	0.008	<0.005	0.018	0.007	2.73	0.008
		Muscle	3	14.5	0.019	0.004	0.016	0.024	0.019	1.24	0.017
Arctic cod	Upernavik 1987	Liver	11	21.0	0.192	0.043	0.111	0.264	0.187	1.27	0.196
(Arctogadus		Muscle	11	21.0	0.280	0.032	0.211	0.319	0.278	1.13	0.287
glacialis)	Ittoqqortoormiit 1985	Liver	3	20.7	0.019	0.011	0.007	0.029	0.016	2.14	0.021
		Muscle	3	20.7	0.065	0.034	0.041	0.104	0.060	1.63	0.051
East siberian cod	Ammassalik 1985	Liver	3	35.9	0.013	0.008	0.008	0.023	0.012	1.73	0.010
(Arctogadus borisovi)		Muscle	3	35.9	0.048	0.020	0.032	0.070	0.045	1.49	0.042
		Spleen	3	35.9	0.019	0.008	0.010	0.025	0.017	1.61	0.020
Silver rockling	Amamassalik 1985	Muscle	3	21.6	0.048	0.016	0.030	0.062	0.046	1.47	0.052
(Onogadus argentatus)											
Northern wollfish	Nuuk 1985	Liver	3	100.7	0.050	0.055	0.015	0.113	0.033	2.95	0.021
(Anarhichas denticulatus)		Kidney	3	100.7	0.034	0.020	0.017	0.056	0.031	1.81	0.031
		Muscle	3	100.7	0.025	0.030	0.005	0.059	0.014	3.55	0.009
		Spleen	3	100.7	0.059	0.058	0.019	0.125	0.042	2.67	0.033
Eelpout	Nanortalik 1985	Liver	3	25.9	0.027	0.004	0.023	0.032	0.027	1.16	0.027
(Lycodes		Spleen	3	25.9	0.027	0.003	0.023	0.029	0.027	1.12	0.028
eudipleurostichus)	Ammassalik 1985	Liver	3	23.3	0.019	0.003	0.015	0.022	0.019	1.20	0.018
		Muscle	3	23.3	0.030	0.002	0.029	0.032	0.030	1.06	0.030
		Spleen	3	23.3	0.026	0.012	0.018	0.040	0.024	1.56	0.019
Eelpout	Ittoqqortoormiit 1985	Liver	3	38.4	0.053	0.015	0.036	0.062	0.052	1.35	0.061
(Lycodes seminudus)		Muscle	3	38.4	0.168	0.073	0.116	0.252	0.159	1.50	0.138
		Spleen	3	38.4	0.048	0.019	0.034	0.070	0.046	1.45	0.040
Arctic eelpout	Ittoqqortoormiit 1985	Liver	3	17.6	0.061	0.038	0.030	0.103	0.054	1.86	0.051
(Lycodes polaris)		Muscle	3	17.6	0.099	0.060	0.032	0.148	0.082	2.29	0.117
	Kong Oscars Fjord 1985	Liver	4	22.9	0.096	0.045	0.033	0.139	0.084	1.91	0.106
Golden redfish	Nuuk 1985	Liver	5	46.4	0.028	0.008	0.019	0.040	0.027	1.32	0.027
(Sebastes marinus)		Kidney	5	46.4	0.039	0.013	0.027	0.056	0.037	1.39	0.038
		Muscle	5	46.4	0.037	0.008	0.027	0.050	0.036	1.25	0.035
		Spleen	3	47.7	0.063	0.039	0.037	0.109	0.056	1.78	0.044
	Nanortalik 1985	Liver	3	23.6	0.021	0.003	0.018	0.024	0.021	1.16	0.021
		Muscle	3	23.6	<0.005	0.002	<0.005	0.007	<0.005	1.70	0.006
Twohorn sculpin	Nanortalik 1985	Muscle	3	7.3	0.053	0.005	0.048	0.057	0.052	1.09	0.053
(Icelus bicornis)	Ammassalik 1985	Muscle	3	6.5	0.104	0.046	0.053	0.143	0.096	1.70	0.118
	Ittoqqortoormiit 1985	Liver	3	7.0	0.041	0.009	0.031	0.048	0.040	1.25	0.043
		Muscle	3	7.0	0.081	0.027	0.054	0.108	0.078	1.41	0.080
	Kong Oscars Fjord 1985	Muscle	3	7.0	0.082	0.047	0.049	0.135	0.074	1.71	0.061

Shorthorn sculpin	Avanersuaq 1987	Liver	24	26.7	0.030	0.021	0.011	0.071	0.024	1.86	0.020
(Myoxocephalus		Muscle	24	26.7	0.072	0.037	0.027	0.165	0.065	1.60	0.061
scorpius)	Maniitsoq 1987	Liver	18	26.8	0.025	0.025	0.006	0.114	0.019	1.98	0.017
		Muscle	18	26.8	0.052	0.045	0.011	0.188	0.040	2.04	0.037
	Nuuk 1987	Liver	3	12.0	0.008	0.005	<0.005	0.011	0.006	2.28	0.010
		Muscle	3	12.0	0.013	0.002	0.010	0.014	0.013	1.18	0.014
	Nanortalik 1985	Liver	7	26.2	0.081	0.135	0.009	0.385	0.037	3.43	0.038
		Kidney	5	28.0	0.052	0.048	0.018	0.137	0.040	2.13	0.037
		Muscle	9	26.1	0.110	0.101	0.020	0.353	0.081	2.30	0.095
		Spleen	4	25.9	0.047	0.064	0.006	0.143	0.024	3.81	0.020
	Ittoqqortoormiit 1985	Liver	3	9.2	0.022	0.004	0.017	0.025	0.021	1.23	0.023
		Muscle	3	9.2	0.034	0.008	0.025	0.041	0.033	1.27	0.034
	Kong Oscars Fjord 1985	Liver	14	16.8	0.031	0.014	0.015	0.055	0.029	1.53	0.025
		Kidney	8	18.9	0.040	0.048	<0.005	0.156	0.024	3.12	0.025
		Muscle	14	16.8	0.066	0.036	0.028	0.156	0.058	1.66	0.057
		Spleen	12	18.1	0.019	0.014	<0.005	0.049	0.012	3.28	0.023
Sea tadpole	Nanortalik 1985	Liver	3	7.8	0.008	0.005	<0.005	0.011	0.006	2.29	0.009
(Careprotus reinhardti)		Muscle	3	7.8	0.006	0.003	<0.005	0.009	0.006	2.01	0.008
Greenland halibut	Nuuk 1985	Liver	5	71.4	0.040	0.040	<0.005	0.105	0.023	4.03	0.027
(Reinhardtius		Kidney	5	71.4	0.034	0.014	0.022	0.051	0.032	1.49	0.026
hippoglossoides)		Muscle	5	71.4	0.035	0.011	0.027	0.052	0.033	1.32	0.028
		Bile	3	75.7	<0.005	.	<0.005	<0.005	<0.005	.	<0.005
	Ammassalik 1985	Liver	3	40.8	0.015	0.005	0.011	0.020	0.014	1.37	0.014
		Kidney	3	40.8	0.017	0.004	0.013	0.022	0.016	1.30	0.016
		Muscle	3	40.8	0.032	0.029	0.013	0.065	0.025	2.34	0.017
		Spleen	3	40.8	0.033	0.022	0.017	0.057	0.028	1.89	0.024

Appendix 4. Selenium in fish from Greenland (µg/g wet weight).

Species	Municipality and year	Tissue	n	Length	A.mean	S.D.	Min.	Max.	G.mean	r.S.D.	Median
Atlantic cod	Nuuk 1986	Liver	5	87.6	1.10	0.336	0.84	1.69	1.07	1.31	0.99
(Gadus morhua)		Muscle	5	87.6	<0.20	.	<0.20	<0.20	<0.20	.	<0.20
Greenland cod	Nuuk 1985	Liver	5	51.4	1.47	0.791	0.95	2.88	1.35	1.54	1.18
(Gadus ogac)		Kidney	5	51.4	1.21	0.135	1.06	1.38	1.21	1.12	1.16
		Muscle	5	51.4	<0.20	.	<0.20	<0.20	<0.20	.	<0.20
		Spleen	4	52.3	2.03	0.277	1.69	2.34	2.02	1.15	2.06
Polar cod	Avanersuaq 1987	Liver	34	14.9	0.92	0.207	0.61	1.39	0.90	1.26	0.92
(Boreogadus saida)		Muscle	38	14.8	0.57	0.199	0.27	1.03	0.54	1.43	0.55
	Nanortalik 1985	Liver	22	12.6	0.64	0.229	<0.20	1.22	0.59	1.62	0.59
		Muscle	22	12.6	0.27	0.099	<0.20	0.47	0.24	1.59	0.27
	Ittoqqortoormiit 1985	Liver	3	14.5	0.86	0.314	0.50	1.08	0.81	1.53	1.00
		Muscle	3	14.5	0.24	0.135	<0.20	0.37	0.21	1.96	0.25
	Kong Oscars Fjord 1985	Liver	3	14.5	1.03	0.442	0.52	1.30	0.95	1.69	1.27
		Muscle	3	14.5	<0.20	0.085	<0.20	0.27	<0.20	1.66	0.20
Arctic cod	Upernavik 1987	Liver	11	21.0	0.35	0.227	<0.20	0.88	0.28	2.07	0.32
(Arctogadus		Muscle	11	21.0	<0.20	0.150	<0.20	0.45	<0.20	1.95	<0.20
glacialis)	Ittoqqortoormiit 1985	Liver	3	20.7	0.94	0.400	0.55	1.35	0.88	1.57	0.92
		Muscle	3	20.7	0.40	0.153	0.25	0.56	0.37	1.49	0.38
Eastsiberian cod	Ammassalik 1985	Liver	3	35.9	0.99	0.135	0.91	1.15	0.99	1.14	0.92
(Arctogadus		Muscle	3	35.9	<0.20	.	<0.20	<0.20	<0.20	.	<0.20
borisovi)		Spleen	3	35.9	3.58	0.952	2.48	4.14	3.48	1.34	4.12
Northern wolffish	Nuuk 1985	Liver	3	100.7	2.74	0.706	2.32	3.55	2.68	1.28	2.34
(Anarhichas		Kidney	3	100.7	1.25	0.674	0.78	2.02	1.14	1.65	0.95
denticulatus)		Muscle	3	100.7	0.21	0.192	<0.20	0.43	<0.20	2.33	<0.20
		Spleen	3	100.7	1.58	0.570	0.93	2.01	1.50	1.51	1.80
Golden redfish	Nuuk 1985	Liver	5	46.4	3.04	1.629	1.69	5.80	2.75	1.61	2.73
(Sebastes marinus)		Kidney	5	46.4	1.39	0.270	1.18	1.85	1.38	1.20	1.37
		Muscle	5	46.4	0.27	0.117	<0.20	0.38	0.25	1.74	0.32
		Spleen	3	47.7	1.65	0.702	1.11	2.45	1.56	1.50	1.41
	Nanortalik 1985	Liver	3	23.6	1.48	0.202	1.25	1.60	1.47	1.15	1.60
		Muscle	3	23.6	<0.20	0.076	<0.20	0.24	<0.20	1.62	0.22
Twohorn sculpin	Ammassalik 1985	Muscle	3	6.5	0.66	0.152	0.50	0.80	0.65	1.27	0.69
(Icelus bicornis)	Ittoqqortoormiit 1985	Liver	3	7.0	2.07	0.364	1.85	2.49	2.05	1.18	1.87
		Muscle	3	7.0	0.84	0.124	0.70	0.94	0.83	1.17	0.87
	Kong Oscars Fjord 1985	Muscle	3	7.0	0.77	0.150	0.68	0.94	0.76	1.21	0.68
Shorthorn sculpin	Avanersuaq 1987	Liver	24	26.7	0.77	0.172	0.47	1.03	0.75	1.26	0.74
(Myoxocephalus		Muscle	24	26.7	0.21	0.112	<0.20	0.59	<0.20	1.68	0.22
scorpius)	Ittoqqortoormiit 1985	Liver	3	9.2	1.59	0.564	1.24	2.24	1.53	1.39	1.29
		Muscle	3	9.2	1.01	0.051	0.97	1.07	1.01	1.05	1.01
Sea tadpole	Nanortalik 1985	Liver	3	7.8	0.90	0.418	0.48	1.32	0.83	1.66	0.89
(Careproctus reinhardti)		Muscle	3	7.8	0.36	0.109	0.26	0.48	0.35	1.36	0.35
Greenland halibut	Nuuk 1985	Liver	5	71.4	2.96	0.965	1.81	4.24	2.83	1.41	3.18
(Reinhardtius		Kidney	5	71.4	0.84	0.145	0.72	1.06	0.84	1.18	0.78
hippoglossoides)		Muscle	5	71.4	<0.20	0.112	<0.20	0.35	<0.20	1.75	<0.20
		Bile	3	75.7	0.21	0.102	<0.20	0.30	<0.20	1.79	0.24
	Ammassalik 1985	Liver	3	40.8	1.11	0.328	0.73	1.33	1.07	1.39	1.26
		Kidney	3	40.8	0.78	0.201	0.61	1.00	0.77	1.29	0.74
		Muscle	3	40.8	0.52	0.578	<0.20	1.18	0.32	3.45	0.29
		Spleen	3	40.8	1.80	0.923	1.15	2.86	1.66	1.61	1.40
Long rough dab	Nanortalik 1985	Liver	3	22.9	1.48	0.703	0.89	2.26	1.38	1.60	1.30
(Hippoglossoides		Kidney	3	22.9	6.30	3.824	1.89	8.62	5.15	2.38	8.40
platessoides)		Muscle	3	22.9	0.41	0.369	<0.20	0.82	0.30	2.87	0.32

Instructions to authors

Two copies of the manuscript, each complete with illustrations, tables, captions, etc. should be sent to the Secretary, Kommissionen for videnskabelige Undersøgelser i Grønland. Manuscripts will be forwarded to referees for evaluation. Authors will be notified as quickly as possible about acceptance, rejection, or desired alterations. The final decision on these matters rests with the editor.

Manuscripts corresponding to less than 16 printed pages (of 6100 type units) including illustrations are not accepted, unless they are part of a special theme issue. Manuscripts that are long in relation to their content will not be accepted without abridgement.

Manuscript

Language. – Manuscripts should be in English (preferred language), French, or German. Authors who are not writing in their native language must have the language of their manuscript corrected before submission.

Place names. – All Greenland place names used in the text and in illustrations must be names authorised by The Greenlandic Language Committee. Authors are advised to submit sketch-maps with all required names to the Secretary for checking before the manuscript is submitted. Names of Greenland localities outside the area with which the paper is concerned should be accompanied by coordinates (longitude and latitude).

Title. – Titles should be as short as possible, with emphasis on words useful for indexing and information retrieval.

Abstract. – An abstract in English must accompany all papers. It should be short (no longer than 250 words), factual, and stress new information and conclusions.

Typescript. – Typescripts must be clean and free of handwritten corrections. Use double spacing throughout, and leave a 4 cm wide margin on the left hand side. Avoid as far as possible dividing words at the right-hand end of a line. Consult a recent issue for general lay-out.

Page I should contain 1) title, 2) name(s) of author(s), 3) abstract, 4) key words (max. 10), 5) author's full postal address(es). Manuscripts should be accompanied by a table of contents, typed on separate sheet(s).

Underlining should only be used in generic and species names. The use of italics in other connections can be indicated by wavy line in pencil under the appropriate words.

Use at most three grades of headings, but do not underline. The grade of heading can be indicated in soft pencil in the left hand margin of one copy of the typescript. Avoid long headings.

Floppy disc. – It may be helpful in the printing procedure if, in addition to the hard copies, the manuscript is also submitted on a DOS-formatted floppy disc. However, editing will be made on the hard copy, and the text file on the disc must be identical to the final version of the manuscript.

References. – References to figures and tables in the text should have the form: Fig. 1, Figs 2-4, Table 3. Bibliographic references in the text are given thus: Shergold (1975: 16) ... (Jago & Daily 1974b).

In the list of references the following style is used:

Boucot, A. J. 1975. Evolution and extinction rate controls. – Elsevier, Amsterdam: 427 pp.

Sweet, W. C. & Bergström, S. M. 1976. Conodont bio-stratigraphy of the Middle and Upper Ordovician of the United States midcontinent. – In: Bassett, M. G. (ed). The Ordovician System: Proceedings of a Palaeontological Association symposium, Birmingham, September 1974: 121-151. University of Wales Press.

Tarling, D. H. 1967. The palaeomagnetic properties of some Tertiary lavas from East Greenland. – Earth and Planetary Science Letters 3: 81-88.

Meddelelser om Grønland, Geoscience (Bioscience, Man & Society) should be abbreviated thus: *Meddr Grønland, Geosci. (Biosci., Man & Soc.)*

Illustrations

General. – Submit two copies of all diagrams, maps, photographs, etc., all marked with number and author's name. Normally all illustrations will be placed in the text.

All figures (including line drawings) must be submitted as glossy photographic prints suitable for direct reproduction, and preferably have the dimensions of the final figure. Do not submit original artwork. Where appropriate the scale should be indicated on the illustration or in the caption.

The size of the smallest letters in illustrations should not be less than 1.3 mm. Intricate tables are often more easily reproduced as text figures than by type-setting; when lettering such tables use »Letraset« or a typewriter with carbon ribbon.

Colour plates may be included at the author's expense, but the editor must be consulted before such illustrations are submitted.

Size. – The width of figures must be that of a column (76.5 mm), 1½ columns (117 mm), or a page (157 mm). The maximum height of a figure (including caption) is 217 mm. Horizontal figures are preferred. If at all possible, fold-out figures and tables should be avoided.

Caption. – Captions to figures must be typed on a separate sheet and submitted, like everything else, in duplicate.

Proofs

Authors receive two page proofs. Prompt return to the editor is requested. Only typographic errors should be corrected in proof; the cost of making alterations to the text and figures at this stage will be charged to the author(s).

Twenty-five copies of the publication are supplied free, fifty if there are two or more authors. Additional copies can be supplied at 55% of the retail price. Manuscripts (including illustrations) are not returned to the author after printing unless specifically requested.

Copyright

Copyright for all papers published by Kommissionen for videnskabelige Undersøgelser i Grønland is vested in the Commission. Those who ask for permission to reproduce material from the Commission's publications are, however, informed that the author's permission must also be obtained if the person is still alive.

Meddelelser om Grønland

Bioscience
Geoscience
Man & Society

Published by
The Commission
for Scientific
Research
in Greenland

Printed in Denmark by Special-Trykkeriet Viborg a-s