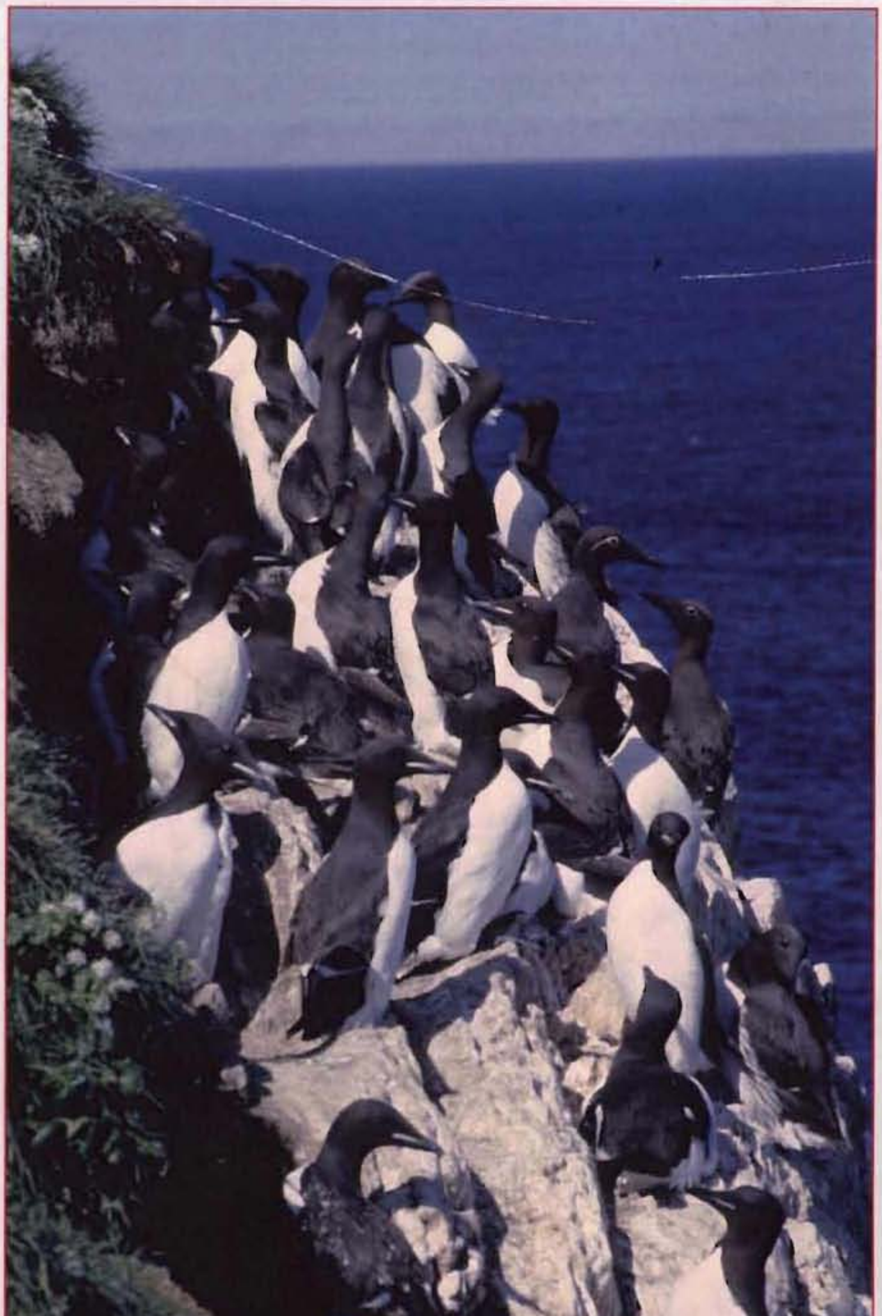
TRACE ELEMENTS IN SEABIRDS FROM THE BARENTS AND NORWEGIAN SEAS, 1991-1993



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The Norwegian Polar Institute is Norway's main institution for research and topographic mapping in Norwegian polar regions. The Institute also advises Norwegian authorities on matters concerning polar environmental management.

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PREFACE

This study is a part of the research project "Environmental contaminants in Arctic seabirds" initiated by a group of experts from the Joint Norwegian-Russian Commission on Environmental Co-operation to study the effect of pollution on marine ecosystems.

The main objective of the project was to study the levels of trace elements (including heavy metals) in different seabird species breeding in the Barents Sea area. There are limited comparable data on environmental pollutants in seabirds from this area, and this report presents such information on trace element levels. The results are a contribution to the Arctic Monitoring and Assessment Programme (AMAP).

The authors wish to express their gratitude to many people, who have devoted their time and expertise to this project. We wish to thank: Hans Erik Karlsen (University of Oslo, Norway), Vidar Bakken and Hallvard Strøm (Norwegian Polar Institute, Tromsø), Drs. Andrey Kondakov, Sergey Marasaev, and Dmitry Matishov (Murmansk Marine Biological Institute), Drs. Ivetta Tatarinkova, Ryurik Chemyakin, and Yury Krasnov (Kandalaksha State Reserve) for their help in collection of samples from Ny-Ålesund, Bjørnøya, Hornøya, West and East Murman coasts and Franz Josef Land. Especially we would like to thank Halvar Ludvigsen for his great help during the expedition to the eastern Barents Sea in 1992. We also want to thank Syverin Lierhagen for analysis of heavy metals at the Norwegian Institute for Nature Research analytical laboratory in Trondheim; Rob Barrett (Tromsø Museum, Norway) and Rune Dietz (National Environmental Research Institute, Denmark) for their constructive comments and criticism of earlier drafts of this report.

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Table of contents

INTRODUCTION

Trace elements, in contrast to chlorinated hydrocarbons, exist in the marine environment in a wide range of concentrations. In high concentrations some trace elements, especially heavy metals, are toxic to marine fauna and flora. The toxic effect of heavy metals differs according to the chemical structure of the elements.

The levels and fate of heavy metals in different marine organisms vary widely depending on the ecology, their feeding rate, migration routes, age, physiology and biochemistry of the species involved. Metals can enter the ecosystem through natural geological processes and anthropogenic sources such as smelters, oil and gas exploitation on the shelf, release from chemical waste dumping, etc. Long-range transported air pollution also includes heavy metals. The anthropogenic sources are many, e.g. power plants, industrial combustion, extraction and distribution of fossil fuels, solvent use, road traffic, waste treatment, agriculture, and some natural processes (AMAP, 1998). The metals that currently cause most concern are arsenic, cadmium, copper, mercury, nickel, lead, and zinc.

Seabirds are widely used to monitor trace element levels due to their wide distribution and high position in the food chain. The detailed knowledge of general seabird ecology, numbers, and productivity of many populations make them particularly appropriate as a choice of biomonitors or bioindicators. Gilbertson *et al.* (1987) provide some evidence indicating that contaminant levels in seabirds have lower coefficients of variation than in fish or marine mammals, and that the confidence interval obtained from the analysis of seabirds is as small as that obtained from a larger sample of fish or mammals.

The Barents Sea is very productive and is inhabited by one of the largest concentrations of seabirds in the world, comprising several million birds. The main groups of seabirds are the alcids, cormorants, gulls, marine ducks, procellariforms, and terns. More than 30 species of seabirds have been registered in the Barents Sea region (Belopol'skii, 1957; Løvenskiold, 1964; Norderhaug *et al.*, 1977).

During recent decades, some seabird populations in the region have declined dramatically (Anker-Nielsen and Barrett, 1991; Krasnov and Barrett, 1995; Anker-Nielsen *et al.*, 1997). However, at present time only limited data exist concerning trace element (including heavy metal) levels in seabirds from this area, especially from the northern and eastern parts of the Barents Sea.

The aim of the present study was to provide the baseline data concerning trace element levels in different seabirds species from the main seabirds colonies in the Barents Sea area for comparative analyses of inter-specific and geographical differences in bioaccumulation patterns of the pollutants.

MATERIALS AND METHODS

Sampling area

Birds were collected in July-August 1991, in May and August 1992, and January 1993 at various seabirds colonies in the Barents Sea and southeastern part of the Norwegian Sea. All birds were collected under licenses from the local environmental authorities. The geographical locations of the sampling sites are shown in Fig. 1 and presented in Table 1.

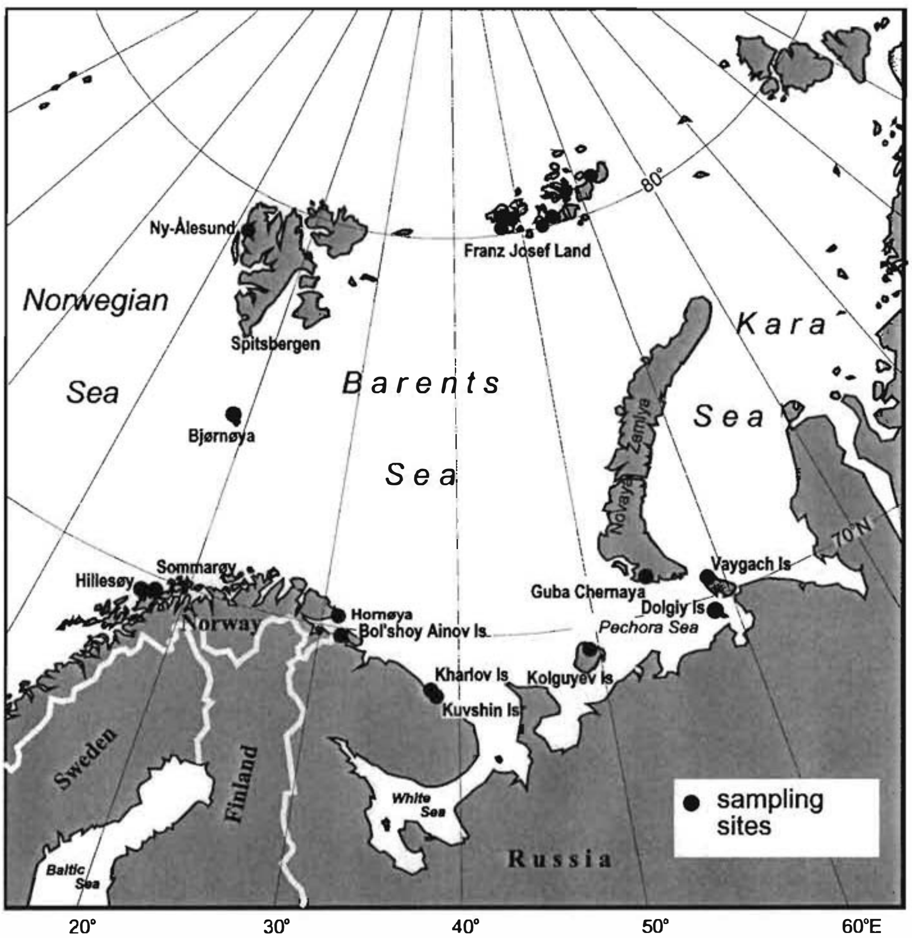

Fig. 1. Map of the Barents and Norwegian Sea sampling areas

The birds were caught with nets or noose poles in the nesting colonies. Those, which were impossible to catch, were shot with a shotgun. All birds were weighed using a Pesola spring balance, and their sex was determined during dissection.

Table 1. Co-ordinates of sampling areas of seabirds collected in 1991-1993

Area	Place	Latitude	Longitude
S-E of the Norwegian Sea (Troms)	Hillesøy	69°38' N	17°59' E
S-E of the Norwegian Sea (Troms)	Sommarøy	69°38' N	18°02' E
S-W of the Barents Sea	Ainov Island	69°50' N	31°34' E
S-W of the Barents Sea	Hornøya	70°22' N	31°10' E
Svalbard Archipelago	Bjørnøya	74°25' N	19°00' E
Svalbard Archipelago	Ny-Ålesund	78°57' N	11°54' E
Seven Islands Archipelago	Kharlov Island	68°49' N	37°20' E
Seven Islands Archipelago	Kuvshin Island	68°44' N	37°32' E
Eastern Murman coast	Guba Podpakhta	69°09' N	35°56' E
Pechora Sea	Dolgiy Island	68°48' N	54°18' E
Pechora Sea	Vaygach Island	70°24' N	58°46' E
Pechora Sea	Kolguyev Island	69°00' N	49°00' E
Novaya Zemlya Archipelago	Guba Chernaya	70°40' N	54°46' E
Franz Josef Land Archipelago	Prince George Land Island	80°10' N	49°15' E
Franz Josef Land Archipelago	Northbrook Island	80°00' N	51°00' E
Franz Josef Land Archipelago	Kuhn Island	81°08' N	58°30' E
Franz Josef Land Archipelago	Hooker Island	80°18' N	53°00' E
Franz Josef Land Archipelago	Etheridge Island	80°05' N	52°23' E
Franz Josef Land Archipelago	Scott-Kelty Island	80°20' N	52°30' E
Franz Josef Land Archipelago	Stolichky Island	81°12' N	58°16' E
Franz Josef Land Archipelago	Mable Island	80°03' N	49°30' E

Materials

Sixteen species of seabirds, belonging to six families (Table 2) were selected for the study.

Table 2. List of bird species collected for trace element analyses

Family, species	Troms		S-W		Sv.		E.M.	S.I.		Pechora Sea				Franz Josef Land								
	Sommarøy	Hilleséy	Ainov Island	Hornøya	Bjørnøya	Ny-Ålesund	Guba Podpakhta	Kharlov Island	Kuvshin Island	Guba Chernaya	Dolgyi Island	Kolguyev Island	Vaygach Island	Mable Island	Etheridge Island	Scott-Kelty Island	Prince George Land	Hooker Island	Kuhn Island	Northbrook Island	Stolichky Island	S-W off
Laridae																						
Kittiwake				■	■	■		■		■			■				■	■	■	■	■	
Herring gull		■	■	■			■															
Great black-backed gull			■				■															
Glaucous gull					■	■				■		■	■				■	■		■	■	
Sternidae																						
Arctic tern															■							
Alcidae																						
Little auk																		■	■			
Brünnich's guillemot				■	■	■		■	■	■				■			■			■		
Common guillemot								■	■													
Razorbill								■	■													
Black guillemot																		■		■	■	
Puffin	■			■		■		■	■													
Anatidae																						
Common eider	■					■									■	■						
King eider											■	■	■									
Long-tailed duck											■											
Procellariidae																						
Fulmar					■	■																■
Phalacrocoracidae																						
Cormorant	■																					

Abbreviations read: S-W - south-western part of the Barents Sea; Sv. - Svalbard Archipelago; E.M. - Eastern Murman coast; S.I. - Seven Islands Archipelago.

Laridae

Kittiwake, *Rissa tridactyla*

The Kittiwake has a circumpolar distribution, breeding in the arctic and boreal zones of the northern hemisphere. About half of the world population breeds in the Barents Sea, on Iceland, and the Faeroe Islands (Lloyd *et al.*, 1991).

The Kittiwakes were collected in colonies on Spitsbergen, Bjørnøya, Hornøya, Seven Islands Archipelago (Kharlov Island), Franz Josef Land (Hooker Island, Prince George Land (Cape Grant), Kuhn Island, Northbrook Island (Cape Flora), Novaya Zemlya (Guba Chernaya) and on the sea near Vaygach Island.

On Svalbard the Kittiwake is the most common gull species. 12 700 pairs breed in Kongsfjorden and Krossfjorden (Spitsbergen) (Mehlum and Fjeld, 1987). The breeding population on Bjørnøya is about 85 000 pairs (Norwegian Polar Institute seabird colony database). Research in the Svalbard area has shown that the most important food organisms for Kittiwake are polar cod, *Boreogadus saida*, capelin, *Mallotus villosus*, euphausiids, *Thysanoessa sp.* and amphipods, *Parathemisto spp.* (Mehlum, 1990; Lønne and Gabrielsen, 1992; Mehlum and Gabrielsen, 1993).

On the East Murman coast (Kola Peninsula) the largest colonies are on Kharlov Island (Seven Islands archipelago). On this island about 15 000 pairs were recorded in 1991 (Krasnov *et al.*, 1995). Between 1958 and 1986, numbers increased on Kharlov by ca. 7% p.a. (from 5 000 pairs to > 28 000), despite a near 50% drop in 1976-1977. Since then a decrease of ca. 4% p.a. (1987-1994) has been recorded on Kharlov (Krasnov and Barrett, 1995). According to Barrett and Krasnov (1996) the main food items of Kittiwake on Kharlov in July are capelin, herring (*Clupea harengus)*, sand eel (*Ammodytes sp.*), and crustaceans.

The Kittiwake population on Hornøya increased from 9 000 pairs in 1974 to 21 000 pairs in 1983 (Furness and Barrett, 1985). Since 1983 the population has been stable or slightly decreasing (R. Barrett, pers. comm.). Capelin was the preferred food (54-95% by mass) on Hornøya in eight of 10 years between 1980 and 1994 (Barrett and Krasnov, 1996).

Kittiwakes have not been documented breeding in the Vaygach Island area. Dement'ev (1951) included the Kittiwake in the list of birds nesting on Vaygach, but according to Uspenskii (1956) the Kittiwake should be excluded from this list. He considered that the Kittiwakes observed by Dement'ev had flown to the Vaygach area from Novaya Zemlya. Karpovich and Kokhanov (1967) observed a small breeding colony (10 nests) on one of the Yanov Islands. The Kittiwakes for our study were collected from a small island situated in Lyamchin Bukhta. There was, however, no colony nearby. Stomach analyses of the birds collected showed that they had been feeding mainly on capelin and mussels, *Mytilus edulis.*

The Franz Josef Land Archipelago is poorly studied and only a few ornithological expeditions have been undertaken during the past years (Belikov and Ryndla, 1984; Uspenskii and Tomkovich, 1986; Frantzen, 1992; Skakuj, 1992; Frantzen *et al.*, 1993). The Kittiwake colony on Hooker Island is one of the biggest in the archipelago and ca. 5000 pairs (Belikov and Ryndla, 1984) breed on the island. Ca. 7000 individual birds were found on Cape Grant (Prince George Land) in 1992, and the other colonies are smaller (Frantzen *et al.*, 1993).

Very little is known about the status and trends of the Kittiwake populations on Novaya Zemlya. Descriptions of birds' colonies in the south of Novaya Zemlya (Chernaya Bay) are given by Gorbunov (1929). The total number of Kittiwakes in Novaya Zemlya was estimated by Uspenskii (1956) to be about 15 - 20 000 pairs.

Ring recoveries and observations of birds at sea have shown that Kittiwakes from the Barents Sea disperse widely over most of the North Atlantic outside the breeding season. Some Kittiwakes move westwards to, e.g. Iceland, Greenland, and

Newfoundland while others disperse southwards to the western boards of Europe (the Faeroes, UK, the North Sea and Bay of Biscay) (Dement'ev, 1934; 1948; 1955; Norderhaug *et al.*, 1977; Barrett and Bakken, 1997). Kittiwakes from the Murman coast, as recoveries indicate, travel in winter to the Newfoundland/Greenland/Iceland area to the Faeroes and countries around the North Sea and Baltic. A few birds were found in the Mediterranean, Caspian and Black Seas, and inland in Austria and Ukraine. Young Kittiwakes tended to remain in their first winter area during the second summer, but as they grew older, more and more birds were recovered in North Norway and the Southern Barents Sea (Nikolaeva *et al.*, 1997). The wintering grounds of Novaya Zemlya Kittiwakes are less known (Coulson, 1966).

Herring gull, *Larus argentatus*

The Herring gull has a circumpolar distribution. In the Barents Sea region, they feed predominantly on marine food items, making up 82 % of their diet (Belopol'skii, 1957). The Herring gull is the typical omnivorous species, eating different types of food and using various feeding strategies. Their diet includes benthic, littoral and pelagic marine and freshwater animals: fish, molluscs, crustaceans, worms, etc. During the summer, the Herring gull will also take other food items, such as eggs and young of other seabirds, small rodents, and insects. This species also scavenges on garbage, and the waste of fishing and hunting (Belopol'skii, 1957; 1971).

In our study, the Herring gulls were collected at Bol'shoi Ainov Island, Hornøya, Hillesøy and Podpakhta Inlet.

In 1958, a total of 670 Herring gulls were recorded on Bol'shoi Ainov Island. By 1970 this number had increased to 8000 individuals (Tatarinkova, 1975). At the end of the 1980's it had decreased to 4000 (Krasnov *et al.*, 1995). 6-7000 pairs breed on the Murman coast (Gerasimova, 1962).

In 1983 the Herring gull population on Hornøya was estimated to about 14 500 breeding pairs. This is the largest Herring gull population in North Norway, and probably in Europe. Fish were the main food items for Herring gull on Hornøya with capelin constituting about 89%, sand eels *Ammodytes sp.* 2% and other items (offal, crabs, seabird's eggs and chicks) 9% of their diet in 1983 (Furness and Barrett, 1985).

In winter, Herring gulls move out of the Barents Sea area in two directions: to the west along the Norwegian coast, and to the south through the mainland, via the river and lake systems of the Kola Peninsula and further through the White and the Baltic Seas. The main wintering areas are the North Sea and Danish Strait (Dement'ev and Vuchetich, 1947; Kokhanov and Skokova, 1967). In warm winters, some Herring gulls often stay in the Barents Sea and in the White Sea (Kaftanovskii, 1941; Bianki, 1959).

Great black-backed gull, *Larus marinus*

The Great black-backed gull is a common nesting gull occurring on both sides of the Atlantic, and in Europe from Brittanny, France, in the south to Svalbard in the north. The diet of this species is very diverse. A major part of its food items is marine animals: fish, crustaceans, molluscs, and sea urchins. During the nesting period, the food also consists of eggs and young of other seabirds. The Great black-backed gull also scavenges on garbage, and the waste of fishing and hunting. They also feed on small mammals and reptiles (Belopol'skii, 1957; 1971; Mehlum, 1990). On Hornøya, the diet consisted of capelin (66%) and offal, crabs, seabird's eggs, and chicks (33%) in 1983 (Furness and Barrett, 1985). On the Ainov Islands, they are also cannibalistic and kleptoparasitic (Boiko *et al.*, 1970).

In our study, the Great black-backed gulls were collected on Bol'shoi Ainov Island, Hornøya, Sommarøy and in the Podpakhta Inlet.

The Great black-backed gull population on Ainov Islands (Western Murman) was about 6000 individuals in 1970 (Tatarinkova, 1975). During the 1980's it decreased to 3-4000 individuals (Krasnov *et al.*, 1995).

On Homøya, the population of Great black-backed gull was 180 breeding pairs in 1983 (Furness and Barrett, 1985).

The northern populations are migratory, while the southern ones are more or less vagrant. The European birds winter along the coast of Western Europe and at the sea in the North Atlantic. Non-breeding birds from the Murman coast winter in the North Sea (Tatarinkova, 1970).

Glaucous gull, *Larus hyperboreus*

The Glaucous gull has a circumpolar distribution in high arctic regions. This species is the most important avian predator in the Barents Sea area. The food spectrum of Glaucous gull is very diverse. During the nesting period it consists mainly of eggs and young of other seabirds. A major part of their diet consists of marine animals collected on the shore and in coastal waters: fish, crustaceans (mainly crab *Hyas araneus*), molluscs, polychaetes. They also feed on waste disposal sites and eat all sorts of carcasses (Uspenskii, 1956; Mehlum, 1990).

The Glaucous gulls collected in the present study are from Svalbard (Ny-Ålesund, Bjørnøya), Kolguyev and Vaygach Islands, Guba Chernaya, and from the Franz Josef Land Archipelago.

Glaucous gulls breed throughout most of Svalbard, either as single pairs or in small colonies. The total breeding population on Svalbard has been roughly estimated to about 10 000 pairs (Mehlum and Bakken, 1994). Little is known about any recent changes in the population. The findings, especially from Bjørnøya, of considerable numbers of dead Glaucous gulls with high levels of polychlorinated biphenyls (PCBs) (Gabrielsen *et al.*, 1995) are an alarming signal that the contamination level may be an important problem reducing survival and possibly also reproduction in some areas (Isaksen and Bakken, 1995). Glaucous gulls from Svalbard feed on eggs and chicks, tundra plants, polychaetes, benthic amphipods, bivalves, crustaceans, *Tunicata sp.*, *Bryozoa sp.*, and fish (*Boreogadus saida* and *Liparis liparis*) (Lydersen *et al.*, 1989).

The Glaucous gull is also a common species in the Novaya Zemlya region. They inhabit both the east and west coasts of the two islands. They are most numerous in the southern part of Novaya Zemlya. The total number of Glaucous gulls in Novaya Zemlya apparently amounts to some tens of thousands of pairs (Uspenskii, 1956). The main food items for adult Glaucous gulls from this region are birds (43%), crustaceans (29%), rodents (14%), fish, and molluscs (7%) (Belopol'skii, 1957).

There are no data on the status and trends of the Glaucous gull population at Kolguyev Island.

The total number of Glaucous gulls breeding in Vaygach area in 1960 was about 220 pairs. Many non-breeding birds were also recorded on this island. The main food items for Glaucous gull from this region in 1960 were crustaceans, dominantly, crabs, *Hyas sp.* (40%), fish (25%), molluscs, mainly, mussels *Mytilus edulis* (13%), other invertebrates (8%), lemmings (9%), birds (3%), and plants (2%) (Karpovich and Kokhanov, 1967).

On Franz Josef Land, Glaucous gulls, single birds or small flocks (10-30 individuals) were observed during expeditions in 1991-1992 (Frantzen *et al.*, 1993).

Glaucous gulls are partly migratory. Many individuals remain in arctic areas throughout the year, while others migrate further south. Some birds from the Svalbard area winter around Iceland and the Faeroe Islands (Vidar Bakken, pers. comm.). Winter movements of Glaucous gulls from Novaya Zemlya depend on the local existence of open water and consequently of food in the area. The wintering grounds are evidently to the west and south of their nesting areas (Dement'ev, 1948).

Sternidae

Arctic tern, *Sterna paradisaea*

The Arctic tern breeds around the pole in arctic and northern temperate areas. In Europe, they breed from the west coast of France and the British Isles north to Svalbard and Franz Josef Land. Their diet consists mainly of fish (predominantly polar cod) and various crustaceans (Mehlum, 1990). In our study, the Arctic terns were collected only on Franz Josef Land (Etheridge Island).

On Franz Josef Land, Arctic terns have been observed regularly at sea and between the islands. They have been found breeding on Etheridge Island in 1992 (Frantzen *et al.*, 1993).

Arctic terns winter in pelagic areas in the southern hemisphere, as far south as the Antarctic. It is one of the migratory birds which travels furthest between summer and winter areas.

Alcidae

Little auk, *Alle alle*

The Little auk is a high-arctic species with a breeding range restricted almost entirely to the high-arctic marine zone. On Franz Josef Land, at which Little auks were collected, this species is common. Information on the size and status of this population is very limited. Golovkin (1984) roughly estimated it to be 250 000 pairs. In 1991-1992, a total of 85 seabird colonies were observed by a Norwegian - Russian - Polish expedition. Sixty one of these colonies were inhabited by Little auks (Norwegian Polar Institute seabird colony database, 1996).

Little auks are divers and catch their prey in the open water masses, near the bottom or at the ice-water interface. Based on diet analyses, Little auks occupy an intermediate place among European alcids. In the Franz Josef Land area in 1991, they fed on pelagic organisms, mainly on *Calanus glacialis* and *C. hyperboreus* (94% by weight). Second of importance were *Apherusa glacialis* and *Parathemisto libellula* (Weslawski and Skakuij, 1992).

Little is known about the winter migration of Little auks from Franz Josef Land. They probably winter not far from their nesting areas, at the ice edge, as do birds from Novaya Zemlya. Antipin (1938) reported that they winter near the north coast of Novaya Zemlya. Occasional birds are found throughout the winter on the coast of the south island of Novaya Zemlya.

Brünnich's guillemot, *Uria lomvia*

The Brünnich's guillemot has a holarctic circumpolar distribution nesting all over the Arctic. This species feeds only at sea. The most common prey of the Brünnich's guillemot is pelagic fish: polar cod, young cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, capelin, herring and small pelagic crustaceans (*Copepoda, Amphipoda, Decapoda* etc.). Altogether, the Brünnich's guillemot from Novaya Zemlya eats more than 20 different marine species during the spring and summer (Belopol'skii, 1957). On Hornøya the main food items of their chicks in 1983 were sand eel (74%) and capelin (26%) (Furness and Barrett, 1985). In summer 1992, the Brünnich's guillemots from Seven Islands archipelago, Bjørnøya and Hornøya fed their chicks mainly on sand eels, capelin, and herring (Krasnov *et al.*, 1995; Barrett and Krasnov, 1996; Barrett *et al.*, 1997).

In sea-ice-covered waters near Svalbard pelagic *Crustacea* (shrimps and amphipods) dominated the diet of Brünnich's guillemot (Lønne and Gabrielsen, 1992). In July 1993 it was found that the diet of Brünnich's guillemots, collected near the polar front area south of Bjørnøya, consisted predominantly of euphausiids *Thysanoessa inermis*, whereas fish played a less important role in the diet of the adult birds (Mehlum *et al.*, in press).

In our study, this species was collected on Svalbard (Bjørnøya, Ny-Ålesund), Hornøya, Guba Chernaya, Seven Islands archipelago (Kuvshin and Kharlov Islands), and in the Franz Josef Land area.

The largest colonies (several over 100 000 pairs) are on Bjørnøya and along the west coast of Spitsbergen. The total population of the Brünnich's guillemot in Svalbard has been estimated to 1 300 000 individuals. Whereas the number of breeding Common guillemot on Bjørnøya declined drastically in 1986-1987, the Brünnich's guillemots increased by approximately 20% in a few years following 1986. There has been a general increase in the population of Brünnich's guillemots in several regions of Svalbard since the middle of the 1980s (Mehlum and Bakken, 1994).

The Brünnich's guillemot is the main species in the Novaya Zemlya bird colonies. The colony in Guba Chernaya has been regularly exploited since the middle 1930's. In some years (1935, 1937) up to 20 000 eggs were collected. The heavy exploitation caused a notable reduction in the number of birds nesting in the colonies. The total number of Brünnich's guillemot was about two million at the end of 1950's. This species then occupied every part of the western coast of Novaya Zemlya that was suitable for colonisation (Uspenskii, 1956).

The numbers of Brünnich's guillemots in colonies on the south side of George Land and at Northbrook Island (Franz Josef Land) were 10 000 and 10-12 000 individuals, respectively in 1992 (Frantzen *et al.*, 1993). Amphipods predominated in the stomachs of Brünnich's guillemot collected in summer 1992 in Franz Josef Land.

The Brünnich's guillemot population on Hornøya was 350 breeding pairs in 1983 (Furness and Barrett, 1985) and more than 500 individuals in 1992 (Krasnov and Barrett, 1995).

Until 1987, on the Eastern Murman coast, the Brünnich's guillemot population on Kharlov Island varied between 1000 to 2000 birds. At Kuvshin Island it was about 3-4000 birds (Krasnov *et al.*, 1995).

Recoveries of ringed Brünnich's guillemots indicate that the majority of birds breeding on Svalbard winter off southwestern Greenland. Others stay in the Barents Sea area and winter at sea, along the ice edge and in open leads in the ice. A large proportion of the Brünnich's guillemots wintering in the Barents Sea probably consists of birds from the Russian areas (Isaksen and Bakken, 1995; Krasnov *et al.*, 1995). Brünnich's guillemots from the Seven Islands winter along the west coast of Greenland, some may stay in the ice-free parts of the southern Barents Sea. Some Brünnich's guillemots from Novaya Zemlya and the Seven Islands winter in polynyas in the White Sea (Nikolaeva *et al.*, 1996).

Common guillemot, *Uria aalge*

The Common guillemot is a low-boreal arctic species. The size of the breeding population in the North Atlantic is estimated to be about 4 million pairs (Nettleship and Birkhead, 1985). In our study, Common guillemots were collected only on the Eastern Murman coast.

Common guillemots feed principally on fish throughout the year (Bradstreet and Brown, 1985). The list of food items for Common guillemot includes more than 40 species. However, fish are always predominant (Belopol'skii, 1957). In Arctic regions, Common guillemot prey may be restricted to one or two fish species (Erikstad and Vader, 1989; Barrett and Furness, 1990). Herring, capelin and sand eel are the main food items of Common guillemot chicks (Barrett *et al.*, 1997) in the southern Barents Sea. On Kharlov, sand eels were the most important prey items fed to Common guillemot chicks during the sampling period in 1992 (Barrett *et al.*, 1997).

On Kharlov Island (Seven Islands Archipelago), the Common guillemot declined in the mid-1950s and mid-60s from 3700 pairs in 1938, but then recovered to reach a maximum of 4200 pairs in 1976. The number of breeding *Uria spp.* on neighbouring Kuvshin Island increased from 2500 pairs in 1938 to 10 000 in 1976 (Shklyarevich, 1977).

Common guillemots from the Barents Sea winter in the southwestern parts of the sea and in areas off the coast of northern Norway (Golovkin, 1990; Krasnov *et al.*, 1995; Nikolaeva *et al.*, 1996).

Razorbill, *Alca torda*

The Razorbill is a low-boreal arctic species confined to the North Atlantic. The total world breeding population is estimated to be around 700 000 (range: 0.3 - 1 million) pairs (Nettleship and Birkhead, 1985). In this study, Razorbills were collected only on the Eastern Murman coast.

According Belopol'skii (1957), the main food items for Razorbill from the Barents Sea area were fish (75%), crustaceans (1.5%), polychaetes (0.7%) and molluscs (0.4%). Razorbills breed in small colonies at a few locations along the Murman coast. In 1991, the number of Razorbills on Kharlov Island was estimated to be about 76 pairs (Krasnov *et al.*, 1995).

Little is known about the migration pattern of Razorbills breeding in Eastern Murman. Tatarinkova and. Golovkin (1990a) considered that Razorbills from the Barents Sea have the same wintering area as those from the White Sea. The majority of birds winter offshore in southern Norway, some in the North Sea.

Black guillemot *Cepphus grylle*

The Black guillemot is a circumpolar polytypic boreo-panarctic species in the Atlantic and Arctic oceans. Birds used in the present study were collected on Franz Josef Land.

Polychaetes and amphipods predominated in the stomachs of Black guillemots collected in late 1991 winter and early spring in Franz Josef Land (Weslawski and Skakuij, 1992).

The number of Black guillemots breeding on Franz Josef Land is about 15 000 pairs (Uspenskii, 1959; Norderhaug *et al.*, 1977). The Black guillemot is known to breed throughout the archipelago either as single pairs, in small groups, or in large colonies. Of the 38 major seabirds' colonies known in Franz Josef Land, 28 are inhabited by Black guillemots (Norderhaug *et al.*, 1977).

The Black guillemots breeding on the Barents Sea islands winter in the coastal zone of the Kola peninsula and offshore in Northern Norway (Tatarinkova and Golovkin, 1990b).

Puffin *Fratercula arctica*

The Puffin is a North Atlantic polytypic boreo-panarctic species restricted to the North Atlantic. The total breeding population is around 5.8 million (range 3.8 - 8.2 million) pairs (Nettleship and Birkhead, 1985). In the present study, Puffins were collected in the southwestern part of the Barents Sea (Bol'shoi Ainov Island and Hornøya), on Svalbard (Ny-Ålesund), along the Eastern Murman coast (Kharlov and Kuvshin Islands) and in Troms (Sommarøy).

The Puffin breeds solitarily or in small colonies in the western parts of Svalbard. The total population is about 10 000 pairs (Mehlum and Bakken, 1994). The small Puffin population of the Kola Peninsula is concentrated in 11 colonies along the Murman coast (Gerasimova, 1962; Skokova, 1962). Numbers of Puffins counted on Bol'shoi Ainov declined progressively from ca 8000 individuals in 1960 to ca. 1500 individuals in 1965, and rose again to 3000 individuals by 1970, a level which has been more or less maintained to the present (Krasnov and Barrett, 1995). On Seven Islands, numbers dropped by over 50% between 1961 and 1979, but have since increased again from ca. 3000 individuals in 1986 to 5500 in 1993 (Krasnov and Barrett, 1995). The population of Puffin on Hornøya was about 5000 pairs in 1983 (Furness and Barrett, 1985). Since then there has been a 2.6% p.a. increase in numbers (Krasnov and Barrett, 1995).

During the summer, adult Puffins feed mainly, but not exclusively, on fish. The importance of invertebrates apparently varies both geographically and seasonally (Belopol'skii, 1957). The Puffin chicks in Eastern Murman in 1989-1993 were fed about 90% of sand eels. On Hornøya, the Puffin chicks' diet consists almost exclusively of capelin and sand eels, but significant proportions of other prey items have also been recorded (Barrett and Krasnov, 1996).

Little is known about were the Svalbard population winters. Some, however, winter in the ice-free parts of the Barents Sea and along the Norwegian coast (Isaksen and Bakken, 1995; R. Barrett, pers. comm.).

Anatidae

Common eider, *Somateria mollissima*

The Common eider is holarctic species and has a circumpolar distribution. In our study, Common eiders were collected in Northern Norway (Sommarøy, Troms), in Svalbard (Ny-Ålesund), and on Franz Josef Land. In Svalbard, the Common eider is the most numerous waterfowl species. The Svalbard population consists of 20-25 000 breeding pairs. The main part of the total population is found along the western coast of Spitsbergen. (Mehlum, 1991). The number of Common eiders on Sommarøy is about 1000 pairs (J.O. Bustnes, pers. comm.).

Common eiders feed on various benthic animals and small crustaceans. Amphipods and molluscs are the most common prey species. In Troms, blue mussels have been found to be very important making up to 46 % of their diet in 1980s. Sea urchins, *Strongylocentrotus droebachiensis* (35%), scallops, *Chlamys islandica,* and fish eggs were also important food items (Bustnes and Erikstad, 1988; 1990).

The Common eiders from Svalbard are migratory. In September, they fly south to the Norwegian coast and to Iceland. In some winters, some individuals may stay in Spitsbergen close to the sea ice (Mehlum, 1990). Birds from Northern Norway winter near the breeding sites (J.O. Bustnes, pers. comm.).

King eider, *Somateria spectabilis*

The King eider has a circumpolar distribution. They nest in large numbers along the coast of Northern Norway, and in the eastern part of the Barents Sea. Samples of King eider were collected at Sommarøy (Troms) and in the Pechora Sea region (on Dolgiy, Kolguyev, and Vaygach Islands).

In 1960, the total number of King eiders breeding on Vaygach was estimated to 125 birds. At Kolguyev Island, the King eider numbers have decreased significantly because of increasing human disturbance (Karpovich and Kokhanov, 1963). No data on the status of the King eider population from Dolgiy Island are available at present.

The King eider feeds on the same benthic species as the Common eider. However the diet is usually more diverse with different proportions of the prey species. On the coast of Troms, the blue mussel and echinoderms were predominant feed items in the 1980s (Bustnes and Erikstad, 1988).

It is probable that most of the King eiders that breed in northwest Russia and on Svalbard winter in the area from the White Sea, along the coast of Finmark, Troms, and down to the northern part of Nordland (Nygård *et al.*, 1988).

Long-tailed duck, *Clangula hyemalis*

The Long-tailed duck has a circumpolar distribution. They are common in the mountain regions of Northern Norway and in the eastern part of the Barents Sea. Their diet consists mainly of invertebrates. They may also feed on some plant matter. The species is mainly migratory (Bakken *et al.*, 1999).

Two Long-tailed ducks were collected in Northern Norway (Sommarøy) and in the Pechora Sea (Dolgiy Island). No data are available concerning the feeding ecology and migration routes of this species from the investigated areas.

Procellariidae

Fulmar, *Fulmarus glacialis*

The Fulmar is a holarctic species. They have a wide distribution in Svalbard (including Bjørnøya). On Franz Josef Land, the Fulmar is one of the most common seabird species. In our study, Fulmars were collected from these two areas only. The largest colonies of Fulmar are on Bjørnøya and along the western coast of Spitsbergen. Mehlum and Bakken (1994) estimated the total breeding population in Svalbard to be between 100 000 and 1 000 000 pairs. Of the 85 seabird colonies observed in the Franz Josef Land, 15 were inhabited by Fulmars (Norwegian Polar Institute seabird colony database, 1996).

The Fulmar feeds on the sea surface on squids, polychaetes, small fish, crustaceans etc. (Mehlum, 1990). In Tikhaya Bay (Hooker Island) in 1991, Fulmar stomachs were found half-empty, with remains of litter and only a few food items. Polar cod and pelagic polychaetes were the primary food items (Weslawski and Skakuij, 1992).

After the breeding period, Fulmars remain in the areas around Svalbard. During the winter they may be also found in the more southern areas of the Barents Sea (Isaksen and Bakken, 1995).

Analytical method

For trace metals determination, samples of liver, kidney and muscles were collected. However, due to the financial situation only liver and muscle samples were analysed. Only titanium tools were used when dissecting the birds. All samples were frozen and stored in a deep-freezer (-20°C) until analysis.

Trace metal determination was done at the Norwegian Institute for Nature Research (NINA, Trondheim). The laboratory has accreditation for trace element analyses (P072).

Samples of muscle and liver of birds were freeze-dried for approximately 24 hours to a final pressure of 0.05 mbar at -53°C, using a CHRIST LDC-1 freeze dryer. Each sample was digested in Scan pure concentrated nitric acid in a microwave oven (Milestone MLS 1200). The elements were determined by atomic absorption spectroscopy (Perkin Elmer Model 1100B). A graphite furnace (HGA 700) with an automatic sampler (AS 70) was used for As, Cr and Se, and a hydride system (FIAS 200) with an automatic sampler (AS 90) for Hg. The other elements (Cd, Cu, Mn and Zn) were analysed by flame AAS.

The accuracy of the analytical procedures was checked against the National Bureau of Standards (NBS) for bovine liver 1577A (Cd, Cu, Hg, Se, and Zn) and dogfish muscle DOLM-1 (As, Cd, Cu, Cr, Hg, Se, and Zn). The accuracy of the analytical procedures was good for most of the metals. However, only about 50 and 70% of the concentrations given for Cr in the two dogfish standards could be detected.

All element concentrations are presented in this report as mg/kg dry weight.

Statistical analysis

The hypothesis of normal distribution was tested using the Lilliefors test. Comparison between means was performed using Student's test for normal distribution data. When the hypothesis of normal distribution had to be rejected, the Kruskal-Wallis and Mann-Whitney U test statistics were used to estimate the significance of differences between the means and to identify homogeneous groups. Homogeneous groups are groups with no significant differences between means. The word "significant" has been used only in the statistical context and is taken to mean that statistical testing indicated a probability of chance occurrence of less than 5%.

Linear regression was used to analyse the relationships between hepatic and muscle element content and between concentration of different elements. Both Pearson and Spearman coefficients of correlation were used for test of linear relationships.

Outside values were checked with box-and-whiskers plot procedure. A box-and-whiskers plot shows the distribution of a quantitative variable. For a plot of a quantitative variable grouped by a qualitative variable, the distribution within each category is displayed. The vertical line inside the box represents the median (the 50th percentile) and the vertical ends of the box represent the lower and upper hinges (the 25th and 75th percentiles) Outside values are data outside the inner fences. Where *Hspread* is the absolute value of the difference between the two hinges, inner fences are defined as:

Lower fence = lower hinge - 1.5 (*Hspread*)
Upper fence = upper hinge + 1.5 (*Hspread*).

All statistical procedures were performed with SYSTAT Ver. 5.0 (Systat Inc.).

Three files were formed from the whole data set. All available data concerning trace element levels in adult birds were used for the study of geographical differences and for the comparison of the results with literature data. Outside values were removed from the whole file (for each species separately) before the testing of significant differences in trace element levels between various species and sexes of birds. The coefficients of correlation between different trace elements were calculated from the same file. After that, appropriate pairs of values of trace element concentrations in liver and muscles of adult individuals were chosen for studying the relationships between them. The differences between average values in the Appendices are connected with different numbers of samples used for the calculations.

Test of significance of differences between metal concentrations in tissues of adult and juvenile birds was applied for Brünnich's guillemots from the Seven Islands Archipelago, Common guillemots from Kuvshin Island, Common eiders from Ny-Ålesund, Glaucous gulls from Franz Josef Land, Kittiwakes from Hooker Island (Franz Josef Land), Herring gulls from Hillesøya, and Herring gulls from Hornøya.

RESULTS

The results of metals and trace elements determination in birds' tissues are presented in Appendix 1.

Cadmium

Geographical differences

Geographical differences in trace element levels were examined using the Brünnich's guillemot, Puffin, Glaucous gull and Kittiwake. These species were most widely presented in our data. The average concentrations of Cd in the liver and muscle of the examined seabird species, and also some additional statistical information are given in Appendix 2. The contents of Cd in liver of birds from various seabird colonies in the Barents and Norwegian Seas are shown in Fig. 2.

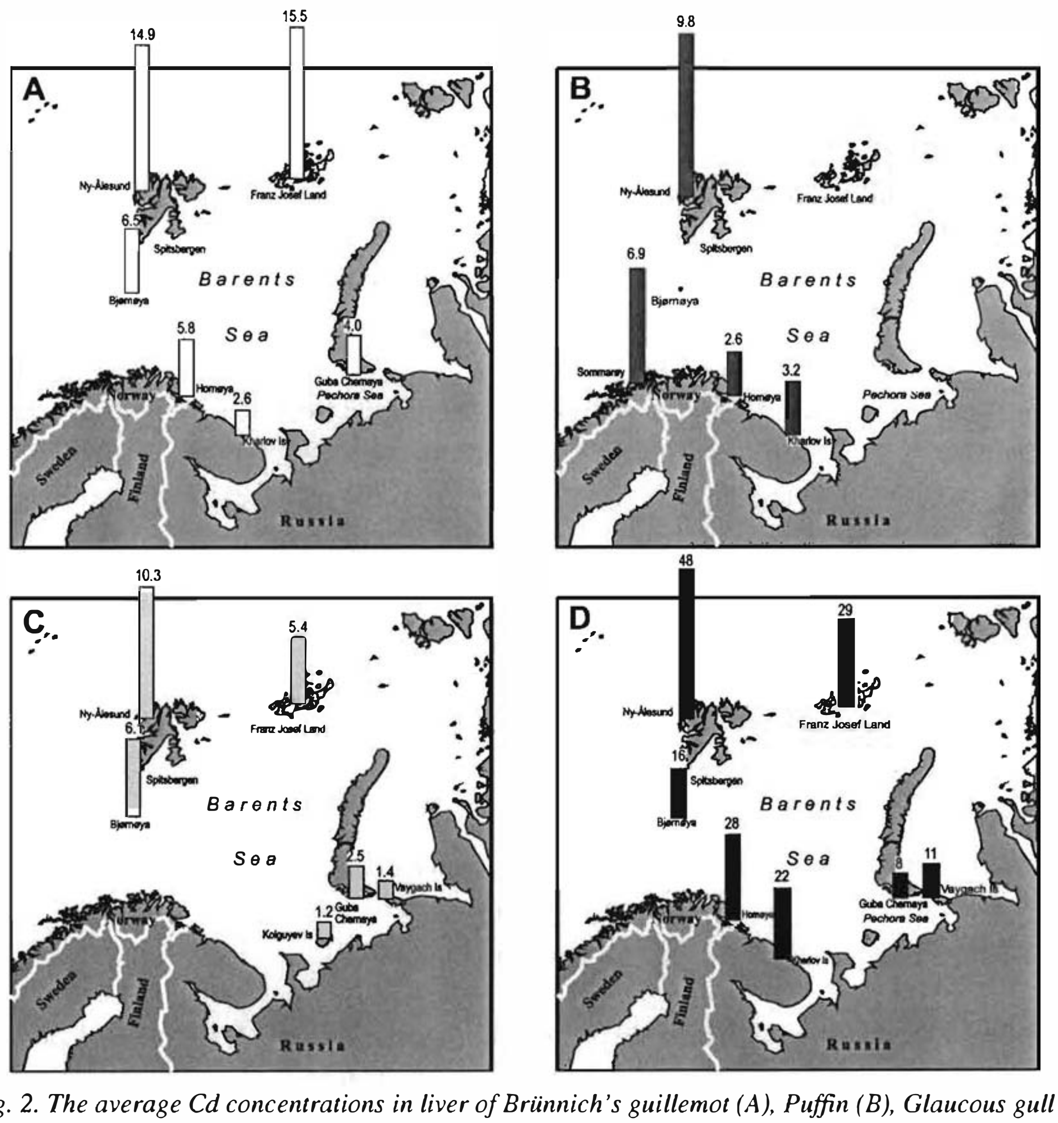

Fig. 2. The average Cd concentrations in liver of Brünnich's guillemot (A), Puffin (B), Glaucous gull (C), and Kittiwake (D) collected in different colonies.

The greatest geographical differences in hepatic Cd levels were found among the Brünnich's guillemots (Fig.2A). They vary from 2.55±1.93 mg/kg (Kharlov Island) to 15.5±5.34 mg/kg (Franz Josef Land). Brünnich's guillemots from different nesting colonies were grouped into three groups in accordance to the hepatic Cd levels. The two first groups have united Kharlov Island, Guba Chernaya, Hornøya, and Bjørnøya areas. Average concentrations of Cd in liver of birds from these colonies varied between 2.55±1.93 to 6.51±2.56 mg/kg. The third group included the Ny-Ålesund and Franz Josef Land areas. Hepatic Cd levels in birds from these regions were 14.9±6.16 and 15.5±5.34 mg/kg, respectively. These levels were significantly higher than those in groups 1 and 2 combined.

Average Cd concentrations in the liver of Puffins varied from 2.60±1.00 (Hornøya) to 9.77±3.21 mg/kg (Ny-Ålesund) (Fig. 2B). Significant differences were found only between birds nesting on Hornøya and Kuvshin Islands, on one side, and Sommarøy and Ny-Ålesund, on the other.

Average Cd concentrations in the liver of Glaucous gulls from Kolguyev Island (1.21±0.46 mg/kg) were significantly lower than those in birds of this species nesting on Bjørnøya (6.06±3.57 mg/kg) and in Ny-Ålesund (10.3±8.51 mg/kg)

The average level of Cd in the liver of Kittiwakes from Ny-Ålesund (48.01±18.62 mg/kg) was significantly higher than in Kittiwakes from the south-eastern part of the Barents Sea - Guba Chernaya (8.14±12.3 mg/kg) and Vaygach Island (11.0±11.9 mg/kg).

No geographical differences were observed in the muscle Cd levels of the four species investigated (Appendix 2). Though Cd levels in muscles of birds nesting in Ny-Ålesund tended to be higher than those in birds from the other regions, the difference was not significant. This is probably due to the high intra-specific variability of the Cd contents.

Nevertheless, the results showed that the maximum levels of Cd were found in birds nesting in the northern part of the Barents Sea, in the Ny-Ålesund area (Spitsbergen) and in the Franz Josef Land Archipelago.

Inter-specific differences

The average Cd concentrations in the liver and muscle of the different species, and the statistical information are given in the Appendix 3. The average Cd levels in liver and a comparison of species levels are presented in Fig. 3.

Average Cd concentrations in liver of birds varied from 1.72±0.39 (Common guillemot) to 40.4±31.5 mg/kg (Fulmar). The statistical analysis enabled us to combine the species into five homogeneous groups. The first group was characterised by the lowest Cd concentrations (from 1.72±0.39 to 4.24±2.26 mg/kg) and included the Common guillemot, Herring gull, Razorbill, Glaucous gull, and Little auk. The average Cd concentrations in liver of birds included in this group were significantly lower than those found in the liver of birds of the other species except the Puffin, King eider, and Black guillemot.

Significantly higher average levels of Cd (from 14.5±5.77 to 40.4±31.5 mg/kg) were found in the liver of birds included in group 5. This group united the Common eider (*Anatidae*), Arctic tern (*Sternidae*), Kittiwake (*Laridae*), and Fulmar (*Procellariidae*) (Fig. 3). At the same time, hepatic Cd levels were significantly lower in *Alcidae* than in other seabird families. It is possible that the comparatively low hepatic Cd levels are characteristic for alcids.

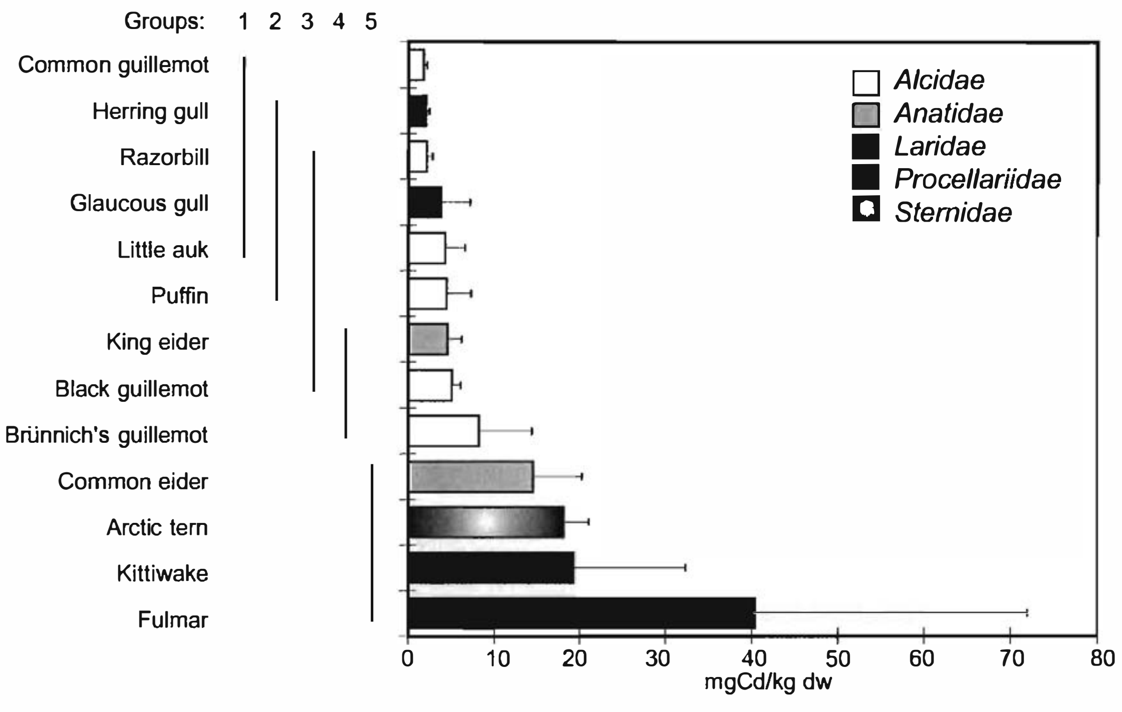

Fig. 3. The average hepatic Cd levels in different seabird species (mg/kg dry weight). Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α=0.05.).

Levels of Cd in the muscle of the investigated species varied from 0.16±0.09 mg/kg (Herring gull) to 5.22±5.06 mg/kg (Fulmar). The level of Cd in the muscle of the Fulmar was significantly higher compared to the other species investigated. The average Cd level in the muscle of the Herring gull was similar to that in the Common guillemot, King eider, Glaucous gull, Razorbill, and Puffin.

Sex-dependent differences

There were no sex-dependent differences in hepatic Cd levels in any of the species studied and in most (8 of 10) muscle comparisons. Significant differences ($p < 0.05$) between the average Cd concentrations were only found in the muscle of males and females Glaucous gulls (0.21±0.14 and 0.38±0.21 mg/kg) and Fulmars (5.29±4.57 and 1.56±0.705 mg/kg), respectively (Appendix 4). In both cases Cd levels were higher in females that in males.

Age differences

Hepatic and muscle Cd levels in adult Brünnich's guillemots were significantly higher than in juvenile birds (Appendix 5). The same was also found for Common guillemots and Herring gulls from Hillesøya. Significant age differences were also found for hepatic tissue of Common eider, Herring gulls from Hornøya and Kittiwakes. Cd contents in liver of adult birds of these species were higher in comparison with juvenile birds. In contrast hepatic Cd concentration in juvenile Common eider was significantly higher than in adult eiders. No significant differences were found for both hepatic and muscle tissues Cd levels of Glaucous gulls.

Relationship between Cd levels in muscle and liver of birds

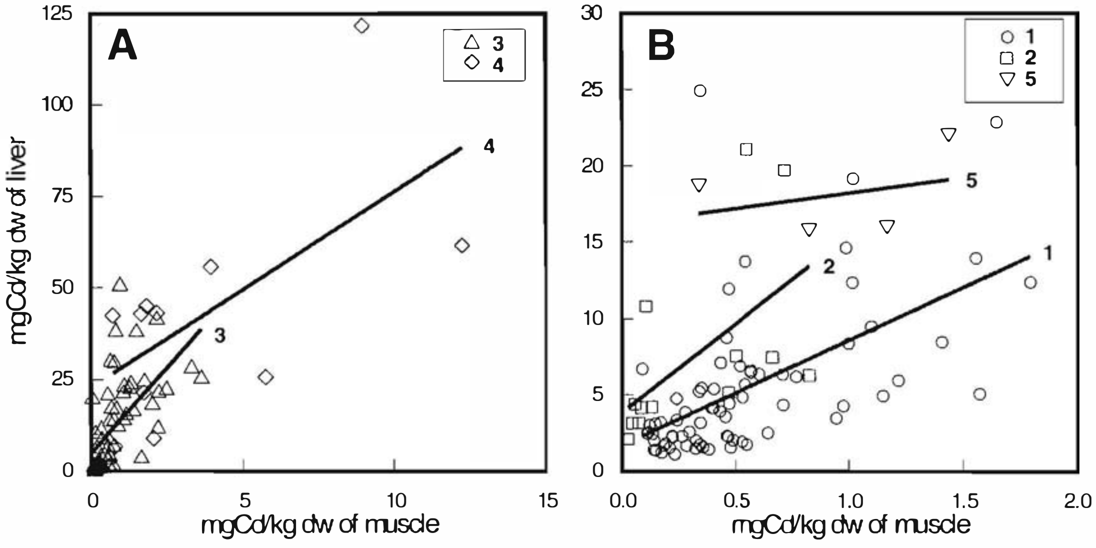

Fig. 4. The relationship between Cd levels in muscle and liver of birds belong to Alcidae (1), Anatidae (2), Laridae (3), Procellariidae (4) and Sternidae (5) families.

Hepatic Cd levels were much higher than those in the muscle in all birds investigated (Fig. 4.) Linear relationships between concentrations of Cd in the muscle and liver of birds were found for all families investigated. Pearson coefficients of correlation for *Alcidae*, *Anatidae*, *Laridae* and *Procellariidae* were 0.569 ($P < 0.001$), 0.565 ($P < 0.050$), 0.612 ($P < 0.001$) and 0.631 ($P < 0.05$), respectively. Coefficients of regression increased in the order: *Procellariidae* (5.3), *Alcidae* (6.9), *Laridae* (9.4), *and Anatidae* (11.6). For further statistical information see Appendix 6.

Zinc

Geographical differences

The result of the analysis of geographical differences in Zn levels is given in Appendix 2. The relative contents of Zn in liver of Brünnich's guillemot, Puffin, Glaucous gull and Kittiwake from different colonies are shown in Fig. 5.

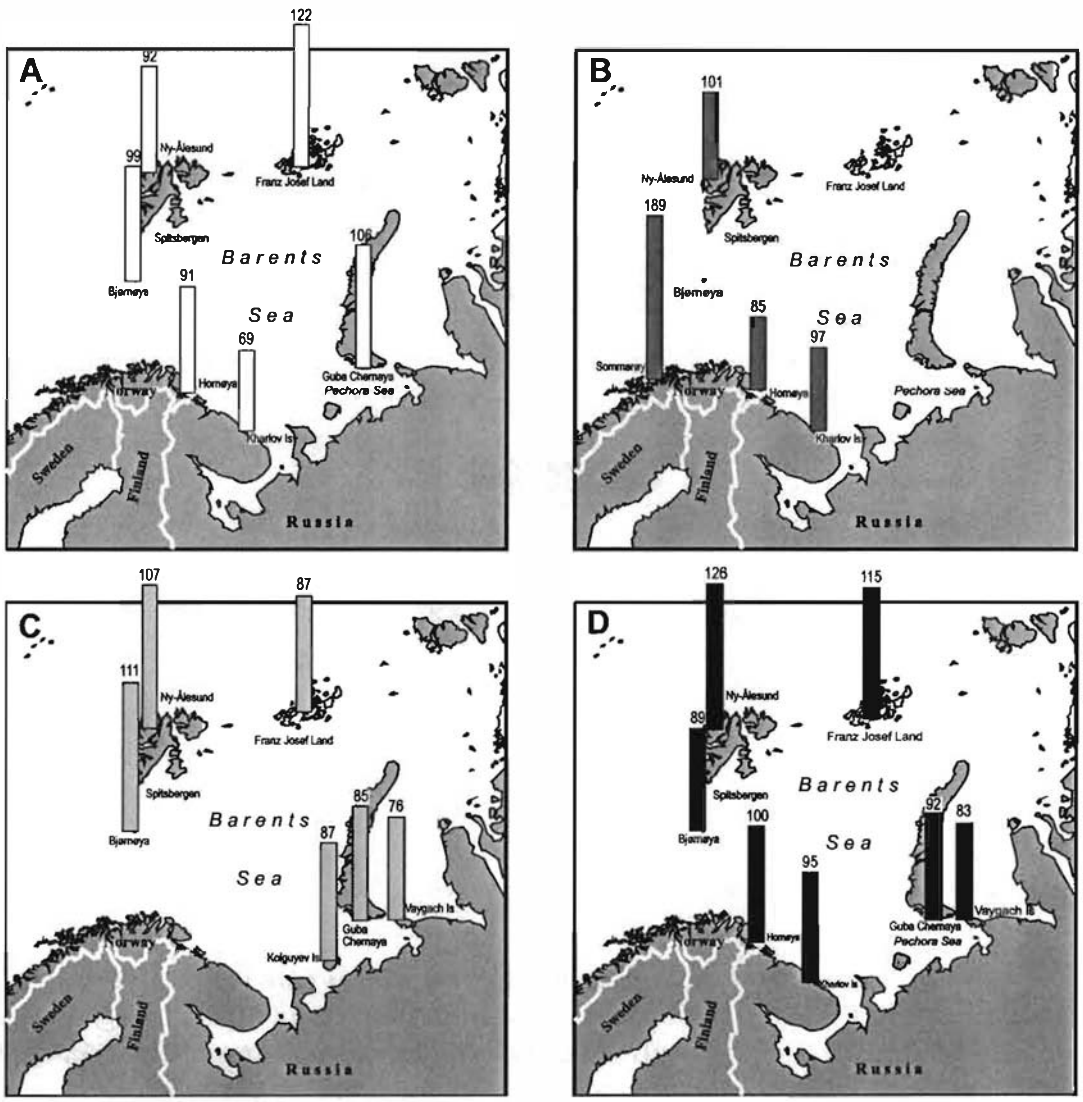

Fig. 5. The average Zn concentrations in liver of Brünnich's guillemot (A), Puffin (B), Glaucous gull (C), and Kittiwake (D) collected in different colonies.

The average hepatic Zn level in Brünnich's guillemots from Kharlov Island (69.3±1.8 mg/kg) was significantly lower than that in the same species from all the other seabird colonies investigated. The highest average value (122±11.9 mg/kg) was found in liver of Brünnich's guillemot, caught on the Franz Josef Land Archipelago (Fig. 5A).

The average Zn concentration in the liver of Puffin from Sommarøy (189±17.5 mg/kg) was significantly higher than in Puffins nesting in other colonies. The same seems to be the case with levels of Zn in the muscle of Puffin (Appendix 2).

The highest Zn concentrations recorded in liver of Kittiwakes were found in birds inhabiting the northern part of the Barents Sea - in Franz Josef Land and Spitsbergen (115±17.3 and 126±16.8 mg/kg, respectively) (Fig. 5D). The levels of Zn in liver of Kittiwake nesting in the eastern part of the Barents Sea (Kharlov Island, Vaygach Island, Guba Chernaya) and on Bjørnøya were significantly lower.

There were no geographical differences in Zn levels in Glaucous gull.

Inter-specific differences

The statistical information on Zn levels in liver and muscle of various bird species is given in Appendix 3. Based on the Zn hepatic levels in all species, we found six groups (Fig. 6).

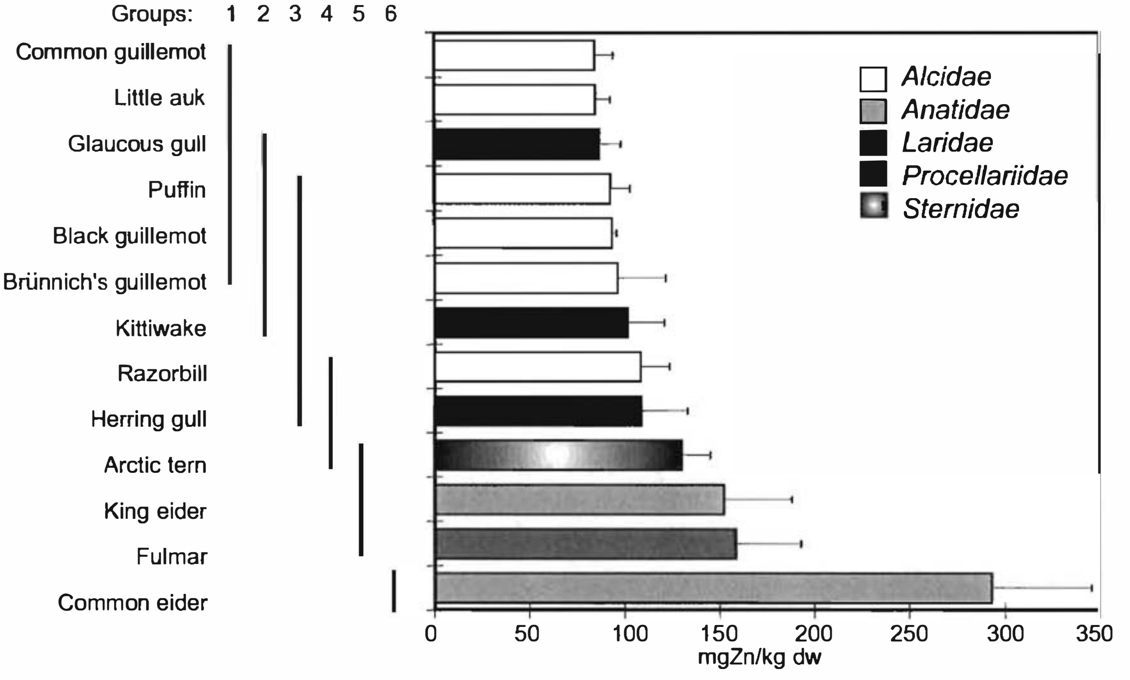

Fig. 6. The average hepatic Zn levels in different seabird species (mg/kg dry weight). Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α=0.05.).

The first three groups united all birds of the *Alcidae* and *Laridae* families. Average Zn concentrations in tissues of these families varied from 84.7±9.5 (Common guillemot) to 109±24.5 mg/kg (Herring gull). The birds of *Sternidae* (Arctic tern), *Anatidae* (King eider) and *Procellariidae* (Fulmar) families were united in group 5. Hepatic Zn levels in King eider (152±36.2 mg/kg) and Fulmar (158±34.6 mg/kg) were significantly higher than those of birds from groups 1-3. The average level of Zn in the liver of Common eider (293±52.6 mg/kg) was significantly higher than in all the other species investigated.

The analyses of muscle tissues gave the opposite result (Appendix 3). For instance, the lowest average concentration of Zn (35.1±3.9mg/kg) was registered in the muscle of Common eider, whereas the average Zn level in muscle of Glaucous gull (68.5±18.5mg/kg) was significantly higher than in all the other species investigated, except the Fulmar and Herring gull.

Sex-dependent differences

No sex-dependent differences were found in hepatic and muscle Zn levels in any of the seabird species investigated (Appendix 4).

Age differences

Significant age differences were found only for Brünnich's guillemots (hepatic and muscle tissues) and for Common guillemots (hepatic tissues). In all cases higher Zn contents were in tissues of juvenile birds (Appendix 5).

Relationship between Zn levels in liver and muscle of birds

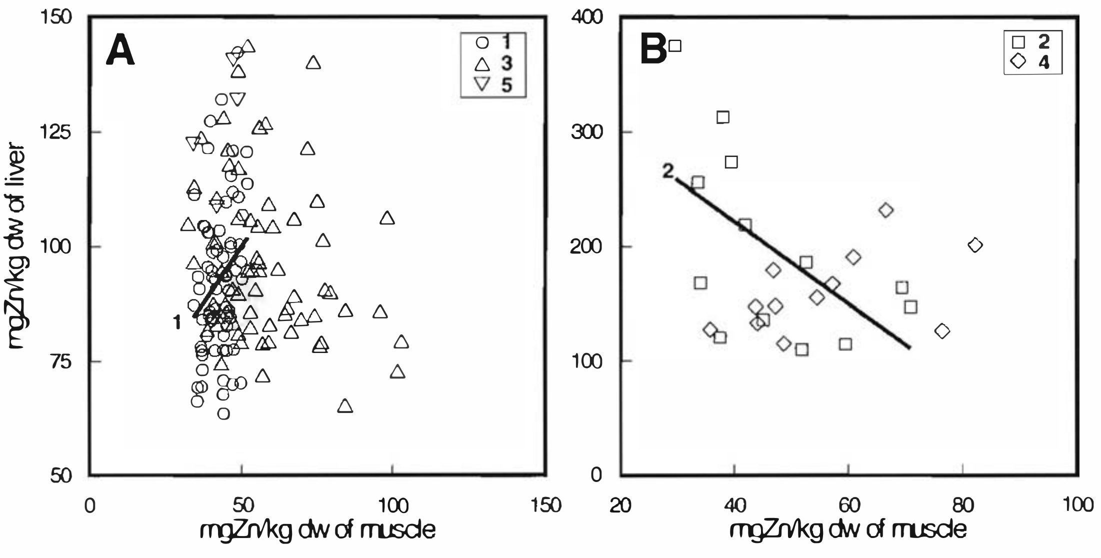

Fig. 7. The relationship between Zn contents in muscle and liver of birds belong to Alcidae (1), Anatidae (2), Laridae (3), Procellariidae (4) and Sternidae (5) families..

Hepatic Zn levels generally exceeded those in muscle tissues (Fig. 7). Linear relationships ($P < 0.05$) between Zn concentrations were found only in the liver and muscle of birds from *Alcidae* and *Anatidae* families (Appendix 6).

Copper

Geographical differences

Average concentrations of Cu in muscle and liver of four bird species are given in Appendix 2. In general Cu levels were quite similar in liver and muscle tissues. A few geographical differences were found in Cu levels in muscle (Fig. 8).

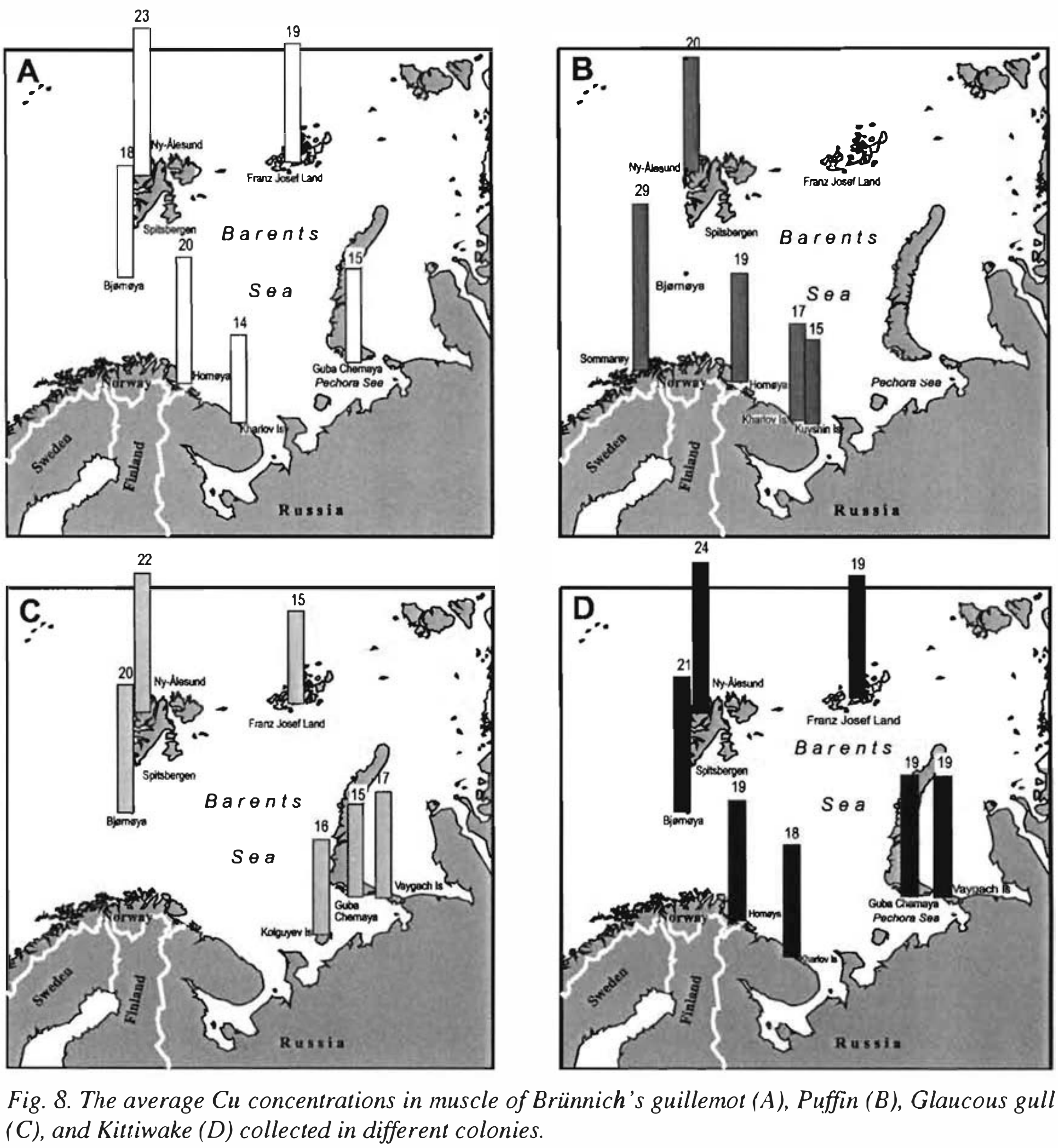

Fig. 8. The average Cu concentrations in muscle of Brünnich's guillemot (A), Puffin (B), Glaucous gull (C), and Kittiwake (D) collected in different colonies.

The highest Cu levels were registered in muscle of birds caught on Spitsbergen. Significant differences were found between the Cu contents in muscle of Brünnich's guillemot from Ny-Ålesund (23.1±1.79 mg/kg) and the same species from the other regions of the Barents Sea. Significant differences were also found between Glaucous gull from Ny-Ålesund and the same species nesting on the Franz Josef Land Archipelago, Kolguyev Island, and Guba Chernaya. Average Cu concentration was significantly higher in muscle of Kittiwakes from Ny-Ålesund than from Franz Josef Land, Kharlov Island, and Vaygach.

The levels of Cu in muscle of Puffin caught in different areas of the Barents Sea were similar, but significantly lower than in birds caught at Sommarøy (Troms). Puffins from Sommarøy differed by high Cu level in hepatic tissue too (Appendix 2).

Inter-specific differences

Hepatic Cu levels in birds belonging to the *Alcidae*, *Laridae*, *Procellariidae*, and *Sternidae* families were low and varied within narrow limits - from 16.5±1.5 (Herring gull) to 28.4±3.0 mg/kg (Arctic tern). Concentrations were much higher in the liver of species belonging to the *Anatidae* family (King eider and Common eider) (84.9±80.6 and 227±26.9 mg/kg, respectively). The average Cu level in Common eider liver was significantly higher than in all other species investigated (Fig. 9).

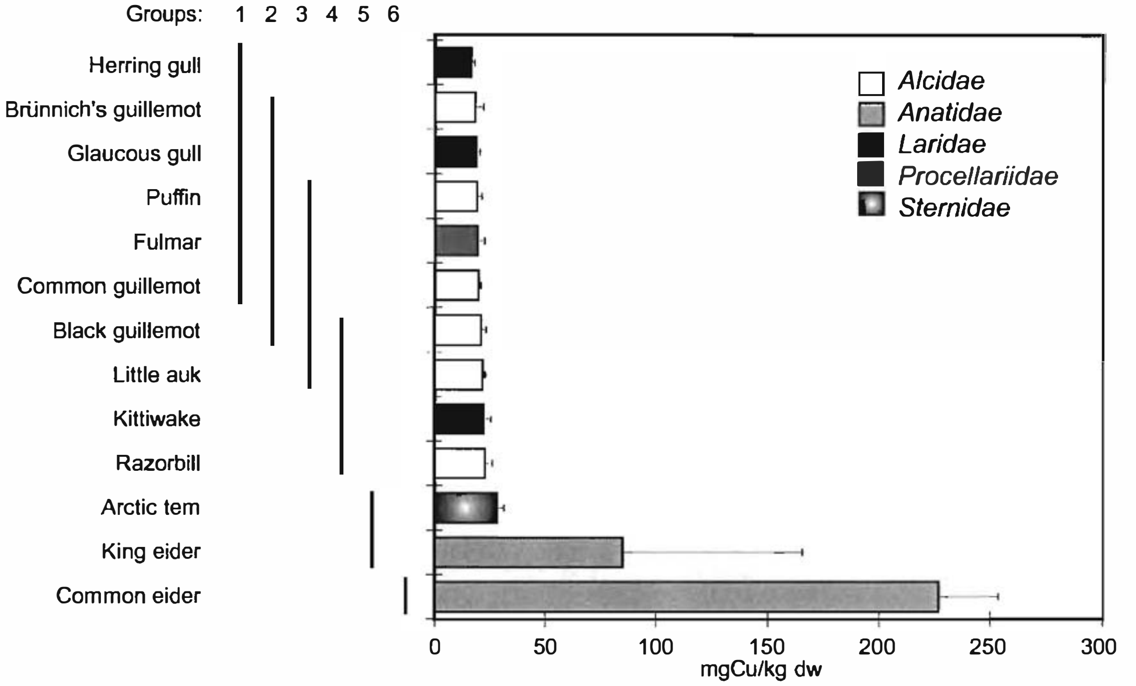

Fig. 9. The average hepatic Cu levels in different seabird species (mg/kg dry weight). Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α=0.05.).

A different picture was observed in muscle tissue. Here the average Cu concentrations varied from 15.9±3.1 mg/kg (Common guillemot) to 23.9±4.7 mg/kg (Little auk). The average Cu concentration in muscle of Little auk was significantly higher than the other species, with the exception of Black guillemot, King eider, and Arctic tern (Appendix 3).

Sex-dependent differences

Sex-dependent differences in tissue Cu levels were only found in the King eider and in the *Laridae* species (Kittiwake and Glaucous gull) (Appendix 4). The average hepatic Cu concentration in males of King eider (196±92.6 mg/kg) was significantly higher ($p<0.05$) than in females (47.9±28.2 mg/kg). In both gull species, Cu levels in female muscle samples were significantly higher than in males. The average concentrations in the muscle of females and males of Glaucous gull and Kittiwake were 19.2±3.68 > 15.7±2.49 and 20.4±1.78 > 18.9±1.85 mg/kg, respectively.

Age differences

Significant age differences were found for Brünnich's guillemots (muscle), Common guillemots (both liver and muscle tissues), and hepatic tissues of Common eider (Appendix 5). Adult birds of these species have higher levels of Cu compared with juveniles.

Relationship between Cu levels in muscle and liver of birds

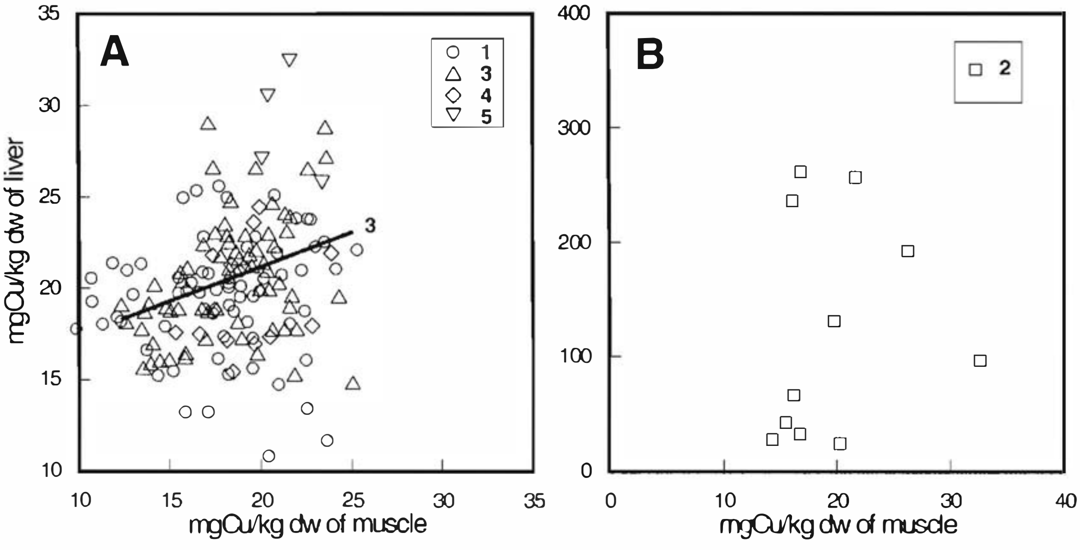

Fig. 10. The relationship between Cu contents in muscle and liver of birds belong to Alcidae (1), Anatidae (2), Laridae (3), Procellariidae (4) and Sternidae (5) families.

A significant linear relationship ($P < 0.01$) was found only for birds of the *Laridae* family (Appendix 6, Fig. 10A). The coefficient of regression was 0.377. This may indicate that an increase in Cu concentrations in the muscle of birds from *Laridae* family is accompanied by a minor increase in Cu in the hepatic tissue.

Manganese

Geographical differences

Because Mn levels were analysed in tissues of birds collected in 1992-1993 only, sample sites were small. Geographical differences in Mn levels were found for Brünnich's guillemot and Puffin only (Fig. 11A,B, Appendix 2).

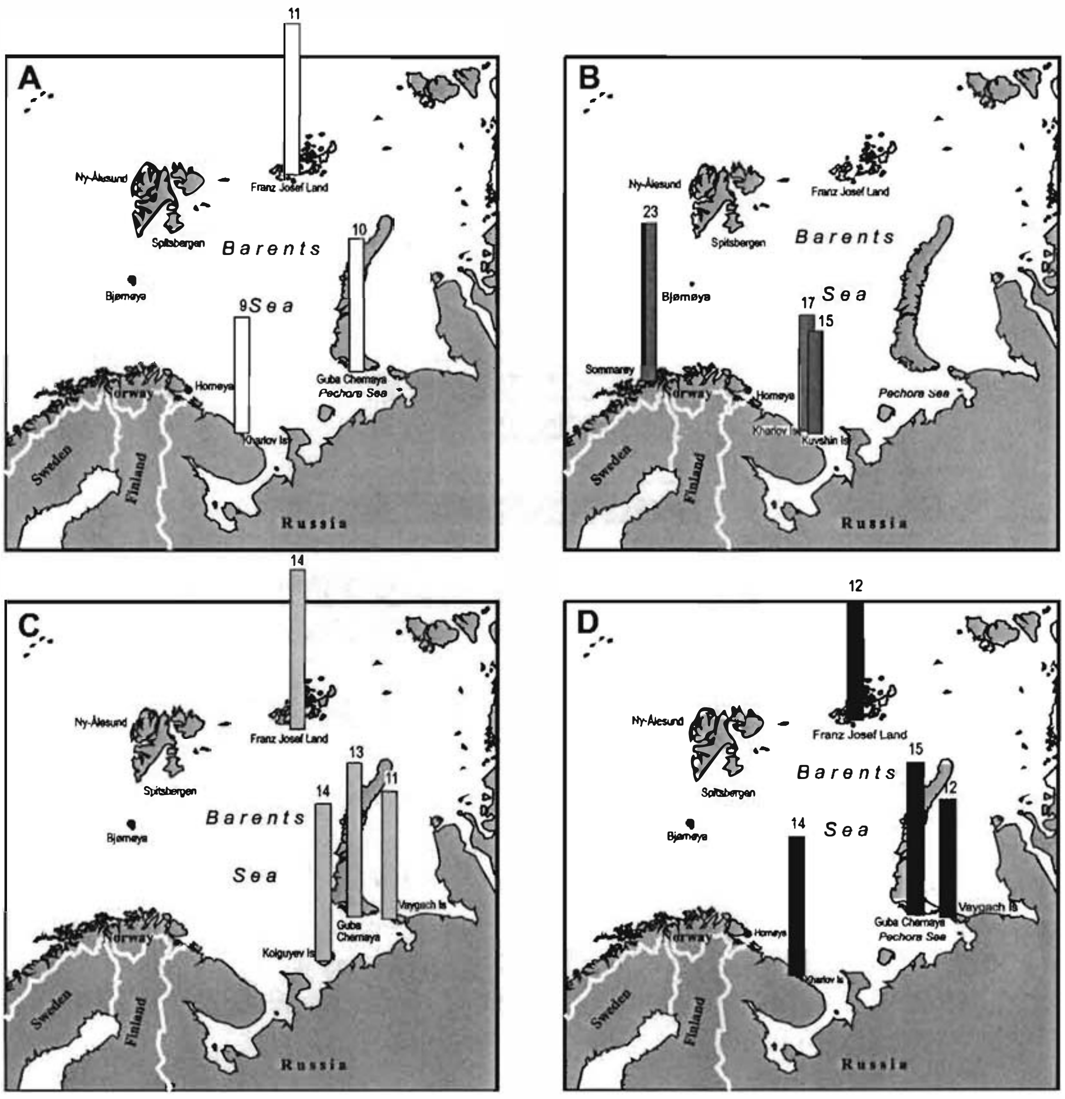

Fig. 11. The average Mn concentrations in liver of Brünnich's guillemot (A), Puffin (B), Glaucous gull (C), and Kittiwake (D) collected in different colonies.

The average Mn level in liver of Brünnich's guillemot from Franz Josef Land (11.2±0.95 mg/kg) was significantly higher than that in the same species from Kharlov Island (Seven Islands Archipelago) (8.59±0.95 mg/kg).

Hepatic Mn levels in Puffin, caught in the Seven Islands Archipelago (15±0.76 - 16.8±1.40 mg/kg) differed significantly from those in Puffin collected on Sommarøy (23.0±1.82 mg/kg). There were no geographical differences in Mn levels in muscle in any of the bird species investigated.

Inter-specific differences

Mn levels in liver and muscle of different bird species are presented in Appendix 3.

The lowest hepatic Mn level was registered in the Little auk, while the highest levels were found in the King eider. The investigated species were divided into four groups according to their Mn levels (Fig. 12). Group 1 included the Little auk, Black guillemot, Brünnich's guillemot, and Herring gull and had the lowest average concentrations of Mn (from 7.1±3.5 up to 12.5±2.5 mg/kg). These concentrations, with the exception of Herring gull, were significantly lower than in all the other species investigated. The highest Mn levels (from 16.1±1.8 to 19.6±4.1mg/kg) were characteristic of birds in group 4. This group included the Fulmar, Arctic tern, Puffin and King eider. Hepatic Mn levels in the Puffin and King eider were significantly higher than in all the other species investigated, except the Fulmar and Arctic tern.

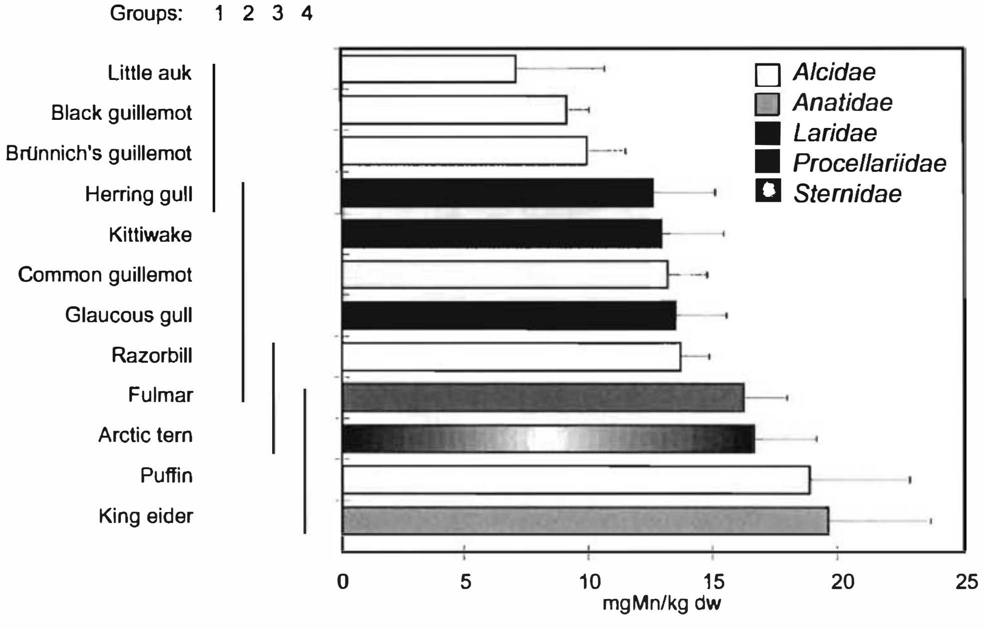

Fig. 12. The average hepatic Mn levels in different seabird species (mg/kg dry weight). Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α=0.05.).

Average Mn concentrations in the muscle of the species investigated varied within small limits (Appendix 3) and the inter-specific differences were minimal. The lowest concentration of Mn was registered in muscle of Common guillemot. The highest was found in muscle of Arctic tern.

Sex-dependent differences

There were no differences between the sexes in Mn levels in any of the species studied. This was true for both muscle and liver samples (Appendix 4).

Age differences

Significant age difference was found only for muscle tissue of Herring gulls from Hillesøya. Adult birds have higher Mn level (Appendix 5).

Relationship between Mn levels in muscle and liver of birds

Variations in Mn contents in hepatic tissue of seabird families examined were independent of the Mn level in their muscle tissues (Appendix 6).

Chromium

Geographical differences

As seen in Appendix 2, nesting areas are divided into two groups for each species in accordance to hepatic levels of Cr. The first group consists of Brünnich's guillemot from Bjørnøya, Hornøya, and Ny-Ålesund. The average Cr concentrations in this group varied from 0.04±0.0 up to 0.05±0.02 mg/kg. Significantly higher Cr concentrations (from 0.16±0.012 up to 0.34±0.28 mg/kg) were found in Brünnich's guillemots from Franz Josef Land, Guba Chernaya, and Kharlov (second group). In Puffins the lowest average hepatic Cr levels were found in birds caught at Hornøya, Ny-Ålesund, and Kharlov Island (from 0.06±0.01 up to 0.14±0.03 mg/kg). Whereas the levels were significantly higher in Puffins from Sommarøy and Kuvshin Island (0.29±0.07 and 0.50±0.60 mg/kg, respectively) Glaucous gulls nesting on Bjørnøya and in Ny-Ålesund had significantly low hepatic Cr levels (0.05±0.01; 0.06±0.03 mg/kg). The lowest hepatic level of Cr in Kittiwakes was found in birds caught in Ny-Ålesund and on Hornøya. Thus, a low Cr content was characteristic of all bird species caught in the Ny-Ålesund area and on Hornøya (Fig. 13).

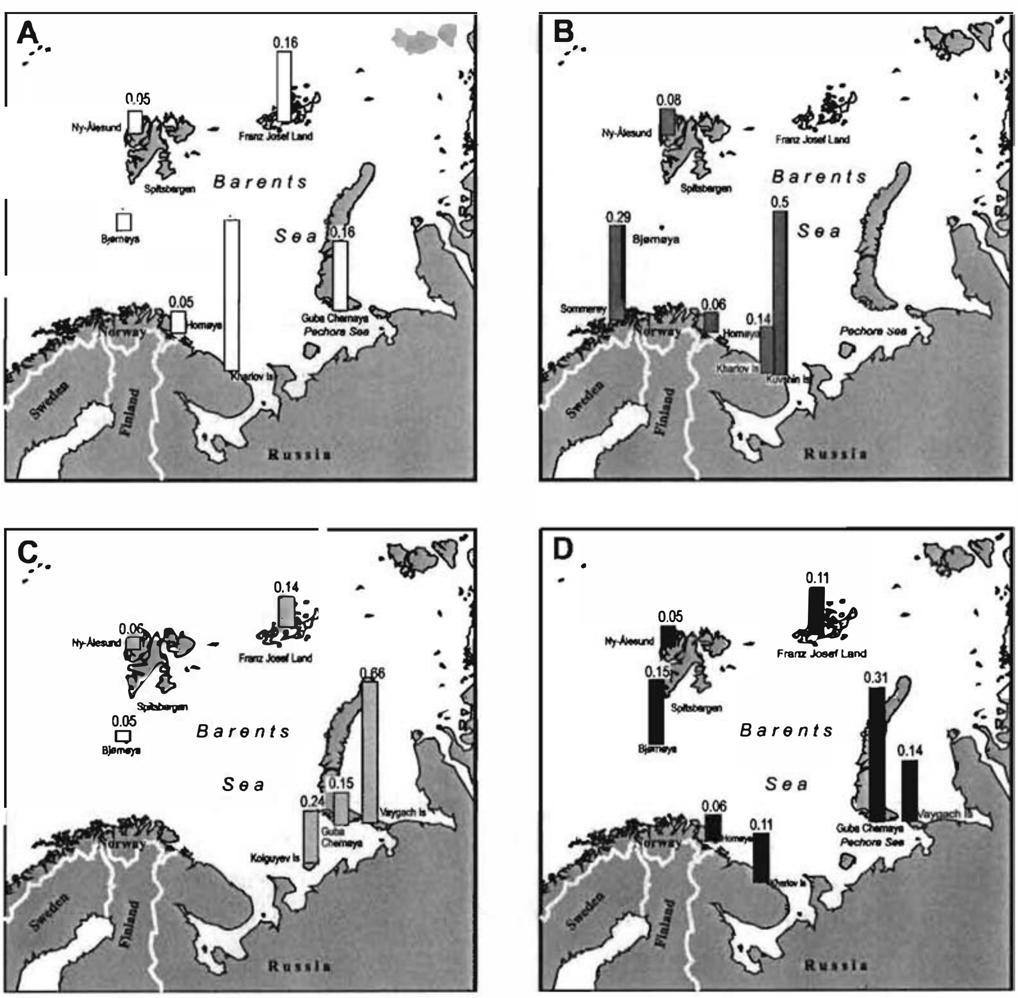

Fig. 13. The average Cr concentrations in liver of Brünnich's guillemot (A), Puffin (B), Glaucous gull (C), and Kittiwake (D) collected in different colonies.

High levels of Cr were found in birds from the Eastern Murman coast (Kharlov and Kuvshin Islands) and in the Pechora Sea area (Vaygach Island, Guba Chernaya). The average Cr concentrations, detected in the liver of Brünnich's guillemot, Puffin, Glaucous gull, and Kittiwake from these areas were 0.34±0.28; 0.50±0.60; 0.66±0.31 and 0.31±0.27 mg/kg, respectively.

Inter-specific differences

Levels of Cr in liver and muscle of different seabird species are presented in Appendix 3. Fig. 14 shows the average hepatic Cr concentrations in all species investigated.

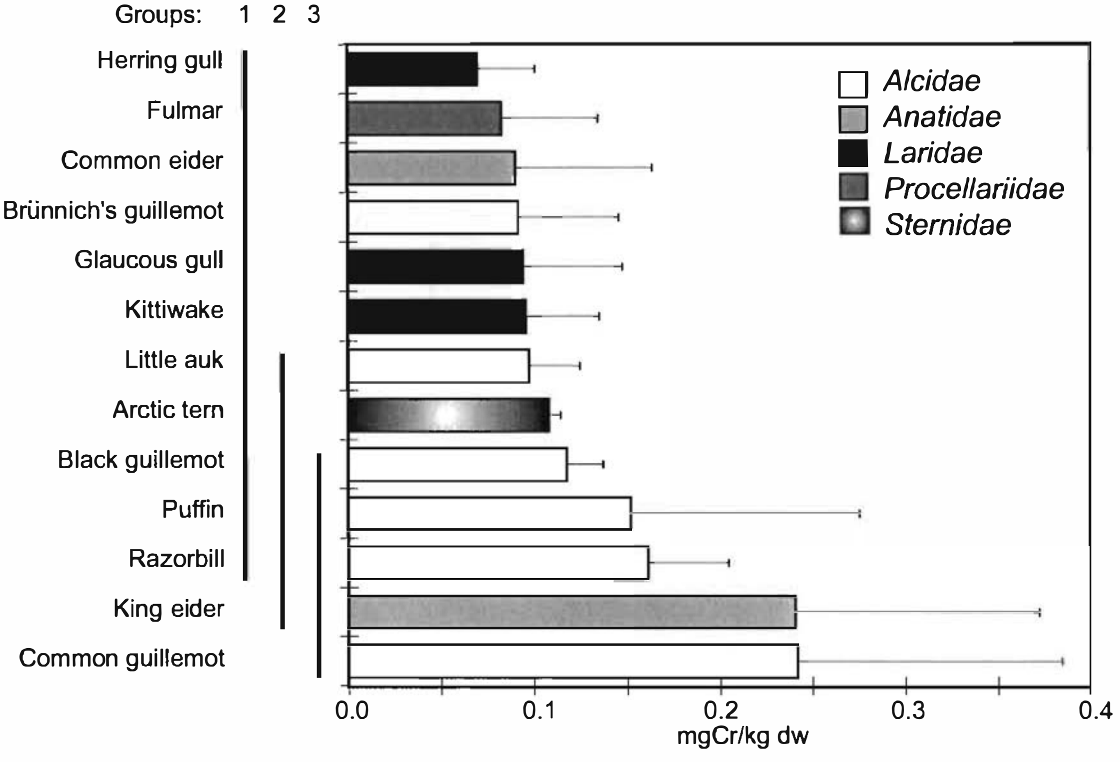

Fig. 14. The average hepatic Cr levels in different seabird species (mg/kg dry weight). Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α=0.05.).

Average Cr concentration in liver varied from 0.07±0.03 mg/kg (Herring gull) to 0.24±0.14 mg/kg (Common guillemot). The latter value was significantly higher than most of the other seabird species investigated, except for Black guillemot, Puffin, Razorbill, and King eider. Significant differences in Cr levels in bird muscle were found only between Common eiders and Glaucous gulls (0.06±0.02; 0.07±0.03 mg/kg, respectively) and Arctic terns (0.15±0.04 mg/kg).

Sex-dependent differences

The average hepatic Cr concentration in male Brünnich's guillemots (0.12±0.05 mg/kg) was significantly higher ($p < 0.05$) than in females (0.07±0.05 mg/kg) (Appendix 4). Significant sex-dependent differences in hepatic Cr levels were not found in any of the other species investigated.

Age differences

Significant age difference was found only for muscle tissue of Glaucous gulls. Juvenile birds have higher Cr level (Appendix 5).

Relationship between Cr concentrations in muscle and liver of seabirds

Fig. 15 shows that hepatic Cr levels in birds belonging to the families: *Anatidae*, *Alcidae*, and *Procellariidae* were higher than those in their muscle. The opposite was found for birds of the *Procellariidae* and *Sternidae* families. Significant coefficients of correlation (P < 0.01) were found between Cr concentrations in muscle and liver of all families examined, except *Sternidae* (see also Appendix 6). Coefficients of regression varied from 0.729 up to 1.03 for the *Alcidae*, *Laridae*, and *Procellariidae*. This coefficient was 3.17 for *Anatidae*.

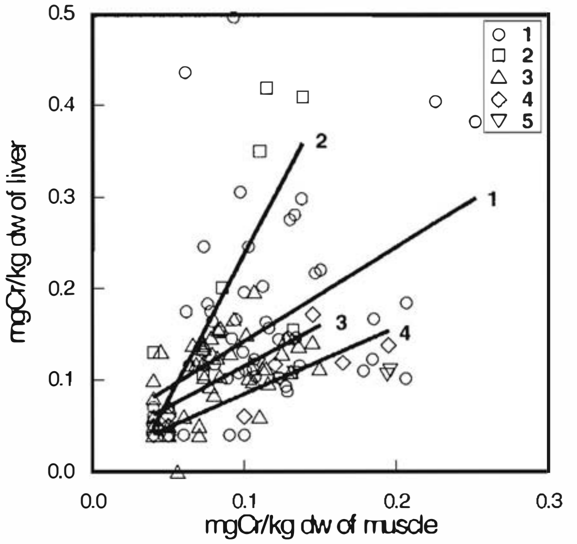

Fig. 15. The relationship between Cr contents in muscle and liver of birds belong to Alcidae (1), Anatidae (2), Laridae (3), Procellariidae (4) and Sternidae (5) families.

Arsenic

Geographical differences

Significantly higher As concentrations were found in liver and muscles of Brünnich's guillemots, Glaucous gulls, and Kittiwakes from Guba Chernaya compared to the other areas (Fig. 16, Appendix 2). There was also a significant difference between As levels in liver of Brünnich's guillemot from Kharlov Island and Hornøya on the one hand and Svalbard and Franz Josef Land on the other (Fig. 16).

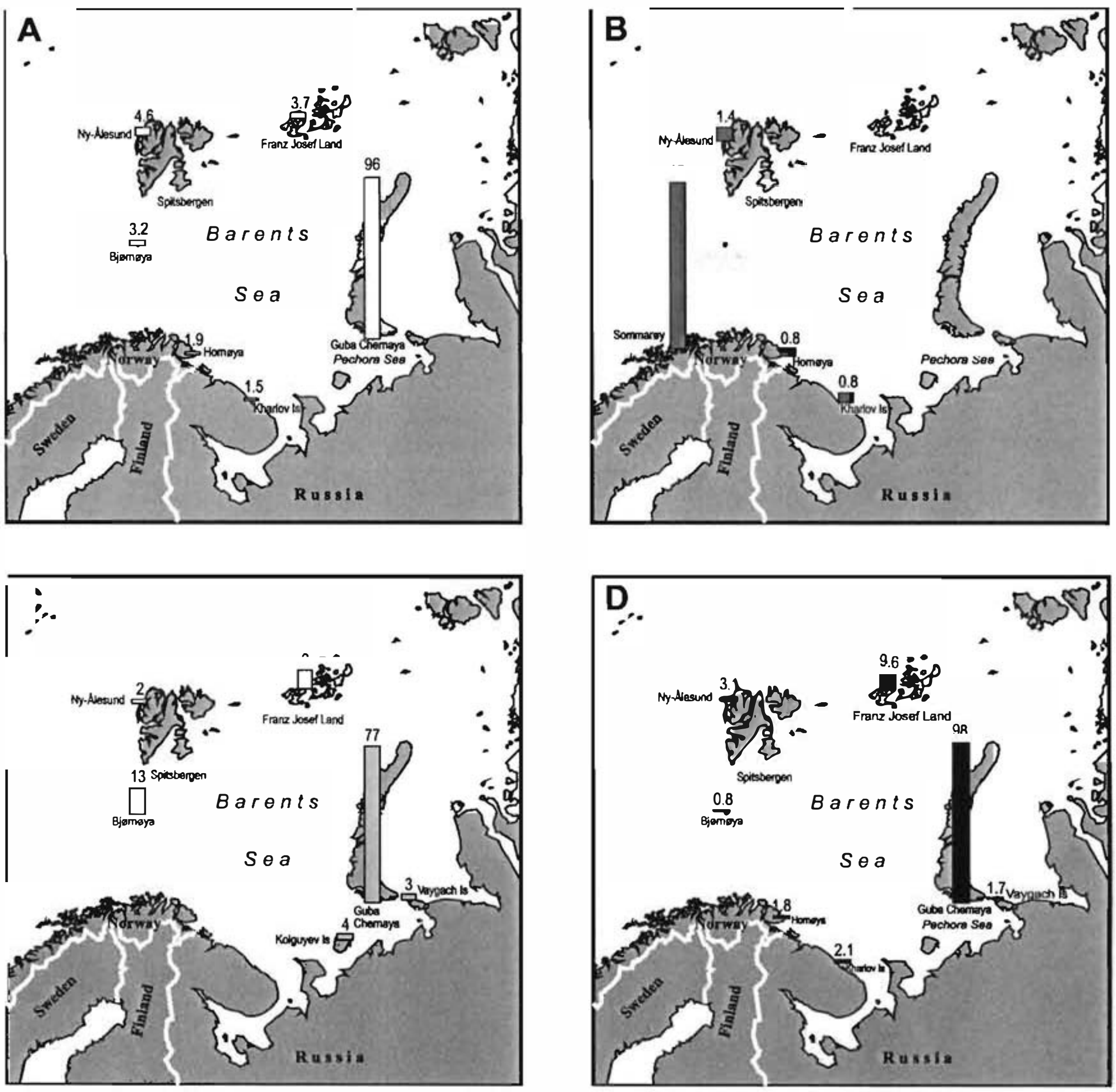

Fig. 16. The average As concentrations in liver of Brünnich's guillemot (A), Puffin (B), Glaucous gull (C), and Kittiwake (D) collected in different colonies.

Significantly higher muscle As level was found in Glaucous gulls from Bjørnøya (3.92±1.98mg/kg) in comparison with the birds from Ny-Ålesund, Vaygach Island, and Kolguyev Island (1.04±0.79 - 1.16±0.78 mg/kg). Significant differences in As muscle levels in Kittiwake were found between birds nesting on Bjørnøya, Kharlov Island, and Hornøya (0.65±0.03 - 0.93±0.90 mg/kg) and on Franz Josef Land (3.42±2.58 mg/kg).

Muscle and hepatic As levels in Puffins from Sommarøy were significantly higher compared to the other areas investigated.

The high As contents in tissues of Brünnich's guillemot, Glaucous gull, and Kittiwake were thus characteristic for birds nesting in Guba Chernaya. The significant differences between levels of As in tissues of seabirds from Guba Chernaya and seabirds caught in other colonies of the Pechora Sea probably indicate a local source of As contamination.

Inter-specific differences

Hepatic levels of As varied over a wide range: from 0.22±0.18 (Common eider) up to 12.77±0.36 mg/kg (Black guillemot) (Fig. 17). The average hepatic As concentrations in Common eider and Black guillemot were, respectively, lower and higher than in any of the other species investigated. The levels of As (from 0.81±0.00 to 1.18±0.47 mg/kg) in the liver of Razorbill, Puffin, King eider, and Common guillemot (group 2), were slightly higher than in the Common eider. In birds of group 3 and 4 significant differences between in the average hepatic As concentrations were found between the Kittiwake (2.22±1.51 mg/kg) and Glaucous gull (4.68±3.24 mg/kg), and between the Kittiwake and Arctic tern (5.72±2.16 mg/kg).

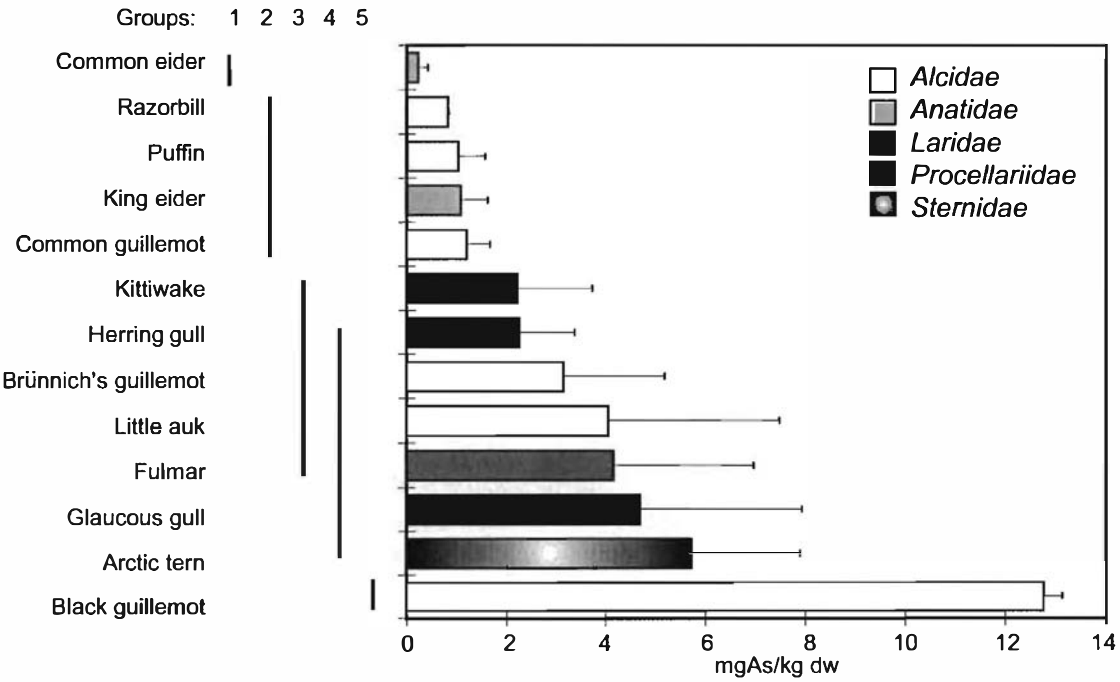

Fig. 17. The average hepatic As levels in different seabird species (mg/kg dry weight). Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α=0.05.).

Levels of As in muscles of birds varied from 0.20±0.11 to 4.25±1.34 mg/kg. Minimum and maximum values were found in the Common eider and Black guillemot, respectively. In general, the results of the analyses of inter-specific differences of As levels in muscle of birds did not contradict those of the hepatic As levels (Appendix 3).

Sex-dependent differences

There were no sex-dependent differences in the hepatic levels of As in any of the seabird species investigated (Appendix 4). Significant sex-dependent differences ($p<0.05$) in the average As levels in muscle were found only in the Razorbill and Arctic tern. In the Razorbill, the average As concentration in female muscle (0.51±0.02 mg/kg) was significantly higher than that in males (0.43±0.02 mg/kg). In Arctic tern the opposite pattern was found: 1.15±0.35 (female) and 1.92±0.10 (male) mg/kg.

Age differences

Significant age differences were found only for hepatic tissues of Common guillemots and Herring gulls from Hornøya. In both cases higher As level was in adult birds (Appendix 5).

Relationship between As levels in muscle and liver of birds

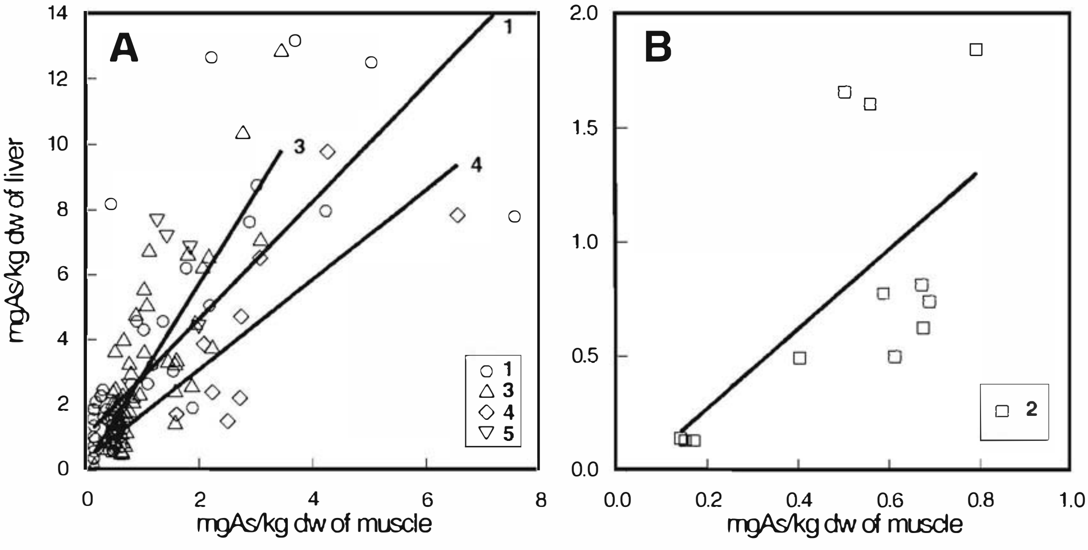

Fig. 18. The relationship between As contents in muscle and liver of birds belong to Alcidae (1), Anatidae (2), Laridae (3), Procellariidae (4) and Sternidae (5) families.

Hepatic As concentrations exceeded those in muscles in most seabirds (Fig. 18). Linear relationships ($P<0.05$) were found between As concentrations in muscle and liver of all examined families, except *Sternidae*. Coefficients of regression varied between 1.38 (*Procellariidae*) to 2.81 (*Laridae*) (see also Appendix 6).

Selenium

Geographical differences

Minimum and maximum levels of Se in muscle of Brünnich's guillemot were registered on Bjørnøya (1.74±0.28) and Kharlov Island (8.02±2.08 mg/kg), respectively (Fig. 19). Both these values were significantly different from those found in other regions of the Barents Sea. When comparing Brünnich's guillemot with other colonies, significant differences in muscle Se levels were only found between birds from Franz Josef Land (2.58±0.38 mg/kg) and Guba Chernaya (4.63±0.83 mg/kg) (Appendix 2).

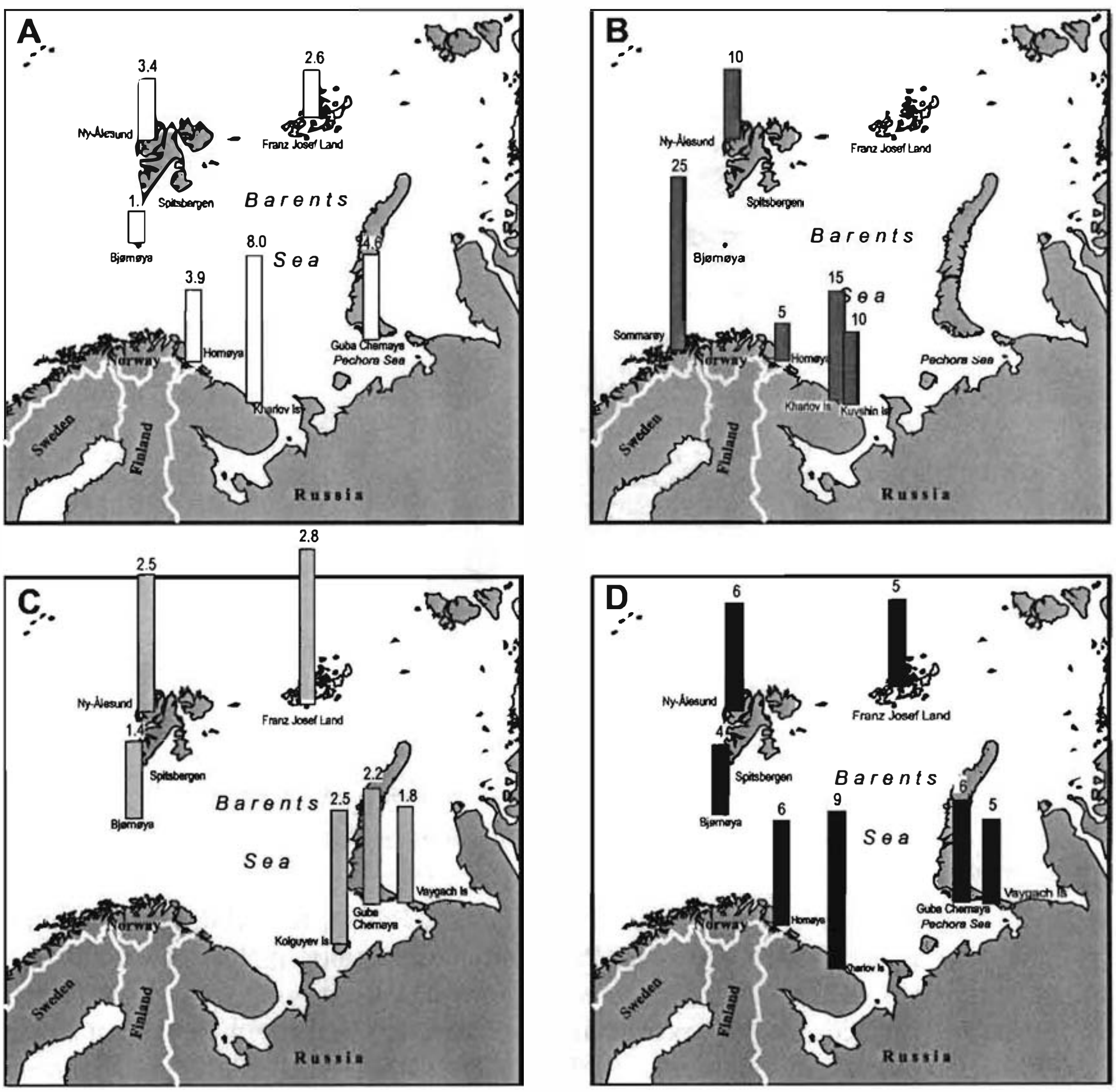

Fig. 19. The average Se concentrations in muscle of Brünnich's guillemot (A), Puffin (B), Glaucous gull (C), and Kittiwake (D) collected in different colonies.

The lowest average Se level in muscle of Puffin was registered in birds from Hornøya (5.32±1.50 mg/kg). This value was significantly lower than in any of the other regions investigated. The highest level of Se was found in muscle of Puffin from Sommarøy

(24.8±14.8 mg/kg). This level was significantly higher than in any other region of the Barents Sea, except for Kharlov Island.

Significantly lower levels of Se were detected in Glaucous gull from Bjørnøya. Significant differences were found between muscle Se levels in Kittiwakes caught on Bjørnøya, Vaygach Island, and Franz Josef Land (from 3.87±0.31 to 4.81±1.93 mg/kg) compared to Kharlov Island (8.83±1.28 mg/kg).

Inter-specific differences

Se levels varied from 3.97±1.21 (Little auk) to 20.9±2.59 mg/kg (Common guillemot). The average hepatic Se levels in Little auk were significantly lower than in any of the other species, except the Herring gull (Appendix3).

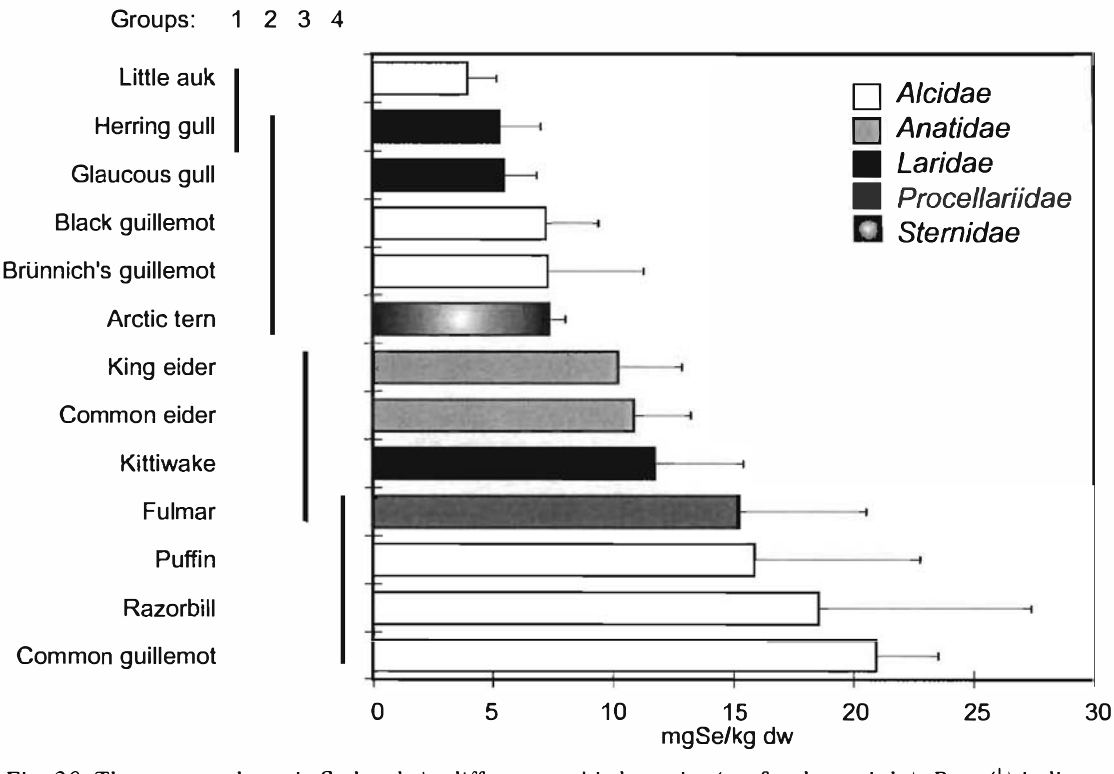

Fig. 20. The average hepatic Se levels in different seabird species (mg/kg dry weight). Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α=0.05.).

As it is seen in Fig. 20, group 4 has united Fulmar, Puffin, Razorbill and Common guillemot. Se levels in liver of Puffin, Razorbill and Common guillemot varied from 15.9±6.89 to 20.9±2.59 mg/kg. These values were significantly higher than in any of the other investigated species, except the Fulmar. Also the muscle levels of Se in Razorbill, Common guillemot and Puffin (8.77±1.08 - 11.37±5.50 mg/kg) were significantly higher than in any of the other species.

Sex-dependent differences

There were no significant sex-dependent differences in hepatic Se levels in any of the species investigated (Appendix 4). A significant differences ($p < 0.05$) in the average

Se levels in muscle were only found between males and females of Arctic tern (3.04±0.18 and 2.41±0.23 mg/kg, respectively).

Age differences

Se concentration in liver and muscle tissue of adult Brünnich's guillemots and Common guillemots was significantly higher than in juvenile birds of these species (Appendix 5). No significant differences were found for the other species investigated.

Relationship between Se levels in muscle and liver of birds

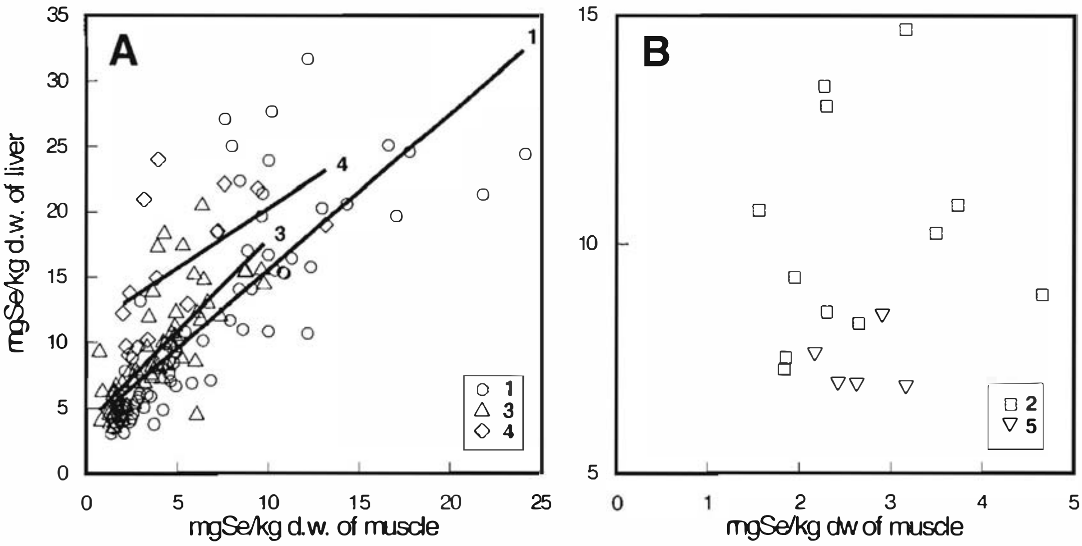

Fig. 21. The relationship between Se contents in muscle and liver of birds belong to Alcidae (1), Anatidae (2), Laridae (3), Procellariidae (4) and Sternidae (5) families..

Hepatic Se levels in birds exceeded those in their muscles (Fig. 21). Linear relationships between Se concentrations in muscle and hepatic tissues were found for following families: *Alcidae* ($P < 0.01$), *Laridae* ($P < 0.01$) and *Procellariidae* ($P < 0.01$) (Fig. 21A). Coefficients of regression were 1.20, 1.41 and 0.914, respectively. (See also Appendix 6).

Mercury

Geographical differences

Significant geographical differences in hepatic Hg levels were found for Brünnich's guillemot and Kittiwake only. Average hepatic concentrations of Hg in Brünnich's guillemot varied from 0.33±0.12 mg/kg (Bjørnøya) to 1.61±0.42 mg/kg (Ny-Ålesund) (Fig. 22). Levels of Hg in the hepatic tissues of Brünnich's guillemot from these two colonies were significantly lower and higher, respectively compared to those in birds from the other regions of the Barents Sea.

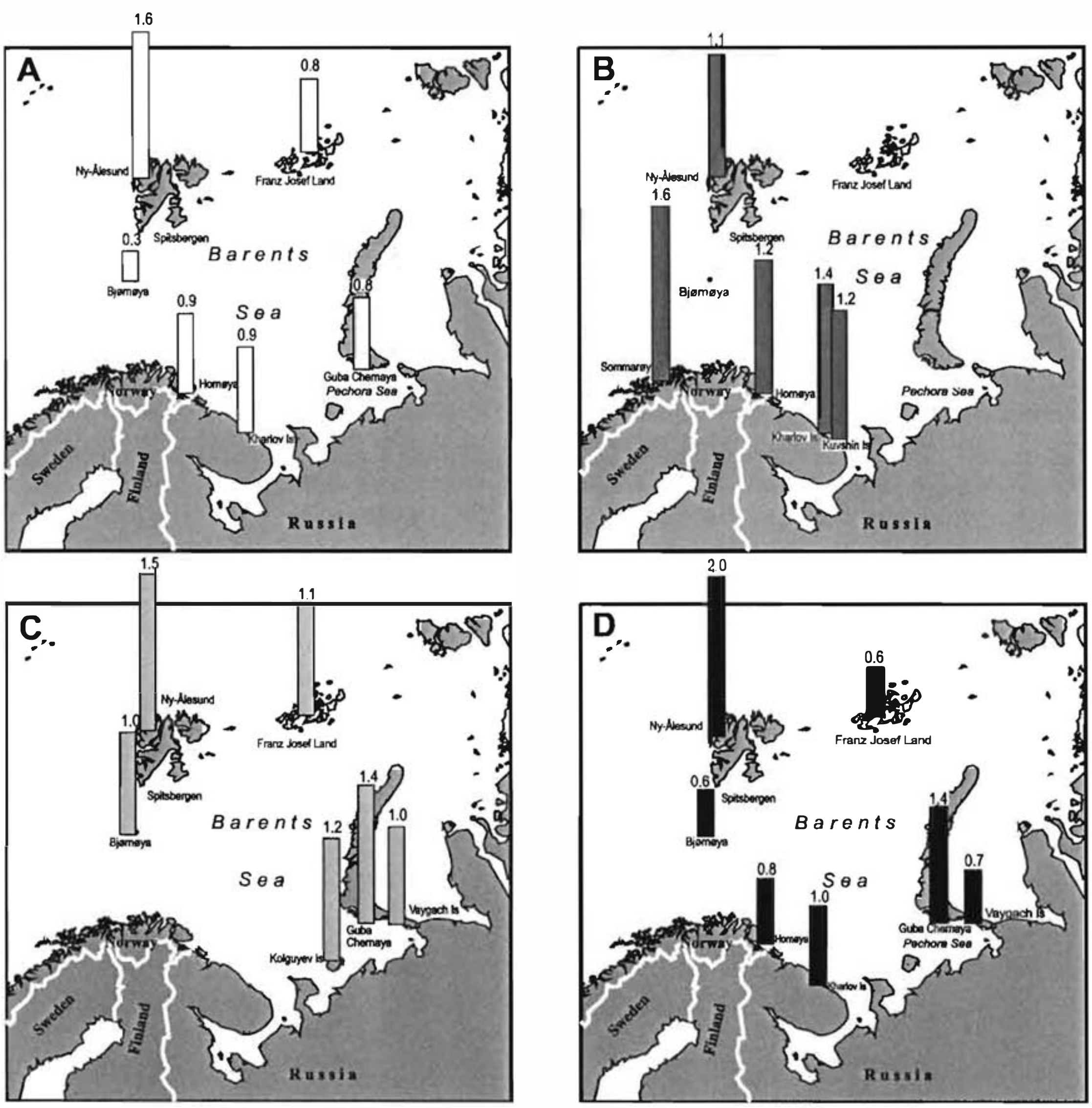

Fig. 22. The contents of Hg in liver of Brünnich's guillemot (A), Puffin (B), Glaucous gull (C), and Kittiwake (D) collected in different colonies.

Significantly higher hepatic Hg levels were found in Kittiwake from Guba Chernaya and Ny-Ålesund (1.44±0.29 - 1.95±0.44 mg/kg).

The average concentration of Hg in muscle of Brünnich's guillemot varied from 0.15±0.08 mg/kg (Bjørnøya) to 0.60±0.09 mg/kg (Ny-Ålesund) (Appendix 2). Levels of Hg found in muscle of Brünnich's guillemot nesting on Bjørnøya were significantly lower compared to other seabird colonies. Significantly lower Hg levels were also found in Brünnich's guillemot from Hornøya and Franz Josef Land (0.32±0.07; 0.32±0.16 mg/kg) compared to Ny-Ålesund (0.60±0.09 mg/kg).

The highest level of Hg in Kittiwake's muscle was found in Guba Chernaya. The average concentration of Hg in muscle of Kittiwake from this colony (0.50±0.07 mg/kg) was significantly higher than at any of the other colonies in the Barents Sea, except for Ny-Ålesund.

This analysis thus indicates a local source of Hg contamination in the Western Spitsbergen area.

Inter-specific differences

Statistical information on Hg levels in liver and muscle of the species investigated is presented in Appendix 3. The average hepatic Hg level in Little auks (0.44±0.25 mg/kg) was significantly lower than in any of the other species, except King eider and Herring gull (Fig. 23).

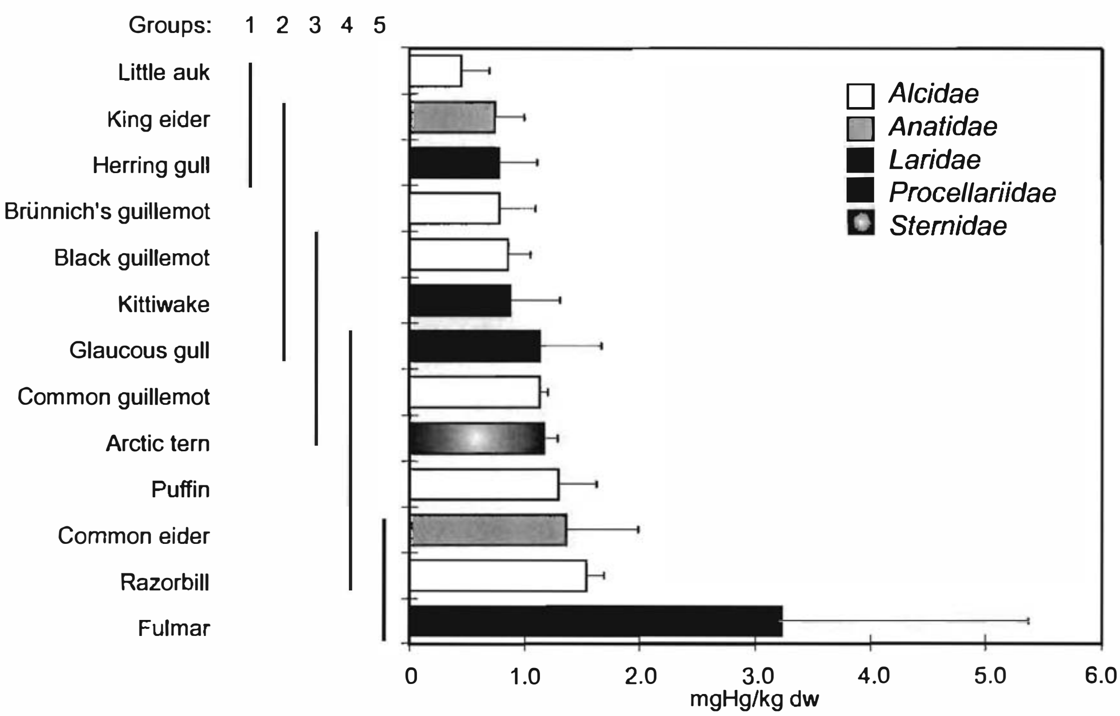

Fig. 23. The average hepatic Hg levels in different seabird species (mg/kg dry weight). Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α=0.05.).

Hepatic Hg level in Fulmar (3.23±2.14mg/kg) was significantly higher than in all the other species, except Common eider and Razorbill.

Sex-dependent differences

There were no significant sex-dependent differences in hepatic Hg levels in any of the bird species investigated (Appendix 4). Sex-dependent difference in Hg levels in muscle of birds was only found in Kittiwake. Here the average Hg level in male muscle (0.317±0.153 mg/kg) was significantly higher ($p<0.05$) than in female muscle (0.231±0.097 mg/kg).

Age differences

Significant differences were found only for hepatic and muscle tissues of Brünnich's guillemots and Common guillemots. Higher Hg levels were detected in adult birds of these species compared to juveniles (Appendix 5).

Relationship between Hg levels in muscle and liver of birds

Fig. 24 illustrates the relationships between concentrations of Hg in muscle and liver of the different families. Appendix 6 summarizes the statistics.

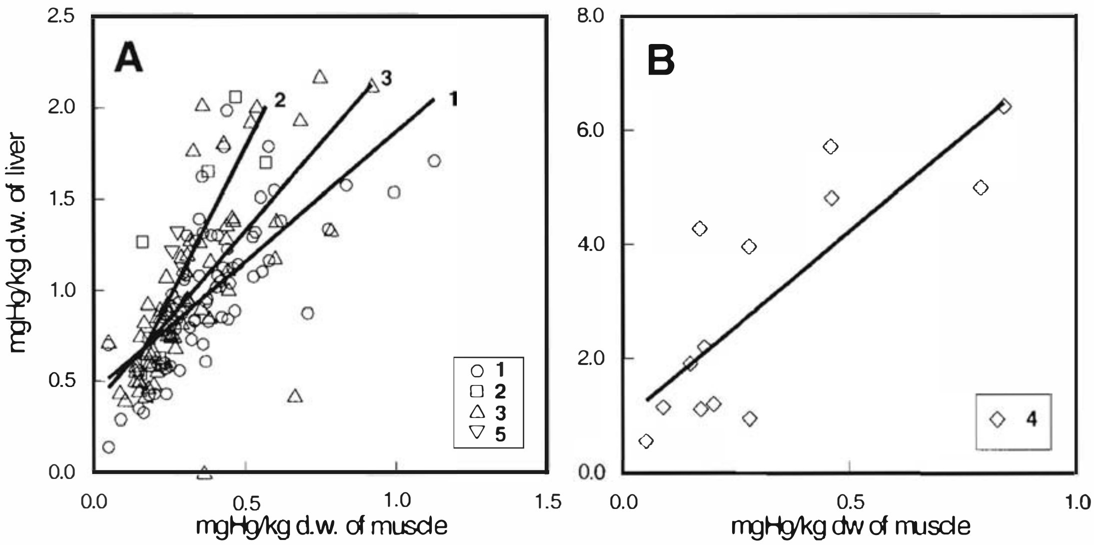

Fig. 24. The relationship between Hg contents in muscle and liver of birds belong to Alcidae (1), Anatidae (2), Laridae (3), Procellariidae (4) and Sternidae (5) families..

Levels of Hg in liver of birds exceeded those in muscle tissues (Fig. 24). There were linear relationships ($P<0.01$) between concentrations of Hg in muscle and liver of birds from all families, except *Sternidae*. The coefficients of regression varied from 1.42 (*Alcidae*) to 6.63 (*Procellariidae*).

Correlations between elements

Statistically significant correlations were found between 23 of 28 possible pairs of elements (Table 3, Appendix 7). More details regarding the most frequently repeated correlations are given below.

Table 3. The significance of association (Pearson correlation coefficient) between elements in liver (L) and muscle (M) of different seabird species. Positive (+) and negative (x) relationships, + (x) is P < 0.050, ++ (xx) is P < 0.010, +++(xxx) is- P < 0.001.

Species	Cd:Zn		Cd:Cu		Cd:Mn		Cd:Cr		Cd:As		Cd:Se		Cd:Hg		Zn:Cu		Zn:Mn	
	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M
Brünnich's guillemot	++		+		+				+						+++			
Common guillemot												+		+				
Little auk										×								
Puffin	+														+++			
Razorbill		++																
Common eider																		
King eider						+												
Glaucous gull	+			++														
Herring gull							×											
Kittiwake	+++		+++								+				+++			
Fulmar	+			++				×								+		
Arctic tern																		

Species	Zn:Cr		Zn:As		Zn:Se		Zn:Hg		Cu:Mn		Cu:Cr		Cu:As		Cu : Se		Cu:Hg	
	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M
Brünnich's guillemot			++			×			++			×						
Common guillemot										+								
Little auk														××				
Puffin						+											+	
Razorbill																		
Common eider	+																	
King eider					×					+++							++	
Glaucous gull												××						
Herring gull																		
Kittiwake			+						+++			×					+	
Fulmar					+		+++										+++	+
Arctic tern																		

Species	Mn:Cr		Mn:As		Mn:Se		Mn:Hg		Cr:As		Cr:Se		Cr:Hg		As:Se		As:Hg		Se:Hg	
	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M
Brünnich's guillemot											+				×					
Common guillemot																				
Little auk																	+	+		×
Puffin		×														++	×			
Razorbill																				
Common eider																				
King eider																				
Glaucous gull												+++		+					++	+++
Herring gull																				
Kittiwake							++				xxx									
Fulmar														xx					+	+
Arctic tern																				

The number of significant correlation coefficients (6 of 24 possible) was found between Zn and Cd (Table 3). Pearson correlation coefficients between concentrations of Zn and Cd in liver of Brünnich's guillemot, Puffin, Glaucous gull, Kittiwake, Fulmar and in muscle of Razorbill were 0.469 (P < 0.010), 0.565 (P < 0.050), 0.520 (P

< 0.050), 0.566 (P < 0.001), 0.655 (P < 0.050) and 0.968 (P < 0.010), respectively. The highest coefficients of regression were found in the equations describing Cd:Zn levels in liver of Kittiwake and Fulmar (0.407 and 0.357, respectively) (Fig. 25A).

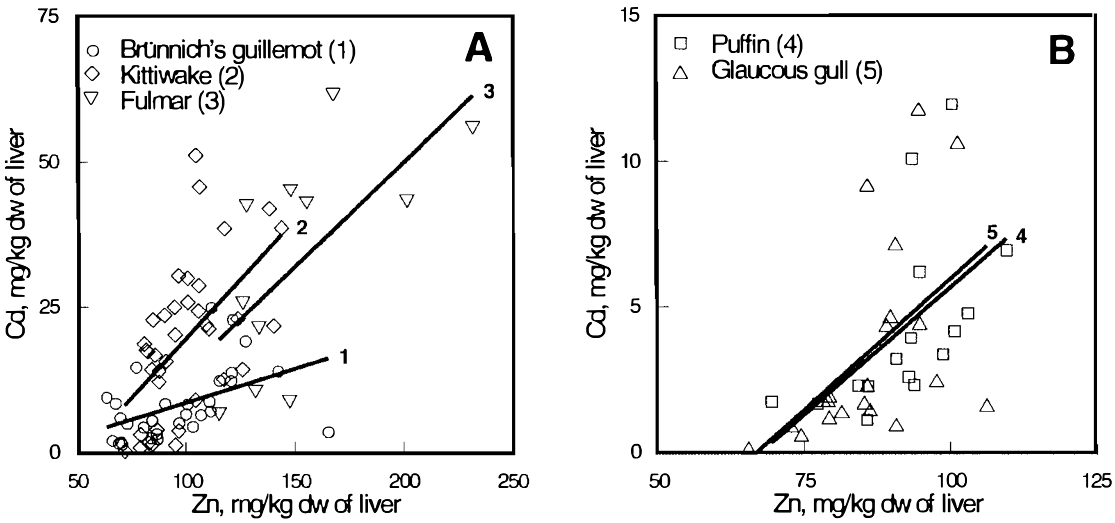

Fig. 25. Relationship between Zn and Cd contents in liver of different seabird species.

Linear Zn:Cu relationships were found in four seabird species. Pearson correlation coefficients between concentrations of Zn and Cu in liver of Brünnich's guillemot, Puffin, Kittiwake and in muscle of Fulmar were: 0.759 (P < 0.001), 0.719 (P < 0.001), 0.540 (P < 0.001) and 0.682 (P < 0.050), respectively. Coefficients of regression of the linear equations (Fig. 26) were very similar and varied from 3.4 to 4.3.

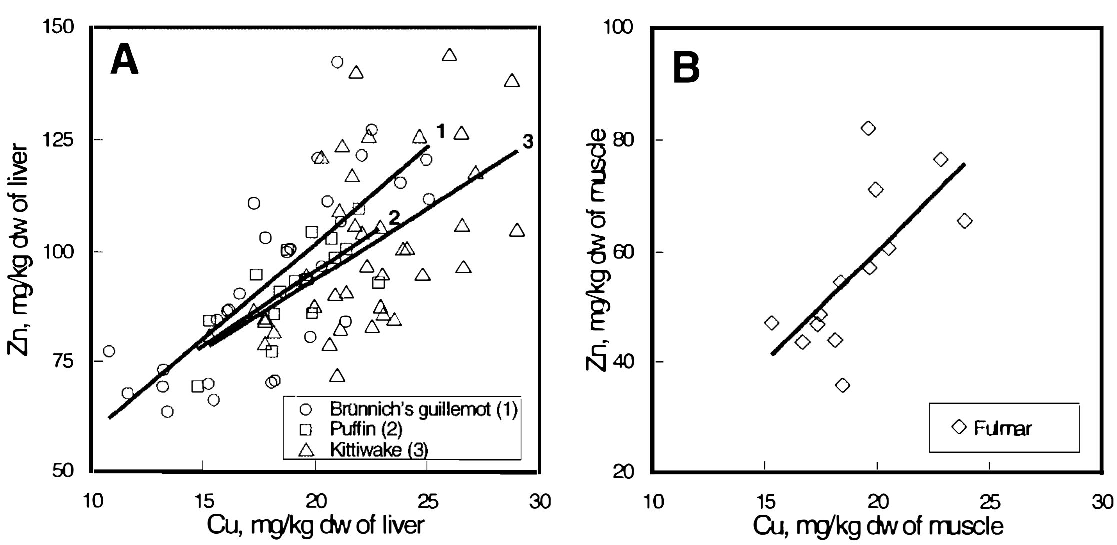

Fig. 26. Relationship between Zn and Cu contents in hepatic (A) and muscle (B) tissues of different seabird species.

Linear Cd:Cu relationships were found in tissues of four seabird species too. Pearson correlation coefficients between concentrations of Cd and Cu in liver of Brünnich's guillemot, Kittiwake, and in muscle of Glaucous gull and Fulmar were 0.463 (P < 0.010), 0.525 (P < 0.001), 0.508 (P < 0.050) and 0.722 (P < 0.010), respectively.

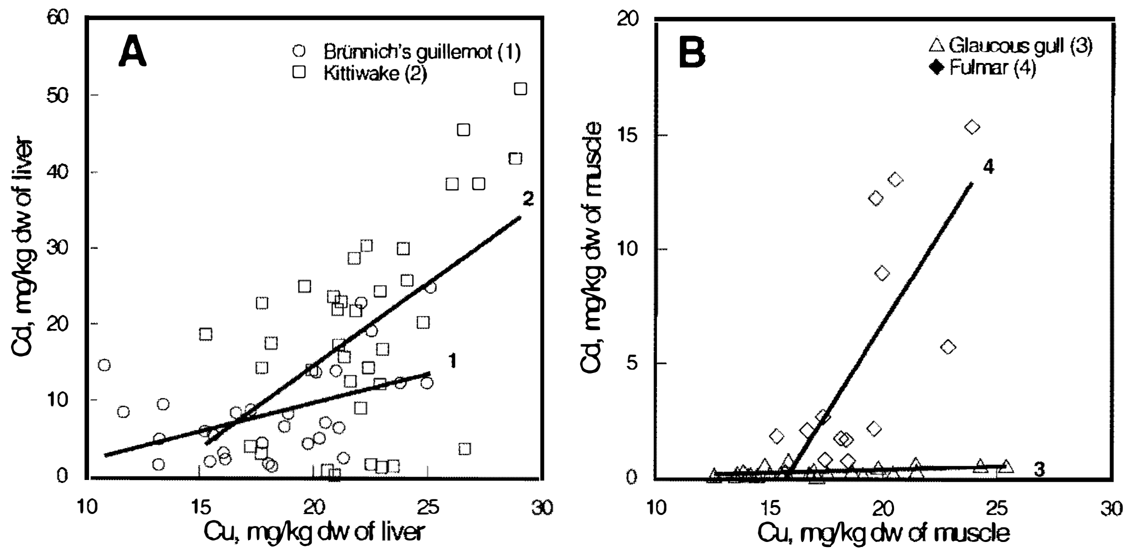

Fig 27. Relationship between Cu and Cd contents in hepatic (A) and muscle (B) tissues of different seabird species.

The steepest slopes of regression were typical for Kittiwake and Fulmar (Fig. 27). When Cu contents increased, the concentrations of Cd also increased by factors 2.18 and 1.60, respectively. In the other species, slope of regression varied from 0.03 (Glaucous gull) to 0.75 (Brünnich's guillemot).

Significant linear Cu:Mn relationships were found in liver of Brünnich's guillemot and Kittiwake. It was also found in muscle of Common guillemot and King eider. Pearson correlation coefficients between Cu and Mn concentrations in tissues of these species were 0.727 ($P < 0.010$), 0.685 ($P < 0.001$), 0.736 ($P < 0.050$) and 0.904 ($P < 0.001$), respectively.

Significant linear Zn:Se relationships were found in tissues of four seabird species. Pearson correlation coefficients between concentrations of Zn and Se in liver of Fulmar and King eider, and in muscle of Brünnich's guillemot and Puffin were 0.616 ($P < 0.050$), -0.711 ($P < 0.050$), -0.446 ($P < 0.050$) and 0.475 ($P < 0.050$), respectively. This indicates that there may be direct and inverse proportional relationships between Zn and Se levels in tissues of seabirds.

Relationships between concentration of Hg and concentration of other elements in seabird tissues were found (Table 3).

Significant linear Cu:Hg relationships were found in tissues of four seabird species (Fig. 28). Pearson correlation coefficients between Cu and Hg concentrations in liver of Puffin, King eider, and Kittiwake and in liver and muscle of Fulmar were authentic on 5%, 1%, 5%, 0.1%, and 5% significance levels, respectively. The maximum and most significant Pearson correlation coefficients were found between Cu and Hg contents in liver of King eider and Fulmar (0.894 and 0.835, respectively). The lowest and highest coefficients of regression (0.006 and 0.625 respectively) (Fig. 28A) were typical for these seabird species. In contrast, coefficients of regression for muscle of Fulmar came to 0.057 only, which was very similar to the values obtained for hepatic tissue of Kittiwake and Puffin (Fig. 28B).

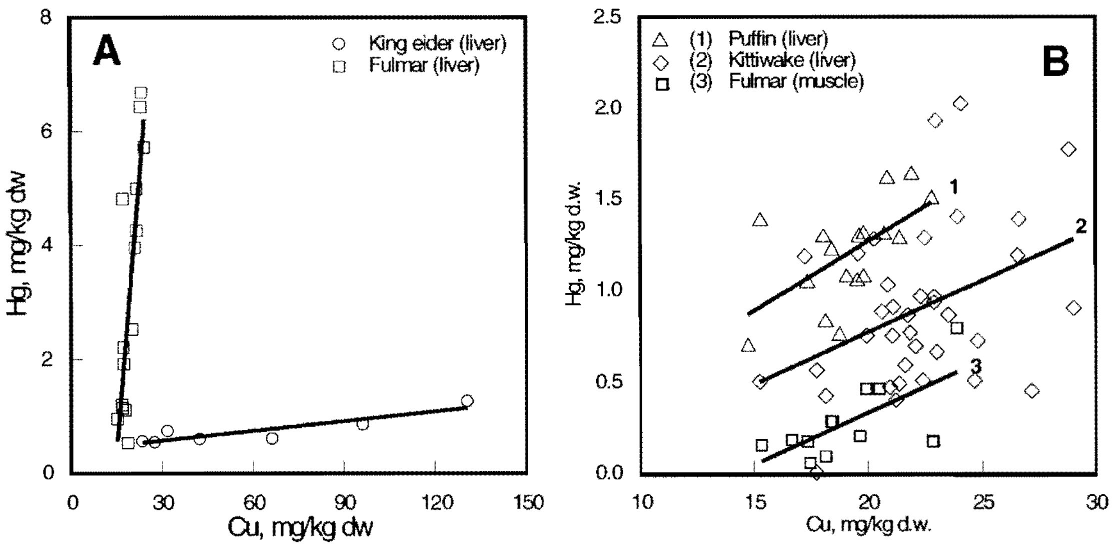

Fig 28. Relationship between Cu and Hg contents in hepatic and muscle tissues of different seabird species.

Significant Pearson correlation coefficients were found between Se and Hg concentrations in liver and muscle of Glaucous gull (0.576, P < 0.010 and 0.638, P < 0.001) and Fulmar (0.615, P < 0.050 and 0.737, P < 0.010) (Fig. 29). It was also found in muscle of Little auk (-0.534, P < 0.050). The relationships between Hg and Se concentrations in bird muscles may be either direct or inverse (Fig. 29B).

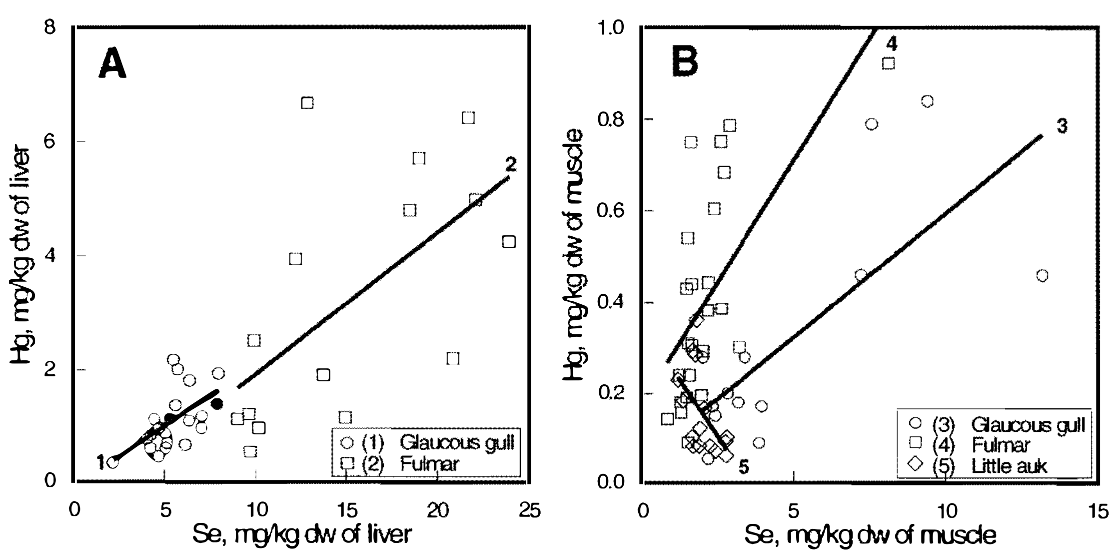

Fig 29. Relationship between Se and Hg contents in hepatic and muscle tissues of different seabird species.

Negative relationships were also found between Hg and Cr concentrations in muscle of Fulmar and between Hg and As concentrations in liver of Puffin (P <0.050) (Table 3.)

DISCUSSION

Inter-specific and geographical differences in element levels

Element levels in seabirds depend on the bird's food ecology, intensity, and timing of exposure in foraging areas, as well as their physiological and biochemical features. They also vary widely among species investigated (Fimreite, 1979; Hutton, 1981; Rainbow, 1989; Nielsen and Dietz, 1989; Wenzel and Gabrielsen, 1995, etc.). The same conclusion could also be drawn from the present study.

Average Cd hepatic concentrations varied from 1.7 ±0.39 (Common guillemot) to 40.4 ±31.5 (Fulmar) mg/kg. Significantly higher Cd levels were found in Fulmar, Kittiwake, Arctic tern, and Common eider. All these seabird species have relatively variable feeding habits. Svalbard Fulmars feed mainly on squids, polychaetes, crustaceans and small fish (Mehlum, 1990). Invertebrates (squid and crustaceans) may accumulate considerable quantities of cadmium (Hamanaka and Ogi, 1984; Macdonald and Sprague, 1988; Rainbow, 1989; Ritterhoff, 1997). Pelagic polychaetes and polar cod are also the main food items for Fulmar in the Franz Josef Land area (Weslawski and Skakuij, 1992). Very often Fulmars in the Barents Sea are feeding on fisheries offal near fishing vessels (del Hoyo *et al.*, 1992). It is also known that the intake of fisheries offal may result in increased Cd concentrations in seabirds (Zunk, 1984). Fish entrails, such as liver and kidney, may contain high levels of Cd (Macdonald and Sprague, 1988). Feeding on fisheries offal may thus be partly responsible for the high levels of Cd in Fulmar. However, Cd levels detected in seabirds are results of two main processes: bioaccumulation mainly via food and biodegradation processes in the bird's organism. Cadmium is bound within the liver to a low molecular weight protein called metallothionein. Cd bound in this way has a long biological half-life and a tendency to accumulate with age (Scheuhammer, 1987). The Fulmar is one of the most long-living species among seabirds (Ollason and Dunnet, 1988). Bioaccumulation of Cd with age may also be one of the possible explanations of high levels detected in this species. Nielsen and Dietz (1989) found higher levels of Cd in older birds in 20 out of 26 comparisons of which eight were significant. Apparently, a combination of different biochemical, biological, and ecological features of this species promote high Cd bioaccumulation in this species. Further investigations are needed to study features of Cd bioaccumulation in Fulmar.

Kittiwakes and Arctic terns from the Barents Sea area also have elevated Cd levels compared to other species. Feeding on invertebrates may be one explanation of high Cd levels in these species. Kittiwakes from the Barents Sea area feed mainly on small fish (cod, polar cod, herring, and capelin) and invertebrates: euphausiids and amphipods *Parathemisto spp.* (Belopol'skii, 1957; 1971; Mehlum, 1990; Mehlum and Gabrielsen, 1995). During the chick rearing, which was the sampling period for the birds analysed in the present study, euphausiids and amphipods were even more frequent in the Kittiwake's diet. Amphipods accounted for 46.3% of the bird stomach contents, and euphausiids, polar cod, while polychaetes accounted for 24.4% (Mehlum and Gabrielsen, 1993; 1995). In Kittiwakes, sampled on Franz Josef Land, *Parathemisto libellula* accounted for almost 90% of the stomach content. Among the marine amphipods, adult hyperiid amphipods of the genus *Parathemisto* had atypically high concentrations of Cd (reaching up to 70 mg/kg d.w.). These are among the highest values reported in the literature for marine invertebrates (Macdonald and Sprague, 1988; Rainbow, 1989; Ritterhoff, 1997). Arctic terns in the Barents Sea area also feed on polar cod and crustaceans (Mehlum, 1990). Therefore, in Kittiwakes and Arctic terns the feeding of on crustaceans and amphipods promotes Cd accumulation. The Kittiwake may also accumulate a significant amount of Cd during their winter migrations to the Greenland Sea, the North Sea, the Baltic Sea, and even to the Black and Caspian Seas and the Mediterranean (Norgenhaug *et al.*, 1977; Barrett and Bakken, 1997; Nikolaeva *et al.*, 1997). Concentrations of Cd in fish and invertebrates from the Barents sea (Zauke *et al.*, 1997; 1999; Savinov *et al.*, 1998) are lower compared with those in the Baltic, North and Greenland Seas (Riget *et al.*, 1997; Dietz *et al.*, 1997; Ritterhoff and Zauke, 1997;) and more southern areas (Bryan, 1976; Clark, 1996).

Common eider in the Barents Sea feed mainly on small crustaceans, amphipods and molluscs (Mehlum, 1990). In Troms (Northern Norway) blue mussels (*Mytilus edulis*) is the main food item in Common eider diet, accounting for 46% of their diet (Bustnes and Erikstad, 1988). Common eiders from Northern Norway winter near their breeding sites (J. O. Bustnes, pers. comm.). Eiders from Svalbard area also winter near the Norwegian coast, but also near Iceland (Mehlum, 1990). Elevated Cd levels in tissues of eiders may be the result of feeding on contaminated food in the coastal areas. Cd levels in blue mussels from the Norwegian coast varied from 0.7 µg/g in mussels from Troms (Killie, 1997) to 76.1 µg/g in those from the west coast of Norway (Sørfjorden) (Knutzen and Skei, 1991). Differences in Cd levels found in Common eider and King eider from the Barents Sea may also support to this hypothesis. Both Common eider and King eider have a similar diet in the Barents Sea area. They have, however, different wintering areas. King eiders that breed in the eastern part of the Barents Sea winter in the White Sea (Nygård *et al.*, 1988). Cd levels found in mussels from the White Sea (Khristoforova, 1994) are similar to those from the Pechora Sea (Savinov *et al.*, 1998) and much lower than along the Norwegian coast (Knutzen and Skei, 1991).

The lowest Cd level was detected in Common guillemot. Fish is the predominant food item for this species in the Barents Sea area (Belopol'skii, 1957; Erikstad and Vader, 1989; Barrett and Furness, 1990). Apparently, the more homogeneous diet promotes low Cd levels in Common guillemot. Levels of Cd in fish from the southern part of the Barents Sea and coastal areas of Northern Norway are also low (Zauke *et al.*, 1997; 1999; Solberg *et al.*, 1997; Green, 1997). Investigations have shown seasonal fluctuations in Cd concentrations in the Common guillemot from northwest Scotland, indicating that in this species cadmium turnover may be faster than previously thought (Stewart *et al.*, 1994). Further studies on seasonal variation in Cd levels in the Barents Sea Common guillemot are recommended.

Geographical differences in hepatic Cd levels were found for Brünnich's guillemots, Puffins, Glaucous gulls and Kittiwakes from different colonies in the Barents Sea area. Muscle Cd levels do not differ significantly in the same species from various colonies. Significant geographical differences in hepatic Cd levels were found between Brünnich's guillemots from Kharlov Island (2.55±1.93 mg/kg) and birds from Ny-Ålesund (14.9±6.16 mg/kg), and from Franz Josef Land (15.5±5.34 mg/kg). This may partly be attributed to differences in dietary exposure between birds. Amphipods, accumulating high Cd levels, were found to be dominant in stomachs of Brünnich's guillemots, collected during summer 1992 on Franz Josef Land, while fish was the main item in the summer diet of birds on Seven Islands (Krasnov *et al.*, 1995; Barrett and Krasnov, 1996; Barrett *et al.*, 1997). Recoveries of ringed Brünnich's guillemots indicate that the majority of Svalbard Brünnich's guillemots winter off southwestern Greenland, whereas birds from the Russian areas winter in the Barents Sea (Isaaksen and Bakken, 1995; Krasnov *et al.*, 1995). According to Nikolaeva *et al.* (1996) Brünnich's guillemots from the Seven Islands winter along the west coast of Greenland. However some birds may stay in the ice-free parts of the southern Barents Sea or winter in a polynya in the White Sea. In the Barents Sea and the White Sea areas Cd levels in fish and invertebrates are general lower than those from the Greenland Sea (Khristoforova, 1994; Plotitsyna and Kireeva, 1996; Zauke *et al.*, 1997; 1999; Dietz *et al.*, 1997; Riget *et al.*, 1997; Ritterhoff and Zauke, 1997; Savinov *et al.*, 1998). Hepatic Cd levels were also significantly different in Puffins from Hornøya and from Kuvshin Island. This may partly be explained by differences in feeding habits (Barrett and Krasnov, 1996).

Average hepatic concentration of Cd in Glaucous Gulls from Kolguyev Island (1.21±0.46 mg/kg) was significantly lower than in birds nesting on Bjørnøya (6.06±3.57 mg/kg) and in Ny-Ålesund (10.3±8.51 mg/kg). There are no published data of Glaucous gull feeding ecology from the Kolguyev area. In the stomach of birds collected in the present study, we found mainly marine organisms of the tidal zone. It is also known that during the nesting period the main food of Glaucous gulls from Svalbard is eggs and chicks of other seabird species (Mehlum, 1990). Probably, these differences in food spectrum and earlier mentioned general low Cd levels in marine organisms from the eastern Barents Sea can explain the significant geographical differences in Cd levels in Glaucous gulls. This explanation can also be applied for geographical differences found in Cd levels in Kittiwakes from the eastern Barents Sea (Guba Chernaya, Vaygach Island) and from Svalbard.

The levels of essential metals, such as Cu and Zn are metabolically regulated in seabird tissues (Schneider *et al.*, 1985). Levels of Cu in all seabird species examined, except Common eider and King eider, were very similar and near a mean 20 mg/kg. However, Common eider had significantly higher Cu levels than all other seabird species examined. The average hepatic concentration in Common eider was twice as high as in King eider, and about 10 times higher than in all other species investigated. Extremely high hepatic Cu concentrations (maximum - 1050 mg/kg w. w) were also found in Common eiders in previous studies in Ny-Ålesund (Norheim and Borch-Iohnsen, 1990). However, hystological studies showed no signs of injury, e.g. necrosis or fibrosis in liver samples. The authors suggested that the variations in Cu concentration found in liver of different seabird species from Ny-Ålesund are a result of differential intake of copper-containing foods. Eiders, feeding mainly on mussels, snails, and crustaceans, many of which have haemocyanin as their blood pigment, had the highest levels among the other species investigated (Norheim and Borch-Iohnsen, 1990). The extremely high, but apparently natural, levels of copper in seabirds from the *Anatidae* family invite further investigation of processes of Cu accumulation, storage, and elimination by these species. The highest Cu levels were found in muscle of birds caught on Spitsbergen. Significant differences were found between the Cu levels in muscle of Brünnich's guillemots from Ny-Ålesund compared to those in the same species from the other regions of the Barents Sea. Average Cu concentrations in muscle of Kittiwakes and Glaucous gulls from Ny-Ålesund were also significantly higher than in the same species from Franz Josef Land and the eastern part of the Barents Sea.

The average Zn levels were slightly more variable than copper levels. The highest hepatic Zn levels were detected in birds from the *Anatidae* family and Fulmar. Levels of Zn in liver of Common eider were 2.5 times those of the Common guillemot and Little auk (which had the lowest levels). It is remarkable that for accumulation levels of Zn in seabird muscles the opposite was observed, and Common eiders had the lowest Zn levels. Zn concentration, probably, increases in the liver of Common eider as a result of starvation. During egg laying, the liver weight in eider is reduced by 63%. From prelaying to hatching, total body weight declines by 46 %, and the liver weight is further reduced to 27% of its original weight (Parker and Holm, 1990).

Significant differences in Zn levels have been found for Brünnich's guillemots and Kittiwakes. The average hepatic Zn level in Brünnich's guillemots from Kharlov Island was significantly lower compared to that in the same species from all other seabird colonies. Significantly higher Zn hepatic levels have been found in Kittiwakes from the northern part of the Barents Sea (Franz Josef Land and Spitsbergen) when compared to the eastern part of the sea. These differences in Zn levels were closely related to the differences in Cd levels in the same species.

The highest average hepatic Mn concentrations were found in King eider, Puffin, Arctic tern and Fulmar. The lowest Mn level was found in Little auk. The inter-specific differences in Mn muscle contents were minimal for all species investigated. Geographical differences in Mn levels have been studied in Puffins and Brünnich's guillemots. Significant differences were found only in hepatic Mn levels. Hepatic levels of Mn in Brünnich's guillemots were significantly higher in birds from Franz Josef Land compared to Kharlov Island. Significantly higher were also Mn levels in Puffins from Sommarøy compared to Seven Islands Archipelago. By contrast, significantly higher levels of Cr were found in birds from the Eastern Murman (Seven Islands and the Pechora Sea area). However, Cr levels in invertebrates and fish from this area are extremely low (Ptotitsyna and Kireeva, 1996). This may indicate that Cr has been accumulated during wintering.

Arsenic levels in examined seabird species from the Barents Sea showed significant geographical differences. The highest concentrations were found in birds collected in the southwest off Novaya Zemlya (Guba Chernaya). Significantly higher As levels were also found in the eastern part of the Barents Sea in bottom sediments (Loring *et al.*, 1995) and in fish (Savinov *et al.*, 1998). It is thus possible that there is a local source of As contamination in this area, probably of natural origin. Toxic effects of these elevated As levels are however not thought to be a problem for seabirds because arsenic which was found in bird's tissues mainly has organic forms. The arsenic organic compounds are more easily excreted and less toxic (CEPA, 1993; Neff, 1997). However, arsenic at 50 ppm in the diet was reported to cause decreased growth in chicks after three weeks of exposure (Howell and Hill, 1978). More studies are needed on arsenic different form levels in birds and their food from the eastern part of the Barents Sea.

Se concentrations varied significantly among the seabird species investigated. The lowest Se levels were found in Little auk, whereas the highest were found in other alcids (Common guillemot, Razorbill, Puffin). Little is known also about the proportion between organic (selenomethionine) and inorganic (sodium selenite) forms of Se in birds (Heinz *et al.*, 1990). Concentrations of Se in the adult bird liver below 10 mg/kg are considered as "background" (Ohlendorf, 1989). Hepatic Se levels in Common guillemots, Razorbills, and Puffins from Seven Islands were twice as high.

The average Se level detected in liver of Brünnich's guillemot from Kharlov Island was significantly higher compared to all other areas. The lowest hepatic level, significantly different from all other areas, was found in birds from Bjørnøya. Further studies on accumulation, elimination, and possible toxic effects of Se on the Barents Sea birds are recommended.

The highest Hg levels were found in Fulmar and Razorbill. The mercury status of these species may be linked to the dietary dominance of fish. In the Barents Sea area Razorbill diet consists 75% of fish (Belopol'skii, 1957). Fulmar often feed on fish offal from fishing ships operating in the Barents Sea. The lowest Hg level was found in tissues of the plankton-eating Little auk. Mercury in zooplankton from the Barents Sea is present mainly (90%) as inorganic form and Hg concentrations in zooplankton are lower than those in pelagic fish (Joiris *et al.*, 1995; 1997).

Significant geographical differences in hepatic Hg levels were found only for Kittiwake and Brünnich's guillemot in the present study. Average hepatic concentrations of Hg in Brünnich's guillemot varied from 0.33±0.12 mg/kg (Bjørnøya) to 1.61±0.42 mg/kg (Ny-Ålesund). These levels were, respectively, significantly lower and higher than those in all other investigated regions of the Barents Sea. Levels of Hg in muscle of Brünnich's guillemot from Bjørnøya was also significantly lower compared to those in birds from other the Barents Sea areas studied.

Significantly higher hepatic Hg levels were found in Kittiwake from Guba Chernaya and Ny-Ålesund, indicating, probably, the local sources in these areas.

Mercury is one of the most toxic elements for seabirds. Spalding *et al* (1994) found that liver Hg concentrations >6 ppm correlated with malnutrition and mortality from chronic disease in Great white herons. However, the authors cautioned against overinterpreting these results because only dead birds were examined. Zillioux and co-authors (1993) in their review of the literature, found that concentrations of mercury in liver between 1 and 2 ppm (wet weight) may be associated with high embryo/duckling mortality and brain lesions. Mercury levels found in the Barents Sea birds were rather low to cause toxic effects. However, total mercury concentration is a poor indicator of the toxic effects. Organic mercury seems to be considerably more toxic to high animals at high trophic levels than inorganic (Wolfe *et al.*, 1998). No data are available on ratio between organic (methyl) form and inorganic Hg in the Barents Sea bird species at present. Dietz *et al.* (1990) have found that in Greenland seabird liver, mercury was mainly organic. Thompson (1996) have found both Hg forms in approximately equal quantities in kidney and liver of Lesser Black-backed Gull from the Atlantic. Wide ranges of methylmercury fractions have also been reported by Fimreite (1974) in Canadian seabirds and Karlog and Clausen (1983) in birds from Danish localities. Inorganic Hg can induce metallothionein synthesis and will bind readily with the protein in birds (Scheuhammer, 1987). Additional studies on mercury binding and on proportion between organic and inorganic forms of Hg in Arctic seabird species are recommended.

Correlation between element concentrations

Cu concentrations in both liver and muscle samples in different seabirds from the Barents Sea area were positively correlated with Cd, Zn, Mn, Hg and negatively correlated with As and Cr levels.

A correlation between Cu and Cd is rare in the seabird literature. A correlation between Cd and Cu were reported only for Lesser black-backed gulls *Larus fuscus* and Cory's Shearwaters *Calonectis diomedea* (Stewart *et al.*, 1996). In the present study Cd:Cu relationships were found in tissues of five seabird species: Brünnick's guillemot, Common guillemot, Kittiwake (liver) and Glaucous gull and Fulmar (muscle).

A linear Zn:Cd relationship was found in liver of five the Barents Sea bird species (Brünnich's guillemot, Puffin, Glaucous gull, Kittiwake and Fulmar) and in the muscle of Razorbill.

A significant positive correlation between Zn and Cd has been reported in many seabird species (Scheuhammer, 1987; Nielsen and Dietz, 1989; Henny *et al.*, 1991; Wenzel and Gabrielsen, 1995; Stewart *et al.*, 1996). Chemically, Zn and Cd are very similar and often associated in nature. This seems to have a physiological sense as these metals (and Cu) are bound to metallothionein and have a tendency to accumulate in parallel. It suggested that a parallel increase of Zn with Cd in seabird tissues has a protective influence against Cd toxicity (Hutton, 1981).

Nielsen and Dietz (1989) have found five significant correlations between Zn and Se concentrations. In the present study were found both negative (muscle of Brünnich's guillemot and liver of King eider) and positive (muscle of Puffin and liver of Fulmar) relationships between Zn and Se concentrations. Only one positive correlation between Cd and Hg concentrations was found in muscle of the Barents Sea Common guillemot. Nielsen and Dietz (1989), however, found a significant Cd and Hg correlation in muscle of King eider, muscle and liver of Black guillemot, in liver of Common eider, in muscle and liver of Brünnich's guillemot and Glaucous gull. The occurrence of a co-accumulation between Cd and mercury has also been shown in a number of studies of Arctic marine mammals from different geographical zones (Hansen *et al.*, 1990). A relationship between concentrations of Cd and Se was found in tissues of Kittiwakes and in muscles of Common guillemots from the Barents Sea area. For Greenland seabirds Nielsen and Dietz (1989) have found a relationship between Cd and Se in tissues of Kittiwakes, Common guillemots, Common and Kind eiders, Glaucous gulls. Positive correlation was found in our study between Se and Hg concentrations in liver and muscle of Glaucous gulls and Fulmars, and in muscle of

Common guillemot. A parallel accumulation of Se and Hg has also been reported for Herring gulls and Great skua (*Catharacta skua*) in the United Kingdom (Hutton, 1981), for liver and kidney of Scottish seabirds (Hutton, 1981), for liver, kidney, and muscle of Greenland seabirds (Nielsen and Dietz, 1989). In marine mammals increment of liver Se and Hg occur on a 1:1 molar basis (Koeman *et al.*, 1973; 1975; Hansen *et al.*, 1990; Dietz *et al.*, 1990). This finding led Koeman *et al.* (1975) to suggest that Se may exert a protective effect by directly binding Hg. It has also been suggested that association between Se and Hg in internal organs of seabird species is a protective mechanism against the toxic effects of mercury (Hutton, 1981; Cuvin-Aralar and Furness, 1991). In all organs of Greenland seabirds (Nielsen and Dietz, 1989), the molar ratio Se:Hg exceeded those for marine mammals by a factor of 10-30 in muscle and 20-50 in kidney. Hutton (1981) also found an excess of Se over Hg on a molar basis in liver and kidney of Scottish seabirds. In Scottish Herring gulls Se exceeded Hg by a factor 5 in liver (Hutton, 1981), while in our study these ratios in Herring gull varied from 11 (Hornøya) to 43 (Ainov Island).

In the present study a negative relationship ($p<0.01$) was found between Hg and Cr concentrations in muscle of Fulmar and between Hg and As concentrations in liver of Puffin ($p<0.01$).

A negative correlation was also found between As and Se in liver of Brünnich's guillemot ($p<0.05$). Selenium and arsenic have been shown to have antagonistic interactive effect when administered simultaneously to mammals (Ganther and Baumann, 1962; Levander, 1972), chickens (Howell and Hill, 1978), and to ducklings (Gamardese *et al.*, 1990).

Age dependence of element concentrations

The relatively weak documentation of the dependence of element concentration on age in our material may primarily be due to a small number of different age classes in all seabird species collected. It was possible to compare element concentrations in tissues of adult and juvenile birds in six seabird species: Brünnich's guillemots from Seven Islands Archipelago, Common guillemots from Kuvshin Island, Common eiders from Ny-Ålesund, Glaucous gulls from Franz Josef Land, Kittiwakes from Hooker Island (Franz Josef Land), Herring gulls from Hillesøya, and Herring gulls from Hornøya.

There were no significant differences for both hepatic and muscle tissues Cd levels in Glaucous gulls.

Hepatic and muscle Cd, Hg, Cu and Se levels in adult Brünnich's guillemots were significantly higher than in juvenile birds. The opposite picture was found for Zn levels in tissues of Brünnich's guillemots. The highest Zn concentrations were found in juveniles. Higher Cd levels were also found in muscle and liver tissues of Common guillemots and Herring gulls from Hillesøya. Significant age differences in Cd levels were also found for hepatic tissue among of Herring gulls from Hornøya and among Kittiwakes. In both species older individuals have higher levels of Cd. In contrast hepatic Cd concentration in juvenile Common eider was significantly higher than in adult eiders. This finding is not in agreement with Nielsen and Dietz (1989). In their study on Greenland eiders they found that older birds carried higher Cd concentrations. In eiders (*S. mollissima* and *S. spectabilis*) four differences were significant at the 5 % level and three at 1% level among nine comparisons.

Furness and Hutton (1979) analysed 13 ringed *Catharacta skua* of known ages between 3 and 12 years. They found significant correlations between element concentrations and bird age, for Cd in kidney at p=0.05 and for Se in kidney at p=0.01. Concerning Hg and Se in liver, significance was reached only at 10% level. On the other hand, Nicholson (1981) did not find any significant correlations between Zn, Cd and Hg concentrations and age in 11 Herring gulls of known age (from 4 to 11 years) from Scotland.

Among six seabird species investigated in the present study mercury increases with age only in muscle and liver of Brünnich's guillemots and Common guillemots from the Barents Sea. Nielsen and Dietz (1989) found no significant age accumulation or even tendency towards higher concentrations of Hg in older birds of five Greenland species. One exception was Black guillemot from Ummannaq that had approximately three times higher Hg content in older individuals when compared to yearlings.

No significant age differences in arsenic levels have been found in the present study between seabirds investigated, with the exception of Common guillemots and Herring gulls from Hornøya. In these birds higher As levels were found in older birds. There are only few data on As levels in seabirds in general, as well as related with the age of the birds. Henny *et al.* (1991), studying trace element levels in Surf scoters (*Melanitta perspicillata*) from the Pacific Northwest, have not found age-related differences for As levels.

Sex dependence of element concentrations

Analysis of the concentrations of eight elements in two tissues of different seabird species from the Barents Sea area showed no significant differences between sexes. Exceptions were found for Cd in muscle of Glaucous gull and Fulmar, Cu in liver of King eider and in muscle of Glaucous gull and Kittiwake, As in muscle of Razorbill and Arctic tern, Se in muscle of Arctic tern and Hg in muscle of Kittiwake. In all species only the 5% level of significance was reached.

This is consistent with the previous results for Greenland and Svalbard seabirds (Nielsen and Dietz, 1989; Norheim and Borch-Iohnsen, 1990). Nielsen and Dietz (1989) have found significant differences only for Zn in muscle of Black guillemot, Zn in kidney of King eider, Hg in liver of Common eider and Se in kidney of King eider. The statistical noise introduced by neglecting sex, as a biological parameter was considered small and not likely to materially affect the results of analysis. In Svalbard Common eider the differences between male and female element levels were not significant (Norheim and Borch-Iohnsen, 1990).

Comparison with other Arctic areas

Data on trace element contents in different Arctic seabird species have been obtained for Greenland (Nielsen and Dietz, 1989; Dietz *et al.*, 1997), Canadian Arctic (Elliot *et al.*, 1992), Siberia (Kim *et al.*, 1996) and Norwegian Arctic areas (Norheim, 1987; Wenzel and Gabrielsen, 1995;

It is difficult to compare results obtained by the authors mentioned above since all have used different analytical methods and ways of presenting data. For comparison purposes we recalculated some of the data presented by Norheim (1987) and Nielsen and Dietz (1989) on a wet weight basis to dry weight. All relevant analytical data on trace element levels in Arctic seabirds are summarised in Table 4. As can be seen from this table our data on Cd levels in the Barents Sea birds are in a line with existing literature data for seabirds from other Arctic regions (Nielsen and Dietz, 1989; Wenzel and Gabrielsen, 1995; Dietz *et al.*, 1990; 1997; etc.).

Table 4. Trace elements in tissue of seabirds from the different Arctic areas, μg/g dry weight

Area, year	Tissue	n	Figure	Cd	Zn	Cu	Cr	Mn	Se	Hg	Source
				Arctic tern							
Northern Siberia,	muscle	10	Mean	0.49	42.3	20.2	n.a.	1.82	n.a.	1.30	Kim *et al.*,1996
1993			SD	0.35	6.3	1.45		0.43		0.75	
Northern Siberia,	liver	10	Mean	15.3	82.6	25.1	n.a.	17.5	n.a.	4.84	Kim *et al.*,1996
1993			SD	7.7	20.6	5.72		7.90		3.66	
				Black guillemot							
Greenland,	muscle	42	Mean	0.77	42.2	n.a.	n.a.	n.a.	2.86	0.73	Nielsen,
1984-1986			SD	0.69	5.88				1.65	0.49	Dietz 1989 **
Greenland,	liver	42	Mean	10.3	103	n.a.	n.a.	n.a.	8.72	2.20	Nielsen,
1984-1986			SD	5.89	15.3				4.54	1.38	Dietz 1989**
				Brünnich's guillemot							
S-W Barents Sea,	liver	14	Mean	5.51	93.9	18.1	n.a.	n.a.	7.05	1.11	Wenzel,
Hornøya. 1992-93			SD	4.24	13.1	2.8			3.48	0.51	Gabrielsen, 1995
S-W Barents Sea,	muscle	14	Mean	0.53	46.1	17.8	n.a.	n.a.	n.a.	0.33	Wenzel,
Hornøya, 1992-93			SD	0.25	8.22	2.4				0.14	Gabrielsen, 1995
Nordenskiöld Land,	liver	9	Mean	13.1	118	27.6	n.a.	n.a.	6.38	2.02	Norheim, 1987*
Svalbard,1980			Min	6.05	104	21.5			3.70	1.01	
			Max	36.0	128	31.6			8.74	3.02	
Greenland,	muscle	20	Mean	1.35	46.6	n.a.	n.a.	n.a.	3.16	0.73	Nielsen,
1984-1986			SD	0.74	9.94				1.37	0.24	Dietz 1989**
Greenland,	liver	20	Mean	25.0	136	n.a.	n.a.	n.a.	7.58	2.63	Nielsen,
1984-1986			SD	9.78	27.2				2.62	0.83	Dietz 1989**
				Common guillemot							
S-W Barents Sea,	liver	10	Mean	3.08	86.7	20	n.a.	n.a.	17.6	1.88	Wenzel,
Hornøya, 1992-93			SD	1.12	14.9	2.9			5.04	0.41	Gabrielsen, 1995
S-W Barents Sea,	muscle	10	Mean	0.18	49.3	19.2	n.a.	n.a.	n.a.	0.42	Wenzel,
Hornøya, 1992-93			SD	0.05	3.34	0.9				0.05	Gabrielsen, 1995
				Puffin							
Canadian Atlantic,	liver	6	Mean	8.9	99.5	15.3	4.35	8.87	11.7	2.60	Elliot *et al.*, 1992
Gull Is., 1988			SD	2.5	15.9	0.69	1.76	1.55	1.60	0.80	
Canadian Atlantic,	liver	6	Mean	5.9	91.1	23.3	1.53	11.3	8.29	1.40	Elliot *et al.*, 1992
Ille St. Marie, 1988			SD	5.1	8.94	3.13	1.40	1.30	3.43	0.52	
				Common eider							
Ny-Ålesund,	liver	10	Mean	38.3	305	1106	n.a.	n.a.	37.7	n.a.	Norheim, Borch-
Spitsbergen, 1986			SD	12.9	122	1105			28.5		Iohnsen, 1990*
Nordenskiöld Land,	liver	9	Mean	14.4	168	907	n.a.	n.a.	29.9	3.36	Norheim, 1987*
Svalbard,1980			Min	7.73	134	23			11.4	1.68	
			Max	31.6	205	3864			84.0	5.71	
Greenland,	muscle	21	Mean	0.68	45.3	n.a.	n.a.	n.a.	4.03	0.57	Nielsen,
1984-1986			SD	1.02	9.0				3.05	0.30	Dietz 1989**
Greenland,	liver	21	Mean	11.9	160	n.a.	n.a.	n.a.	27.4	3.09	Nielsen,
1984-1986			SD	7.05	58.6				18.6	2.02	Dietz 1989**
				King eider							
Northern Siberia, 1993	muscle	1		0.66	32	19	n.a.	1.46	n.a.	0.29	Kim *et al.*,1996
Northern Siberia, 1993	liver	1		25.5	201	696	n.a.	41.6	n.a.	5.75	Kim *et al.*,1996
Greenland,	muscle	21	Mean	1.43	45	n.a.	n.a.	n.a.	3.33	0.52	Nielsen,
1984-1986			SD	1.54	6.22				2.34	0.29	Dietz 1989**
Greenland,	liver	21	Mean	20.4	167	n.a.	n.a.	n.a.	27.1	2.07	Nielsen,
1984-1986			SD	14.5	50.7				21.2	1.39	Dietz 1989**
				Long-tailed duck							

Area, year	Tissue	n	Figure	Cd	Zn	Cu	Cr	Mn	Se	Hg	Source
Greenland,	muscle	5	Mean	0.80	42.7	n.a.	n.a.	n.a.	3.24	0.40	Nielsen,
1984-1986			SD	0.69	7.41				2.00	0.10	Dietz 1989**
Greenland,	liver	5	Mean	17.4	112	n.a.	n.a.	n.a.	10.5	2.13	Nielsen,
1984-1986			SD	13.4	23.8				6.54	0.64	Dietz 1989**
					Fulmar						
Nordenskiöld Land,	liver	10	Mean	57.1	245	20.8	n.a.	n.a.	10.1	7.06	Norheim, 1987*
Svalbard,1980			Min	20.5	168	18.8			4.70	2.02	
			Max	108	319	22.5			21.5	14.1	
Greenland,	muscle	17	Mean	4.74	62.2	n.a.	n.a.	n.a.	8.36	0.92	Nielsen,
1984-1986			SD	5.46	22.4				2.98	0.39	Dietz 1989**
Greenland,	liver	17	Mean	34.8	173	n.a.	n.a.	n.a.	28.7	7.38	Nielsen,
1984-1986			SD	20.5	65.7				7.66	4.44	Dietz 1989**
					Glaucous gull						
Northern Siberia, 1993	muscle	1		0.13	78.1	13.0	n.a.	1.38	n.a.	0.5	Kim *et al.*,1996
Northern Siberia, 1993	liver	1		3.90	86.5	12.8	n.a.	6.25	n.a.	3.28	Kim *et al.*,1996
Nordenskiöld Land,	liver	11	Mean	12.1	108	24.5	n.a.	n.a.	7.39	5.38	Norheim, 1987*
Svalbard,1980			Min	1.34	87.4	18.5			4.37	2.69	
			Max	31.6	158	33.6			12.1	7.73	
Greenland,	muscle	15	Mean	1.36	83.3	n.a.	n.a.	n.a.	5.26	2.50	Nielsen,
1984-1986			SD	1.29	15.0				4.21	1.39	Dietz 1989**
Greenland,	liver	15	Mean	37.6	144	n.a.	n.a.	n.a.	16.4	8.72	Nielsen,
1984-1986			SD	37.7	46.7				12.7	4.74	Dietz 1989**
					Herring gull						
Canadian Atlantic,	liver	6	Mean	3.6	90.1	16.8	1.04	12.4	3.21	1.70	Elliot *et al.*, 1992
Gull Is., 1988			SD	1.8	16.2	2.12	1.21	2.35	0.84	0.67	
Canadian Atlantic,	liver	6	Mean	5.4	129	12.2	1.23	14.9	3.36	1.50	Elliot *et al.*, 1992
Kent Is., 1988			SD	5.0	26.2	2.05	1.18	2.07	0.62	0.53	
Canadian Atlantic,	liver	6	Mean	1.7	84.7	30.6	n.a.	14.3	3.20	0.69	Elliot *et al.*, 1992
Manawagonish Is			SD	0.4	8.56	20.6		1.18	0.67	0.18	
Northern Siberia,	muscle	6	Mean	0.91	62.1	14.2	n.a.	1.31	n.a.	0.72	Kim *et al.*,1996
1993			SD	0.22	7.9	1.72		0.29		0.30	
Northern Siberia,	liver	6	Mean	26.3	141	19.9	n.a.	12.6	n.a.	4.01	Kim *et al.*,1996
1993			SD	16.1	68	3.48		3.2		2.14	
					Kittiwake						
S-W Barents Sea,	liver	22	Mean	14.4	112	19.6	n.a.	n.a.	16.9	2.85	Wenzel,
Hornøya, 1992-93			SD	11.3	52.3	5.7			9.5	1.02	Gabrielsen, 1995
S-W Barents Sea,	muscle	27	Mean	1.24	53.5	18.1	n.a.	n.a.	n.a.	0.58	Wenzel,
Hornøya, 1992-93			SD	0.64	7.05	1.25				0.22	Gabrielsen, 1995
Greenland,	muscle	15	Mean	1.52	50.4	n.a.	n.a.	n.a.	9.34	0.54	Nielsen,
1984-1986			SD	1.20	9.07				5.67	0.37	Dietz 1989**
Greenland,	liver	15	Mean	25.7	119	n.a.	n.a.	n.a.	32.0	2.10	Nielsen,
1984-1986			SD	13.3	25.8				20.5	1.43	Dietz 1989**
					Little auk						
Nordenskiöld Land,	liver	9	Mean	14.4	124	28.2	n.a.	n.a.	8.74	1.68	Norheim, 1987*
Svalbard,1980			Min	8.06	104	22.8			5.04	1.34	
			Max	19.5	144	31.6			15.1	2.35	
Greenland,	muscle	13	Mean	1.30	54.4	n.a.	n.a.	n.a.	8.81	0.49	Nielsen,
1984-1986			SD	0.60	26.7				5.46	0.28	Dietz 1989**
Greenland,	liver	13	Mean	17.4	122	n.a.	n.a.	n.a.	19.7	1.61	Nielsen,
1984-1986			SD	8.57	13.6				8.77	0.92	Dietz 1989**

* recalculated from wet wt with factor 3.36 (see Dietz *et al.*, 1996); ** recalculated from wet wt with the factors obtained for each bird group (see Nielsen, Dietz, 1989); n.a. - not analysed.

Trace element levels in birds from Hornøya are in good agreement with Wenzel and Gabrielsen (1995) data for the same species from this area. However, levels of Cd and Hg found in Common guillemot liver from Seven Islands are two times lower than in the same species from Hornøya (Wenzel and Gabrielsen, 1995). The average Cd hepatic level in Brünnich's guillemot from Hornøya and Seven Islands in the present study was also two times lower compared with Wenzel and Gabrielsen (1995), while Hg levels were similar.

Nielsen and Dietz (1989), Dietz *et al.* (1990; 1997) and Braune (pers. comm.) have also found the highest Cd levels in Fulmars and Kittiwakes from Greenland and Canadian Arctic. The average hepatic Cd level in Fulmars from the Barents Sea area is slightly higher than in Greenland Fulmars, whereas Cd levels in liver of Kittiwakes from the Barents Sea are lower compared to Kittiwakes from Greenland (Nielsen and Dietz, 1989). Levels of Cd in Fulmars from Bjørnøya are similar to Greenland seabirds (Nielsen and Dietz, 1989).

A comparison of Cd levels in Fulmar's tissues (Ny-Ålesund, Svalbard) with data from Norheim (1987) in 1980 at Nordenskiöld Land (Svalbard) has shown a two times increase of Cd level in Fulmars from Svalbard. Tissue levels of Cd in Fulmars from Franz Josef Land are much lower than in birds from Greenland (Nielsen and Dietz, 1989) and Svalbard (Norheim, 1987).

Our data on Cd levels in Brünnich's guillemots from Ny-Ålesund are similar to those found for this species in Nordenskiöld Land, whereas levels of Zn, Cu and Se are lower than reported by Norheim (1987). In general, for Brünnich's guillemots from the whole Barents Sea area Cd and Hg levels are 2,5 times lower than in the same species from Greenland (Nielsen and Dietz, 1989). Hepatic and muscle Cd and Hg levels in Black guillemots from Franz Josef Land are also two times lower than in this species from Greenland (Nielsen and Dietz, 1989).

Arctic terns from the Barents Sea area have similar Cd level as the same species from the Northern Siberia. However, the Hg level in the Barents Sea terns is four times lower when compared with Siberian terns (Kim *et al.*, 1996).

The highest average Cd level found in liver of Puffins from Ny-Ålesund is comparable to those for Puffins from Gull Island (Canada). However, the Hg level is two times lower in the Barents Sea Puffins (Elliott *et al.*, 1992).

In general, even the highest levels of the most toxic elements like Cd and Hg found in seabirds from the Barents Sea were low compared to those in the same or similar seabird species from other areas (Nielsen and Dietz, 1989; Elliott *et al.*, 1992; Kim *et al.*, 1996). As a monitor of total exposure, or as an indicator of the body burden of Cd, the concentration of liver tissue is considered as the best measure (Scheuhammer, 1987). The liver accumulates approximately half of the body burden of Cd. The Cd content of the liver is extremely stable, and the liver is generally resistant to the toxic effects of Cd (Goyer *et al.*, 1984). The hepatic Cd levels in the Barents Sea seabirds do not exceed levels of this element, indicated of increased environmental exposure to Cd (Scheuhammer, 1987). The same conclusion can be applied for Hg content in the Barents Sea seabird species. Thus, the levels we report seem to be natural and are a result of the accumulation and storage processes in marine animals, rather than from global pollution, although this latter cannot yet be ruled out. Data on metallothionein concentrations in seabirds need to be collected in order to understand the mechanism of bioaccumulation and possible toxic effects of trace elements in Arctic seabirds.

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Appendices

Appendix 1. Trace element levels in tissues of seabirds from the Barents Sea and Norwegian Sea areas.

Table 1.1. Mean levels of trace elements (mg/kg dry wt.) in Brünnich's guillemot (Uria lomvia). Mean - arithmetic mean, SD - standard deviation, GM - geometric mean, N - number of samples.

Area, year	Sex, age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					S-W Barents Sea							
Hornøya, 1991	F+M	liver	5	Mean	5.80	91.2	16.9	n.d.	0.05	1.86	7.53	0.88
				SD	*1.98*	*14.9*	*2.9*		*0.02*	*0.25*	*2.01*	*0.17*
				GM	5.51	90.3	16.7	n.d.	0.05	1.85	7.32	0.86
				Median	5.46	86.5	16.1	n.d.	0.05	1.85	6.72	0.91
Hornøya, 1991	F+M	muscle	4	Mean	0.57	39.9	19.8	n.d.	0.05	0.17	3.88	0.32
				SD	*0.39*	*5.2*	*2.2*		*0.01*	*0.06*	*0.98*	*0.07*
				GM	0.50	39.6	19.7	n.d.	0.05	0.16	3.78	0.31
				Median	0.39	39.4	19.9	n.d.	0.05	0.15	3.89	0.32
					Svalbard Archipelago							
Bjørnøya, 1991	F	liver	5	Mean	6.51	99.0	18.0	n.d.	0.04	3.18	4.27	0.33
				SD	*2.56*	*10.3*	*2.0*		*0.00*	*0.83*	*0.57*	*0.12*
				GM	5.92	98.5	17.9	n.d.	0.04	3.11	4.24	0.30
				Median	6.61	[illegible]	17.3	n.d.	0.04	3.04	4.35	0.35
Bjørnøya, 1991	F	muscle	5	Mean	0.61	47.2	17.7	n.d.	0.06	1.09	1.74	0.15
				SD	*0.22*	*2.2*	*2.3*		*0.03*	*0.48*	*0.28*	*0.08*
				GM	0.59	47.2	17.6	n.d.	0.06	0.96	1.72	0.13
				Median	0.57	46.5	18.5	n.d.	0.05	1.18	1.82	0.15
Ny-Ålesund, 1991	F+M	liver	5	Mean	14.9	91.5	16.1	n.d.	0.05	4.61	5.49	1.61
				SD	*6.16*	*30.5*	*5.8*		*0.00*	*2.65*	*1.89*	*0.42*
				GM	13.9	87.6	15.3	n.d.	0.05	3.97	5.26	1.56
				Median	14.6	77.3	13.4	n.d.	0.05	4.56	5.03	1.71
Ny-Ålesund, 1991	F+M	muscle	5	Mean	1.23	40.7	23.1	n.d.	0.05	0.79	3.36	0.60
				SD	*0.29*	*3.2*	*1.80*		*0.00*	*0.61*	*0.81*	*0.09*
				GM	1.21	40.6	23.0	n.d.	0.05	0.61	3.29	0.59
				Median	1.10	39.6	23.5	n.d.	0.05	0.67	3.17	0.62
					Franz Josef Land Archipelago							
George Land, 1992	M	liver	2	Mean	19.3	116	22.6	11.40	0.25	1.69	8.16	0.65
				SD	*7.91*	*6.4*	*3.5*	*1.80*	*0.15*	*0.24*	*7.10*	*0.11*
				GM	18.5	116	22.5	11.40	0.23	1.68	6.44	0.65
				Median	19.3	116	22.6	11.40	0.25	1.69	8.16	0.65
George Land, 1992	M	muscle	2	Mean	0.45	47.1	19.8	1.80	0.10	0.37	2.52	0.28
				SD	*0.14*	*0.0*	*1.3*	*0.20*	*0.02*	*0.01*	*0.64*	*0.06*
				GM	0.43	47.1	19.8	1.80	0.10	0.37	2.48	0.28
				Median	0.45	47.1	19.8	1.80	0.10	0.37	2.52	0.28
Northbrook, 1992	F+M	liver	2	Mean	13.1	131	23.0	11.10	0.10	5.30	4.26	0.58
				SD	*1.13*	*15.4*	*2.8*	*0.20*	*0.00*	*0.35*	*0.40*	*0.01*
				GM	13.1	131	22.9	11.10	0.10	5.30	4.25	0.58
				Median	13.1	131	23.0	11.10	0.10	5.30	4.26	0.58
Northbrook, 1992	F+M	muscle	2	Mean	1.29	50.1	15.4	1.80	0.17	2.65	2.48	0.23
				SD	*0.38*	*2.3*	*3.9*	*0.20*	*0.06*	*0.65*	*0.12*	*0.00*
				GM	1.26	50.1	15.2	1.80	0.16	2.61	2.48	0.23
				Median	1.29	50.1	15.4	1.80	0.17	2.65	2.48	0.23
Mable Is., 1992	M	liver	1		12.4	115	23.8	10.60	0.09	4.30	6.07	1.55
Melba Is., 1992	M	muscle	1		1.79	46.5	22.6	2.30	0.13	1.02	2.92	0.60

Table 1.1. (Continued).

Area, year	Sex, age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
				Pechora Sea, Novaya Zemlya Archipelago								
Guba Chernaya, 1992	F+M	liver	5	Mean	3.98	106	24.9	9.95	0.16	96.4	6.27	0.79
				SD	*1.00*	*34.5*	*11.6*	*1.56*	*0.02*	*70.9*	*0.90*	*0.11*
				GM	3.86	102	23.3	9.86	0.16	63.1	6.21	0.79
				Median	4.36	96.8	20.3	10.3	0.16	112	6.66	0.84
Guba Chernaya, 1992	F+M	muscle	5	Mean	0.87	59.9	14.7	2.16	0.18	46.7	4.63	0.43
				SD	*0.43*	*38.9*	*3.2*	*0.42*	*0.08*	*28.0*	*0.83*	*0.18*
				GM	0.80	52.9	14.3	2.13	0.16	36.5	4.57	0.40
				Median	0.71	44.2	15.1	2.06	0.19	51.0	4.64	0.42
				Seven Islands Archipelago								
Kharlov Is, 1992	F+M	liver	5	Mean	2.55	69.3	16.0	8.59	0.34	1.48	13.94	0.93
				SD	*1.93*	*1.8*	*2.1*	*0.95*	*0.28*	*0.72*	*4.06*	*0.07*
				GM	2.17	69.3	15.9	8.55	0.28	1.35	13.5	0.93
				Median	1.75	70.0	15.5	8.12	0.18	1.26	12.9	0.94
Kharlov Is, 1992	F+M	muscle	5	Mean	0.60	42.4	13.8	2.30	0.09	0.61	8.02	0.37
				SD	*0.36*	*6.7*	*1.9*	*0.44*	*0.02*	*0.13*	*2.08*	*0.07*
				GM	0.54	42.0	13.7	2.27	0.09	0.60	7.79	0.37
				Median	0.49	44.1	14.4	2.43	0.09	0.59	8.72	0.38
Kuvshin Is, 1992	juv	liver	5	Mean	0.17	90.7	13.5	10.3	0.14	0.70	3.06	0.07
				SD	*0.05*	*4.2*	*1.1*	*1.43*	*0.03*	*0.12*	*0.39*	*0.01*
				GM	0.16	90.6	13.5	10.2	0.14	0.69	3.04	0.07
				Median	0.18	92.0	13.7	10.4	0.14	0.67	2.85	0.07
Kuvshin Is, 1992	juv	muscle	5	Mean	0.06	57.0	7.6	2.19	0.12	0.76	2.05	0.05
				SD	*0.02*	*3.8*	*1.0*	*0.68*	*0.05*	*0.19*	*0.29*	*0.00*
				GM	0.05	56.8	7.6	2.12	0.11	0.74	2.03	0.05
				Median	0.05	56.7	8.1	1.83	0.09	0.65	1.90	0.05

"n.d."- not determined

Table 1.2. Mean levels of trace elements (mg/kg dry wt) in tissues of Common guillemot (Uria aalge). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex, age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
						Seven Islands Archipelago						
Kuvshin Is, 1992	juv	liver	3	Mean	0.38	96.9	15.7	13.5	0.17	0.61	3.30	0.10
				SD	*0.12*	*6.0*	*0.9*	*1.49*	*0.08*	*0.11*	*0.09*	*0.00*
				GM	0.37	96.8	15.7	13.4	0.16	0.60	3.30	0.10
				Median	0.43	98.7	16.0	14.3	0.12	0.57	3.26	0.10
Kuvshin Is., 1992	juv	muscle	3	Mean	0.04	58.9	8.7	1.74	0.13	1.02	1.68	0.06
				SD	*0.01*	*2.3*	*2.2*	*0.37*	*0.05*	*0.47*	*0.29*	*0.00*
				GM	0.04	58.8	8.5	1.71	0.13	0.96	1.66	0.06
				Median	0.05	59.5	8.1	1.91	0.11	0.85	1.82	0.06
Kuvshin Is., 1992	F+M	liver	5	Mean	1.98	80.4	19.9	13.0	0.24	1.34	18.7	1.08
				SD	*0.56*	*7.0*	*0.8*	*1.66*	*0.13*	*0.52*	*3.94*	*0.09*
				GM	1.93	80.2	19.8	12.9	0.21	1.24	18.3	1.08
				Median	1.82	77.3	20.1	13.2	0.17	1.39	20.3	1.10
Kuvshin Is., 1992	F+M	muscle	5	Mean	0.28	40.1	14.4	1.80	0.08	0.60	11.9	0.50
				SD	*0.05*	*3.1*	*3.5*	*0.51*	*0.02*	*0.32*	*2.11*	*0.09*
				GM	0.28	40.0	14.1	1.75	0.08	0.55	11.7	0.49
				Median	0.28	41.2	15.5	1.60	0.06	0.48	12.7	0.53
Kharlov Is., 1992	F+M	liver	5	Mean	1.69	89.0	23.4	13.2	0.39	1.03	21.3	1.09
				SD	*0.52*	*10.4*	*7.7*	*1.74*	*0.35*	*0.40*	*3.56*	*0.28*
				GM	1.63	88.5	22.5	13.1	0.28	0.96	21.0	1.06
				Median	1.41	87.2	20.3	13.8	0.25	0.95	22.3	1.09
Kharlov Is., 1992	F+M	muscle	5	Mean	0.15	40.1	17.3	1.58	0.09	0.48	8.74	0.33
				SD	*0.02*	*5.9*	*1.9*	*0.15*	*0.01*	*0.06*	*1.26*	*0.05*
				GM	0.15	39.8	17.2	1.58	0.09	0.47	8.67	0.33
				Median	0.14	37.9	17.6	1.55	0.08	0.46	8.45	0.30

Table 1.3. Mean levels of trace elements (mg/kg dry wt) in tissues of Puffin (Fratercula arctica). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					S-W Barents Sea							
Hornøya, 1991	F+M	liver	5	Mean	2.60	84.6	17.6	n.d.	0.06	0.79	9.18	1.22
				SD	*1.00*	*11.9*	*2.6*		*0.01*	*0.56*	*1.68*	*0.35*
				GM	2.45	83.9	17.5	n.d.	0.06	0.65	9.07	1.17
				Median	2.29	84.3	18.1	n.d.	0.06	0.56	8.45	1.30
Hornøya, 1991	F+M	muscle	5	Mean	0.29	40.6	19.2	n.d.	0.04	0.20	5.32	0.31
				SD	*0.10*	*3.0*	*2.0*		*0.00*	*0.12*	*1.50*	*0.15*
				GM	0.28	40.5	19.1	n.d.	0.04	0.18	5.18	0.25
				Median	0.27	40.5	18.3	n.d.	0.04	0.14	4.81	0.36
					Svalbard Archipelago							
Ny Ålesund, 1991	F+M	liver	5	Mean	9.77	101	19.5	n.d.	0.08	1.36	11.9	1.12
				SD	*3.21*	*6.7*	*1.7*		*0.08*	*0.61*	*3.48*	*0.32*
				GM	9.33	100	19.4	n.d.	0.06	1.26	11.4	1.08
				Median	10.1	101	19.6	n.d.	0.04	1.35	11.0	1.06
Ny Ålesund, 1991	F+M	muscle	5	Mean	0.77	43.3	20.2	n.d.	0.08	0.21	9.87	0.40
				SD	*0.42*	*4.6*	*1.6*		*0.05*	*0.08*	*2.12*	*0.17*
				GM	0.70	43.1	20.1	n.d.	0.07	0.20	9.67	0.38
				Median	0.62	44.8	19.9	n.d.	0.05	0.17	10.8	0.35
					Seven Islands Archipelago							
Kuvshin Is., 1992	M	liver	4	Mean	2.68	90.8	19.5	15.0	0.50	1.04	14.0	1.17
				SD	*1.30*	*7.0*	*1.5*	*0.76*	*0.60*	*0.47*	*2.25*	*0.23*
				GM	2.41	90.6	19.4	15.0	0.50	0.95	13.9	1.15
				Median	2.73	88.4	19.1	15.1	0.31	1.01	14.8	1.26
Kuvshin Is., 1992	M	muscle	4	Mean	0.32	43.4	14.8	2.26	0.49	0.47	10.5	0.46
				SD	*0.14*	*3.3*	*3.5*	*0.92*	*0.67*	*0.02*	*1.38*	*0.09*
				GM	0.29	43.3	14.5	2.13	0.25	0.47	10.4	0.45
				Median	0.31	43.8	14.0	2.08	0.18	0.47	10.2	0.48
Kharlov Is., 1992	F+M	liver	3	Mean	3.22	96.6	21.1	16.8	0.14	0.79	27.1	1.37
				SD	*1.35*	*5.6*	*1.6*	*1.40*	*0.03*	*0.30*	*3.95*	*0.12*
				GM	3.06	96.5	21.0	16.8	0.14	0.75	26.9	1.37
				Median	2.59	93.9	20.7	16.6	0.13	0.69	25.1	1.31
Kharlov Is., 1992	F+M	muscle	3	Mean	0.25	44.7	17.0	2.11	0.08	0.52	15.5	0.44
				SD	*0.04*	*5.7*	*4.1*	*0.07*	*0.01*	*0.09*	*2.95*	*0.10*
				GM	0.25	44.5	16.7	2.11	0.08	0.51	15.3	0.43
				Median	0.24	45.1	16.9	2.14	0.08	0.48	16.6	0.41
					S-E Norwegian Sea, Troms							
Sommarøy, 1993	F+M	liver	5	Mean	6.87	189	52.9	23.0	0.29	16.9	21.3	1.60
				SD	*5.02*	*17.5*	*10.3*	*1.80*	*0.07*	*4.90*	*3.50*	*0.36*
				GM	5.64	189	52.1	23.0	0.28	16.2	21.1	1.56
				Median	6.36	187	49.0	22.0	0.28	18.5	21.3	1.78
Sommarøy, 1993	F+M	muscle	5	Mean	0.39	67.5	29.2	1.90	0.15	6.95	24.8	0.45
				SD	*0.28*	*5.2*	*4.4*	*0.20*	*0.04*	*2.82*	*14.8*	*0.10*
				GM	0.28	67.3	29.0	1.88	0.14	6.40	21.9	0.44
				Median	0.45	66.3	28.7	1.93	0.13	7.63	21.9	0.44

"n.d."- not determined

Table 1.4. Mean levels of trace elements (mg/kg dry wt.) in Black guillemot (Cepphus grylle). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex, age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					Franz Josef Land Archipelago							
Northbrook,1992	M	liver	1		5.24	110	23.8	9.60	0.11	14.3	9.50	1.12
Northbrook,1992	M	muscle	1		0.34	45.6	22.0	2.00	0.18	5.7	4.20	0.43
Stolichky Is.,	F	liver	2	Mean	5.89	93.2	19.3	8.80	0.11	11.3	8.30	0.81
1992				*SD*	*0.69*	*3.4*	*0.9*	*0.80*	*0.00*	*2.6*	*0.70*	*0.03*
				GM	5.87	93.2	19.3	8.74	0.11	11.2	8.30	0.81
				Median	5.89	93.2	19.3	8.76	0.11	11.3	8.31	0.81
Stolichky Is.,	M	muscle	2	Mean	0.50	37.6	17.5	2.20	0.10	4.1	2.30	0.27
1992				*SD*	*0.14*	*1.9*	*0.1*	*0.00*	*0.00*	*0.6*	*0.30*	*0.00*
				GM	0.49	37.6	17.5	2.24	0.10	4.1	2.32	0.27
				Median	0.50	37.6	17.5	2.24	0.10	4.1	2.33	0.27
Hooker Is., 1992	adult	liver	2	Mean	4.01	87.7	21.7	9.10	0.21	12.6	4.90	0.76
				SD	*0.21*	*9.3*	*0.9*	*1.50*	*0.09*	*0.1*	*0.50*	*0.25*
				GM	4.01	87.5	21.7	9.08	0.20	12.6	4.89	0.74
				Median	4.01	87.7	21.7	9.14	0.21	12.6	4.91	0.76
Hooker Is., 1992	adult	muscle	2	Mean	0.34	41.9	23.6	2.50	0.12	3.6	2.10	0.31
				SD	*0.09*	*2.4*	*0.8*	*0.13*	*0.02*	*2.0*	*0.16*	*0.08*
				GM	0.33	41.8	23.6	2.49	0.12	3.3	2.04	0.31
				Median	0.34	41.9	23.6	2.49	0.12	3.6	2.05	0.31

Table 1.5. Mean levels of trace elements (mg/kg dry wt) in tissues of Little auk (Alle alle). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					Franz Josef Land Archipelago							
Hooker Is., 1991	M	liver	2	Mean	6.64	81.4	21.4	n.d.	0.06	1.06	4.86	0.24
				SD	*0.99*	*10.3*	*1.3*		*0.00*	*0.37*	*0.90*	*0.02*
				GM	6.60	81.0	21.4	n.d.	0.05	1.02	4.81	0.23
				Median	6.64	81.4	21.4	n.d.	0.06	1.06	4.86	0.24
Hooker Is., 1991	F+M	muscle	10	Mean	0.81	36.9	25.3	n.d.	0.07	0.42	2.13	0.10
				SD	*0.34*	*3.8*	*4.7*		*0.02*	*0.20*	*0.55*	*0.05*
				GM	0.75	36.7	24.9	n.d.	0.06	0.38	2.06	0.09
				Median	0.81	36.3	26.2	n.d.	0.07	0.41	2.08	0.09
Kuhn Is., 1992	F	liver	6	Mean	3.44	79.5	22.9	7.06	0.11	5.05	3.67	0.51
				SD	*1.96*	*18.5*	*2.8*	*3.54*	*0.00*	*3.39*	*1.21*	*0.26*
				GM	2.40	77.2	22.8	6.16	0.11	3.98	3.45	0.45
				Median	3.65	84.1	21.9	6.36	0.11	5.00	3.87	0.49
Kuhn Is., 1992	F	muscle	6	Mean	0.86	46.8	21.4	2.97	0.14	3.60	2.20	0.32
				SD	*1.04*	*16.6*	*3.8*	*1.49*	*0.05*	*2.97*	*1.19*	*0.18*
				GM	0.47	45.0	21.2	2.74	0.14	2.61	2.01	0.29
				Median	0.54	40.3	21.0	2.57	0.13	2.96	1.77	0.29

"n.d."- not determined

Table 1.6. Mean levels of trace elements (mg/kg dry wt) in tissues of Razorbill (Alca torda). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					Seven Islands Archipelago							
Kuvshin Is., 1992	F+M	liver	5	Mean	2.08	108	23.0	12.9	0.16	0.89	18.5	1.71
				SD	*0.65*	*15.1*	*3.1*	*1.97*	*0.04*	*0.32*	*8.86*	*0.42*
				GM	2.00	108	22.9	12.7	0.16	0.85	16.5	1.68
				Median	1.92	103	25.0	13.1	0.15	0.81	17.0	1.57
Kuvshin Is., 1992	F+M	muscle	5	Mean	0.32	46.0	15.2	2.62	0.17	0.48	7.68	0.88
				SD	*0.17*	*3.9*	*2.8*	*0.93*	*0.11*	*0.05*	*2.61*	*0.19*
				GM	0.28	45.9	14.9	2.49	0.15	0.47	7.18	0.86
				Median	0.22	44.0	15.8	2.56	0.13	0.48	8.41	0.84

"n.d."- not determined

Table 1.7. Mean levels of trace elements (mg/kg dry wt) in tissues of Common eider (Somateria mollissima). Mean - arithmetic mean, SD - standard deviation, GM - geometric mean, N - number of samples.

Area, year	Sex, age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					Svalbard Archipelago							
Ny-Ålesund, 1991	juv	liver	2	Mean	44.9	559	65.0	n.d.	0.07	0.15	16.4	2.56
				SD	*3.55*	*63.6*	*26.1*		*0.02*	*0.01*	*3.11*	*1.20*
				GM	44.8	557	62.3	n.d.	0.06	0.15	16.2	2.41
				Median	44.9	559	65.0	n.d.	0.07	0.15	16.4	2.56
Ny-Ålesund, 1991	juv	muscle	2	Mean	0.85	49.1	21.3	n.d.	0.07	0.15	4.66	0.39
				SD	*0.46*	*19.9*	*7.1*		*0.03*	*0.00*	*0.76*	*0.11*
				GM	0.78	47.0	20.7	n.d.	0.07	0.14	4.63	0.38
				Median	0.85	49.1	21.3	n.d.	0.07	0.15	4.66	0.39
Ny-Ålesund, 1991	F+M	liver	3	Mean	17.2	281	228	n.d.	0.07	0.13	9.21	1.80
				SD	*5.57*	*29.1*	*32.8*		*0.05*	*0.01*	*0.90*	*0.22*
				GM	16.5	280	226	n.d.	0.06	0.13	9.18	1.79
				Median	19.7	274	236	n.d.	0.04	0.13	8.89	1.70
Ny-Ålesund, 1991	F+M	muscle	4	Mean	0.43	36.4	19.7	n.d.	0.06	0.15	3.17	0.40
				SD	*0.26*	*2.8*	*5.4*		*0.02*	*0.01*	*1.16*	*0.16*
				GM	0.35	36.3	19.2	n.d.	0.05	0.15	3.02	0.37
				Median	0.45	36.3	18.9	n.d.	0.05	0.15	2.91	0.43
					Franz Josef Land Archipelago							
Scott-Kelty Is., 1991	juv	liver	5	Mean	0.30	122	114	n.d.	0.16	4.36	5.14	0.08
				SD	*0.07*	*10.1*	*29.9*		*0.26*	*0.47*	*0.28*	*0.01*
				GM	0.29	122	111	n.d.	0.08	4.34	5.13	0.08
				Median	0.26	124	111	n.d.	0.05	4.34	5.10	0.07
Scott-Kelty Is., 1991	juv	muscle	5	Mean	0.08	72.8	18.1	n.d.	0.12	2.78	1.32	0.04
				SD	*0.03*	*7.4*	*2.4*		*0.07*	*0.11*	*0.34*	*0.00*
				GM	0.08	72.5	18.0	n.d.	0.10	2.78	1.29	0.04
				Median	0.08	71.5	18.0	n.d.	0.10	2.72	1.17	0.04
Etheridge Is., 1992	juv	liver	9	Mean	6.79	125	206	15.9	0.14	3.20	9.77	1.05
				SD	*2.92*	*11.5*	*96.9*	*3.87*	*0.07*	*1.33*	*4.22*	*0.44*
				GM	4.92	124	173	15.5	0.12	2.92	8.96	0.86
				Median	7.69	126	223	16.1	0.13	3.24	9.05	1.15
Etheridge Is., 1992	juv	muscle	8	Mean	0.42	45.4	22.9	2.05	0.20	0.79	1.74	0.20
				SD	*0.22*	*4.2*	*3.3*	*0.20*	*0.14*	*0.29*	*0.58*	*0.03*
				GM	0.37	45.2	22.7	2.04	0.17	0.73	1.65	0.19
				Median	0.33	45.0	22.7	2.08	0.14	0.88	1.76	0.21
					S-E Norwegian Sea, Troms							
Sommarøy, 1992	F	liver	1		7.57	376	76.2	15.2	0.20	0.49	13.5	0.63
Sommarøy, 1992	F	muscle	1		0.50	29.6	10.6	1.16	0.09	0.40	2.27	0.22

"n.d."- not determined

Table 1.8. Mean levels of trace elements (mg/kg dry wt) in tissues of King eider (Somateria spectabilis). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					Pechora Sea							
Dolgiy Is., 1992	F+M	liver	5	Mean	3.61	145	106	20.7	0.15	0.69	13.1	1.29
				SD	*0.97*	*30.9*	*95.7*	*5.20*	*0.04*	*0.13*	*5.24*	*1.25*
				GM	3.49	143	76.5	20.2	0.15	0.68	12.3	0.97
				Median	4.17	136	66.1	18.9	0.15	0.74	13.0	0.61
Dolgiy Is., 1992	F+M	muscle	5	Mean	0.07	45.7	16.6	1.63	0.15	0.65	2.37	0.21
				SD	*0.04*	*10.5*	*2.1*	*0.27*	*0.13*	*0.04*	*0.53*	*0.07*
				GM	0.06	44.8	16.5	1.61	0.12	0.65	2.33	0.20
				Median	0.06	45.0	16.2	1.65	0.08	0.67	2.30	0.18
Kolguyev Is., 1992	F	liver	3	Mean	5.65	159	50.5	18.3	0.80	1.70	8.75	0.72
				SD	*2.23*	*55.3*	*39.8*	*2.33*	*0.67*	*0.13*	*1.79*	*0.15*
				GM	5.31	153	41.5	18.2	0.65	1.70	8.63	0.71
				Median	6.29	148	31.7	17.4	0.42	1.66	8.26	0.74
Kolguyev Is., 1992	F+M	muscle	4	Mean	0.41	52.1	23.4	2.75	0.10	0.75	1.97	0.22
				SD	*0.39*	*13.2*	*6.8*	*0.68*	*0.03*	*0.29*	*0.48*	*0.07*
				GM	0.23	50.9	22.7	2.69	0.09	0.71	1.93	0.21
				Median	0.37	47.8	22.1	2.48	0.09	0.68	1.83	0.23
Vaygach Is., 1992	M	liver	1		5.18	164	446	17.4	0.35	5.36	10.9	3.03
Vaygach Is,. 1992	M	muscle	1		0.47	69.3	34.6	3.31	0.11	2.54	3.74	0.59

Table 1.9. Levels of trace elements (mg/kg dry wt) in tissues of Long-tailed duck (Clangula hyemalis). N - number of samples.

Area, year	Sex	Tissue	N	Cd	Zn	Cu	Mn	Cr	As	Se	Hg
						Pechora Sea					
Dolgiy Is., 1992	M	liver	1	7.68	144	26.0	21.7	0.15	1.91	8.94	4.59
Dolgiy Is.,1992	M	muscle	1	0.26	42.0	26.0	2.35	0.23	0.52	2.37	0.68

Table 1.10. Mean levels of trace elements (mg/kg dry wt) in tissues of Great black-backed gull (Larus marinus). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex, age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					S-W Barents Sea							
Ainov Is., 1992	M	liver	1*		0.58	96.6	14.5	8.92	0.21	0.46	6.29	1.52
Ainov Is., 1992	M	muscle	1*		0.04	51.0	15.9	1.96	0.12	0.39	2.57	0.19
					Eastern Murman							
Guba Podpakhta, 1992	juv	liver	2	Mean	0.20	76.1	12.5	9.41	0.17	3.18	3.21	0.19
				SD	*0.05*	*7.6*	*2.2*	*1.78*	*0.00*	*0.18*	*0.23*	*0.04*
				GM	0.19	75.9	12.3	9.32	0.17	3.17	3.20	0.19
				Median	0.20	76.1	12.5	9.41	0.17	3.18	3.21	0.19
Guba Podpakhta, 1992	juv	muscle	2	Mean	0.05	65.7	13.2	2.00	0.11	2.32	1.33	0.09
				SD	*0.00*	*1.4*	*0.5*	*0.27*	*0.02*	*1.12*	*0.05*	*0.02*
				GM	0.05	65.7	13.2	1.99	0.11	2.18	1.33	0.09
				Median	0.05	65.7	13.2	2.00	0.11	2.32	1.33	0.09

* - found dead.

Table 1.11. Mean levels of trace elements (mg/kg dry wt) in tissues of Glaucous gull (Larus hyperboreus). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex, age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					Svalbard Archipelago							
Bjørnøya., 1991	F+M	liver	5	Mean	6.06	111	19.7	n.d.	0.05	12.8	5.25	1.02
				SD	*3.57*	*37.9*	*2.9*		*0.00*	*4.33*	*0.66*	*0.57*
				GM	5.29	107	19.5	n.d.	0.05	12.1	5.22	0.92
				Median	4.67	94.8	19.5	n.d.	0.05	12.9	5.07	0.92
Bjørnøya., 1991	F+M	muscle	5	Mean	[illegible].45	50.6	20.2	n.d.	0.04	3.92	1.41	0.29
				SD	*0.15*	*5.1*	*2.8*		*0.00*	*1.98*	*0.14*	*0.15*
				GM	0.43	50.4	20.1	n.d.	0.04	3.63	1.40	0.27
				Median	0.45	49.5	19.8	n.d.	0.04	3.09	1.47	0.24
Ny Ålesund, 1991	juv	liver	1		4.85	107	19.0	n.d.	0.05	2.13	5.29	1.25
Ny Ålesund, 1991	juv	muscle	1		0.08	52.2	20.7	n.d.	0.04	1.36	1.50	0.28
Ny Ålesund, 1991	F+M	liver	4	Mean	10.3	107	24.1	n.d.	0.06	1.98	5.44	1.54
				SD	*8.51*	*29.0*	*3.4*		*0.03*	*1.61*	*2.18*	*1.10*
				GM	4.12	1[illegible]4.	23.9	n.d.	0.05	1.23	4.96	1.17
				Median	11.[illegible]	118.	25.6	n.d.	0.05	1.87	6.37	1.45
Ny Ålesund, 1991	F+M	muscle	4	Mean	0.66	65.3	21.9	n.d.	0.05	0.80	2.52	0.73
				SD	*0.66*	*17.0*	*2.6*		*0.00*	*0.59*	*1.94*	*0.56*
				GM	0.46	63.6	21.8	n.d.	0.05	0.60	2.12	0.58
				Median	0.42	63.3	21.5	n.d.	0.05	0.75	1.59	0.59
					Franz Josef Land Archipelago							
George Land, 1992	F	liver	2	Mean	4.28	84.5	16.1	16.3	0.15	4.92	9.54	1.36
				SD	*4.09*	*8.8*	*0.1*	*0.30*	*0.07*	*2.34*	*2.35*	*0.03*
				GM	3.15	84.2	16.1	16.3	0.14	4.64	9.39	1.36
				Median	4.28	84.5	16.1	16.3	0.15	4.92	9.54	1.36
George Land, 1992	F	muscle	2	Mean	0.43	65.2	15.2	2.00	0.09	1.87	2.65	0.70
				SD	*0.46*	*15.0*	*1.0*	*0.40*	*0.02*	*0.42*	*0.36*	*0.13*
				GM	0.28	64.4	15.1	2.02	0.09	1.85	2.64	0.69
				Median	0.43	65.2	15.2	2.04	0.09	1.87	2.65	0.70
Northbrook, 1992	M	liver	1		1.41	81.4	15.6	11.4	0.11	5.58	28.5	2.12
Northbrook, 1992	M	muscle	1		0.09	66.4	13.6	1.94	0.11	1.03	8.16	0.92
Stolichky Is., 1992	M	liver	3	Mean	7.38	91.1	19.3	13.3	0.14	12.9	4.39	0.59
				SD	*4.44*	*9.0*	*0.8*	*0.80*	*0.00*	*5.31*	*0.33*	*0.16*
				GM	6.10	90.8	19.3	13.2	0.14	12.0	4.29	0.58
				Median	9.17	86.0	18.9	13.3	0.14	15.5	4.21	0.59
Stolichky Is., 1992	M	muscle	3	Mean	0.30	75.3	14.7	1.5[illegible]	0.07	2.55	1.22	0.13
				SD	*0.23*	*21.6*	*0.4*	*0.20*	*0.02*	*1.32*	*0.35*	*0.04*
				GM	0.25	73.1	14.7	1.49	0.06	2.27	1.18	0.12
				Median	0.20	76.8	14.8	1.38	0.07	2.83	1.29	0.14
Hooker Is., 1992	juv	liver	9	Mean	2.37	129	18.4	14.7	0.13	10.5	7.29	1.47
				SD	*2.13*	*87.2*	*2.9*	*3.10*	*0.04*	*7.01*	*5.45*	*0.77*
				GM	1.53	114	18.2	14.4	0.13	8.96	6.03	1.29
				Median	1.25	101	17.6	14.8	0.12	8.12	5.48	1.33
Hooker Is., 1992	juv	muscle	9	Mean	0.21	78.6	15.6	1.80	0.18	2.98	2.48	0.62
				SD	*0.22*	*27.1*	*1.6*	*0.40*	*0.09*	*1.80*	*1.65*	*0.47*
				GM	0.10	74.7	15.5	1.74	0.17	2.50	2.07	0.48
				Median	0.24	70.1	15.2	1.72	0.15	2.51	1.84	0.46
					Pechora Sea, Novaya Zemlya Archipelago							
Guba Chernaya, 1992	F+M	liver	3	Mean	2.54	84.8	19.3	13.4	0.15	76.8	6.20	1.38
				SD	*1.59*	*5.2*	*0.9*	*1.10*	*0.02*	*8.27*	*1.55*	*0.54*
				GM	2.25	84.7	19.3	13.4	0.15	76.6	6.08	1.31
				Median	1.79	86.2	18.9	13.0	0.16	75.8	5.61	1.36
Guba Chernaya, 1992	F+M	muscle	3	Mean	0.23	76.0	14.9	1.81	0.08	28.4	2.18	0.50
				SD	*0.08*	*8.5*	*1.1*	*0.21*	*0.00*	*9.25*	*0.53*	*0.16*
				GM	0.22	75.7	14.9	1.80	0.08	27.5	2.14	0.49
				Median	0.18	76.4	15.5	1.74	0.08	23.6	2.18	0.44

Table 1.11. (Continued)

Area, year	Sex, age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					Pechora Sea							
Kolguyev Is., 1992	M	liver	5	Mean	1.21	87.2	18.6	13.7	0.24	3.59	6.00	1.21
				SD	*0.46*	*12.3*	*1.1*	*2.69*	*0.22*	*1.79*	*0.96*	*0.57*
				GM	1.13	86.6	18.6	13.5	0.29	3.26	5.94	1.12
				Median	1.20	85.3	18.7	12.3	0.25	3.00	5.49	1.12
Kolguyev Is., 1992	M	muscle	5	Mean	0.16	68.5	15.6	1.88	0.10	1.16	2.52	0.42
				SD	*0.09*	*20.6*	*3.2*	*0.33*	*0.05*	*0.78*	*0.48*	*0.21*
				GM	0.13	66.0	15.4	1.86	0.09	0.96	2.48	0.38
				Median	0.11	64.5	14.1	1.75	0.11	0.80	2.62	0.39
Vaygach Is., 1992	F	liver	2	Mean	1.42	76.1	18.9	11.2	0.66	2.91	4.33	0.97
				SD	*0.73*	*4.7*	*0.0*	*0.00*	*0.31*	*0.70*	*0.13*	*0.20*
				GM	1.33	76.0	18.9	11.2	0.62	2.86	4.33	0.96
				Median	1.42	76.1	18.9	11.2	0.66	2.91	4.33	0.97
Vaygach Is., 1992	F	muscle	2	Mean	0.19	102	17.2	2.44	0.08	1.04	1.82	0.30
				SD	*0.01*	*1.0*	*0.6*	*0.67*	*0.05*	*0.79*	*0.25*	*0.00*
				GM	0.19	102	17.2	2.39	0.07	0.87	1.81	0.30
				Median	0.19	102	17.2	2.44	0.08	1.04	1.82	0.30

"n.d."- not determined

Table 1.12. Mean levels of trace elements (mg/kg dry wt) in tissues of Herring gull (Larus argentatus). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex age	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
						S-W Barents Sea						
Hornøya, 1991	juv	liver	2	Mean	0.09	84.7	15.2	n.d.	0.05	0.58	3.66	0.14
				SD	*0.06*	*2.8*	*3.0*		*0.01*	*0.28*	*0.52*	*0.00*
				GM	0.07	84.6	15.1	n.d.	0.05	0.54	3.64	0.14
				Median	0.09	84.7	15.2	n.d.	0.05	0.58	3.66	0.14
Hornøya, 1991	juv	muscle	2	Mean	0.10	132	17.7	n.d.	0.10	3.04	2.62	0.04*
				SD	*0.12*	*125*	*11.7*		*0.08*	*0.88*	*2.02*	
				GM	0.05	97.6	15.7	n.d.	0.08	2.97	2.20	0.04
				Median	0.10	132	17.7	n.d.	0.10	3.04	2.62	0.04
Hornøya, 1991	F+M	liver	4	Mean	2.18	163	16.4	n.d.	0.05	2.59	4.68	1.11
				SD	*0.27*	*101*	*1.9*		*0.02*	*1.32*	*1.20*	*0.67*
				GM	2.16	144	16.3	n.d.	0.05	2.32	4.57	0.95
				Median	2.11	130	15.9	n.d.	0.05	2.59	4.37	1.02
Hornøya, 1991	F+M	muscle	3	Mean	0.22	57.2	17.8	n.d.	0.05	0.98	1.32	0.24
				SD	*0.09*	*29.1*	*6.6*		*0.00*	*0.41*	*0.40*	*0.13*
				GM	0.20	52.7	17.0	n.d.	0.05	0.93	1.28	0.21
				Median	0.22	47.4	15.9	n.d.	0.05	0.77	1.42	0.26
Ainov Is., 1992	juv	liver	2	Mean	0.15	213	16.7	11.3	0.10	0.43	2.99	0.18
				SD	*0.10*	*185*	*2.4*	*0.14*	*0.04*	*0.02*	*1.35*	*0.11*
				GM	0.13	169	16.6	11.3	0.10	0.43	2.83	0.16
				Median	0.15	213	16.7	11.3	0.10	0.43	2.99	0.18
Ainov Is., 1992	juv	muscle	2	Mean	0.02	64.1	12.3	1.34	0.12	0.45	1.45	0.08
				SD	*0.00*	*12.9*	*6.2*	*0.22*	*0.03*	*0.04*	*1.03*	*0.06*
				GM	0.02	63.4	11.5	1.33	0.12	0.45	1.25	0.07
				Median	0.02	64.1	12.3	1.34	0.12	0.45	1.45	0.08
Ainov Is., 1992	M	liver	1		0.53	83.0	15.9	9.70	n.d.	0.98	7.03	0.42
Ainov Is., 1992	M	muscle	1		0.07	59.3	14.0	1.45	0.10	0.40	1.98	0.67
						Eastern Murman						
Guba Podpakhta, 1992	juv	liver	5	Mean	0.29	148	23.5	13.6	0.20	3.50	3.24	0.19
				SD	*0.09*	*46.4*	*12.6*	*3.44*	*0.10*	*1.16*	*0.64*	*0.05*
				GM	0.27	141	21.3	13.3	0.18	3.31	3.19	0.18
				Median	0.28	163	19.1	13.5	0.16	3.96	3.21	0.16
Guba Podpakhta, 1992	juv	muscle	5	Mean	0.08	69.6	9.2	1.61	0.14	4.36	1.29	0.10
				SD	*0.03*	*6.6*	*3.1*	*0.43*	*0.04*	*0.95*	*0.18*	*0.03*
				GM	0.08	69.3	8.8	1.56	0.13	4.27	1.28	0.10
				Median	0.07	68.7	8.2	1.65	0.13	4.58	1.38	0.09
						S-E Norwegian Sea, Troms						
Hillesøy, May , 1992	adult	liver	2	Mean	1.67	113	16.9	13.9	0.10	2.20	5.69	0.88
				SD	*0.04*	*12.0*	*1.2*	*0.98*	*0.01*	*0.34*	*2.87*	*0.18*
				GM	1.67	113	16.9	13.9	0.10	2.19	5.32	0.87
				Median	1.67	113	16.9	13.9	0.10	2.20	5.69	0.88
Hillesøy, May , 1992	adult	muscle	2	Mean	0.13	63.6	14.2	1.89	0.13	1.05	2.54	0.35
				SD	*0.01*	*11.6*	*1.1*	*0.16*	*0.02*	*0.74*	*1.44*	*0.14*
				GM	0.13	63.0	14.2	1.89	0.13	0.91	2.33	0.33
				Median	0.13	63.6	14.2	1.89	0.13	1.05	2.54	0.35
Hillesøy, August, 1992	juv	liver	5	Mean	0.29	125	24.0	17.2	0.14	2.90	3.40	0.15
				SD	*0.12*	*22.3*	*10.9*	*2.50*	*0.04*	*2.20*	*0.40*	*0.07*
				GM	0.27	124	22.5	17.1	0.14	2.42	3.41	0.13
				Median	0.29	127	19.4	16.7	0.14	1.90	3.34	0.13
Hillesøy, August, 1992	juv	muscle	5	Mean	0.02	55.0	12.0	1.30	0.11	2.30	1.10	0.04
				SD	*0.00*	*5.4*	*2.1*	*0.20*	*0.01*	*0.80*	*0.10*	*0.02*
				GM	0.02	54.7	11.8	1.26	0.11	2.22	1.06	0.04
				Median	0.02	56.0	13.2	1.25	0.11	1.91	1.09	0.04

"n.d."- not determined, * N = 1

Table 1.13. Mean levels of trace elements (mg/kg dry wt) in Kittiwake (Rissa tridactyla). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					S-W Barents Sea							
Hornøya, 1991	F+M	liver	5	Mean	27.8	99.6	25.3	n.d.	0.06	1.83	22.4	0.80
				SD	*13.3*	*11.5*	*7.6*		*0.00*	*0.42*	*9.83*	*0.31*
				GM	25.9	99.0	24.4	n.d.	0.06	1.80	20.5	0.75
				Median	24.4	105	22.9	n.d.	0.06	1.60	25.9	0.90
Hornøya, 1991	F+M	muscle	5	Mean	1.06	43.6	19.5	n.d.	0.10	0.93	5.92	0.20
				SD	*0.49*	*8.9*	*2.1*		*0.11*	*0.90*	*1.54*	*0.07*
				GM	0.97	42.8	19.4	n.d.	0.07	0.68	5.73	0.20
				Median	0.97	41.7	18.7	n.d.	0.05	0.65	6.12	0.18
					Svalbard Archipelago							
Bjørnøya., 1991	F+M	liver	4	Mean	16.2	88.6	18.2	n.d.	0.15	0.82	14.3	0.58
				SD	*5.89*	*10.7*	*2.8*		*0.19*	*0.26*	*4.97*	*0.08*
				GM	15.3	88.2	18.0	n.d.	0.09	0.79	13.5	0.57
				Median	16.5	84.6	17.7	n.d.	0.06	0.82	15.7	0.56
Bjørnøya., 1991	F+M	muscle	4	Mean	1.48	63.3	21.2	n.d.	0.06	0.65	3.87	0.19
				SD	*0.95*	*11.1*	*1.0*		*0.03*	*0.03*	*0.31*	*0.06*
				GM	1.16	62.5	21.2	n.d.	0.05	0.64	3.86	0.19
				Median	1.55	65.0	21.6	n.d.	0.05	0.64	3.79	0.18
Ny-Ålesund, 1991	F+M	liver	5	Mean	48.0	126	25.1	n.d.	0.05	3.12	15.1	1.95
				SD	*18.6*	*16.8*	*3.2*		*0.00*	*1.18*	*4.17*	*0.44*
				GM	45.0	125	25.0	n.d.	0.05	2.96	14.6	1.90
				Median	41.9	127	26.0	n.d.	0.05	2.59	14.9	2.02
Ny-Ålesund, 1991	F+M	muscle	5	Mean	1.93	49.1	23.7	n.d.	0.07	1.01	5.94	0.43
				SD	*1.23*	*6.2*	*3.6*		*0.03*	*0.52*	*1.21*	*0.13*
				GM	1.58	48.8	23.5	n.d.	0.06	0.92	5.84	0.41
				Median	2.16	48.6	22.6	n.d.	0.07	0.83	6.36	0.36
					Franz Josef Land Archipelago							
Hooker Is., 1991	juv	liver	3	Mean	4.16	88.5	24.1	n.d.	0.05	13.9	4.83	0.35
				SD	*3.66*	*9.8*	*0.8*		*0.00*	*2.11*	*1.53*	*0.21*
				GM	2.39	88.2	24.1	n.d.	0.05	13.8	4.65	0.30
				Median	4.33	86.5	24.5	n.d.	0.05	13.8	5.25	0.43
Hooker Is., 1991	juv	muscle	3	Mean	0.22	62.9	20.1	n.d.	0.06	6.91	1.12	0.05
				SD	*0.27*	*6.0*	*1.3*		*0.03*	*1.13*	*0.64*	*0.03*
				GM	0.10	62.7	20.1	n.d.	0.05	6.85	1.01	0.04
				Median	0.12	60.2	20.7	n.d.	0.04	6.64	0.80	0.03
Hooker Is., 1991	F+M	liver	2	Mean	18.5	90.5	23.9	n.d.	0.05	24.4	8.59	0.69
				SD	*2.45*	*6.6*	*1.2*		*0.00*	*8.51*	*1.15*	*0.04*
				GM	18.4	90.3	23.9	n.d.	0.04	23.7	8.55	0.69
				Median	18.5	90.5	23.9	n.d.	0.05	24.4	8.59	0.69
Hooker Is., 1991	F+M	muscle	2	Mean	0.72	53.5	17.9	n.d.	0.05	7.00	1.76	0.11
				SD	*0.98*	*12.0*	*0.6*		*0.00*	*0.83*	*1.47*	*0.08*
				GM	0.18	52.8	17.9	n.d.	0.04	6.98	1.42	0.09
				Median	0.72	53.5	17.9	n.d.	0.05	7.00	1.76	0.11
George Land, 1992	F+M	liver	2	Mean	45.1	119	25.7	13.4	0.12	9.05	13.1	0.79
				SD	*32.7*	*13.2*	*6.6*	*4.00*	*0.02*	*3.39*	*3.16*	*0.06*
				GM	38.7	118	25.3	13.1	0.12	8.73	12.9	0.79
				Median	45.1	119	25.7	13.4	0.12	9.05	13.1	0.79
George Land, 1992	F+M	muscle	2	Mean	1.98	51.5	18.5	1.91	0.09	4.08	5.30	0.21
				SD	*0.33*	*10.6*	*0.4*	*0.15*	*0.02*	*3.22*	*0.87*	*0.06*
				GM	1.97	51.0	18.5	1.91	0.09	3.38	5.26	0.21
				Median	1.98	51.5	18.5	1.91	0.09	4.08	5.30	0.21
Northbrook, 1992	F+M	liver	2	Mean	18.1	133	22.1	11.2	0.11	3.71	14.0	0.64
				SD	*5.25*	*10.2*	*0.4*	*0.09*	*0.02*	*0.10*	*2.21*	*0.18*
				GM	17.7	133	22.1	11.2	0.10	3.71	13.9	0.62
				Median	18.1	133	22.1	11.2	0.11	3.71	14.0	0.64

Table 1.13. (Continued).

Area, year	Sex	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
Northbrook, 1992	F+M	muscle	3	Mean	1.23	56.8	18.7	1.97	0.07	1.56	6.49	0.18
				SD	*0.56*	*16.1*	*1.6*	*0.15*	*0.00*	*0.61*	*2.02*	*0.06*
				GM	1.15	55.3	18.7	1.96	0.07	1.48	6.29	0.17
				Median	1.07	55.7	19.4	1.89	0.07	1.42	5.78	0.15
Stolichky Is., 1992	F	liver	2	Mean	37.0	122	23.1	12.0	0.13	5.10	7.65	0.55
				SD	*34.6*	*6.2*	*2.1*	*3.11*	*0.03*	*5.14*	*4.26*	*0.06*
				GM	27.8	121	23.1	11.8	0.13	3.58	7.03	0.55
				Median	37.0	122	23.1	12.0	0.13	5.10	7.65	0.55
Stolichky Is., 1992	F	muscle	2	Mean	1.68	52.4	19.7	2.01	0.13	1.43	5.45	0.16
				SD	*1.10*	*4.9*	*1.3*	*0.02*	*0.00*	*1.27*	*0.84*	*0.04*
				GM	1.49	52.3	19.7	2.01	0.13	1.11	5.42	0.16
				Median	1.68	52.4	19.7	2.01	0.13	1.43	5.45	0.16
Kuhn Is., 1992	F+M	liver	3	Mean	25.7	111	23.3	11.2	0.13	6.92	9.36	0.45
				SD	*11.6*	*17.5*	*3.4*	*2.50*	*0.02*	*4.84*	*1.76*	*0.05*
				GM	24.1	110	23.1	11.0	0.13	5.35	9.26	0.44
				Median	23.0	118	21.4	11.5	0.14	7.58	8.37	0.45
Kuhn Is., 1992	F+M	muscle	3	Mean	1.31	43.2	21.1	1.97	0.25	3.78	4.43	0.15
				SD	*0.17*	*5.7*	*2.2*	*0.54*	*0.11*	*2.70*	*0.47*	*0.05*
				GM	1.31	43.0	21.0	1.93	0.23	2.68	4.41	0.15
				Median	1.29	45.9	20.2	1.74	0.25	4.96	4.47	0.15
				Pechora Sea, Novaya Zemlya Archipelago								
Chernaya Bay, 1992	F+M	liver	5	Mean	8.14	92.4	22.7	15.2	0.31	98.1	13.7	1.44
				SD	*12.3*	*7.4*	*3.4*	*3.16*	*0.27*	*69.0*	*9.84*	*0.29*
				GM	3.95	92.2	22.4	14.9	0.22	79.2	11.8	1.42
				Median	3.73	95.0	23.0	15.7	0.13	62.4	9.80	1.39
Chernaya Bay, 1992	F+M	muscle	5	Mean	0.80	47.1	19.3	1.99	0.09	26.4	5.76	0.50
				SD	*0.50*	*12.2*	*1.7*	*0.14*	*0.02*	*23.2*	*3.61*	*0.07*
				GM	0.71	45.9	19.3	1.99	0.08	18.6	5.11	0.49
				Median	0.60	41.9	19.0	2.02	0.08	12.8	4.30	0.46
				Pechora Sea								
Vaygach Is., 1992	F+M	liver	6	Mean	11.0	82.8	20.4	11.7	0.14	1.65	9.10	0.66
				SD	*11.9*	*8.5*	*1.5*	*1.61*	*0.02*	*1.06*	*1.80*	*0.37*
				GM	4.17	82.4	20.4	11.6	0.14	1.42	8.97	0.77
				Median	8.55	80.8	20.8	11.2	0.14	1.29	8.47	0.81
Vaygach Is., 1992	F+M	muscle	6	Mean	0.42	52.2	19.3	1.86	0.10	0.49	4.78	0.28
				SD	*0.32*	*6.3*	*1.9*	*0.29*	*0.03*	*0.06*	*1.05*	*0.07*
				GM	0.31	51.8	19.2	1.84	0.10	0.49	4.69	0.27
				Median	0.43	54.3	20.2	1.89	0.10	0.50	4.50	0.27
				Seven Islands Archipelago								
Kharlov Is., 1992	F+M	liver	5	Mean	22.3	94.9	23.1	13.8	0.11	2.10	17.7	0.98
				SD	*16.8*	*10.4*	*2.2*	*1.31*	*0.02*	*1.64*	*6.72*	*0.14*
				GM	14.1	94.5	23.0	13.7	0.11	1.65	16.9	0.97
				Median	23.6	90.3	22.9	13.8	0.11	1.66	15.5	0.96
Kharlov Is., 1992	F+M	muscle	5	Mean	2.48	56.5	18.1	2.09	0.15	0.76	8.83	0.29
				SD	*1.74*	*16.2*	*1.6*	*0.50*	*0.14*	*0.15*	*1.28*	*0.08*
				GM	1.98	54.7	18.0	2.03	0.12	0.75	8.75	0.28
				Median	2.20	48.9	18.0	2.15	0.08	0.71	9.39	0.29

"n.d."- not determined

Table 1.14. Mean levels of trace elements (mg/kg dry wt) in tissues of Fulmar (Fulmarus glacialis). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
						Svalbard Archipelago						
Bjørnøya., 1991	F+M	liver	5	Mean	36.6	142	18.4	n.d.	0.06	2.86	10.2	1.95
				SD	*19.3*	*18.8*	*2.4*		*0.00*	*2.24*	*1.22*	*1.29*
				GM	31.3	141	18.3	n.d.	0.06	2.25	10.1	1.66
				Median	42.4	132	17.9	n.d.	0.06	1.70	9.91	1.20
Bjørnøya., 1991	F	muscle	4	Mean	5.10	56.0	19.8	n.d.	0.07	1.10	2.63	0.23
				SD	*5.25*	*16.7*	*2.1*		*0.03*	*0.89*	*0.61*	*0.06*
				GM	3.04	54.1	19.8	n.d.	0.07	0.75	2.58	0.23
				Median	3.70	55.9	19.1	n.d.	0.08	1.07	2.57	0.24
Ny Ålesund, 1991	F+M	liver	5	Mean	109	268	22.1	n.d.	0.04	3.73	18.8	5.72
				SD	*61.1*	*87.0*	*2.8*		*0.01*	*2.6*[illegible]	*3.69*	*0.83*
				GM	94.2	258	22.0	n.d.	0.04	3.11	18.5	5.67
				Median	122	232	23.3	n.d.	0.04	2.38	19.0	5.71
Ny Ålesund, 1991	F+M	muscle	5	Mean	8.71	69.3	22.0	n.d.	0.05	4.83	8.60	0.72
				SD	*5.69*	*8.1*	*2.8*		*0.00*	*3.47*	*2.90*	*0.26*
				GM	6.88	68.9	21.9	n.d.	0.05	3.99	8.24	0.68
				Median	8.96	66.5	20.5	n.d.	0.05	2.72	7.59	0.79
						Franz Josef Land Archipelago						
S-W part, 1992	F+M	liver	5	Mean	16.4	144	18.5	16.1	0.15	10.2	16.6	2.01
				SD	*17.8*	*23.7*	*1.9*	*1.76*	*0.03*	*4.72*	*5.72*	*1.42*
				GM	15.4	143	18.5	16.1	0.15	9.23	15.8	1.61
				Median	8.84	148	17.6	15.5	0.14	9.77	14.9	1.92
S-W part, 1992	F+M	muscle	5	Mean	1.82	46.0	17.0	2.29	0.16	4.21	3.11	0.13
				SD	*0.68*	*2.2*	*1.1*	*0.24*	*0.03*	*1.37*	*0.82*	*0.06*
				GM	1.69	46.0	17.0	2.28	0.15	4.03	3.02	0.12
				Median	1.82	46.8	17.3	2.29	0.15	4.27	3.17	0.15

"n.d."- not determined

Table 1.15. Mean levels of trace elements (mg/kg dry wt) in Arctic tern (Sterna paradisaea). Mean - arithmetic mean, SD - standard deviation, GM -geometric mean, N - number of samples.

Area, year	Sex	Tissue	N		Cd	Zn	Cu	Mn	Cr	As	Se	Hg
						Franz Josef Land Archipelago						
Etheridge Is., 1992	F+M	liver	5	Mean	16.3	130	28.4	16.6	0.11	5.72	7.34	1.08
				SD	*4.70*	*14.9*	*3.0*	*2.55*	*0.00*	*2.16*	*0.67*	*0.21*
				GM	15.7	129	28.3	16.4	0.11	5.31	7.32	1.07
				Median	15.9	132	27.1	17.0	0.11	6.82	6.94	1.11
Etheridge Is., 1992	F+M	muscle	5	Mean	0.94	59.2	23.1	2.99	0.15	1.45	2.67	0.28
				SD	*0.41*	*37.0*	*4.0*	*0.30*	*0.04*	*0.49*	*0.39*	*0.06*
				GM	0.85	52.7	22.8	2.98	0.15	1.38	2.64	0.27
				Median	0.95	47.0	21.6	2.88	0.13	1.43	2.64	0.28

*Table 1.16. Levels of trace elements (mg/kg dry wt.) in Cormorant (*Phalacrocorex aristotelis*). N - number of samples*

Area, year	Sex	Tissue	N	Cd	Zn	Cu	Mn	Cr	As	Se	Hg
					S-E Norwegian Sea, Troms						
Sommarøy, 1992	M	liver	1	0.39	90.6	26.6	11.5	0.20	0.58	9.72	4.58
Sommarøy, 1992	M	muscle	1	0.03	53.6	19.1	2.2	0.12	1.04	3.03	1.58

Appendix 2. Geographical differences

Table 2.1. Trace elements in liver of Brünnich's guillemot from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation. N - number of samples.

Element	Area	N	Mean mg/g d.w.	SD	Groups 1	2	3
Cd	Kharlov Island	5	2.55	1.93	|		
	Guba Chernaya	5	3.98	1.00	|	|	
	Hornøya	5	5.80	1.98	|	|	
	Bjørnøya	5	6.51	2.56		|	
	Ny-Ålesund	5	14.9	6.16			|
	Franz Josef Land	5	15.4	5.34			|
Zn	Kharlov Island	5	69.3	1.77	|		
	Hornøya	5	91.2	14.9		|	
	Ny-Ålesund	5	91.5	30.5		|	
	Bjørnøya	5	99.0	10.3		|	
	Guba Chernaya	5	106	34.5		|	
	Franz Josef Land	5	122	11.9		|	
Cu	Kharlov Island	5	16.0	2.10	|		
	Ny-Ålesund	5	16.1	5.76	|	|	
	Hornøya	5	16.9	2.88	|	|	
	Bjørnøya	5	18.0	2.02	|	|	
	Franz Josef Land	5	23.0	2.31		|	
	Guba Chernaya	5	24.9	11.6		|	
Mn	Kharlov Island	5	8.59	0.950	|		
	Guba Chernaya	5	9.95	1.56	|	|	
	Franz Josef Land	5	11.2	0.950		|	
Cr	Bjørnøya	5	0.040	0.000	|		
	Ny-Ålesund	5	0.050	0.010	|		
	Hornøya	5	0.050	0.020	|		
	Franz Josef Land	5	0.160	0.120		|	
	Guba Chernaya	5	0.160	0.020		|	
	Kharlov Island	5	0.340	0.280		|	
As	Kharlov Island	5	1.48	0.720	|		
	Hornøya	5	1.86	0.250	|		
	Bjørnøya	5	3.18	0.830		|	
	Franz Josef Land	5	3.66	1.860		|	
	Ny-Ålesund	5	4.61	2.650		|	
	Guba Chernaya	5	96.4	70.9			|
Se	Bjørnøya	5	4.27	0.570	|		
	Ny-Ålesund	5	5.49	1.89	|		
	Franz Josef Land	5	6.19	4.06	|		
	Guba Chernaya	5	6.27	0.900	|		
	Hornøya	5	7.53	2.01	|		
	Kharlov Island	5	13.9	4.06		|	
Hg	Bjørnøya	5	0.330	0.120	|		
	Guba Chernaya	5	0.790	0.110		|	
	Franz Josef Land	5	0.800	0.420		|	
	Hornøya	5	0.880	0.170		|	
	Kharlov Island	5	0.930	0.070		|	
	Ny-Ålesund	5	1.61	0.420			|

Table 2.2. Trace elements in muscle of Brünnich's guillemot from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation. N - number of samples.

Element	Area	N	Mean mg/g d.w.	SD	Groups 1	2	3	4
Cd	Hornøya	4	0.570	0.390	│			
	Kharlov Island	5	0.600	0.360	│			
	Bjørnøya	5	0.610	0.220	│			
	Guba Chernaya	5	0.870	0.430	│			
	Franz Josef Land	5	1.05	0.620	│			
	Ny-Ålesund	5	1.23	0.290	│			
Zn	Hornøya	4	39.9	5.21	│			
	Ny-Ålesund	5	40.7	3.21	│			
	Kharlov Island	5	42.4	6.67	│	│		
	Bjørnøya	5	47.2	2.24	│	│		
	Franz Josef Land	5	48.2	2.12		│		
	Guba Chernaya	5	59.9	38.9		│		
Cu	Kharlov Island	5	13.8	1.91	│			
	Guba Chernaya	5	14.6	3.20	│	│		
	Bjørnøya	5	17.7	2.33	│	│		
	Franz Josef Land	5	18.6	3.74	│	│		
	Hornøya	4	19.8	2.24		│		
	Ny-Ålesund	5	23.1	1.79			│	
Mn	Franz Josef Land	5	1.92	0.260	│			
	Guba Chernaya	5	2.16	0.420	│			
	Kharlov Island	5	2.30	0.440	│			
Cr	Ny-Ålesund	5	0.050	0.010	│			
	Hornøya	4	0.050	0.010	│			
	Bjørnøya	5	0.060	0.030	│	│		
	Kharlov Island	5	0.090	0.020		│		
	Franz Josef Land	5	0.130	0.040			│	
	Guba Chernaya	5	0.180	0.080			│	
As	Hornøya	4	0.170	0.060	│			
	Kharlov Island	5	0.610	0.130		│		
	Ny-Ålesund	5	0.790	0.610		│		
	Bjørnøya	5	1.09	0.480		│		
	Franz Josef Land	5	1.41	1.20		│		
	Guba Chernaya	5	46.7	28.0			│	
Se	Bjørnøya	5	1.74	0.280	│			
	Franz Josef Land	5	2.58	0.380		│		
	Ny-Ålesund	5	3.36	0.810		│	│	
	Hornøya	4	3.88	0.980		│	│	
	Guba Chernaya	5	4.63	0.830			│	
	Kharlov Island	5	8.02	2.08				│
Hg	Bjørnøya	5	0.150	0.080	│			
	Hornøya	4	0.320	0.070		│		
	Franz Josef Land	5	0.320	0.160		│		
	Kharlov Island	5	0.370	0.070		│	│	
	Guba Chernaya	5	0.430	0.180		│	│	
	Ny-Ålesund	5	0.600	0.090			│	

Table 2.3. Trace elements in liver of Puffin from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test (α = 0.05). Arithmetic mean and standard deviation. N - number of samples.

Element	Area	N	Mean mg/g d.w.	SD	Groups 1	Groups 2
Cd	Hornøya	5	2.60	1.00	│	
	Kuvshin Island	4	2.68	1.30	│	
	Kharlov Island	3	3.22	1.35	│	│
	Sommarøy	5	6.87	5.02		│
	Ny-Ålesund	5	9.77	3.21		│
Zn	Hornøya	5	84.6	11.8	│	
	Kuvshin Island	4	90.8	7.00	│	
	Kharlov Island	3	96.6	5.63	│	
	Ny-Ålesund	5	100	6.72	│	
	Sommarøy	5	189	17.5		│
Cu	Hornøya	5	17.6	2.58	│	
	Kuvshin Island	4	19.4	1.49	│	
	Ny-Ålesund	5	19.5	1.68	│	
	Kharlov Island	3	21.1	1.61	│	
	Sommarøy	3	52.9	10.3		│
Mn	Kuvshin Island	5	15.0	0.76	│	
	Kharlov Island	3	16.8	1.40	│	
	Sommarøy	4	23.0	1.82		│
Cr	Hornøya	5	0.06	0.01	│	
	Ny-Ålesund	5	0.08	0.08	│	
	Kharlov Island	3	0.14	0.03	│	
	Sommarøy	5	0.29	0.07		│
	Kuvshin Island	4	0.50	0.60		│
As	Hornøya	5	0.79	0.56	│	
	Kharlov Island	5	0.79	0.30	│	
	Kuvshin Island	4	1.04	0.47	│	
	Ny-Ålesund	3	1.36	0.61	│	
	Sommarøy	5	16.9	4.89		│
Se	Hornøya	5	9.18	1.68	│	
	Ny-Ålesund	5	11.9	3.48	│	
	Kuvshin Island	4	14.0	2.25	│	
	Sommarøy	3	21.3	3.47		│
	Kharlov Island	5	27.1	3.95		│
Hg	Ny-Ålesund	5	1.12	0.32	│	
	Kuvshin Island	5	1.17	0.23	│	
	Hornøya	3	1.22	0.35	│	
	Kharlov Island	5	1.37	0.12	│	
	Sommarøy	4	1.60	0.36	│	

Table 2.4. Trace elements in muscle of Puffin. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation. N - number of samples.

Element	Area	N	Mean mg/g d.w.	SD	Groups 1	Groups 2	Groups 3
Cd	Kharlov Island	3	0.25	0.04	│		
	Hornøya	5	0.29	0.10	│		
	Kuvshin Island	4	0.32	0.14	│		
	Sommarøy	5	0.39	0.28	│		
	Ny-Ålesund	5	0.77	0.42	│		
Zn	Hornøya	5	40.6	2.97	│		
	Ny-Ålesund	5	43.3	4.61	│		
	Kuvshin Island	4	43.4	3.31	│		
	Kharlov Island	3	44.7	5.67	│		
	Sommarøy	5	67.4	5.23		│	
Cu	Kuvshin Island	4	14.8	3.50	│		
	Kharlov Island	3	17.0	4.08	│		
	Hornøya	5	19.2	2.03	│		
	Ny-Ålesund	5	20.2	1.65	│		
	Sommarøy	5	29.2	4.40		│	
Mn	Sommarøy	5	1.89	0.25	│		
	Kharlov Island	3	2.11	0.07	│		
	Kuvshin Island	4	2.26	0.92	│		
Cr	Hornøya	5	0.04	0.00	│		
	Ny-Ålesund	5	0.08	0.05	│	│	
	Kharlov Island	3	0.08	0.01	│	│	
	Sommarøy	5	0.15	0.04		│	│
	Kuvshin Island	4	0.49	0.67			│
As	Hornøya	5	0.20	0.12	│		
	Ny-Ålesund	5	0.21	0.08	│		
	Kuvshin Island	4	0.47	0.02		│	
	Kharlov Island	3	0.52	0.09		│	
	Sommarøy	5	6.95	2.82			│
Se	Hornøya	5	5.32	1.50	│		
	Ny-Ålesund	5	9.87	2.12		│	
	Kuvshin Island	4	10.5	1.38		│	
	Kharlov Island	3	15.5	2.95		│	│
	Sommarøy	5	24.8	14.8			│
Hg	Hornøya	5	0.31	0.15	│		
	Ny-Ålesund	5	0.40	0.17	│		
	Kharlov Island	3	0.44	0.10	│		
	Sommarøy	5	0.45	0.10	│		
	Kuvshin Island	4	0.46	0.09	│		

Table 2.5. Trace elements in liver of Glaucous gull from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation. N - number of samples.

Element	Area	N	Mean mg/g d.w.	SD	Groups 1	2	3	4
Cd	Kolguyev Island	5	1.21	0.46	x			
	Vaygach Island	2	1.42	0.73	x	x		
	Guba Chernaya	3	2.54	1.59	x	x		
	Franz Josef Land	6	5.35	4.16	x	x		
	Bjørnøya	5	6.06	3.57		x		
	Ny-Ålesund	4	10.3	8.51		x		
Zn	Vaygach Island	3	76.1	4.66	x			
	Guba Chernaya	5	84.8	5.17	x			
	Kolguyev Island	6	87.2	12.3	x			
	Franz Josef Land	4	87.3	8.14	x			
	Ny-Ålesund	5	107	29.0	x			
	Bjørnøya		111	37.9	x			
Cu	Franz Josef Land	6	17.6	1.91	x			
	Kolguyev Island	5	18.6	1.11	x			
	Vaygach Island	2	18.9	0.01	x			
	Guba Chernaya	3	19.3	0.94	x			
	Bjørnøya	5	19.7	2.91	x			
	Ny-Ålesund	4	24.1	3.41	x			
Mn	Vaygach Island	3	11.2	0.01	x			
	Guba Chernaya	5	13.4	1.10	x			
	Kolguyev Island	6	13.7	2.69	x			
	Franz Josef Land		14.0	2.02	x			
Cr	Bjørnøya	5	0.05	0.01	x			
	Ny-Ålesund	4	0.06	0.03	x			
	Franz Josef Land	6	0.14	0.03		x		
	Guba Chernaya	3	0.15	0.02		x		
	Kolguyev Island	4	0.24	0.22		x		
	Vaygach Island	2	0.66	0.31		x		
As	Ny-Ålesund	4	1.98	1.61	x			
	Vaygach Island	2	2.91	0.70	x	x		
	Kolguyev Island	5	3.59	1.79	x	x		
	Franz Josef Land	6	9.01	5.51		x	x	
	Bjørnøya	5	12.8	4.33			x	
	Guba Chernaya	3	76.8	8.27				x
Se	Vaygach Island	2	4.33	0.13	x			
	Bjørnøya	5	5.25	0.66	x			
	Ny-Ålesund	4	5.44	2.18	x			
	Kolguyev Island	5	6.00	0.96	x			
	Guba Chernaya	3	6.20	1.55	x			
	Franz Josef Land	6	10.1	9.43	x			
Hg	Vaygach Island	2	0.97	0.20	x			
	Bjørnøya	5	1.02	0.57	x			
	Franz Josef Land	6	1.10	0.63	x			
	Kolguyev Island	5	1.21	0.57	x			
	Guba Chernaya	3	1.38	0.54	x			
	Ny-Ålesund	4	1.54	1.10	x			

Table 2.6. Trace elements in muscle of Glaucous gull from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation. N - number of samples.

Element	Area	N	Mean mg/g d.w.	SD	Groups 1	Groups 2	Groups 3
Cd	Kolguyev Island	5	0.16	0.09	│		
	Vaygach Island	2	0.19	0.01	│		
	Guba Chernaya	3	0.23	0.08	│		
	Franz Josef Land	6	0.31	0.28	│		
	Bjørnøya	5	0.45	0.15	│		
	Ny-Ålesund	4	0.66	0.66	│		
Zn	Bjørnøya	5	50.6	5.12	│		
	Ny-Ålesund	4	65.3	16.9	│	│	
	Kolguyev Island	5	68.5	20.6	│	│	
	Franz Josef Land	6	70.4	16.1	│	│	
	Guba Chernaya	3	76.0	8.48	│	│	
	Vaygach Island	2	102	0.98		│	
Cu	Franz Josef Land	6	14.6	0.78	│		
	Guba Chernaya	3	14.9	1.14	│	│	
	Kolguyev Island	5	15.6	3.16	│	│	
	Vaygach Island	2	17.2	0.56	│	│	│
	Bjørnøya	5	20.2	2.80		│	│
	Ny-Ålesund	4	21.9	2.60			│
Mn	Franz Josef Land	6	1.75	0.36	│		
	Guba Chernaya	3	1.81	0.21	│		
	Kolguyev Island	5	1.88	0.33	│		
	Vaygach Island	2	2.44	0.67	│		
Cr	Bjørnøya	5	0.04	0.00	│		
	Ny-Ålesund	4	0.05	0.01	│	│	
	Vaygach Island	2	0.08	0.05	│	│	
	Guba Chernaya	3	0.08	0.00	│	│	
	Franz Josef Land	6	0.08	0.02		│	
	Kolguyev Island	5	0.10	0.05		│	
As	Ny-Ålesund	4	0.80	0.59	│		
	Vaygach Island	2	1.04	0.79	│		
	Kolguyev Island	5	1.16	0.78	│		
	Franz Josef Land	6	2.07	1.05	│	│	
	Bjørnøya	5	3.92	1.98		│	
	Guba Chernaya	3	28.4	9.25			│
Se	Bjørnøya	5	1.41	0.14	│		
	Vaygach Island	2	1.82	0.25	│	│	
	Guba Chernaya	3	2.18	0.53		│	
	Ny-Ålesund	4	2.52	1.94		│	
	Kolguyev Island	5	2.52	0.48		│	
	Franz Josef Land	6	2.85	2.71		│	
Hg	Bjørnøya	5	0.29	0.15	│		
	Vaygach Island	2	0.30	0.01	│		
	Kolguyev Island	5	0.42	0.21	│		
	Franz Josef Land	6	0.45	0.37	│		
	Guba Chernaya	3	0.50	0.16	│		
	Ny-Ålesund	4	0.73	0.56	│		

Table 2.7. Trace elements in liver of Kittiwakes from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation. N - number of samples.

Element	Area	N	Mean mg/g d.w.	SD	Groups 1	2	3	4
Cd	Guba Chernaya	5	8.14	12.3	|			
	Vaygach Island	6	11.0	11.9	|			
	Bjørnøya	4	16.2	5.89	|	|		
	Kharlov Island	5	22.3	16.8	|	|		
	Hornøya	5	27.8	13.3	|	|		
	Franz Josef Land	11	28.6	19.3	|	|		
	Ny-Ålesund	5	48.0	18.6		|		
Zn	Vaygach Island	6	82.8	8.53	|			
	Bjørnøya	4	88.6	10.6	|			
	Guba Chernaya	5	92.4	7.40	|			
	Kharlov Island	5	94.9	10.4	|			
	Hornøya	5	99.6	11.5	|	|		
	Franz Josef Land	11	114	17.3		|		
	Ny-Ålesund	5	126	16.8		|		
Cu	Bjørnøya	4	18.2	2.84	|			
	Vaygach Island	6	20.4	1.54	|	|		
	Guba Chernaya	5	22.7	3.42	|	|		
	Kharlov Island	5	23.1	2.17	|	|		
	Franz Josef Land	11	23.6	2.95		|		
	Ny-Ålesund	5	25.1	3.19		|		
	Hornøya	5	25.3	7.63		|		
Mn	Vaygach Island	6	11.7	1.61	|			
	Franz Josef Land	9	11.8	2.38	|			
	Kharlov Island	5	13.8	1.31	|			
	Guba Chernaya	5	15.2	3.16	|			
Cr	Ny-Ålesund	5	0.05	0.01	|			
	Hornøya	5	0.06	0.01	|			
	Franz Josef Land	11	0.11	0.04		|		
	Kharlov Island	5	0.11	0.02		|		
	Vaygach Island	6	0.14	0.02		|		
	Bjørnøya	4	0.15	0.19		|		
	Guba Chernaya	6	0.31	0.27		|		
As	Bjørnøya	4	0.82	0.26	|			
	Vaygach Island	6	1.65	1.06	|	|		
	Hornøya	3	1.83	0.42	|	|		
	Kharlov Island	5	2.10	1.64	|	|		
	Ny-Ålesund	5	3.12	1.18		|	|	
	Franz Josef Land	11	9.58	8.54			|	
	Guba Chernaya	5	98.1	69.0				|
Se	Vaygach Island	6	9.10	1.80	|			
	Franz Josef Land	11	10.4	3.26	|	|		
	Guba Chernaya	5	13.7	9.84	|	|	|	
	Bjørnøya	4	14.3	4.97	|	|	|	
	Ny-Ålesund	5	15.1	4.17	|	|	|	
	Kharlov Island	5	17.7	6.72		|	|	
	Hornøya	5	22.4	9.83			|	
Hg	Bjørnøya	4	0.58	0.08	|			
	Franz Josef Land	11	0.61	0.15	|			
	Vaygach Island	6	0.66	0.37	|	|		
	Hornøya	5	0.80	0.31	|	|		
	Kharlov Island	5	0.98	0.14		|		
	Guba Chernaya	5	1.44	0.29			|	
	Ny-Ålesund	5	1.95	0.44			|	

Table 2.8. Trace elements in muscle of Kittiwakes from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation.

Element	Area	N	Mean mg/g d.w.	SD	Groups 1	2	3	4
Cd	Vaygach Island	6	0.42	0.32	│			
	Guba Chernaya	5	0.80	0.50	│	│		
	Hornøya	5	1.06	0.49	│	│		
	Franz Josef Land	12	1.37	0.66		│		
	Bjørnøya	4	1.48	0.95		│		
	Ny-Ålesund	5	1.93	1.23		│		
	Kharlov Island	5	2.48	1.74		│		
Zn	Hornøya	5	43.6	8.85	│			
	Guba Chernaya	5	47.1	12.2	│			
	Ny-Ålesund	5	49.1	6.20	│			
	Franz Josef Land	12	51.2	10.3	│			
	Vaygach Island	6	52.1	6.30	│			
	Kharlov Island	5	56.5	16.2	│			
	Bjørnøya	4	63.3	11.1	│			
Cu	Kharlov Island	5	18.1	1.59	│			
	Franz Josef Land	12	19.3	1.74	│			
	Vaygach Island	6	19.3	1.88	│			
	Guba Chernaya	5	19.3	1.70	│	│		
	Hornøya	5	19.4	2.07	│	│		
	Bjørnøya	4	21.2	1.02	│	│		
	Ny-Ålesund	5	23.7	3.56		│		
Mn	Vaygach Island	6	1.86	0.29	│			
	Franz Josef Land	10	1.97	0.27	│			
	Guba Chernaya	5	1.99	0.14	│			
	Kharlov Island	5	2.09	0.50	│			
Cr	Bjørnøya	5	0.06	0.03	│			
	Ny-Ålesund	4	0.07	0.03	│			
	Guba Chernaya	4	0.09	0.02	│			
	Hornøya	4	0.10	0.11	│			
	Vaygach Island	6	0.10	0.03	│			
	Franz Josef Land	12	0.12	0.09	│			
	Kharlov Island	5	0.15	0.14	│			
As	Vaygach Island	6	0.49	0.06	│			
	Bjørnøya	4	0.65	0.03		│		
	Kharlov Island	5	0.76	0.15		│		
	Hornøya	5	0.93	0.90		│		
	Ny-Ålesund	5	1.01	0.52		│	│	
	Franz Josef Land	12	3.42	2.58			│	
	Guba Chernaya	5	26.4	23.2				│
Se	Bjørnøya	4	3.87	0.31	│			
	Vaygach Island	6	4.78	1.05	│			
	Franz Josef Land	12	4.81	1.93	│			
	Guba Chernaya	5	5.76	3.61	│	│		
	Hornøya	5	5.92	1.54	│	│		
	Ny-Ålesund	5	5.94	1.21	│	│		
	Kharlov Island	5	8.83	1.28		│		
Hg	Franz Josef Land	12	0.16	0.06	│			
	Bjørnøya	4	0.19	0.06	│	│		
	Hornøya	5	0.20	0.07	│	│		
	Vaygach Island	6	0.28	0.07		│	│	
	Kharlov Island	5	0.29	0.08		│	│	
	Ny-Ålesund	5	0.43	0.13			│	│
	Guba Chernaya	5	0.50	0.07				│

Appendix 3. Inter-specific differences.

Table 3.1. Trace elements in liver of seabirds from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation.

Element	Species	Family	Mean mg/g d.w.	SD	Groups 1	2	3	4	5	6
Cd	Common guillemot	*Alcidae*	1.72	0.39	x					
	Herring gull	*Laridae*	2.01	0.34	x	x				
	Razorbill	*Alcidae*	2.08	0.65	x	x	x			
	Glaucous gull	*Laridae*	3.74	3.39	x	x	x			
	Little auk	*Alcidae*	4.24	2.26	x	x	x			
	Puffin	*Alcidae*	4.38	2.87		x	x			
	King eider	*Anatidae*	4.47	1.66			x	x		
	Black guillemot	*Alcidae*	5.01	1.02			x	x		
	Brünnich's guillemot	*Alcidae*	8.20	6.17				x		
	Common eider	*Anatidae*	14.5	5.77					x	
	Arctic tern	*Sternidae*	18.1	2.94					x	
	Kittiwake	*Laridae*	19.3	13.1					x	
	Fulmar	*Procellariidae*	40.4	31.5					x	
Zn	Common guillemot	*Alcidae*	84.7	9.5	x					
	Little auk	*Alcidae*	85.1	7.7	x					
	Glaucous gull	*Laridae*	87.2	10.9	x	x				
	Puffin	*Alcidae*	92.9	10.2	x	x	x			
	Black guillemot	*Alcidae*	93.6	2.5	x	x	x			
	Brünnich's guillemot	*Alcidae*	96.5	25.0	x	x	x			
	Kittiwake	*Laridae*	101	19.0		x	x			
	Razorbill	*Alcidae*	108	15.1			x	x		
	Herring gull	*Laridae*	109	24.5			x	x		
	Arctic tern	*Sternidae*	130	14.9				x	x	
	King eider	*Anatidae*	152	36.2					x	
	Fulmar	*Procellariidae*	158	34.6					x	
	Common eider	*Anatidae*	293	52.6						x
Cu	Herring gull	*Laridae*	16.5	1.5	x					
	Brünnich's guillemot	*Alcidae*	18.2	3.8	x	x				
	Glaucous gull	*Laridae*	18.7	1.8	x	x				
	Puffin	*Alcidae*	19.2	2.1	x	x	x			
	Fulmar	*Procellariidae*	19.7	2.9	x	x	x			
	Common guillemot	*Alcidae*	19.9	1.2	x	x	x			
	Black guillemot	*Alcidae*	21.1	2.0		x	x	x		
	Little auk	*Alcidae*	21.7	1.2			x	x		
	Kittiwake	*Laridae*	22.3	3.2				x		
	Razorbill	*Alcidae*	23.0	3.1				x		
	Arctic tern	*Sternidae*	28.4	3.0					x	
	King eider	*Anatidae*	84.9	80.6					x	
	Common eider	*Anatidae*	226	26.9						x
Mn	Little auk	*Alcidae*	7.1	3.5	x					
	Black guillemot	*Alcidae*	9.1	0.9	x					
	Brünnich's guillemot	*Alcidae*	9.9	1.5	x					
	Herring gull	*Laridae*	12.5	2.5	x	x				
	Kittiwake	*Laridae*	12.9	2.5		x				
	Common guillemot	*Alcidae*	13.1	1.6		x				
	Glaucous gull	*Laridae*	13.4	2.1		x				
	Razorbill	*Alcidae*	13.6	1.2		x	x			
	Fulmar	*Procellariidae*	16.1	1.8		x	x	x		
	Arctic tern	*Sternidae*	16.6	2.5			x	x		
	Puffin	*Alcidae*	18.8	4.0				x		
	King eider	*Anatidae*	19.6	4.1				x		

Table 3.1. (Continued).

Element	Species	Family	Mean (mg/g d.w.)	SD	Groups 1	2	3	4	5	6
Cr	Herring gull	*Laridae*	0.07	0.03	x					
	Fulmar	*Procellariidae*	0.08	0.05	x					
	Common eider	*Anatidae*	0.09	0.07	x					
	Brünnich's guillemot	*Alcidae*	0.09	0.05	x					
	Glaucous gull	*Laridae*	0.09	0.05	x					
	Kittiwake	*Laridae*	0.10	0.04	x					
	Little auk	*Alcidae*	0.10	0.03	x	x				
	Arctic tern	*Sternidae*	0.11	0.00	x	x				
	Black guillemot	*Alcidae*	0.12	0.02	x	x	x			
	Puffin	*Alcidae*	0.15	0.12	x	x	x			
	Razorbill	*Alcidae*	0.16	0.04	x	x	x			
	King eider	*Anatidae*	0.24	0.13		x	x			
	Common guillemot	*Alcidae*	0.24	0.14			x			
As	Common eider	*Anatidae*	0.22	0.18	x					
	Razorbill	*Alcidae*	0.81	0.00		x				
	Puffin	*Alcidae*	1.01	0.54		x				
	King eider	*Anatidae*	1.07	0.54		x				
	Common guillemot	*Alcidae*	1.18	0.47		x				
	Kittiwake	*Laridae*	2.22	1.51			x			
	Herring gull	*Laridae*	2.25	1.11			x	x		
	Brünnich's guillemot	*Alcidae*	3.14	2.03			x	x		
	Little auk	*Alcidae*	4.05	3.41			x	x		
	Fulmar	*Procellariidae*	4.15	2.80			x	x		
	Glaucous gull	*Laridae*	4.68	3.24				x		
	Arctic tern	*Sternidae*	5.72	2.16				x		
	Black guillemot	*Alcidae*	12.80	0.36					x	
Se	Little auk	*Alcidae*	3.97	1.21	x					
	Herring gull	*Laridae*	5.30	1.70	x	x				
	Glaucous gull	*Laridae*	5.48	1.35		x				
	Black guillemot	*Alcidae*	7.20	2.19		x				
	Brünnich's guillemot	*Alcidae*	7.28	3.99		x				
	Arctic tern	*Sternidae*	7.34	0.67		x				
	King eider	*Anatidae*	10.20	2.65			x			
	Common eider	*Anatidae*	10.86	2.35			x			
	Kittiwake	*Laridae*	11.73	3.69			x			
	Fulmar	*Procellariidae*	15.23	5.30			x	x		
	Puffin	*Alcidae*	15.88	6.89				x		
	Razorbill	*Alcidae*	18.54	8.86				x		
	Common guillemot	*Alcidae*	20.92	2.59				x		
Hg	Little auk	*Alcidae*	0.44	0.25	x					
	King eider	*Anatidae*	0.74	0.26	x	x				
	Herring gull	*Laridae*	0.78	0.33	x	x				
	Brünnich's guillemot	*Alcidae*	0.78	0.31		x				
	Black guillemot	*Alcidae*	0.85	0.20		x	x			
	Kittiwake	*Laridae*	0.87	0.43		x	x			
	Glaucous gull	*Laridae*	1.13	0.54		x	x	x		
	Common guillemot	*Alcidae*	1.13	0.07			x	x		
	Arctic tern	*Sternidae*	1.17	0.11			x	x		
	Puffin	*Alcidae*	1.29	0.33				x		
	Common eider	*Anatidae*	1.36	0.63				x	x	
	Razorbill	*Alcidae*	1.54	0.15				x	x	
	Fulmar	*Procellariidae*	3.23	2.14					x	

Table 3.2. Trace elements in muscle of seabirds from the Barents Sea. Bars (|) indicate homogeneous groups according to the Kruskal-Wallis test ($\alpha = 0.05$). Arithmetic mean and standard deviation.

Element	Species	Family	Mean mg/g d.w.	SD	Groups 1	2	3	4	5	6
Cd	Herring gull	*Laridae*	0.16	0.09	|					
	Common guillemot	*Alcidae*	0.21	0.08	|	|				
	King eider	*Anatidae*	0.25	0.30	|	|				
	Glaucous gull	*Laridae*	0.29	0.19	|	|				
	Razorbill	*Alcidae*	0.32	0.17	|	|				
	Puffin	*Alcidae*	0.37	0.19		|				
	Black guillemot	*Alcidae*	0.41	0.12		|	|			
	Common eider	*Anatidae*	0.45	0.23		|	|			
	Little auk	*Alcidae*	0.69	0.38			|	|		
	Brünnich's guillemot	*Alcidae*	0.83	0.45			|	|		
	Arctic tern	*Sternidae*	0.94	0.41			|	|		
	Kittiwake	*Laridae*	1.25	0.86				|		
	Fulmar	*Procellariidae*	5.22	5.06					|	
Zn	Common eider	*Anatidae*	35.1	3.9	|					
	Little auk	*Alcidae*	37.9	3.5	|					
	Common guillemot	*Alcidae*	40.1	4.5	|	|				
	Black guillemot	*Alcidae*	40.9	3.7	|	|				
	Arctic tern	*Sternidae*	42.9	6.6	|	|				
	Brünnich's guillemot	*Alcidae*	44.2	5.7		|				
	Puffin	*Alcidae*	44.9	7.4		|	|			
	Razorbill	*Alcidae*	46.0	3.9		|	|	|		
	King eider	*Anatidae*	50.6	12.6		|	|	|		
	Kittiwake	*Laridae*	51.5	11.0			|	|		
	Fulmar	*Procellariidae*	57.2	13.8				|	|	
	Herring gull	*Laridae*	59.7	19.4				|	|	
	Glaucous gull	*Laridae*	68.5	18.5					|	
Cu	Common guillemot	*Alcidae*	15.9	3.1	|					
	Razorbill	*Alcidae*	16.4	1.0	|					
	Glaucous gull	*Laridae*	17.4	3.5	|	|				
	Herring gull	*Laridae*	17.6	6.0	|	|				
	Common eider	*Anatidae*	17.9	6.2	|	|				
	Brünnich's guillemot	*Alcidae*	18.0	4.0	|	|				
	Fulmar	*Procellariidae*	19.1	2.4	|	|				
	Puffin	*Alcidae*	19.3	4.4	|	|				
	Kittiwake	*Laridae*	19.6	1.9		|				
	Black guillemot	*Alcidae*	20.8	3.1		|	|			
	King eider	*Anatidae*	21.1	7.2		|	|			
	Arctic tern	*Sternidae*	21.4	1.5		|	|			
	Little auk	*Alcidae*	23.9	4.7			|			
Mn	Common guillemot	*Alcidae*	1.60	0.22	|					
	Herring gull	*Laridae*	1.75	0.28	|	|				
	Glaucous gull	*Laridae*	1.82	0.30	|	|	|			
	Puffin	*Alcidae*	1.94	0.32	|	|	|			
	Kittiwake	*Laridae*	2.00	0.27		|	|			
	Brünnich's guillemot	*Alcidae*	2.13	0.39		|	|	|		
	King eider	*Anatidae*	2.24	0.80		|	|	|		
	Razorbill	*Alcidae*	2.27	0.55		|	|	|		
	Fulmar	*Procellariidae*	2.29	0.24		|	|	|		
	Black guillemot	*Alcidae*	2.29	0.22			|	|		
	Little auk	*Alcidae*	2.38	0.40			|	|		
	Arctic tern	*Sternidae*	2.87	0.12				|		

Table 3.2. (Continued)

Element	Species	Family	Mean mg/g d.w.	SD	Groups 1	2	3	4	5	6
Cr	Common eider	*Anatidae*	0.06	0.02	x					
	Glaucous gull	*Laridae*	0.07	0.03	x					
	Kittiwake	*Laridae*	0.08	0.03	x	x				
	Herring gull	*Laridae*	0.08	0.04	x	x				
	Common guillemot	*Alcidae*	0.08	0.02	x	x				
	Little auk	*Alcidae*	0.09	0.04	x	x				
	Brünnich's guillemot	*Alcidae*	0.09	0.05	x	x				
	Fulmar	*Procellariidae*	0.09	0.05	x	x				
	King eider	*Anatidae*	0.10	0.03	x	x				
	Puffin	*Alcidae*	0.10	0.06	x	x				
	Razorbill	*Alcidae*	0.12	0.02	x	x				
	Black guillemot	*Alcidae*	0.12	0.03	x	x				
	Arctic tern	*Sternidae*	0.15	0.04		x				
As	Common eider	*Anatidae*	0.20	0.11	x					
	Puffin	*Alcidae*	0.32	0.17	x	x				
	Common guillemot	*Alcidae*	0.47	0.05		x				
	Razorbill	*Alcidae*	0.48	0.05		x				
	King eider	*Anatidae*	0.64	0.09			x			
	Herring gull	*Laridae*	0.91	0.49			x			
	Kittiwake	*Laridae*	0.91	0.59			x			
	Brünnich's guillemot	*Alcidae*	1.02	1.46			x			
	Little auk	*Alcidae*	1.29	1.38			x	x		
	Arctic tern	*Sternidae*	1.45	0.49			x	x	x	
	Glaucous gull	*Laridae*	1.96	1.62				x	x	
	Fulmar	*Procellariidae*	3.04	1.94					x	x
	Black guillemot	*Alcidae*	4.25	1.34						x
Se	Little auk	*Alcidae*	1.99	0.50	x					
	Herring gull	*Laridae*	2.13	1.15	x					
	Glaucous gull	*Laridae*	2.15	1.41	x					
	Black guillemot	*Alcidae*	2.19	0.25	x	x				
	King eider	*Anatidae*	2.35	0.69	x	x	x			
	Arctic tern	*Sternidae*	2.67	0.39	x	x	x			
	Common eider	*Anatidae*	2.99	1.08	x	x	x			
	Brünnich's guillemot	*Alcidae*	3.39	1.36		x	x			
	Fulmar	*Procellariidae*	4.93	3.31			x	x		
	Kittiwake	*Laridae*	5.42	1.96				x		
	Razorbill	*Alcidae*	8.77	1.08					x	
	Common guillemot	*Alcidae*	10.3	2.32					x	
	Puffin	*Alcidae*	11.4	5.50					x	
Hg	Little auk	*Alcidae*	0.15	0.10	x					
	King eider	*Anatidae*	0.21	0.06	x	x				
	Kittiwake	*Laridae*	0.27	0.14		x				
	Arctic tern	*Sternidae*	0.28	0.02		x	x			
	Fulmar	*Procellariidae*	0.32	0.25		x	x			
	Black guillemot	*Alcidae*	0.32	0.08		x	x			
	Brünnich's guillemot	*Alcidae*	0.36	0.18		x	x			
	Common eider	*Anatidae*	0.37	0.16		x	x			
	Herring gull	*Laridae*	0.38	0.20		x	x			
	Puffin	*Alcidae*	0.39	0.12			x			
	Glaucous gull	*Laridae*	0.41	0.23			x			
	Common guillemot	*Alcidae*	0.41	0.11			x			
	Razorbill	*Alcidae*	0.88	0.19				x		

Appendix 4. Sex-dependent differences

Table 4.1. Differences between mean Cd concentrations in tissues of males and females. Arithmetic mean and standard deviation. LIP - Lilliefors's probabilities, P - significant difference probabilities, N - number of samples.

Species	Sex	Tissue	N	Mean	SD	LIP	P
Brünnich's guillemot	male	Liver	13	8.78	6.68	0.163	0.759
Brünnich's guillemot	female	Liver	16	7.72	6.12	0.011	
Brünnich's guillemot	male	Muscle	13	0.786	0.440	0.402	0.511
Brünnich's guillemot	female	Muscle	16	0.868	0.467	0.010	
Common guillemot	male	Liver	5	1.83	0.430	1.000	0.327
Common guillemot	female	Liver	4	1.58	0.337	1.000	
Common guillemot	male	Muscle	5	0.188	0.079	0.213	0.347
Common guillemot	female	Muscle	5	0.240	0.079	0.266	
Puffin	female	Liver	10	4.79	2.92	0.310	0.248
Puffin	male	Liver	8	3.82	3.09	0.061	
Puffin	female	Muscle	11	0.421	0.200	0.881	0.620
Puffin	male	Muscle	8	0.374	0.161	0.651	
Razorbill	female	Liver	3	2.20	0.812	0.616	0.564
Razorbill	male	Liver	2	1.89	0.491	1.000	
Razorbill	female	Muscle	3	0.384	0.207	0.295	0.564
Razorbill	male	Muscle	2	0.216	0.008	1.000	
King eider	female	Liver	6	4.61	1.98	0.744	0.317
King eider	male	Liver	2	3.67	0.711	1.000	
King eider	female	Muscle	6	0.297	0.353	0.023	0.505
King eider	male	Muscle	2	0.065	0.029	1.000	
Glaucous gull	male	Liver	13	3.99	4.04	0.000	0.804
Glaucous gull	female	Liver	10	3.41	2.46	0.166	
Glaucous gull	male	Muscle	13	0.209	0.135	0.224	0.040
Glaucous gull	female	Muscle	11	0.383	0.213	0.603	
Herring gull	female	Liver	2	1.98	0.064	1.000	I.D.T.
Herring gull	male	Liver	1	2.18			
Herring gull	female	Muscle	2	0.214	0.131	1.000	0.439
Herring gull	male	Muscle	2	0.143	0.110	1.000	
Kittiwake	female	Liver	17	21.6	10.7	1.000	0.190
Kittiwake	male	Liver	20	17.3	14.7	0.486	
Kittiwake	female	Muscle	19	1.28	0.879	0.080	0.675
Kittiwake	male	Muscle	21	1.19	0.865	0.460	
Fulmar	female	Liver	8	50.4	33.2	0.183	0.153
Fulmar	male	Liver	3	23.7	18.4	1.000	
Fulmar	female	Muscle	10	5.29	4.57	0.211	0.176
Fulmar	male	Muscle	3	1.56	0.705	1.000	
Arctic tern	male	Liver	1	15.9			I.D.T.
Arctic tern	female	Liver	3	18.8	3.14	1.000	
Arctic tern	male	Muscle	2	1.06	0.157	1.000	0.564
Arctic tern	female	Muscle	3	0.869	0.552	1.000	

I.D.T. - insufficient data for test

Table 4.2. Differences between mean Zn concentrations in tissues of males and females. Arithmetic mean and standard deviation. LIP - Lilliefors's probabilities, P - significant difference probabilities, N - number of samples.

Species	Sex	Tissue	N	Mean	SD	LIP	P
Brünnich's guillemot	male	Liver	13	96.4	29.6	0.202	0.792
Brünnich's guillemot	female	Liver	16	96.4	22.5	1.000	
Brünnich's guillemot	male	Muscle	12	44.2	4.72	0.048	0.745
Brünnich's guillemot	female	Muscle	16	43.3	5.55	0.584	
Common guillemot	male	Liver	5	87.0	11.8	0.562	0.465
Common guillemot	female	Liver	5	82.5	7.25	0.040	
Common guillemot	male	Muscle	5	38.5	3.80	0.029	0.347
Common guillemot	female	Muscle	5	41.7	4.90	0.417	
Puffin	female	Liver	9	92.9	10.6	0.406	0.847
Puffin	male	Liver	8	93.0	10.4	0.386	
Puffin	female	Muscle	10	43.8	7.96	0.008	0.524*
Puffin	male	Muscle	9	46.1	6.93	0.031	
Razorbill	female	Liver	3	104	9.40	1.000	0.564
Razorbill	male	Liver	2	115	24.3	1.000	
Razorbill	female	Muscle	3	47.6	4.65	1.000	0.564
Razorbill	male	Muscle	2	43.7	0.407	1.000	
King eider	female	Liver	6	149	40.3	1.000	0.739
King eider	male	Liver	2	153	46.4	1.000	
King eider	female	Muscle	6	50.5	13.2	1.000	0.739
King eider	male	Muscle	2	45.1	10.6	1.000	
Glaucous gull	male	Liver	12	89.1	9.39	0.185	0.339
Glaucous gull	female	Liver	10	84.9	12.6	0.652	
Glaucous gull	male	Muscle	13	66.8	18.5	1.000	0.744
Glaucous gull	female	Muscle	12	70.3	19.1	0.300	
Herring gull	female	Liver	1	113			I.D.T.
Herring gull	male	Liver	2	83.1	0.245	1.000	
Herring gull	female	Muscle	2	62.1	39.4	1.000	1.000
Herring gull	male	Muscle	2	53.3	8.41	1.000	
Kittiwake	female	Liver	19	104	18.8	0.588	0.480
Kittiwake	male	Liver	22	99.9	19.3	0.238	
Kittiwake	female	Muscle	19	53.6	11.2	0.255	0.388
Kittiwake	male	Muscle	22	50.1	10.8	0.922	
Fulmar	female	Liver	9	164	33.5	1.000	0.518
Fulmar	male	Liver	3	150	45.6	0.518	
Fulmar	female	Muscle	10	56.0	13.0	0.910	0.866
Fulmar	male	Muscle	3	58.3	20.8	0.265	
Arctic tern	male	Liver	2	124	22.7	1.000	0.564
Arctic tern	female	Liver	3	133	11.9	1.000	
Arctic tern	male	Muscle	2	44.4	3.66	1.000	1.000
Arctic tern	female	Muscle	2	41.3	10.3	1.000	

I.D.T. - insufficient data for test

Table 4.3. Differences between mean Cu concentrations in tissues of males and females. Arithmetic mean and standard deviation. LIP - Lilliefors's probabilities, P - significant difference probabilities, N - number of samples.

Species	Sex	Tissue	N	Mean	SD	LIP	P
Brünnich's guillemot	male	Liver	12	18.2	4.76	1.000	0.745
Brünnich's guillemot	female	Liver	16	18.3	3.24	0.245	
Brünnich's guillemot	male	Muscle	13	17.5	3.88	1.000	0.693
Brünnich's guillemot	female	Muscle	16	18.2	4.19	1.000	
Common guillemot	male	Liver	4	20.3	1.48	1.000	0.624
Common guillemot	female	Liver	5	19.6	1.08	0.449	
Common guillemot	male	Muscle	5	16.7	3.46	0.082	0.251
Common guillemot	female	Muscle	5	15.1	2.74	0.503	
Puffin	female	Liver	9	18.5	2.37	0.964	0.248
Puffin	male	Liver	8	20.0	1.66	0.058	
Puffin	female	Muscle	10	18.3	3.96	0.764	0.744
Puffin	male	Muscle	9	19.5	4.38	0.355	
Razorbill	female	Liver	3	23.6	3.30	0.146	0.248
Razorbill	male	Liver	2	22.3	3.82	1.000	
Razorbill	female	Muscle	3	16.6	1.10	1.000	I.D.T.
Razorbill	male	Muscle	1	15.8			
King eider	female	Liver	6	47.9	28.2	0.376	0.046
King eider	male	Liver	2	196	92.6	1.000	
King eider	female	Muscle	6	19.3	6.82	0.069	0.505
King eider	male	Muscle	2	18.4	2.07	1.000	
Glaucous gull	male	Liver	12	18.7	1.65	0.501	0.792
Glaucous gull	female	Liver	10	18.7	2.16	0.178	
Glaucous gull	male	Muscle	13	15.7	2.49	0.088	0.011
Glaucous gull	female	Muscle	12	19.2	3.68	0.501	
Herring gull	female	Liver	2	17.0	2.98	1.000	1.000
Herring gull	male	Liver	2	16.2	0.383	1.000	
Herring gull	female	Muscle	2	18.7	8.99	1.000	1.000
Herring gull	male	Muscle	2	14.9	1.35	1.000	
Kittiwake	female	Liver	18	21.9	3.19	0.832	0.447
Kittiwake	male	Liver	21	22.6	3.22	0.151	
Kittiwake	female	Muscle	19	20.4	1.77	0.517	0.019
Kittiwake	male	Muscle	21	18.9	1.85	1.000	
Fulmar	female	Liver	10	19.3	3.08	0.029	0.735
Fulmar	male	Liver	3	19.9	3.35	0.728	
Fulmar	female	Muscle	9	18.8	2.24	1.000	0.644
Fulmar	male	Muscle	3	18.4	1.11	1.000	
Arctic tern	male	Liver	2	28.8	2.46	1.000	0.564
Arctic tern	female	Liver	3	28.1	3.78	0.150	
Arctic tern	male	Muscle	2	20.2	0.238	1.000	0.121
Arctic tern	female	Muscle	2	22.5	1.25	1.000	

I.D.T. - insufficient data for test

Table 4.4. Differences between mean Mn concentrations in tissues of males and females. Arithmetic mean and standard deviation. LIP - Lilliefors's probabilities, P - significant difference probabilities, N - number of samples.

Species	Sex	Tissue	N	Mean	SD	LIP	P
Brünnich's guillemot	male	Liver	10	9.88	1.51	1.000	0.903
Brünnich's guillemot	female	Liver	5	9.94	1.81	0.581	
Brünnich's guillemot	male	Muscle	10	2.03	0.332	0.017	0.221
Brünnich's guillemot	female	Muscle	5	2.31	0.469	1.000	
Common guillemot	male	Liver	5	12.6	1.93	0.574	0.602
Common guillemot	female	Liver	5	13.6	1.23	0.706	
Common guillemot	male	Muscle	4	1.60	0.176	1.000	0.806
Common guillemot	female	Muscle	5	1.59	0.273	0.248	
Puffin	female	Liver	5	18.5	4.49	0.383	0.465
Puffin	male	Liver	5	17.1	2.81	0.120	
Puffin	female	Muscle	5	1.89	0.343	1.000	0.624
Puffin	male	Muscle	4	2.08	0.363	1.000	
Razorbill	female	Liver	2	13.6	0.495	1.000	1.000
Razorbill	male	Liver	2	13.8	1.95	1.000	
Razorbill	female	Muscle	2	2.68	0.169	1.000	0.121
Razorbill	male	Muscle	2	1.85	0.451	1.000	
King eider	female	Liver	6	19.5	3.72	0.501	0.739
King eider	male	Liver	2	20.7	7.65	1.000	
King eider	female	Muscle	6	2.17	0.902	0.801	0.739
King eider	male	Muscle	2	1.80	0.222	1.000	
Glaucous gull	male	Liver	10	13.4	2.01	0.497	0.828
Glaucous gull	female	Liver	6	13.4	2.35	0.412	
Glaucous gull	male	Muscle	10	1.76	0.306	0.049	0.270
Glaucous gull	female	Muscle	5	1.95	0.266	1.000	
Herring gull	female	Liver	n.a.				I.D.T.
Herring gull	male	Liver	1	9.70			
Herring gull	female	Muscle	n.a.				I.D.T.
Herring gull	male	Muscle	1	1.45			
Kittiwake	female	Liver	11	12.6	2.30	0.243	0.702
Kittiwake	male	Liver	14	13.1	2.76	0.015	
Kittiwake	female	Muscle	11	2.03	0.233	0.537	0.543
Kittiwake	male	Muscle	13	1.96	0.315	0.987	
Fulmar	female	Liver	3	17.2	1.45	0.437	0.083
Fulmar	male	Liver	2	14.6	0.234	1.000	
Fulmar	female	Muscle	3	2.24	0.322	0.186	0.564
Fulmar	male	Muscle	2	2.36	0.100	1.000	
Arctic tern	male	Liver	2	16.1	3.97	1.000	0.564
Arctic tern	female	Liver	3	16.9	2.167	1.000	
Arctic tern	male	Muscle	1	3.03			I.D.T.
Arctic tern	female	Muscle	3	2.81	0.074	1.000	

n.a. - not analysed; I.D.T. - insufficient data for test

Table 4.5. Differences between mean Cr concentrations in tissues of males and females. Arithmetic mean and standard deviation. LIP - Lilliefors's probabilities, P - significant difference probabilities, N - number of samples.

Species	Sex	Tissue	N	Mean	SD	LIP	P
Brünnich's guillemot	male	Liver	11	0.117	0.052	0.069	0.043
Brünnich's guillemot	female	Liver	15	0.073	0.051	0.000	
Brünnich's guillemot	male	Muscle	13	0.096	0.041	0.701	0.147
Brünnich's guillemot	female	Muscle	15	0.080	0.056	0.001	
Common guillemot	male	Liver	5	0.295	0.174	0.626	0.327
Common guillemot	female	Liver	4	0.175	0.053	0.788	
Common guillemot	male	Muscle	5	0.088	0.018	0.871	0.465
Common guillemot	female	Muscle	5	0.078	0.021	0.140	
Puffin	female	Liver	11	0.139	0.121	0.035	0.901
Puffin	male	Liver	8	0.121	0.094	0.474	
Puffin	female	Muscle	10	0.099	0.067	0.442	0.514
Puffin	male	Muscle	9	0.076	0.035	0.322	
Razorbill	female	Liver	3	0.153	0.040	1.000	0.564
Razorbill	male	Liver	2	0.174	0.061	1.000	
Razorbill	female	Muscle	2	0.114	0.020	1.000	1.000
Razorbill	male	Muscle	2	0.123	0.034	1.000	
King eider	female	Liver	5	0.242	0.158	0.124	0.699
King eider	male	Liver	2	0.182	0.039	1.000	
King eider	female	Muscle	6	0.092	0.028	0.133	I.D.T.
King eider	male	Muscle	1	0.132			
Glaucous gull	male	Liver	10	0.097	0.055	0.137	0.623
Glaucous gull	female	Liver	10	0.091	0.055	0.032	
Glaucous gull	male	Muscle	12	0.073	0.033	0.217	0.386
Glaucous gull	female	Muscle	12	0.064	0.028	0.014	
Herring gull	female	Liver	2	0.065	0.021	1.000	I.D.T.
Herring gull	male	Liver	1	0.040			
Herring gull	female	Muscle	2	0.045	0.007	1.000	0.245
Herring gull	male	Muscle	2	0.075	0.036	1.000	
Kittiwake	female	Liver	18	0.094	0.038	0.041	0.977
Kittiwake	male	Liver	20	0.097	0.042	0.194	
Kittiwake	female	Muscle	18	0.074	0.034	0.012	0.186
Kittiwake	male	Muscle	19	0.085	0.029	0.581	
Fulmar	female	Liver	10	0.082	0.052	0.000	0.673
Fulmar	male	Liver	3	0.110	0.066	1.000	
Fulmar	female	Muscle	9	0.083	0.052	0.026	0.267
Fulmar	male	Muscle	3	0.120	0.061	0.392	
Arctic tern	male	Liver	2	0.107	0.002	1.000	0.564
Arctic tern	female	Liver	3	0.109	0.008	1.000	
Arctic tern	male	Muscle	2	0.163	0.043	1.000	0.564
Arctic tern	female	Muscle	3	0.143	0.047	0.363	

I.D.T. - insufficient data for test

Table 4.6. Differences between mean As concentrations in tissues of males and females. Arithmetic mean and standard deviation. LIP - Lilliefors's probabilities, P - significant difference probabilities, N - number of samples.

Species	Sex	Tissue	N	Mean	SD	LIP	P
Brünnich's guillemot	male	Liver	11	2.95	2.09	0.011	0.511
Brünnich's guillemot	female	Liver	14	3.39	2.07	0.307	
Brünnich's guillemot	male	Muscle	10	1.23	2.23	0.000	0.639
Brünnich's guillemot	female	Muscle	14	0.883	0.660	0.614	
Common guillemot	male	Liver	5	0.991	0.327	1.000	0.175
Common guillemot	female	Liver	5	1.37	0.539	1.000	
Common guillemot	male	Muscle	5	0.455	0.027	0.967	0.462
Common guillemot	female	Muscle	4	0.485	0.065	1.000	
Puffin	female	Liver	9	1.01	0.452	0.892	0.773
Puffin	male	Liver	8	1.01	0.654	0.019	
Puffin	female	Muscle	9	0.282	0.158	0.010	0.248
Puffin	male	Muscle	8	0.369	0.176	0.288	
Razorbill	female	Liver	2	0.814	0.013	1.000	I.D.T.
Razorbill	male	Liver	1	0.809			
Razorbill	female	Muscle	3	0.508	0.021	0.632	0.053
Razorbill	male	Muscle	2	0.427	0.015	1.000	
King eider	female	Liver	6	1.21	0.543	0.220	0.182
King eider	male	Liver	2	0.638	0.197	1.000	
King eider	female	Muscle	6	0.649	0.102	0.299	0.505
King eider	male	Muscle	2	0.601	0.017	1.000	
Glaucous gull	male	Liver	9	5.05	3.46	0.433	0.825
Glaucous gull	female	Liver	9	4.31	3.17	0.396	
Glaucous gull	male	Muscle	12	1.80	1.17	0.111	0.895
Glaucous gull	female	Muscle	10	2.15	2.09	0.162	
Herring gull	female	Liver	2	1.50	0.453	1.000	1.000
Herring gull	male	Liver	2	2.17	1.69	1.000	
Herring gull	female	Muscle	2	0.740	0.042	1.000	1.000
Herring gull	male	Muscle	2	0.924	0.744	1.000	
Kittiwake	female	Liver	13	1.88	1.31	0.161	0.322
Kittiwake	male	Liver	15	2.51	1.66	0.209	
Kittiwake	female	Muscle	15	0.902	0.641	0.000	0.693
Kittiwake	male	Muscle	16	0.881	0.572	0.004	
Fulmar	female	Liver	9	3.99	3.25	0.124	0.480
Fulmar	male	Liver	2	4.74	0.020	1.000	
Fulmar	female	Muscle	10	2.92	2.15	0.576	0.390
Fulmar	male	Muscle	2	3.79	1.49	1.000	
Arctic tern	male	Liver	2	5.60	1.72	1.000	0.564
Arctic tern	female	Liver	3	5.79	2.80	0.222	
Arctic tern	male	Muscle	2	1.91	0.101	1.000	0.053
Arctic tern	female	Muscle	3	1.15	0.347	0.702	

I.D.T. - insufficient data for test

Table 4.7. Differences between mean Se concentrations in tissues of males and females. Arithmetic mean and standard deviation. LIP - Lilliefors's probabilities, P - significant difference probabilities, N - number of samples.

Species	Sex	Tissue	N	Mean	SD	LIP	P
Brünnich's guillemot	male	Liver	13	7.75	4.74	0.024	0.595
Brünnich's guillemot	female	Liver	16	6.93	3.52	0.012	
Brünnich's guillemot	male	Muscle	12	3.88	1.42	0.657	0.100
Brünnich's guillemot	female	Muscle	14	3.02	1.27	0.593	
Common guillemot	male	Liver	4	21.3	2.34	1.000	0.624
Common guillemot	female	Liver	5	20.6	3.01	1.000	
Common guillemot	male	Muscle	5	10.5	2.95	1.000	0.754
Common guillemot	female	Muscle	5	10.1	1.81	0.129	
Puffin	female	Liver	11	15.4	7.64	0.139	0.909
Puffin	male	Liver	9	16.0	7.03	0.274	
Puffin	female	Muscle	10	9.44	5.17	0.364	0.102
Puffin	male	Muscle	9	12.9	5.85	0.403	
Razorbill	female	Liver	3	16.0	10.24	1.000	0.248
Razorbill	male	Liver	2	22.3	7.50	1.000	
Razorbill	female	Muscle	2	8.01	0.574	1.000	0.121
Razorbill	male	Muscle	2	9.52	0.924	1.000	
King eider	female	Liver	6	9.35	2.20	1.000	I.D.T.
King eider	male	Liver	1	14.7			
King eider	female	Muscle	6	2.03	0.392	0.445	0.096
King eider	male	Muscle	2	2.87	0.406	1.000	
Glaucous gull	male	Liver	12	5.67	1.27	0.722	0.622
Glaucous gull	female	Liver	11	5.27	1.47	0.830	
Glaucous gull	male	Muscle	13	2.42	1.86	0.005	0.313
Glaucous gull	female	Muscle	11	1.83	0.493	0.020	
Herring gull	female	Liver	2	5.23	1.60	1.000	0.439
Herring gull	male	Liver	2	5.83	1.69	1.000	
Herring gull	female	Muscle	2	1.27	0.552	1.000	0.439
Herring gull	male	Muscle	2	1.70	0.393	1.000	
Kittiwake	female	Liver	16	12.4	3.64	1.000	0.181
Kittiwake	male	Liver	20	11.2	3.74	0.019	
Kittiwake	female	Muscle	18	5.49	1.94	0.974	0.384
Kittiwake	male	Muscle	22	5.34	2.07	0.032	
Fulmar	female	Liver	10	15.9	5.55	0.525	0.499
Fulmar	male	Liver	3	12.5	2.64	1.000	
Fulmar	female	Muscle	10	4.99	3.74	0.008	0.866
Fulmar	male	Muscle	3	3.87	1.70	1.000	
Arctic tern	male	Liver	2	7.64	1.10	1.000	1.000
Arctic tern	female	Liver	3	7.14	0.38	0.151	
Arctic tern	male	Muscle	2	3.04	0.175	1.000	0.053
Arctic tern	female	Muscle	3	2.41	0.231	1.000	

I.D.T. - insufficient data for test

Table 4.8. Differences between mean Hg concentrations in tissues of males and females. Arithmetic mean and standard deviation. LIP - Lilliefors's probabilities, P - significant difference probabilities, N - number of samples.

Species	Sex	Tissue	N	Mean	SD	LIP	P
Brünnich's guillemot	male	Liver	12	0.884	0.256	0.304	0.165
Brünnich's guillemot	female	Liver	14	0.671	0.337	0.676	
Brünnich's guillemot	male	Muscle	13	0.407	0.146	0.607	0.174
Brünnich's guillemot	female	Muscle	16	0.333	0.196	0.065	
Common guillemot	male	Liver	4	1.16	0.081	0.811	0.157
Common guillemot	female	Liver	3	1.09	0.025	0.385	
Common guillemot	male	Muscle	5	0.439	0.127	0.819	0.602
Common guillemot	female	Muscle	5	0.391	0.099	0.855	
Puffin	female	Liver	11	1.17	0.268	0.907	0.224
Puffin	male	Liver	9	1.31	0.299	0.895	
Puffin	female	Muscle	11	0.360	0.128	0.289	0.591
Puffin	male	Muscle	8	0.413	0.091	0.949	
Razorbill	female	Liver	2	1.43	0.141	1.000	0.121
Razorbill	male	Liver	2	1.64	0.095	1.000	
Razorbill	female	Muscle	3	0.803	0.180	1.000	0.248
Razorbill	male	Muscle	2	0.983	0.207	1.000	
King eider	female	Liver	6	0.650	0.123	0.079	I.D.T.
King eider	male	Liver	1	1.27			
King eider	female	Muscle	6	0.194	0.048	0.318	0.505
King eider	male	Muscle	2	0.238	0.107	1.000	
Glaucous gull	male	Liver	12	1.24	0.644	0.147	0.564
Glaucous gull	female	Liver	12	1.02	0.410	1.000	
Glaucous gull	male	Muscle	13	0.431	0.275	0.782	0.862
Glaucous gull	female	Muscle	11	0.378	0.183	0.344	
Herring gull	female	Liver	1	0.770			I.D.T.
Herring gull	male	Liver	2	0.846	0.600	1.000	
Herring gull	female	Muscle	2	0.180	0.113	1.000	0.121
Herring gull	male	Muscle	2	0.508	0.223	1.000	
Kittiwake	female	Liver	19	0.774	0.410	0.283	0.160
Kittiwake	male	Liver	20	0.970	0.439	0.220	
Kittiwake	female	Muscle	19	0.231	0.097	0.734	0.035
Kittiwake	male	Muscle	22	0.317	0.153	0.424	
Fulmar	female	Liver	10	3.25	2.03	0.353	0.612
Fulmar	male	Liver	3	2.78	3.39	0.223	
Fulmar	female	Muscle	10	0.319	0.216	0.036	0.032
Fulmar	male	Muscle	2	0.070	0.025	1.000	
Arctic tern	male	Liver	1	1.11			I.D.T.
Arctic tern	female	Liver	3	1.19	0.134	1.000	
Arctic tern	male	Muscle	1	0.290			I.D.T.
Arctic tern	female	Muscle	2	0.269	0.012	1.000	

I.D.T. - insufficient data for test

Appendix 5. Age differences

Table 5.1. Differences between mean metal concentrations in tissue of juvenile and adult birds. Mean - arithmetic mean, SD - standard deviation, P - significant differences probabilities according to the Mann-Whitney U test. N - number of samples.

Element	Species	Area	Tissue	Age	N	Mean	SD	P
Cd	Brünnich's guillemot	Seven Islands	Liver	A	5	2.55	1.93	0.009
				J	5	0.167	0.052	
			Muscle	A	5	0.598	0.355	0.009
				J	5	0.056	0.024	
Cd	Common guillemot	Kuvshin Island	Liver	A	5	1.98	0.564	0.025
				J	3	0.382	0.120	
			Muscle	A	5	0.280	0.054	0.025
				J	3	0.043	0.014	
Cd	Common eider	Ny-Ålesund	Liver	A	3	17.2	5.57	0.025
				J	2	44.9	3.55	
			Muscle	A	4	0.431	0.265	0.355
				J	2	0.845	0.460	
Cd	Glaucous gull	Franz Josef Land	Liver	A	6	5.35	4.16	0.239
				J	9	2.37	2.13	
			Muscle	A	6	0.309	0.282	0.346
				J	9	0.209	0.216	
Cd	Herring gull	Hillesøya	Liver	A	2	1.67	0.036	0.025
				J	5	0.290	0.123	
			Muscle	A	2	0.130	0.012	0.025
				J	5	0.019	0.002	
Cd	Herring gull	Hornøya	Liver	A	4	2.18	0.269	0.025
				J	2	0.086	0.064	
			Muscle	A	3	0.216	0.093	0.248
				J	2	0.098	0.122	
Cd	Kittiwake	Hooker Island	Liver	A	2	18.5	2.45	0.025
				J	3	4.16	3.66	
			Muscle	A	2	0.717	0.980	0.564
				J	3	0.221	0.273	
Zn	Brünnich's guillemot	Seven Islands	Liver	A	5	69.3	1.77	0.009
				J	5	90.7	4.23	
			Muscle	A	5	42.4	6.67	0.009
				J	5	57.0	3.79	
Zn	Common guillemot	Kuvshin Island	Liver	A	5	80.4	7.03	0.053
				J	3	96.9	6.01	
			Muscle	A	5	40.1	3.15	0.025
				J	3	58.9	2.30	
Zn	Common eider	Ny-Ålesund	Liver	A	3	281	29.1	0.083
				J	2	559	63.6	
			Muscle	A	4	36.4	2.78	0.355
				J	2	49.1	19.9	
Zn	Glaucous gull	Franz Josef Land	Liver	A	6	87.3	8.14	0.099
				J	9	129	87.2	
			Muscle	A	6	70.4	16.1	0.637
				J	9	78.6	27.1	

Table 5.1. (continued)

Element	Species	Area	Tissue	Age	N	Mean	SD	P
Zn	Herring gull	Hornøya	Liver	A	4	163	101	0.165
				J	2	84.7	2.76	
			Muscle	A	3	57.2	29.1	0.564
				J	2	132	125	
Zn	Kittiwake	Hooker Island	Liver	A	2	90.5	6.58	1.000
				J	3	88.5	9.81	
			Muscle	A	2	53.5	12.0	0.564
				J	3	62.9	5.97	
Cu	Brünnich's guillemot	Seven Islands	Liver	A	5	16.0	2.10	0.047
				J	5	13.5	1.14	
			Muscle	A	5	13.8	1.92	0.009
				J	5	7.61	0.981	
Cu	Common guillemot	Kuvshin Island	Liver	A	5	19.9	0.776	0.025
				J	3	15.7	0.939	
			Muscle	A	5	14.4	3.50	0.025
				J	3	8.70	2.23	
Cu	Common eider	Ny-Ålesund	Liver	A	3	228	32.8	0.025
				J	2	65.0	26.1	
			Muscle	A	4	19.7	5.38	0.643
				J	2	21.3	7.06	
Cu	Glaucous gull	Franz Josef Land	Liver	A	6	17.6	1.91	0.239
				J	9	18.4	2.89	
			Muscle	A	6	14.7	0.784	0.814
				J	9	15.6	1.63	
Cu	Herring gull	Hillesøya	Liver	A	2	16.9	1.19	0.053
				J	5	24.0	10.9	
			Muscle	A	2	14.2	1.09	0.121
				J	5	12.0	2.10	
Cu	Herring gull	Hornøya	Liver	A	4	16.4	1.89	0.643
				J	2	15.2	3.02	
			Muscle	A	3	17.8	6.56	1.000
				J	2	17.7	11.7	
Cu	Kittiwake	Hooker Island	Liver	A	2	23.9	1.25	1.000
				J	3	24.1	0.825	
			Muscle	A	2	17.9	0.601	0.083
				J	3	20.1	1.31	
Mn	Brünnich's guillemot	Seven Islands	Liver	A	5	8.59	0.950	0.028
				J	5	10.3	1.43	
			Muscle	A	5	2.31	0.438	0.347
				J	5	2.19	0.681	
Mn	Common guillemot	Kuvshin Island	Liver	A	5	13.0	1.66	0.655
				J	3	13.5	1.49	
			Muscle	A	5	1.80	0.510	0.655
				J	3	1.74	0.367	
Mn	Common eider	Ny-Ålesund	Liver	A	n.a.			I.D.T.
				J	n.a.			
			Muscle	A	n.a.			I.D.T.
				J	n.a.			
Mn	Glaucous gull	Franz Josef Land	Liver	A	6	14.0	2.02	0.637
				J	9	14.7	3.13	
			Muscle	A	6	1.76	0.364	0.480
				J	9	1.79	0.410	
Mn	Herring gull	Hillesøya	Liver	A	2	13.9	0.980	0.053
				J	5	17.2	2.534	
			Muscle	A	2	1.89	0.164	0.048
				J	5	1.27	0.174	
Mn	Herring gull	Hornøya	Liver	A	n.a.			I.D.T
				J	n.a.			
			Muscle	A	n.a.			I.D.T
				J	n.a.			

Table 5.1. (continued)

Element	Species	Area	Tissue	Age	N	Mean	SD	P
Mn	Kittiwake	Hooker Island	Liver	A	n.a.			I.D.T
				J	n.a.			
			Muscle	A	n.a.			I.D.T
				J	n.a.			
Cr	Brünnich's guillemot	Seven Islands	Liver	A	5	0.344	0.278	0.180
				J	5	0.142	0.027	
			Muscle	A	5	0.091	0.020	0.602
				J	5	0.117	0.050	
Cr	Common guillemot	Kuvshin Island	Liver	A	5	0.239	0.130	0.456
				J	3	0.168	0.083	
			Muscle	A	5	0.080	0.025	0.180
				J	3	0.132	0.047	
Cr	Common eider	Ny-Ålesund	Liver	A	3	0.070	0.052	0.554
				J	2	0.065	0.021	
			Muscle	A	4	0.058	0.022	0.453
				J	2	0.070	0.028	
Cr	Glaucous gull	Franz Josef Land	Liver	A	6	0.138	0.033	0.814
				J	9	0.130	0.037	
			Muscle	A	6	0.083	0.025	0.034
				J	9	0.183	0.089	
Cr	Herring gull	Hillesøya	Liver	A	2	0.104	0.011	0.245
				J	5	0.141	0.041	
			Muscle	A	2	0.132	0.024	0.245
				J	5	0.110	0.012	
Cr	Herring gull	Hornøya	Liver	A	4	0.053	0.019	1.000
				J	2	0.050	0.014	
			Muscle	A	3	0.047	0.006	0.761
				J	2	0.100	0.085	
Cr	Kittiwake	Hooker Island	Liver	A	2	0.045	0.007	0.739
				J	3	0.047	0.006	
			Muscle	A	2	0.045	0.007	1.000
				J	3	0.057	0.029	
As	Brünnich's guillemot	Seven Islands	Liver	A	5	1.48	0.721	0.056
				J	5	0.697	0.118	
			Muscle	A	5	0.614	0.125	0.251
				J	5	0.760	0.187	
As	Common guillemot	Kuvshin Island	Liver	A	5	1.34	0.520	0.050
				J	3	0.609	0.107	
			Muscle	A	5	0.604	0.324	0.101
				J	3	1.02	0.467	
As	Common eider	Ny-Ålesund	Liver	A	3	0.133	0.006	0.128
				J	2	0.150	0.014	
			Muscle	A	4	0.153	0.013	0.453
				J	2	0.145	0.007	
As	Glaucous gull	Franz Josef Land	Liver	A	6	9.01	5.51	0.117
				J	8	10.5	7.01	
			Muscle	A	6	2.07	1.05	0.602
				J	8	2.98	1.80	
As	Herring gull	Hillesøya	Liver	A	2	2.20	0.343	0.699
				J	5	2.95	2.17	
			Muscle	A	2	1.05	0.741	0.083
				J	5	2.32	0.769	
As	Herring gull	Hornøya	Muscle	A	3	0.977	0.411	0.064
				J	2	3.04	0.884	
			Liver	A	4	2.59	1.32	0.053
				J	2	0.575	0.276	
As	Kittiwake	Hooker Island	Liver	A	2	24.4	8.51	0.083
				J	3	13.9	2.11	
			Muscle	A	2	7.00	0.834	1.000
				J	3	6.91	1.13	
Se	Brünnich's guillemot	Seven Islands	Liver	A	5	13.9	4.06	0.009
				J	5	3.06	0.390	

Table 5.1. (continued)

Element	Species	Area	Tissue	Age	N	Mean	SD	P
			Muscle	A	5	8.02	2.08	0.009
				J	5	2.05	0.287	
Se	Common guillemot	Kuvshin Island	Liver	A	5	18.7	3.94	0.025
				J	3	3.30	0.089	
			Muscle	A	5	11.9	2.11	0.025
				J	3	1.68	0.292	
Se	Common eider	Ny-Ålesund	Liver	A	3	9.21	0.904	0.083
				J	2	16.4	3.11	
			Muscle	A	4	3.17	1.16	0.165
				J	2	4.66	0.764	
Se	Glaucous gull	Franz Josef Land	Liver	A	6	10.1	9.43	0.239
				J	9	7.29	5.45	
			Muscle	A	6	2.85	2.71	0.480
				J	9	2.49	1.65	
Se	Herring gull	Hillesøya	Liver	A	2	5.69	2.87	0.245
				J	5	3.43	0.448	
			Muscle	A	2	2.54	1.44	0.053
				J	5	1.07	0.114	
Se	Herring gull	Hornøya	Liver	A	4	4.68	1.20	0.165
				J	2	3.66	0.523	
			Muscle	A	3	1.32	0.399	0.564
				J	2	2.62	2.02	
Se	Kittiwake	Hooker Island	Liver	A	2	8.59	1.15	0.083
				J	3	4.83	1.53	
			Muscle	A	2	1.76	1.47	0.564
				J	3	1.12	0.643	
Hg	Common guillemot	Kuvshin Island	Liver	A	5	1.08	0.089	0.009
				J	3	0.099	0.005	
			Muscle	A	5	0.497	0.088	0.009
				J	3	0.061	0.003	
Hg	Brünnich's guillemot	Seven Islands	Liver	A	5	0.927	0.067	0.025
				J	5	0.069	0.013	
			Muscle	A	5	0.373	0.069	0.025
				J	5	0.047	0.009	
Hg	Common eider	Ny-Ålesund	Liver	A	3	1.80	0.224	0.248
				J	2	2.56	1.20	
			Muscle	A	4	0.403	0.162	0.643
				J	2	0.385	0.106	
Hg	Glaucous gull	Franz Josef Land	Liver	A	6	1.10	0.633	0.814
				J	9	1.47	0.767	
			Muscle	A	6	0.450	0.367	0.480
				J	9	0.620	0.468	
Hg	Herring gull	Hillesøya	Liver	A	2	0.882	0.178	0.053
				J	5	0.145	0.075	
			Muscle	A	2	0.345	0.143	0.053
				J	5	0.040	0.020	
Hg	Herring gull	Hornøya	Liver	A	4	1.11	0.669	0.060
				J	2	0.140	0.000	
			Muscle	A	3	0.240	0.130	I.D.T
				J	1	0.040		
Hg	Kittiwake	Hooker Island	Liver	A	2	0.690	0.042	0.083
				J	3	0.353	0.206	
			Muscle	A	2	0.110	0.085	0.248
				J	3	0.047	0.029	

"n.a." - not analysed; I.D.T. - insufficient data for test.

Appendix 6. Relationship between trace element concentrations in hepatic and muscle tissues of seabirds.

*Table 6.1. Coefficients of equations ($Y = BX + A$) of relationship between element concentrations in muscle (X) and liver (Y) of seabirds and some statistical information: arithmetic mean values (m_x, m_y), Lilliefors probability (LIP), coefficient of determination (R^2), Pearson (*Spearman) coefficients of correlation (R). N - number of samples.*

Element	Family	N	m_x	m_y	LIP_X	LIP_Y	R	B	A	R^2
			mg/kg d. w.							
Cd	*Alcidae*	72	0.53	5.37	0.000	0.000	0.621*	6.88	1.69	0.324
	Anatidae	13	0.33	7.64	0.006	0.009	0.780*	11.5	3.85	0.319
	Laridae	63	0.78	12.1	0.000	0.000	0.761*	9.39	4.80	0.374
	Procellariidae	11	3.81	43.2	0.009	0.241	0.636*	5.34	22.8	0.398
	Sternidae	4	0.94	18.1	1.000	0.588	0.328			
Zn	*Alcidae*	68	42.6	92.8	0.286	0.209	0.273	0.984	50.8	0.075
	Anatidae	13	46.4	199	0.394	0.293	-0.580	-3.59	365	0.336
	Laridae	68	58.1	98.1	0.001	0.003	-0.220*			
	Procellariidae	12	55.3	160	0.446	0.903	0.498			
	Sternidae	4	42.9	125	1.000	1.000	0.542			
Cu	*Alcidae*	68	18.0	19.5	1.000	0.110	0.071			
	Anatidae	11	19.7	124	0.106	0.438	0.162			
	Laridae	66	18.3	20.5	0.705	0.257	0.347	0.377	13.6	0.120
	Procellariidae	13	19.1	19.3	0.742	0.072	0.248			
	Sternidae	4	21.4	25.4	0.924	0.320	-0.329			
Mn	*Alcidae*	48	2.03	12.6	0.611	0.153	-0.231			
	Anatidae	10	2.11	19.1	0.674	0.056	-0.275			
	Laridae	42	1.91	13.1	0.247	0.142	0.166			
	Procellariidae	5	2.29	16.1	0.989	0.695	0.161			
	Sternidae	4	2.87	17.4	1.000	0.894	0.183			
Cr	*Alcidae*	67	0.10	0.14	0.010	0.000	0.608*	1.02	0.040	0.252
	Anatidae	11	0.09	0.19	0.582	0.194	0.778	3.17	-0.079	0.605
	Laridae	58	0.07	0.09	0.001	0.000	0.660*	0.891	0.026	0.403
	Procellariidae	13	0.09	0.08	0.002	0.000	0.868*	0.729	0.012	0.773
	Sternidae	5	0.15	0.11	0.343	1.000	-0.160			
As	*Alcidae*	61	0.97	2.79	0.000	0.000	0.545*	1.80	1.037	0.597
	Anatidae	12	0.50	0.79	0.264	0.073	0.660	1.74	-0.078	0.436
	Laridae	52	1.05	3.04	0.000	0.000	0.722*	2.81	0.108	0.673
	Procellariidae	11	2.59	3.90	0.280	0.146	0.809	1.38	0.319	0.655
	Sternidae	5	1.46	5.72	1.000	0.197	0.352			
Se	*Alcidae*	69	6.82	11.7	0.000	0.001	0.890*	1.20	3.56	0.647
	Anatidae	12	2.65	10.2	0.264	0.691	0.132			
	Laridae	64	3.73	9.06	0.071	0.009	0.801*	1.41	3.81	0.571
	Procellariidae	14	4.94	15.6	0.011	0.758	0.701*	0.914	11.1	0.328
	Sternidae	5	2.67	7.34	1.000	0.091	0.021			
Hg	*Alcidae*	68	0.39	1.00	0.005	1.000	0.769*	1.42	0.444	0.485
	Anatidae	11	0.27	1.02	0.142	0.049	0.782*	3.29	0.130	0.719
	Laridae	67	0.32	0.97	0.001	0.005	0.774*	1.91	0.367	0.516
	Procellariidae	13	0.32	3.02	0.026	0.212	0.744*	6.63	0.916	0.660
	Sternidae	3	0.28	1.21	1.000	1.000	-0.481			

(dark shading) $P < 0.01$ (light shading) $P < 0.05$ according to both Pearson and Spearman coefficients of correlation.

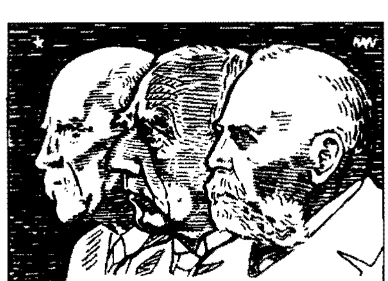
Appendix 7. Corellations between trace element concentrations

*Table 7.1. Correlations between trace element contents in hepatic and muscle tissues of different seabird species. Pearson (*Spearman) coefficients correlation (R), probabilities (P), coefficient of determination (R^2) and coefficients of linear regression $Y = BX + A$. N - number of samples.*

Family, species	Tissue	Y	X	N	R	P	R^2	A	B
Alcidae									
Brünnich's guillemot	Liver	Cd	Zn	30	0.469	< 0.010	0.220	-2.98	0.116
	Liver	Cd	Cu	29	0.463	< 0.050	0.214	-5.40	0.754
	Liver	Cd	Mn	15	0.664	< 0.010	0.441	-21.3	2.89
	Liver	Cd	As	26	0.412	< 0.050	0.170	4.74	1.30
	Liver	Zn	Cu	29	0.790*	< 0.001	0.576	15.4	4.32
	Liver	Zn	As	26	0.706	< 0.001	0.498	68.3	9.25
	Liver	Cu	Mn	14	0.785*	< 0.001	0.529	2.39	1.71
	Liver	Cr	Se	27	0.396	< 0.050	0.157	0.038	0.009
	Liver	As	Se	26	-0.436	< 0.050	0.186	4.65	-0.204
	Muscle	Zn	Se	26	-0.437*	< 0.050	0.199	50.4	-1.83
	Muscle	Cu	Cr	29	-0.462	< 0.050	0.213	21.4	-37.5
Common guillemot	Muscle	Cd	Se	10	0.745*	< 0.050	0.504	-0.036	0.024
	Muscle	Cu	Mn	9	0.900*	< 0.001	0.542	-1.35	10.7
	Muscle	Hg	Cd	10	0.648*	< 0.050	0.446	0.216	0.930
Little auk	Liver	Hg	As	8	0.888	< 0.010	0.789	0.175	0.066
	Muscle	Cd	As	12	-0.664	< 0.050	0.441	0.966	-0.196
	Muscle	Cu	As	12	-0.610	< 0.010	0.372	26.6	-2.03
	Muscle	Hg	As	12	0.814	< 0.010	0.663	0.100	0.057
	Muscle	Hg	Se	15	-0.570*	< 0.050	0.285	0.357	-0.102
Puffin	Liver	Cd	Zn	16	0.821*	< 0.001	0.319	-11.8	0.174
	Liver	Zn	Cu	17	0.645*	< 0.010	0.517	27.4	3.41
	Liver	Hg	Cu	17	0.632*	< 0.010	0.356	-0.267	0.077
	Liver	Hg	As	17	-0.499*	< 0.050	0.268	1.47	-0.264
	Muscle	Zn	Se	18	0.739	< 0.001	0.546	34.9	0.851
	Muscle	Mn	Cr	10	-0.709*	< 0.050	0.496	2.45	-3.37
	Muscle	As	Se	17	0.594	< 0.010	0.353	0.080	0.025
Razorbill	Muscle	Cd	Zn	5	1.000*	< 0.001	0.937	-1.65	0.043
Anatidae									
Common eider	Liver	Zn	Cr	5	0.979	< 0.010	0.958	229	703
King eider	Liver	Zn	Se	8	-0.714*	< 0.050	0.506	246	-9.68
	Liver	Hg	Cu	7	0.857*	< 0.010	0.799	0.397	0.006
	Muscle	Cd	Mn	10	0.805	< 0.010	0.648	-0.424	0.298
	Muscle	Cu	Mn	10	0.867*	< 0.001	0.817	2.88	8.12
Laridae									
Glaucous gull	Liver	Cd	Zn	21	0.626*	< 0.010	0.270	-12.0	0.179
	Liver	Hg	Se	22	0.658*	< 0.010	0.332	-0.116	0.220
	Muscle	Cd	Cu	24	0.508	< 0.050	0.258	-0.193	0.028
	Muscle	Cu	Cr	24	-0.503	< 0.050	0.252	21.5	-58.1
	Muscle	Cr	Se	23	0.515	< 0.050	0.265	0.046	0.011
	Muscle	Hg	Cr	23	0.474	< 0.050	0.225	0.157	3.65
	Muscle	Hg	Se	24	0.638	< 0.001	0.407	0.179	0.106
Herring gull	Liver	Cd	Cr	6	-0.928*	< 0.010	0.771	2.87	-9.52

Table 7.1. (Continued).

Family, species	Tissue	Y	X	N	R	P	R^2	A	B
Kittiwake	Liver	Cd	Zn	37	0.605*	< 0.001	0.320	-21.1	0.407
	Liver	Cd	Cu	36	0.384*	< 0.001	0.276	-29.0	2.17
	Liver	Cd	Se	32	0.421*	< 0.050	0.134	2.76	1.28
	Liver	Zn	Cu	39	0.555	< 0.001	0.292	29.6	3.20
	Liver	Zn	As	28	0.446	< 0.050	0.199	88.6	6.24
	Liver	Cu	Mn	24	0.703*	< 0.001	0.469	13.7	0.669
	Liver	Hg	Cu	37	0.354*	< 0.050	0.162	-0.369	0.057
	Liver	Hg	Mn	25	0.527*	< 0.010	0.300	-0.273	0.088
	Liver	Cr	Se	34	-0.511	< 0.010	0.261	0.162	-0.005
	Muscle	Cu	Cr	37	-0.353	< 0.050	0.115	21.2	-19.0
Procellariidae									
Fulmar	Liver	Cd	Zn	11	0.773*	< 0.010	0.429	-21.8	0.357
	Liver	Zn	Se	13	0.615*	< 0.050	0.379	99.1	4.10
	Liver	Hg	Zn	13	0.890*	< 0.001	0.808	-5.79	0.055
	Liver	Hg	Cu	15	0.745*	< 0.001	0.697	-9.09	0.625
	Liver	Hg	Se	15	0.636*	< 0.050	0.378	-0.558	0.249
	Muscle	Cd	Cu	13	0.665*	< 0.050	0.521	-25.1	1.59
	Muscle	Cd	Cr	13	-0.561	< 0.050	0.315	10.3	-54.7
	Muscle	Zn	Cu	13	0.720*	< 0.010	0.465	-20.5	4.03
	Muscle	Hg	Cu	12	0.688	< 0.050	0.473	-0.819	0.057
	Muscle	Hg	Cr	12	-0.643	< 0.050	0.413	0.614	-3.08
	Muscle	Hg	Se	13	0.737	< 0.010	0.543	0.052	0.054


HANSEN AMUNDSEN SVERDRUP