SC/F13/SP23

Trace elements in minke whales (*Balaenoptera acutorostrata*) from Icelandic waters.

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Summary

The trace elements As, Se, Hg, Cd, Pb, Cu, Cr, Ni, Mn, Fe and Zn were analysed in skin, muscle tissue, kidneys, and livers of 25 minke whales from Icelandic waters. Additionally, cadmium was analysed in ovaries and testes. The animals selected for this study represented the areas north and south of Iceland, equal sex ratios from both areas and as large a length span as was possible.

In many cases there are differences between results for the muscle samples at different sampling sites. Comparison of anterior (D1) and posterior (D4) dorsal muscle reveals that there is significantly higher concentrations of Se, Mn, Zn, Cu, Hg, Pb, and Fe in D1 than in D4. In some cases the difference is consideable as for example in the case of Zn and Mn, where their levels in D1 are two times their levels in D4 on a dry weight basis. In the case of As, howevere, D4 is higher than D1 by a factor of two on a wet weight basis (three times on a dry weight basis). No conclusion could be inferred regarding Ni since the levels are less than the detection limit for most of the samples. For the elements analysed in lateral and posterior muscle (M4.5) (Se, Hg, Zn, As, Cu, Fe, and Mn), all but Mn gave the same result at both D1 and M4.5 while Mn gave two times higher level at M4.5 than D1 on a dry weight basis. These findings need to be taken into consideration when sampling of muscle tissue is planned for the analysis of trace elements in minke whales at least.

No element showed an effect of neither area nor sex for any of the tissues analysed in this study. Hg showed a significant linear increase with length for all the tissues (skin, muscle, liver, and kidney). Hepatic Se-levels increase with length while the Se-levels in skin decrease with length. Cadmium levels increase with length in both livers and kidneys. The cadmium levels in gonads do not show any effect of area, length or sex. The cadmium levels in gonads increase with Cd-levels in both livers and kidneys.

From comparisons with other minke whales stocks it may be concluded that Icelandic minke whales differ from other stocks in the N-Atlantic as regards especially cadmium and mercury levels. Although the hepatic and nephritic cadmium levels of SE-Greenlandic minke whales seem to be similar to their Icelandic counterparts, the cadmium level of muscle tissue is lower in the Icelandic minke whales as are the mercury levels in livers, kisneys and muscle. The Antarctic minke whale differs from the Icelandic minke whales in their hepatic levels of cadmium and selenium as well as higher hepatic levels of copper while the content of copper is lower in the skin of Antarctic compared to Icelandic minke whales. However, Antarctic minkes are much lower in mercury than their N-Atlantic counterparts

When comparing levels in skin and levels in other tissues, no correlation could be found in any of the trace elements studied except in the case of mercury (muscle, livers, and kidneys)

and selenium (only muscle). The mercury level in skin is proportional to the levels of mercury found in muscle tissue and a good correlation is obtained where a relationship close to 1:1 is found if levels in skin are expressed on a dry weight basis and the levels in muscle on a wet weight basis. There is also a fairly good correlation between levels of mercury in skin and levels in both livers and kidneys albeit the relationship is not 1:1. Whether these relationships hold in time or for other stocks of minke whales warrants further studies. Selenium in muscle (wet weight) correlates linearly with levels of selenium in the skin (wet weight) but the intercept and the slope are large. It may therefore be concluded that for the Icelandic minke whales at least, that skin biopsies are generally not valid for predicting trace element concentrations in internal organs except in the case of total mercury in muscle tissue.

Introduction

The common minke whale (*Balaenoptera acutorostrata*) is the most abundant baleen whale species in the Icelandic continental shelf area. Like other baleen whales, minke whales are migratory animals spending the summer at relatively high latitude feeding areas and the winters at lower latitude breeding areas (Horwood, 1990). Minke whales are found all around the North Atlantic during summer, from Canada to the North Sea, Svalbard and to Novaya Zemlya region of the western Russian arctic (Hobbs *et al*., 2003). Minke whales are also found in the Pacific and in the Antarctic although as a different species there (*Balaenoptera bonaerensis)*. This renders them a suitable species to monitor pollutants in a comparable way across vast marine areas of the earth but marine mammals have often been used for detecting both spatial and temporal trends in inorganic pollutants (Bowles, 1999). Various studies have used differences in levels of contaminants to identify different stocks of marine mammals (Born *et al*., 2003). The use of biopsies have been discussed as a tool for monitoring contaminants in marine mammals and some validation trials have been carried out for organochlorines (Gautier *et al*., 1997a; Gautier *et al*., 1997b; SC/F13/SP22) but none to our knowledge on trace elements.

The objectives of this study were to examine whether there was a difference between minke populations within Icelandic water with respect to trace elements, to see if the Icelandic stock differed from other minke whale stocks in the North Atlantic, as well as in the Antarctic and N-Pacific, and finally to validate biopsies for monitoring trace elements in the Icelandic minke whale stock.

The study is a part of a wide ranging research programme on the biology and feeding ecology of minke whales in Icelandic waters (Marine Research Institute 2003).

Materials and methods

Sampling

Sampling of minke whales for trace elements took place in the years 2003 and 2004. The animals selected for this study represented the areas north and south of Iceland, equal sex ratios from both areas and as large a length span as was possible. Samples were taken of meat, kidneys, livers, skin (as a biopsy), and gonads. Sampling took place at D4 for skin and muscle and additional samples of meat at D1, see Figure 1. The samples of meat were taken underneath the blubber sample while samples of livers and kidneys were taken from the middle of the organs. The size of each sample was about 1 kg except for the gondas where only small pieces were taken, packed in two plastic bags, sample marking in the outer bag. Both blubber and meat were frozen at -20°C until the samples were preapared for analysis.

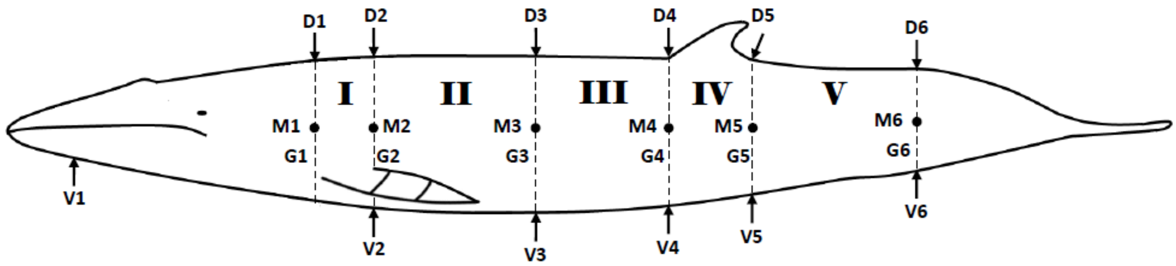

Figure 1. Sampling for organic contaminants were taken at D4 (Figure from SC/F13/SP8)

Sample preparation

The samples were homogenized in a mincing machine (steel bowl and knives). After thawing, slices of tissues were taken from all sides of the samples before they were minced. Since many of the samples were also used for organic contaminants (SC/F13/SP22), the cleaning was first done by acetone and water after which the bowl and knives were washed with a mixture of 2% Na_2EDTA/2% Na_3citrate and finally with ample amounts of water.

Analysis

The elements As, Se, Hg, Cd, Pb, Cu, Cr, Ni, Mn, Fe and Zn were analysed in all tissues except for the gonads which were only analysed for cadmium.

Digestion of samples for all elements except As, Se, and Hg were either done in quartz acid digestion bombs (Uhrberg, 1983) or by dry ashing (Jorhem and Sundström, 1993; Jorhem. 2000) where all samples for Cd, Zn, Cu, Mn, and Zn were digested in bombs while all samples for Pb, Ni, and Cr were digested by dy ashing. Thses elements were analysed by FAA by Perkin Elmer 1100B using impact bead and D_2-backgriund correction.

The analysis of mercury was carried out by CVAA based on the digestion method of Hatch and Ott (1968) and analysed by Coleman MAS-50 coupled to Perkin Elmer 1100B.

The analysis of As and Se were carried out by HGAA (MHS-20 connected to Perkin Elmer 430) by sodium borohydride after digestion in a $Mg(NO_3)_2$-melt and dry ashing. Subsamples of the resulting solution was treated with hydrochloric acid prior to analysis of Se to convert all Se to selenite. Due to high concentratioins of Se in the skin samples, the analysis of As in skin was carried out after treating the solutions with potassium iodide to reduce Se to its metal form.

All samples were analysed in duplicate, different weights of samples used each time to ascertain proportionality and/or linearity of the results.

Several certified reference materials were used as well as standard additions to all tissue types and all elements analysed. The reference materials were bovine liver (BCR-185R), pig kidney (BCR-186), bovine muscle (BCR-184), DORM-2, DOLT-3, and TORT-2. In all cases were satisfactory recoveries obtained for all the trace elements. Additionally, the laboratory participated sucessfully in a proficiency testing for trace elements in foods coordinated by the National Food Administration, Sweden.

Results and discussions

The results are summarised in Table 1.

Variability in element results in muscle across the animals

In many cases were there differences between results for the muscle samples at the three different sampling sites. Comparison of D1 and D4 reveals that there is significantly higher concentrations of Se, Mn, Zn, Cu, Hg, Pb, and Fe in D1 than in D4 (paired two sided t-test; $p<0.05$), both on a wet weight basis and dry weight basis. In some cases the difference is consideable as for example in the case of Zn and Mn, where their levels in D1 are two times their levels in D4 on a dry weight basis. However, the levels are equal in the case of Cr and Cd on a wet weight basis while Cd is higher in D1 than D4 on a dry weight basis. In the case of As, D4 is higher than D1 by a factor of two on a wet weight basis (three times on a dry weight basis). No conclusion could be inferred regarding Ni since the levels are less than the detection limit for most of the samples.

For the elements analysed in M4.5 (Se, Hg, Zn, As, Cu, Fe, and Mn), all but Mn gave the same result at both D1 and M4.5 (paied two sided t-test; $p>0.05$) while Mn gave two times higher level at M4.5 than D1.

These findings need to be taken into consideration when sampling of muscle tissue is planned for the analysis of trace elements.

Effect of sex, length and area within Icealndic waters

Log-transformed concentrations were linearly regressed on length, sex, and area for all the tissue types. None of the elements showed an effect of neither area nor sex for any of the tissues analysed in this study.

Hg showed a significant linear increase with length ($p<0.05$) for all the tissues (skin, muscle, liver, and kidney), and, additionally, decreased with level of Se in skin.

Hepatic Se-levels increase with length while the Se-levels in skin decrease with length.

Cadmium levels increase with length in both livers and kidneys. The cadmium levels in gonads do not show any effect of area, length or sex, *i.e.* the levels are the same in both ovaries and testes (t-test; $p>0.05$). The cadmium levels in gonads (log-transformed) increase linearly with Cd-levels in livers, kidneys and muscle.

There is a significant correlation ($p<0.05$) between levels in kidneys and livers for Se, As, Cd, Cu, Hg, Mn, and Zn (but not for Cr, Fe, and Pb).

Table 1. Levels of elements in minke whale tissues ona wet weight basis. Note the different units for elements.

	n	Tissue	Unit	Mean	SD		n	Tissue	Unit	Mean	SD
Se	23	Skin	µg/g	7,55	4,96	**Fe**	23	Skin	µg/g	7	5
	25	Liver	µg/g	1,61	0,31		24	Liver	µg/g	120	121
	25	Kidney	µg/g	1,54	0,32		23	Kidney	µg/g	70	49
	25	D1 muscle	µg/g	0,22	0,06		23	D1 muscle	µg/g	52	21
	22	D4 muscle	µg/g	0,19	0,03		22	D4 muscle	µg/g	36	16
	11	M4,5 muscle	µg/g	0,22	0,05		11	M4,5 muscle	µg/g	48	16
As	23	Skin	µg/kg	267	122	**Mn**	24	Skin	µg/g	0.067	0.040
	25	Liver	µg/kg	324	173		25	Liver	µg/g	3,91	1,06
	25	Kidney	µg/kg	182	77		24	Kidney	µg/g	0,99	0,41
	25	D1 muscle	µg/kg	105	51		24	D1 muscle	µg/g	0,11	0,02
	23	D4 muscle	µg/kg	315	257		23	D4 muscle	µg/g	0,08	0,02
	11	M4,5 muscle	µg/kg	162	122		11	M4,5 muscle	µg/g	0,23	0,10
Cd	20	Skin	µg/g	0,02	0,01	**Ni***	20	Skin	µg/kg	51	25
	25	Liver	µg/g	1,97	0,87		25	Liver	µg/kg	<1-12	
	24	Kidney	µg/g	9,8	4,7		25	Kidney	µg/kg	<1-15	
	25	D1 muscle	µg/g	0,017	0,009		5	D1 muscle	µg/kg	<1	
	23	D4 muscle	µg/g	0,014	0,010		24	D4 muscle	µg/kg	<1-4	
	17	M4,5 muscle	µg/g	0,83	0,65						
	8	Ovaries	µg/g	0,62	0,58	**Pb**	23	Skin	µg/kg	164	40
	11	Testes	µg/g	0,84	0,74		25	Liver	µg/kg	27	15
							25	Kidney**	µg/kg	30	20
Cr	22	Skin	µg/kg	415	383		7	D1 muscle	µg/kg	47	14
	23	Liver	µg/kg	21	29		24	D4 muscle	µg/kg	28	11
	25	Kidney	µg/kg	9	4						
	7	D1 muscle	µg/kg	27	15	**Zn**	24	Skin	µg/g	15,5	2,3
	24	D4 muscle	µg/kg	29	12		25	Liver	µg/g	32,9	5,5
							24	Kidney	µg/g	21,9	3,7
Cu	24	Skin	µg/g	0,59	0,10		25	D1 muscle	µg/g	11,2	3,0
	25	Liver	µg/g	4,02	0,93		23	D4 muscle	µg/g	7,6	2,4
	24	Kidney	µg/g	2,57	0,49		11	M4,5 muscle	µg/g	8,5	2,5
	25	D1 muscle	µg/g	0,59	0,09						
	23	D4 muscle	µg/g	0,41	0,10						
	11	M4,5 muscle	µg/g	0,60	0,10						
Hg	24	Skin	µg/kg	40	21						
	25	Liver	µg/kg	372	255						
	25	Kidney	µg/kg	285	179						
	25	D1 muscle	µg/kg	119	64						
	23	D4 muscle	µg/kg	107	72						
	11	M4,5 muscle	µg/kg	99	42						

*For Ni only few results were above detection levels apart from the skin: 3 in the case of livers, 6 in the case of kidneys, none in case of D1 muscle, and 2 in the case of D4 muscle. Therefore, only ranges are give for theses tissues for Ni.

**For Pb in kidneys, six samples were below the detection limit of 6 µg/kg ww (treated as zero when calculating mean and SD).

Comparisons with other minke whale stocks

Mercury

Figure 2 shows the levels of mercury in different tissues of the minke whale where it is seen that livers and kidneys have higher levels than muscle and especially skin. Figure 3 shows the

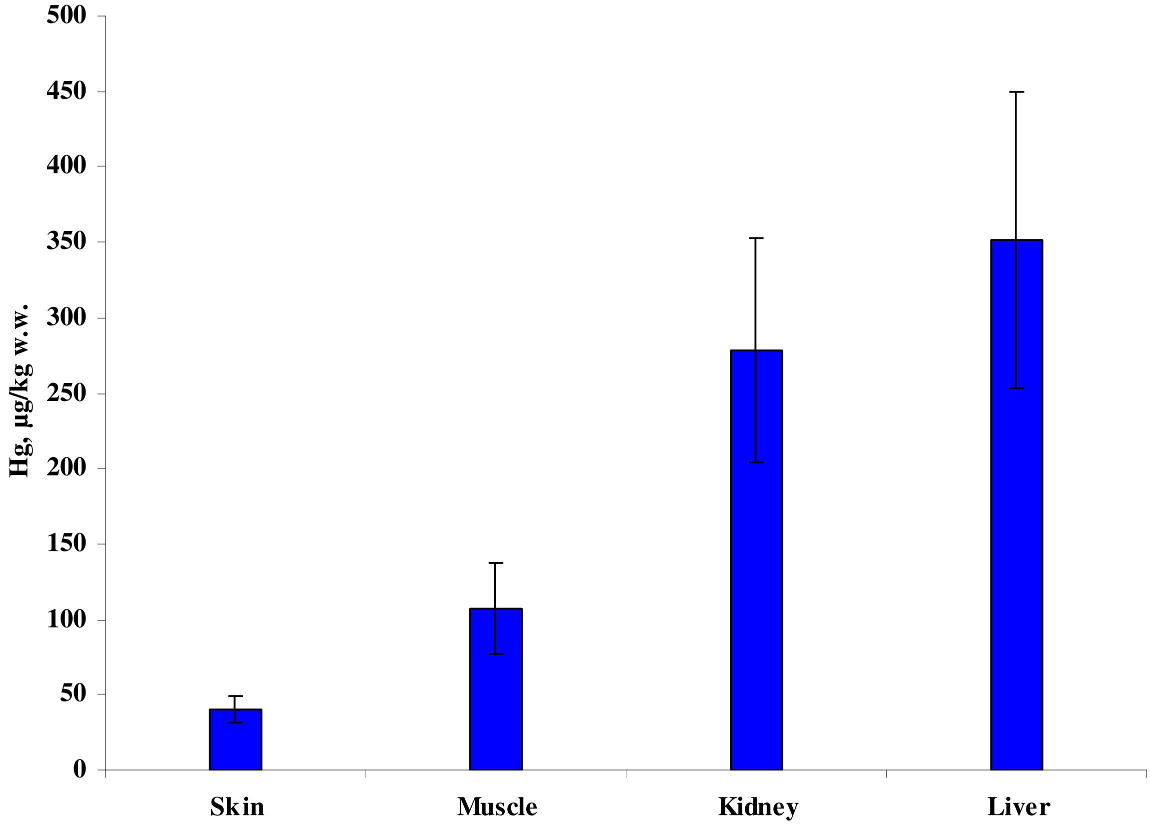

Figure 2. Mercury in tissues of minke whales on a wet weight basis from Icelandic waters.The bars of each column represent 95% confidence intervals.

comparison between mercury levels in livers of minke whale stocks from the N-Atlantic and the Antarctic. Similar hepatic mercury levels as those shown for the Antarctic minke whale were found for 19 southern minke whales by Kunito *et al.* (2002). Mean hepatic mercury levels in Antarctic minke whales on a wet weight basis were found to be between 23.7 (1- 5 years) and 92.6 µg/kg (26 years) (*Honda et al.* 2006), lower than that of the Icelandic minke whales, 69-1162 µg/kg wet weight. The hepatic mercury levels in the Icelandic stock are similar to those of SW-Greenland and Barents Sea, higher than the level found in the Antarctic minke whales and at Svalbard while the minke whale populations at SE-Greenland, Jan Mayen, Lofoten, and North Sea are higher in hepatic mercury.

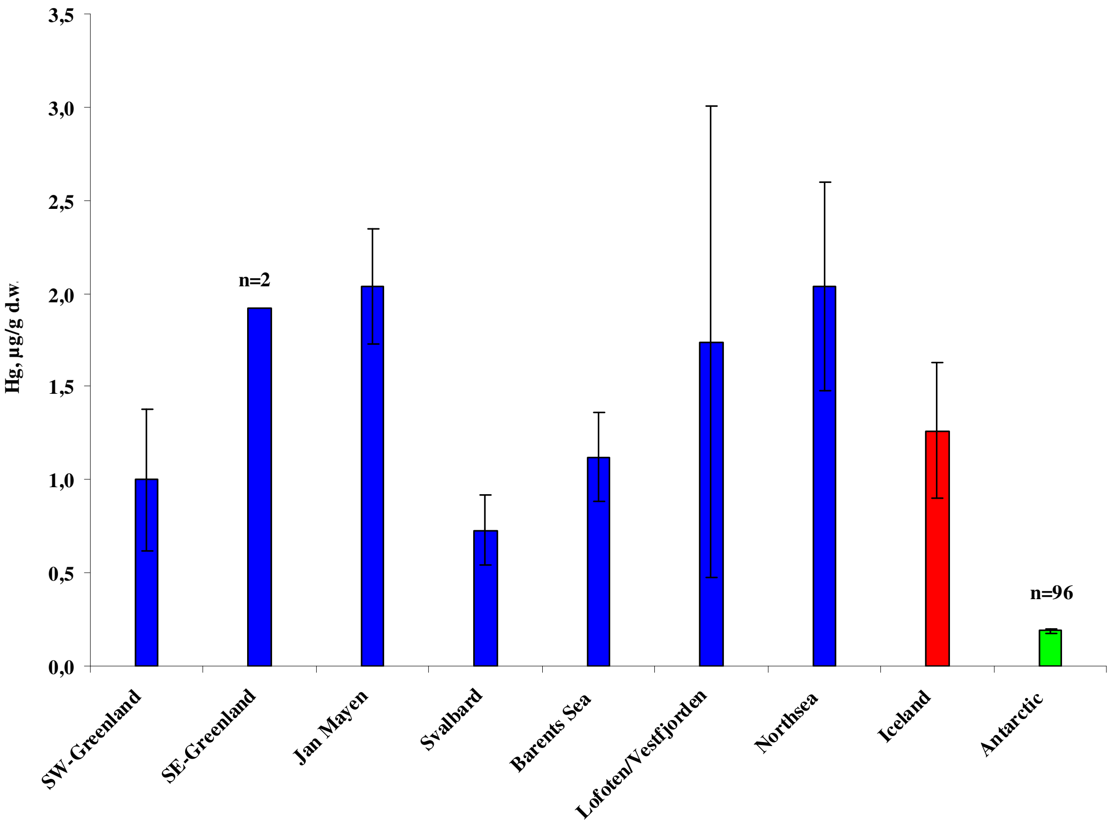

Figure 3. Mercury in livers of minke whales from the N-Atlantic and the Antarctic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003) while the data for the Antarctic derive from Honda *et al.* (1987).

The trends revealed in Figure 3 are also borne out for nephritic and muscular levels of mercury, Figures 4 and 5. Mercury levels in muscle tissue of 23 N-Pacific minke whales on the Korean market was evaluated from data of Endo *et al.* (2007) and found to be 0.23±0.11 (SD) µg/g wet weight, which is significantly higher (t-test; p<<0.05) and twice the value for the 25 Icelandic minke whales, 0.12±0.06 (SD) wet weight.

Skin from southern minke whales was found to contain 76±37 (SD) µg/kg dry weight in males (n = 117) and 55±21 (SD) µg/kg dry weight in females (n = 35) (Kunita *et al*., 2002) to be compared with 133±72 (SD) µg/kg of 24 Icelandic minke whales. These values for the Antarctic minke whales are lower than those of the Icelandic minke whale but the difference is much less than that found for the hepatic levels in Figure 3.

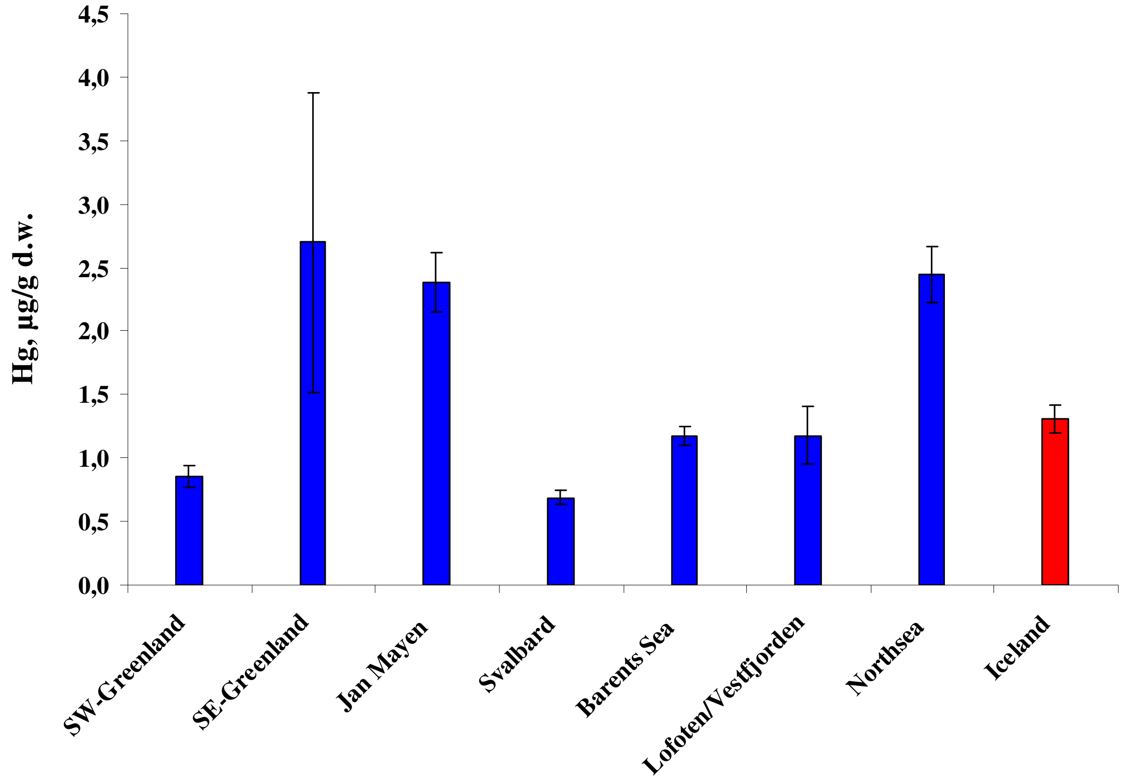

Figure 4. Mercury levels in kidneys of minke whales from the N-Atlantic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003).

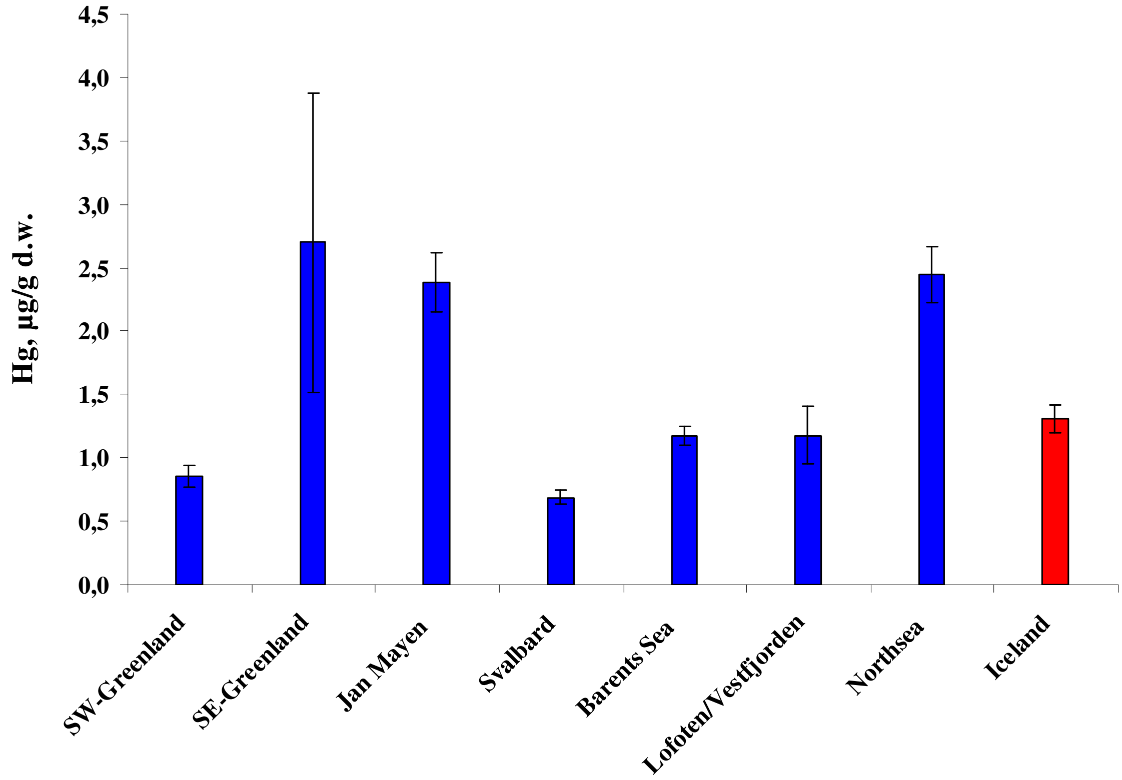

Figure 5. Mercury levels in muscle tissue of minke whales from the N-Atlantic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003).

Cadmium

Figure 6 shows the levels of cadmium in different tissues of the Icelandic minke whales where it can be seen that the levels in kidneys with the highest levels are about 1000 time higher than the lecels found in muscle and skin.

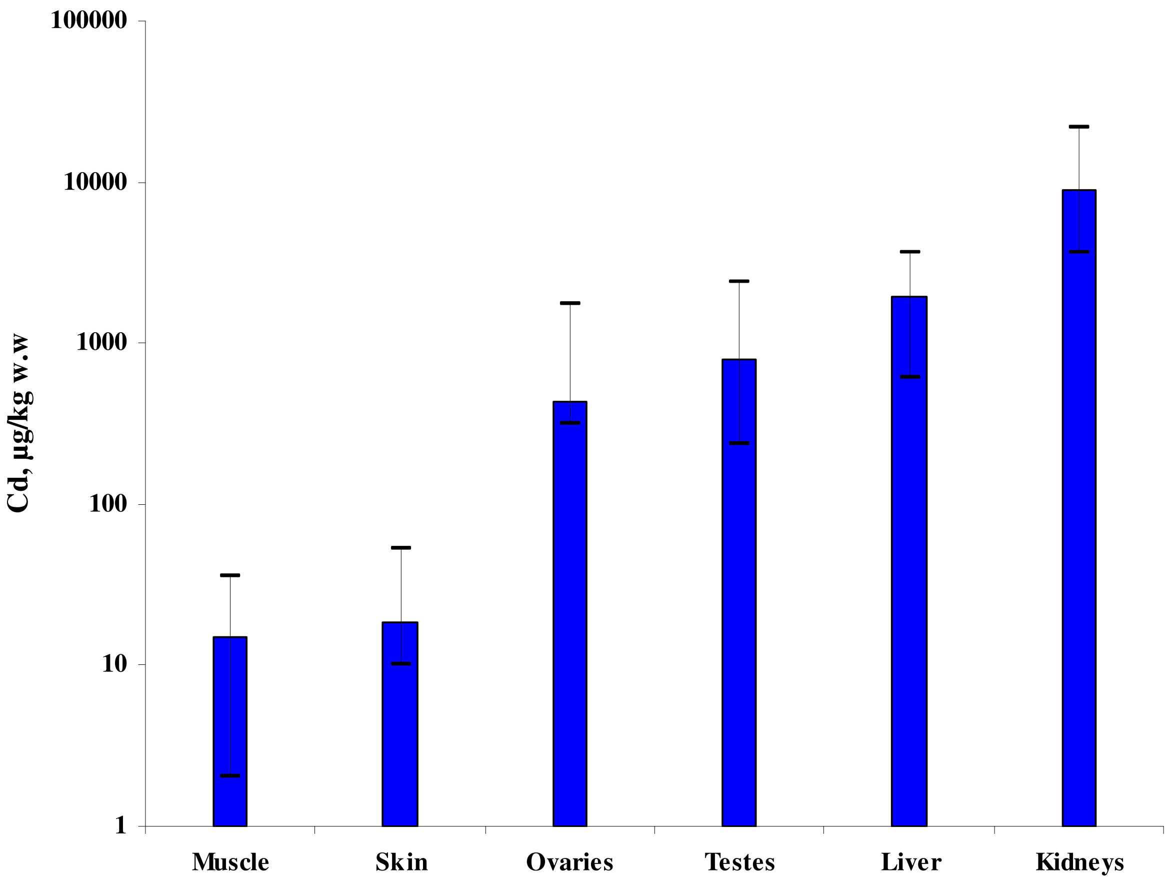

Figure 6. Levels of cadmium in tissues of minke whales on awet weight basis. The bars on each column represent minima and maxima of the values. Note the logaritmic y-axis.

Figure 7 shows the comparison of hepatic cadmium levels in minke whales of the N-Atlantic where it can be seen that the levels are highest in the Icelandic minke whales livers but a trend in levels is seen from SE-Greenland to the east and south, the levels being lowest in the North Sea. The hepatic levels of minke whales of W-Greenland have been found to be of median value 0.90 (0.50-14.45) µg/g wet weight (n = 17) (Hansen *et al*., 1990), which is lower than that for the Icelandic minke whales: 1.9 (0.61-3.6). Higher levels of hepatic cadmium levels in fin whales (*B. Physalus*) from Iceland compared to fin whales from Spanish waters were found by Sanpera *et al.* (1996). However, when compared with hepatic cadmium levels in Antarctic minke whales, the levels in the southern ocean is much higher than those found in Icelandic waters and the N-Atlantic, Figure 8. The levels in the Antarctic are very high compared to the N-Atlantic but somewhat lower values have been found by Honda *et al.* (1986 and 1987) while their upper ranges are similar to those found by Kunita *et al.* (2002). Figures 9 and 10 show the nephritic and muscular levels of cadmium in the N-Atlantic and seen that the kidneys reveal the same picture as the livers while the muscle tissue has a totally different pattern to that of livers and kidneys where the lowest values are found in Icelandic minke whales, which are similar to those of the North Sea and Lofoten.

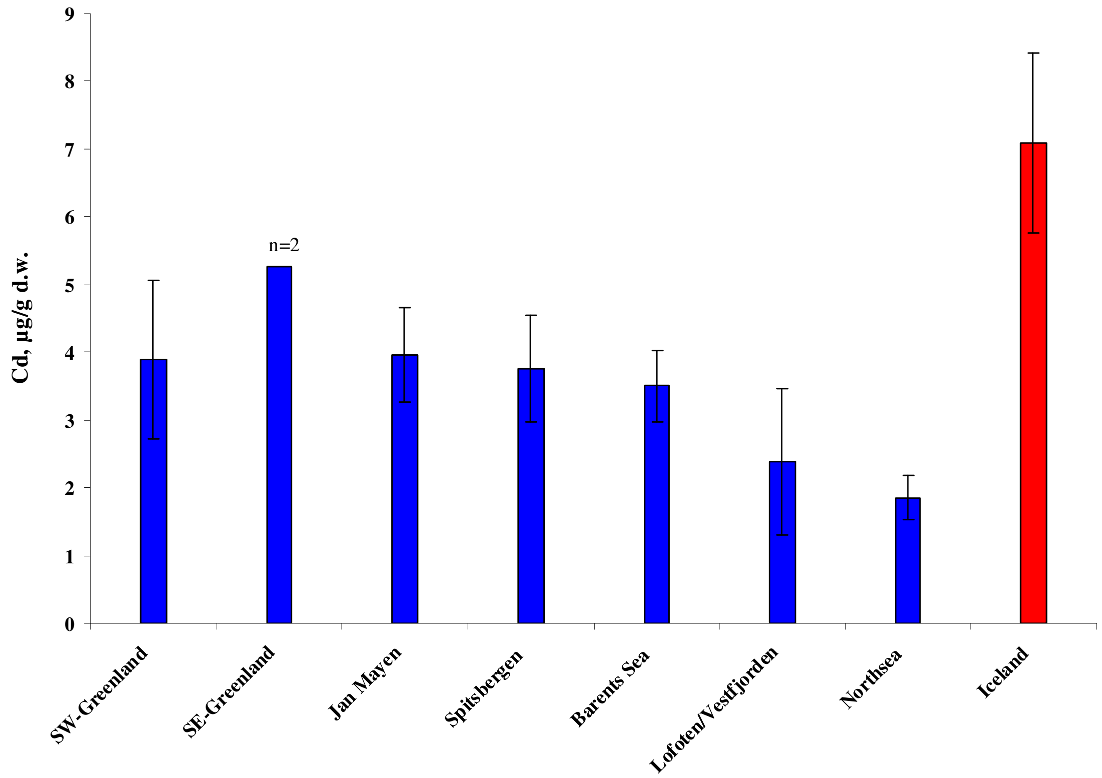

Figure 7. Cadmium levels in livers of minke whales from the N-Atlantic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003).

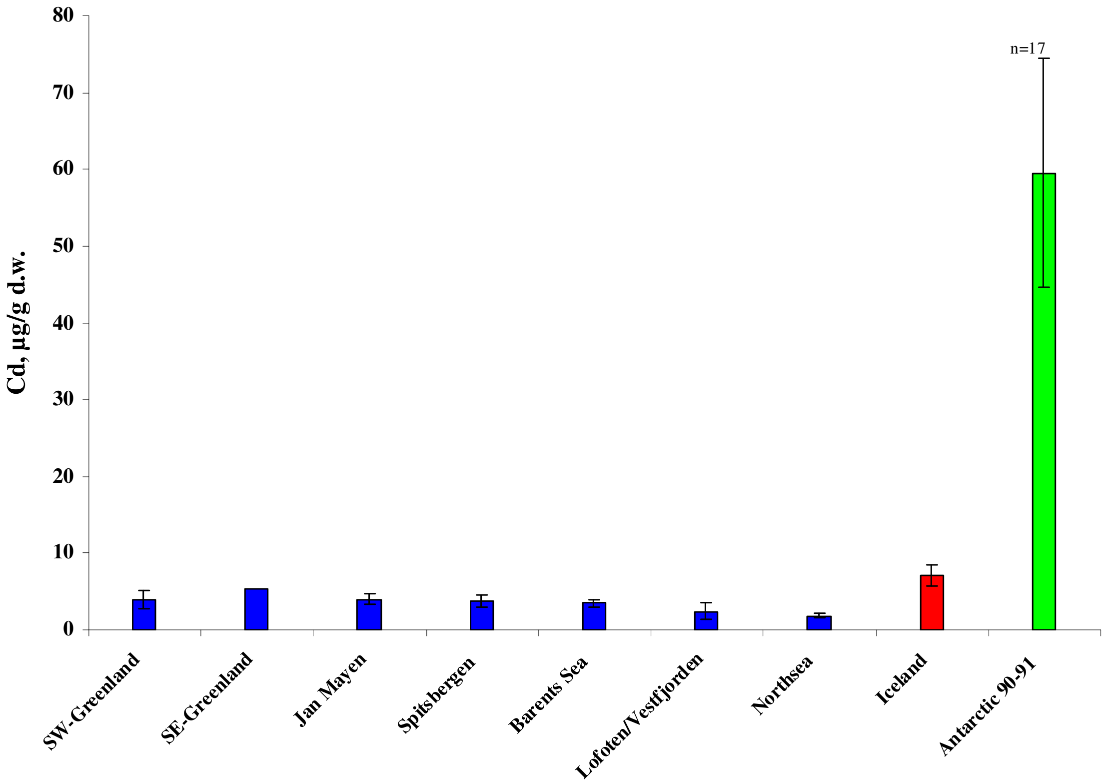

Figure 8. Cadmium levels in livers of minke whales from the N-Atlantic and the Antarctic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003) while the datat from the Antarctic derive from Kunita et al. (2002).

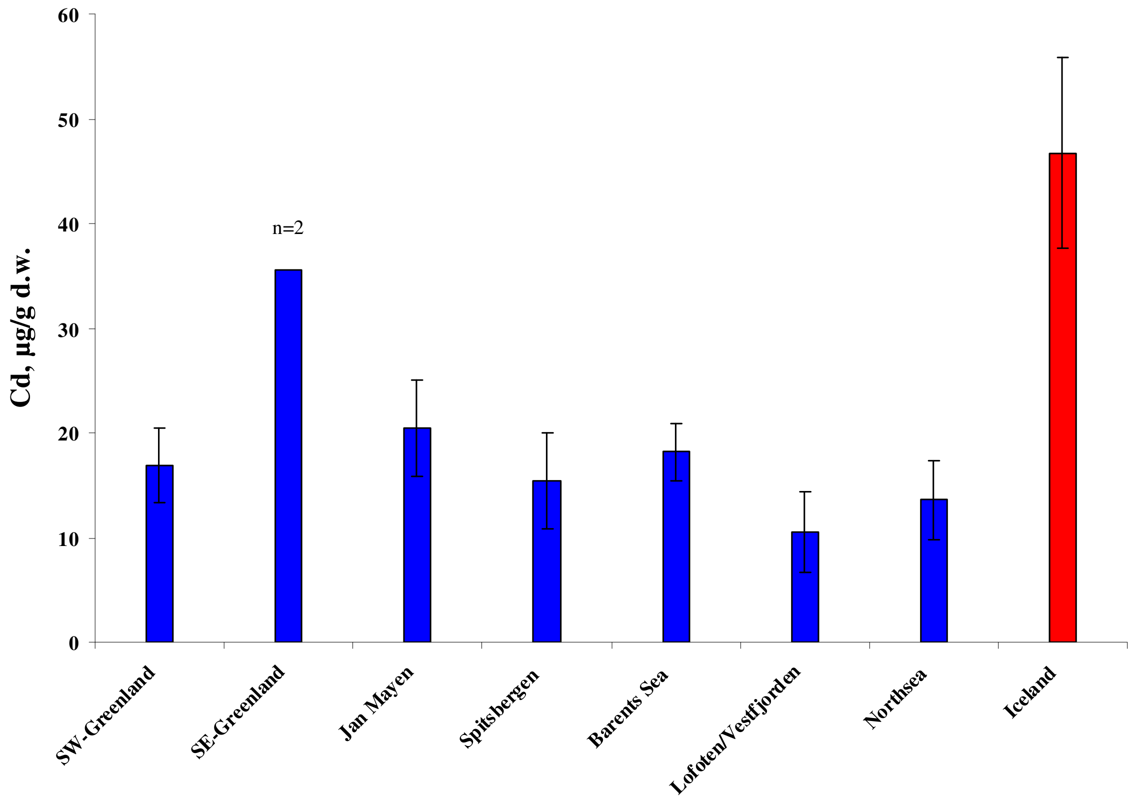

Figure 9. Cadmium levels in kidneys of minke whales from the N-Atlantic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003).

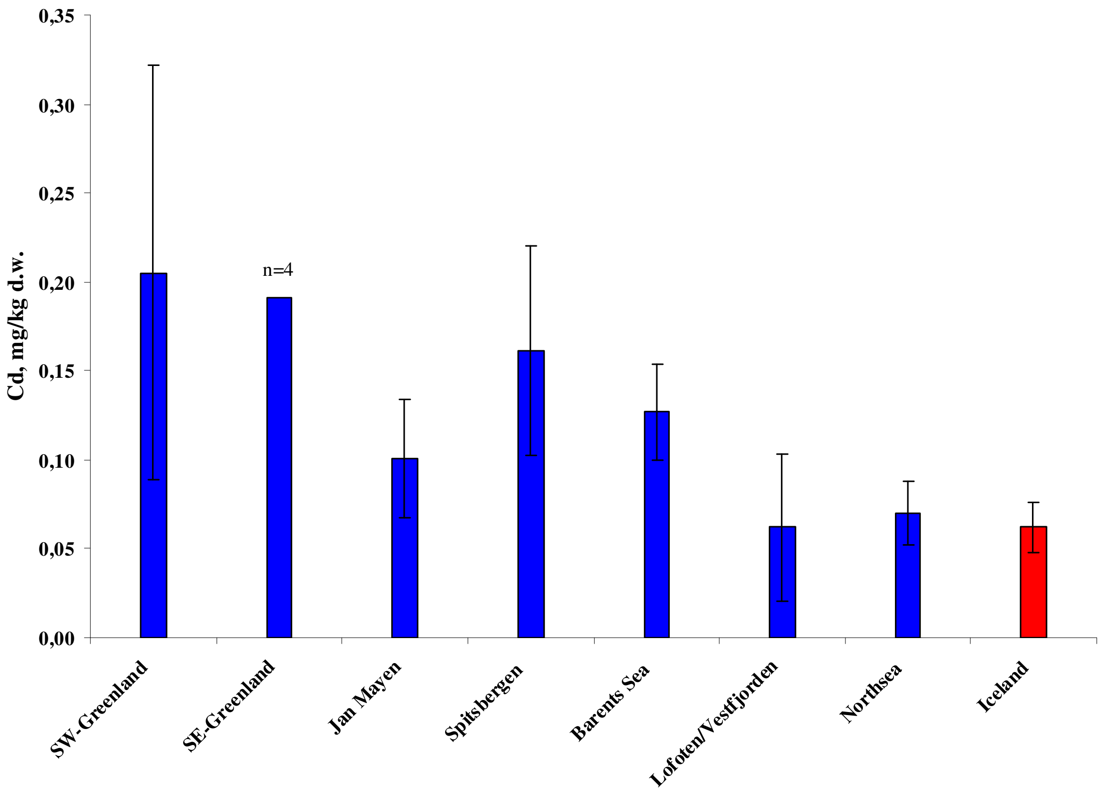

Figure 10. Cadmium levels in muscle tissue of minke whales from the N-Atlantic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003).

Selenium

Figure 11 shows the levels of selenium in different tissues of the Icelandic minke whale revealing the very high concentrations in the skin.

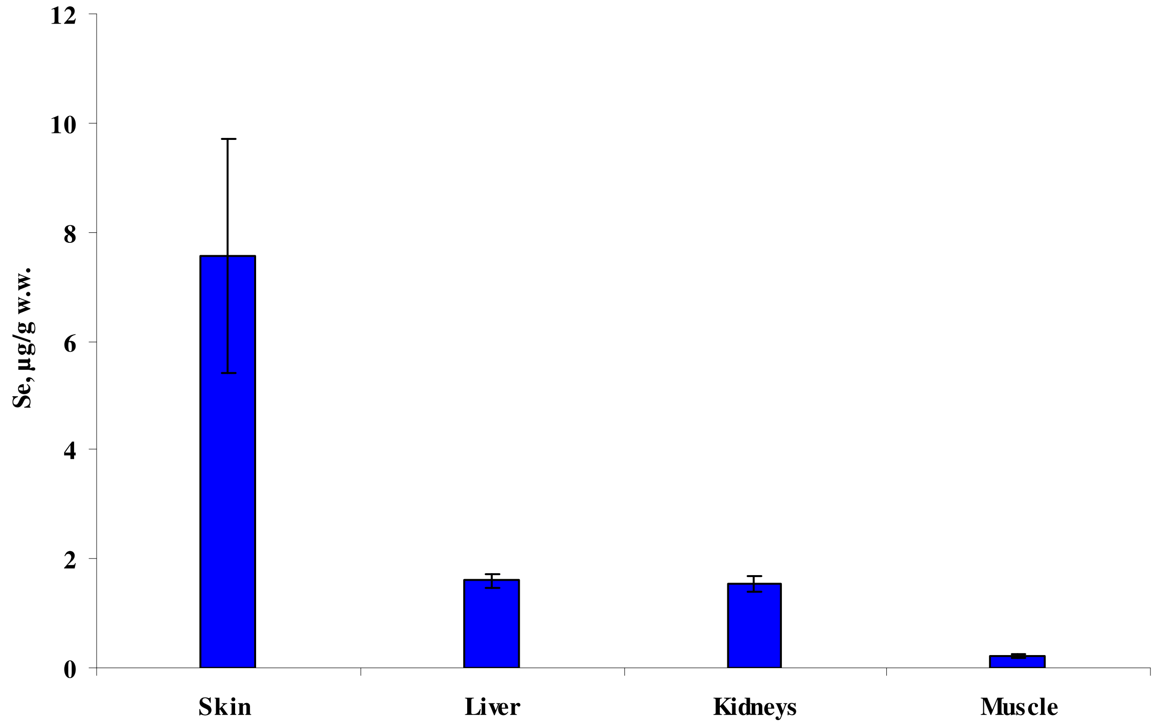

Figure 11. Levels of selenium in tissues of minke whales on awet weight basis. The bars on each column represent 95% confidence limits.

In Figure 12 comparison is made between hepatic selenium levels in Icelandic minke whales and other stocks in the N-Atlantic and in the Antarctic revealing fairly similar levels in all the the N-Atlantic stocks while the level in the Antarctic is much higher. Thus, as selenium like cadmium are at much higher levels in the Antarctic than in the N-Atlantic. The levels in kidneys and muscle tissue of the N-Atlantic minke whales show the same general pattern as the livers, Figures 13 and 14.

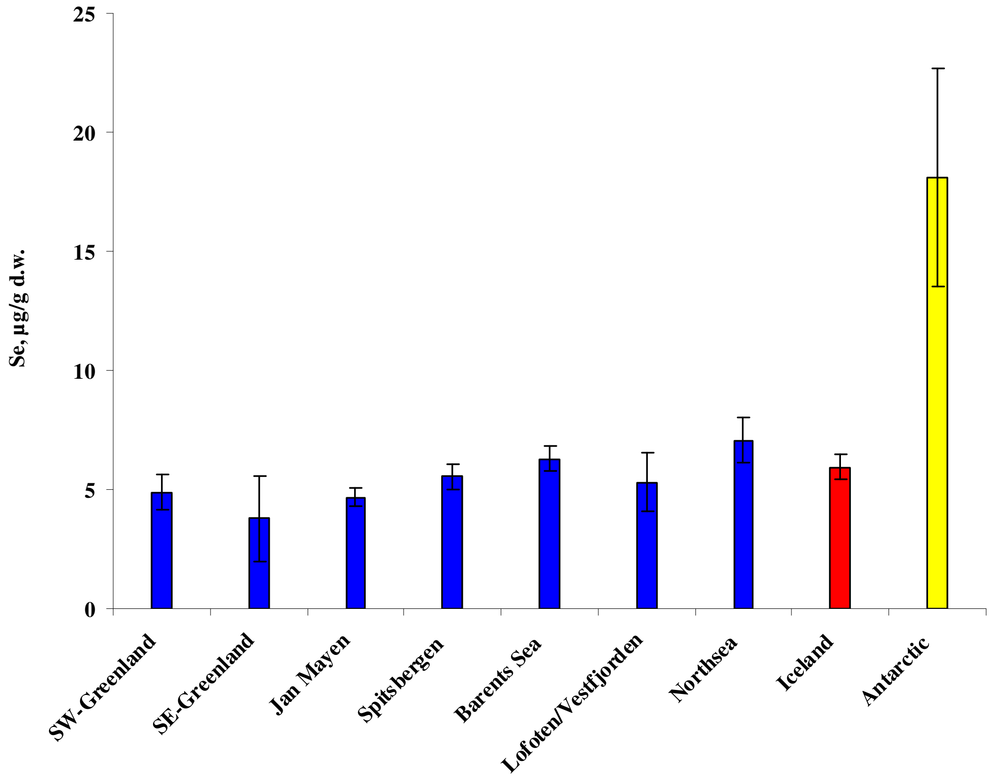

Figure 12. Selenium levels in livers of minke whales from the N-Atlantic and the Antarctic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003) while the datat from the Antarctic derive from Kunita *et al*. (2002).

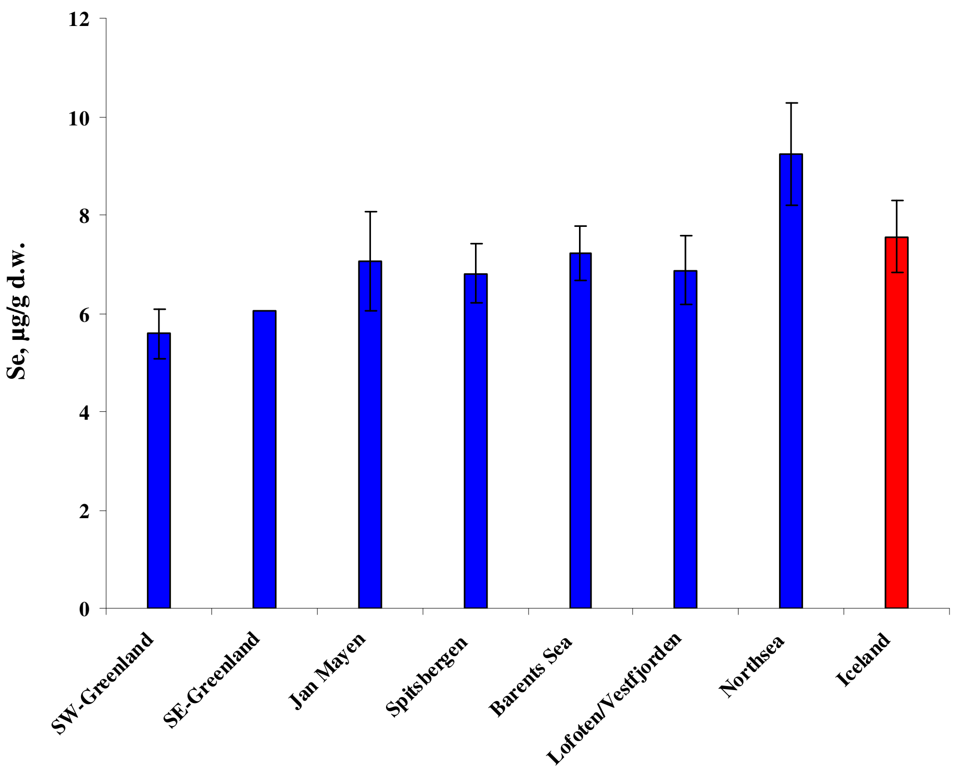

Figure 13. Selenium levels in kidneys of minke whales from the N-Atlantic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003).

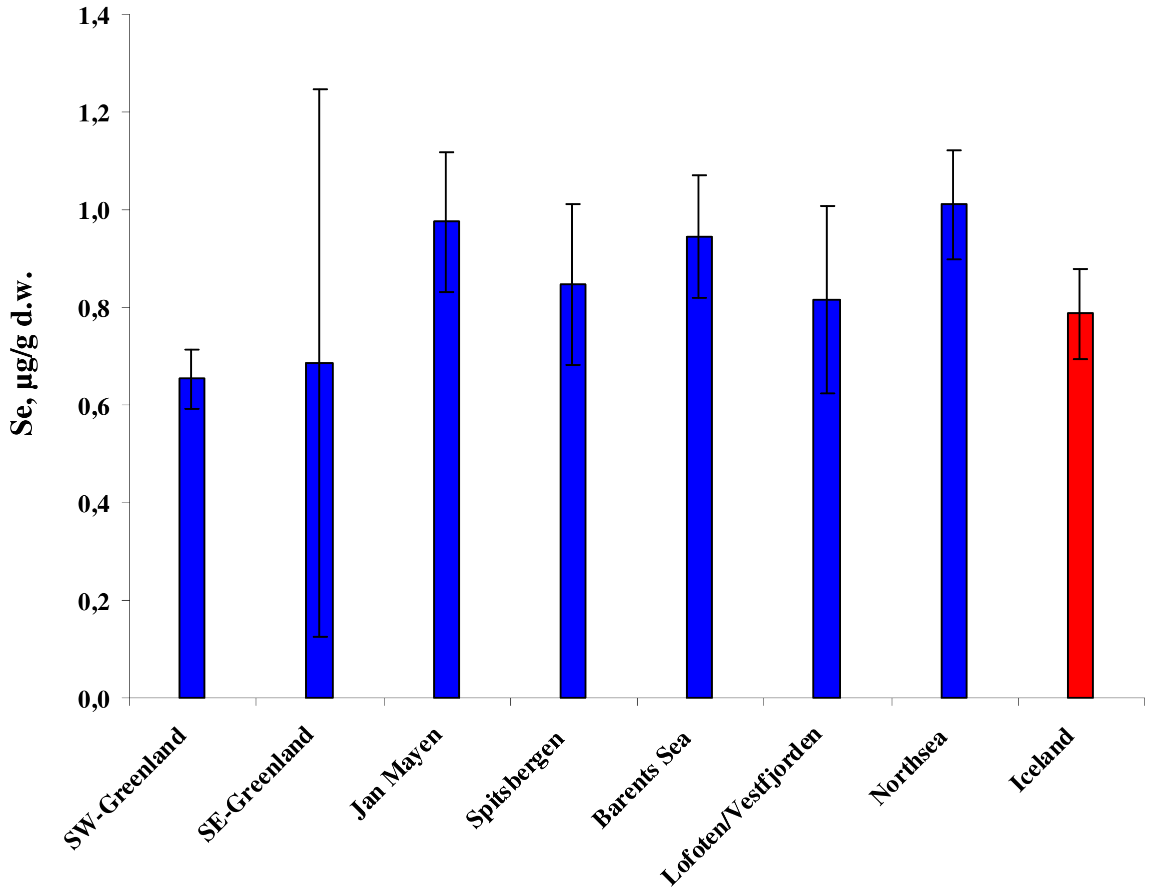

Figure 14. Selenium levels in muscle tissue of minke whales from the N-Atlantic on a dry weight basis. The bars on each column represent the 95% confidence intervals. Data blue column data derive from Born *et al.* (2003).

Zinc

The zinc concentrations in different tissues of the Icelandic minke whale are shown in Figure 15, muscle with highest level and liver with the highest level.

Compared with W-Greenlandic minke whales, where hepatic median level was found to be 34.5 µg/g w.w., ranging 26.4-48.0 (n = 17) (Hansen *et al.*, 1990) , the Icelandic minke whales are very similar with a median 33.0 and ranging 21.8-42.5 µg/g w.w. Levels of zinc in kidneys and muscle of the W-Greenlandic minke whales are also very similar to those of the Icelandic minke whale.

The Antarctic minke whale was found to contain hepatic zinc-level with an average of 186±49 (SD) µg/g d.w., ranging 117-282 (n = 17) (Kunita *et al.*, 2002). Similar but somewhat lower hepatic zinc levels were also found in Antarctic minke whales by Honda *et al.* (1987), average 142±25 (n=96) and 156±31 (n=39) for males and females, respectively. These levels are somewhat higher than in the Icelandic minke whales where the average hepatic zinc level is 119±22 (SD) µg/g d.w., ranging 72-158 µg/g d.w.

Skin of Antarctic minke whales have average values of 67±19 (n=122) and 62±10 (n=39) µg/g d.w. for males and females, respectively (Kunita *et al.*, 2002), similar to the Icelandic minke whale, 57±7 µg/g d.w.

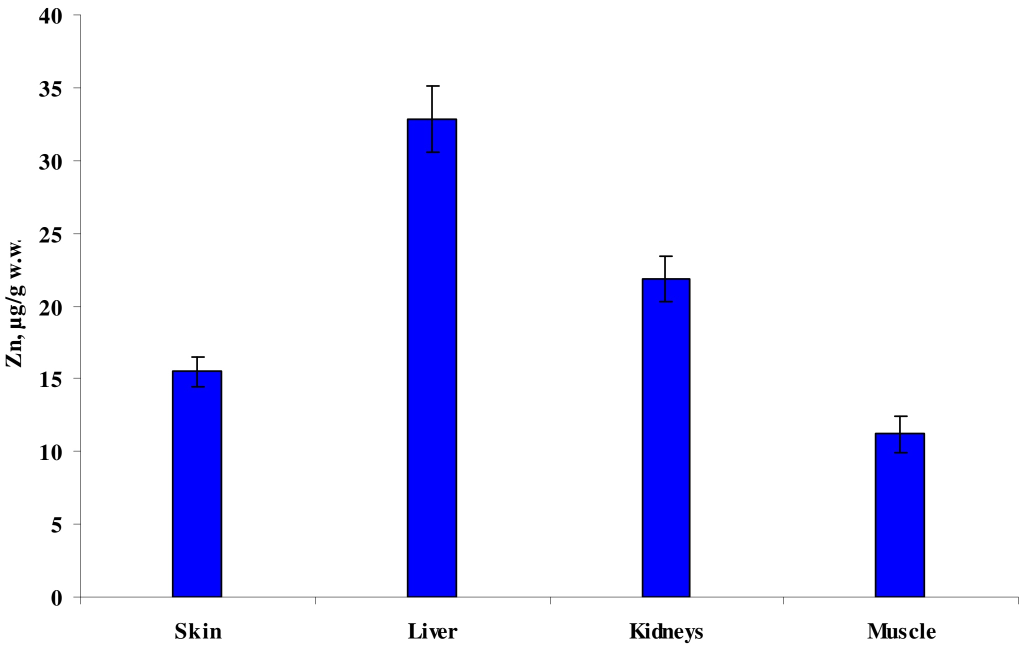

Figure 15. Levels of zinc in tissues of minke whales on awet weight basis. The bars on each column represent 95% confidence limits.

Chromium

Chromium levels found in livers of Antarctic minke whales were 6.88±2.71 (SD) (2.86-6.39) µg/g d.w. for 17 males (Kunita *et al*., 2002), much higher values than found in this study for the Icelandic minke whales: 0.08±0.12 (SD) (0.01-0.63) µg/g d.w. However, levels of chromium on a dry weight basis in the skin of Antarctic minke whales were found by Kunita *et al*. (2002) to be 2.26±1.15 (SD) (n=122) for males and 2.06±1.15 (SD) (n=39 for females, similar to the levels in skin of the Icelandic minke whale: 1.40±1.32 (0.31-4.88) µg/g d.w.

Lead

Lead levels in Antarctic minke whale livers were 0.41±0.14 (SD) (0.15-0.79) (n=96) and 0.42±0.22 (SD) (0.11-2.55) (n=39) µg/g d.w. in males and females, respectively (Honda *et al*., 1987) while the Icelandic minke whale has much lower hepatic lead level of 0.09±0.05 (0.03-0.24) µg/g d.w.

Copper

Copper levels found in livers of Antarctic minke whales were 24.2±8.1 (SD) (14.8-42.4) µg/g d.w. for 17 males (Kunita *et al*., 2002), higher values than found in this study for the Icelandic minke whales: 14.6±3.2 (SD) (9.5-22.1) µg/g d.w. Somewhat lower levels of copper in Antarctic minke whale livers were found by Honda *et al.* (1987). However, levels of copper on a dry weight basis in skin of Antarctic minke whales were found by Kunita *et al*. (2002) to be 1.57±0.78 (SD) (n=122) for males and 1.25±0.67 (SD) (n=39 for females, lower levels than in skin of the Icelandic minke whale: 2.0±0.3 (SD) (1.56-2.76) µg/g d.w.

Manganese

Manganese levels found in livers of Antarctic minke whales were 18.6±6.2 (SD) (9.99-31.9) µg/g d.w. for 17 males (Kunita *et al*., 2002), somewhat higher values than found in this study for the Icelandic minke whales: 14.3±4.2 (SD) (7.31-24.47) µg/g d.w. Somewhat lower levels in Antarctic minke whale livers than their Icelandic counterparts were found by Honda *et al.*

(1987): 10.0±.2.5 (SD) µg/g d.w. for 96 males and 10.1±2.4 (SD) µg/g d.w. for 39 females. However, levels of manganese on a dry weight basis in skin of Antarctic minke whales were found by Kunita *et al*. (2002) to be 0.135±0.089 (SD) (n=122) for males and 0.097±0.059 (SD) (n=39 for females, lower levels than in skin of the Icelandic minke whale: 0.23±0.13 (0.07-0.53) µg/g d.w.

Iron

Iron in livers of Antarctic minke whales was found to be 5.34±5.76 (SD) (0.06-32.1) mg/g d.w. in males (n=96) and 1.94±1.81 (SD) (0.11-6.40) mg/g d.w. in females (n=39) (Honda *et al*., 1987), similar to their counterpart in Icelandic waters: 4.43±4.73 (SD) (0.12-18.61) mg/g d.w.

Arsenic and nickel

No comparable data could be found for these elements in minke whale tissues.

In summary it may be concluded that Icelandic minke whales differ from other stocks in the N-Atlantic as regards especially cadmium and mercury levels. Although the hepatic and nephritic cadmium levels of SE-Greenlandic minke whales seem to be similar to their Icelandic counterparts, the cadmium level of muscle tissue is lower in the Icelandic minke whales as are the mercury levels in livers, kisneys and muscle. The Antarctic minke whale differs from the Icelandic minke whales in their heepatic levels of cadmium and selenium as well as higher hepatic levels of copper while the content of copper is lower in the skin of Antarctic compared to Icelandic minke whales.

Biopsies

When comparing levels in skin and levels in other tissues, no correlation could be found in any of the trace elements studied except in the case of mercury (muscle, livers, and kidneys) and selenium (only muscle). The mercury level in skin is proportional to the levels of mercury found in muscle tissue and a good correlation is obtained where a relationship close to 1:1 is found if levels in skin are expressed on a dry weight basis and the levels in muscle on a wet weight basis, Figure 16. The 95% CI of the slope is 0.84-0.94. There is also a fairly good correlation between levels of mercury in skin and levels in both livers and kidneys albeit the relationship is not 1:1. Regression of mercury in livers and kidneys on their levels in skin (dry weight basis) gave a slope of about three in the case of liver and a slope of about two in the case of kidneys. Whether these relationships hold in time or for other stocks of minke whales warrants further studies. Selenium in muscle (wet weight) correlates linearly with levels of selenium in the skin (wet weight) but the intercept and the slope are large, *i.e.* an intercept of 158±13 (SE) µg/kg w.w. and a slope of 8.4±1.4, Figure 17.

It may therefore be concluded that for the Icelandic minke whales at least, that skin biopsies are generally not valid for predicting trace element concentrations in internal organs except in the case of total mercury in muscle tissue.

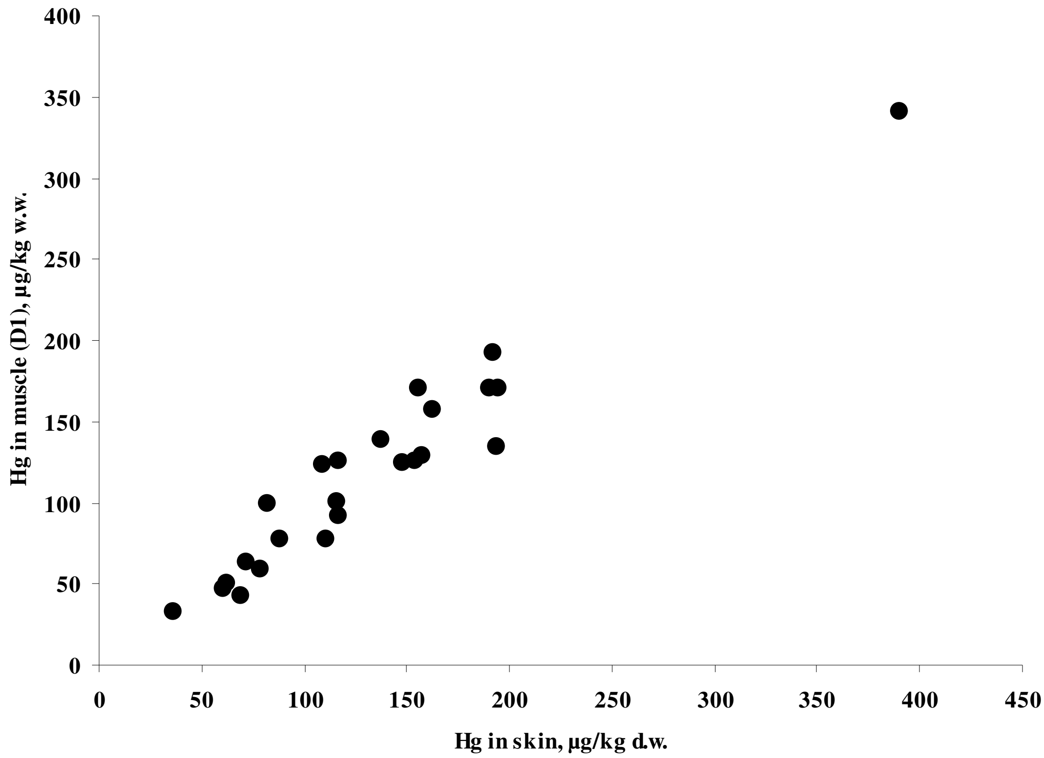

Figure 16. The muscle level of mercury on a wet weight basis as a function of the mercury levels in the skin on a dry weight basis.

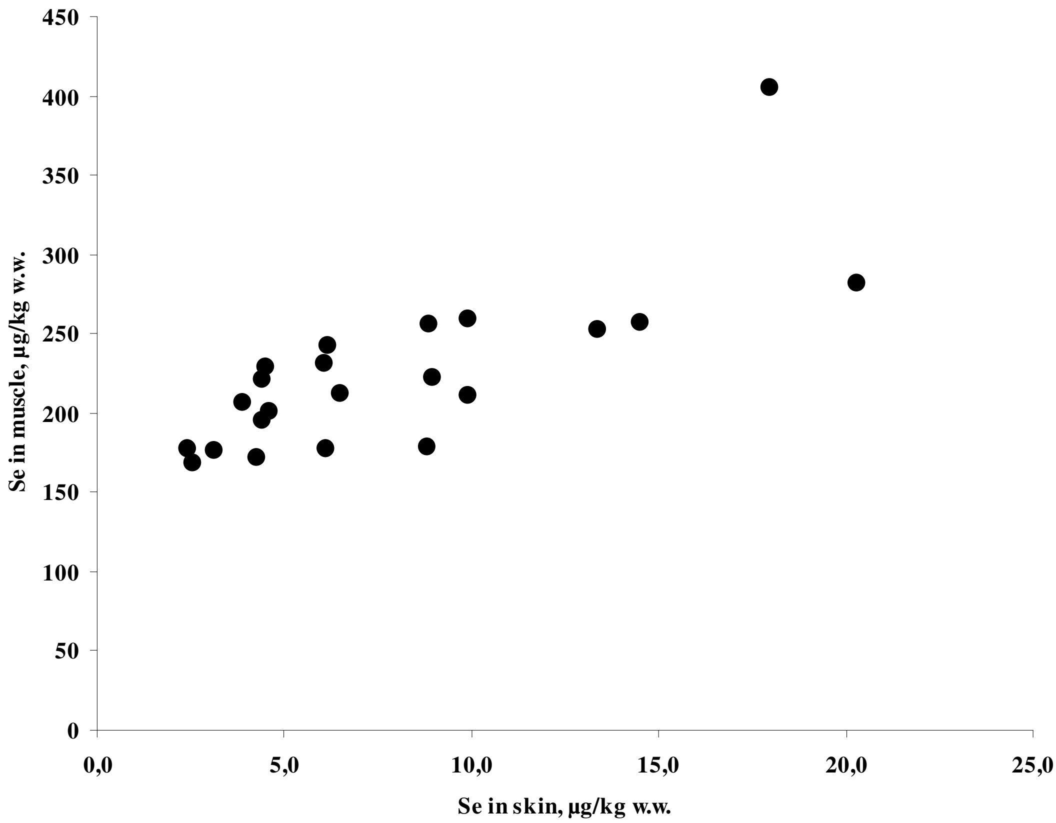

Figure 17. The muscle level of selenium on a wet weight basis as a function of the selenium levels in the skin on a wet weight basis.

Conclusions

In many cases there are differences between results for the muscle samples at different sampling sites. Comparison of D1 and D4 reveals that there is significantly higher concentrations of Se, Mn, Zn, Cu, Hg, Pb, and Fe in D1 than in D4. In some cases the difference is consideable as for example in the case of Zn and Mn, where their levels in D1 are two times their levels in D4 on a dry weight basis. In the case of As, howevere, D4 is higher than D1 by a factor of two on a wet weight basis (three times on a dry weight basis). No conclusion could be inferred regarding Ni since the levels are less than the detection limit for most of the samples. For the elements analysed in M4.5 (Se, Hg, Zn, As, Cu, Fe, and Mn), all but Mn gave the same result at both D1 and M4.5 while Mn gave two times higher level at M4.5 than D1 on a dry weight basis. These findings need to be taken into consideration when sampling of muscle tissue is planned for the analysis of trace elements in minke whales at least.

No element showed an effect of neither area nor sex for any of the tissues analysed in this study. Hg showed a significant linear increase with length for all the tissues (skin, muscle, liver, and kidney). Hepatic Se-levels increase with length while the Se-levels in skin decrease with length. Cadmium levels increase with length in both livers and kidneys. The cadmium levels in gonads do not show any effect of area, length or sex. The cadmium levels in gonads increase with Cd-levels in both livers and kidneys.

From comparisons with other minke whales stocks it may be concluded that Icelandic minke whales differ from other stocks in the N-Atlantic as regards especially cadmium and mercury levels. Although the hepatic and nephritic cadmium levels of SE-Greenlandic minke whales seem to be similar to their Icelandic counterparts, the cadmium level of muscle tissue is lower in the Icelandic minke whales as are the mercury levels in livers, kisneys and muscle. The Antarctic minke whale differs from the Icelandic minke whales in their hepatic levels of cadmium and selenium as well as higher hepatic levels of copper while the content of copper is lower in the skin of Antarctic compared to Icelandic minke whales. However, Antarctic minkes are much lower in mercury than their N-Atlantic counterparts.

When comparing levels in skin and levels in other tissues, no correlation could be found in any of the trace elements studied except in the case of mercury (muscle, livers, and kidneys) and selenium (only muscle). The mercury level in skin is proportional to the levels of mercury found in muscle tissue and a good correlation is obtained where a relationship close to 1:1 is found if levels in skin are expressed on a dry weight basis and the levels in muscle on a wet weight basis. There is also a fairly good correlation between levels of mercury in skin and levels in both livers and kidneys albeit the relationship is not 1:1. Whether these relationships hold in time or for other stocks of minke whales warrants further studies. Selenium in muscle (wet weight) correlates linearly with levels of selenium in the skin (wet weight) but the intercept and the slope are large. It may therefore be concluded that for the Icelandic minke whales at least, that skin biopsies are generally not valid for predicting trace element concentrations in internal organs except in the case of total mercury in muscle tissue.

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