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Cadmium and Copper Levels in Seals, Penguins and Skuas from the Weddell Sea in 1982/1983

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Summary. Samples of muscle, liver and kidney of Weddell and crabeater seals, Adélie and emperor penguins, and McCormick's skuas collected in the Weddell Sea in the summer 1982/83 were analysed for cadmium and copper. In general, the study aimed at contributing to the establishment of base-line data on potential pollutants in Antarctic ecosystems. In particular, it aimed at increasing the amount of data on Cd and Cu levels in the same species that that had been collected and analysed two years eralier, thus improving the possibility of statistical analyses into relationships between metal contents and biological parameters or sampling-sites of the animals, but the data basis is still too small for the letter purpose. In all species together, concentration ranges (on dry weight basis) were 0.16–0.77, 3.7–96.8 and 15.6–491 mg cadmium and 1.6–21.4, 14.9–149 and 12.6–47.7 mg copper per kg in muscles, livers and kidneys, respectively. The relatively high levels of both metals in all species analysed, in connexion with the available literature, suggest that levels in marine mammals and birds can only, if at all, to a minor extent reflect differences in environmental concentrations of these metals.

Introduction

In contrast to e.g. several radionuclides, organochlorine pesticides and polychlorinated biphenyls which, almost certainly, only occur in the marine environment due to human activities, heavy metals have always been natural constituents of the biogeochemical cycles. Thus, to assess the extent of contamination by heavy metals, it is necessary to estimate the proportion of their occurrence which is due to anthropogenic origin. This can be done most easily if their natural base-line concentrations are known (Anderlini et al. 1972).

The Antarctic, albeit most remote from the major sources of anthropogenic influences, has since the finding of DDT in its wildlife by Sladen et al. (1966) repeatedly been shown to be reached by environmental contaminants; however, organochlorine levels in its biota are still relatively low as compared to those of e.g. the North Sea (cf. Schneider et al. 1985). Bearing in mind the natural occurrence of heavy metals, their concentrations in Antarctic biota may thus be regarded as at least close to natural base-line levels. Information on heavy metal concentrations in Antarctic biota, however, is still scare.

Since deposits of minerals, coal and oil have been detected in the Antarctic, rising ore and energy prices might soon intensify exploration and make commercial exploitation economically attractive (Holdgate and Tinker 1979). Such activities would dramatically increase the danger of oil and/or heavy metal contamination.

Bearing in mind *inter alia* these considerations, the Alfred Wegener Institute for Polar Research has, ever since it was founded in 1980, collected samples for analyses for potential pollutants of almost all seals and birds that have been sampled for investigations e.g. into their age and sex composition, feeding ecology or parasitology. Some of the results of the analyses for organochlorines and heavy metals in the material sampled in the season 1980/81 are being published elsewhere (Schneider et al. 1985).

This present study aimed at contributing to the establishment of base-line data on potential contaminants in Antarctic ecosystems and, more on a global level, in marine mammals and birds. In particular, it was intended to increase the amount of data on Cd and Cu levels in the same species, i.e. Weddell and crabeater seals, Adélie and emperor penguins, and McCormick's skuas, thus, by combination of both data sets, improving the possibility of statistical analyses into relationships between metal concentrations in the tissues and age, sex or sampling-site of the animals, since these factors could be supposed to possibly affect metal concentrations.

Material and Methods

A total of nine crabeater seals (*Lobodon carcinophagus*), eight Weddel seals (*Leptonychotes weddelli*), four emperor penguins (*Aptenodytes fosteri*), five Adélie penguins (*Pygoscelis adeliae*) and ten McCormick's skuas (*Catharacta maccormicki*) were collected in the Atka Bay and – some of the seals only – in the Gould Bay, from January to March 1983, by Drs. H. E. Drescher and J. Plötz. The animals were transferred on board *RV Polarstern* or *RV Polarbjørn*, respectively.

The numbers of animals per species and sampling-area, their sex compositions and mean weights are listed in Tables 1 and 2. All seals and two of the emperor penguins were immediately dissected on board the research vessel, and samples of kidney, liver and pectoral muscle were placed in polyethylene bags which were then thermally sealed and stored at −20 °C. The remaining birds were frozen *in toto* and stored on the ships and, after their return, carefully thawed and dissected in the institute's lab, where the tissue samples were stored in the same way. Whilst sampling, precautions were always taken to avoid contamination.

Prior to analysis, the samples were freeze-dried and subsequently homogenized in an agate mortar mill. Aliquots of the homogenates were weighed into PTFE vessels to which 3 ml HNO_3 and 1 ml $HClO_4$ (both concentrated, suprapur®, MERCK) were added. The vessels were then covered with PTFE lids, placed in aluminium blocks, slowly heated to 130 °C for 6 h and subsequently to 250 °C for at least 15 h, according to the procedure described by Kruse (1980). After complete sample mineralization and acid evaporation, the residual matrix was dissolved in 1 ml concentrated HNO_3 and transferred to volumetric flasks. The solutions were then adjusted with bidistilled water to the following volumes which in pre-tests had been found to be most suitable for the atomic absorption spectrophotometric measurements for the tissues and reference materials employed for the quality control of the analyses:

- 4 ml for the muscle samples and IAEA-certified reference material MA-A-2 (fish flesh homogenate)
- 5 ml for the liver and kidney samples and IAEA-certified reference material MA-M-1 (copepod homogenate), and
- 10 ml for NBS Standard Reference Material (SRM) 1566 (oyster tissue).

A Perkin-Elmer 300 SG/HGA 76 B single beam flameless atomic absorption spectrophotometer (AAS) equipped with a D_2 background corrector, and an AS-1 autosampler was used for the measurements. Three replicates of 20 µl per sample were injected. After preliminary analyses of the Standard Reference Material, the best results were obtained by calibration of the instrument with external standards for Cu, and with the standard addition method for Cd. The standard analytical conditions of the instrument, as outlined in the supplier's manual, were used for all determinations.

Results and Discussion

Obviously, the analytical results did not reveal any relationship between metal content and sex or size of the animals. Neither did a combination with the results obtained for the same species sampled in 1981 (Schneider et al. 1985) yield such a relationship. Therefore, the sizes and metal concentrations of the animals analysed during this present study were summarized as arithmetric means and standard deviations, which are presented in Tables 1 and 2. The sex compositions are included as additional information.

Generally, the metal concentrations of the tissues analysed here compare well with those obtained in our previous study and some data reported by other authors which are listed as reference in Tables 3 and 4.

Copper

As expected, Cu in seals was always highest in livers, followed by kidney and muscle (cf. Eisler 1981; Wagemann and Muir 1984). The latter authors, when overviewing and evaluating the literature on heavy metal concentrations in marine mammals from the North Atlantic and including some samples from the Antartic, noted that the livers of leopard seals (*Hydrurga leptonyx*) from the Antarctic contained the highest copper levels reported for seal livers. A comparison with the data on seals from the North Sea which is certainly more heavily contaminated than the Antarctic, as given by e.g. Drescher et al. 1977; Duinker et al. 1979, reveals that Antarctic seals contain at least as high Cu levels. Eisler (1981) concluded from his compilation of copper levels in pinnipeds that "it is probable that copper is not accumulated in excess of immediate metabolic needs by marine mammals."

In the birds examained, Cu was also in most cases highest in liver, followed by kidney and muscle; however, the differences of tissue levels between tissues was remarkably smaller than in the seals, those between liver and kidney were not significant. The liver Cu concentrations of the skuas and penguins compare well with the levels reported by Anderlini et al. (1972) for livers of

Table 1. Copper in seals and birds from the Weddell Sea. (Mean concentrations ± standard deviation in µg/g dry weight)

Species and station	Female/male		Weight (kg)	Muscle	Tissue liver	Kidney
Crabeater seal						
Gould Bay	2	2	180.4 ± 14.8	2.4 ± 0.73	51.8 ± 31.0	29.1 ± 14.1
Atka Bay	3	2	170.2 ± 29.6	5.0 ± 2.2	74.0 ± 42.8	33.3 ± 7.9
Weddell seal						
Gould Bay	1	1	221.8 ± 15.2	2.5 ± 0.6	44.6 ± 40.2	31.9 ± 1.3
Atka Bay	2	4	278.1 ± 82.5	3.6 ± 1.1	74.1 ± 36.5	24.0 ± 5.4
Emperor penguin						
Atka Bay	4	–	27.2 ± 3.8	5.5 ± 2.0	23.4 ± 4.0	19.1 ± 3.0
Adélie penguin						
Atka Bay	3	2	5.3 ± 0.9	8.2 ± 2.4	19.9 ± 5.8	17.8 ± 4.1
McCormick's skua						
Atka Bay	6	4	1.3 ± 0.13	12.3 ± 3.8	28.3 ± 5.6	31.1 ± 5.1

Table 2. Cadmium in seals and birds from the Weddell Sea. (Mean concentrations ± standard deviation in µg/g dry weight)

Species and station	Female/male		Weight (kg)	Muscle	Tissue liver	Kidney
Crabeater seal						
Gould Bay	2	2	180.4 ± 14.8	nd	14.0 ± 9.0	72.9 ± 28.1
Atka Bay	3	2	170.2 ± 29.6	0.44 ± 0.20	38.8 ± 42.8	102.1 ± 63.6
Weddell seal						
Gould Bay	1	1	221.8 ± 15.2	nd	12.7 ± 5.5	71.5 ± 26.9
Atka Bay	2	4	278.1 ± 82.5	0.24 ± 0.08	20.1 ± 11.5	135.2 ± 35.1
Emperor penguin						
Atka Bay	4	–	27.2 ± 3.8	0.35 ± 0.09	27.7 ± 15.6	270.2 ± 126.8
Adélie penguin						
Atka Bay	3	2	5.3 ± 0.9	0.32 ± 0.02	7.5 ± 2.4	263.8 ± 216.6
McCormick's skua						
Atka Bay	6	4	1.3 ± 0.13	0.44 ± 0.22	27.0 ± 16.8	142.3 ± 43.4

Table 3. Copper concentrations in seals and marine birds by other authors referred to in this study (µg/g dry weight or [a] wet weight; arithmetic means ± standard deviation *or range*, number of samples analysed). n.a. = not analysed

Species	Location	Muscle	Liver	Kidney	Source
Crabeater seal	Gould Bay	3.30 ± 0.99 (2)	49.8 ± 1.7 (2)	28.9 ± 4.7 (2)	Schneider et al. (1985)
	Atka Bay	2.80 ± 0.28 (4)	79.6 ± 27.0 (4)	43.4 ± 13.6 (4)	Schneider et al. (1985)
Weddell seal	Gould Bay	3.00 ± 1.13 (2)	16.7 ± 0 (2)	21.9 ± 4.0 (2)	Schneider et al. (1985)
	Atka Bay	2.80 ± 0.24 (7)	44.5 ± 21.3 (7)	35.8 ± 12.3 (7)	Schneider et al. (1985)
Weddell seal	"Antarctic"	[a]0.53 (1)	[a]18.6 (1)	n.a.	"Wagemann, unpublished" in
Leopard seal	"Antarctic"	[a]0.65 ± 0.26 (15)	[a]44.6 ± 20.0 (15)	n.a.	Wagemann and Muir (1984)
Harbour seal	German Wadden Sea	n.a.	[a]*2.6 – 17.0* (58)	[a]*2.3 – 4.0* (16)	Drescher et al. (1977)
Harbour seal	Dutch Wadden Sea	n.a.	[a]*2.0 – 20.0* (8)	[a]*4.8 – 5.1* (2)	Duinker et al. (1979)
Emperor penguin	Gould Bay	3.70 ± 1.44 (7)	30.7 ± 14.5 (9)	21.2 ± 11.1 (8)	Schneider et al. (1985)
	Atka Bay	3.70 ± 0.93 (3)	61.8 ± 36.5 (3)	24.8 ± 4.0 (3)	Schneider et al. (1985)
Adélie penguin	Atka Bay	7.23 ± 1.01 (8)	22.9 ± 6.9 (9)	15.9 ± 3.4 (9)	Schneider et al. (1985)
South polar skua	Gould Bay	20.3 ± 1.20 (3)	15.4 ± 1.3 (3)	28.0 ± 8.8 (3)	Schneider et al. (1985)
	Atka Bay	13.8 ± 0.95 (3)	20.9 ± 5.1 (3)	25.4 ± 5.7 (3)	Schneider et al. (1985)
Wilson's petrel	Hallett Station	46.8 ± 17.2	18.7 ± 2.3	n.a.	Anderlini et al. (1972)
	Palmer Station	41.3 ± 10.0	17.4 ± 1.8	n.a.	Anderlini et al. (1972)
Snow petrel	Hallett Station	40.9 ± 7.1	18.1 ± 2.1	n.a.	Anderlini et al. (1972)

Antarctic petrels, whereas their muscle Cu levels were somewhat higher.

Eisler (1981), compiling the available data on Cu in mainly coastal marine birds, stated that human activities contribute significantly to avian tissue burdens, whereas Anderlini et al. (1972), comparing concentrations in closely related Antarctic and North American sea bird species, came to the conclusion that, since copper is an essential element and therefore likely to be metabolically regulated, concentrations are similar in all individuals of related species. Thus, the usefulness of marine birds and mammals for monitoring of environmental contamination by copper must be doubted.

Nevertheless, the data on Cu levels in seals presented here (Table 1) as well as those from our previous investigation (Table 3) reveal a tendency of elevated levels in the Atka Bay as compared to the Gould Bay; the reason for this difference is not yet clear, but seasonal variations might play a rôle.

Cadmium

In all animals examined, cadmium levels were significantly higher in renal tissue than in hepatic tissue, concentrations in the muscle samples being very much lower, in some cases below the detection limit. This finding is well in accordance with the conclusions by Eisler (1981) for marine mammals and birds and Wagemann and Muir (1984) for pinnipeds and cetaceans.

The Cd concentrations of Antarctic seal tissues determined in this present study compare well with those of our previous investigation (Schneider et al. 1985) and those given by Schneppenheim (1981) and Wagemann (Wagemann and Muir 1984) and those given by Schneppenheim (1981) and Wagemann (Wagemann and Muir 1984), listed in Table 4. Similarly high tissue Cd levels have been found in ringed seals (*Phoca hispida*) from the Canadian Arctic (Wagemann) and West Greenland (Johansen et al. 1980). In contrast, grey seals (*Hali-*

Table 4. Cadmium concentrations in seals and marine birds by other authors referred to in this study (μg/g dry weight or [a] wet weight; arithmetric means ± standard deviation *or range,* number of samples analysed). n.a. = not analysed

Species	Location	Muscle	Liver	Kidney	Source
Crabeater seal	Gould Bay	0.20 ± 0.11 (2)	13.7 ± 5.9 (2)	98.7 ± 43.1 (2)	Schneider et al. (1985)
Crabeater seal	Atka Bay	0.17 ± 0.08 (3)	34.7 ± 15.8 (4)	139.4 ± 87.1 (4)	Schneider et al. (1985)
Weddell seal	Gould Bay	0.20 ± 0.13 (2)	14.9 ± 5.0 (2)	114.6 ± 43.8 (2)	Schneider et al. (1985)
Weddell seal	Atka Bay	0.21 ± 0.12 (7)	22.7 ± 10.2 (7)	174.3 ± 67.3 (7)	Schneider et al. (1985)
Crabeater seal	Weddell Sea	n.a.	6.7 ± 0.6 (?)	42.5 ± 0.7 (?)	Schneppenheim (1981)[b]
Weddell seal	"Antractic"	[a]0.01 (1)	[a]1.6 (1)	n.a.	Wagemann[c]
Leopard seal	"Antarctic"	[a]0.01 (15)	[a]5.1 ± 7.4 (15)	n.a.	Wagemann[c]
Ringed seal	Baffin Island	[a]0.16 ± 0.08 (3)	[a]5.8 ± 4.0 (15)	n.a.	Fallis[c]
Ringed seal	Baffin Island	[a]0.05 ± 0.01 (7)	[a]5.5 ± 0.8 (5)	[a]27.9 (1)	Fallis[c]
Ringed seal	West Greenland	[a]0.15 ± 0.06 (7)	[a]17.0 ± 9.0 (12)	n.a.	Johansen et al. (1980)
Ringed seal	West Greenland	[a]0.07 ± 0.10(29)	[a]7.3 ± 3.0 (29)	37.4 ± 33.7 (29) [a]	Johansen et al. (1980)
Grey seal	East Coast Scotld.	n.a.	[a]*0.05 – 8.49*(67)	[a]*0.10 – 15.1* (72)	McKie et al. (1980)
Harbour seal	German Wadden Sea	n.a.	[a]*0.01 – 0.20*(58)	[a]*0.06 – 0.38* (16)	Drescher et al. (1977)
Harbour seal	Dutch Wadden Sea	n.a.	*0.03 – 0.21* (8)	[a]*0.15 – 0.17* (2)	Duinker et al. (1979)
Emperor penguin	Gould Bay	0.28 ± 0.37 (5)	5.7 ± 7.7 (8)	23.8 ± 39.3 (8)	Schneider et al. (1985)
Emperor penguin	Atka Bay	1.67 ± 1.03 (2)	48.3 ± 21.0 (3)	382 ± 199 (3)	Schneider et al. (1985)
Adélie penguin	Atka Bay	0.30 ± 0.14 (8)	15.2 ± 7.0 (9)	175 ± 88.1 (9)	Schneider et al. (1985)
South polar skua	Gould Bay	0.32 ± 0.10 (3)	26.2 ± 2.3 (3)	179 ± 74.1 (3)	Schneider et al. (1985)
South polar skua	Atka Bay	0.16 ± 0.04 (3)	17.3 ± 5.7 (3)	132 ± 8.4 (3)	Schneider et al. (1985)
Adélie penguin	Weddell Sea	0.45 ± 0.07	19.8 ± 0.7	173 ± 12.3	Schneppenheim (1981)[b]
Wilson's petrel	Hallett Station	3.67 ± 2.14	20.3 ± 5.8	n.a.	Anderlini et al. (1972)
	Palmer Station	3.25 ± 0.97	20.7 ± 4.9	n.a.	Anderlini et al. (1972)
Snow petrel	Hallett Station	5.57 ± 1.88	27.7 ± 12.2	n.a.	Anderlini et al. (1972)
Ashy petral	California	8.00 ± 4.52	53.2 ± 20.5	n.a.	Anderlini et al. (1972)
Great skua	Shetland Islands	n.a.	*1 – 31*	*13 – 336*	Furness and Hutton (1979)

[b] The unit of figures in Schneppenheim (1981) must read "ppm" instead of "ppb"(Schneppenheim, personal communication)
[c] Quoted as "unpublished" by Wagemann and Muir (1984)

choerus grypus) and harbour seals (*Phoca hispida*) from the North Sea have been reported at remarkably lower Cd levels (McKie et al. 1980; Drescher et al. 1977; Duinker et al. 1979), even if their data (Table 4) are corrected for tissue dry weight. A possible explanation for the elevated levels in the Antarctic seals may be that crabeater seals feed mainly on krill and Weddell seals largely on cephalopods and, to some extent, also on krill, species of both of which have been reported to contain relatively high Cd body burdens (Stoeppler and Brandt 1979; Schneppenheim 1981; Martin and Flegal 1975; thus, their dietary intake could be higher than that of the North Sea seals, which mainly depend on fish with their comparatively low cadmium contents (Eisler 1981). Arctic ringed seals, on the other hand, are known to feed, to some extent, on pelagic crustaceans, such as amphipods, euphausiaceans and shrimps, many species of which have also been shown to contain relatively high Cd levels (cf. Eisler 1981). Species differences and age dependencies of Cd levels in seals (cf. Eisler 1981; Wagemann and Muir 1984) might also be involved in some of the differences, but even the age groups of harbour seals (Drescher et al. 1977) and grey seals (McKie et al. 1980) from the North Sea with the highest Cd contents did not reach the values of the Arctic and Antarctic species.

The Cd levels in the analysed birds are well in accordance with our previous results and with those of some other authors (cf. Table 4). The data furthermore compare well with those given for other sea birds, such as *Fraterculária arctica, Fulmaris glacialis, Oceanodroma levcorhoa* and *Puffinus puffinus* from St. Kilda, Scotland, by Bull et al. (1977).

Anderlini et al. (1972), comparing Cd concentrations in petrels and tern eggs from the Antarctic and from North America, found rather similar concentrations at both sites. Therefore, these authors conclude for sea birds as Holden (1978) does for marine mammals, that the general impression is that there are only minor differences between comparable species of sea birds, or marine mammals, respectively, and between localities, suggesting that the differences in environmental levels, as may be caused by contamination, are not necessarily reflected in tissue levels of these animals. However, much more research into the mechanisms of uptake, storage and release of metals in these animals and into the rôle of metallothioneins and other compounds in determining tissue levels particularly for Cd, Cu and Zn is required to allow for more definite conclusions.

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