Technical Report

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Element composition of biota, water and sediment in the Forsmark area, Baltic Sea

Concentrations, bioconcentration factors and partitioning coefficients (K_d) of 48 elements

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August 2008

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Keywords: Ecosystems, Biosphere, K_d, Forsmark, Site-investigation, Stoichiometry, C/N, C/P, CNP, Chemistry.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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Abstract

In this study the elemental composition of biota, water and sediment from a shallow bay in the Forsmark region have been determined. The report presents data for 48 different elements (Al, As, Ba, Br, C, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Er, Eu, F, Fe, Gd, Hg, Ho, I, K, Li, Lu, Mg, Mn, N, Na, Nd, Ni, P, Pb, Pr, Ra, Rb, S, Se, Si, Sm, Tb, Th, Ti, Tm, V, Yb, Zn, Zr) in all major functional groups of the coastal ecosystem (phytoplankton, zooplankton, benthic microalgae, macroalgae, macrophytes, benthic herbivores, benthic filter feeders, benthic detrivores, planktivorous fish, benthic omnivorous fish, carnivorous fish, dissolved and particulate matter in the water and the sediment) during spring 2005.

The overall aim of the study is to contribute to a better understanding of ecological properties and processes that govern uptake and transfer of trace elements, heavy-metals, radionuclides and other non-essential elements/contaminants in coastal environments of the Baltic Sea. In addition, the data was collected to provide site-specific Bioconcentration Factors (BCF), Biomagnification Factors (BMF), partitioning coefficients (K_d) and element ratios (relative to carbon) for use in ongoing SKB safety assessments. All these values, as well as the element concentration data from which they are derived, are presented here. As such, this is mainly a data report, although initial interpretations of the data also are presented and discussed. Reported data include element concentrations, CNP-stoichiometry, and multivariate data analysis.

Elemental concentrations varied greatly between organisms and environmental components, depending on the function of the elements, and the habitat, ecosystem function, trophic level and morphology (taxonomy) of the organisms. The results show for intstance that food intake and metabolism strongly infleunce the elemental composistion of organisms. The three macrophytes had quite similar elemental compositition (despite their taxonomic differences) and the primary consumers were generally more similar to the primary producers than the secondary consumers were. Many elements decreased stepwise up trophic levels. Most elements were lower in fish compared to other organisms with the exceptions of C, N, P, Se (and to a lesser extent K, Zn, S, Ca, Rb, Hg). Shellbearing organisms showed the highest concentrations of Ca, and phytoplankton and benthic microalgae contained the highest levels of Si.

As well as being of ecological interest, these data will enable realistic predictions of radionuclide distributions in the environment in the event of their release from, for example, a future deep repository. This in turn will contribute to, for example, more reliable dose estimates to organisms and humans from radionuclides potentially released from the repository.

Sammanfattning

I den här studien har grundämnessammansättningen i biota, vatten och sediment i en grund vik i närheten av Forsmarsk undersökts. Rapporten presenterar data för 48 olika grundämnen (Al, As, Ba, Br, C, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Er, Eu, F, Fe, Gd, Hg, Ho, I, K, Li, Lu, Mg, Mn, N, Na, Nd, Ni, P, Pb, Pr, Ra, Rb, S, Se, Si, Sm, Tb, Th, Ti, Tm, V, Yb, Zn, Zr) i alla större funktionella organismgrupper i kustekosystemet (växtplankton, djurplankton, bentiska mikroalger, makroalger, makrofyter, bentiska herbivorer, bentiska filtrerare, bentiska detrivorer, fisk (planktivor, bentisk omnivor, carnivor)), samt i löst och partikulärt material i vattnet och i sedimentet, under våren 2005.

Det övergripande syftet med denna studie är att bidra till en bättre förståelse av de ekologiska egenskaper och processer som styr upptag och transport av spårämnen, tungmetaller, radionuklider och andra icke-essentiella ämnen (miljögifter) i Östersjöns kustekosystem. Dessa data samlades dessutom in för att möjliggöra plats-specifika uppsakttningar av biokoncentrationsfaktorer (Bioconcentration Factors, BCF), biomagnifikations faktorer (Biomagnification Factors, BMF), fördelningskoefficienter (Partitioning Coefficients, K_d) och grundämneskvoter (relativt till kol) för pågående säkerhetsanalyser på SKB. Alla dessa data, samt grundämneskoncentrationer som de är baserade på, är presenterade i denna rapport. Rapporten är huvudsakligen en datarapport, men en del inledande tolkningar av data presenteras också. Dessa innefattar grundämneskoncentrationer, CNP-stökiometri, och multivariata dataanalyser.

Resultaten visar på en betydande variation i grundämneskoncentration mellan organismer och andra komponenter i miljön. Detta verkar bero dels på grundämnets funktion och dels på habitat, ekosystemfunktion, trofisk nivå och morfologi (taxonomi) hos organismen. Resultaten visar tex att födointag och metaboliska processer påverkar grundämnessammansättningen i de olika organismerna. De tre makrofyterna hade ganska lik sammansättning (trots att de tillhör olika taxonomiska grupper) och primärkonsumenterna var generellt sett mer lika primärproducenterna än vad sekundärkonsumenterna var. Många ämnen uppvisar också en stegvis minskning uppåt i näringsväven. De flesta ämnen förekom i lägre koncentrationer i fisk jämfört med andra organismgrupper med undantag av C, N, P, Se (och i mindre omfattning K, Zn, S, Ca, Rb, Hg). Skalbärande organismer hade de högsta halterna av Ca och växtplankton och bentiska mikroalger de högsta Si-halterna.

Förutom att dessa resultat är av ekologiskt intresse, möjliggör dessa data även realistiska förutsägelser av hur radionuklider fördelas i miljön om de skulle läcka ut från t ex ett djupförvar för uttjänat kärnbränsle. Detta bidrar i sin tur t ex till att mer trovärdiga dosuppskattningar till biota och människan kan göras.

Contents

1 Introduction

1.1 Background

Aquatic environments are often the ultimate sink for contaminants and elements released to the environment. Their distribution and recirculation within these systems are governed by a multitude of abiotic and biotic processes. Dissolved elements/contaminants may accumulate in biota from the water phase, whereas particulate forms may be obtained from organic material (food) or sediments. Once taken up into biota, elements/contaminants may be transferred further up in the food web by grazing organisms and predators. Alternatively, elements/contaminants may be permanently buried in bottom sediments, or subsequently remobilized from sediments by processes such as resuspension, bioturbation, microbial mineralization and bioaccumulation. Other important factors involved in accumulation of elements/contaminants in biota are the intrinsic physiological and morphological properties of the respective organism/species. The ways that organisms interact with each other and with their abiotic environment can be strongly and reciprocally influenced by the elemental requirements (nutrients and trace elements) of the organisms involved and the balance of chemical elements in their environment /Elser and Urabe 1999/. This may also influence the uptake of non-essential elements. A way to study this further is to determine the ecological stoichiometry of the components of the ecosystem, and analyze and correlate ratios of elements in biota with those of their surrounding environment and food sources.

Ecological stoichiometry is the study of the balances of chemical elements of components, interactions and processes in ecosystems /Reiners 1986, Elser et al. 1996, Hessen 1997, Elser et al. 2000/. This field of science provides a tool for analysing how the chemical balance affects production, nutrient cycling and food web dynamics in ecosystems /Sterner and Elser 2002/. Ecological stoichiometry may also help to identify constraints and consequences of the existing mass balance of multiple chemical elements in ecological interactions /e.g. Elser et al. 1996, Hessen 1997/. A better understanding of stoichiometrical properties of ecological components may therefore help improve our ability to describe and predict the dispersal and uptake of excessive nutrients, trace elements and non-essential elements in the environment.

The Swedish Nuclear Fuel and Waste Management Company (SKB) is presently undertaking site investigations at two different locations on the east coast of Sweden (Forsmark and Simpevarp), with the objective of generating site-specific models of the current state of the geosphere, the biosphere and human land use /e.g. SKB 2006ab/. The site models are the foundation for the safety assessment that SKB is performing to identify a possible location for a geological repository for spent nuclear fuel /SKB 2006c/. An important component of the safety assessment is a radionuclide dispersal model, which estimates the environmental transport and distribution of radionuclides that could potentially be released from the repository to the biosphere in the future /e.g. Avila et al. 2006, Kumblad et al. 2006/.

The current study, where all major functional ecosystem components (biota, water and sediment) collected from a shallow bay in the Forsmark region were analysed for their chemical composition (48 chemical elements), will provide data for parts of the SKB safety assessment. This report compiles all information on collecting procedures, sample preparation and chemical analyses and presents all data obtained in the project.

1.2 Aims

The overall aim of this study is to contribute to a better understanding of ecological properties and processes that govern uptake and transfer of trace elements, heavy metals, radionuclides and other non-essential elements in coastal environments of the Baltic Sea.

More specifically, the aims are to:

- determine the ecological stoichiometry (overall elemental composition) in key functional organism groups of the coastal Baltic Sea food-web,
- determine the residues of trace elements and non-essential elements, and
- elucidate trophic levels and food-web relationships.

Ultimately, this information will be the basis for mechanistic generic dispersion (exposure) models and detailed analysis of the correlations of stoichiometric properties and trophic dynamics with uptake and enrichment of non-essential elements in the food-web. This however, is beyond the scope of the present report.

1.3 This report

The report presents data for 48 different elements (Figure 1-1) in all major functional components of a coastal ecosystem (phytoplankton, zooplankton, benthic microalgae, macroalgae, macrophytes, benthic herbivores, benthic filter feeders, benthic detrivores, planktivorous fish, benthic omnivorous fish, carnivorous fish, dissolved and particulate matter in the water, sediment, and porewater, (Figure 1-2) during spring 2005.

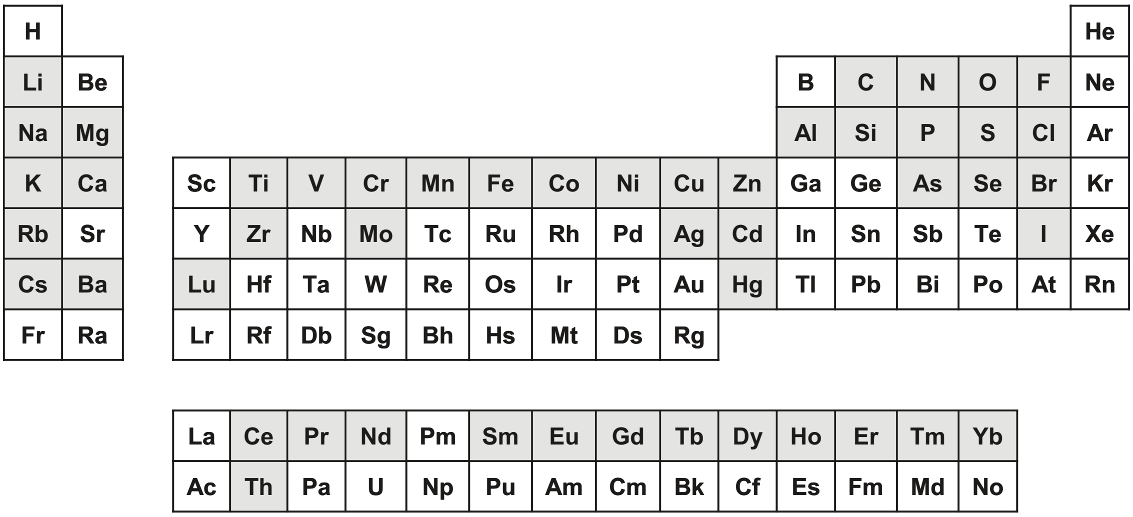

Figure 1-1. *Periodic table of elements. Shaded boxes indicate the elements analysed in this study.*

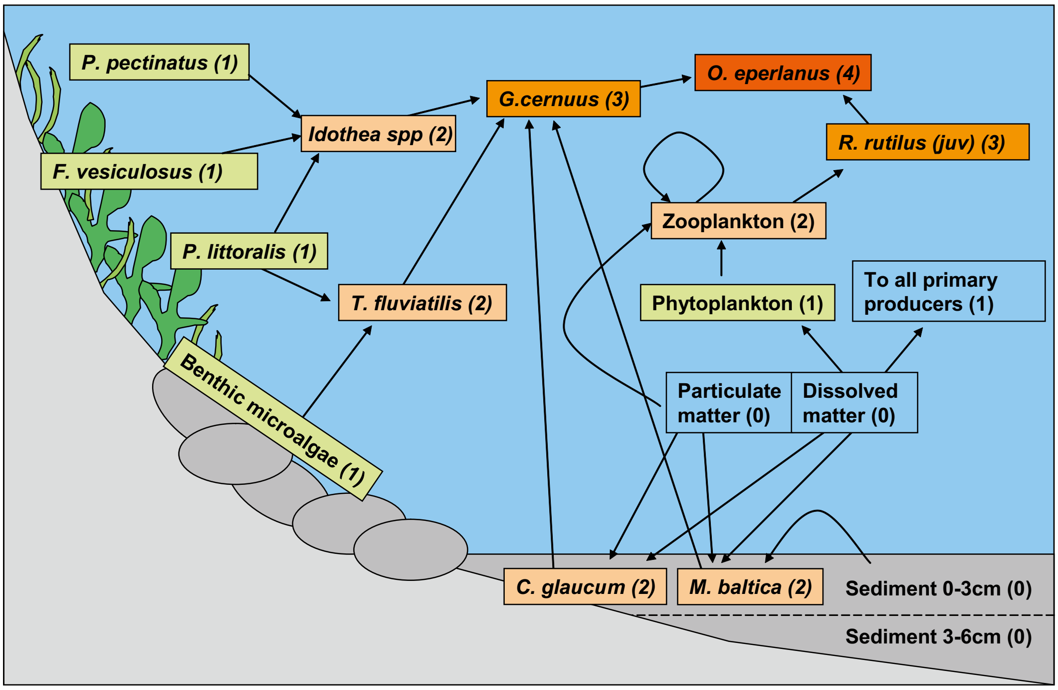

Figure 1-2. *Schematic illustration of the components of the shallow coastal ecosystem at Tixlan Bay (NW Baltic Proper) sampled in this study, including assumed food-web structure and trophic level (0, 1, 2, 3 or 4). For full species names see Table 2-2.*

The report is mainly a data report although initial interpretations of the data also are presented and discussed. All raw data as well as derived variables (results) obtained in this study are included and presented as follows:

Variable	Unit	Location
Element concentration	(mg/kg dw)	3.1 and Appendix 1–7
Element concentration	(mol/kg dw)	Appendix 8–14
CNP-stoichiometry:		
% (C, N or P) of dry weight	(%)	
Concentration (on weight basis)	(g/kg dw)	3.2
Concentration (on molar basis)	(mol/kg dw)	
C:N, C:P, N:P-ratios	(g/g)	
Ratios relative to carbon (on dry weight basis)	(mgX/kg dw)/(mgC/kg dw)	Appendix 15–20
Multivariate data analysis (PCA)	–	3.3
Biomagnification factors for three selected food web pathways (on dry and wet weight basis)	(mg/kg dw)/(mg/kg dw) (mg/kg ww)/(mg/kg ww)	3.4
Bioconcentration factors (on wet weight basis)	(kg/kg ww)/(kg/kg)	3.5 and Appendix 21–24
Bioconcentration factors (on carbon basis)	(kg/kg C)/(kg/kg)	3.5 and Appendix 25–28
Partitioning coefficients (on dry weight basis)	(kg/kg dw)/(kg/m^3)	3.6 and Appendix 29

2 Methods

2.1 Study Site

The selected study area for this project is Tixlan Bay in the Forsmark area (NW Baltic Proper) which is located within the area of interest for the potential localisation of a geological repository for spent nuclear fuel (Figure 2-1 and 2-2, Table 2-1). An extensive monitoring programme is performed in this area by the Swedish Nuclear Fuel and Waste Management Co (SKB), providing a substantial amount of site-specific background data (Wijnbladh et al in prep).

2.1.1 Environmental parameters

Water measurements of various physical and chemical characteristics taken one week before sample collection indicate a well-mixed water column, as might be expected just after icemelt. Nearer land the water had slightly higher temperature, salinity, pH and dissolved O_2, and slightly lower PAR (Photosynthetically Active Radiation) and turbidity, but these differences were very small (Figure 2-3). Values for all parameters were typical for the area and time of the year.

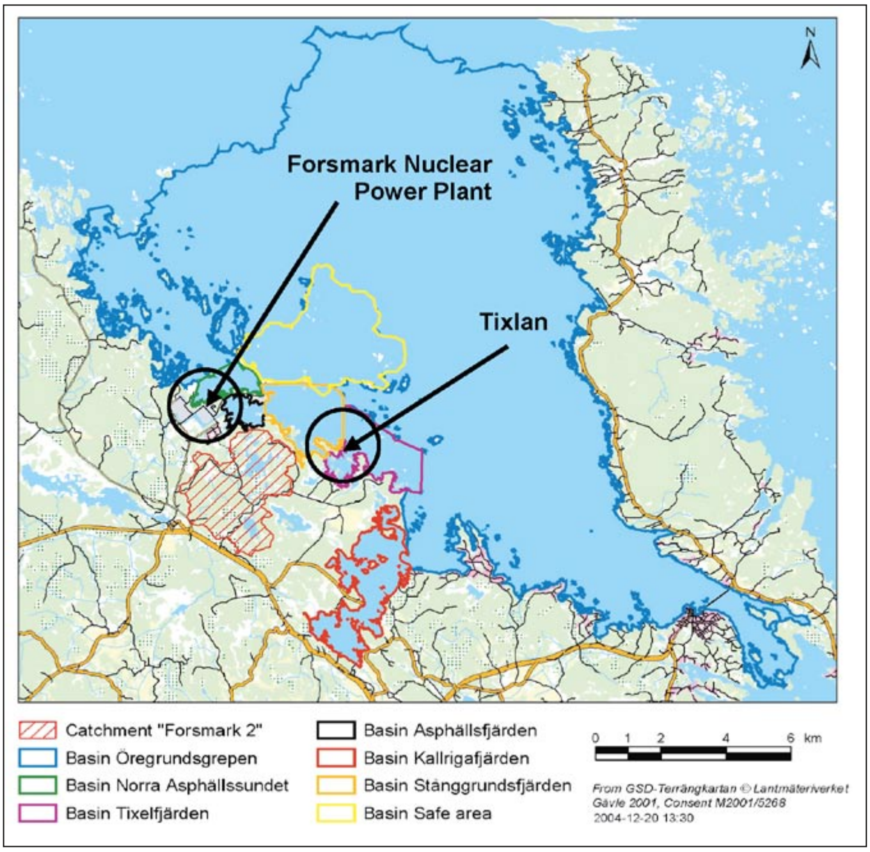

Figure 2-1. The location of the sampling area (Tixlan Bay), Forsmark Nuclear Power Plant and the marine basins in the Forsmark site investigation area.

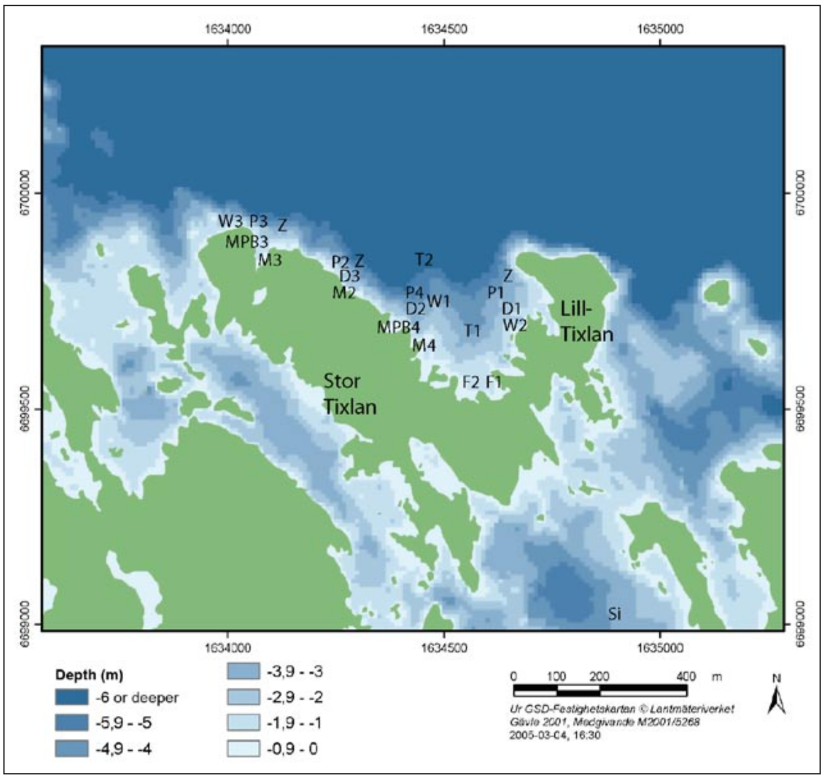

Figure 2-2. *The sampling area, Tixlan Bay. Sampling positions marked according to Table 2-1.*

Table 2-1. Sampling information. PA = position approximate.

Date (2005)	Sample type	Site code	Position (RT 90) E	N	Water depth (m)	Water temp. (°C)	Notes
12 Apr	Water 1	W1	1634362	6699805	6.5	2.4	middle of bay
	Water 2	W2	1634611	6699799	4.2	2.3	stony bottom
	Water 3	W3	1634050	6699950			PA
	Fish net 1	F1	1634550	6699630	2.5–3.0	2.6	
13 Apr	Phytobenthos 2	M2	1634214	6699894	5.4	2.4	stony bottom
	Phytoplankton 1	P1	1634650	6699822	3.2	2.3	muddy bottom
	Phytoplankton 2	P2	1634214	6699894	5.4	2.4	stony bottom
	Fish net 2	F2	1634500	6699630			PA
14 Apr	Phytobenthos 2	M2	1634214	6699894	c. 1		
	Phytobenthos 3	M3	1634050	6699950	c. 1		PA
	Phytoplankton 2	P2	1634214	6699894			
	Phytoplankton 3	P3	1634050	6699950			PA
15 Apr	Phytobenthos 4	M4	1634426	6699777	c. 1		PA
	Benthic microalgae 4	MPB4	1634426	6699777	c. 2		PA
	Phytoplankton 4	P4	1634426	6699777	c. 6		PA
	Phytoplankton 1	P1	1634623	6699843	c. 5		
	Phytoplankton 3	P3	1634060	6699974	c. 5		
18 Apr	Dive 1 (Core 1, Sed 1)	D1	1634623	6699843	7.2	5.7	PA
	Dive 2 (Core 2)	D2	1634397	6699854	7.2		
	Dive 3 (Core 3)	D3	1634230	6699926	8		
19 Apr	Sediment 2		1634397	6699854	c. 7		PA
	Benthic microalgae 3	MPB3	1634050	6699950	c. 2		PA
9 Jun	Zooplankton	Z	1634090	6699923	4.9	12.3	samples 0–3 m, PA
			1634350	6699932	8.3		samples 0–5 m, PA
			1634600	6699900	5.9		samples 0–4 m, PA
10 Apr	Sediment	Si	1634833	6699014	5.4	c. 2.5	collected 2008 for Si analysis
2008							
4 Apr	Environmental	T1	1634550	6699700			see figure 2-3
		T2	1634500	6699900			

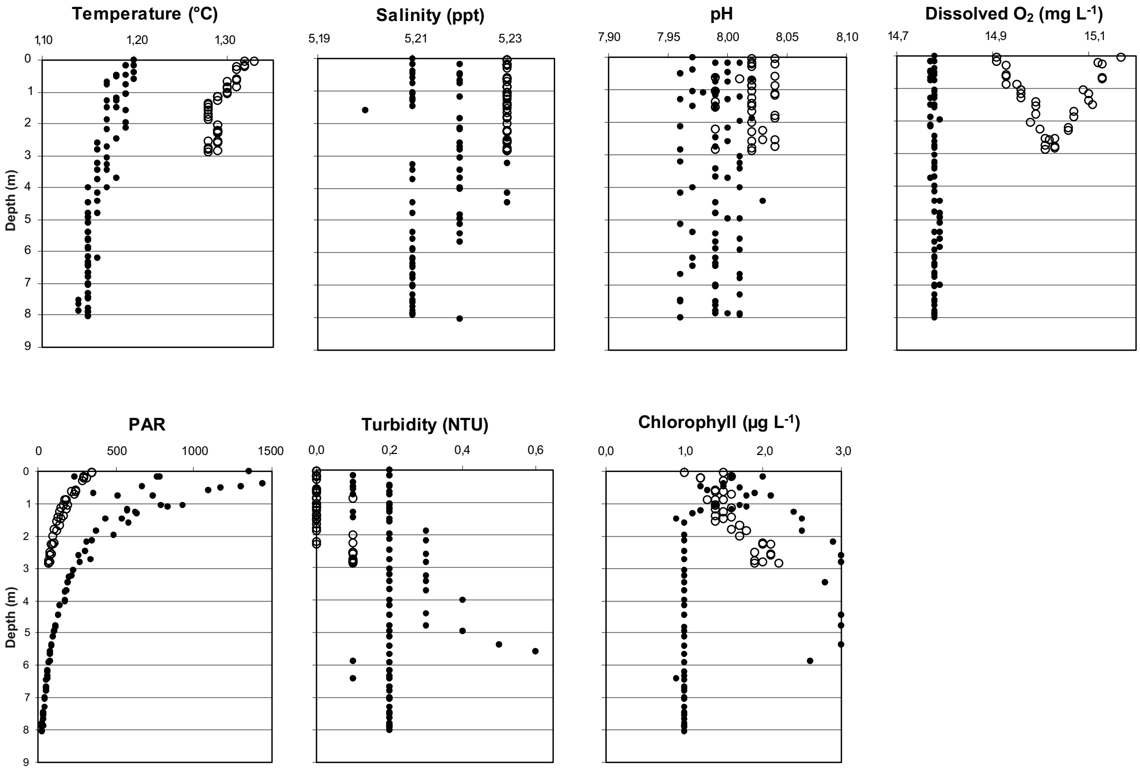

Figure 2-3. *Temperature, salinity, pH, dissolved O_2, PAR (Photosynthetically Active Radiation), turbidity and chlorophyll content in water column at the sample site, 4 April 2005 (1–2 weeks before sampling) at two places at the sample site (T1: open symbols, and T2: filled symbols.*

2.2 Sample collection

All samples (except zooplankton) were collected between 12–20 April 2005 in the bay between the north side of the islands of Stor and Lill-Tixlan, between the Forsmark nuclear power station and the town of Öregrund, NW Baltic Proper (Figures 2-1 and 2-2). (An exception to this is the sediment samples used for Si sediment and porewater analyses that were collected in April 2008 in Tixelfjärden.) The islands are semi-exposed with a rocky shore, and have rocky shallows (down to c. 5–6 m) with occasional large boulders giving way to a sandy mud substrate. Zooplankton samples were collected on 9 June 2005 as previous attempts in April and May yielded too little material for analysis.

All samples were collected at three different localities in the bay and treated as different replicates. The samples were collected either from a small boat, or by snorkellers/divers for the following different analyses:

- M-analysis (Al, As, Ba, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Gd, Hg, Ho, K, Li, Lu, Mg, Mn, Mo, Na, Nd, Ni, P, Pb, Pr, Rb, S, Se, Si, Sm, Tb, Th, Ti, Tm, V, Yb, Zn, Zr).
- I/Br-analysis (I, Br).
- F/Cl-analysis (F, Cl).
- CNP-analysis (C, N, P; different fractions of CNP were also analysed in water samples).

Samples were stored in acid-washed or factory-new plastic containers and frozen whole as soon as possible after collection. Contamination risks were minimized by not using hand cream or sun lotion during the fieldwork and sample preparation, always using lab gloves, handling the samples as little as possible, using plastic or Teflon equipment instead of metal (e.g. plastic scissors, scalpels, forceps), turning off the boat engine while taking samples and taking samples upstream/upwind of the boat. Control samples were taken wherever contamination risks were possible (e.g. of tap water, un-pumped sea water etc) and were found in all cases to contain extremely low (background) levels of possible contaminants.

Twenty-two different types of samples were collected from the shallow ecosystem, representing all the major ecological functional groups, as well as water (dissolved and particulate fractions) and sediment samples. Table 2-2 presents a summary of the collected samples. Further details on the methods used are given below. The same procedure was followed at three different positions in the bay to obtain (where possible) three replicate samples.

2.2.1 Water samples

Integrated water samples of 10 L were collected (0–4 m water depth) at three different locations in the bay using a metal-free pump.

Table 2-2. Summary of samples collected for chemical analysis.

Type of sample / Name	Function (trophic level)	Number of samples taken (n)*			
		M	I/Br	F/Cl	CNP
Plankton					
Phytoplankton	Primary producer (1)	3	3	3	3
Zooplankton	Grazer (2)	1	1	0	1
Phytobenthic flora					
Benthic microalgae	Primary producer (1)	2	2	2	2
Fucus vesiculosus	Primary producer (1)	3	2	2	3
Pilayella littoralis	Primary producer (1)	3	2	2	3
Potamogeton pectinatus	Primary producer (1)	3	0	0	3
Phytobenthic fauna					
Theodoxus fluviatilis	Grazer (2)	2	2	2	3
Idothea spp	Grazer (2)	2	0	0	2
Soft bottom fauna					
Cerastoderma glaucum	Filter feeder (2)	2	0	0	2
Macoma baltica	Filter / Deposit feeder (2)	3	2	2	3
Fish					
Rutilus rutilus (Roach)	Planktivore (3)	3	2	2	3
Gymnocephalus cernuus (Ruffe)	Benthic omnivore (3)	3	2	2	3
Osmerus eperlanus (Smelt)	Carnivore (4)	3	2	2	3
Sediment[#]					
Sediment 0–3 cm	Sediment (0)	3	3	3	3
Sediment 3–6 cm	Sediment (0)	3	3	3	3
Water					
Porewater 0–3 cm	Dissolved matter (0)	3	0	0	0
Porewater 3–6 cm	Dissolved matter (0)	1	0	0	0
Particulate organic matter	Particluate matter (0)	3	2	2	3
Dissolved inorganic matter	Dissolved matter (0)	3	2	2	3
Dissolved organic matter	Dissolved matter (0)	0	0	0	3
Whole water	Whole water (0)	0	0	0	3

* When possible three replicates were collected, but due to small sample amounts available and/or economic constraints, less samples were occasionally collected.

[#] Sediment sample 0–5 cm for Si-analysis, n=1.

M-, I/Br- and F/Cl analyses

For the **particulate organic matter (POM)** analysis the 10 L sample was shaken thoroughly and a 1 L sub-sample was removed for each of the M-, I/Br- and F/Cl-analysis. The samples were frozen.

For the **dissolved inorganic matter (DIM)** analyses a 10 L sample was shaken thoroughly and a sub-sample of 60 ml was filtered through presoaked disposable filters (45 µm). The filtered water was frozen and the filters discarded.

CNP analysis

For the **particulate organic matter (POM)** analyses the 10 L sample was shaken thoroughly and between 300–700 ml filtered through a preburnt (500°C) and presoaked (distilled water) GF/F filter. The exact volumes were recorded. The filter was saved for POC (particulate organic carbon) and PON (particulate organic nitrogen) analysis (folded into a foil packet and saved in a plastic container). The procedure was repeated with a separate filter for POP (particulate organic phosphorus) analysis, and repeated with a similar volume of distilled water in order to obtain a background value for particle concentrations. All filters were frozen.

For analysis of **dissolved inorganic matter (DIM)** and **dissolved organic matter (DOM)** a 10 L sample was collected and shaken thoroughly. A c.50 ml subsample was saved frozen for total N and P analysis and another subsample was filtered through a presoaked (distilled water) disposable filter. Approximately 20 ml of the filtered water was saved frozen for each of DOM, DIC and DIN/DIP analyses.

2.2.2 Phytoplankton

A depth-integrated water sample (from 1 m above the bottom to the surface, usually about 0–4 m) was pumped directly into two nested plankton nets with mesh sizes 60 µm and 20 µm. The fraction retained on the 20 µm net was washed out into plastic containers (using on-site (unfiltered) water) and saved in a cold box. There was very little material on the 60 µm net. Later examination of both fractions under a microscope showed that there was more or less no zooplankton present in either fraction. This sampling was repeated at 4 different sites on repeated occasions during the week and samples from each site pooled and stored cold.

In the lab, the samples were concentrated by sieving them on a 20 µm plastic sieve. After the first sampling occasion, the concentrated sample was saved in a plastic tube in the fridge and added to after the second sample had been treated in the same way two days later. This total sample was then mixed thoroughly before sub-samples were taken and frozen for M, I/Br, F/Cl and CNP analyses.

2.2.3 Zooplankton

Zooplankton were collected on 9 June 2005, as previous attempts in April and May yielded too little material for analysis. Water was pumped continuously (using a submergible pump) into nested 100 µm and 60 µm nets. A depth-integrated sample was taken from c. 1 m above the seabed up to the surface. The 100 µm and 60 µm fractions from all sites were eventually pooled in order to have enough material for analysis. Inspection of the samples under the microscope indicated that there was initially some phytoplankton present, particularly in the 60 µm fraction. To separate the phyto- and zooplankton the samples were first left in a coldroom overnight to allow the heavier diatoms to settle out. The overlying water of both fractions was then siphoned off, and contained mostly zooplankton with a few green algae colonies and diatoms. The remaining heavier fraction contained mostly diatoms but also significant numbers of zooplankton. This fraction was further diluted with brackish water and poured into light-separation funnels where the light source was placed above. Repeated settling and light-separation enabled a relatively clean zooplankton fraction to be collected from the water column while most of the diatoms settled to the bottom and were discarded. However, some contamination by algae and diatoms could not be avoided. The zooplankton suspension was concentrated by pouring it through a 50 µm sieve. This was divided into two samples for CNP- and M-analyses.

2.2.4 Benthic microalgae

Stones were collected in shallow (1–2 m) water. The surface organic film was brushed off using a toothbrush and the resulting suspension was sieved through 400 µm (to remove large debris) and 20 µm plastic sieves. The 20 µm fraction was further concentrated by a combination of centrifuging (3–5 minutes at 4,500 rpm) and sieving through the 20 µm sieve. The resulting sample was mixed thoroughly, divided into sub-samples for the different analyses and frozen.

2.2.5 Macroalgae, macrophytes and phytobenthic fauna

Macroalgae (*P. littoralis*, *F. vesiculosus*) and macrophyte samples (*P. pectinatus*) were collected by snorkellers, who cut (using a plastic knife) or pulled free whole plants into mesh bags. In the laboratory, phytobenthic fauna (*Idothea* spp, *T. fluviatilis*) were picked out of the plants, using plastic tools in sorting trays. As this procedure took some time, the fauna were kept in the fridge in field-collected brackish water until sufficient animals had been separated. These species were chosen as they were most abundant. Other species (e.g. *Gammarus*, chironomid larvae) were not present in sufficient numbers to obtain enough material for analysis.

F. vesiculosus samples were taken from the outermost parts of the plants, avoiding or removing any epiphytes or epifauna. *P. pectinatus* plants were relatively clean and whole plants were collected (without roots). Filamentous algae were either collected whole in the field or were removed from other algal species in the laboratory. Inspection under the microscope indicated that this mostly consisted of *P. littoralis*.

2.2.6 Soft bottom benthos

Surface (0–10 cm) sediment was collected at 7–8 m depth by (i) divers using a plastic scoop and mesh bags and (ii) by Ekman grabs from the boat. The sediment was rinsed through a plastic sieve (mesh size c. 2 mm) with brackish water in the lab until just coarse sandy sediment and gravel were left. *M. baltica* and *C. glaucum* were picked out of this sediment; they were generally in the size range 5–20 mm, although a few smaller individuals were also included. No other species were abundant enough to obtain enough material for analysis.

2.2.7 Fish

Fish nets were laid in the eastern part of the bay on two consecutive evenings and collected the next morning. Eight species were collected (roach (*Rutilus rutilus*), ruffe (*Gymnocephalus cernuus*), smelt (*Osmerus eperlanus*), perch (*Perca fluviatilis*), one viviparous blenny/black goby (*Zoarces viviparous/Gobius niger*), 1 pike (*Esox lucius*), a few herring (*Clupea harengus*), 1 burbot (*Lota lota*)), of which only the first three were sufficiently abundant to provide enough replicate samples. These also represented three different functional groups: planktonivores – small *R. rutilus*; benthic omnivores – *G. cernuus*; carnivores (piscivores) – *O. eperlanus*. The length and wet weight of each fish was recorded and the fish then frozen whole in separate Ziploc bags.

Individual whole fish were processed for CNP analysis in the following way. All entrails were removed, and the whole fish weighed and then homogenised to a smooth liquid in a household blender, together with a small (known) amount of distilled water. The suspension was dried in preweighed aluminium forms at 60°C. The resulting dried fish sample was ground into a fine powder using a pestle and mortar and a centrifuge grinder.

Preparation of fish for other analyses was done in two different ways:

a) all organs were removed from the body cavity, a slice was taken through the fish, which was then homogenized and then treated as for other samples,

b) the whole fish was weighed and dissolved in a known volume of aqua regia (HNO_3 and HCl), a known volume of which was sent for analysis. Cl, Br, F and I were not analysed in these samples. A blank control was also analysed; aqua regia that had been left for the same time in the same type of glass container, without a fish.

Results from both of these analyses are presented in the data tables (see Appendices). However, all data analyses presented in the results section of this report are based on the first fish dataset, i.e. the fish slices, as we consider these data to be more reliable (see section 3.7).

2.2.8 Sediment and porewater

Kajak cores were taken by divers at 7–8 m depth and carefully brought up to the surface in a rack. The cores were sliced shortly afterwards into two sections (0–3 cm, 3–6 cm) and the slices saved in individual Ziploc bags which were kept in the fridge until they were processed. The bag contents were then mixed thoroughly and divided into 60 ml centrifuge tubes. The sediment was centrifuged for 20 minutes at 4,500 rpm. Any pore water extracted was removed with a disposable plastic pipette, transferred to a 60 ml syringe and filtered through a disposable (presoaked) filter and the filtered water saved. Sediment samples were then taken from the remaining sediment from two centrifuge tubes. Very little pore water was extracted this way, probably because the sediment was very sandy. Therefore, only 'M-analyses' were carried out, and only on pore water from the 0–3 cm slices, and one 3–6 cm slice.

Sediment and porewater samples for Si analyses were taken at a slightly different location and in a different year (see Table 2-1) using a Kajak gravity corer. The top 5 cm was used for the analysis.

2.2.9 Chemical analyses

Analyses of C, N and P were carried out using standard methods at the accredited laboratory at the Department of Systems Ecology, Stockholm University.

Analyses of all other elements, as well as P, were carried out using standard spectrometry methods at ALS Scandinavia AB.

2.2.10 Data handling and analysis

Concentrations below limits of detection

In some cases, elements were present in concentrations that were below the limits of detection. In the analyses reports received from ALS Scandinavia AB these were presented (for example) as < 0.0002 mg kg^{-1}. Comparison with other replicates or other samples where exact values were available suggested that these concentrations were often only slightly lower than the detection limit. These data ('<x') were therefore converted to 'x' for further data handling. Although not strictly accurate, this was considered a better option than having missing data in the dataset or setting these values to zero, as it avoided loss of information. In the data tables in the Appendices, these values are shaded in grey.

Concentrations and element ratios

All concentrations were converted to parts per million (ppm), i.e. either as mg kg^{-1} or mg L^{-1}, and also converted to molar concentrations (mol kg^{-1} or mol L^{-1}). Ratios of element:C were then calculated for all elements, based both on mass and molar concentrations.

Average concentrations (± standard deviation) and element: C ratios (± confidence intervals) were calculated for each sample type and element, based on both mass and molar data. Confidence intervals for rations were calculated using the following error propagation formula (Jan-Olof Persson, pers. comm. Mathematical Statistics Department, Stockholm University), which takes into account the variability in both carbon and element data:

$$= \sqrt{\left(\left(\frac{SD_{Element}}{\sqrt{n_{Element}}} \right)^2 \cdot \frac{1}{\overline{X}_C^{\,2}} \right) + \left(\left(\frac{SD_C}{\sqrt{n_C}} \right)^2 \cdot \frac{\overline{X}_{Element}^{\,2}}{\overline{X}_C^{\,4}} \right)}$$

SD_C and $SD_{Element}$ are the standard deviations of the mean values of the carbon and (non-carbon) element concentrations, respectively; $\overline{X}_c$ is the mean concentration of carbon and $\overline{X}_{Element}$ is the mean concentration of the selected element; and n_c and $n_{Element}$ are the number of replicates for carbon and selected element analyses. Note that *n* varies depending on the element and the sample type (Table 2-2).

Biomagnification Factors (BMF)

In order to determine if there was any biomagnification up the food chain, BMFs were calculated for three selected food chains in the ecosystem: 1) *Fucus vesiculosus – Idothea* spp. – *Gymnocephalus cernuus – Osmerus eperlanus*; 2) sediment – *Macoma balthica – Gymnocephalus cernuus – Osmerus operlanus*; and 3) phytoplankton – zooplankton – *Rutilus rutilus – Osmerus eperlanus*.

$$BMF = \frac{element\ concentration\ in\ organism}{element\ concentration\ in\ food}$$

BMFs were calculated on both a wet and dry weight basis (see Tables 3-4a and b).

Bioconcentration Factors (BCF)

Bioconcentration factors (BCF) are referred to by many different names depending on the context and author, e.g. Concentration Ratios (CR), Transfer Factors (TF) and Bioaccumulation Factors (BAF). The definition of BCF used in this study is the ratio between the concentration of the element in the biota and the concentration of the element in the surrounding environmental media (water). Two types of BCF are presented in this study:

BCF_{WW} = kg/kg ww (wet weight) in biota per kg/kg water (i.e. DIM).

BCF_C = kg/kg C (carbon) in biota per kg/kg water (i.e. DIM).

Partitioning coefficient (K_d)

The partitioning coefficient (K_d) is the ratio between the concentration of the element in the solid phase of a media and the concentration of the element in the aquatic phase of a media. K_d is in this study presented both for the water column and the sediment.

K_d = kg/kg dw (dry weight) in the solid phase per kg/m^3 in the liquid phase.

Multivariate analyses

Principal component analysis (PCA) was used to explore the data and identify groups of samples based on the concentrations of elements (mg kgdw^{-1}). Canoco 4.5 software was used. Data was $\log_{10}$ transformed to reduce the biasing effect of extremely low or high element concentrations, and standardised to reduce the effect of large standard deviations.

Dissolved inorganic matter (DIM) and porewater (PW) samples contained extremely low concentrations of all elements in comparison to all other types of samples, and thus distorted the graphs to such an extent that differences between other types of samples were obscured. DIM and PW samples were thus excluded from these analyses.

Two separate analyses were carried out, as data for some elements was lacking for some sample types:

Analysis 1. Samples of *P. pectinatus*, *Idothea* spp. *C. glaucum* and zooplankton (POT, IDO, CAR, ZP) were omitted, as they lacked data for Cl, Br, I and F. All other sample types and all elements were thus included in this analysis (Figure 3-9a, b).

Analysis 2. Cl, Br, I and F were omitted, but all sample types were included (Figure 3-10a, b).

The main elements responsible for clusters of samples were also identified using the SIMPER (similarity percentages) routine in the software PRIMER v5. Data was in this case fourth-root transformed prior to analysis.

3 Results and discussion

3.1 Element concentrations

The elemental concentrations of Al, As, Ba, Br, C, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Er, Eu, F, Fe, Gd, Hg, Ho, I, K, Li, Lu, Mg, Mn, Mo, N, Na, Nd, Ni, P, Pb, Pr, Rb, S, Se, Si, Sm, Tb, Th, Ti, Tm, V, Yb, Zn, Zr in phytoplankton, zooplankton, benthic microalgae, macroalgae (*F. vesiculosus* and *P. littoralis*), macrophytes (*P. pectinatus*), benthos (*C. glaucum*, *M. baltica*, *T. fluviatilis*, *Idothea* spp.), and fish (*G. cernuus, O. eperlanus, R. rutilus*) are presented in Figures 3-1–3-6 (raw data in Appendix 1-7).

The concentrations of the elements range widely between different elements and organisms. To try to facilitate the interpretation of the data the results have been grouped with regard to both concentration range in the organisms and type of element, i.e. if they are a structural component (e.g. C, N, P), trace element (e.g. Mg, Fe, Mn, Si, Na), or other essential or non-essential element.

Carbon, nitrogen and **phosphorus** are the main structural elements in all biota. These elements were therefore found in high concentrations in all organisms. The fish, plants, *Idothea* spp. and zooplankton had approximately twice as high carbon concentrations than in molluscs, benthic microalgae and phytoplankton (Figure 3-1). This is mainly due to the large amount of Ca in the shell (and therefore less carbon totally) of the shell-bearing molluscs and to the large amounts of Si in the microalgae which to a large extent were composed by silaceous diatoms (see further Figure 3-3). Regarding nitrogen and phosphorus there were more than twice as high concentrations in fish, *Idothea* spp. and zooplankton compared to the rest (Figure 3-1). For fish this is probably because bone tissue is rich in calcium, magnesium, and phosphate ions, and that more advanced organisms use more energy demanding biochemical processes which involve phosphate rich compounds such as the energy storing nucleotide triphosphates (e.g. ATP and GTP) and coenzymes (e.g. NADH, NADPH).

Magnesium, iron and manganese are elements that are important constituents in various enzymes in biota. The concentrations of these three elements varied greatly among the organisms included in this study.

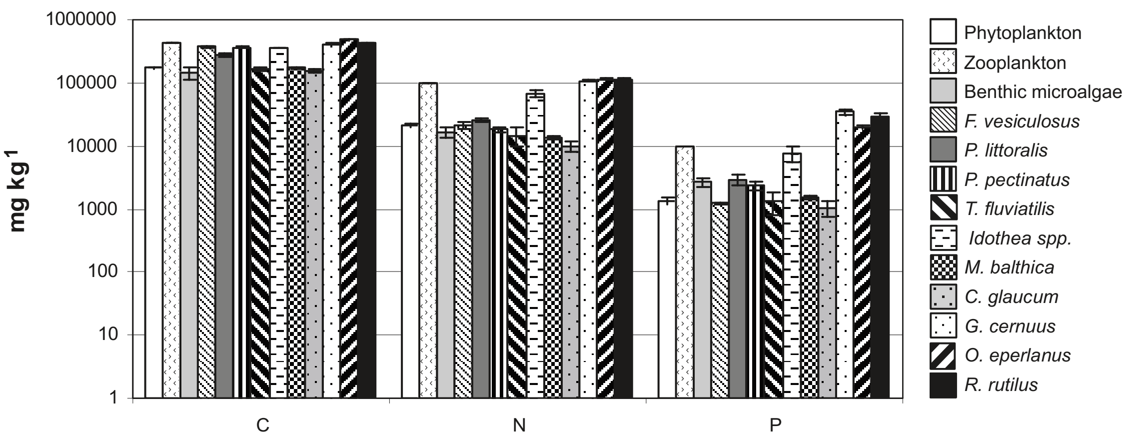

Figure 3-1. *Concentration (mg kgdw^{-1}) of C, N and P in biota in Tixlan bay, Northern Baltic Proper; mean and SD. Note the log scale on the y-axis.*

The three main functions **magnesium (Mg)** has in biota are (i) the general involvement with phosphate compounds and phosphate metabolism, (ii) the binding function in chlorophyll pigments, and (iii) association with some essential steps in carbon assimilation and metabolism. Consequently it is not surprising that plants were found to have much higher magnesium concentrations than animals (Figure 3-2). The exceptions to this are *Idothea* spp. and zooplankton. The role of **iron (Fe)** in organisms is complicated. It is present in many enzymes and proteins and is involved in e.g. oxidation-reduction catalysis and bioenergetics, and is connected to many control systems and to several acid-base reactions. In this study the highest Fe concentrations were found in benthic microalgae and fairly high in phytoplankton and *P. littoralis* (Figure 3-2). The importance of **manganese (Mn)** in living systems is considerable, especially in plants, but is poorly understood in many areas. One of its most important functions is the involvement in O_2 release by photosystem II in plants. The two other well-known enzymes which contain Mn (and also evolve O_2) are the superoxide dismutase of prokaryotes and of the organelles of eukaryotes, and the catalase of lactobacilli. In the organisms included in this study the highest Mn concentration was found in benthic microalgae which was several magnitudes higher than the other organisms (Figure 3-2). Among the rest of the organisms the plants had approximately twice as high Mn concentrations than the animals, which also could be expected (Figure 3-2).

Calcium (Ca) plays an important role in all advanced biological systems. The control of metabolic pathways is often governed by a calcium-dependent step (e.g. Ca-ATPase mediated pumps). Ca is also involved in triggering processes (e.g. in synapses, hormone releases), controlling processes (e.g. morphogenesis, fertilization) and catalysis processes (e.g. digestive enzymes, blood clotting). Outside cells, Ca is involved in multiple structural and cross-linking functions such as bone, shells, teeth and cell walls. As a consequence the highest Ca concentrations in the material found in this study were found in the shell-bearing organisms (*T. fluviatilis*, *M. baltica* and *C. glaucum*) and in the crustaceans (*Idothea* spp. and zooplankton) having exoskeleton (Figure 3-3). **Silicon (Si)** is very abundant in various forms in minerals and soils. It is required only in small amounts (trace element) in most higher animals. In contrast, in plants and many unicellular organisms, such as diatoms, silicon is a major element often having a turnover rate that is only one order of magnitude less than carbon. This pattern is also reflected in our data where there are very high concentrations in the phytoplankton (that mainly consists of diatoms), and in the other plant species with the exception of *F. vesiculosus*. High concentrations in the benthic microalgae probably reflect the presence of large amounts of diatoms, both benthic and pelagic (settled out from the water column).

There are large amounts of sodium, potassium and chloride ions in sea water. They are also vital components in organisms, as these elements are involved in osmotic control and electrolytic equilibrium. In this study, the concentration of **sodium (Na)** was extremely high in

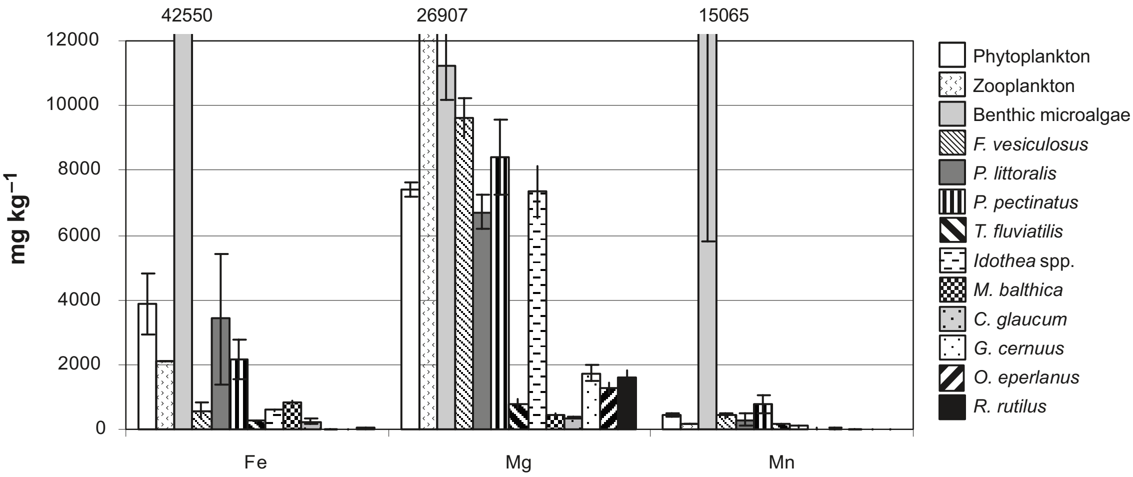

Figure 3-2. *Concentration (mg kgdw^{-1}) of Fe Mg and Mn in biota in Tixlan bay, Northern Baltic Proper; mean and SD.*

the zooplankton sample, and there was then a decreasing concentration from phytoplankton and plants to invertebrates and lowest in fish (Figure 3-3). This probably reflects the organisms' different abilities to control the concentration difference between the ambient water and their interior environments. The same pattern can be observed for **chlorine (Cl)** although the difference in concentration between plants and animals is larger (Figure 3-3). It should also be noted that in samples with a high water content, Na and Cl are also higher, suggesting that a significant amount of these may be derived from Na and Cl ions in the water, rather than the samples.

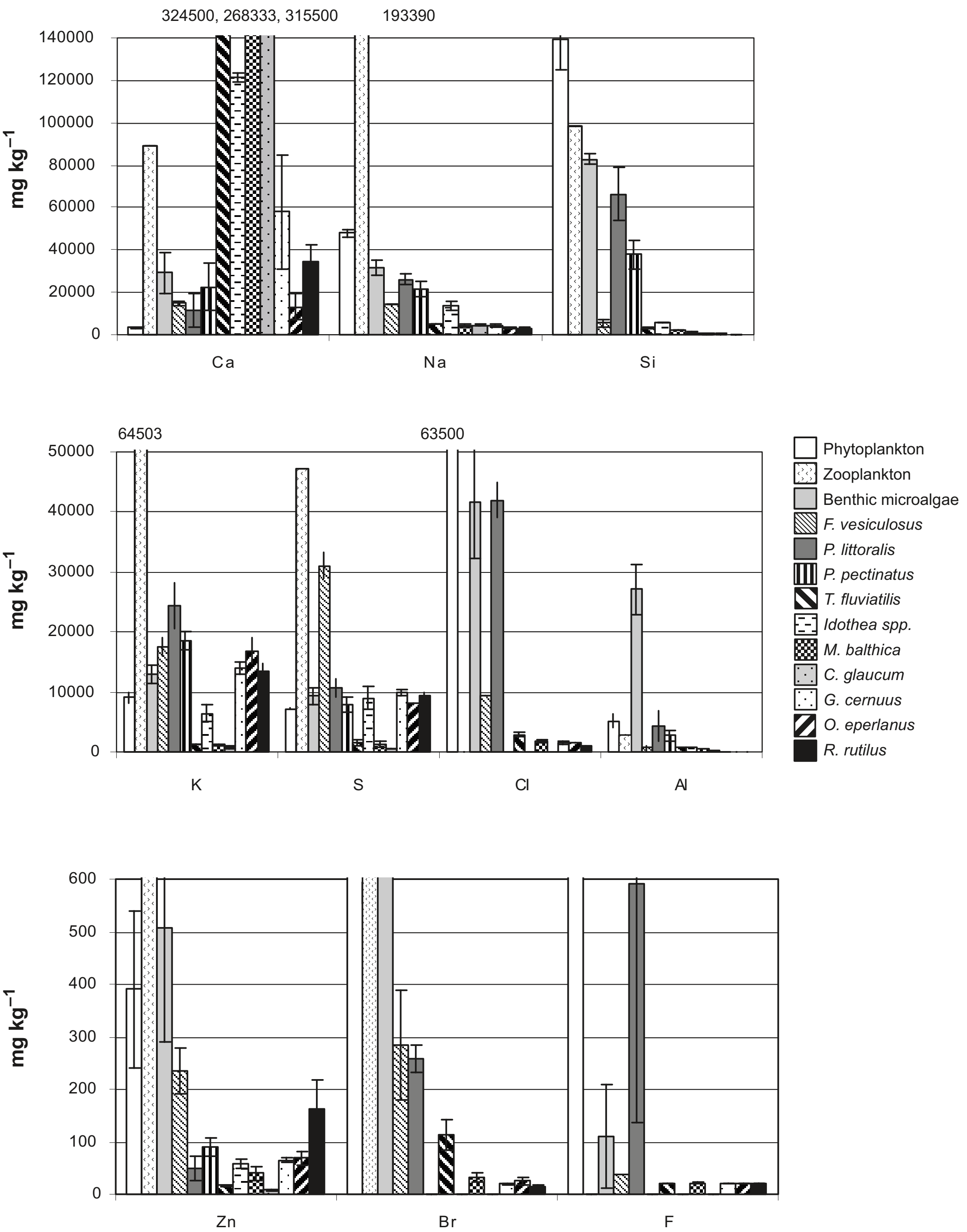

Figure 3-3. *Concentration (mg kgdw^{-1}) of Ca, Na, Si, K, S, Cl, Al, Zn, Br and F in biota in Tixlan bay, Northern Baltic Proper; mean and SD (note the different scales).*

For **potassium (K)**, however, there were similar concentrations in plants and fish but about an order of magnitude lower in the invertebrate organisms (Figure 3-3).

Sulphur (S) has a vast biochemistry in living organisms. Much S is incorporated into the sulphur-containing amino acids, cysteine and methionine, and used in proteins or enzymes. S is also involved in many acid-base reactions. When it reacts as a base it may bind H^+ and a range of transition metals including e.g. V, Fe, Cu, Ni, Zn and Mo (metallothioneins). The sulphur concentrations found in the samples analysed in this study were quite similar among all different organisms with the exception of *F. vesiculosus* and zooplankton, which both had concentrations more than twice as high as the rest of the samples (Figure 3-3). In the case of *Fucus*, this could be because it possesses an active sulphate uptake system (identified for *F. vesiculosus serratus* by /Coughlan 1977/), used to produce S-rich metallothioneins (gene identified by /Morris et al. 1999/) for the protection against metal toxicity.

The halogen elements **iodine (I), fluorine (F)** and **bromine (Br)** were most abundant in the plant species, with the latter two also present in high concentrations in phytoplankton (Figures 3-3 and 3-4). Marine macroalgae have a high ability to fix halide ions and many different halogenated compounds have been detected in red and brown algae. Many of these secondary metabolites are thought to have an anti-microbial and/or anti-grazing role. Phytoplankton are known to emit halogenated compounds as volatile organic compounds.

The highest concentrations of **zinc (Zn)** were found in phytoplankton, fish and algae, although it was present in all samples (Figure 3-3). Zinc is an essential element for all organisms, mainly due to its enzymatic role; it is an integral part of a number of metalloenzymes, and hundreds of proteins have been identified that need zinc for their functions. In addition, it has structural role in filamentous keratin-like structures and chromosomes and is important in DNA-regulatory functions. Zinc is a co-factor for the enzyme carbonic anhydrase which catalyses a critical rate-limiting step for carbon use in photosynthesis, and has been shown to limit plankton growth when deficient. Fish accumulate zinc from both water and dietary sources; however, dietary zinc is more efficiently absorbed than waterborne zinc.

Barium (Ba) has no known function in biological systems. However, unusually high accumulation has been shown to occur in some species of e.g. rhizopods, coelenterates and molluscs. In our samples the Ba concentrations were quite high compared to elements considered as trace elements (e.g. Cu, Ni). The highest concentrations were found in benthic microalgae and *F. vesiculosus* (Figure 3-4)).

Copper (Cu) is an essential element for all living organisms, having a variety of functions: it is essential in the respiratory pigment haemocyanin (present in most molluscs and crustaceans) and in the binding agent to transcription factors; and it is involved in oxygen transport in various proteins. This is also reflected in our data where (apart form phyto- and zooplankton and benthic microalgae) the highest concentrations were found in *Idothea* spp. *M. baltica* and *T. fluviatilis* (Figure 3-4).

Titanium (Ti) has no known biological role. There is some evidence that it can accumulate in some marine species, including phytoplankton. Ti is a common element in the earth's crust, thus potentially explaining its presence in the sediment-dwelling bivalves *M. baltica* and *C. glaucum* (Figure 3-4). **Aluminium (Al)** is also a non-essential element, but is extremely abundant in the earth's crust. In this study it was most abundant in the benthic microalgae, phytoplankton, *P. littoralis* and zooplankton.

Nickel (Ni) is also an essential metal to most organisms. Ni has various functions in bacteria and other primitive forms of life. In higher organisms the activity of nickel is confined to one enzyme, urease. In our samples the Ni concentration in benthic microalgae was highest (130 mg kg dw^{-1}). The rest of the organisms had concentrations of one magnitude lower (*F. vesiculosus*) or less (Figure 3-4).

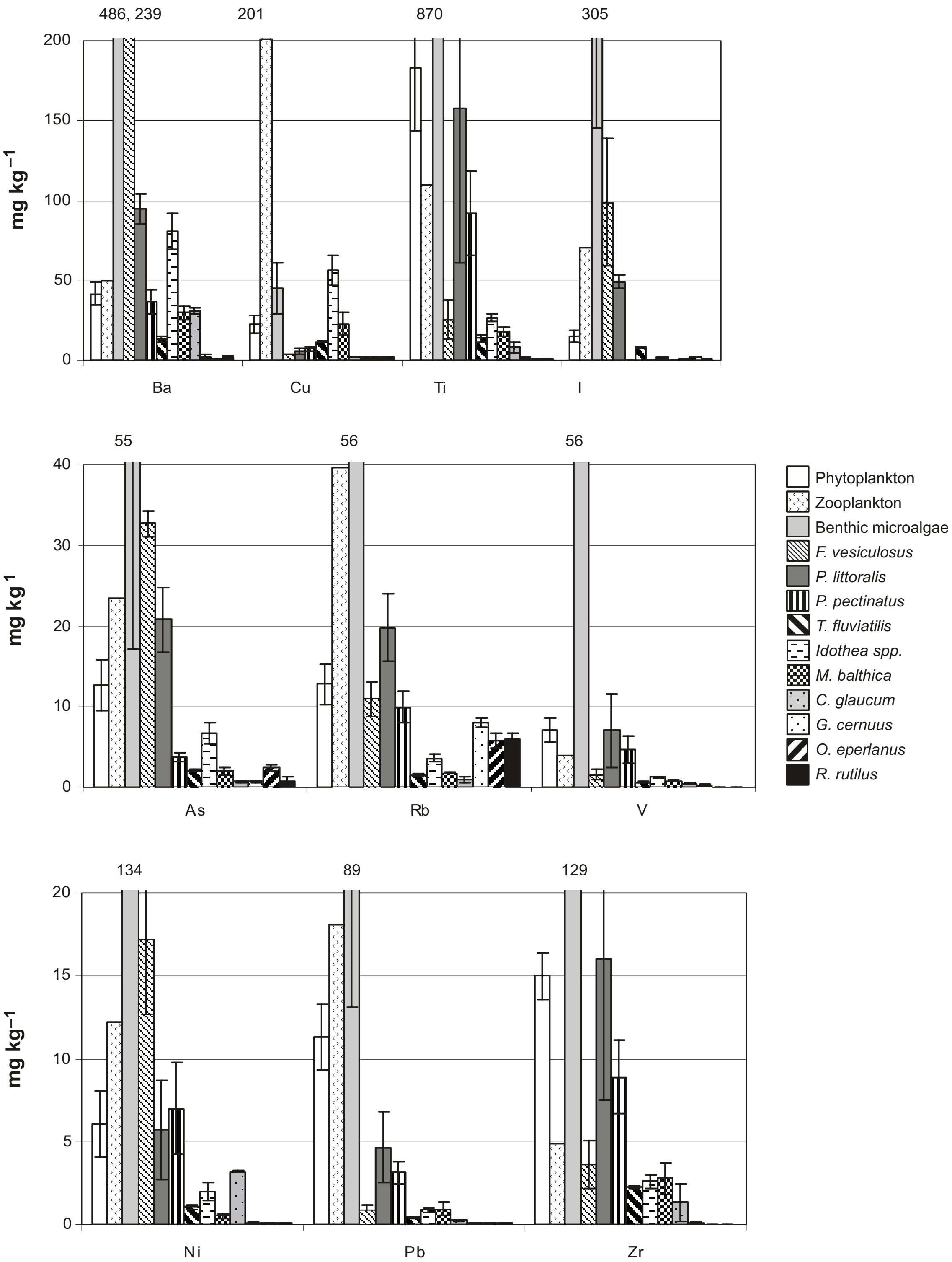

Figure 3-4. *Concentration (mg kgdw^{-1}) of Ba, Cu, Ti, I, As, Rb, V, Ni, Pb and Zr in biota in Tixlan bay, Northern Baltic Proper; mean and SD (note the different scales).*

Zirconium (Zr), **Rubidium (Rb)**, **Arsenic (As)**, **Lead (Pb)** and **Vanadium (V)** have no or very limited biological functions. **As** is known to be an ultra trace element for red algae and **V** is known to be accumulated in sea squirts where it might have a fundamental role. The concentrations of these elements in our samples followed the pattern described for Ni, i.e. highest concentration in benthic microalgae and much lower in the rest of the organisms where the highest were found in *F. vesiculosus* and the other plants (Figure 3-4). The concentrations in zooplankton were variable.

Lithium (Li) is not an essential element but can interfere with biochemical processes by interacting with phosphate-containing molecules, e.g. of the Na^+/K^+ pumps and inositol phosphates. In our study the Li concentrations were highest in plankton and benthic microalgae, but also fairly high in the plants, especially *P. littoralis.* The levels were lowest in fish (Figure 3-5).

Chromium (Cr) is an essential element for higher animals where it is an important component of the glucose tolerance factor (GTF) and LMw(Cr) complex, which are involved in glucose metabolism and insulin signalling. In higher concentrations Cr is toxic, both to animals and plants. Benthic microalgae, phytoplankton, *P. littoralis* and *P. pectinatus* had the highest Cr concentrations among the organisms analysed in this study (Figure 3-5).

Cobalt (Co) is a vital component of vitamin B12 which in turn is included in many enzymes. The Co concentrations in our samples were highest in benthic microalgae, which was a magnitude higher than in phytoplankton and plants. Among the rest of the organisms the crustacean *Idothea* spp. had the highest concentration. **Thorium (Th)** has no known biological role and show a similar concentration pattern as Co (Figure 3-5).

Selenium (Se) is an essential element to many organisms. This element occurs in a number of forms in small molecules, has quite considerable importance in reductive metabolism in bacteria, and a large number of proteins in mammals are known to contain selenium (in this case associated with oxidative metabolism). The Se concentrations in the biota included in this study showed a somewhat different pattern than most other trace elements analysed with twice as high concentrations in fish (and zooplankton) compared to all other biota (Figure 3-5).

Cadmium (Cd) has no biological role and is a toxic metal to most organisms. The concentrations of the organisms in this study (up to 5 mg kg dw^{-1}) were in the same range as found for herring (liver) sampled at Landsort in the Swedish EPA monitoring project during the last 10 years (1–4 mg kg dw^{-1}). Among the samples in this study zooplankton, *F. vesiculosus*, benthic microalgae and *Idothea* spp. had the highest concentrations (Figure 3-5). The concentrations of **mercury (Hg)**, which is also a toxic metal, were quite low in all samples. Hg levels in herring muscle sampled in the southern Bothnian Bay have ranged between approximately 0.05 to 0.1 mg kg ww^{-1} in Naturvårdsverket's monitoring program. The Hg concentration in fish in this study were approximately 0.3 mg kg dw^{-1} in all species which is similar to the monitoring program.

Molybdenum (Mo) is present in many enzymes, e.g. in nitrogenases which are the enzymes used by some organisms to fix atmospheric nitrogen gas (N_2). The Mo concentrations in these samples were quite similar among the different species with the exception of benthic microalgae and *P. pectinatus* which had about a magnitude higher concentration (Figure 3-5).

The **caesium (Cs)** concentrations were in the same range as e.g. Mo and also quite even between the species, which the exception of benthic microalgae (that was about one magnitude higher than the others) (Figure 3-5).

In Figure 3-6 the concentrations of **actinides** and **lanthanides** in biota are shown. None of these elements have any known biological functions. The concentrations were low, less than 0.05 mg kg dw^{-1} for all elements in all biota, except for in zooplankton, where the concentrations were much higher than in the other biota. For cerium (**Ce**) and neodymium (**Nd**) the concentrations were slightly higher in all biota compared to the other actinides and lanthanides.

The information on biological uses of the various elements is drawn mainly from /Fraústo da Silva and Williams 2001, Sterner and Elser 2002/, where more details can also be found.

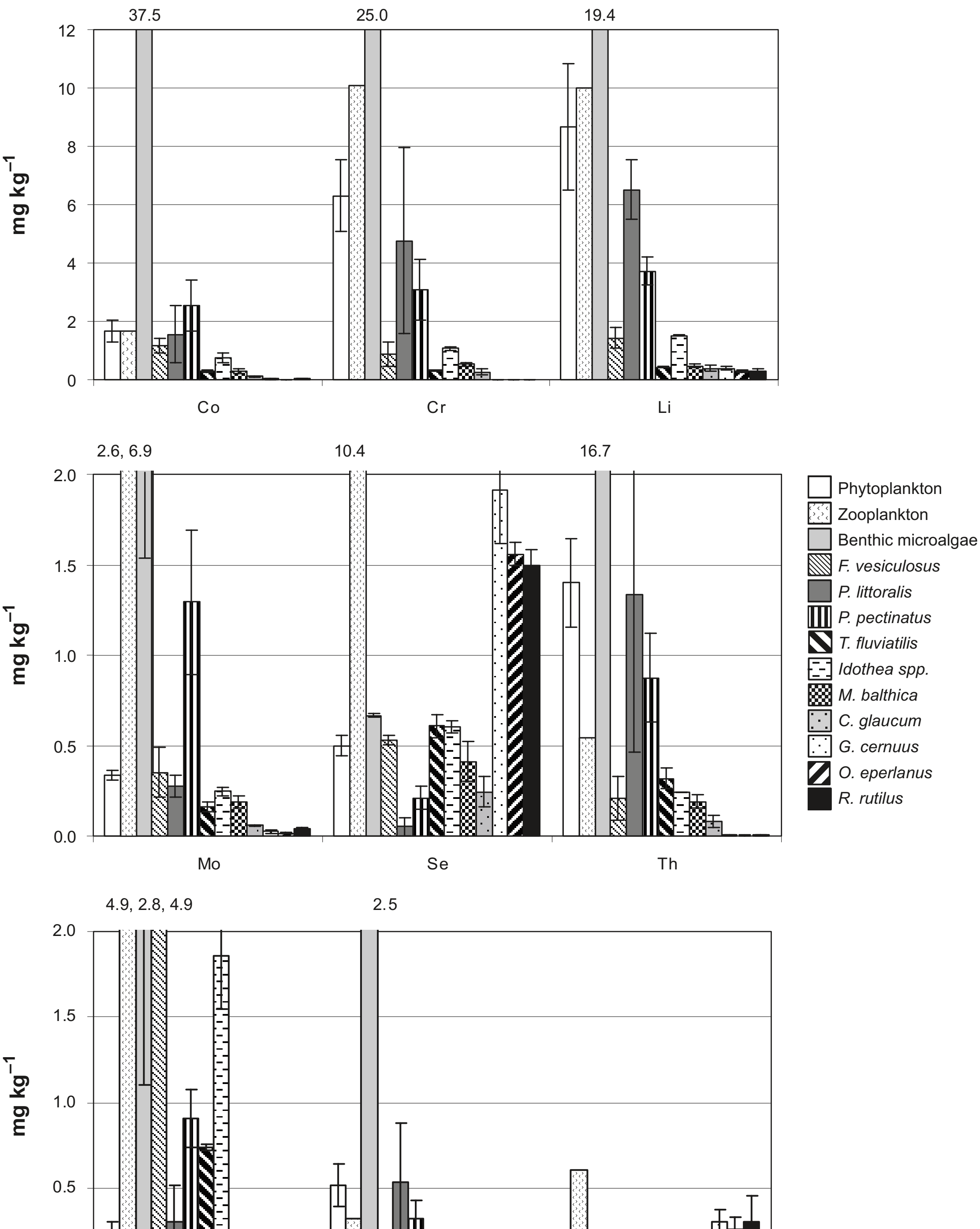

Figure 3-5. *Concentration (mg kgdw^{-1}) of Co, Cr, Li, Mo, Se, Th, Cd, Cs and Hg in biota in Tixlan bay, Northern Baltic Proper; mean and SD (note the different scales).*

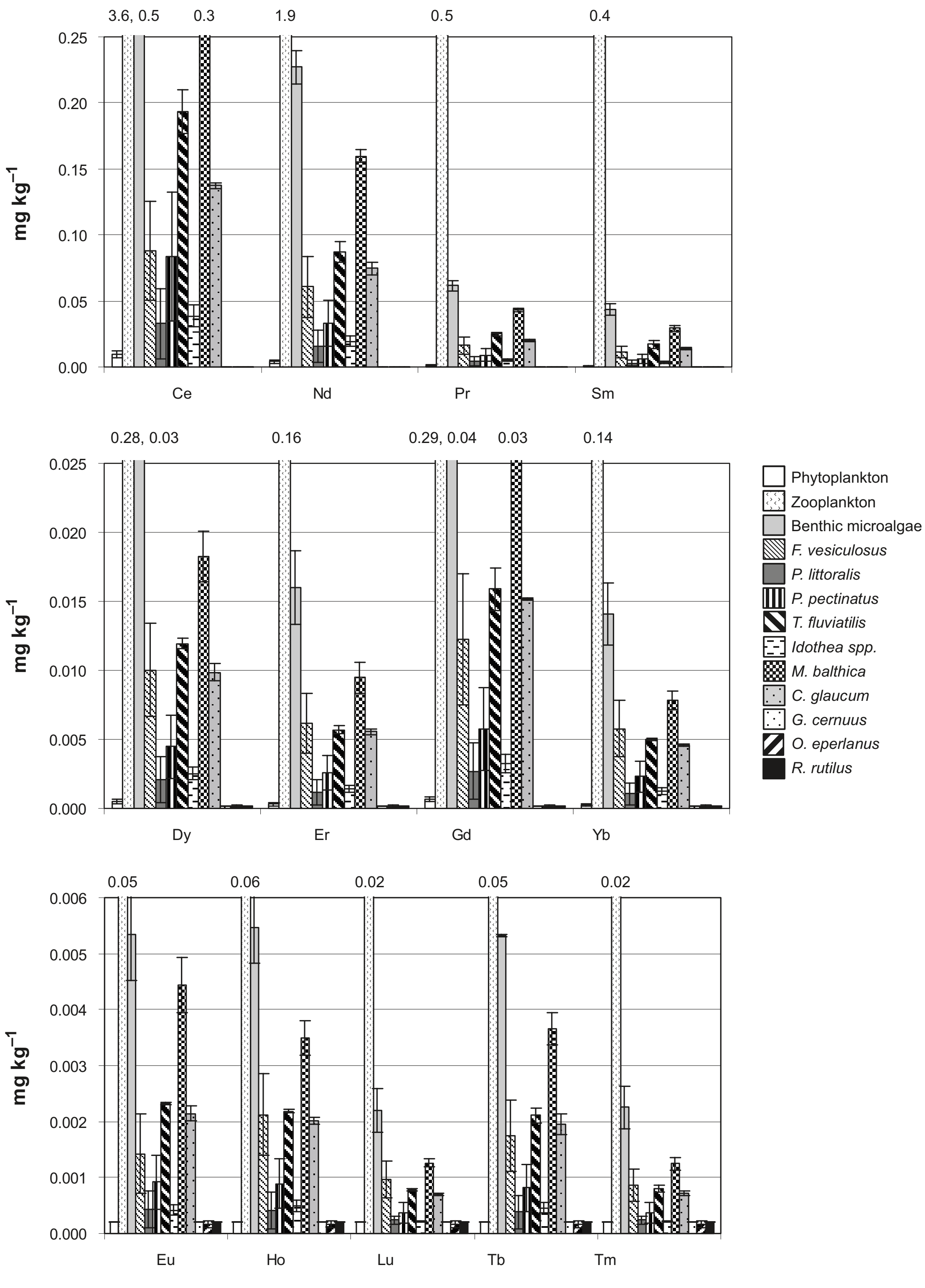

Figure 3-6. *Concentration (mg kgdw^{-1}) of Ce, Nd, Pr, Sm, Dy, Er, Gd, Yb, Eu, Ho, Lu, Tb and Tm in biota in Tixlan bay, Northern Baltic Proper; mean and SD (note the different scales).*

3.2 CNP stoichiometry

In Tables 3-1, 3-2 and 3-3 the carbon, nitrogen and phosphorus composition of the ecosystem components of Tixlan Bay are presented in various forms.

The C, N and P content differ between the different components (Table 3-1). The plants and the fish have the highest amounts of carbon (28–48% dry weight) compared to the rest of the organisms. The least amount of carbon was found in phytoplankton and the molluscs (15–17%). The nitrogen content was substantially higher in fish (11–12%) than other organisms (1–3%), with the exception of zooplankton (10%). The same pattern was shown for phosphorus, where the fish consisted of 2–3.5% P, zooplankton 1% and the rest 0.1–0.3% P.

Both the upper (0–3 cm) and lower (3–6 cm) sediment layer had low organic content, only 0.4/0.2% C, 0.05/0.03% N and 0.04/0.03% P (% dry weight). The particulate matter in the water column had a substantially higher content of organic matter than the sediment particles; 3.3% C, 0.4% N and 0.06% P.

Site specific ratios of C, N and P in organisms, DIM, POM and sediment from the Tixlan Bay, both on weight basis and molar basis are presented in Table 3-2.

In Table 3-3 conversion factors for converting data to/from wet weight, dry weight or carbon weight, are presented for all biota (data are derived from the sample preparation).

Table 3-1. Concentrations of carbon (C), nitrogen (N) and phosphorus (P) in biota, POM, DIM and sediment (% of dw, g/kg dw, mol/kg dw). Samples were analysed at Department of Systems Ecology, Stockholm University.

	% of dw			g kg dw^{-1}			mol kg dw^{-1}		
	C	N	P	C	N	P	C	N	P
Phytoplankton	17.37	2.11	0.13	173	21	1	14.46	1.50	0.04
Benthic microalgae	14.40	1.67	0.27	144	17	3	11.99	1.19	0.09
F. vesiculosus	37.33	2.17	0.12	373	22	1	31.08	1.55	0.04
P. littoralis	28.47	2.54	0.29	285	25	3	23.70	1.81	0.09
P. pectinatus	36.10	1.84	0.24	361	18	2	30.06	1.31	0.08
Zooplankton	42.70	9.71	0.95	427	97	9	35.55	6.93	0.31
T. fluviatilis	16.45	1.46	0.13	165	15	1	13.70	1.04	0.04
Idothea spp	23.39	2.92	0.30	234	29	3	19.47	2.08	0.10
M. baltica	17.13	1.36	0.15	171	14	2	14.27	0.97	0.05
C. glaucum	15.35	1.01	0.11	154	10	1	12.78	0.72	0.03
G. cernuus	41.20	10.77	3.44	412	108	34	34.30	7.69	1.11
O. eperlanus	48.20	11.57	1.98	482	116	20	40.13	8.26	0.64
R. rutilus	42.83	11.47	2.96	428	115	30	35.66	8.19	0.95
POM (L^{-1})	3.75E–5	4.30E–6	6.40E–7	3.75E–4	4.30E–5	6.40E–6	3.12E–5	3.07E–6	2.07E–7
POM (g dw^{-1} part.)	3.26	0.37	0.06	33	4	1	2.71	0.27	0.02
DIM (L^{-1})	1.46E–3	2.18E–5	5.57E–7	1.46E–2	2.18E–4	5.57E–6	1.22E–3	1.56E–5	1.80E–7
Sediment 0–3 cm	0.44	0.05	0.04	4	1	0	0.37	0.04	0.01
Sediment 3–6 cm	0.24	0.03	0.03	2	0	0	0.20	0.02	0.01

Table 3-2. C:N, C:P and N:P ratios based on weight and moles for biota, POM, DIM and sediment from Tixlan Bay, Northern Baltic Proper.

	Based on weight			Based on mol		
	C:N	C:P	N:P	C:N	C:P	N:P
Phytoplankton	8.3	133.7	16.1	9.6	344.9	35.7
Benthic microalgae	8.6	54.0	6.3	10.0	139.3	13.9
F. vesiculosus	17.3	301.5	17.5	20.2	777.5	38.7
P. littoralis	11.2	100.6	8.9	13.1	259.5	19.7
P. pectinatus	19.7	154.3	7.9	23.0	398.0	17.4
Zooplankton	4.4	45.0	10.2	5.1	116.2	22.6
T. fluviatilis	11.8	135.6	11.4	13.7	349.8	25.3
Idothea spp	10.4	99.9	9.6	12.2	257.5	21.2
M. baltica	12.6	115.1	9.1	14.7	296.9	20.1
C. glaucum	15.3	145.0	9.5	17.9	374.0	21.0
G. cernuus	3.8	12.0	3.1	4.5	31.0	6.9
O. eperlanus	4.2	24.5	5.9	4.9	63.1	13.0
R. rutilus	3.7	14.7	3.9	4.4	37.9	8.7
POM	8.7	59.2	6.8	10.1	152.7	15.0
DIM	67.3	2,662.7	39.4	78.5	6,866.6	87.2
Sediment 0–3 cm	8.3	13.7	1.6	9.7	35.2	3.6
Sediment 3–6 cm	9.1	8.0	0.9	10.6	20.5	2.0

Table 3-3. Conversion factors to/from wet content, dry content, carbon content (on weight basis) for biota, POM and sediment from Tixlan Bay, Northern Baltic Proper.

	Wet content % ww	Dry content % dw	Dry to wet gdw / gww	Wet to dry gww / gdw	Carbon to dry gC / gdw	Dry to carbon gdw / gC
Phytoplankton	97.93	2.07	0.02	48.31	0.17	5.76
Benthic microalgae	94.24	5.76	0.06	17.35	0.14	6.94
F. vesiculosus	79.26	20.74	0.21	4.82	0.37	2.68
P. littoralis	91.83	8.17	0.08	12.24	0.28	3.51
P. pectinatus	88.88	11.12	0.11	9.00	0.36	2.77
Zooplankton	99.17	0.83	0.01	121.12	0.43	2.34
T. fluviatilis	67.00	33.00	0.33	3.03	0.16	6.08
Idothea spp	83.32	16.68	0.17	5.99	0.36	2.77
M. baltica	67.05	32.95	0.33	3.03	0.17	5.84
C. glaucum	69.27	30.73	0.31	3.25	0.15	6.51
G. cernuus	84.01	15.99	0.16	6.26	0.43	2.33
O. eperlanus	84.04	15.96	0.16	6.27	0.41	2.43
R. rutilus	90.81	9.19	0.09	10.89	0.48	2.07
POM	99.999	0.001	0.00001	87,719	0.03	30.69
Sediment 0–3 cm	24.03	75.97	0.76	1.32	0.004	225.56
Sediment 3–6 cm	22.93	77.07	0.77	1.30	0.002	416.67

The correlation between phosphorus and nitrogen concentrations in the organisms included in this study shows a clear increase with trophic level (Figure 3-7). This is because the higher trophic levels are occupied by more advanced organisms (fish) which both have more advanced biochemistry (involving phosphate-rich compounds such as ATP, GTP, NADPH) and have a skeleton which is a phosphate-rich tissue.

The trends shown in Figure 3-7 are confirmed by multivariate analysis of the data (Figure 3-8), where there is a gradient from sediment (low C) to fish (high C) (right to left) and where the fish cluster out separately from the other organisms due to their high P content.

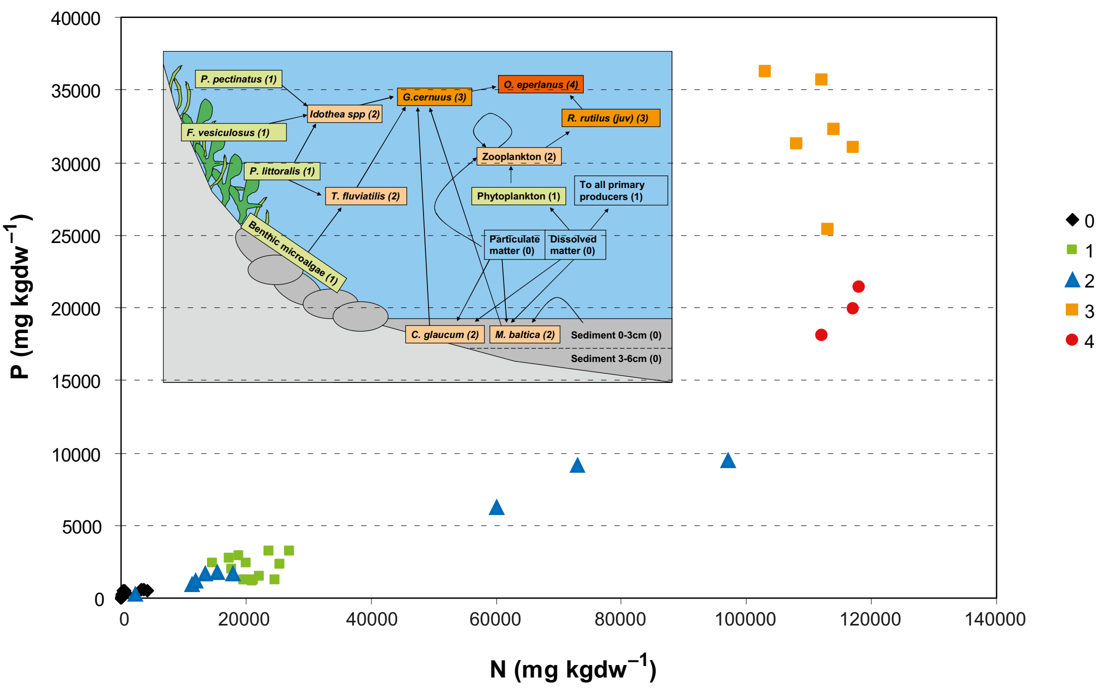

Figure 3-7. *Correlation between phosphorus (P) and nitrogen (N) concentrations in organisms at five trophic levels.*

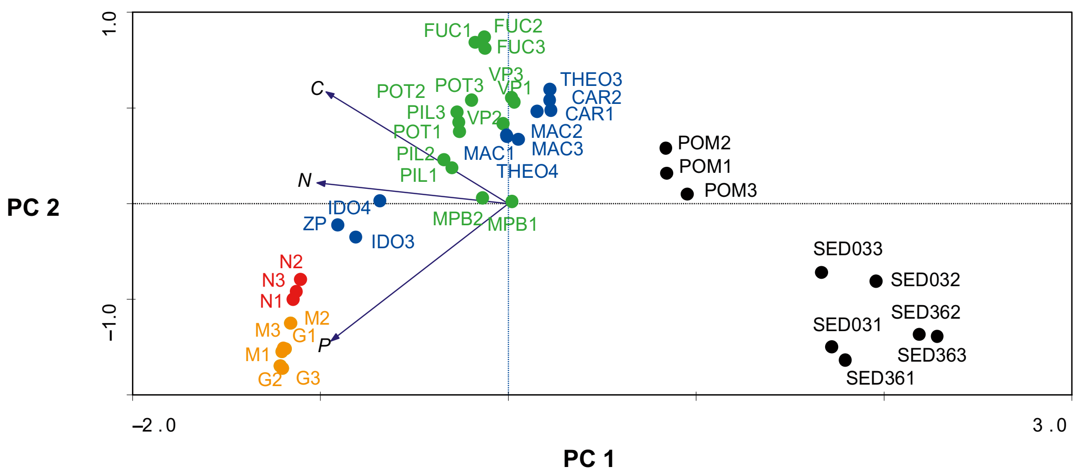

Figure 3-8. *PCA plot based only on CNP data (concentrations by dry weight). Colours represent trophic level: black = trophic group 0 (sediment (SED), particulate organic matter (POM)); green = trophic group 1 (primary producers – macroalgae (PIL, FUC, POT), phytoplankton (VP), benthic microalgae (MPB)), blue = trophic group 2 (primary consumers – molluscs (THEO, MAC, CAR), crustaceans (IDO), zooplankton (ZP)), orange = trophic group 3 (secondary consumers – R. rutilus (M) and G. cernuus (G)), red = trophic group 4 (tertiary consumers – O. eperlanus (N)).*

3.3 Multivariate data analysis

Figures 3-9 and 3-10 present multivariate PCA plots based on two subsets of the dataset (see 2.2.10). Individual samples and sample types that cluster close to each other have a more similar elemental composition those that are more distant.

Each type of sample clusters separately from the other sample types, indicating a distinct elemental composition. Due to the multidimensional nature of the data it is difficult to draw direct conclusions from these PCA plots as to which elements most influence the sample clusters. However, similarity percentages (SIMPER) analysis could in some cases indicate which elements were particularly influential, and these could be easily explained, for example:

- high concentration of Si in phytoplankton and in benthic microalgae indicates abundant diatoms,
- high concentration of Ca in molluscs (shell) and fish (bone),
- sediment samples are similar because of a combination of slightly higher concentrations of Fe, Al, Ca, Mg.

More interestingly, broader categories of sample types (e.g. primary producers, consumers, trophic groups) also show similarities and often cluster together in the same area of the plots.

The first principle component (PC1) generally explains around 55% of the multivariate variation. It separates POM and, to a lesser degree, zooplankton and fish, from the rest of the samples. PC1 is strongly affected by the higher than average concentrations of lanthanoid elements in POM, which is possibly an artefact. Otherwise, a few of the trace elements also contribute, for example, Cr, Mo, Ba, Cd, Cs.

The second and third components account for approximately 20% and 13% of the variation, respectively, and separate out most of the sample groups from each other. Benthic microalgae and fish lie furthest out on PC2, which is particularly influenced by Fe, Co, Ni, V, Mn, I and Th. Benthic microalgae, sediment and *F. vesiculosus* lie along PC3, where S, C, Mg, N and Zr are important.

3.4 Biomagnification factors (BMF)

Tables 3-4a and b present biomagnification factors (BMF) calculated for animals assumed to consume food according to three different pathways in the ecosystem (Figure 3-11); BMFs in Table 3-4a are based on dry weight and in 6b on wet weight. The tables present how many times higher the concentration of an element in an organism is compared to the concentration in the food source. The estimated biomagnification factors are colour coded from yellow to dark orange (where yellow represent 5–9 times higher concentration in the organism, pale orange 10–99, dark orange > 100 times higher).

There were no clear patterns or trends in the BMF data from this study. Apart from the biomagnification factors estimated for zooplankton there were only a few elements that showed an accumulation more than one order of magnitude higher in the organism compared to its food source, based either on wet weight or on dry weight. BMFs (on dry weight basis) that were 10 or higher in food **pathway I** were found for two organisms and elements only; *Idothea* spp. that had a BMF of 14 for Cu, and *G. cernuus* that had a BMF of 10 for Hg (Table 3-4a). BMFs for pathway I on wet weight basis were very similar to those based on dry weight.

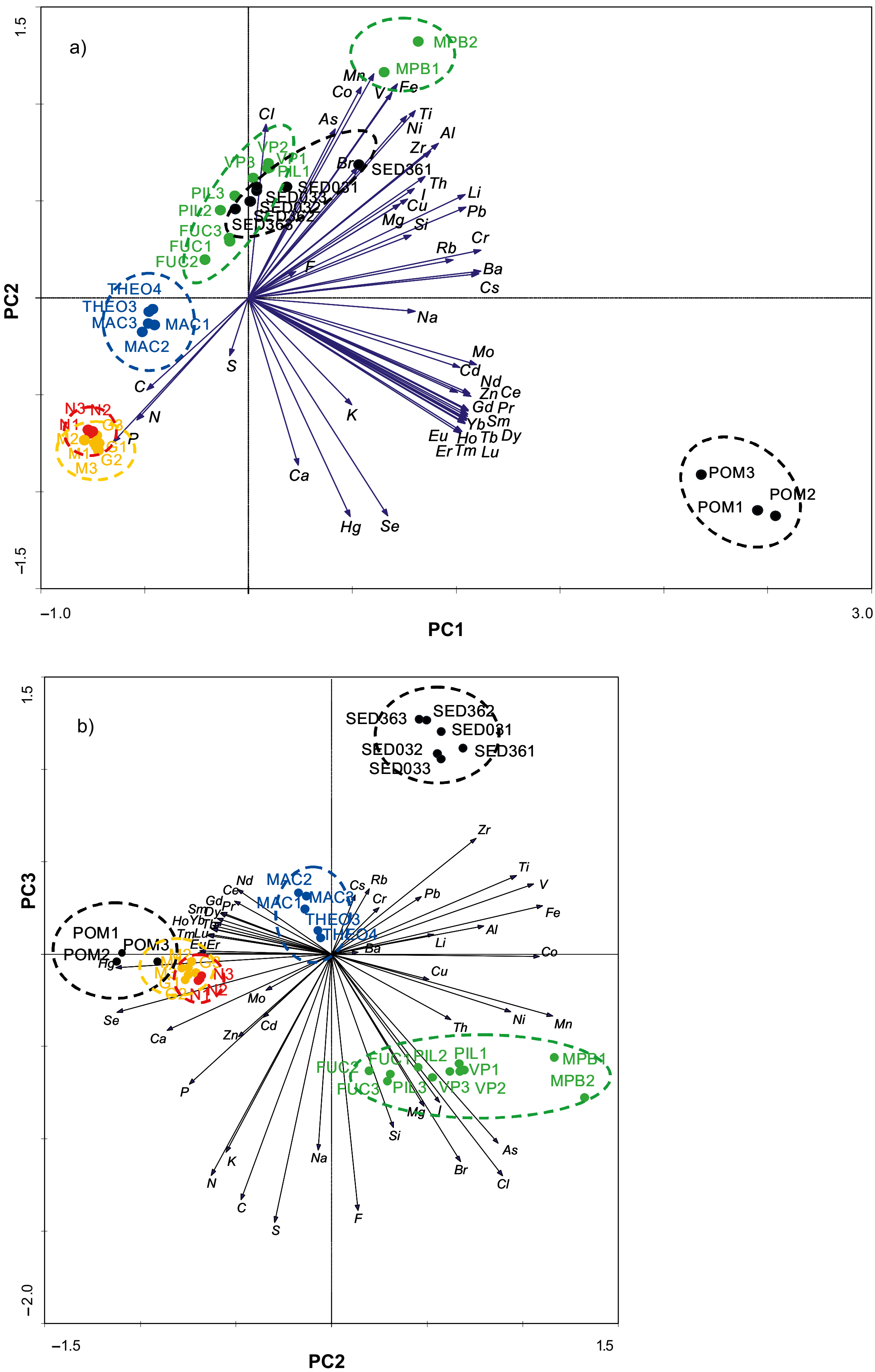

Figure 3-9. *PCA plot based on concentrations (mg kg dw^{-1}) of all elements for all samples except DIM, PW POT, IDO, CAR, ZP: a) first and second components (PC1, PC2), b) 2nd and 3rd components (Colour coding in all graphs is trophic level, as described in Figure 3-8).*

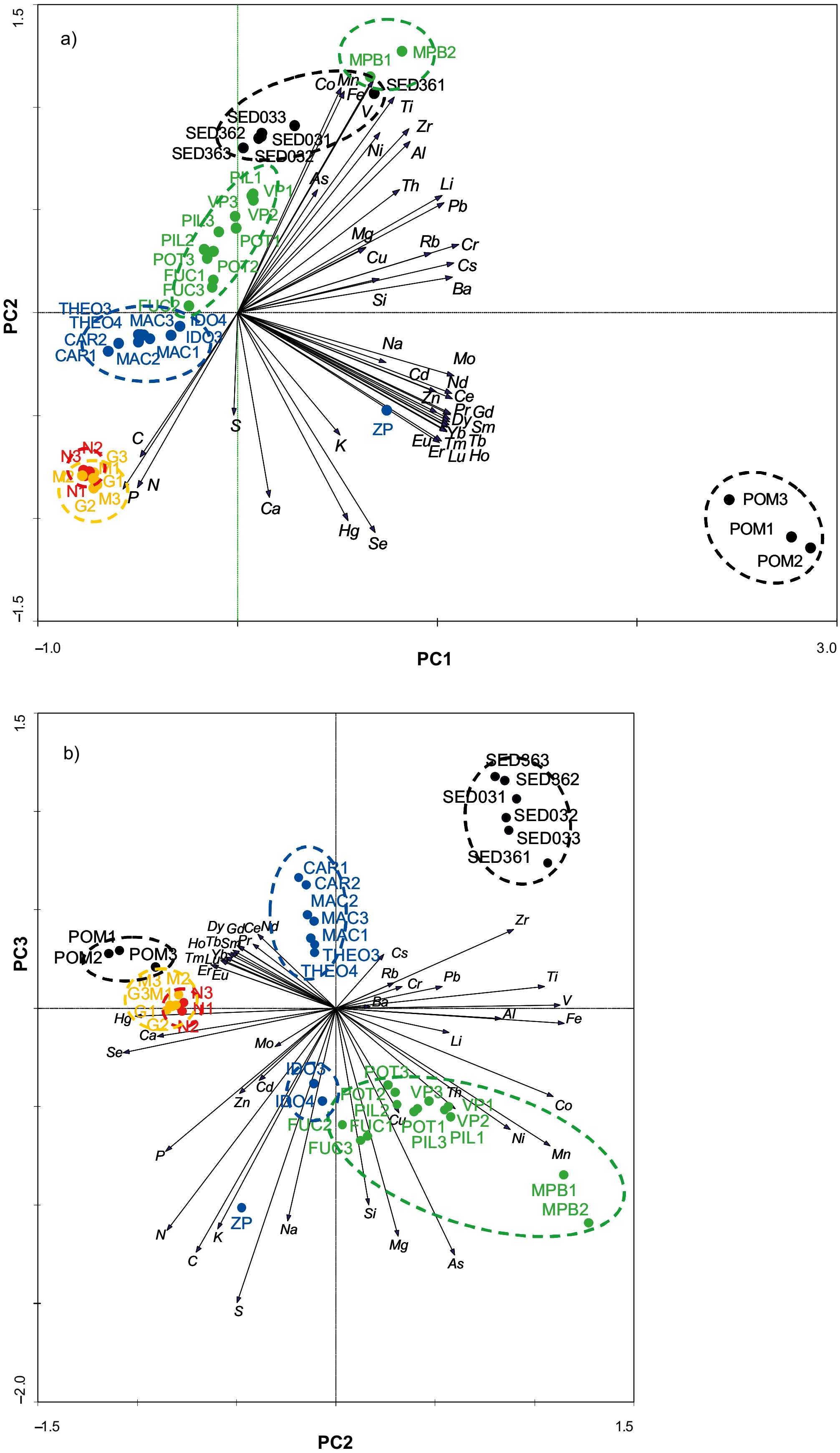

Figure 3-10. *PCA plot based on all samples except DIM and PW and concentrations (mg kgdw^{-1}) of all elements except Cl, Br, I, F: a) first and second components (PC1, PC2), b) 2nd and 3rd components (Colour coding in all graphs is trophic level, as described in Figure 3-8).*

Table 3-4a. Biomagnification factors (BMF) [(mg/kgdw)/(mg/kgdw)] for organisms in the three trophic transfer pathways: (I) *F. vesiculosus* – *Idothea* spp. – *G. cernuus* (ruffe) – *O. eperlanus* (smelt), (II) Sediment – *M. baltica* – *G. cernuus* (ruffe) – *O. eperlanus* (smelt), (III) Phytoplankton – Zooplankton – *R. rutilus* (roach) – *O. eperlanus* (smelt). The estimates were based on concentration per dry weight biota and concentration in their respective food source.

	***Idothea* spp.**	*G. cernuus*	*O. eperlanus*	*M. baltica*	*G. cernuus*	*O. eperlanus*	**Zoo-plankton**	*R. rutilus*	*O. eperlanus*
Al	1	0	0	0	0	0	1	0	1
As	0	0	3	1	0	3	2	0	3
Ba	0	0	0	0	0	0	1	0	0
Br			1	1	1	1	10	0	2
C	1	1	1	39	2	1	2	1	1
Ca	8	0	0	158	0	0	26	0	0
Cd	0	0	1	1	0	1	20	0	0
Ce	0	0	1	0	0	1	374	0	1
Cl			1	2	1	1			2
Co	1	0	1	0	0	1	1	0	0
Cr	1	0	0	0	0	0	2	0	1
Cs	1	0	2	0	1	2	1	0	3
Cu	14	0	1	4	0	1	9	0	1
Dy	0	0	1	0	0	1	525	0	1
Er	0	0	1	0	0	1	526	0	1
Eu	0	0	1	0	0	1	240	0	1
F			1	33	1	1			1
Fe	1	0	1	0	0	1	1	0	0
Gd	0	0	1	0	0	1	435	0	1
Hg	1	10	1	0	8	1	11	1	1
Ho	0	0	1	0	0	1	300	0	1
I			2	0	1	2	5	0	2
K	0	2	1	1	11	1	7	0	1
Li	1	0	1	0	1	1	1	0	1
Lu	0	1	1	0	0	1	120	0	1
Mg	1	0	1	0	4	1	4	0	1
Mn	0	0	1	0	0	1	0	0	1
Mo	1	0	1	1	0	1	8	0	0
N	3	2	1	26	8	1	5	1	1
Na	1	0	1	1	1	1	4	0	1
Nd	0	0	1	0	0	1	460	0	1
Ni	0	0	1	0	0	1	2	0	1
P1	6	4	1	4	23	1	7	3	1
P2	5	5	0	6	18	0	27	0	1
Pb	1	0	1	0	0	1	2	0	1
Pr	0	0	1	0	0	1	441	0	1
Rb	0	2	1	0	5	1	3	0	1
S	0	1	1	3	8	1	7	0	1
Se	1	3	1	8	5	1	21	0	1
Si	1	0	1	0	0	1	1	0	3
Sm	0	0	1	0	0	1	496	0	1
Tb	0	0	1	0	0	1	240	0	1
Th	1	0	1	0	0	1	0	0	1
Ti	1	0	0	0	0	0	1	0	0
Tm	0	1	1	0	0	1	120	0	1
V	1	0	0	0	0	0	1	0	1
Yb	0	0	1	0	0	1	521	0	1
Zn	0	1	1	1	2	1	3	0	0
Zr	1	0	0	0	0	0	0	0	1
			= 5–9			= 10–99			> 100

Table 3-4b. Bioamagnification factors (BMF) [(mg/kgww)/(mg/kgww)] for organisms in the three trophic transfer pathways: (I) *F. vesiculosus* – *Idothea* spp. – *G. cernuus* (ruffe) – *O. eperlanus* (smelt), (II) Sediment – *M. baltica* – *G. cernuus* (ruffe) – *O. eperlanus* (smelt), (III) Phytoplankton – Zooplankton – *R. rutilus* (roach) – *O. eperlanus* (smelt). The estimates were based on concentration per dry weight biota and concentration in their respective food source.

	***Idothea* spp.**	*G. cernuus*	*O. eperlanus*	*M. baltica*	*G. cernuus*	*O. eperlanus*	**Zoo-plankton**	*R. rutilus*	*O. eperlanus*
Al	1	0	0	0	0	0	0	0	2
As	0	0	3	0	0	3	1	0	5
Ba	0	0	0	0	0	0	0	0	0
Br			1	1	0	1	4	0	3
C	1	1	1	3	2	1	1	7	1
Ca	7	0	0	68	0	0	10	4	1
Cd	0	0	1	0	0	1	8	0	1
Ce	0	0	1	0	0	1	149	0	1
Cl			1	1	0	1			3
Co	1	0	1	0	0	1	0	0	1
Cr	1	0	0	0	0	0	1	0	1
Cs	1	0	2	0	0	2	0	1	5
Cu	12	0	1	2	0	1	4	0	1
Dy	0	0	1	0	0	1	209	0	1
Er	0	0	1	0	0	1	210	0	1
Eu	0	0	1	0	0	1	96	0	1
F			1	14	0	1			2
Fe	1	0	1	0	0	1	0	0	1
Gd	0	0	1	0	0	1	173	0	1
Hg	1	9	1	0	4	1	4	6	1
Ho	0	0	1	0	0	1	120	0	1
I			2	0	0	2	2	0	4
K	0	2	1	0	6	1	3	2	2
Li	1	0	1	0	0	1	0	0	2
Lu	0	1	1	0	0	1	48	0	1
Mg	1	0	1	0	2	1	1	1	1
Mn	0	0	1	0	0	1	0	1	1
Mo	1	0	1	0	0	1	3	0	1
N	3	2	1	2	8	1	2	8	1
Na	1	0	1	1	0	1	2	0	2
Nd	0	0	1	0	0	1	183	0	1
Ni	0	0	1	0	0	1	1	0	2
P1	6	4	1	0	23	1	3	22	1
P2	4	4	0	2	9	0	11	5	1
Pb	1	0	1	0	0	1	1	0	1
Pr	0	0	1	0	0	1	176	0	1
Rb	0	2	1	0	2	1	1	2	2
S	0	1	1	1	4	1	3	2	1
Se	1	3	1	4	2	1	8	2	2
Si	1	0	1	0	0	1	0	0	5
Sm	0	0	1	0	0	1	198	0	1
Tb	0	0	1	0	0	1	96	0	1
Th	1	0	1	0	0	1	0	0	2
Ti	1	0	0	0	0	0	0	0	1
Tm	0	1	1	0	0	1	48	0	1
V	1	0	0	0	0	0	0	0	2
Yb	0	0	1	0	0	1	208	0	1
Zn	0	1	1	0	1	1	1	2	1
Zr	1	0	0	0	0	0	0	0	2
			= 5–9			= 10–99			> 100

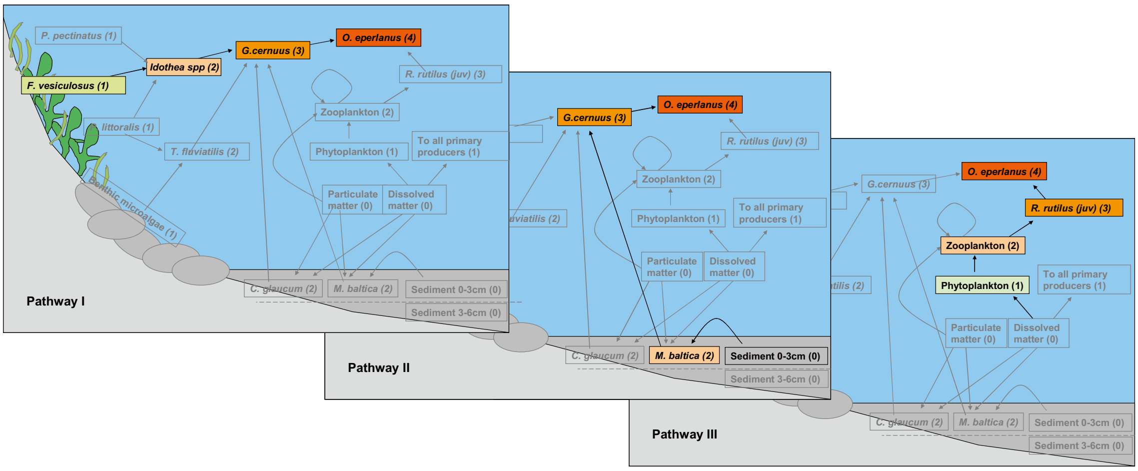

Figure 3-11. *Assumed food pathways for organisms for which the transfer of elements between organisms have been estimated (Table 3-4a and 3-4b).*

In food **pathway II** BMFs (on dry weight basis) were 10 or higher only for macroelements. For *M. baltica* the BMFs for C, F and N were 39, 33 and 26 respectively. The BMF for Ca (also in *M. baltica*) was 158, which probably is due to its Ca-rich shell. *G. cernuus* in food pathway II had a BMF for K and P of 11 and 23/18 respectively compared to their food source *M. baltica*, which probably is a result of the more advanced biochemistry in fish compared to molluscs. The BMFs for food pathway II based on wet weight were slightly lower than those based on dry weight.

Food **pathway III** suggests high BMFs for most elements in zooplankton, including lanthanoids and actinoids (see also Figure 3-6). However, these estimates must be used with caution since the zooplankton data only originate from one integrated sample. BMFs based on zooplankton concentrations are also strongly affected by whether they are based on wet or dry weight, due to the high water content of zooplankton.

3.5 Bioconcentration factors (BCFs)

Bioconcentration factors were calculated for all elements and all types of biota, based on the difference between biota concentrations and dissolved concentrations in the water (DIM). Two sets of bioconcentration factors were calculated, based either on wet weight or C content data (Appendices 21–28); the main trends are presented in Table 3-5.

Bioconcentration factors based on the difference between biota concentrations and the total concentrations in the water (i.e. dissolved (DIM) *and* particulate (POM) matter) showed similar trends, apart from a few notable differences:

- Al and Ti were no longer among the highest BCF values,
- Cu and C had appeared amongst the five highest for some of the invertebrates (Cu) and fish (C),
- Mn and Fe were no longer among the lowest BCFs,
- The following elements were present among the lowest BCFs; Er (primary producers and *Idothea* spp.), Ba (various), and Ce, Nd, Al (fish).

Table 3-5. The elements and biota which showed the highest and lowest BCFs. The summary is based on the five highest and five lowest BCF values for each biota type.

BCF based on biota/DIM (either by wet wt or C-content)		
Highest BCFs	Al, Ti	All biota except fish.
	Fe	All biota except fish (and except *Idothea* when based on C).
	Mn	Benthic microalgae (and *P. pectinatus*, *T. fluviatilis* when based on weight).
	Hg	Fish.
	N	Fish (and *Idothea* when based on C).
	P	All except benthic microalgae.
	Si	Phytoplankton.
	Co	Benthic microalgae.
	Cd	F. vesiculosus.
	Se	*G. cernuus*, *O. eperlanus.*
	Zn	*R. rutilus* (and zooplankton when based on C).
Lowest BCFs	Ho, Eu	Phytoplankton.
	Na	All except phytoplankton.
	S	*T. fluviatilis*, *M. balthica*, *C. glaucum* (and zooplankton when based on C).
	Li	*F. vesiculosus*, *C. glaucum* (and zooplankton when based on C).
	Lu	Phytoplankton, *P. littoralis*, *P. pectinatus*, *Idothea*.
	Mg	All except phytoplankton, *F. vesiculosus*, *P. littoralis* (and *P. pectinatus*/ zooplankton depending on method).
	K	C. glaucum.
	Mn, Fe	Zooplankton.
	Tm	Phytoplankton, *P. pectinatus*, *Idothea.*
	Tb	All except *T. fluviatilis*, *M. balthica*, *C. glaucum* (and except zooplankton when based on weight).
	Br and Cl	All biota where measured except phytoplankton.

3.6 Partitioning coefficients (K_d)

Partitioning coefficients (K_d) were estimated from the concentrations of all elements in POM and water (Figure 3-12a, K_dI in Appendix 29) and in the sediment and the porewater (Figure 3-12b, K_dII and K_dIII in 29). Since the sediment cores sampled were divided into an upper part (0–3 cm depth) and a lower (3–6 cm depth), two sediment K_d values per element have been calculated.

The K_d values for water (i.e. POM/DIM) ranged over eight orders of magnitude, from Al (K_d 74,671 (kg/kgdw)/(kg/m^3)) and Zn (63,643) to Cl (0.0005) and Br (0.01) (elements with $K_d > 1$ shown in Figure 3-12a). The elements with $K_d < 1$ were As, F, Na, Mg, S, Br and Cl (in decreasing order of K_d values). Apart from Al and Zn, the next highest K_d were found for Ti, Ba, Ce, Cd and Zr (also in decreasing order).

A K_d-value above 1,000 indicates that the element concentration was higher in the dissolved than in the particulate phase (since K_d expresses the concentration of the particulate fraction (kg/kgdw) in relation to the dissolved fraction (kg/m^3)), For the water this is the case for Al, Zn, Ti, Ba, Ce, Cd, Zr, Si and Fe, and for the sediment this was the case for Zr, Ti and Al (only in the lower part of the sediment).

Figure 3-12b presents sediment K_d values for those elements having a K_d value of one or higher.

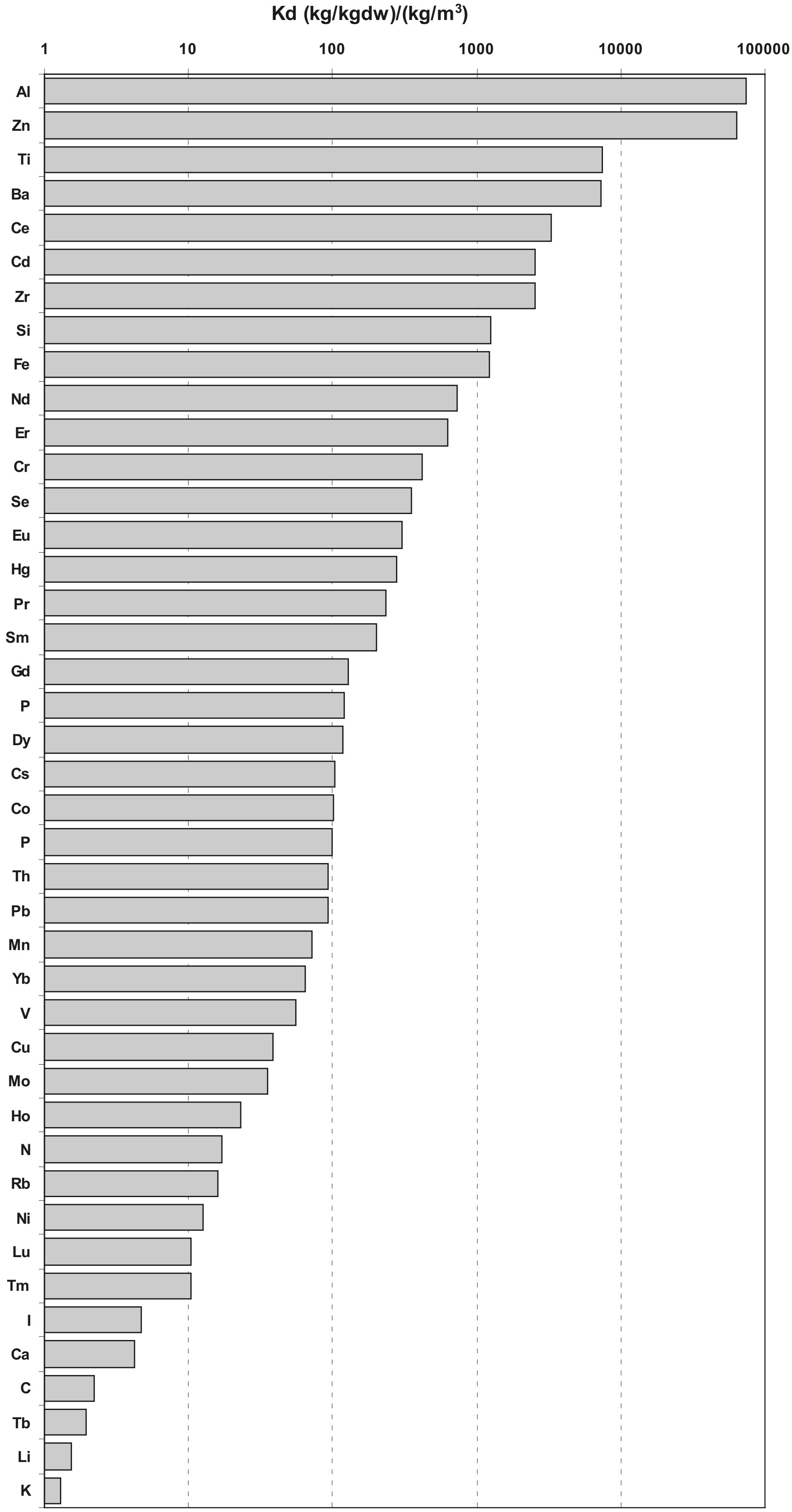

Figure 3-12a. *Partitioning coefficients (K_d) [(kg/kgdw)/(kg/m^3)] for water (POM/DIM, n = 3/3), Tixlan Bay, Northern Baltic Proper. Only elements having a Kd value higher than 1 are shown in the graph.*

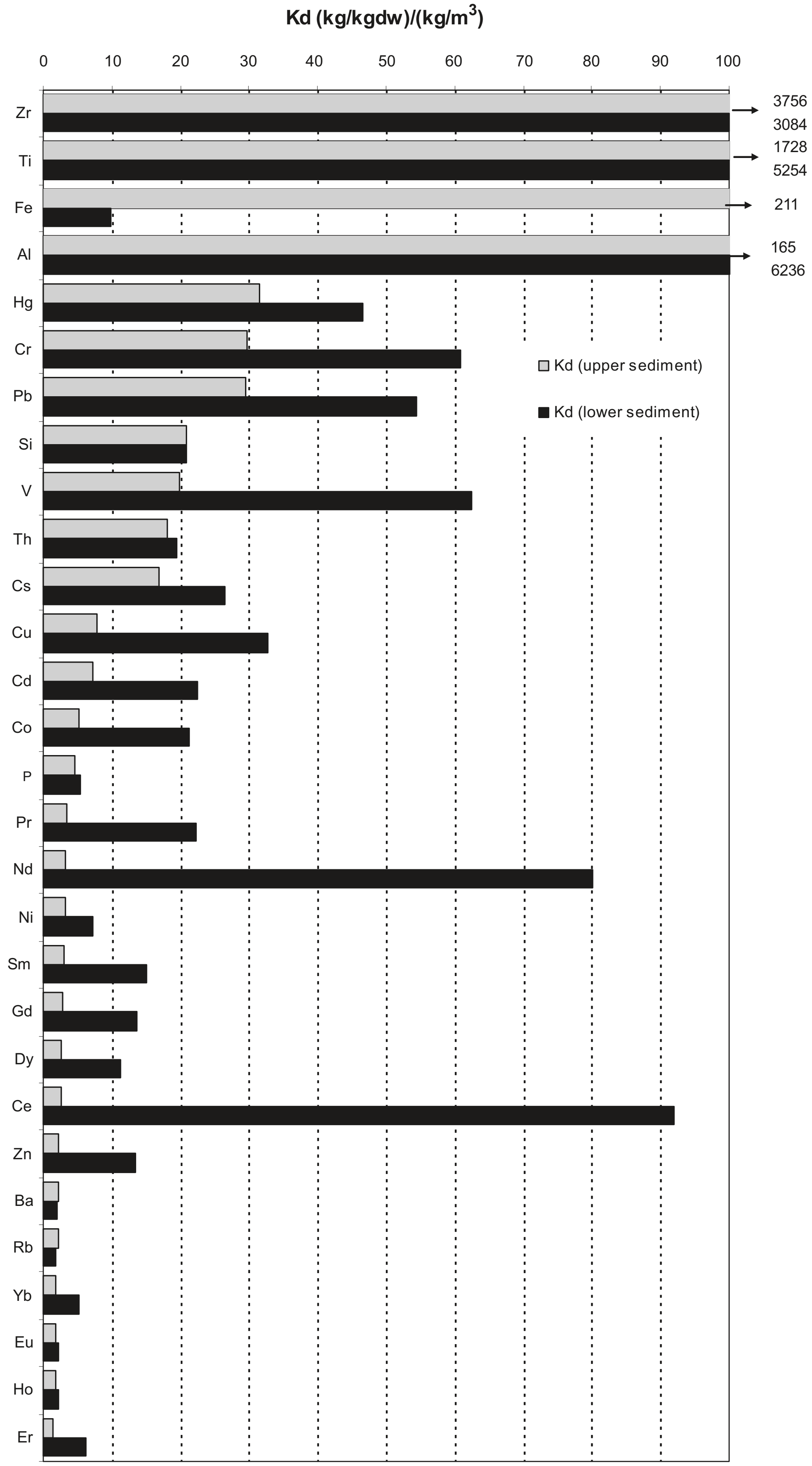

Figure 3-12b. *Partitioning coefficients (K_d) [(kg/kgdw)/(kg/m^3)] for upper sediment (0–3 cm, n=3/3) and lower sediment (3–6 cm, n=3/1) for Tixlan Bay, Northern Baltic Proper. Only elements having a K_d value higher than 1 are shown in the graph.*

The highest sediment K_d estimated for this area was 5,254 m^3 kg dw^{-1} (for Ti, lower part of sediment). For most elements the K_d differed substantially between the upper part and the lower part of the sediment. For all elements but Fe the K_d for the lower part of the sediment was much higher than for the upper part. However, for Ba, Eu, Ho, P, Rb, Th and Zr the K_d was about the same in both sediment layers.

The highest K_d values for the upper sediment layer were found for Zr (~ 3,750), Ti (~ 1,700), Fe (~ 200), and Al (165) whereas for Hg, Cr, Pb, V, Th, Cs ranged between 30 and 10. The rest were lower than 10.

The K_d in the lower sediment layer followed the same pattern as the upper layer but had generally higher values. The K_d of Al, Ce and Nd were 38, 36 and 24 times higher respectively in the lower sediment layer. The rest differed within the range 2–6 times (except those element having the same K_d in both layers).

3.7 Reliability of the data and limitations of the study

3.7.1 Data quality

Extreme care was taken to avoid contamination of the samples (see 2.2), and we believe that we have succeeded in keeping the samples as clean as possible. The only possible contamination sources are small metal parts in the end of the plankton net, the lead boat anchor and dive weights, and chemicals in fuel, oil and boat paint. However, in general, it is apparent that concentrations of most elements are what one might expect in a relatively clean environment. Comparisons with data from monitoring studies in the Baltic region, where available (e.g. Naturvårdsverket) show that there is negligible pollution in this area, and thus this study site is ideal for investigating ecological relationships and ecological stoichiometry. There are a few cases where the data should be treated with caution:

The concentration of most elements in **zooplankton** is remarkably high. The reason for this is not clear but could be due to contamination of the single sample obtained (one sample with pooled material from the whole bay). However, the C:N:P-ratio of the sample is 112:22:1 (by mole) which is fairly close to the Redfield ratio 106:16:1 and the CNP content (ratios, percentages, etc.) of the sample are also in the same range as the other organisms sampled in the study, suggesting that this is indeed a representative zooplankton sample.

Concentration data for **benthic microalgae** were also very high for some elements (actinides and lanthanides, Mn, Mg, Fe, Si) compared to other biota (with the exception of zooplankton). This is probably due to the samples containing sediment and organic particles and diatoms that had settled out from the water column. The methods used to collect these samples unfortunately did not allow separation of benthic microalgae from this other material. Likewise, **phytoplankton** samples probably contain POM, although much of this will consist of dead phytoplankton.

To be able to make relevant comparisons in our data set we wanted to analyse whole individuals of all biota. However, this is methodologically difficult for large organisms with bony body parts such as **fish**. We therefore used two different methods to attempt to obtain 'whole fish' data, neither of which was wholly successful. The first, slices of fish taken in the middle of the body, comprise disproportionally high amounts of muscle compared to whole fish. However, these data are thought to be more reliable than those derived from the second method (dissolving whole fish in aqua regia), where blank controls (aqua regia with no fish) showed fairly high concentrations of many elements (see Appendix 4). Because of this we have decided to report all fish data but to use the results from the analyses of the fish slices in the data analyses and derivation of quotas and bioconcentration factors.

3.7.2 Sampling design and data interpretation

This study provides a snapshot of a dynamic environment, presenting the concentrations of a multitude of elements in a range of organisms from a single time point. In reality, natural variation in concentrations of elements can be large, varying for example with season, life stage of the organism etc. /e.g. Liess and Hillebrand 2005/. However, studies of this kind are limited by the large expense of sample analysis, and as our main interest was in determining patterns across the whole ecosystem, we chose to sample a large number of organisms at the expense of temporal replication. When considering these results it should be remembered that different patterns may have been observed at different times of the year.

In addition, whereas element concentrations in short-lived species and sessile or relatively immobile species probably reflect their immediate environment, concentrations of elements in longer-lived and/or mobile species integrate environmental conditions over time and/or space. Thus, their stoichiometry will probably not directly reflect the immediate environment measured in this study.

Despite the large number of organism types sampled in this study, there are of course many organisms that were not analysed, either due to them being difficult or too scarce to collect, or due to budget restrictions. We assume that we have sampled the most abundant species at that site and time point, and thus cover most of the major trophic interactions that were present. However, when we assume certain trophic groups and food pathways (Figures 1-2, 3-11) and base our BMF calculations on those we may have missed some organism groups in the food web and of trophic transfer pathways. In some cases it is also difficult to know the food sources of organisms, or they may have multiple food sources, making these types of calculations and analyses difficult.

4 General Discussion and Conclusions

4.1 Ecology

Given the assumptions and limitations discussed above (3.7), this is still the first time that residues of so many elements have been determined in Baltic organisms, and that the CNP stoichiometry of all key organisms in a Baltic ecosystem has been elucidated. Thus, this is an important first step towards a description of the ecological stoichiometry of Baltic Sea ecosystems and we see the following trends:

The data in this study clearly show that that there is a difference in chemical composition between plants and animals, organisms at different trophic levels, and organisms of different functional groups. Both multivariate and univariate analyses of data in this study show this both for carbon and nutrients as well as for other elements. This indicates that food intake and metabolism has a strong influence on the stoichiometry of an organism.

4.1.1 Plants – Animals

Plants (macrophytes and macroalgae) generally have much higher concentrations of the following elements compared to animals: Mg, halogens, Si, Ti, and to a lesser extent Ni, Zr, As, Pb, V, Li and Cr. The three plants are quite similar in chemical composition, despite their taxonomic differences. The main differences are that *F. vesiculosus* has much lower P, higher Ba and S and slightly higher concentrations of some metals (Cd, Zn, Ni) than the other plants. Of all the animals analysed, *Idothea* spp. are most similar to the plants in terms of element composition. This is presumably because it consumes these plant species, unlike the other primary consumers that have as their main food sources periphyton (*T. fluviatilis*), particulate matter in the water column or sediment (*M. balthica* and *C. glaucum*) or phytoplankton (zooplankton).

4.1.2 Trophic groups

Some of the primary producers, the plants, have been discussed above. The other two primary producers (phytoplankton and benthic microalgae) are often different to the plants: phytoplankton have higher concentrations of Si, Na, Cl, Cu, Pb, Li, Cr, Hg, Br and Zn and lower C, Ca, Ba, actinoids and lanthanoids than the plants; benthic microalgae have lower C, Ca and Ba than the plants, but otherwise most other elements are higher (see also discussion in 3.7).

Within the animals, primary consumers are generally more similar in composition to the primary producers than are secondary consumers. Primary consumers are also relatively similar to their immediate environment: *M. balthica* and *C. glaucum* show similarities to sediment composition, *Idothea* spp. to the plants, and zooplankton to POM. Zooplankton also has a fairly similar stoichiometry to phytoplankton.

There is a general stepwise decrease up trophic groups (consumers) for Fe, Mn, Ca, Si, Ti, Ba, Ni, Zr, Cr, Co, Cd, Th, Mo, all actinoids and lanthanoids. Secondary consumers have higher concentrations than primary consumers of K, S, Rb, Se and Hg. Tertiary consumers are represented only by *O. eperlanus*, so conclusions should be drawn with care. In general, *O. eperlanus* is generally quite similar to the secondary consumers, but with slightly lower P, Mg, Fe, Ca, S, Ba, Pb, Cr, Co, Mo, Ti, actinoids and lanthanoids, and slightly higher N, K, As, Cs, Br and I.

4.1.3 Fish

It should be noted that the secondary and tertiary consumers in this study are represented entirely by fish. These three fish species are the only vertebrates included in this study, so some of the observed trends may be due to their taxonomic and physiological differences, rather than (or as well as) their trophic status. In general, concentrations of most elements in fish are lower than in other groups. The exceptions are C, N, P and Se, and to a lesser extent K, Zn, S, Ca and Rb. Structural elements in bone and collagen contain large amounts of Ca, C, P and N, and the more advanced vertebrate enzymatic systems may also contribute to high concentrations of N and P and possibly also Se. Fish also had much higher Hg concentrations than other organisms. This is probably because they have much longer life spans and therefore have longer to accumulate this element.

4.1.4 Special cases

As well as the general trends described above, there are certain organisms and elements that show special characteristics, mainly due to their structural characteristics. For example: shellbearing organisms such as *M. balthica*, *C. glaucum* and *T. fluviatilis* have high concentrations of Ca; phytoplankton and benthic microalgae to a large extent comprise diatoms, and thus contain a lot of Si.

4.2 Relevance of ecological stoichiometry for safety assessments for radionuclides

Safety assessments are performed to support decisions about localisation and performance of nuclear facilities /Chapman and McCombie 2003/. In the region where this study was performed, a safety assessment for a nuclear waste repository is currently underway /e.g. SKB 2006c/, which is based on a site description of the area /e.g. Wijnbladh et al. in prep, Lindborg et al. 2006/. The site description includes, among other things, ecosystem models describing the distribution and fluxes of organic matter (carbon and nutrients) in and between catchment areas or basins of the area.

In the safety assessment, these descriptions and models are used to estimate the fate of elements (radionuclides) that may be released from the underground repository to the ecosystem above. Such estimates may be done in several ways.

One common approach to estimate the uptake of elements (radionuclides) by organisms is to combine data describing concentrations of elements (radionuclides) in water with bioconcentration factors (BCFs) obtained either from the international literature /e.g. IAEA 1985/, or from the site (this study). A similar approach is to use biomagnification factors (BMFs), which is more ecologically relevant but requires an insight of food web structure and access to adequate BMFs. Both of these methods (the former more than the latter) contribute to a "black box" type of modelling.

A more transparent method to estimate element uptake by organisms is to combine an ecological model describing the distribution and fluxes of carbon with element (or radionuclide) to carbon ratios (this study). Thus, this latter approach is based on the assumption that the uptake of elements (radionuclides) is more related to the consumption rate, type of food ingested and metabolic processes (i.e. dynamics of organic matter in the ecosystem) than diffusion from the surrounding environment.

In the safety assessment performed by SKB both approaches are implemented. This is further described in e.g. /Avila et al. 2006, Lindborg et al. 2006, SKB 2006c/.

4.3 Conclusions

This analysis gives a fascinating insight into how the natural distribution of elements is strongly related to the ecology and biology of the organisms. Elemental concentrations vary greatly between organisms and environmental components, depending on: the function of the elements (e.g. structural, trace, essential or non-essential); the habitat of the organisms (e.g. pelagic, benthic, littoral); the ecosystem function/trophic level of the organisms (e.g. primary producer, suspension feeder, predator); the morphology (taxonomy) of the organism. Just as C:N:P ratios can tell us much about organism biology, ecology and health, we may be able to begin to use other element ratios in a similar way, for example to identify those elements that may be important in limiting organism growth or performance and/or those elements that are ecologically abundant.

The concentration data, and resulting biomagnification factors, bioconcentration factors and element: C ratios will be of direct use to SKB's ecosystem modelling as apart of the ongoing safety assessment. The data not only enable a overview of the current natural distribution of elements in the marine ecosystem, but will enable realistic predictions of radionuclide distributions in biota in the event of their release from, for example, a future deep repository. This in turn will contribute to, for example, more reliable dose estimates to organisms and humans from radionuclides potentially released from the repository.

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7 Appendices

Grey shaded cells indicate averages based on data where at least one of the original values was less than the limit of detection, i.e. ‘<x’ (and was taken as ‘x’ in the calculation).

For phosphorus there are two measurements: P1 which is P measured at Department of Systems Ecology, Stockholm University and, P2 which is P measured by ALS Scandinavia AB, Umeå.

Summary of Appendices:

Appendix 1–7. Average concentrations and stdv (mg/kg dw) of elements in biota, DIM, POM, porewater and sediment.

Appendix 8–14. Average concentrations and stdv (mol/kg dw) of elements in biota, DIM, POM, porewater and sediment.

Appendix 15–20. Average element ratios and stdv (based on concentrations, mg/kg dw) in biota, DIM, POM, porewater and sediment. Normalised to carbon.

Appendix 21–24. Bioconcentration factors (BCF_{WW}) [(kg/kgww)/(kg/kg)] for biota. The estimate was based on concentration per wet weight biota and concentration in dissolved fraction in water (DIM).

Appendix 25–28. Bioconcentration factors (BCF_C) [(kg/kgC)/(kg/kg)] for biota. The estimate was based on concentration per kg C biota and concentration in dissolved fraction in water (DIM).

Appendix 29. Partitioning coefficients (Kd) [(kg/kgdw)/(kg/m^3)] for water column (Kd I, n=3/3), upper sediment (Kd II 0–3 cm, n=3/3) and lower sediment (Kd III, 3–6 cm, n=3/1).

Appendix 1

Average concentrations and stdv (mg/kg dw) of elements in phytoplankton (n=3), zooplankton (n=1) and benthic microalgae (n=2).

	Phytoplankton mg/kg dw			Zooplankton mg/kg dw			Benthic microalgae mg/kg dw		
Al	5.2E+03	±	1.2E+03	2.9E+03	±	–	2.7E+01	±	4.2E+00
As	1.3E+01	±	3.2E+00	2.3E+01	±	–	5.5E+01	±	3.8E+01
Ba	4.2E+01	±	7.2E+00	5.0E+01	±	–	4.9E–01	±	1.9E–01
Br	1.3E+03	±	1.3E+02	1.3E+04	±	–	1.0E+03	±	2.3E+02
C	1.7E+05	±	4.5E+03	4.3E+05	±	–	1.4E+05	±	3.0E+04
Ca	3.4E+03	±	2.0E+02	8.9E+04	±	–	2.9E+01	±	9.7E+00
Cd	2.5E–01	±	4.9E–02	4.9E+00	±	–	2.8E+00	±	1.7E+00
Ce	9.5E–03	±	2.6E–03	3.6E+00	±	–	4.8E–01	±	3.1E–02
Cl	6.4E+04	±	2.1E+03	no data	±	–	4.2E+04	±	9.2E+03
Co	1.7E+00	±	3.9E–01	1.7E+00	±	–	3.7E+01	±	2.3E+01
Cr	6.3E+00	±	1.2E+00	1.0E+01	±	–	2.5E+01	±	1.1E+00
Cs	5.1E–01	±	1.3E–01	3.2E–01	±	–	2.5E+00	±	1.4E–01
Cu	2.3E+01	±	5.5E+00	2.0E+02	±	–	4.5E+01	±	1.6E+01
Dy	5.3E–04	±	1.6E–04	2.8E–01	±	–	2.9E–02	±	9.9E–04
Er	3.0E–04	±	9.5E–05	1.6E–01	±	–	1.6E–02	±	2.7E–03
Eu	2.0E–04	±	0.0E+00	4.8E–02	±	–	5.4E–03	±	8.3E–04
F	9.7E+02	±	4.9E+01	no data	±	–	1.1E+02	±	9.8E+01
Fe	3.9E+03	±	9.3E+02	2.1E+03	±	–	4.3E+04	±	1.4E+04
Gd	6.6E–04	±	2.0E–04	2.9E–01	±	–	3.9E–02	±	1.6E–03
Hg	5.6E–02	±	6.7E–03	6.0E–01	±	–	1.2E–01	±	1.4E–02
Ho	2.0E–04	±	0.0E+00	6.0E–02	±	–	5.5E–03	±	6.5E–04
I	1.5E+01	±	3.7E+00	7.1E+01	±	–	3.1E+02	±	1.6E+02
K	9.0E+03	±	8.5E+02	6.5E+04	±	–	1.3E+04	±	1.6E+03
Li	8.7E+00	±	2.2E+00	1.0E+01	±	–	1.9E+01	±	2.2E+00
Lu	2.0E–04	±	0.0E+00	2.4E–02	±	–	2.2E–03	±	4.0E–04
Mg	7.4E+03	±	2.3E+02	2.7E+04	±	–	1.1E+04	±	1.1E+03
Mn	4.5E+02	±	6.2E+01	1.7E+02	±	–	1.5E+04	±	9.2E+03
Mo	3.4E–01	±	2.6E–02	2.6E+00	±	–	6.9E+00	±	5.4E+00
N	2.1E+04	±	1.2E+03	9.7E+04	±	–	1.7E+04	±	3.0E+03
Na	4.8E+04	±	1.9E+03	1.9E+05	±	–	3.2E+04	±	3.8E+03
Nd	4.1E–03	±	1.2E–03	1.9E+00	±	–	2.3E–01	±	1.3E–02
Ni	6.1E+00	±	2.0E+00	1.2E+01	±	–	1.3E+02	±	9.2E+01
P1	1.3E+03	±	1.6E+02	9.5E+03	±	–	2.7E+03	±	4.0E+02
P2	2.1E+03	±	4.5E+02	5.7E+04	±	–	3.1E+03	±	3.3E+02
Pb	1.1E+01	±	2.0E+00	1.8E+01	±	–	8.9E+01	±	7.6E+01
Pr	1.1E–03	±	3.2E–04	4.8E–01	±	–	6.2E–02	±	4.0E–03
Rb	1.3E+01	±	2.5E+00	4.0E+01	±	–	5.6E+01	±	2.4E+00
S	7.2E+03	±	2.1E+02	4.7E+04	±	–	9.3E+03	±	1.4E+03
Se	5.0E–01	±	5.8E–02	1.0E+01	±	–	6.7E–01	±	9.9E–03
Si	1.4E+05	±	1.4E+04	9.8E+04	±	–	8.3E+04	±	2.3E+03
Sm	7.5E–04	±	2.3E–04	3.7E–01	±	–	4.4E–02	±	4.2E–03
Tb	2.0E–04	±	0.0E+00	4.8E–02	±	–	5.3E–03	±	2.1E–05
Th	1.4E+00	±	2.5E–01	5.4E–01	±	–	1.7E+01	±	6.0E+00
Ti	1.8E+02	±	3.9E+01	1.1E+02	±	–	8.7E+02	±	8.8E+01
Tm	2.0E–04	±	0.0E+00	2.4E–02	±	–	2.3E–03	±	3.8E–04
V	7.0E+00	±	1.6E+00	3.8E+00	±	–	5.6E+01	±	1.6E+01
Yb	2.8E–04	±	8.4E–05	1.4E–01	±	–	1.4E–02	±	2.3E–03
Zn	3.9E+02	±	1.5E+02	1.0E+03	±	–	5.1E+02	±	2.2E+02
Zr	1.5E+01	±	1.4E+00	4.9E+00	±	–	1.3E+02	±	1.3E+01

Appendix 2

Average concentrations and stdv (mg/kg dw) of elements in *F. vesiculosus* (n=3), *P. littoralis* (n=3) and *P. pectinatus* (n=3).

	F. vesiculosus mg/kg dw			*P. littoralis* mg/kg dw			*P. pectinatus* mg/kg dw		
Al	6.7E+02	±	3.6E+02	4.3E+03	±	2.6E+03	2.7E+03	±	9.2E+02
As	3.3E+01	±	1.6E+00	2.1E+01	±	4.0E+00	3.7E+00	±	5.8E–01
Ba	2.4E+02	±	3.8E+01	9.5E+01	±	9.3E+00	3.7E+01	±	7.5E+00
Br	2.8E+02	±	1.0E+02	2.6E+02	±	2.7E+01	no data	±	no data
C	3.7E+05	±	8.1E+03	2.8E+05	±	1.7E+04	3.6E+05	±	1.3E+04
Ca	1.5E+04	±	9.5E+02	1.1E+04	±	7.8E+03	2.3E+04	±	1.1E+04
Cd	4.9E+00	±	1.2E+00	3.0E–01	±	2.2E–01	9.1E–01	±	1.7E–01
Ce	8.8E–02	±	3.7E–02	3.3E–02	±	2.7E–02	8.4E–02	±	4.9E–02
Cl	9.3E+03	±	0.0E+00	4.2E+04	±	2.8E+03	no data	±	no data
Co	1.2E+00	±	2.5E–01	1.5E+00	±	9.8E–01	2.6E+00	±	8.7E–01
Cr	8.7E–01	±	4.2E–01	4.8E+00	±	3.2E+00	3.1E+00	±	1.0E+00
Cs	9.0E–02	±	4.7E–02	5.3E–01	±	3.5E–01	3.2E–01	±	1.1E–01
Cu	3.9E+00	±	1.9E–01	5.4E+00	±	2.1E+00	7.4E+00	±	1.4E+00
Dy	1.0E–02	±	3.4E–03	2.1E–03	±	1.7E–03	4.5E–03	±	2.3E–03
Er	6.2E–03	±	2.2E–03	1.2E–03	±	9.2E–04	2.6E–03	±	1.2E–03
Eu	1.4E–03	±	7.2E–04	4.3E–04	±	3.3E–04	9.2E–04	±	4.9E–04
F	3.8E+01	±	7.1E–01	5.9E+02	±	4.5E+02	no data	±	no data
Fe	5.7E+02	±	2.5E+02	3.4E+03	±	2.0E+03	2.2E+03	±	6.3E+02
Gd	1.2E–02	±	4.7E–03	2.7E–03	±	2.0E–03	5.7E–03	±	3.0E–03
Hg	2.3E–02	±	4.2E–03	2.6E–02	±	1.2E–02	2.8E–02	±	2.9E–03
Ho	2.1E–03	±	7.3E–04	4.1E–04	±	3.2E–04	8.9E–04	±	4.4E–04
I	9.9E+01	±	4.0E+01	4.9E+01	±	4.2E+00	no data	±	no data
K	1.8E+04	±	1.4E+03	2.4E+04	±	3.8E+03	1.9E+04	±	1.6E+03
Li	1.4E+00	±	3.6E–01	6.5E+00	±	1.0E+00	3.7E+00	±	4.8E–01
Lu	9.6E–04	±	3.2E–04	2.4E–04	±	6.4E–05	3.7E–04	±	1.8E–04
Mg	9.6E+03	±	6.3E+02	6.7E+03	±	5.3E+02	8.4E+03	±	1.2E+03
Mn	4.2E+02	±	9.4E+01	2.8E+02	±	1.9E+02	7.7E+02	±	2.6E+02
Mo	3.5E–01	±	1.4E–01	2.7E–01	±	6.2E–02	1.3E+00	±	4.0E–01
N	2.2E+04	±	2.6E+03	2.5E+04	±	1.7E+03	1.8E+04	±	1.5E+03
Na	1.4E+04	±	3.1E+02	2.6E+04	±	2.5E+03	2.2E+04	±	3.8E+03
Nd	6.1E–02	±	2.3E–02	1.6E–02	±	1.2E–02	3.3E–02	±	1.8E–02
Ni	1.7E+01	±	4.5E+00	5.7E+00	±	3.0E+00	7.0E+00	±	2.8E+00
P1	1.2E+03	±	5.2E+01	2.9E+03	±	5.4E+02	2.4E+03	±	3.6E+02
P2	1.3E+03	±	1.1E+02	2.5E+03	±	4.5E+02	2.6E+03	±	3.5E+02
Pb	8.3E–01	±	3.3E–01	4.6E+00	±	2.1E+00	3.1E+00	±	6.9E–01
Pr	1.6E–02	±	6.2E–03	4.2E–03	±	3.3E–03	9.0E–03	±	4.8E–03
Rb	1.1E+01	±	2.1E+00	2.0E+01	±	4.2E+00	9.9E+00	±	2.0E+00
S	3.1E+04	±	2.2E+03	1.1E+04	±	1.5E+03	7.8E+03	±	1.3E+03
Se	5.3E–01	±	2.4E–02	5.1E–02	±	5.3E–02	2.1E–01	±	6.4E–02
Si	5.5E+03	±	1.7E+03	6.6E+04	±	1.2E+04	3.8E+04	±	6.9E+03
Sm	1.1E–02	±	4.2E–03	2.9E–03	±	2.3E–03	6.0E–03	±	3.2E–03
Tb	1.8E–03	±	6.4E–04	3.8E–04	±	2.9E–04	8.1E–04	±	4.3E–04
Th	2.1E–01	±	1.2E–01	1.3E+00	±	8.7E–01	8.8E–01	±	2.4E–01
Ti	2.5E+01	±	1.2E+01	1.6E+02	±	9.7E+01	9.2E+01	±	2.6E+01
Tm	8.7E–04	±	2.9E–04	2.4E–04	±	6.9E–05	3.6E–04	±	1.9E–04
V	1.6E+00	±	6.1E–01	7.0E+00	±	4.5E+00	4.6E+00	±	1.7E+00
Yb	5.8E–03	±	2.0E–03	1.0E–03	±	8.2E–04	2.3E–03	±	1.1E–03
Zn	2.3E+02	±	4.4E+01	4.9E+01	±	2.2E+01	8.9E+01	±	1.7E+01
Zr	3.6E+00	±	1-4E+00	1.6E+01	±	8.4E+00	8.9E+00	±	2.2E+00

Appendix 3

Average concentrations and stdv (mg/kg dw) of elements in *T. fluviatilis* (n=2), *Idothea* spp. (n=2), *M. baltica* (n=3) and *C. glaucum* (n=3).

	T. fluviatilis **mg/kg dw**			***Idothea*** **spp. mg/kg dw**			***M. baltica*** **mg/kg dw**			***C. glaucum*** **mg/kg dw**		
Al	6.9E–01	±	1.6E–02	7.4E–01	±	2.0E–02	6.0E–01	±	6.7E–02	2.7E–01	±	8.8E–02
As	2.1E+00	±	1.5E–01	6.7E+00	±	1.3E+00	2.0E+00	±	4.5E–01	6.7E–01	±	5.6E–02
Ba	1.3E+01	±	1.8E+00	8.1E+01	±	1.1E+01	3.0E+01	±	4.2E+00	3.1E+01	±	2.1E+00
Br	1.1E+02	±	3.0E+01	no data	±	no data	3.2E+01	±	8.4E+00	no data	±	no data
C	1.6E+05	±	1.1E+04	3.6E+05	±	7.1E+03	1.7E+05	±	1.2E+04	1.5E+05	±	7.1E+02
Ca	3.2E+05	±	7.1E+02	1.2E+05	±	2.1E+03	2.7E+05	±	4.9E+04	3.2E+05	±	2.2E+04
Cd	7.3E–01	±	1.8E–02	1.9E+00	±	3.0E–01	1.6E–01	±	7.4E–02	1.6E–01	±	2.8E–02
Ce	1.9E–01	±	1.6E–02	3.9E–02	±	8.3E–03	3.2E–01	±	1.2E–02	1.4E–01	±	2.1E–03
Cl	2.9E+03	±	2.8E+02	no data	±	no data	1.9E+03	±	2.1E+02	no data	±	no data
Co	3.0E–01	±	4.1E–02	7.6E–01	±	1.7E–01	3.0E–01	±	6.7E–02	1.1E–01	±	1.4E–02
Cr	3.2E–01	±	3.5E–02	1.1E+00	±	5.7E–02	5.2E–01	±	4.3E–02	2.6E–01	±	1.0E–01
Cs	3.8E–02	±	5.9E–03	9.6E–02	±	4.3E–03	5.5E–02	±	3.1E–03	2.5E–02	±	1.3E–02
Cu	1.2E+01	±	2.1E–01	5.7E+01	±	9.5E+00	2.3E+01	±	6.9E+00	1.7E+00	±	3.0E–01
Dy	1.2E–02	±	3.5E–04	2.5E–03	±	4.5E–04	1.8E–02	±	1.9E–03	9.9E–03	±	6.2E–04
Er	5.7E–03	±	3.1E–04	1.4E–03	±	2.8E–04	9.5E–03	±	1.1E–03	5.6E–03	±	2.3E–04
Eu	2.3E–03	±	2.8E–05	4.2E–04	±	9.2E–05	4.4E–03	±	4.9E–04	2.1E–03	±	1.3E–04
F	2.1E+01	±	7.1E–01	no data	±	no data	2.2E+01	±	2.1E+00	no data	±	no data
Fe	2.5E+02	±	6.4E+00	5.9E+02	±	3.0E+01	8.1E+02	±	9.7E+01	2.4E+02	±	1.1E+02
Gd	1.6E–02	±	1.6E–03	3.3E–03	±	6.6E–04	2.9E–02	±	2.7E–03	1.5E–02	±	7.1E–05
Hg	2.6E–02	±	5.5E–03	3.1E–02	±	3.1E–03	3.8E–02	±	7.4E–03	1.3E–02	±	2.6E–03
Ho	2.2E–03	±	3.5E–05	4.9E–04	±	9.9E–05	3.5E–03	±	3.0E–04	2.0E–03	±	5.7E–05
I	8.1E+00	±	3.3E–01	no data	±	no data	1.6E+00	±	3.5E–01	no data	±	no data
K	1.2E+03	±	2.1E+01	6.5E+03	±	1.3E+03	1.2E+03	±	1.3E+02	7.6E+02	±	1.4E+02
Li	4.4E–01	±	9.2E–03	1.5E+00	±	2.1E–02	4.8E–01	±	4.4E–02	3.9E–01	±	1.1E–01
Lu	7.8E–04	±	2.1E–05	2.1E–04	±	1.4E–05	1.3E–03	±	7.5E–05	7.0E–04	±	2.1E–05
Mg	7.9E+02	±	1.3E+02	7.3E+03	±	7.8E+02	4.4E+02	±	3.8E+01	3.5E+02	±	4.8E+01
Mn	1.6E+02	±	0.0E+00	8.5E+01	±	1.8E+01	2.5E+01	±	5.3E+00	2.3E+01	±	8.8E+00
Mo	1.6E–01	±	2.6E–02	2.5E–01	±	2.5E–02	1.9E–01	±	3.3E–02	5.8E–02	±	5.4E–03
N	1.5E+04	±	4.7E+03	6.7E+04	±	9.1E+03	1.4E+04	±	1.8E+03	1.0E+04	±	7.8E+02
Na	5.0E+03	±	1.8E+02	1.4E+04	±	2.2E+03	4.2E+03	±	5.3E+02	4.7E+03	±	5.2E+02
Nd	8.7E–02	±	7.9E–03	1.9E–02	±	3.9E–03	1.6E–01	±	5.0E–03	7.5E–02	±	4.5E–03
Ni	1.1E+00	±	1.5E–01	2.0E+00	±	5.2E–01	5.2E–01	±	1.2E–01	3.2E+00	±	4.2E–02
P1	1.3E+03	±	5.0E+02	7.7E+03	±	2.1E+03	1.5E+03	±	2.9E+02	1.1E+03	±	5.7E+01
P2	1.4E+03	±	9.2E+01	6.9E+03	±	3.9E+02	1.8E+03	±	6.1E+02	6.8E+02	±	1.2E+02
Pb	4.3E–01	±	4.9E–02	9.0E–01	±	1.3E–01	9.5E–01	±	3.8E–01	2.4E–01	±	1.3E–02
Pr	2.5E–02	±	1.4E–03	5.2E–03	±	1.0E–03	4.3E–02	±	1.7E–03	2.0E–02	±	8.5E–04
Rb	1.5E+00	±	1.5E–01	3.6E+00	±	4.1E–01	1.7E+00	±	1.0E–01	9.2E–01	±	3.2E–01
S	1.5E+03	±	4.9E+02	9.0E+03	±	1.8E+03	1.3E+03	±	4.4E+02	5.8E+02	±	4.1E+01
Se	6.1E–01	±	6.4E–02	6.0E–01	±	3.5E–02	4.1E–01	±	1.1E–01	2.4E–01	±	8.6E–02
Si	3.1E+03	±	1.6E+02	5.7E+03	±	2.1E+01	2.0E+03	±	4.4E+02	9.9E+02	±	1.5E+02
Sm	1.7E–02	±	2.8E–03	3.5E–03	±	6.2E–04	3.0E–02	±	2.2E–03	1.4E–02	±	1.1E–03
Tb	2.1E–03	±	1.3E–04	4.6E–04	±	9.2E–05	3.7E–03	±	2.9E–04	2.0E–03	±	1.8E–04
Th	3.2E–01	±	5.9E–02	2.4E–01	±	2.8E–03	1.9E–01	±	3.6E–02	8.2E–02	±	3.4E–02
Ti	1.4E+01	±	2.4E+00	2.7E+01	±	2.7E+00	1.8E+01	±	2.9E+00	8.1E+00	±	3.4E+00
Tm	8.0E–04	±	6.4E–05	2.1E–04	±	1.4E–05	1.2E–03	±	1.2E–04	7.2E–04	±	4.2E–05
V	6.2E–01	±	8.0E–02	1.3E+00	±	9.9E–02	7.9E–01	±	1.3E–01	3.9E–01	±	1.0E–01
Yb	5.0E–03	±	5.7E–05	1.2E–03	±	2.5E–04	7.8E–03	±	6.9E–04	4.6E–03	±	7.1E–05
Zn	1.7E+01	±	1.8E+00	5.7E+01	±	8.3E+00	3.9E+01	±	1.3E+01	7.3E+00	±	8.2E–01
Zr	2.2E+00	±	1.1E–01	2.6E+00	±	4.2E–01	2.8E+00	±	9.4E–01	1.3E+00	±	1.1E+00

Appendix 4

Average concentrations and stdv (mg/kg dw for fish, mg/L for blank) of elements in *G. cernuus* (Ruffe, n=3), *O. eperlanus* (Smelt, n=3), *R. rutilus* (Roach, n=3) and blank (aqua regia, n=1). Analyses of whole fish samples.

	G. cernuus mg/kg dw			*O. eperlanus* mg/kg dw			*R. rutilus* mg/kg dw			Blank mg/L
Al	4.1E+01	±	2.3E+01	1.0E+01	±	8.7E–01	8.5E+00	±	1.0E–01	3.9E–01
As	2.8E+01	±	0.0E+00	3.1E+01	±	6.6E–01	2.9E+01	±	0.0E+00	1.0E+00
Ba	2.5E+00	±	3.8E–01	6.6E–01	±	7.1E–02	2.1E+00	±	1.0E–01	3.5E–03
Br	no data		no data	no data		no data	no data		no data	no data
C	no data		no data	no data		no data	no data		no data	no data
Ca	5.0E+01	±	7.5E–01	2.0E+01	±	2.5E+00	5.2E+01	±	1.5E+00	2.5E–04
Cd	3.2E–02	±	6.3E–03	3.2E–02	±	9.2E–03	4.9E–02	±	7.7E–03	1.7E–04
Ce	1.2E–01	±	8.9E–02	9.9E–03	±	3.5E–03	1.2E–02	±	2.4E–03	2.7E–04
Cl	no data		no data	no data		no data	no data		no data	no data
Co	9.1E–02	±	3.0E–02	3.9E–02	±	1.2E–02	5.4E–02	±	2.4E–03	6.3E–04
Cr	5.8E–01	±	8.2E–02	5.6E–01	±	6.3E–02	4.4E–01	±	5.5E–02	2.3E–02
Cs	3.6E–02	±	5.2E–03	4.5E–02	±	5.4E–03	1.7E–02	±	0.0E+00	6.0E–04
Cu	2.8E+00	±	3.6E–01	3.0E+00	±	4.3E–01	3.9E+00	±	7.7E–01	3.1E–02
Dy	8.0E–03	±	5.6E–03	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
Er	4.8E–03	±	2.3E–03	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
Eu	2.8E–03	±	0.0E+00	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
F	no data		no data	no data		no data	no data		no data	no data
Fe	1.0E–01	±	5.2E–02	2.9E–02	±	5.4E–03	5.0E–02	±	6.3E–03	8.1E–04
Gd	1.1E–02	±	8.2E–03	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
Hg	1.8E–01	±	2.2E–02	1.6E–01	±	6.5E–02	1.3E–01	±	3.3E–02	2.0E–04
Ho	2.8E–03	±	0.0E+00	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
I	no data		no data	no data		no data	no data		no data	no data
K	9.9E+00	±	2.5E–01	1.3E+01	±	3.0E–01	1.1E+01	±	8.4E–02	4.0E–04
Li	6.3E–01	±	1.3E–01	8.3E–01	±	5.4E–01	7.2E–01	±	2.1E–01	2.9E–02
Lu	2.8E–03	±	0.0E+00	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
Mg	1.3E+00	±	1.5E–02	1.2E+00	±	6.9E–02	1.7E+00	±	2.2E–02	1.0E–04
Mn	5.6E+00	±	1.5E–01	1.2E+01	±	1.2E+00	8.8E+00	±	1.3E+00	8.3E–03
Mo	5.9E–02	±	1.4E–02	5.1E–02	±	2.8E–03	1.2E–01	±	6.0E–03	1.1E–03
N	no data	±	no data	no data	±	no data	no data		no data	no data
Na	4.8E+00	±	2.5E–01	4.1E+00	±	6.6E–01	3.5E+00	±	4.4E–02	1.0E–03
Nd	5.6E–02	±	4.3E–02	3.3E–03	±	2.1E–04	4.7E–03	±	9.4E–04	1.0E–04
Ni	4.7E–01	±	2.8E–02	4.6E–01	±	4.9E–02	5.5E–01	±	2.2E–01	1.5E–02
P1	no data	±	no data	no data	±	no data	no data		no data	no data
P2	3.1E+04	±	7.5E+02	1.7E+04	±	1.2E+03	3.1E+04	±	5.0E+02	2.0E–02
Pb	2.1E–01	±	4.1E–02	1.7E–01	±	6.2E–02	1.9E–01	±	2.6E–02	2.6E–03
Pr	1.6E–02	±	1.1E–02	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
Rb	8.3E+00	±	5.6E–01	5.2E+00	±	4.2E–02	5.4E+00	±	3.5E–01	6.0E–04
S	7.8E+00	±	2.7E–01	8.8E+00	±	3.8E–01	8.1E+00	±	3.1E–01	4.0E–04
Se	1.1E+00	±	6.3E–02	1.1E+00	±	2.1E–01	9.9E–01	±	9.9E–02	6.6E–04
Si	4.9E–02	±	2.1E–03	3.9E–02	±	5.9E–03	2.9E–02	±	6.3E–03	8.5E–03
Sm	1.0E–02	±	7.6E–03	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
Tb	2.8E–03	±	0.0E+00	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
Th	1.1E–02	±	2.1E–18	1.2E–02	±	2.6E–04	1.2E–02	±	0.0E+00	4.0E–04
Ti	1.8E+00	±	1.2E+00	1.2E–01	±	3.2E–02	1.4E–01	±	2.5E–02	7.0E–03
Tm	2.8E–03	±	0.0E+00	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
V	4.0E–01	±	2.0E–01	3.7E–02	±	3.2E–03	5.9E–02	±	1.5E–02	6.8E–04
Yb	4.9E–03	±	1.9E–03	3.1E–03	±	6.6E–05	2.9E–03	±	0.0E+00	1.0E–04
Zn	8.9E+01	±	7.5E+00	1.2E+02	±	5.2E+01	2.2E+02	±	1.0E+01	1.9E–02
Zr	3.6E–02	±	4.3E–04	6.3E–02	±	7.8E–02	3.5E–02	±	9.4E–03	3.6E–03

Appendix 5

Average concentrations and stdv (mg/kg dw) of elements in *G. cernuus* (Ruffe, n=3), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). Analyses of mixed fish slices.

	G. cernuus mg/kg dw			*O. eperlanus* mg/kg dw			*R. rutilus* mg/kg dw		
Al	3.3E+00	±	3.7E+00	7.9E–01	±	9.8E–02	7.7E–01	±	6.3E–01
As	7.0E–01	±	1.2E–01	2.4E+00	±	4.2E–01	7.8E–01	±	5.6E–01
Ba	2.1E+00	±	1.3E+00	4.6E–01	±	1.6E–01	2.1E+00	±	7.9E–01
Br	1.9E+01	±	9.2E–01	2.5E+01	±	7.1E+00	1.5E+01	±	8.4E–02
C	4.1E+05	±	1.1E+04	4.8E+05	±	1.0E+04	4.3E+05	±	1.3E+04
Ca	5.8E+04	±	2.7E+04	1.3E+04	±	6.1E+03	3.4E+04	±	8.2E+03
Cd	1.0E–02	±	3.2E–03	1.1E–02	±	5.1E–03	3.5E–02	±	1.4E–02
Ce	2.9E–04	±	1.3E–04	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Cl	1.6E+03	±	2.1E+02	1.5E+03	±	0.0E+00	9.3E+02	±	6.0E–03
Co	2.3E–02	±	8.7E–03	1.3E–02	±	6.9E–04	3.1E–02	±	4.2E–03
Cr	2.0E–02	±	5.2E–04	1.0E–02	±	0.0E+00	1.3E–02	±	5.8E–03
Cs	3.7E–02	±	7.7E–03	5.8E–02	±	2.7E–03	2.1E–02	±	5.9E–04
Cu	1.8E+00	±	5.0E–01	1.6E+00	±	4.0E–01	1.9E+00	±	1.4E–01
Dy	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Er	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Eu	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
F	2.0E+01	±	0.0E+00	2.0E+01	±	0.0E+00	2.0E+01	±	0.0E+00
Fe	2.2E+01	±	4.7E+00	1.6E+01	±	5.1E+00	3.8E+01	±	2.0E+01
Gd	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Hg	3.0E–01	±	7.0E–02	2.6E–01	±	7.0E–02	3.1E–01	±	1.5E–01
Ho	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
I	1.0E+00	±	2.3E–01	2.0E+00	±	6.4E–02	8.0E–01	±	0.0E+00
K	1.4E+04	±	9.5E+02	1.7E+04	±	2.1E+03	1.4E+04	±	1.2E+03
Li	3.8E–01	±	6.3E–02	3.0E–01	±	2.8E–02	2.8E–01	±	7.9E–02
Lu	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Mg	1.7E+03	±	2.6E+02	1.2E+03	±	1.7E+02	1.6E+03	±	1.9E+02
Mn	4.8E+00	±	2.4E+00	6.2E+00	±	8.3E–01	7.9E+00	±	5.4E+00
Mo	2.5E–02	±	9.0E–03	1.6E–02	±	5.0E–03	3.8E–02	±	1.0E–02
N	1.1E+05	±	4.5E+03	1.2E+05	±	3.2E+03	1.1E+05	±	2.1E+03
Na	4.3E+03	±	4.7E+02	3.5E+03	±	3.4E+02	2.9E+03	±	4.4E+02
Nd	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Ni	9.7E–02	±	4.6E–02	8.5E–02	±	6.9E–03	8.7E–02	±	3.0E–02
P1	3.4E+04	±	2.7E+03	2.0E+04	±	1.7E+03	3.0E+04	±	3.7E+03
P2	3.2E+04	±	1.0E+04	1.4E+04	±	2.4E+03	2.4E+04	±	3.9E+03
Pb	7.8E–02	±	1.9E–02	5.9E–02	±	1.3E–02	8.5E–02	±	3.6E–02
Pr	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Rb	8.0E+00	±	5.4E–01	5.8E+00	±	9.0E–01	5.9E+00	±	7.5E–01
S	9.9E+03	±	5.3E+02	8.1E+03	±	1.3E+02	9.4E+03	±	4.6E+02
Se	1.9E+00	±	2.9E–01	1.6E+00	±	6.1E–02	1.5E+00	±	9.0E–02
Si	3.7E+02	±	5.0E+02	2.1E+02	±	2.6E+02	7.1E+01	±	2.3E+01
Sm	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Tb	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Th	5.2E–03	±	2.1E–03	3.3E–03	±	5.8E–04	3.7E–03	±	1.2E–03
Ti	1.3E+00	±	7.2E–01	3.0E–01	±	1.9E–01	6.8E–01	±	3.3E–01
Tm	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
V	2.3E–01	±	2.2E–01	2.9E–02	±	9.5E–03	2.3E–02	±	7.6E–03
Yb	2.0E–04	±	0.0E+00	1.7E–04	±	5.8E–05	2.0E–04	±	0.0E+00
Zn	6.4E+01	±	4.7E+00	6.8E+01	±	1.3E+01	1.6E+02	±	5.5E+01
Zr	1.3E–01	±	6.9E–02	2.7E–02	±	3.8E–03	2.0E–02	±	2.0E–03

Appendix 6

Average concentrations and stdv (µg/g dw; µg/L; mg/L) of elements in POM (n=3), POM (n=3) and DIM (n=3).

	POM µg/g dw			POM µg/L			DIM mg/L		
Al	1.0E+05	±	1.4E+04	1.1E+00	±	1.2E–01	1.3E–03	±	1.8E–04
As	5.6E+00	±	2.6E–01	6.4E–05	±	6.2E–07	7.0E–03	±	1.7E–03
Ba	1.2E+05	±	2.2E+04	1.4E+00	±	2.0E–01	1.7E–02	±	2.0E–04
Br	2.2E+02	±	1.0E+01	2.6E–03	±	2.5E–05	1.7E+01	±	3.3E+00
C	3.3E+04	±	6.4E+03	3.8E–01	±	7.3E–02	1.5E+01	±	4.6E–01
Ca	3.4E+05	±	6.8E+04	3.9E+00	±	6.9E–01	8.1E+01	±	5.8E–02
Cd	4.7E+01	±	4.9E+00	5.4E–04	±	4.4E–05	1.8E–05	±	3.4E–06
Ce	3.3E+01	±	5.2E+00	3.7E–04	±	4.6E–05	1.0E–05	±	0.0E+00
Cl	1.4E+03	±	6.4E+02	1.6E–02	±	8.5E–03	2.8E+03	±	7.1E+00
Co	1.3E+00	±	1.8E–01	1.4E–05	±	1.7E–06	1.2E–05	±	4.0E–06
Cr	2.7E+02	±	3.6E+01	3.1E–03	±	3.0E–04	6.4E–04	±	1.3E–04
Cs	6.3E+00	±	9.0E–01	7.1E–05	±	8.0E–06	6.0E–05	±	0.0E+00
Cu	3.0E+01	±	4.5E+00	3.4E–04	±	3.9E–05	7.8E–04	±	1.6E–05
Dy	1.2E+00	±	1.4E–01	1.3E–05	±	1.2E–06	1.0E–05	±	0.0E+00
Er	6.4E+00	±	9.6E–01	7.2E–05	±	9.2E–06	1.0E–05	±	0.0E+00
Eu	3.0E+00	±	7.5E–01	3.4E–05	±	7.6E–06	1.0E–05	±	0.0E+00
F	8.6E+01	±	5.7E+00	1.0E–03	±	0.0E+00	3.0E–01	±	0.0E+00
Fe	3.0E+03	±	1.8E+02	3.4E–02	±	1.6E–03	2.5E–03	±	1.2E–04
Gd	1.3E+00	±	1.8E–01	1.5E–05	±	1.6E–06	1.0E–05	±	0.0E+00
Hg	5.6E–01	±	2.6E–02	6.4E–06	±	6.2E–08	2.0E–06	±	0.0E+00
Ho	2.3E–01	±	3.4E–02	2.6E–06	±	3.1E–07	1.1E–05	±	0.00E+00
I	1.1E+02	±	5.1E+00	1.3E–03	±	1.2E–05	2.4E–02	±	5.2E–03
K	8.4E+04	±	1.0E+04	9.5E–01	±	8.6E–02	6.4E+01	±	9.5E–01
Li	4.2E+01	±	3.6E+00	4.8E–04	±	2.6E–05	2.7E–02	±	6.0E–04
Lu	1.0E–01	±	1.7E–02	1.2E–06	±	1.6E–07	1.0E–05	±	0.0E+00
Mg	1.0E+04	±	8.2E+02	1.1E–01	±	5.2E–03	1.8E+02	±	5.8E–01
Mn	1.5E+02	±	7.7E+00	1.7E–03	±	3.5E–05	2.0E–03	±	1.5E–04
Mo	6.0E+01	±	9.5E+00	6.8E–04	±	8.6E–05	1.7E–03	±	1.2E–05
N	3.7E+03	±	5.6E+02	4.3E–02	±	6.5E–03	2.2E–01	±	1.1E–02
Na	2.4E+05	±	2.7E+04	2.7E+00	±	2.2E–01	1.5E+03	±	5.2E+01
Nd	9.0E+00	±	1.2E+00	1.0E–04	±	1.1E–05	1.2E–05	±	1.2E–06
Ni	1.2E+01	±	1.5E+00	1.3E–04	±	1.4E–05	9.4E–04	±	5.6E–05
P1	5.6E+02	±	4.8E+01	6.4E–03	±	5.6E–04	5.6E–03	±	7.0E–04
P2	6.2E+02	±	7.1E+01	7.0E–03	±	6.6E–04	5.1E–03	±	2.6E–04
Pb	1.7E+02	±	2.4E+01	2.0E–03	±	2.1E–04	1.9E–03	±	1.8E–03
Pr	2.4E+00	±	2.8E–01	2.7E–05	±	2.5E–06	1.0E–05	±	0.0E+00
Rb	2.9E+02	±	4.1E+01	3.3E–03	±	3.6E–04	1.9E–02	±	2.6E–04
S	4.9E+03	±	5.6E+02	5.5E–02	±	6.8E–03	1.3E+02	±	1.0E+00
Se	1.1E+01	±	5.1E–01	1.3E–04	±	1.2E–06	3.2E–05	±	2.1E–05
Si	4.9E+05	±	3.1E+04	5.6E+00	±	2.9E–01	3.9E–01	±	2.0E–02
Sm	2.0E+00	±	2.9E–01	2.3E–05	±	2.8E–06	1.0E–05	±	0.0E+00
Tb	1.9E–01	±	2.0E–02	2.2E–06	±	1.6E–07	1.0E–04	±	0.0E+00
Th	3.7E+00	±	4.2E–01	4.2E–05	±	3.5E–06	4.0E–05	±	0.0E+00
Ti	4.1E+02	±	3.6E+01	4.7E–03	±	2.5E–04	5.5E–05	±	2.0E–05
Tm	1.0E–01	±	1.7E–02	1.2E–06	±	1.6E–07	1.0E–05	±	0.0E+00
V	7.0E+00	±	9.8E–01	8.0E–05	±	9.8E–06	1.3E–04	±	1.3E–05
Yb	6.5E–01	±	8.6E–02	7.4E–06	±	7.9E–07	1.0E–05	±	0.0E+00
Zn	9.3E+04	±	1.1E+04	1.1E+00	±	9.1E–02	1.5E–03	±	3.6E–04
Zr	1.5E+02	±	1.6E+01	1.7E–03	±	1.3E–04	6.0E–05	±	0.0E+00

Appendix 7

Average concentrations and stdv (mg/kg dw; mg/L) of elements in sediment 0–3 cm (n=3), sediment 3–6 cm (n=3), porewater 0–3 cm (n=3) and porewater 3–6 cm (n=1).

	Sediment 0–3 cm mg/kg dw			Sediment 3–6 cm mg/kg dw			Porewater 0–3 cm mg/L			Porewater 3–6 cm mg/L		
Al	4.4E+00	±	6.1E–01	9.2E+00	±	1.0E+01	2.7E–02	±	1.7E–02	1.5E–03	±	–
As	2.0E+00	±	4.4E–01	2.4E+00	±	1.9E+00	5.2E–03	±	3.3E–04	7.3E–03	±	–
Ba	1.2E+02	±	1.5E+01	1.1E+02	±	2.9E+01	5.1E–02	±	3.2E–02	5.7E–02	±	–
Br	2.7E+01	±	7.1E–02	1.3E+01	±	3.8E+00	no data	±	no data	no data	±	–
C	4.4E+03	±	1.2E+03	2.4E+03	±	9.8E+02	no data	±	no data	no data	±	–
Ca	1.7E+03	±	2.0E+02	2.0E+03	±	1.4E+03	8.5E+01	±	2.8E+00	8.2E+01	±	–
Cd	2.0E–01	±	6.1E–02	1.6E–01	±	3.6E–02	2.7E–05	±	7.6E–06	7.3E–06	±	–
Ce	7.8E–01	±	3.1E–01	1.3E+00	±	1.4E+00	3.1E–04	±	1.7E–04	1.4E–05	±	–
Cl	8.8E+02	±	2.8E+01	8.3E+02	±	3.5E+01	no data	±	no data	no data	±	–
Co	2.5E+00	±	4.3E–01	4.7E+00	±	5.0E+00	4.8E–04	±	1.6E–04	2.2E–04	±	–
Cr	1.2E+01	±	3.3E+00	2.1E+01	±	2.4E+01	3.9E–04	±	3.2E–05	3.4E–04	±	–
Cs	1.2E+00	±	6.0E–02	1.6E+00	±	5.4E–01	7.2E–05	±	4.5E–06	6.0E–05	±	–
Cu	5.6E+00	±	1.6E+00	1.1E+01	±	1.2E+01	7.2E–04	±	1.2E–04	3.2E–04	±	–
Dy	8.9E–02	±	4.1E–02	1.1E–01	±	8.7E–02	3.3E–05	±	1.7E–05	1.0E–05	±	–
Er	3.0E–02	±	1.0E–02	6.2E–02	±	5.1E–02	2.1E–05	±	9.3E–06	1.0E–05	±	–
Eu	1.8E–02	±	9.6E–03	2.1E–02	±	1.6E–02	1.0E–05	±	3.5E–07	1.0E–05	±	–
F	6.5E–01	±	7.1E–02	6.0E–01	±	0.0E+00	no data	±	no data	no data	±	–
Fe	6.6E+03	±	8.7E+02	1.2E+04	±	1.3E+04	3.1E–02	±	1.4E–02	1.2E+00	±	–
Gd	1.1E–01	±	4.9E–02	1.4E–01	±	1.0E–01	3.9E–05	±	2.0E–05	1.0E–05	±	–
Hg	1.0E–01	±	9.5E–03	9.3E–02	±	5.8E–03	3.5E–06	±	1.5E–06	2.0E–06	±	–
Ho	1.7E–02	±	7.5E–03	2.1E–02	±	1.7E–02	1.0E–05	±	0.0E+00	1.0E–05	±	–
I	6.6E+00	±	1.1E–01	2.7E+00	±	9.4E–01	no data	±	no data	no data	±	–
K	1.2E+03	±	2.3E+02	2.7E+03	±	3.2E+03	7.4E+01	±	2.0E+00	8.9E+01	±	–
Li	7.5E+00	±	1.2E+00	1.0E+01	±	5.9E+00	3.1E–02	±	1.2E–03	3.5E–02	±	–
Lu	6.8E–03	±	2.6E–03	8.4E–03	±	7.2E–03	1.0E–05	±	0.0E+00	1.0E–05	±	–
Mg	1.8E+03	±	2.4E+02	3.5E+03	±	3.8E+03	1.7E+02	±	6.0E+00	1.6E+02	±	–
Mn	2.1E+02	±	1.6E+02	2.3E+02	±	2.5E+02	5.3E–01	±	3.0E–01	2.4E–01	±	–
Mo	2.0E–01	±	7.4E–02	2.7E–01	±	2.0E–01	4.1E–03	±	1.8E–03	8.1E–03	±	–
N	5.3E+02	±	1.5E+02	2.7E+02	±	1.2E+02	no data	±	no data	no data	±	–
Na	2.9E+03	±	3.7E+03	9.3E+02	±	4.4E+02	1.4E+03	±	3.5E+01	1.5E+03	±	–
Nd	5.7E–01	±	2.3E–01	8.0E–01	±	6.7E–01	1.7E–04	±	9.4E–05	1.0E–05	±	–
Ni	5.1E+00	±	6.4E–01	1.1E+01	±	1.3E+01	1.6E–03	±	8.7E–05	1.5E–03	±	–
P1	3.5E+02	±	1.3E+02	3.1E+02	±	1.6E+02	no data	±	no data	no data	±	–
P2	3.2E+02	±	4.7E+01	3.3E+02	±	1.8E+02	7.0E–02	±	3.2E–02	6.1E–02	±	–
Pb	2.0E+01	±	8.9E–01	2.3E+01	±	3.4E+00	6.9E–04	±	4.9E–05	4.2E–04	±	–
Pr	1.6E–01	±	6.0E–02	2.2E–01	±	1.8E–01	4.6E–05	±	2.6E–05	1.0E–05	±	–
Rb	6.0E+01	±	4.6E+00	5.8E+01	±	2.5E+01	2.8E–02	±	6.7E–04	3.1E–02	±	–
S	4.9E+02	±	1.6E+02	4.8E+02	±	1.7E+02	1.4E+02	±	5.5E+00	1.4E+02	±	–
Se	5.0E–02	±	1.4E–02	4.1E–02	±	1.4E–02	2.4E–04	±	1.1E–04	1.2E–04	±	–
Si*	2.5E+05	±	0.0E+00	2.5E+05	±	0.0E+00	1.2E+01	±	0.0E+00	1.2E+01	±	0.0E+00
Sm	1.1E–01	±	5.1E–02	1.5E–01	±	1.2E–01	3.8E–05	±	2.1E–05	1.0E–05	±	–
Tb	1.6E–02	±	7.8E–03	2.0E–02	±	1.6E–02	1.0E–04	±	0.0E+00	1.0E–04	±	–
Th	7.3E–01	±	4.1E–01	7.8E–01	±	5.7E–01	4.0E–05	±	0.0E+00	4.0E–05	±	–
Ti	1.0E+03	±	8.9E+02	7.0E+02	±	4.9E+02	6.0E–04	±	2.5E–04	1.3E–04	±	–
Tm	6.1E–03	±	2.9E–03	8.2E–03	±	6.5E–03	1.0E–05	±	0.0E+00	1.0E–05	±	–
V	1.9E+01	±	7.3E+00	3.1E+01	±	3.5E+01	9.3E–04	±	1.1E–04	5.0E–04	±	–
Yb	4.1E–02	±	2.0E–02	5.2E–02	±	4.4E–02	2.3E–05	±	1.0E–05	1.0E–05	±	–
Zn	3.6E+01	±	7.2E+00	5.1E+01	±	3.8E+01	1.6E–02	±	2.7E–03	3.7E–03	±	–
Zr	2.5E+02	±	2.3E+02	1.9E+02	±	1.6E+02	6.6E–05	±	1.0E–05	6.0E–05	±	–

* Sediment and porewater used for Si-analyses sampled on another occasion and location (see Table 2-1).

Appendix 8

Average concentrations and stdv (mol/kg dw) of elements in phytoplankton (n=3), zooplankton (n=1) and benthic microalgae (n=2).

	Phytoplankton mol/kg dw			Zooplankton mol/kg dw			Benthic microalgae mol/kg dw		
Al	1.9E–01	±	4.4E–02	1.1E–01	±	–	1.0E+00	±	1.5E–01
As	1.7E–04	±	4.2E–05	3.1E–04	±	–	7.3E–04	±	5.0E–04
Ba	3.0E–04	±	5.2E–05	3.6E–04	±	–	3.5E–03	±	1.3E–03
Br	1.6E–02	±	1.6E–03	1.7E–01	±	–	1.3E–02	±	2.8E–03
C	1.4E+01	±	3.8E–01	3.6E+01	±	–	1.2E+01	±	2.5E+00
Ca	8.5E–02	±	5.0E–03	2.2E+00	±	–	7.3E–01	±	2.4E–01
Cd	2.2E–06	±	4.4E–07	4.3E–05	±	–	2.5E–05	±	1.5E–05
Ce	6.8E–08	±	1.8E–08	2.5E–05	±	–	3.4E–06	±	2.2E–07
Cl	1.8E+00	±	6.0E–02	no data	±	–	1.2E+00	±	2.6E–01
Co	2.8E–05	±	6.5E–06	2.9E–05	±	–	6.4E–04	±	3.9E–04
Cr	1.2E–04	±	2.3E–05	1.9E–04	±	–	4.8E–04	±	2.2E–05
Cs	3.9E–06	±	9.5E–07	2.4E–06	±	–	1.9E–05	±	1.1E–06
Cu	3.6E–04	±	8.6E–05	3.2E–03	±	–	7.1E–04	±	2.5E–04
Dy	3.2E–09	±	9.8E–10	1.7E–06	±	–	1.8E–07	±	6.1E–09
Er	1.8E–09	±	5.7E–10	9.3E–07	±	–	9.6E–08	±	1.6E–08
Eu	1.3E–09	±	0.0E+00	3.2E–07	±	–	3.5E–08	±	5.5E–09
F	5.1E–02	±	2.6E–03	no data	±	–	5.8E–03	±	5.2E–03
Fe	6.9E–02	±	1.7E–02	3.7E–02	±	–	7.6E–01	±	2.5E–01
Gd	4.2E–09	±	1.3E–09	1.8E–06	±	–	2.5E–07	±	1.0E–08
Hg	2.8E–07	±	3.3E–08	3.0E–06	±	–	5.9E–07	±	7.1E–08
Ho	1.2E–09	±	0.0E+00	3.6E–07	±	–	3.3E–08	±	3.9E–09
I	1.2E–04	±	2.9E–05	5.6E–04	±	–	2.4E–03	±	1.3E–03
K	2.9E–01	±	2.7E–02	2.1E+00	±	–	4.2E–01	±	5.3E–02
Li	1.3E–03	±	3.1E–04	1.4E–03	±	–	2.8E–03	±	3.2E–04
Lu	1.1E–09	±	0.0E+00	1.4E–07	±	–	1.3E–08	±	2.3E–09
Mg	3.0E–01	±	9.3E–03	1.1E+00	±	–	4.6E–01	±	4.4E–02
Mn	8.2E–03	±	1.1E–03	3.1E–03	±	–	2.7E–01	±	1.7E–01
Mo	3.5E–06	±	2.7E–07	2.7E–05	±	–	7.2E–05	±	5.6E–05
N	1.5E+00	±	8.6E–02	6.9E+00	±	–	1.2E+00	±	2.1E–01
Na	2.1E+00	±	8.1E–02	8.4E+00	±	–	1.4E+00	±	1.7E–01
Nd	2.8E–08	±	8.3E–09	1.3E–05	±	–	1.6E–06	±	8.8E–08
Ni	1.0E–04	±	3.4E–05	2.1E–04	±	–	2.3E–03	±	1.6E–03
P1	4.2E–02	±	5.2E–03	3.1E–01	±	–	8.6E–02	±	1.3E–02
P2	6.8E–02	±	1.5E–02	1.8E+00	±	–	9.9E–02	±	1.1E–02
Pb	5.5E–05	±	9.7E–06	8.8E–05	±	–	4.3E–04	±	3.7E–04
Pr	7.7E–09	±	2.3E–09	3.4E–06	±	–	4.4E–07	±	2.9E–08
Rb	1.5E–04	±	2.9E–05	4.6E–04	±	–	6.6E–04	±	2.8E–05
S	2.2E–01	±	6.4E–03	1.5E+00	±	–	2.9E–01	±	4.3E–02
Se	6.3E–06	±	7.3E–07	1.3E–04	±	–	8.4E–06	±	1.3E–07
Si	4.9E+00	±	4.9E–01	3.5E+00	±	–	2.9E+00	±	8.3E–02
Sm	5.0E–09	±	1.5E–09	2.5E–06	±	–	2.9E–07	±	2.8E–08
Tb	1.3E–09	±	0.0E+00	3.0E–07	±	–	3.4E–08	±	1.3E–10
Th	6.0E–06	±	1.1E–06	2.3E–06	±	–	7.2E–05	±	2.6E–05
Ti	3.8E–03	±	8.1E–04	2.3E–03	±	–	1.8E–02	±	1.8E–03
Tm	1.2E–09	±	0.0E+00	1.4E–07	±	–	1.3E–08	±	2.3E–09
V	1.4E–04	±	3.0E–05	7.5E–05	±	–	1.1E–03	±	3.1E–04
Yb	1.6E–09	±	4.8E–10	8.3E–07	±	–	8.1E–08	±	1.3E–08
Zn	6.0E–03	±	2.3E–03	1.6E–02	±	–	7.8E–03	±	3.3E–03
Zr	1.6E–04	±	1.6E–05	5.4E–05	±	–	1.4E–03	±	1.4E–04

Appendix 9

Average concentrations and stdv (mol/kg dw) of elements in *F. vesiculosus* (n=3), *P. littoralis* (n=3) and *P. pectinatus* (n=3).

	F. vesiculosus mol/kg dw			*P. littoralis* mol/kg dw			*P. pectinatus* mol/kg dw		
Al	2.5E–02	±	1.3E–02	1.6E–01	±	9.7E–02	1.0E–01	±	3.4E–02
As	4.4E–04	±	2.1E–05	2.8E–04	±	5.3E–05	5.0E–05	±	7.7E–06
Ba	1.7E–03	±	2.8E–04	6.9E–04	±	6.8E–05	2.7E–04	±	5.5E–05
Br	3.6E–03	±	1.3E–03	3.2E–03	±	3.4E–04	no data	±	no data
C	3.1E+01	±	6.8E–01	2.4E+01	±	1.4E+00	3.0E+01	±	1.1E+00
Ca	3.7E–01	±	2.4E–02	2.8E–01	±	2.0E–01	5.6E–01	±	2.7E–01
Cd	4.4E–05	±	1.1E–05	2.7E–06	±	1.9E–06	8.1E–06	±	1.5E–06
Ce	6.3E–07	±	2.7E–07	2.4E–07	±	1.9E–07	6.0E–07	±	3.5E–07
Cl	2.6E–01	±	0.0E+00	1.2E+00	±	8.0E–02	no data	±	no data
Co	2.0E–05	±	4.2E–06	2.6E–05	±	1.7E–05	4.3E–05	±	1.5E–05
Cr	1.7E–05	±	8.1E–06	9.2E–05	±	6.1E–05	5.9E–05	±	2.0E–05
Cs	6.8E–07	±	3.5E–07	4.0E–06	±	2.6E–06	2.4E–06	±	8.3E–07
Cu	6.2E–05	±	2.9E–06	8.4E–05	±	3.2E–05	1.2E–04	±	2.3E–05
Dy	6.2E–08	±	2.1E–08	1.3E–08	±	1.0E–08	2.8E–08	±	1.4E–08
Er	3.7E–08	±	1.3E–08	7.0E–09	±	5.5E–09	1.5E–08	±	7.4E–09
Eu	9.4E–09	±	4.7E–09	2.9E–09	±	2.2E–09	6.0E–09	±	3.2E–09
F	2.0E–03	±	3.7E–05	3.1E–02	±	2.4E–02	no data	±	no data
Fe	1.0E–02	±	4.6E–03	6.1E–02	±	3.6E–02	3.8E–02	±	1.1E–02
Gd	7.8E–08	±	3.0E–08	1.7E–08	±	1.3E–08	3.7E–08	±	1.9E–08
Hg	1.2E–07	±	2.1E–08	1.3E–07	±	5.8E–08	1.4E–07	±	1.4E–08
Ho	1.3E–08	±	4.4E–09	2.5E–09	±	2.0E–09	5.4E–09	±	2.7E–09
I	7.8E–04	±	3.1E–04	3.9E–04	±	3.3E–05	no data	±	no data
K	5.7E–01	±	4.6E–02	7.8E–01	±	1.2E–01	6.0E–01	±	5.0E–02
Li	2.1E–04	±	5.2E–05	9.4E–04	±	1.5E–04	5.4E–04	±	7.0E–05
Lu	5.5E–09	±	1.9E–09	1.4E–09	±	3.6E–10	2.1E–09	±	1.0E–09
Mg	4.0E–01	±	2.6E–02	2.8E–01	±	2.2E–02	3.5E–01	±	4.9E–02
Mn	7.7E–03	±	1.7E–03	5.2E–03	±	3.4E–03	1.4E–02	±	4.8E–03
Mo	3.7E–06	±	1.4E–06	2.9E–06	±	6.4E–07	1.3E–05	±	4.2E–06
N	1.5E+00	±	1.9E–01	1.8E+00	±	1.2E–01	1.3E+00	±	1.1E–01
Na	6.2E–01	±	1.3E–02	1.1E+00	±	1.1E–01	9.4E–01	±	1.7E–01
Nd	4.2E–07	±	1.6E–07	1.1E–07	±	8.6E–08	2.3E–07	±	1.2E–07
Ni	2.9E–04	±	7.7E–05	9.7E–05	±	5.0E–05	1.2E–04	±	4.7E–05
P1	4.0E–02	±	1.7E–03	9.4E–02	±	1.7E–02	7.7E–02	±	1.2E–02
P2	4.2E–02	±	3.5E–03	8.1E–02	±	1.5E–02	8.4E–02	±	1.1E–02
Pb	4.0E–06	±	1.6E–06	2.2E–05	±	1.0E–05	1.5E–05	±	3.3E–06
Pr	1.1E–07	±	4.4E–08	3.0E–08	±	2.3E–08	6.4E–08	±	3.4E–08
Rb	1.3E–04	±	2.4E–05	2.3E–04	±	4.9E–05	1.2E–04	±	2.4E–05
S	9.7E–01	±	6.7E–02	3.3E–01	±	4.7E–02	2.4E–01	±	3.9E–02
Se	6.7E–06	±	3.0E–07	6.4E–07	±	6.7E–07	2.7E–06	±	8.1E–07
Si	2.0E–01	±	6.2E–02	2.4E+00	±	4.4E–01	1.3E+00	±	2.5E–01
Sm	7.6E–08	±	2.8E–08	2.0E–08	±	1.5E–08	4.0E–08	±	2.2E–08
Tb	1.1E–08	±	4.0E–09	2.4E–09	±	1.8E–09	5.1E–09	±	2.7E–09
Th	8.9E–07	±	5.2E–07	5.7E–06	±	3.7E–06	3.8E–06	±	1.0E–06
Ti	5.2E–04	±	2.6E–04	3.3E–03	±	2.0E–03	1.9E–03	±	5.4E–04
Tm	5.1E–09	±	1.7E–09	1.4E–09	±	4.1E–10	2.1E–09	±	1.1E–09
V	3.0E–05	±	1.2E–05	1.4E–04	±	8.9E–05	9.0E–05	±	3.3E–05
Yb	3.3E–08	±	1.2E–08	6.0E–09	±	4.8E–09	1.3E–08	±	6.6E–09
Zn	3.6E–03	±	6.7E–04	7.5E–04	±	3.4E–04	1.4E–03	±	2.7E–04
Zr	3.9E–05	±	1.6E–05	1.8E–04	±	9.3E–05	9.8E–05	±	2.4E–05

Appendix 10

Average concentrations and stdv (mol/kg dw) of elements in *T. fluviatilis* (n=2), *Idothea* spp. (n=2), *M. baltica* (n=3) and *C. glaucum* (n=3).

	T. fluviatilis **mol/kg dw**			***Idothea*** **spp. mol/kg dw**			***M. baltica*** **mol/kg dw**			***C. glaucum*** **mol/kg dw**		
Al	2.5E–02	±	5.8E–04	2.7E–02	±	7.3E–04	2.2E–02	±	2.5E–03	1.0E–02	±	3.2E–02
As	2.8E–05	±	2.0E–06	8.9E–05	±	1.7E–05	2.7E–05	±	6.1E–06	9.0E–06	±	7.5E–07
Ba	9.4E–05	±	1.3E–05	5.9E–04	±	8.0E–05	2.2E–04	±	3.1E–05	2.3E–04	±	1.5E–05
Br	1.4E–03	±	3.7E–04	no data	±	no data	4.0E–04	±	1.1E–04	no data	±	no data
C	1.4E+01	±	8.8E–01	3.0E+01	±	5.9E–01	1.4E+01	±	1.0E+00	1.3E+01	±	5.9E–02
Ca	8.1E+00	±	1.8E–02	3.0E+00	±	5.3E–02	6.7E+00	±	1.2E+00	7.9E+00	±	5.5E–01
Cd	6.5E–06	±	1.6E–07	1.7E–05	±	2.7E–06	1.4E–06	±	6.6E–07	1.5E–06	±	2.5E–07
Ce	1.4E–06	±	1.2E–07	2.8E–07	±	6.0E–08	2.3E–06	±	8.9E–08	9.8E–07	±	1.5E–08
Cl	8.2E–02	±	8.0E–03	no data	±	no data	5.2E–02	±	6.0E–03	no data	±	no data
Co	5.1E–06	±	7.0E–07	1.3E–05	±	2.9E–06	5.0E–06	±	1.1E–06	1.8E–06	±	2.3E–07
Cr	6.1E–06	±	6.8E–07	2.1E–05	±	1.1E–06	1.0E–05	±	8.4E–07	5.0E–06	±	1.9E–06
Cs	2.8E–07	±	4.4E–08	7.2E–07	±	3.2E–08	4.2E–07	±	2.3E–08	1.9E–07	±	9.5E–08
Cu	1.8E–04	±	3.3E–06	8.9E–04	±	1.5E–04	3.6E–04	±	1.1E–04	2.7E–05	±	4.7E–06
Dy	7.4E–08	±	2.2E–09	1.6E–08	±	2.8E–09	1.1E–07	±	1.1E–08	6.1E–08	±	3.8E–09
Er	3.4E–08	±	1.9E–09	8.4E–09	±	1.6E–09	5.7E–08	±	6.8E–09	3.3E–08	±	1.4E–09
Eu	1.5E–08	±	1.9E–10	2.7E–09	±	6.0E–10	2.9E–08	±	3.2E–09	1.4E–08	±	8.8E–10
F	1.1E–03	±	3.7E–05	no data	±	no data	1.1E–03	±	1.1E–04	no data	±	no data
Fe	4.5E–03	±	1.1E–04	1.0E–02	±	5.3E–04	1.4E–02	±	1.7E–03	4.3E–03	±	1.9E–03
Gd	1.0E–07	±	9.9E–09	2.1E–08	±	4.2E–09	1.9E–07	±	1.7E–08	9.6E–08	±	4.5E–10
Hg	1.3E–07	±	2.7E–08	1.6E–07	±	1.6E–08	1.9E–07	±	3.7E–08	6.3E–08	±	1.3E–08
Ho	1.3E–08	±	2.1E–10	3.0E–09	±	6.0E–10	2.1E–08	±	1.8E–09	1.2E–08	±	3.4E–10
I	6.4E–05	±	2.6E–06	no data	±	no data	1.3E–05	±	2.8E–06	no data	±	no data
K	3.8E–02	±	6.8E–04	2.1E–01	±	4.3E–02	4.0E–02	±	4.2E–03	2.5E–02	±	4.7E–03
Li	6.3E–05	±	1.3E–06	2.2E–04	±	3.1E–06	6.9E–05	±	6.3E–06	5.6E–05	±	1.6E–05
Lu	4.4E–09	±	1.2E–10	1.2E–09	±	8.1E–11	7.2E–09	±	4.3E–10	4.0E–09	±	1.2E–10
Mg	3.2E–02	±	5.5E–03	3.0E–01	±	3.2E–02	1.8E–02	±	1.6E–03	1.5E–02	±	2.0E–03
Mn	2.9E–03	±	0.0E+00	1.6E–03	±	3.2E–04	4.5E–04	±	9.6E–05	4.2E–04	±	1.6E–04
Mo	1.7E–06	±	2.7E–07	2.6E–06	±	2.7E–07	2.0E–06	±	3.5E–07	6.0E–07	±	5.6E–08
N	1.0E+00	±	3.3E–01	4.8E+00	±	6.5E–01	9.7E–01	±	1.3E–01	7.2E–01	±	5.6E–02
Na	2.2E–01	±	8.0E–03	6.0E–01	±	9.5E–02	1.8E–01	±	2.3E–02	2.0E–01	±	2.3E–02
Nd	6.1E–07	±	5.5E–08	1.3E–07	±	2.7E–08	1.1E–06	±	3.5E–08	5.2E–07	±	3.1E–08
Ni	1.8E–05	±	2.5E–06	3.4E–05	±	8.8E–06	8.9E–06	±	2.0E–06	5.5E–05	±	7.2E–07
P1	4.2E–02	±	1.6E–02	2.5E–01	±	6.8E–02	4.9E–02	±	9.3E–03	3.4E–02	±	1.8E–03
P2	4.4E–02	±	3.0E–03	2.2E–01	±	1.3E–02	5.8E–02	±	2.0E–02	2.2E–02	±	3.8E–03
Pb	2.1E–06	±	2.4E–07	4.3E–06	±	6.2E–07	4.6E–06	±	1.8E–06	1.1E–06	±	6.5E–08
Pr	1.8E–07	±	1.0E–08	3.7E–08	±	7.2E–09	3.1E–07	±	1.2E–08	1.4E–07	±	6.0E–09
Rb	1.8E–05	±	1.7E–06	4.2E–05	±	4.8E–06	2.0E–05	±	1.2E–06	1.1E–05	±	3.7E–06
S	4.8E–02	±	1.5E–02	2.8E–01	±	5.7E–02	4.0E–02	±	1.4E–02	1.8E–02	±	1.3E–03
Se	7.7E–06	±	8.1E–07	7.6E–06	±	4.4E–07	5.2E–06	±	1.4E–06	3.1E–06	±	1.1E–06
Si	1.1E–01	±	5.8E–03	2.0E–01	±	7.6E–04	7.0E–02	±	1.6E–02	3.5E–02	±	5.3E–03
Sm	1.1E–07	±	1.9E–08	2.3E–08	±	4.1E–09	2.0E–07	±	1.4E–08	9.3E–08	±	7.1E–09
Tb	1.3E–08	±	8.5E–10	2.9E–09	±	5.8E–10	2.3E–08	±	1.8E–09	1.2E–08	±	1.2E–09
Th	1.4E–06	±	2.5E–07	1.0E–06	±	1.2E–08	8.2E–07	±	1.5E–07	3.5E–07	±	1.5E–07
Ti	2.9E–04	±	5.0E–05	5.6E–04	±	5.6E–05	3.8E–04	±	6.1E–05	1.7E–04	±	7.0E–05
Tm	4.7E–09	±	3.8E–10	1.2E–09	±	8.4E–11	7.4E–09	±	6.9E–10	4.3E–09	±	2.5E–10
V	1.2E–05	±	1.6E–06	2.5E–05	±	1.9E–06	1.6E–05	±	2.6E–06	7.6E–06	±	2.0E–06
Yb	2.9E–08	±	3.3E–10	7.1E–09	±	1.5E–09	4.5E–08	±	4.0E–09	2.7E–08	±	4.1E–10
Zn	2.5E–04	±	2.7E–05	8.7E–04	±	1.3E–04	6.0E–04	±	1.9E–04	1.1E–04	±	1.3E–05
Zr	2.5E–05	±	1.2E–06	2.9E–05	±	4.7E–06	3.0E–05	±	1.0E–05	1.4E–05	±	1.2E–05

Appendix 11

Average concentrations and stdv (mol/kg dw) of elements in *G. cernuus* (Ruffe, n=3), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). Analyses of whole fish samples.

	G. cernuus mol/kg dw			*O. eperlanus* mol/kg dw			*R. rutilus* mol/kg dw		
Al	1.5E–03	±	8.5E–04	3.7E–04	±	3.2E–05	3.2E–04	±	3.9E–06
As	3.8E–04	±	0.0E+00	4.1E–04	±	8.8E–06	3.9E–04	±	0.0E+00
Ba	1.8E–05	±	2.8E–06	4.8E–06	±	5.2E–07	1.5E–05	±	7.6E–07
Br	no data		no data	no data		no data	no data		no data
C	no data		no data	no data		no data	no data		no data
Ca	1.2E–03	±	1.9E–05	4.9E–04	±	6.2E–05	1.3E–03	±	3.6E–05
Cd	2.8E–07	±	5.6E–08	2.8E–07	±	8.2E–08	4.4E–07	±	6.8E–08
Ce	8.8E–07	±	6.4E–07	7.1E–08	±	2.5E–08	8.9E–08	±	1.7E–08
Cl	no data		no data	no data		no data	no data		no data
Co	1.5E–06	±	5.0E–07	6.6E–07	±	2.0E–07	9.2E–07	±	4.1E–08
Cr	1.1E–05	±	1.6E–06	1.1E–05	±	1.2E–06	8.5E–06	±	1.1E–06
Cs	2.7E–07	±	3.9E–08	3.4E–07	±	4.1E–08	1.3E–07	±	0.0E+00
Cu	4.4E–05	±	5.7E–06	4.8E–05	±	6.8E–06	6.1E–05	±	1.2E–05
Dy	4.9E–08	±	3.5E–08	1.9E–08	±	4.0E–10	1.8E–08	±	0.0E+00
Er	2.9E–08	±	1.3E–08	1.8E–08	±	3.9E–10	1.7E–08	±	0.0E+00
Eu	1.9E–08	±	0.0E+00	2.0E–08	±	4.3E–10	1.9E–08	±	0.0E+00
F	no data		no data	no data		no data	no data		no data
Fe	1.8E–06	±	9.3E–07	5.2E–07	±	9.6E–08	8.9E–07	±	1.1E–07
Gd	7.0E–08	±	5.2E–08	1.9E–08	±	4.2E–10	1.8E–08	±	0.0E+00
Hg	9.1E–07	±	1.1E–07	8.0E–07	±	3.2E–07	6.5E–07	±	1.6E–07
Ho	1.7E–08	±	0.0E+00	1.9E–08	±	4.0E–10	1.8E–08	±	0.0E+00
I	no data		no data	no data		no data	no data		no data
K	3.2E–04	±	8.1E–06	4.1E–04	±	9.6E–06	3.6E–04	±	2.7E–06
Li	9.1E–05	±	1.8E–05	1.2E–04	±	7.8E–05	1.0E–04	±	3.0E–05
Lu	1.6E–08	±	0.0E+00	1.7E–08	±	3.8E–10	1.7E–08	±	0.0E+00
Mg	5.3E–05	±	6.0E–07	4.8E–05	±	2.8E–06	6.8E–05	±	9.0E–07
Mn	1.0E–04	±	2.6E–06	2.1E–04	±	2.2E–05	1.6E–04	±	2.4E–05
Mo	6.2E–07	±	1.4E–07	5.3E–07	±	2.9E–08	1.2E–06	±	6.2E–08
N	no data		no data	no data		no data	no data		no data
Na	2.1E–04	±	1.1E–05	1.8E–04	±	2.9E–05	1.5E–04	±	1.9E–06
Nd	3.9E–07	±	3.0E–07	2.3E–08	±	1.5E–09	3.2E–08	±	6.5E–09
Ni	8.0E–06	±	4.8E–07	7.9E–06	±	8.3E–07	9.3E–06	±	3.7E–06
P1	no data		no data	no data		no data	no data		no data
P2	1.0E+00	±	2.4E–02	5.6E–01	±	3.7E–02	1.0E+00	±	1.6E–02
Pb	1.0E–06	±	2.0E–07	8.3E–07	±	3.0E–07	9.3E–07	±	1.2E–07
Pr	1.1E–07	±	8.1E–08	2.2E–08	±	4.7E–10	2.1E–08	±	0.0E+00
Rb	9.7E–05	±	6.5E–06	6.1E–05	±	4.9E–07	6.4E–05	±	4.1E–06
S	2.4E–04	±	8.6E–06	2.7E–04	±	1.2E–05	2.5E–04	±	9.7E–06
Se	1.4E–05	±	7.9E–07	1.4E–05	±	2.7E–06	1.3E–05	±	1.3E–06
Si	1.7E–06	±	7.6E–08	1.4E–06	±	2.1E–07	1.0E–06	±	2.3E–07
Sm	6.8E–08	±	5.1E–08	2.0E–08	±	4.4E–10	1.9E–08	±	0.0E+00
Tb	1.8E–08	±	0.0E+00	1.9E–08	±	4.1E–10	1.8E–08	±	0.0E+00
Th	4.9E–08	±	0.0E+00	5.3E–08	±	1.1E–09	5.0E–08	±	0.0E+00
Ti	3.8E–05	±	2.5E–05	2.4E–06	±	6.8E–07	3.0E–06	±	5.1E–07
Tm	1.7E–08	±	0.0E+00	1.8E–08	±	3.9E–10	1.7E–08	±	0.0E+00
V	7.8E–06	±	3.9E–06	7.3E–07	±	6.3E–08	1.2E–06	±	3.0E–07
Yb	2.8E–08	±	1.1E–08	1.8E–08	±	3.8E–10	1.7E–08	±	0.0E+00
Zn	1.4E–03	±	1.2E–04	1.9E–03	±	7.9E–04	3.4E–03	±	1.6E–04
Zr	3.9E–07	±	4.7E–09	6.9E–07	±	8.6E–07	3.8E–07	±	1.0E–07

Appendix 12

Average concentrations and stdv (mol/mg dw) of elements in *G. cernuus* (Ruffe, n=3), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). Analyses of mixed fish slices.

	G. cernuus mol/kg dw			*O. eperlanus* mol/kg dw			*R. rutilus* mol/kg dw		
Al	1.2E–04	±	1.4E–04	2.9E–05	±	3.6E–06	2.9E–05	±	2.3E–05
As	9.3E–06	±	1.6E–06	3.2E–05	±	5.6E–06	1.0E–05	±	7.4E–06
Ba	1.5E–05	±	9.7E–06	3.4E–06	±	1.2E–06	1.5E–05	±	5.7E–06
Br	2.4E–04	±	1.2E–05	3.1E–04	±	8.8E–05	1.9E–04	±	1.5E–05
C	3.4E+01	±	9.5E–01	4.0E+01	±	8.7E–01	3.6E+01	±	1.1E+00
Ca	1.4E+00	±	6.8E–01	3.2E–01	±	1.5E–01	8.5E–01	±	2.1E–01
Cd	8.9E–08	±	2.9E–08	9.7E–08	±	4.5E–08	3.1E–07	±	1.3E–07
Ce	2.1E–09	±	9.3E–10	1.2E–09	±	4.1E–10	1.4E–09	±	0.0E+00
Cl	4.4E–02	±	6.0E–03	4.2E–02	±	0.0E+00	2.6E–02	±	1.5E–02
Co	3.9E–07	±	1.5E–07	2.2E–07	±	1.2E–08	5.3E–07	±	7.2E–08
Cr	3.9E–07	±	1.0E–08	1.9E–07	±	0.0E+00	2.6E–07	±	1.1E–07
Cs	2.8E–07	±	5.8E–08	4.3E–07	±	2.0E–08	1.6E–07	±	4.4E–09
Cu	2.8E–05	±	7.9E–06	2.5E–05	±	6.3E–06	3.1E–05	±	2.1E–06
Dy	1.2E–09	±	0.0E+00	1.0E–09	±	3.6E–10	1.2E–09	±	0.0E+00
Er	1.2E–09	±	0.0E+00	1.0E–09	±	3.5E–10	1.2E–09	±	0.0E+00
Eu	1.3E–09	±	0.0E+00	1.1E–09	±	3.8E–10	1.3E–09	±	0.0E+00
F	1.1E–03	±	0.0E+00	1.1E–03	±	0.0E+00	1.1E–03	±	1.5E–02
Fe	4.0E–04	±	8.4E–05	2.8E–04	±	9.1E–05	6.9E–04	±	3.6E–04
Gd	1.3E–09	±	2.5E–25	1.1E–09	±	3.7E–10	1.3E–09	±	2.5E–25
Hg	1.5E–06	±	3.5E–07	1.3E–06	±	3.5E–07	1.5E–06	±	7.5E–07
Ho	1.2E–09	±	0.0E+00	1.0E–09	±	3.5E–10	1.2E–09	±	0.0E+00
I	8.2E–06	±	1.8E–06	1.5E–05	±	5.0E–07	6.3E–06	±	1.0E–04
K	4.5E–01	±	3.1E–02	5.4E–01	±	6.8E–02	4.4E–01	±	3.7E–02
Li	5.5E–05	±	9.1E–06	4.3E–05	±	4.0E–06	4.0E–05	±	1.1E–05
Lu	1.1E–09	±	0.0E+00	9.5E–10	±	3.3E–10	1.1E–09	±	0.0E+00
Mg	7.1E–02	±	1.1E–02	5.1E–02	±	6.8E–03	6.7E–02	±	7.7E–03
Mn	8.7E–05	±	4.4E–05	1.1E–04	±	1.5E–05	1.4E–04	±	9.9E–05
Mo	2.6E–07	±	9.3E–08	1.7E–07	±	5.2E–08	3.9E–07	±	1.1E–07
N	7.7E+00	±	3.2E–01	8.3E+00	±	2.3E–01	8.2E+00	±	1.5E–01
Na	1.9E–01	±	2.1E–02	1.5E–01	±	1.5E–02	1.3E–01	±	1.9E–02
Nd	1.4E–09	±	0.0E+00	1.2E–09	±	4.0E–10	1.4E–09	±	0.0E+00
Ni	1.7E–06	±	7.8E–07	1.5E–06	±	1.2E–07	1.5E–06	±	5.1E–07
P1	1.1E+00	±	8.8E–02	6.4E–01	±	5.3E–02	9.5E–01	±	1.2E–01
P2	1.0E+00	±	3.4E–01	4.4E–01	±	7.6E–02	7.8E–01	±	1.2E–01
Pb	3.8E–07	±	9.2E–08	2.8E–07	±	6.1E–08	4.1E–07	±	1.8E–07
Pr	1.4E–09	±	0.0E+00	1.2E–09	±	4.1E–10	1.4E–09	±	0.0E+00
Rb	9.4E–05	±	6.3E–06	6.8E–05	±	1.0E–05	7.0E–05	±	8.8E–06
S	3.1E–01	±	1.7E–02	2.5E–01	±	4.2E–03	2.9E–01	±	1.4E–02
Se	2.4E–05	±	3.7E–06	2.0E–05	±	7.7E–07	1.9E–05	±	1.1E–06
Si	1.3E–02	±	1.8E–02	7.5E–03	±	9.4E–03	2.5E–03	±	8.3E–04
Sm	1.3E–09	±	0.0E+00	1.1E–09	±	3.8E–10	1.3E–09	±	0.0E+00
Tb	1.3E–09	±	0.0E+00	1.0E–09	±	3.6E–10	1.3E–09	±	0.0E+00
Th	2.3E–08	±	9.2E–09	1.4E–08	±	2.5E–09	1.6E–08	±	5.0E–09
Ti	2.8E–05	±	1.5E–05	6.2E–06	±	4.0E–06	1.4E–05	±	6.8E–06
Tm	1.2E–09	±	0.0E+00	9.9E–10	±	3.4E–10	1.2E–09	±	0.0E+00
V	4.6E–06	±	4.3E–06	5.8E–07	±	1.9E–07	4.4E–07	±	1.5E–07
Yb	1.2E–09	±	0.0E+00	9.6E–10	±	3.3E–10	1.2E–09	±	0.0E+00
Zn	9.8E–04	±	7.2E–05	1.0E–03	±	2.0E–04	2.5E–03	±	8.4E–04
Zr	1.4E–06	±	7.5E–07	2.9E–07	±	4.2E–08	2.2E–07	±	2.1E–08

Appendix 13

Average concentrations and stdv (mol/kg dw; mol/g dw; mol/L; mol/L) of elements in POM (n=3), POM (n=3) and DIM (n=3).

	POM mol/g dw			POM mol/L			DIM mol/L		
Al	3.7E+00	±	5.2E–01	4.2E–05	±	4.6E–06	5.0E–08	±	6.8E–09
As	7.5E–05	±	3.4E–06	8.5E–10	±	8.2E–12	9.3E–08	±	2.3E–08
Ba	9.0E–01	±	1.6E–01	1.0E–05	±	1.5E–06	1.2E–07	±	1.5E–09
Br	2.8E–03	±	1.3E–04	3.2E–08	±	3.1E–10	2.1E–04	±	4.2E–05
C	2.7E+00	±	5.3E–01	3.1E–05	±	6.1E–06	1.2E–03	±	3.8E–05
Ca	8.6E+00	±	1.7E+00	9.7E–05	±	1.7E–05	2.0E–03	±	1.4E–06
Cd	4.2E–04	±	4.4E–05	4.8E–09	±	3.9E–10	1.6E–10	±	3.0E–11
Ce	2.3E–04	±	3.7E–05	2.7E–09	±	3.3E–10	7.1E–11	±	0.0E+00
Cl	3.8E–02	±	1.8E–02	4.5E–07	±	2.4E–07	8.0E–02	±	2.0E–04
Co	2.1E–05	±	3.0E–06	2.4E–10	±	2.9E–11	2.1E–10	±	6.9E–11
Cr	5.2E–03	±	7.0E–04	5.9E–08	±	5.8E–09	1.2E–08	±	2.5E–09
Cs	4.7E–05	±	6.8E–06	5.4E–10	±	6.0E–11	4.5E–10	±	0.0E+00
Cu	4.7E–04	±	7.1E–05	5.4E–09	±	6.2E–10	1.2E–08	±	2.4E–10
Dy	7.2E–06	±	8.8E–07	8.2E–11	±	7.4E–12	6.2E–11	±	0.0E+00
Er	3.8E–05	±	5.7E–06	4.3E–10	±	5.5E–11	6.0E–11	±	0.0E+00
Eu	2.0E–05	±	4.9E–06	2.2E–10	±	5.0E–11	6.6E–11	±	0.0E+00
F	4.5E–03	±	3.0E–04	5.3E–08	±	0.0E+00	1.6E–05	±	0.0E+00
Fe	5.4E–02	±	3.2E–03	6.1E–07	±	2.9E–08	4.4E–08	±	2.1E–09
Gd	8.1E–06	±	1.2E–06	9.2E–11	±	1.0E–11	6.4E–11	±	0.0E+00
Hg	2.8E–06	±	1.3E–07	3.2E–11	±	3.1E–13	1.0E–11	±	0.0E+00
Ho	1.4E–06	±	2.1E–07	1.6E–11	±	1.9E–12	6.1E–11	±	0.0E+00
I	8.8E–04	±	4.0E–05	1.0E–08	±	9.7E–11	1.9E–07	±	4.1E–08
K	2.7E+00	±	3.4E–01	3.1E–05	±	2.8E–06	2.1E–03	±	3.1E–05
Li	6.0E–03	±	5.2E–04	6.9E–08	±	3.7E–09	3.9E–06	±	8.6E–08
Lu	6.0E–07	±	9.5E–08	6.8E–12	±	8.9E–13	5.7E–11	±	0.0E+00
Mg	4.1E–01	±	3.4E–02	4.7E–06	±	2.1E–07	7.6E–03	±	2.4E–05
Mn	2.7E–03	±	1.4E–04	3.0E–08	±	6.4E–10	3.7E–08	±	2.7E–09
Mo	6.3E–04	±	9.9E–05	7.1E–09	±	9.0E–10	1.8E–08	±	1.2E–10
N	2.7E–01	±	4.0E–02	3.1E–06	±	4.6E–07	1.6E–05	±	7.6E–07
Na	1.0E+01	±	1.2E+00	1.2E–04	±	9.5E–06	6.5E–02	±	2.3E–03
Nd	6.2E–05	±	8.5E–06	7.1E–10	±	7.8E–11	8.6E–11	±	8.2E–12
Ni	2.0E–04	±	2.6E–05	2.3E–09	±	2.3E–10	1.6E–08	±	9.6E–10
P1	1.8E–02	±	1.6E–03	2.1E–07	±	1.8E–08	1.8E–07	±	2.3E–08
P2	2.0E–02	±	2.3E–03	2.3E–07	±	2.1E–08	1.7E–07	±	8.4E–09
Pb	8.4E–04	±	1.2E–04	9.6E–09	±	1.0E–09	9.1E–09	±	8.7E–09
Pr	1.7E–05	±	2.0E–06	1.9E–10	±	1.8E–11	7.1E–11	±	0.0E+00
Rb	3.4E–03	±	4.8E–04	3.9E–08	±	4.3E–09	2.2E–07	±	3.1E–09
S	1.5E–01	±	1.7E–02	1.7E–06	±	2.1E–07	4.1E–03	±	3.1E–05
Se	1.4E–04	±	6.5E–06	1.6E–09	±	1.6E–11	4.0E–10	±	2.6E–10
Si	1.7E+01	±	1.1E+00	2.0E–04	±	1.0E–05	1.4E–05	±	7.0E–07
Sm	1.3E–05	±	2.0E–06	1.5E–10	±	1.8E–11	6.7E–11	±	0.0E+00
Tb	1.2E–06	±	1.3E–07	1.4E–11	±	1.0E–12	6.3E–10	±	0.0E+00
Th	1.6E–05	±	1.8E–06	1.8E–10	±	1.5E–11	1.7E–10	±	3.2E–26
Ti	8.6E–03	±	7.4E–04	9.7E–08	±	5.3E–09	1.2E–09	±	4.1E–10
Tm	6.2E–07	±	9.9E–08	7.1E–12	±	9.2E–13	5.9E–11	±	0.0E+00
V	1.4E–04	±	1.9E–05	1.6E–09	±	1.9E–10	2.5E–09	±	2.6E–10
Yb	3.7E–06	±	5.0E–07	4.3E–11	±	4.6E–12	5.8E–11	±	0.0E+00
Zn	1.4E+00	±	1.7E–01	1.6E–05	±	1.4E–06	2.2E–08	±	5.6E–09
Zr	1.7E–03	±	1.8E–04	1.9E–08	±	1.4E–09	6.6E–10	±	1.3E–25

Appendix 14

Average concentrations and stdv (mol/kg dw; mol/L) of elements in sediment 0–3 cm (n=3), sediment 3–6 cm (n=3), porewater 0–3 cm (n=3) and porewater 3–6 cm (n=1).

	Sediment 0–3 cm mol/kg dw			Sediment 3–6 cm mol/kg dw			Porewater 0–3 cm mol/L			Porewater 3–6 cm mol/L		
Al	1.6E–01	±	2.3E–02	3.4E–01	±	3.7E–01	1.0E–06	±	6.3E–07	5.4E–08	±	0.0E+00
As	2.6E–05	±	5.8E–06	3.2E–05	±	2.5E–05	6.9E–08	±	4.4E–09	9.8E–08	±	0.0E+00
Ba	8.6E–04	±	1.1E–04	8.3E–04	±	2.1E–04	3.7E–07	±	2.3E–07	4.2E–07	±	0.0E+00
Br	3.4E–04	±	8.8E–07	1.6E–04	±	4.8E–05	no data	±	no data	no data	±	no data
C	3.7E–01	±	1.0E–01	2.0E–01	±	8.2E–02	no data	±	no data	no data	±	no data
Ca	4.3E–02	±	5.0E–03	5.1E–02	±	3.4E–02	2.1E–03	±	6.9E–05	2.0E–03	±	0.0E+00
Cd	1.8E–06	±	5.4E–07	1.5E–06	±	3.2E–07	2.4E–10	±	6.8E–11	6.5E–11	±	0.0E+00
Ce	5.6E–06	±	2.2E–06	9.2E–06	±	9.8E–06	2.2E–09	±	1.2E–09	1.0E–10	±	0.0E+00
Cl	2.5E–02	±	8.0E–04	2.3E–02	±	1.0E–03	no data	±	no data	no data	±	no data
Co	4.3E–05	±	7.3E–06	7.9E–05	±	8.6E–05	8.2E–09	±	2.6E–09	3.7E–09	±	0.0E+00
Cr	2.2E–04	±	6.4E–05	4.0E–04	±	4.6E–04	7.5E–09	±	6.1E–10	6.6E–09	±	0.0E+00
Cs	9.2E–06	±	4.5E–07	1.2E–05	±	4.0E–06	5.4E–10	±	3.4E–11	4.5E–10	±	0.0E+00
Cu	8.9E–05	±	2.5E–05	1.7E–04	±	1.9E–04	1.1E–08	±	1.9E–09	5.1E–09	±	0.0E+00
Dy	5.5E–07	±	2.5E–07	6.9E–07	±	5.4E–07	2.1E–10	±	1.1E–10	6.2E–11	±	0.0E+00
Er	1.8E–07	±	6.0E–08	3.7E–07	±	3.1E–07	1.2E–10	±	5.5E–11	6.0E–11	±	0.0E+00
Eu	1.2E–07	±	6.3E–08	1.4E–07	±	1.0E–07	6.7E–11	±	2.3E–12	6.6E–11	±	0.0E+00
F	3.4E–05	±	3.7E–06	3.2E–05	±	0.0E+00	no data	±	no data	no data	±	no data
Fe	1.2E–01	±	1.6E–02	2.2E–01	±	2.4E–01	5.6E–07	±	2.4E–07	2.2E–05	±	0.0E+00
Gd	6.8E–07	±	3.1E–07	8.6E–07	±	6.5E–07	2.5E–10	±	1.2E–10	6.4E–11	±	0.0E+00
Hg	5.0E–07	±	4.7E–08	4.7E–07	±	2.9E–08	1.7E–11	±	7.5E–12	1.0E–11	±	0.0E+00
Ho	1.0E–07	±	4.6E–08	1.3E–07	±	1.0E–07	6.1E–11	±	0.0E+00	6.1E–11	±	0.0E+00
I	5.2E–05	±	8.9E–07	2.1E–05	±	7.4E–06	no data	±	no data	no data	±	no data
K	3.9E–02	±	7.3E–03	8.8E–02	±	1.0E–01	2.4E–03	±	6.4E–05	2.9E–03	±	0.0E+00
Li	1.1E–03	±	1.7E–04	1.5E–03	±	8.5E–04	4.5E–06	±	1.7E–07	5.0E–06	±	0.0E+00
Lu	3.9E–08	±	1.5E–08	4.8E–08	±	4.1E–08	5.7E–11	±	0.0E+00	5.7E–11	±	0.0E+00
Mg	7.2E–02	±	9.9E–03	1.4E–01	±	1.6E–01	6.9E–03	±	2.5E–04	6.5E–03	±	0.0E+00
Mn	3.9E–03	±	3.0E–03	4.2E–03	±	4.5E–03	9.6E–06	±	5.5E–06	4.3E–06	±	0.0E+00
Mo	2.1E–06	±	7.8E–07	2.8E–06	±	2.1E–06	4.2E–08	±	1.9E–08	8.4E–08	±	0.0E+00
N	3.8E–02	±	1.1E–02	1.9E–02	±	8.2E–03	no data	±	no data	no data	±	no data
Na	1.3E–01	±	1.6E–01	4.1E–02	±	1.9E–02	6.1E–02	±	1.5E–03	6.5E–02	±	0.0E+00
Nd	4.0E–06	±	1.6E–06	5.6E–06	±	4.6E–06	1.2E–09	±	6.5E–10	6.9E–11	±	0.0E+00
Ni	8.6E–05	±	1.1E–05	1.9E–04	±	2.1E–04	2.7E–08	±	1.5E–09	2.6E–08	±	0.0E+00
P1	1.1E–02	±	4.2E–03	1.0E–02	±	5.1E–03	no data	±	no data	no data	±	no data
P2	1.0E–02	±	1.5E–03	1.1E–02	±	5.9E–03	2.3E–06	±	1.0E–06	2.0E–06	±	0.0E+00
Pb	9.8E–05	±	4.3E–06	1.1E–04	±	1.6E–05	3.3E–09	±	2.4E–10	2.0E–09	±	0.0E+00
Pr	1.1E–06	±	4.3E–07	1.6E–06	±	1.3E–06	3.3E–10	±	1.9E–10	7.1E–11	±	0.0E+00
Rb	7.0E–04	±	5.4E–05	6.8E–04	±	2.9E–04	3.2E–07	±	7.8E–09	3.6E–07	±	0.0E+00
S	1.5E–02	±	5.0E–03	1.5E–02	±	5.4E–03	4.3E–03	±	1.7E–04	4.3E–03	±	0.0E+00
Se	6.4E–07	±	1.8E–07	5.2E–07	±	1.8E–07	3.0E–09	±	1.4E–09	1.5E–09	±	0.0E+00
Si*	8.9E+00	±	0.0E+00	8.9E+00	±	0.0E+00	4.27E–04	±	0.0E+00	4.27E–04	±	0.0E+00
Sm	7.4E–07	±	3.4E–07	1.0E–06	±	8.0E–07	2.5E–10	±	1.4E–10	6.7E–11	±	0.0E+00
Tb	1.0E–07	±	4.9E–08	1.3E–07	±	1.0E–07	6.3E–10	±	0.0E+00	6.3E–10	±	0.0E+00
Th	3.1E–06	±	1.8E–06	3.3E–06	±	2.4E–06	1.7E–10	±	3.2E–26	1.7E–10	±	0.0E+00
Ti	2.2E–02	±	1.8E–02	1.5E–02	±	1.0E–02	1.2E–08	±	5.3E–09	2.8E–09	±	0.0E+00
Tm	3.6E–08	±	1.7E–08	4.9E–08	±	3.8E–08	5.9E–11	±	0.0E+00	5.9E–11	±	0.0E+00
V	3.6E–04	±	1.4E–04	6.2E–04	±	6.9E–04	1.8E–08	±	2.2E–09	9.9E–09	±	0.0E+00
Yb	2.4E–07	±	1.2E–07	3.0E–07	±	2.5E–07	1.3E–10	±	6.1E–11	5.8E–11	±	0.0E+00
Zn	5.4E–04	±	1.1E–04	7.7E–04	±	5.9E–04	2.4E–07	±	4.1E–08	5.7E–08	±	0.0E+00
Zr	2.7E–03	±	2.6E–03	2.0E–03	±	1.8E–03	7.2E–10	±	1.1E–10	6.6E–10	±	0.0E+00

* Sediment and porewater used for Si–analyses sampled on another occasion and location (see Table 2-1).

Appendix 15

Average element ratios and stdv (on concentrations, mg/kg dw) in phytoplankton (n=3), zooplankton (n=1) and benthic microalgae (n=2). Normalised to carbon.

	Phytoplankton Element/C			Zooplankton Element/C			Benthic microalgae Element/C		
Al	3.0E–02	±	4.0E–03	6.8E–03	±	–	1.9E–01	±	3.4E–02
As	7.3E–05	±	1.1E–05	5.5E–05	±	–	3.6E–04	±	1.9E–04
Ba	2.4E–04	±	2.4E–05	1.2E–04	±	–	3.3E–03	±	1.0E–03
Br	7.6E–03	±	4.4E–04	3.1E–02	±	–	7.2E–03	±	1.5E–03
C	1.0E+00	±	0.0E+00	1.0E+00	±	–	1.0E+00	±	0.0E+00
Ca	2.0E–02	±	7.2E–04	2.1E–01	±	–	2.0E–01	±	5.6E–02
Cd	1.4E–06	±	1.7E–07	1.1E–05	±	–	1.9E–05	±	8.8E–06
Ce	5.5E–08	±	8.6E–09	8.4E–06	±	–	3.4E–06	±	5.1E–07
Cl	3.7E–01	±	8.9E–03	0.0E+00	±	–	2.9E–01	±	6.2E–02
Co	9.7E–06	±	1.3E–06	3.9E–06	±	–	2.5E–04	±	1.2E–04
Cr	3.6E–05	±	4.1E–06	2.4E–05	±	–	1.8E–04	±	2.6E–05
Cs	3.0E–06	±	4.2E–07	7.6E–07	±	–	1.7E–05	±	2.6E–06
Cu	1.3E–04	±	1.8E–05	4.7E–04	±	–	3.1E–04	±	9.0E–05
Dy	3.0E–09	±	5.3E–10	6.5E–07	±	–	2.0E–07	±	2.9E–08
Er	1.7E–09	±	3.2E–10	3.7E–07	±	–	1.1E–07	±	2.1E–08
Eu	1.2E–09	±	1.7E–11	1.1E–07	±	–	3.7E–08	±	6.8E–09
F	5.6E–03	±	1.8E–04	0.0E+00	±	–	7.1E–04	±	5.0E–04
Fe	2.2E–02	±	3.1E–03	4.9E–03	±	–	2.9E–01	±	8.2E–02
Gd	3.8E–09	±	6.7E–10	6.8E–07	±	–	2.8E–07	±	4.0E–08
Hg	3.2E–07	±	2.3E–08	1.4E–06	±	–	8.3E–07	±	1.4E–07
Ho	1.2E–09	±	1.7E–11	1.4E–07	±	–	3.8E–08	±	6.4E–09
I	8.8E–05	±	1.2E–05	1.7E–04	±	–	2.0E–03	±	8.4E–04
K	5.2E–02	±	2.9E–03	1.5E–01	±	–	9.3E–02	±	1.5E–02
Li	5.0E–05	±	7.2E–06	2.3E–05	±	–	1.4E–04	±	2.2E–05
Lu	1.2E–09	±	1.7E–11	5.6E–08	±	–	1.5E–08	±	3.0E–09
Mg	4.3E–02	±	9.8E–04	6.3E–02	±	–	7.9E–02	±	1.3E–02
Mn	2.6E–03	±	2.1E–04	4.0E–04	±	–	1.0E–01	±	4.8E–02
Mo	1.9E–06	±	9.0E–08	6.0E–06	±	–	4.5E–05	±	2.7E–05
N	1.2E–01	±	4.4E–03	2.3E–01	±	–	1.2E–01	±	2.2E–02
Na	2.8E–01	±	7.4E–03	4.5E–01	±	–	2.2E–01	±	3.7E–02
Nd	2.3E–08	±	4.0E–09	4.4E–06	±	–	1.6E–06	±	2.4E–07
Ni	3.5E–05	±	6.6E–06	2.9E–05	±	–	8.8E–04	±	4.7E–04
P1	7.6E–03	±	5.5E–04	2.2E–02	±	–	1.9E–02	±	3.3E–03
P2	1.2E–02	±	1.5E–03	1.3E–01	±	–	2.2E–02	±	3.5E–03
Pb	6.5E–05	±	6.7E–06	4.2E–05	±	–	5.8E–04	±	3.8E–04
Pr	6.3E–09	±	1.1E–09	1.1E–06	±	–	4.4E–07	±	6.5E–08
Rb	7.4E–05	±	8.4E–06	9.3E–05	±	–	4.0E–04	±	5.8E–05
S	4.1E–02	±	9.3E–04	1.1E–01	±	–	6.5E–02	±	1.2E–02
Se	2.9E–06	±	2.0E–07	2.4E–05	±	–	4.7E–06	±	6.8E–07
Si	8.0E–01	±	4.8E–02	2.3E–01	±	–	5.9E–01	±	8.5E–02
Sm	4.3E–09	±	7.5E–10	8.7E–07	±	–	3.1E–07	±	4.9E–08
Tb	1.2E–09	±	1.7E–11	1.1E–07	±	–	3.8E–08	±	5.4E–09
Th	8.1E–06	±	8.2E–07	1.3E–06	±	–	1.2E–04	±	3.4E–05
Ti	1.1E–03	±	1.3E–04	2.6E–04	±	–	6.2E–03	±	9.8E–04
Tm	1.2E–09	±	1.7E–11	5.6E–08	±	–	1.6E–08	±	3.0E–09
V	4.1E–05	±	5.2E–06	8.9E–06	±	–	3.9E–04	±	9.5E–05
Yb	1.6E–09	±	2.8E–10	3.4E–07	±	–	9.8E–08	±	1.8E–08
Zn	2.3E–03	±	5.0E–04	2.4E–03	±	–	3.4E–03	±	1.2E–03
Zr	8.7E–05	±	4.9E–06	1.1E–05	±	–	9.1E–04	±	1.4E–04

Appendix 16

Average element ratios and stdv (on concentrations, mg/kg dw) in *F. vesiculosus* (n=3), *P. littoralis* (n=3) and *P. pectinatus* (n=3). Normalised to carbon.

	F. vesiculosus **Element/C**			***P. littoralis*** **Element/C**			***P. pectinatus*** **Element/C**		
Al	1.8E–03	±	5.5E–04	1.5E–02	±	5.3E–03	7.5E–03	±	1.5E–03
As	8.8E–05	±	2.7E–06	7.3E–05	±	8.5E–06	1.0E–05	±	9.5E–07
Ba	6.4E–04	±	5.9E–05	3.3E–04	±	2.2E–05	1.0E–04	±	1.2E–05
Br	7.7E–04	±	1.6E–04	8.8E–04	±	6.3E–05	0.0E+00	±	0.0E+00
C	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00
Ca	4.0E–02	±	1.6E–03	4.1E–02	±	1.6E–02	6.3E–02	±	1.8E–02
Cd	1.3E–05	±	1.9E–06	1.1E–06	±	4.4E–07	2.5E–06	±	2.8E–07
Ce	2.4E–07	±	5.8E–08	1.2E–07	±	5.4E–08	2.3E–07	±	7.8E–08
Cl	2.5E–02	±	3.1E–04	1.4E–01	±	7.7E–03	0.0E+00	±	0.0E+00
Co	3.1E–06	±	3.8E–07	5.6E–06	±	2.0E–06	7.1E–06	±	1.4E–06
Cr	2.3E–06	±	6.5E–07	1.7E–05	±	6.5E–06	8.5E–06	±	1.7E–06
Cs	2.4E–07	±	7.2E–08	1.9E–06	±	7.2E–07	8.9E–07	±	1.8E–07
Cu	1.0E–05	±	3.2E–07	1.9E–05	±	4.2E–06	2.1E–05	±	2.3E–06
Dy	2.7E–08	±	5.3E–09	7.6E–09	±	3.4E–09	1.3E–08	±	3.7E–09
Er	1.7E–08	±	3.3E–09	4.3E–09	±	1.9E–09	7.1E–09	±	2.0E–09
Eu	3.8E–09	±	1.1E–09	1.6E–09	±	6.7E–10	2.6E–09	±	7.8E–10
F	1.0E–04	±	1.7E–06	2.0E–03	±	9.2E–04	0.0E+00	±	0.0E+00
Fe	1.5E–03	±	3.9E–04	1.2E–02	±	4.1E–03	6.0E–03	±	1.0E–03
Gd	3.3E–08	±	7.3E–09	9.8E–09	±	4.2E–09	1.6E–08	±	4.8E–09
Hg	6.2E–08	±	6.5E–09	9.2E–08	±	2.4E–08	7.7E–08	±	4.9E–09
Ho	5.7E–09	±	1.1E–09	1.5E–09	±	6.6E–10	2.5E–09	±	7.0E–10
I	2.7E–04	±	6.2E–05	1.7E–04	±	1.0E–05	0.0E+00	±	0.0E+00
K	4.7E–02	±	2.3E–03	8.5E–02	±	8.2E–03	5.1E–02	±	2.7E–03
Li	3.8E–06	±	5.6E–07	2.3E–05	±	2.2E–06	1.0E–05	±	8.0E–07
Lu	2.6E–09	±	5.0E–10	8.4E–10	±	1.3E–10	1.0E–09	±	2.9E–10
Mg	2.6E–02	±	1.0E–03	2.4E–02	±	1.4E–03	2.3E–02	±	2.0E–03
Mn	1.1E–03	±	1.5E–04	1.0E–03	±	3.8E–04	2.2E–03	±	4.2E–04
Mo	9.5E–07	±	2.1E–07	9.7E–07	±	1.3E–07	3.6E–06	±	6.5E–07
N	5.8E–02	±	4.1E–03	8.9E–02	±	4.5E–03	5.1E–02	±	2.7E–03
Na	3.8E–02	±	6.8E–04	9.1E–02	±	6.0E–03	5.9E–02	±	6.2E–03
Nd	1.6E–07	±	3.6E–08	5.7E–08	±	2.5E–08	9.2E–08	±	2.8E–08
Ni	4.6E–05	±	7.0E–06	2.1E–05	±	6.0E–06	1.9E–05	±	4.4E–06
P1	3.3E–03	±	9.1E–05	1.0E–02	±	1.1E–03	6.6E–03	±	5.9E–04
P2	3.4E–03	±	1.8E–04	8.9E–03	±	9.6E–04	7.2E–03	±	5.8E–04
Pb	2.2E–06	±	5.1E–07	1.7E–05	±	4.3E–06	8.7E–06	±	1.1E–06
Pr	4.3E–08	±	9.6E–09	1.5E–08	±	6.7E–09	2.5E–08	±	7.6E–09
Rb	2.9E–05	±	3.2E–06	7.0E–05	±	8.8E–06	2.8E–05	±	3.3E–06
S	8.3E–02	±	3.5E–03	3.7E–02	±	3.3E–03	2.2E–02	±	2.1E–03
Se	1.4E–06	±	4.1E–08	1.9E–07	±	1.1E–07	5.9E–07	±	1.0E–07
Si	1.5E–02	±	2.7E–03	2.3E–01	±	2.6E–02	1.1E–01	±	1.1E–02
Sm	3.1E–08	±	6.5E–09	1.1E–08	±	4.6E–09	1.7E–08	±	5.2E–09
Tb	4.7E–09	±	9.9E–10	1.4E–09	±	6.0E–10	2.3E–09	±	6.8E–10
Th	5.5E–07	±	1.9E–07	4.8E–06	±	1.8E–06	2.4E–06	±	3.9E–07
Ti	6.7E–05	±	1.9E–05	5.7E–04	±	2.0E–04	2.6E–04	±	4.2E–05
Tm	2.3E–09	±	4.4E–10	8.5E–10	±	1.4E–10	1.0E–09	±	3.0E–10
V	4.2E–06	±	9.5E–07	2.5E–05	±	9.2E–06	1.3E–05	±	2.7E–06
Yb	1.5E–08	±	3.1E–09	3.8E–09	±	1.7E–09	6.4E–09	±	1.8E–09
Zn	6.3E–04	±	6.9E–05	1.8E–04	±	4.5E–05	2.5E–04	±	2.8E–05
Zr	9.6E–06	±	2.2E–06	5.7E–05	±	1.7E–05	2.5E–05	±	3.6E–06

Appendix 17

Average element ratios and stdv (on concentrations, mg/kg dw) in *T. fluviatilis* (n=2), *Idothea* spp. (n=2), *M. baltica* (n=3) and *C. glaucum* (n=2). Normalised to carbon.

	T. fluviatilis Element/C			*Idothea* spp. Element/C			*M. baltica* Element/C			*C. glaucum* Element/C		
Al	4.2E–03	±	2.0E–04	2.1E–03	±	4.8E–05	3.5E–03	±	2.7E–04	1.8E–03	±	4.0E–04
As	1.3E–05	±	8.7E–07	1.9E–05	±	2.5E–06	1.2E–05	±	1.6E–06	4.4E–06	±	2.6E–07
Ba	7.8E–05	±	8.7E–06	2.2E–04	±	2.2E–05	1.7E–04	±	1.6E–05	2.0E–04	±	9.8E–06
Br	6.8E–04	±	1.3E–04	0.0E+00	±	0.0E+00	1.8E–04	±	2.9E–05	0.0E+00	±	0.0E+00
C	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00
Ca	2.0E+00	±	9.0E–02	3.4E–01	±	6.2E–03	1.6E+00	±	1.8E–01	2.1E+00	±	1.0E–01
Cd	4.5E–06	±	2.2E–07	5.1E–06	±	6.0E–07	9.3E–07	±	2.5E–07	1.1E–06	±	1.3E–07
Ce	1.2E–06	±	8.8E–08	1.1E–07	±	1.6E–08	1.9E–06	±	8.7E–08	9.0E–07	±	1.0E–08
Cl	1.8E–02	±	1.5E–03	0.0E+00	±	0.0E+00	1.1E–02	±	8.4E–04	0.0E+00	±	0.0E+00
Co	1.8E–06	±	2.0E–07	2.1E–06	±	3.4E–07	1.7E–06	±	2.4E–07	6.9E–07	±	6.3E–08
Cr	1.9E–06	±	1.8E–07	3.0E–06	±	1.2E–07	3.0E–06	±	1.9E–07	1.7E–06	±	4.6E–07
Cs	2.3E–07	±	2.7E–08	2.7E–07	±	9.2E–09	3.2E–07	±	1.7E–08	1.6E–07	±	5.8E–08
Cu	7.0E–05	±	3.3E–06	1.6E–04	±	1.9E–05	1.3E–04	±	2.4E–05	1.1E–05	±	1.4E–06
Dy	7.3E–08	±	3.6E–09	7.0E–09	±	8.9E–10	1.1E–07	±	7.6E–09	6.4E–08	±	2.8E–09
Er	3.5E–08	±	2.1E–09	3.9E–09	±	5.4E–10	5.6E–08	±	4.4E–09	3.6E–08	±	1.1E–09
Eu	1.4E–08	±	6.5E–10	1.1E–09	±	1.8E–10	2.6E–08	±	2.0E–09	1.4E–08	±	6.2E–10
F	1.3E–04	±	6.4E–06	0.0E+00	±	0.0E+00	1.2E–04	±	8.8E–06	0.0E+00	±	0.0E+00
Fe	1.5E–03	±	7.5E–05	1.6E–03	±	6.2E–05	4.7E–03	±	3.8E–04	1.6E–03	±	4.9E–04
Gd	9.7E–08	±	8.0E–09	9.0E–09	±	1.3E–09	1.7E–07	±	1.2E–08	9.9E–08	±	4.6E–10
Hg	1.6E–07	±	2.5E–08	8.7E–08	±	6.2E–09	2.2E–07	±	2.6E–08	8.2E–08	±	1.2E–08
Ho	1.3E–08	±	6.2E–10	1.4E–09	±	1.9E–10	2.1E–08	±	1.3E–09	1.3E–08	±	2.6E–10
I	4.9E–05	±	2.6E–06	0.0E+00	±	0.0E+00	9.5E–06	±	1.3E–06	0.0E+00	±	0.0E+00
K	7.2E–03	±	3.4E–04	1.8E–02	±	2.6E–03	7.2E–03	±	5.2E–04	4.9E–03	±	6.6E–04
Li	2.7E–06	±	1.3E–07	4.2E–06	±	7.1E–08	2.8E–06	±	1.9E–07	2.5E–06	±	5.0E–07
Lu	4.7E–09	±	2.3E–10	5.8E–10	±	2.9E–11	7.4E–09	±	3.9E–10	4.5E–09	±	9.9E–11
Mg	4.8E–03	±	6.1E–04	2.0E–02	±	1.6E–03	2.6E–03	±	1.7E–04	2.3E–03	±	2.2E–04
Mn	9.7E–04	±	4.4E–05	2.4E–04	±	3.5E–05	1.4E–04	±	1.9E–05	1.5E–04	±	4.1E–05
Mo	9.7E–07	±	1.2E–07	6.8E–07	±	5.1E–08	1.1E–06	±	1.2E–07	3.8E–07	±	2.5E–08
N	8.8E–02	±	2.0E–02	1.8E–01	±	1.8E–02	7.9E–02	±	6.8E–03	6.5E–02	±	3.6E–03
Na	3.0E–02	±	1.6E–03	3.8E–02	±	4.3E–03	2.4E–02	±	2.0E–03	3.0E–02	±	2.4E–03
Nd	5.3E–07	±	4.2E–08	5.4E–08	±	7.7E–09	9.4E–07	±	4.1E–08	4.9E–07	±	2.1E–08
Ni	6.5E–06	±	7.0E–07	5.5E–06	±	1.0E–06	3.0E–06	±	4.1E–07	2.1E–05	±	2.1E–07
P1	7.8E–03	±	2.2E–03	2.1E–02	±	4.1E–03	8.8E–03	±	1.0E–03	6.9E–03	±	2.6E–04
P2	8.3E–03	±	5.5E–04	1.9E–02	±	8.1E–04	1.0E–02	±	2.1E–03	4.4E–03	±	5.4E–04
Pb	2.6E–06	±	2.4E–07	2.5E–06	±	2.6E–07	5.5E–06	±	1.3E–06	1.5E–06	±	6.2E–08
Pr	1.5E–07	±	9.2E–09	1.4E–08	±	2.0E–09	2.5E–07	±	1.2E–08	1.3E–07	±	3.9E–09
Rb	9.1E–06	±	7.6E–07	1.0E–05	±	8.2E–07	9.9E–06	±	5.3E–07	6.0E–06	±	1.5E–06
S	9.4E–03	±	2.1E–03	2.5E–02	±	3.6E–03	7.4E–03	±	1.5E–03	3.8E–03	±	1.9E–04
Se	3.7E–06	±	3.2E–07	1.7E–06	±	7.2E–08	2.4E–06	±	3.9E–07	1.6E–06	±	3.9E–07
Si	1.9E–02	±	1.1E–03	1.6E–02	±	2.2E–04	1.2E–02	±	1.5E–03	6.4E–03	±	6.8E–04
Sm	1.0E–07	±	1.3E–08	9.7E–09	±	1.2E–09	1.7E–07	±	1.0E–08	9.1E–08	±	4.9E–09
Tb	1.3E–08	±	8.2E–10	1.3E–09	±	1.8E–10	2.1E–08	±	1.3E–09	1.3E–08	±	8.5E–10
Th	1.9E–06	±	2.7E–07	6.7E–07	±	1.1E–08	1.1E–06	±	1.3E–07	5.3E–07	±	1.6E–07
Ti	8.5E–05	±	1.1E–05	7.4E–05	±	5.4E–06	1.1E–04	±	1.1E–05	5.3E–05	±	1.5E–05
Tm	4.9E–09	±	3.5E–10	5.8E–10	±	2.9E–11	7.3E–09	±	4.9E–10	4.7E–09	±	2.0E–10
V	3.8E–06	±	3.8E–07	3.5E–06	±	2.0E–07	4.6E–06	±	4.8E–07	2.5E–06	±	4.7E–07
Yb	3.0E–08	±	1.4E–09	3.4E–09	±	5.0E–10	4.6E–08	±	3.0E–09	3.0E–08	±	3.4E–10
Zn	1.0E–04	±	8.9E–06	1.6E–04	±	1.6E–05	2.3E–04	±	4.3E–05	4.8E–05	±	3.8E–06
Zr	1.4E–05	±	7.7E–07	7.2E–06	±	8.4E–07	1.6E–05	±	3.2E–06	8.5E–06	±	5.2E–06

Appendix 18

Average element ratios and stdv (on concentrations, mg/kg dw) in *G. cernuus* (Ruffe, n=3), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). Normalised to carbon. Analysis of mixed fish slices.

	G. cernuus Element/C			*O. eperlanus* Element/C			*R. rutilus* Element/C		
Al	8.0E–06	±	5.2E–06	1.6E–06	±	1.2E–07	1.8E–06	±	8.6E–07
As	1.7E–06	±	1.7E–07	5.0E–06	±	5.0E–07	1.8E–06	±	7.5E–07
Ba	5.0E–06	±	1.9E–06	9.7E–07	±	1.9E–07	5.0E–06	±	1.1E–06
Br	4.6E–05	±	1.5E–06	5.1E–05	±	8.5E–06	3.5E–05	±	1.7E–06
C	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00
Ca	1.4E–01	±	3.8E–02	2.7E–02	±	7.3E–03	8.0E–02	±	1.1E–02
Cd	2.4E–08	±	4.5E–09	2.2E–08	±	6.1E–09	8.3E–08	±	2.0E–08
Ce	7.1E–10	±	1.8E–10	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Cl	3.8E–03	±	3.0E–04	3.1E–03	±	3.9E–05	2.2E–03	±	4.3E–05
Co	5.5E–08	±	1.2E–08	2.7E–08	±	9.0E–10	7.3E–08	±	5.8E–09
Cr	4.9E–08	±	1.1E–09	2.1E–08	±	2.6E–10	3.1E–08	±	7.8E–09
Cs	9.0E–08	±	1.1E–08	1.2E–07	±	3.5E–09	4.9E–08	±	1.2E–09
Cu	4.3E–06	±	7.1E–07	3.2E–06	±	4.8E–07	4.5E–06	±	2.0E–07
Dy	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Er	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Eu	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
F	4.8E–05	±	7.7E–07	4.1E–05	±	5.2E–07	4.7E–05	±	8.4E–07
Fe	5.4E–05	±	6.6E–06	3.2E–05	±	6.1E–06	9.0E–05	±	2.7E–05
Gd	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Hg	7.3E–07	±	9.9E–08	5.4E–07	±	8.4E–08	7.2E–07	±	2.0E–07
Ho	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
I	2.5E–06	±	3.2E–07	4.0E–06	±	9.2E–08	1.9E–06	±	3.4E–08
K	3.4E–02	±	1.4E–03	3.5E–02	±	2.6E–03	3.2E–02	±	1.7E–03
Li	9.3E–07	±	9.0E–08	6.1E–07	±	3.5E–08	6.6E–07	±	1.1E–07
Lu	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Mg	4.2E–03	±	3.7E–04	2.6E–03	±	2.0E–04	3.8E–03	±	2.6E–04
Mn	1.2E–05	±	3.4E–06	1.3E–05	±	1.0E–06	1.9E–05	±	7.4E–06
Mo	6.1E–08	±	1.3E–08	3.3E–08	±	6.0E–09	8.8E–08	±	1.4E–08
N	2.6E–01	±	7.6E–03	2.4E–01	±	4.9E–03	2.7E–01	±	5.6E–03
Na	1.0E–02	±	6.8E–04	7.2E–03	±	4.2E–04	6.8E–03	±	6.0E–04
Nd	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Ni	2.3E–07	±	6.4E–08	1.8E–07	±	8.5E–09	2.0E–07	±	4.0E–08
P1	8.4E–02	±	4.1E–03	4.1E–02	±	2.0E–03	6.9E–02	±	5.1E–03
P2	7.8E–02	±	1.5E–02	2.9E–02	±	2.9E–03	5.6E–02	±	5.3E–03
Pb	1.9E–07	±	2.7E–08	1.2E–07	±	1.5E–08	2.0E–07	±	4.9E–08
Pr	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Rb	1.9E–05	±	8.2E–07	1.2E–05	±	1.1E–06	1.4E–05	±	1.0E–06
S	2.4E–02	±	8.3E–04	1.7E–02	±	2.6E–04	2.2E–02	±	7.4E–04
Se	4.6E–06	±	4.1E–07	3.2E–06	±	8.3E–08	3.5E–06	±	1.4E–07
Si	9.2E–04	±	7.0E–04	4.3E–04	±	3.2E–04	1.7E–04	±	3.1E–05
Sm	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Tb	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Th	1.3E–08	±	3.0E–09	6.9E–09	±	7.0E–10	8.6E–09	±	1.6E–09
Ti	3.2E–06	±	1.0E–06	6.2E–07	±	2.3E–07	1.6E–06	±	4.4E–07
Tm	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
V	5.7E–07	±	3.1E–07	6.1E–08	±	1.1E–08	5.2E–08	±	1.0E–08
Yb	4.9E–10	±	7.7E–12	3.4E–10	±	6.9E–11	4.7E–10	±	8.4E–12
Zn	1.6E–04	±	7.0E–06	1.4E–04	±	1.5E–05	3.8E–04	±	7.5E–05
Zr	3.2E–07	±	9.7E–08	5.5E–08	±	4.6E–09	4.8E–08	±	2.8E–09

Appendix 19

Average element ratios and stdv (on concentrations, mg/kg dw) in *G. cernuus* (Ruffe, n=3), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). Normalised to carbon data from analyses of mixed fish slices. All other data from analysis of whole fish samples.

	G. cernuus Element/C			*O. eperlanus* Element/C			*R. rutilus* Element/C		
Al	1.0E–04	±	3.2E–05	2.1E–05	±	1.1E–06	2.0E–05	±	3.8E–07
As	6.9E–05	±	1.1E–06	6.4E–05	±	1.1E–06	6.8E–05	±	1.2E–06
Ba	6.1E–06	±	5.5E–07	1.4E–06	±	8.7E–08	4.8E–06	±	1.7E–07
Br	no data		no data	no data		no data	no data		no data
C	no data		no data	no data		no data	no data		no data
Ca	1.2E–04	±	2.2E–06	4.1E–05	±	3.0E–06	1.2E–04	±	2.9E–06
Cd	7.7E–08	±	8.9E–09	6.6E–08	±	1.1E–08	1.1E–07	±	1.1E–08
Ce	3.0E–07	±	1.3E–07	2.1E–08	±	4.2E–09	2.9E–08	±	3.3E–09
Cl	no data		no data	no data		no data	no data		no data
Co	2.2E–07	±	4.2E–08	8.1E–08	±	1.4E–08	1.3E–07	±	4.0E–09
Cr	1.4E–06	±	1.2E–07	1.2E–06	±	7.6E–08	1.0E–06	±	7.6E–08
Cs	8.6E–08	±	7.4E–09	9.4E–08	±	6.6E–09	4.1E–08	±	7.3E–10
Cu	6.8E–06	±	5.2E–07	6.3E–06	±	5.3E–07	9.1E–06	±	1.0E–06
Dy	1.9E–08	±	7.9E–09	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
Er	1.2E–08	±	3.2E–09	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
Eu	6.9E–09	±	1.1E–10	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
F	no data		no data	no data		no data	no data		no data
Fe	2.5E–07	±	7.3E–08	6.0E–08	±	6.5E–09	1.2E–07	±	8.7E–09
Gd	2.7E–08	±	1.2E–08	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
Hg	4.4E–07	±	3.2E–08	3.3E–07	±	7.8E–08	3.0E–07	±	4.5E–08
Ho	6.9E–09	±	1.1E–10	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
I	no data		no data	no data		no data	no data		no data
K	2.4E–05	±	5.2E–07	2.6E–05	±	4.8E–07	2.6E–05	±	4.8E–07
Li	1.5E–06	±	1.8E–07	1.7E–06	±	6.5E–07	1.7E–06	±	2.8E–07
Lu	6.9E–09	±	1.1E–10	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
Mg	3.1E–06	±	5.4E–08	2.4E–06	±	8.8E–08	3.9E–06	±	7.6E–08
Mn	1.3E–05	±	3.0E–07	2.4E–05	±	1.5E–06	2.0E–05	±	1.8E–06
Mo	1.4E–07	±	1.9E–08	1.1E–07	±	3.6E–09	2.8E–07	±	9.4E–09
N	no data		no data	no data		no data	no data		no data
Na	1.2E–05	±	4.0E–07	8.6E–06	±	7.9E–07	8.2E–06	±	1.6E–07
Nd	1.4E–07	±	6.0E–08	6.9E–09	±	2.7E–10	1.1E–08	±	1.3E–09
Ni	1.1E–06	±	4.4E–08	9.6E–07	±	6.0E–08	1.3E–06	±	2.9E–07
P1	no data		no data	no data		no data	no data		no data
P2	7.5E–02	±	1.6E–03	3.6E–02	±	1.5E–03	7.3E–02	±	1.5E–03
Pb	5.1E–07	±	5.7E–08	3.6E–07	±	7.4E–08	4.5E–07	±	3.6E–08
Pr	3.8E–08	±	1.6E–08	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
Rb	2.0E–05	±	8.4E–07	1.1E–05	±	1.4E–07	1.3E–05	±	5.2E–07
S	1.9E–05	±	4.9E–07	1.8E–05	±	5.1E–07	1.9E–05	±	5.4E–07
Se	2.7E–06	±	9.8E–08	2.3E–06	±	2.5E–07	2.3E–06	±	1.4E–07
Si	1.2E–07	±	3.5E–09	8.2E–08	±	7.1E–09	6.8E–08	±	8.6E–09
Sm	2.5E–08	±	1.1E–08	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
Tb	6.9E–09	±	1.1E–10	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
Th	2.7E–08	±	4.4E–10	2.5E–08	±	4.5E–10	2.7E–08	±	4.9E–10
Ti	4.5E–06	±	1.7E–06	2.4E–07	±	3.9E–08	3.4E–07	±	3.4E–08
Tm	6.9E–09	±	1.1E–10	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
V	9.6E–07	±	2.8E–07	7.7E–08	±	4.0E–09	1.4E–07	±	2.0E–08
Yb	1.2E–08	±	2.7E–09	6.4E–09	±	1.1E–10	6.8E–09	±	1.2E–10
Zn	2.2E–04	±	1.1E–05	2.5E–04	±	6.2E–05	5.2E–04	±	1.7E–05
Zr	8.7E–08	±	1.5E–09	1.3E–07	±	9.3E–08	8.1E–08	±	1.3E–08

Appendix 20

Average element ratios and stdv (on concentrations; µg/g dw, mg/L, mg/kg dw) in POM (n=3), DIM (n=3), and sediment 0–3 cm and 3–6 cm. Normalised to carbon.

	POM Element/C			DIM Element/C			Sediment 0–3 cm Element/C			Sediment 3–6 cm Element/C		
Al	3.1E+00	±	4.3E–01	9.1E–05	±	7.4E–06	1.0E+00	±	1.8E–01	3.2E+00	±	2.6E+00
As	1.8E–04	±	2.0E–05	4.8E–04	±	6.9E–05	4.4E–04	±	9.0E–05	9.2E–04	±	5.1E–04
Ba	3.8E+00	±	5.7E–01	1.1E–03	±	2.2E–05	2.8E–02	±	4.6E–03	5.0E–02	±	1.3E–02
Br	7.0E–03	±	8.0E–04	1.1E+00	±	1.3E–01	7.2E–03	±	9.6E–04	5.1E–03	±	1.5E–03
C	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00	1.0E+00	±	0.0E+00
Ca	1.1E+01	±	1.7E+00	5.5E+00	±	1.0E–01	4.0E–01	±	6.6E–02	8.0E–01	±	3.9E–01
Cd	1.5E–03	±	1.9E–04	1.3E–06	±	1.4E–07	4.6E–05	±	1.1E–05	7.2E–05	±	1.8E–05
Ce	1.0E–03	±	1.5E–04	6.8E–07	±	1.2E–08	1.9E–04	±	4.8E–05	4.5E–04	±	3.5E–04
Cl	4.2E–02	±	1.2E–02	1.9E+02	±	3.5E+00	2.4E–01	±	3.1E–02	3.1E–01	±	8.2E–02
Co	3.9E–05	±	5.4E–06	8.4E–07	±	1.6E–07	5.9E–04	±	1.1E–04	1.6E–03	±	1.3E–03
Cr	8.4E–03	±	1.1E–03	4.4E–05	±	5.1E–06	2.7E–03	±	6.0E–04	7.2E–03	±	6.1E–03
Cs	1.9E–04	±	2.7E–05	4.1E–06	±	7.5E–08	2.9E–04	±	4.4E–05	6.8E–04	±	2.0E–04
Cu	9.3E–04	±	1.3E–04	5.3E–05	±	1.1E–06	1.3E–03	±	2.9E–04	3.6E–03	±	3.1E–03
Dy	3.7E–05	±	4.8E–06	6.8E–07	±	1.2E–08	2.1E–05	±	6.2E–06	4.3E–05	±	2.4E–05
Er	2.0E–04	±	2.8E–05	6.8E–07	±	1.2E–08	6.9E–06	±	1.7E–06	2.3E–05	±	1.4E–05
Eu	9.1E–05	±	1.7E–05	6.8E–07	±	1.2E–08	4.4E–06	±	1.4E–06	8.3E–06	±	4.3E–06
F	2.7E–03	±	3.1E–04	2.1E–02	±	3.7E–04	1.8E–04	±	2.5E–05	2.3E–04	±	5.9E–05
Fe	9.4E–02	±	1.1E–02	1.7E–04	±	5.5E–06	1.5E+00	±	2.6E–01	4.2E+00	±	3.4E+00
Gd	4.0E–05	±	5.5E–06	6.8E–07	±	1.2E–08	2.6E–05	±	7.4E–06	5.2E–05	±	2.8E–05
Hg	1.8E–05	±	2.0E–06	1.4E–07	±	2.5E–09	2.3E–05	±	3.8E–06	4.3E–05	±	9.3E–06
Ho	7.2E–06	±	1.0E–06	6.8E–07	±	1.2E–08	4.1E–06	±	1.2E–06	8.1E–06	±	4.5E–06
I	3.5E–03	±	4.0E–04	1.6E–03	±	2.1E–04	1.8E–03	±	2.3E–04	1.1E–03	±	3.5E–04
K	2.6E+00	±	3.4E–01	4.4E+00	±	8.9E–02	2.7E–01	±	5.2E–02	9.4E–01	±	8.1E–01
Li	1.3E–03	±	1.6E–04	1.9E–03	±	4.2E–05	1.7E–03	±	3.1E–04	4.2E–03	±	1.8E–03
Lu	3.2E–06	±	4.7E–07	6.8E–07	±	1.2E–08	1.6E–06	±	4.2E–07	3.1E–06	±	1.9E–06
Mg	3.1E–01	±	3.7E–02	1.3E+01	±	2.3E–01	4.1E–01	±	7.0E–02	1.2E+00	±	9.9E–01
Mn	4.6E–03	±	5.3E–04	1.4E–04	±	6.4E–06	5.1E–02	±	2.2E–02	8.0E–02	±	6.4E–02
Mo	1.9E–03	±	2.7E–04	1.2E–04	±	2.1E–06	4.6E–05	±	1.2E–05	1.0E–04	±	5.6E–05
N	1.2E–01	±	1.6E–02	1.5E–02	±	5.0E–04	1.2E–01	±	2.7E–02	1.1E–01	±	3.8E–02
Na	7.3E+00	±	9.5E–01	1.0E+02	±	2.8E+00	7.9E–01	±	5.0E–01	3.9E–01	±	1.4E–01
Nd	2.8E–04	±	3.8E–05	8.5E–07	±	4.9E–08	1.4E–04	±	3.6E–05	3.0E–04	±	1.8E–04
Ni	3.6E–04	±	4.9E–05	6.4E–05	±	2.5E–06	1.2E–03	±	2.0E–04	3.8E–03	±	3.2E–03
P1	1.8E–02	±	2.1E–03	3.8E–04	±	2.9E–05	8.2E–02	±	2.1E–02	1.3E–01	±	4.9E–02
P2	1.9E–02	±	2.5E–03	3.5E–04	±	1.2E–05	7.6E–02	±	1.3E–02	1.3E–01	±	5.5E–02
Pb	5.4E–03	±	7.4E–04	1.3E–04	±	7.1E–05	4.8E–03	±	7.3E–04	1.0E–02	±	2.4E–03
Pr	7.3E–05	±	9.6E–06	6.8E–07	±	1.2E–08	3.8E–05	±	9.7E–06	8.4E–05	±	4.8E–05
Rb	9.1E–03	±	1.2E–03	1.3E–03	±	2.5E–05	1.4E–02	±	2.2E–03	2.9E–02	±	8.3E–03
S	1.5E–01	±	1.9E–02	9.1E+00	±	1.7E–01	1.1E–01	±	2.7E–02	2.4E–01	±	6.3E–02
Se	3.5E–04	±	4.0E–05	2.2E–06	±	8.1E–07	1.1E–05	±	2.5E–06	1.7E–05	±	5.3E–06
Si*	1.5E+01	±	1.8E+00	2.7E–02	±	9.1E–04	5.9E+01	±	8.9E+00	1.16E+02	±	2.53E+01
Sm	6.2E–05	±	8.7E–06	6.8E–07	±	1.2E–08	2.7E–05	±	7.7E–06	5.7E–05	±	3.3E–05
Tb	6.1E–06	±	7.6E–07	6.8E–06	±	1.2E–07	3.8E–06	±	1.2E–06	7.6E–06	±	4.4E–06
Th	1.2E–04	±	1.5E–05	2.7E–06	±	5.0E–08	1.7E–04	±	5.9E–05	3.0E–04	±	1.6E–04
Ti	1.3E–02	±	1.6E–03	3.8E–06	±	7.8E–07	2.6E–01	±	1.2E–01	2.7E–01	±	1.4E–01
Tm	3.2E–06	±	4.7E–07	6.8E–07	±	1.2E–08	1.5E–06	±	4.4E–07	3.1E–06	±	1.8E–06
V	2.2E–04	±	3.0E–05	8.7E–06	±	5.4E–07	4.4E–03	±	1.2E–03	1.1E–02	±	9.0E–03
Yb	2.0E–05	±	2.7E–06	6.8E–07	±	1.2E–08	9.9E–06	±	3.0E–06	1.9E–05	±	1.2E–05
Zn	2.9E+00	±	3.8E–01	1.0E–04	±	1.4E–05	8.2E–03	±	1.6E–03	1.9E–02	±	1.0E–02
Zr	4.7E–03	±	6.0E–04	4.1E–06	±	7.5E–08	6.0E–02	±	3.2E–02	6.8E–02	±	4.3E–02

* Sediment and porewater used for Si-analyses sampled on another occasion and location (see Table 2-1).

Appendix 21

Bioconcentration factors (BCF_{ww}) [(kg/kgww)/(kg/kg)] for phytoplankton (n=3), benthic microalgae (n=2), *F. vesiculosus* (n=3), *P. littoralis* (n=3) and *P. pectinatus* (n=3). The estimate was based on concentration per wet weight biota and concentration in dissolved fraction in water (DIM). Shaded element indicate that DIM data was below detection limit, other shaded cells indicate that biota data was below detection limit.

	Phytoplankton (kg/kgww)/(kg/kg)	Benthic microalgae (kg/kgww)/(kg/kg)	*F. vesiculosus* (kg/kgww)/(kg/kg)	*P. littoralis* (kg/kgww)/(kg/kg)	*P. pectinatus* (kg/kgww)/(kg/kg)
Al	8.0E+04	1.2E+06	1.0E+05	2.6E+05	2.2E+05
As	3.7E+01	4.5E+02	9.7E+02	2.4E+02	5.9E+01
Ba	5.1E+01	1.7E+03	2.9E+03	4.6E+02	2.4E+02
Br	1.6E+00	3.6E+00	3.6E+00	1.3E+00	no data
C	2.5 E+02	5.7 E+02	1.5 E+03	1.1 E+03	1.4 E+03
Ca	8.7E–01	2.1E+01	3.8E+01	1.1E+01	3.1E+01
Cd	2.8E+02	8.8E+03	5.6E+04	1.3E+03	5.5E+03
Ce	2.0E+01	2.8E+03	1.8E+03	2.7E+02	9.3E+02
Cl	4.6E–01	8.4E–01	6.8E–01	1.2E+00	no data
Co	2.8E+03	1.7E+05	2.0E+04	1.0E+04	2.3E+04
Cr	2.0E+02	2.2E+03	2.8E+02	6.1E+02	5.3E+02
Cs	1.8E+02	2.4E+03	3.1E+02	7.2E+02	5.9E+02
Cu	6.0E+02	3.3E+03	1.0E+03	5.6E+02	1.1E+03
Dy	1.1E+00	1.6E+02	2.1E+02	1.7E+01	5.0E+01
Er	6.1E–01	9.2E+01	1.3E+02	9.6E+00	2.8E+01
Eu	4.1E–01	3.1E+01	3.0E+01	3.5E+00	1.0E+01
F	6.7E+01	2.1E+01	2.6E+01	1.6E+02	no data
Fe	3.2E+04	9.9E+05	4.8E+04	1.1E+05	9.7E+04
Gd	1.4E+00	2.2E+02	2.5E+02	2.2E+01	6.4E+01
Hg	5.8E+02	3.4E+03	2.4E+03	1.1E+03	1.5E+03
Ho	4.1E–01	3.2E+01	4.1E+01	3.3E+00	9.0E+00
I	1.3E+01	7.4E+02	8.6E+02	1.7E+02	no data
K	2.9E+00	1.2E+01	5.6E+01	3.1E+01	3.2E+01
Li	6.6E+00	4.1E+01	1.1E+01	1.9E+01	1.5E+01
Lu	4.1E–01	1.3E+01	2.0E+01	1.9E+00	4.1E+00
Mg	8.3E–01	3.5E+00	1.1E+01	3.0E+00	5.1E+00
Mn	4.6E+03	4.3E+05	4.3E+04	1.1E+04	4.2E+04
Mo	4.1E+00	2.4E+02	4.3E+01	1.3E+01	8.5E+01
N	2.0 E+03	4.4 E+03	5.7 E+03	6.7 E+03	4.9 E+03
Na	6.6E–01	1.2E+00	2.0E+00	1.4E+00	1.6E+00
Nd	6.8E+00	1.1E+03	1.0E+03	1.0E+02	3.0E+02
Ni	1.3E+02	8.2E+03	3.8E+03	5.0E+02	8.3E+02
P1	4.9 E+03	2.7 E+04	1.3 E+04	3.0 E+04	2.5 E+04
P2	8.5E+03	3.5E+04	5.2E+04	4.0E+04	5.6E+04
Pb	1.2E+02	2.7E+03	9.1E+01	2.0E+02	1.8E+02
Pr	2.3E+00	3.6E+02	3.4E+02	3.4E+01	9.9E+01
Rb	1.4E+01	1.7E+02	1.2E+02	8.7E+01	5.9E+01
S	1.1E+00	4.0E+00	4.8E+01	6.5E+00	6.5E+00
Se	3.2E+02	1.2E+03	3.4E+03	1.3E+02	7.3E+02
Si	7.4E+03	1.2E+04	2.9E+03	1.4E+04	1.1E+04
Sm	1.6E+00	2.5E+02	2.4E+02	2.4E+01	6.7E+01
Tb	4.1E–02	3.1E+00	3.6E+00	3.1E–01	9.0E–01
Th	7.2E+02	2.4E+04	1.1E+03	2.7E+03	2.4E+03
Ti	6.8E+04	9.1E+05	9.3E+04	2.3E+05	1.9E+05
Tm	4.1E–01	1.3E+01	1.8E+01	2.0E+00	4.0E+00
V	1.1E+03	2.5E+04	2.5E+03	4.5E+03	4.0E+03
Yb	5.7E–01	8.1E+01	1.2E+02	8.5E+00	2.6E+01
Zn	5.5E+03	2.0E+04	3.3E+04	2.7E+03	6.7E+03
Zr	5.2E+03	1.2E+05	1.2E+04	2.2E+04	1.7E+04

Appendix 22

Bioconcentration factors (BCF_{ww}) [(kg/kgww)/(kg/kg)] for zooplankton (n=1), *T. fluviatilis* (n=2) and *Idothea* spp. (n=2), *M. baltica* (n=3), and *C. glaucum* (n=2). The estimate was based on concentration per wet weight biota and concentration in dissolved fraction in water (DIM). Shaded element indicate that DIM data was below detection limit, other shaded cells indicate that biota data was below detection limit.

	Zooplankton (kg/kgww)/(kg/kg)	*T. fluviatilis* (kg/kgww)/(kg/kg)	*Idothea* spp. (kg/kgww)/(kg/kg)	*M. baltica* (kg/kgww)/(kg/kg)	*C. glaucum* (kg/kgww)/(kg/kg)
Al	1.8E+04	1.7E+05	9.2E+04	1.5E+05	6.2E+04
As	2.8E+01	1.0E+02	1.6E+02	9.5E+01	2.9E+01
Ba	2.4E+01	2.5E+02	8.0E+02	5.8E+02	5.7E+02
Br	6.6E+00	2.3E+00	no data	6.3E–01	no data
C	2.4 E+02	6.5 E+02	1.4 E+03	6.7 E+02	6.0 E+02
Ca	9.1E+00	1.3E+03	2.5E+02	1.1E+03	1.2E+03
Cd	2.2E+03	1.3E+04	1.7E+04	2.9E+03	2.7E+03
Ce	2.9E+03	6.4E+03	6.4E+02	1.1E+04	4.2E+03
Cl	no data	3.4E–01	no data	2.2E–01	no data
Co	1.1E+03	8.1E+03	1.0E+04	7.9E+03	2.6E+03
Cr	1.3E+02	1.6E+02	2.8E+02	2.7E+02	1.2E+02
Cs	4.5E+01	2.1E+02	2.7E+02	3.0E+02	1.3E+02
Cu	2.1E+03	4.9E+03	1.2E+04	9.7E+03	6.8E+02
Dy	2.3E+02	3.9E+02	4.2E+01	6.0E+02	3.0E+02
Er	1.3E+02	1.9E+02	2.3E+01	3.1E+02	1.7E+02
Eu	4.0E+01	7.7E+01	6.9E+00	1.5E+02	6.6E+01
F	no data	2.3E+01	no data	2.4E+01	no data
Fe	7.0E+03	3.4E+04	4.0E+04	1.1E+05	3.0E+04
Gd	2.4E+02	5.2E+02	5.5E+01	9.6E+02	4.7E+02
Hg	2.5E+03	4.3E+03	2.6E+03	6.2E+03	1.9E+03
Ho	5.0E+01	7.2E+01	8.2E+00	1.2E+02	6.2E+01
I	2.5E+01	1.1E+02	no data	2.2E+01	no data
K	8.3E+00	6.0E+00	1.7E+01	6.3E+00	3.6E+00
Li	3.0E+00	5.3E+00	9.2E+00	5.7E+00	4.4E+00
Lu	2.0E+01	2.6E+01	3.5E+00	4.1E+01	2.1E+01
Mg	1.2E+00	1.4E+00	6.6E+00	7.9E–01	5.9E–01
Mn	7.0E+02	2.6E+04	7.0E+03	4.0E+03	3.4E+03
Mo	1.3E+01	3.1E+01	2.4E+01	3.7E+01	1.1E+01
N	3.7 E+03	3.9 E+03	1.8 E+04	3.6 E+03	2.7 E+03
Na	1.1E+00	1.1E+00	1.5E+00	9.2E–01	9.5E–01
Nd	1.2E+03	2.3E+03	2.6E+02	4.2E+03	1.8E+03
Ni	1.1E+02	3.7E+02	3.5E+02	1.8E+02	1.0E+03
P1	1.4 E+04	1.3 E+04	7.9 E+04	1.6 E+04	1.1 E+04
P2	9.2E+04	8.8E+04	2.3E+05	1.2E+05	4.1E+04
Pb	7.9E+01	7.5E+01	8.0E+01	1.7E+02	3.9E+01
Pr	4.0E+02	8.2E+02	8.6E+01	1.4E+03	6.1E+02
Rb	1.8E+01	2.7E+01	3.2E+01	3.0E+01	1.5E+01
S	2.9E+00	3.8E+00	1.1E+01	3.2E+00	1.3E+00
Se	2.7E+03	6.3E+03	3.2E+03	4.3E+03	2.4E+03
Si	2.1E+03	2.6E+03	2.5E+03	1.7E+03	7.8E+02
Sm	3.1E+02	5.6E+02	5.8E+01	9.8E+02	4.3E+02
Tb	4.0E+00	7.0E+00	7.6E–01	1.2E+01	6.0E+00
Th	1.1E+02	2.6E+03	1.0E+03	1.6E+03	6.3E+02
Ti	1.6E+04	8.3E+04	8.0E+04	1.1E+05	4.5E+04
Tm	2.0E+01	2.6E+01	3.5E+00	4.1E+01	2.2E+01
V	2.5E+02	1.6E+03	1.6E+03	2.1E+03	9.3E+02
Yb	1.2E+02	1.6E+02	2.1E+01	2.6E+02	1.4E+02
Zn	5.9E+03	3.7E+03	6.5E+03	8.9E+03	1.5E+03
Zr	6.7E+02	1.2E+04	7.2E+03	1.5E+04	6.7E+03

Appendix 23

Bioconcentration factors (BCF_{ww}) [(kg/kgww)/(kg/kg)] for *G. cernuus* (Ruffe, n=1), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). The estimate was based on concentration per wet weight biota and concentration in dissolved fraction in water (DIM). Shaded element indicate that DIM data was below detection limit, other shaded cells indicate that biota data was below detection limit. Analysis of whole fish samples.

	G. cernuus (kg/kgww)/(kg/kg)	*O. eperlanus* (kg/kgww)/(kg/kg)	*R. rutilus* (kg/kgww)/(kg/kg)
Al	4.9E+03	1.2E+03	5.8E+02
As	6.5E+02	7.0E+02	3.8E+02
Ba	2.4E+01	6.2E+00	1.1E+01
Br	no data	no data	no data
C	no data	no data	no data
Ca	9.9E–02	3.8E–02	5.8E–02
Cd	2.7E+02	2.7E+02	2.4E+02
Ce	2.0E+03	1.6E+02	1.1E+02
Cl	no data	no data	no data
Co	1.2E+03	5.0E+02	4.1E+02
Cr	1.4E+02	1.4E+02	6.3E+01
Cs	9.5E+01	1.2E+02	2.7E+01
Cu	5.8E+02	6.2E+02	4.6E+02
Dy	1.3E+02	4.9E+01	2.7E+01
Er	7.6E+01	4.9E+01	2.7E+01
Eu	4.5E+01	4.9E+01	2.7E+01
F	no data	no data	no data
Fe	6.7E+00	1.9E+00	1.9E+00
Gd	1.7E+02	4.9E+01	2.7E+01
Hg	1.5E+04	1.3E+04	6.0E+03
Ho	4.5E+01	4.9E+01	2.7E+01
I	no data	no data	no data
K	2.4E–02	3.1E–02	1.6E–02
Li	3.7E+00	4.8E+00	2.4E+00
Lu	4.5E+01	4.9E+01	2.7E+01
Mg	1.1E–03	1.0E–03	8.3E–04
Mn	4.4E+02	9.1E+02	3.9E+02
Mo	5.6E+00	4.8E+00	6.4E+00
N	no data	no data	no data
Na	5.1E–04	4.4E–04	2.1E–04
Nd	7.2E+02	4.3E+01	3.4E+01
Ni	8.0E+01	7.8E+01	5.3E+01
P1	no data	no data	no data
P2	9.6E+05	5.4E+05	5.6E+05
Pb	1.8E+01	1.5E+01	9.4E+00
Pr	2.5E+02	4.9E+01	2.7E+01
Rb	7.1E+01	4.5E+01	2.7E+01
S	9.4E–03	1.1E–02	5.6E–03
Se	5.5E+03	5.5E+03	2.9E+03
Si	2.0E–02	1.6E–02	6.9E–03
Sm	1.6E+02	4.9E+01	2.7E+01
Tb	4.5E+00	4.9E+00	2.7E+00
Th	4.5E+01	4.9E+01	2.7E+01
Ti	5.3E+03	3.4E+02	2.4E+02
Tm	4.5E+01	4.9E+01	2.7E+01
V	5.0E+02	4.6E+01	4.2E+01
Yb	7.8E+01	4.9E+01	2.7E+01
Zn	9.7E+03	1.3E+04	1.4E+04
Zr	9.5E+01	1.7E+02	5.3E+01

Appendix 24

Bioconcentration factors (BCF_{ww}) [(kg/kgww)/(kg/kgww)] for *G. cernuus* (Ruffe, n=1), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). The estimate was based on concentration per wet weight biota and concentration in dissolved fraction in water (DIM). Shaded element indicate that DIM data was below detection limit, other shaded cells indicate that biota data was below detection limit. Analysis of mixed fish slices.

	G. cernuus (kg/kgww)/(kg/kg)	*O. eperlanus* (kg/kgww)/(kg/kg)	*R. rutilus* (kg/kgww)/(kg/kg)
Al	3.9E+02	9.4E+01	5.3E+01
As	1.6E+01	5.5E+01	1.0E+01
Ba	2.0E+01	4.4E+00	1.2E+01
Br	1.8E–01	2.4E–01	8.3E–02
C	1.6E+03	1.9E+03	1.7E+03
Ca	1.1E+02	2.6E+01	3.9E+01
Cd	8.7E+01	9.4E+01	1.8E+02
Ce	4.6E+00	2.7E+00	1.8E+00
Cl	8.7E–02	8.4E–02	3.0E–02
Co	2.9E+02	1.7E+02	2.3E+02
Cr	5.0E+00	2.5E+00	1.9E+00
Cs	9.9E+01	1.5E+02	3.2E+01
Cu	3.6E+02	3.2E+02	2.3E+02
Dy	3.2E+00	2.7E+00	1.8E+00
Er	3.2E+00	2.7E+00	1.8E+00
Eu	3.2E+00	2.7E+00	1.8E+00
F	1.1E+01	1.1E+01	6.1E+00
Fe	1.5E+03	1.0E+03	1.4E+03
Gd	3.2E+00	2.7E+00	1.8E+00
Hg	2.4E+04	2.1E+04	1.4E+04
Ho	3.2E+00	2.7E+00	1.8E+00
I	7.0E+00	1.3E+01	3.1E+00
K	3.5E+01	4.2E+01	1.9E+01
Li	2.2E+00	1.7E+00	9.4E–01
Lu	3.2E+00	2.7E+00	1.8E+00
Mg	1.5E+00	1.1E+00	8.1E–01
Mn	3.8E+02	4.9E+02	3.6E+02
Mo	2.4E+00	1.5E+00	2.0E+00
N	2.8E+04	3.1E+04	3.0E+04
Na	4.6E–01	3.7E–01	1.8E–01
Nd	2.6E+00	2.1E+00	1.5E+00
Ni	1.7E+01	1.4E+01	8.5E+00
P1	3.6E+05	2.0E+05	3.1E+05
P2	1.0E+06	4.3E+05	4.3E+05
Pb	6.6E+00	5.0E+00	4.1E+00
Pr	3.2E+00	2.7E+00	1.8E+00
Rb	6.9E+01	5.0E+01	2.9E+01
S	1.2E+01	9.7E+00	6.5E+00
Se	9.6E+03	7.8E+03	4.3E+03
Si	1.5E+02	8.7E+01	1.7E+01
Sm	3.2E+00	2.7E+00	1.8E+00
Tb	3.2E–01	2.7E–01	1.8E–01
Th	2.1E+01	1.3E+01	8.4E+00
Ti	3.8E+03	8.5E+02	1.1E+03
Tm	3.2E+00	2.7E+00	1.8E+00
V	2.9E+02	3.7E+01	1.6E+01
Yb	3.2E+00	2.7E+00	1.8E+00
Zn	7.0E+03	7.5E+03	1.0E+04
Zr	3.5E+02	7.0E+01	3.1E+01

Appendix 25

Bioconcentration factors (BCF_C) [(kg/kgC)/(kg/kg)] for phytoplankton (n=3), benthic micro-algae (n=2), *F. vesiculosus* (n=3), *P. littoralis* (n=3) and *P. pectinatus* (n=3). The estimate was based on concentration per kg C in biota and concentration in dissolved fraction in water (DIM). Shaded element indicate that DIM data was below detection limit, other shaded cells indicate that biota data was below detection limit.

	Phytoplankton (kg/kgC/(kg/kg)	Benthic microalgae (kg/kgC)/(kg/kg)	*F. vesiculosus* (kg/kgC)/(kg/kg)	*P. littoralis* (kg/kgC)/(kg/kg)	*P. pectinatus* (kg/kgC)/(kg/kg)
Al	2.2E+07	1.4E+08	1.3E+06	1.1E+07	5.6E+06
As	1.0E+04	5.4E+04	1.3E+04	1.0E+04	1.5E+03
Ba	1.4E+04	2.0E+05	3.8E+04	2.0E+04	6.1E+03
Br	4.6E+02	4.4E+02	4.6E+01	5.5E+01	no data
C	6.8E+04	6.8E+04	6.8E+04	6.8E+04	6.8E+04
Ca	2.4E+02	2.5E+03	4.9E+02	4.9E+02	7.7E+02
Cd	7.8E+04	1.1E+06	7.2E+05	5.7E+04	1.4E+05
Ce	5.5E+03	3.4E+05	2.4E+04	1.2E+04	2.3E+04
Cl	1.3E+02	1.0E+02	8.8E+00	5.2E+01	no data
Co	7.8E+05	2.1E+07	2.5E+05	4.4E+05	5.7E+05
Cr	5.6E+04	2.7E+05	3.6E+03	2.6E+04	1.3E+04
Cs	4.9E+04	2.8E+05	4.0E+03	3.1E+04	1.5E+04
Cu	1.7E+05	4.0E+05	1.3E+04	2.4E+04	2.6E+04
Dy	3.0E+02	2.0E+04	2.7E+03	7.4E+02	1.2E+03
Er	1.7E+02	1.1E+04	1.7E+03	4.1E+02	7.1E+02
Eu	1.2E+02	3.7E+03	3.8E+02	1.5E+02	2.5E+02
F	1.9E+04	2.5E+03	3.3E+02	6.9E+03	no data
Fe	9.0E+06	1.2E+08	6.2E+05	4.9E+06	2.4E+06
Gd	3.8E+02	2.7E+04	3.3E+03	9.5E+02	1.6E+03
Hg	1.6E+05	4.1E+05	3.1E+04	4.5E+04	3.8E+04
Ho	1.2E+02	3.8E+03	5.7E+02	1.4E+02	2.5E+02
I	3.7E+03	8.9E+04	1.1E+04	7.2E+03	no data
K	8.1E+02	1.4E+03	7.3E+02	1.3E+03	8.0E+02
Li	1.8E+03	4.9E+03	1.4E+02	8.4E+02	3.8E+02
Lu	1.2E+02	1.5E+03	2.6E+02	8.3E+01	1.0E+02
Mg	2.3E+02	4.2E+02	1.4E+02	1.3E+02	1.3E+02
Mn	1.3E+06	5.1E+07	5.5E+05	4.9E+05	1.1E+06
Mo	1.1E+03	2.8E+04	5.6E+02	5.7E+02	2.1E+03
N	5.6E+05	5.3E+05	2.7E+05	4.1E+05	2.3E+05
Na	1.8E+02	1.5E+02	2.6E+01	6.1E+01	4.0E+01
Nd	1.9E+03	1.3E+05	1.3E+04	4.5E+03	7.4E+03
Ni	3.7E+04	9.9E+05	4.9E+04	2.1E+04	2.1E+04
P1	1.4E+06	3.3E+06	6.0E+05	1.8E+06	1.2E+06
P2	2.4E+06	4.2E+06	6.7E+05	1.7E+06	1.4E+06
Pb	3.4E+04	3.3E+05	1.2E+03	8.6E+03	4.6E+03
Pr	6.3E+02	4.3E+04	4.3E+03	1.5E+03	2.5E+03
Rb	4.0E+03	2.1E+04	1.6E+03	3.7E+03	1.5E+03
S	3.1E+02	4.9E+02	6.3E+02	2.8E+02	1.6E+02
Se	9.0E+04	1.4E+05	4.5E+04	5.6E+03	1.8E+04
Si	2.1E+06	1.5E+06	3.8E+04	6.0E+05	2.7E+05
Sm	4.3E+02	3.0E+04	3.1E+03	1.0E+03	1.7E+03
Tb	1.2E+01	3.7E+02	4.7E+01	1.3E+01	2.3E+01
Th	2.0E+05	2.9E+06	1.4E+04	1.2E+05	6.1E+04
Ti	1.9E+07	1.1E+08	1.2E+06	1.0E+07	4.6E+06
Tm	1.2E+02	1.6E+03	2.3E+02	8.4E+01	1.0E+02
V	3.2E+05	3.1E+06	3.3E+04	1.9E+05	1.0E+05
Yb	1.6E+02	9.8E+03	1.5E+03	3.7E+02	6.4E+02
Zn	1.5E+06	2.4E+06	4.3E+05	1.2E+05	1.7E+05
Zr	1.4E+06	1.5E+07	1.6E+05	9.4E+05	4.1E+05

Appendix 26

Bioconcentration factors (BCF_C) [(kg/kgC)/(kg/kg)] for zooplankton (n=1), *T. fluviatilis* (n=2) and *Idothea* spp. (n=2), *M. baltica* (n=3), and *C. glaucum* (n=2). The estimate was based on concentration per kg C in biota and concentration in dissolved fraction in water (DIM). Shaded element indicate that DIM data was below detection limit, other shaded cells indicate that biota data was below detection limit.

	Zooplankton (kg/kgC/(kg/kg)	*T. fluviatilis* (kg/kgC)/(kg/kg)	*Idothea* spp. (kg/kgC)/(kg/kg)	*M. baltica* (kg/kgC)/(kg/kg)	*C. glaucum* (kg/kgC)/(kg/kg)
Al	5.0E+06	3.1E+03	1.5E+03	2.6E+03	1.3E+03
As	7.8E+03	1.8E+03	2.6E+03	1.7E+03	6.2E+02
Ba	6.9E+03	4.7E+03	1.3E+04	1.0E+04	1.2E+04
Br	1.9E+03	4.1E+01	no data	1.1E+01	no data
C	7.1E+02	6.8E+04	6.8E+04	6.8E+04	6.8E+04
Ca	2.6E+03	2.4E+04	4.1E+03	1.9E+04	2.5E+04
Cd	6.2E+05	2.4E+05	2.8E+05	5.2E+04	5.8E+04
Ce	8.4E+05	1.2E+05	1.1E+04	1.9E+05	9.0E+04
Cl	7.3E–01	6.2E+00	no data	3.8E+00	no data
Co	3.2E+05	1.5E+05	1.7E+05	1.4E+05	5.6E+04
Cr	3.7E+04	3.0E+03	4.6E+03	4.7E+03	2.6E+03
Cs	1.3E+04	3.8E+03	4.4E+03	5.4E+03	2.7E+03
Cu	6.0E+05	9.0E+04	2.0E+05	1.7E+05	1.4E+04
Dy	6.5E+04	7.3E+03	7.0E+02	1.1E+04	6.4E+03
Er	3.7E+04	3.5E+03	3.9E+02	5.5E+03	3.6E+03
Eu	1.1E+04	1.4E+03	1.1E+02	2.6E+03	1.4E+03
F	5.1E+00	4.2E+02	no data	4.2E+02	no data
Fe	2.0E+06	6.2E+05	6.6E+05	1.9E+06	6.3E+05
Gd	6.8E+04	9.7E+03	9.1E+02	1.7E+04	9.9E+03
Hg	7.0E+05	7.9E+04	4.3E+04	1.1E+05	4.1E+04
Ho	1.4E+04	1.3E+03	1.4E+02	2.0E+03	1.3E+03
I	6.5E+02	2.1E+03	no data	4.0E+02	no data
K	2.3E+03	1.1E+02	2.8E+02	1.1E+02	7.7E+01
Li	8.5E+02	9.7E+01	1.5E+02	1.0E+02	9.3E+01
Lu	5.6E+03	4.7E+02	5.8E+01	7.3E+02	4.5E+02
Mg	3.4E+02	2.6E+01	1.1E+02	1.4E+01	1.3E+01
Mn	2.0E+05	4.8E+05	1.2E+05	7.1E+04	7.3E+04
Mo	3.6E+03	5.8E+02	4.0E+02	6.5E+02	2.2E+02
N	5.7E+03	4.1E+05	8.5E+05	3.7E+05	3.0E+05
Na	3.0E+02	2.0E+01	2.5E+01	1.6E+01	2.0E+01
Nd	3.5E+05	4.3E+04	4.3E+03	7.5E+04	3.9E+04
Ni	3.1E+04	6.9E+03	5.8E+03	3.2E+03	2.2E+04
P1	1.5E+05	1.4E+06	3.8E+06	1.6E+06	1.2E+06
P2	2.6E+07	1.6E+06	3.7E+06	2.0E+06	8.7E+05
Pb	2.3E+04	1.4E+03	1.3E+03	2.9E+03	8.2E+02
Pr	1.1E+05	1.5E+04	1.4E+03	2.5E+04	1.3E+04
Rb	5.0E+03	4.9E+02	5.4E+02	5.3E+02	3.2E+02
S	8.3E+02	7.0E+01	1.9E+02	5.6E+01	2.8E+01
Se	7.6E+05	1.2E+05	5.2E+04	7.6E+04	5.0E+04
Si	5.9E+05	4.9E+04	4.1E+04	3.0E+04	1.7E+04
Sm	8.7E+04	1.0E+04	9.7E+02	1.7E+04	9.1E+03
Tb	1.1E+03	1.3E+02	1.3E+01	2.1E+02	1.3E+02
Th	3.2E+04	4.8E+04	1.7E+04	2.8E+04	1.3E+04
Ti	4.7E+06	1.5E+06	1.3E+06	1.9E+06	9.6E+05
Tm	5.6E+03	4.8E+02	5.8E+01	7.3E+02	4.7E+02
V	7.0E+04	3.0E+04	2.7E+04	3.6E+04	2.0E+04
Yb	3.4E+04	3.0E+03	3.4E+02	4.6E+03	3.0E+03
Zn	1.7E+06	6.9E+04	1.1E+05	1.6E+05	3.3E+04
Zr	1.9E+05	2.3E+05	1.2E+05	2.7E+05	1.4E+05

Appendix 27

Bioconcentration factors (BCF_C) [(kg/kgC)/(kg/kg)] for *G. cernuus* (Ruffe, n=1), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). The estimate was based on concentration per kg C in biota and concentration in dissolved fraction in water (DIM). Shaded element indicate that DIM data was below detection limit, other shaded cells indicate that biota data was below detection limit. Analysis of whole fish samples.

	G. cernuus (kg/kgC/(kg/kg)	*O. eperlanus* (kg/kgC)/(kg/kg)	*R. rutilus* (kg/kgC)/(kg/kg)
Al	1.7E+07	4.5E+06	7.2E+04
As	8.3E+02	6.9E+03	9.4E+03
Ba	1.7E+04	6.2E+03	3.5E+02
Br	no data	no data	no data
C	no data	no data	no data
Ca	6.1E+01	2.3E+03	1.4E+00
Cd	2.2E+04	5.5E+05	4.0E+03
Ce	3.1E+05	7.4E+05	2.9E+04
Cl	no data	no data	no data
Co	9.2E+05	2.8E+05	1.7E+04
Cr	7.9E+04	3.3E+04	2.1E+03
Cs	6.4E+04	1.1E+04	1.4E+03
Cu	3.3E+04	5.3E+05	8.4E+03
Dy	2.7E+04	5.7E+04	1.9E+03
Er	1.5E+04	3.2E+04	1.1E+03
Eu	5.2E+03	1.0E+04	6.6E+02
F	no data	no data	no data
Fe	1.2E+07	1.8E+06	9.7E+01
Gd	3.3E+04	6.0E+04	2.6E+03
Hg	1.1E+05	6.2E+05	2.1E+05
Ho	5.2E+03	1.2E+04	6.6E+02
I	no data	no data	no data
K	1.0E+02	2.1E+03	3.6E–01
Li	9.2E+02	7.6E+02	5.4E+01
Lu	2.0E+03	5.0E+03	6.6E+02
Mg	4.6E+01	3.0E+02	1.6E–02
Mn	2.7E+05	1.7E+05	6.4E+03
Mo	3.9E+02	3.2E+03	8.2E+01
N	no data	no data	no data
Na	1.5E+00	2.7E+02	7.5E–03
Nd	1.6E+05	3.1E+05	1.1E+04
Ni	2.9E+04	2.7E+04	1.2E+03
P1	no data	no data	no data
P2	1.6E+05	2.3E+07	1.4E+07
Pb	2.9E+04	2.0E+04	2.6E+02
Pr	5.4E+04	1.0E+05	3.7E+03
Rb	7.6E+03	4.4E+03	1.0E+03
S	8.7E+00	7.4E+02	1.4E–01
Se	3.1E+03	6.7E+05	8.1E+04
Si	7.8E+02	5.2E+05	2.9E–01
Sm	3.6E+04	7.7E+04	2.4E+03
Tb	4.9E+02	1.0E+03	6.6E+01
Th	4.7E+04	2.8E+04	6.6E+02
Ti	3.1E+07	4.1E+06	7.8E+04
Tm	2.0E+03	5.0E+03	6.6E+02
V	6.0E+05	6.2E+04	7.3E+03
Yb	1.3E+04	3.0E+04	1.1E+03
Zn	8.4E+04	1.5E+06	1.4E+05
Zr	7.5E+06	1.7E+05	1.4E+03

Appendix 28

Bioconcentration factors (BCF_C) [(kg/kgC)/(kg/kg)] for *G. cernuus* (Ruffe, n=1), *O. eperlanus* (Smelt, n=3) and *R. rutilus* (Roach, n=3). The estimate was based on concentration per kg C in biota and concentration in dissolved fraction in water (DIM). Shaded element indicate that DIM data was below detection limit, other shaded cells indicate that biota data was below detection limit. Analysis of mixed fish slices.

	G. cernuus (kg/kgC/(kg/kg)	O. eperlanus (kg/kgC)/(kg/kg)	R. rutilus (kg/kgC)/(kg/kg)
Al	5.9E+03	1.2E+03	1.3E+03
As	2.4E+02	7.2E+02	2.6E+02
Ba	3.0E+02	5.7E+01	3.0E+02
Br	2.8E+00	3.1E+00	2.1E+00
C	6.8E+04	6.8E+04	6.8E+04
Ca	1.7E+03	3.3E+02	9.8E+02
Cd	1.3E+03	1.2E+03	4.5E+03
Ce	7.0E+01	3.5E+01	4.7E+01
Cl	1.3E+00	1.1E+00	7.7E–01
Co	4.5E+03	2.2E+03	5.9E+03
Cr	7.7E+01	3.2E+01	4.8E+01
Cs	1.5E+03	2.0E+03	8.2E+02
Cu	5.5E+03	4.2E+03	5.8E+03
Dy	4.9E+01	3.5E+01	4.7E+01
Er	4.9E+01	3.5E+01	4.7E+01
Eu	4.9E+01	3.5E+01	4.7E+01
F	1.6E+02	1.4E+02	1.6E+02
Fe	2.2E+04	1.3E+04	3.6E+04
Gd	4.9E+01	3.5E+01	4.7E+01
Hg	3.6E+05	2.7E+05	3.6E+05
Ho	4.9E+01	3.5E+01	4.7E+01
I	1.1E+02	1.7E+02	7.8E+01
K	5.3E+02	5.4E+02	4.9E+02
Li	3.4E+01	2.2E+01	2.4E+01
Lu	4.9E+01	3.5E+01	4.7E+01
Mg	2.3E+01	1.4E+01	2.0E+01
Mn	5.7E+03	6.3E+03	9.1E+03
Mo	3.6E+01	2.0E+01	5.2E+01
N	1.2E+06	1.1E+06	1.2E+06
Na	6.9E+00	4.8E+00	4.5E+00
Nd	3.9E+01	2.8E+01	3.8E+01
Ni	2.5E+02	1.9E+02	2.1E+02
P1	1.5E+07	7.4E+06	1.2E+07
P2	1.5E+07	5.6E+06	1.1E+07
Pb	1.0E+02	6.5E+01	1.1E+02
Pr	4.9E+01	3.5E+01	4.7E+01
Rb	1.0E+03	6.4E+02	7.5E+02
S	1.8E+02	1.3E+02	1.7E+02
Se	1.5E+05	1.0E+05	1.1E+05
Si	2.3E+03	1.1E+03	4.2E+02
Sm	4.9E+01	3.5E+01	4.7E+01
Tb	4.9E+00	3.5E+00	4.7E+00
Th	3.2E+02	1.7E+02	2.1E+02
Ti	5.8E+04	1.1E+04	2.9E+04
Tm	4.9E+01	3.5E+01	4.7E+01
V	4.5E+03	4.8E+02	4.1E+02
Yb	4.9E+01	3.5E+01	4.7E+01
Zn	1.1E+05	9.7E+04	2.6E+05
Zr	5.3E+03	9.2E+02	8.0E+02

Appendix 29

Partitioning coefficients (Kd) [(kg/kgdw)/(kg/m³)] for water column (Kd I, n=3/3), upper sediment (Kd II 0–3 cm, n=3/3) and lower sediment (Kd III, 3–6 cm, n=3/1). Grey shading indicates that the particulate phase concentrations were below detection limits. * indicates that the dissolved phase concentrations were also below detection limits.

	Kd I (water column) (kg/kgdw/(kg/m³)	Kd II (upper sediment) (kg/kgdw/(kg/m³)	Kd III (lower sediment) (kg/kgdw/(kg/m³)
Al	7.5E+04	1.6E+02	6.2E+03
As	8.0E–01 *	3.8E–01 *	3.3E–01
Ba	7.3E+03	2.3E+00	2.0E+00
Br	1.4E–02	no data	no data
C	2.2E+00	no data	no data
Ca	4.2E+00	2.0E–02	2.5E–02
Cd	2.6E+03	7.3E+00	2.3E+01
Ce	3.3E+03 *	2.6E+00	9.2E+01
Cl	4.8E–04	no data	no data
Co	1.0E+02 *	5.3E+00	2.1E+01
Cr	4.2E+02	3.0E+01	6.1E+01
Cs	1.0E+02 *	1.7E+01	2.7E+01 *
Cu	3.9E+01	7.9E+00	3.3E+01
Dy	1.2E+02 *	2.7E+00	1.1E+01 *
Er	6.4E+02 *	1.4E+00 *	6.2E+00 *
Eu	3.0E+02 *	1.8E+00 *	2.1E+00 *
F	2.9E–01 *	no data	no data
Fe	1.2E+03	2.1E+02	9.9E+00
Gd	1.3E+02 *	2.8E+00	1.4E+01 *
Hg	2.8E+02 *	3.1E+01 *	4.7E+01 *
Ho	2.3E+01 *	1.7E+00 *	2.1E+00 *
I	4.7E+00	no data	no data
K	1.3E+00	1.6E–02	3.1E–02
Li	1.5E+00	2.4E–01	3.0E–01
Lu	1.0E+01 *	6.8E–01 *	8.4E–01 *
Mg	5.4E–02	1.0E–02	2.2E–02
Mn	7.2E+01	4.0E–01	9.6E–01
Mo	3.6E+01	5.0E–02	3.3E–02
N	1.7E+01	no data	no data
Na	1.6E–01	2.1E–03	6.3E–04
Nd	7.3E+02	3.3E+00	8.0E+01 *
Ni	1.3E+01	3.2E+00	7.3E+00
P1	1.0E+02	no data	no data
P2	1.2E+02	4.6E+00	5.5E+00
Pb	9.3E+01	3.0E+01	5.4E+01
Pr	2.4E+02 *	3.4E+00	2.2E+01 *
Rb	1.6E+01	2.2E+00	1.9E+00
S	3.6E–02	3.6E–03	3.5E–03
Se	3.5E+02 *	2.1E–01	3.6E–01
Si*	1.3E+03	2.08E+01	2.08E+01
Sm	2.0E+02 *	3.0E+00	1.5E+01 *
Tb	1.9E+00 *	1.6E–01 *	2.0E–01 *
Th	9.3E+01 *	1.8E+01 *	1.9E+01 *
Ti	7.4E+03	1.7E+03	5.3E+03
Tm	1.0E+01 *	6.1E–01 *	8.2E–01 *
V	7.3E–03	2.0E+01	6.3E+01
Yb	6.5E+01 *	1.8E+00	5.2E+00 *
Zn	6.4E+04	2.3E+00	1.4E+01
Zr	2.5E+03 *	3.8E+03 *	3.1E+03 *

* Sediment and porewater used for Si-analyses sampled on another occasion and location (see Table 2-1).