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Abstract : Soils in New Caledonia are particularly rich in metals among which Fe and Ni are intensively exploited. Due to important natural erosion in tropical latitudes and to mining activities, coastal waters are enriched in Co, Cr, Fe and Ni. In deeper waters lives a cephalopod species which is considered as a living fossil, the nautilus *Nautilus macromphalus*. In this study, 12 traces elements were analysed in the tissues of 4 nautilus specimens. Results showed high metal concentrations compared to data available for cephalopod from temperate waters. These concentrations were often in the same order than those encountered in bivalves or gastropods from contaminated areas. Relatively high concentrations of Ni and Cr in the hemolymph strongly suggest a high exposure of *N. macromphalus* to these metals. Among the tissues, the digestive gland have the highest concentrations of Cd, Co, Fe, V and Zn while for Ag, Al, As, Cr and Ni, renal and pericardial appendages exhibited the highest values. Despite this, the digestive gland contained the largest quantities of all metals with the exception of As and Mn which were mainly found in the body muscular remains. These results highlighted the major role of digestive gland and excreting organs in the metabolism of metals in these cephalopod species.

Keywords: New Caledonia ; trace metals ; cephalopods ; digestive gland ; nautilus

Introduction

Cephalopods play a key role in many marine ecosystems (Amaratunga 1983, Rodhouse 1989). Trace elements have been investigated extensively in many marine organisms but rarely in cephalopods. Some elements are essential, others toxic, and for a number of them the role is still not known. The studies concerning trace elements in cephalopods molluscs are limited to species targeted by commercial fisheries such as the cuttlefish *Sepia officinalis* (Decleir et al. 1978, Schipp & Hevert 1978, Miramand & Bentley 1992, Bustamante 1998), the octopuses *Octopus vulgaris* and *Eledone cirrhosa* (Ghiretti-Magaldi et al. 1958, Rocca 1969, Renzoni et al. 1973, Froesch & Packard 1979, Ueda et al. 1979, Miramand & Guary 1980, Miramand & Bentley 1992, Barghigiani et al. 1993, Rossi et al. 1993, Bustamante 1998), some Ommastrephid squids (Martin & Flegal 1975, Ueda et al. 1979, Smith 1983, Smith et al. 1984, Finger & Smith 1987, Yamada et al. 1997, Bustamante 1998) and some Loliginid squids (Martin & Flegal 1975, Yamada et al. 1997, Bustamante 1998). Among these species, high levels of metals have generally been recorded, the digestive gland of Coleidae concentrating many trace elements, such as cadmium, copper, silver or zinc (Martin & Flegal 1975, Smith et al. 1984, Miramand & Guary 1980, Finger & Smith 1987, Miramand & Bentley 1992, Bustamante 1998, Bustamante et al 1998a). The most striking feature is that the digestive gland stores most of the total cadmium, reaching up 98% in some species (Bustamante 1998).

Present cephalopods comprise two subclasses: the Coleoidae, with ca 650 species and the Nautiloidae with a single genus (*Nautilus*) and an as yet undetermined number of species (3 to 7 according to the authors). *Nautilus* is the last representative of the ectocochleate cephalopods and is considered as a living fossil. This taxon shares a number of common anatomical structures with present cephalopods, but some organs are specific to *Nautilus*.

Among the nautilus species, *Nautilus macromphalus* is endemic to the New Caledonian waters. In this area, natural erosion and mining activity have provoked an enrichment of several metals, mainly Co, Cr, Fe and Ni, of the New Caledonian waters and consequently in the coral reef food webs (Monniot et al. 1994). These authors have described the metal enrichment in several species of filter-feeding ascidians from the shallow waters. But no data are available on species living off the New Caledonia coast.

For these reasons, levels of trace elements in the tissues of *Nautilus macromphalus* from New Caledonia were investigated here and compared to previous results reported for Coleoid species.

Materials & Methods

Sampling and sample preparation

2 males and 2 females *Nautilus macromphalus* were taken in baited traps from the barrier reef off Nouméa (New Caledonia). Samples were frozen upon arrival at the Nouméa Aquarium in individual plastic bags. Each individual was weighed and sexed. The digestive gland, gills, renal and pericardial appendages, digestive tract and genital tract were totally removed. In addition, pieces of muscle and crop were sampled to determine metal concentrations. The remains of the animals were thus composed of arms, the rest of the muscles and the rest of the crop. The stomach was emptied before metal analysis.

Analytical procedure

Tissue samples were dried for several days at 80°C to constant weight. Two aliquots of approx. 300 mg of each homogenised dry sample were digested with 4 ml of 65 % HNO_3 and 1 ml of 70 % $HClO_4$ at 80°C until the solution was clear. After evaporation, the residues were dissolved in 0.3 N nitric acid.

Cadmium, Copper and Zinc were determined both by atomic absorption spectrophotometry (AAS) and by induced coupled plasma mass spectrophotometry (ICP-MS). Other elements (Ag, As, Al, Co, Cr, Fe, Mn, Ni and V) were analysed only by ICP-MS.

Appliances used for metals determination were a Varian spectrophotometer Vectra 250 Plus with Deuterium background correction and a Varian ICP-MS Ultra Mass 700. Reference tissues, dogfish liver DOLT-2 (NRCC), Orchard-Leaves (NBS) and MA-A-2 fish-flesh standard (IAEA), were treated and analysed in the same way as the samples. The results for the standard reference materials (Table 1) are in good agreement with certified values. The detection limits were (µg/g dry wt): 0.002 (Ag), 0.005 (Al), 0.15 (As), 0.005 (Cd), 0.005 (Co), 0.005 (Cr), 0.027 (Cu), 0.15 (Fe), 0.017 (Mn), 0.002 (Ni), 0.005 (V) and 0.15 (Zn). Metal concentrations in tissues are given relatively to the dry weight ($\mu g.g^{-1}$ dry wt) while the distribution percentages were calculated for wet weight.

Results

Metal concentration in the organs of nautilus are reported in Figure 1. The percentage of heavy metals in each tissue are shown in Figure 2.

Mean metal concentrations in whole *Nautilus macromphalus* were 2.4 µg Ag.g^{-1}, 19.1 µg Al.g^{-1}, 186 µg As.g^{-1}, 16.0 µg Cd.g^{-1}, 2.7 µg Co.g^{-1}, 2.6 µg Cr.g^{-1}, 73 µg Cu.g^{-1}, 258 µg Fe.g^{-1}, 17µg Mn.g^{-1}, 6.7 µg Ni.g^{-1}, 3.2 µg V.g^{-1} and 260 µg Zn.g^{-1} (Figure 1). Variation coefficients ranged from 10% for As to 45% for Co and Ni.

Metal levels in soft tissues

In the four sampled nautilus, the digestive gland was the major site of concentration for Cd, Co, Fe, V and Zn with 28.2-60.5 µg Cd.g^{-1}, 4.4-12.5 µg Co.g^{-1}, 477-953 µg Fe.g^{-1}, 6.4-10.6 µg V.g^{-1} and 515-963 µg Zn.g^{-1} (Figure 1). The digestive gland also concentrated Ag, As, Cr, Cu and Ni at levels closed to the highest concentrations recorded in the other tissues with 1.1-6.8 µg Ag.g^{-1}, 133-194 µg As.g^{-1}, 3.4-5.5 µg Cr.g^{-1} 78-174 µg Cu.g^{-1} and 9.0-26.3 µg Ni.g^{-1} (Figure 1).

Ag, Al, As, Cr and Ni concentrations were also remarkable in excreting tissues, i.e. renal and pericardial appendages, which exhibited the highest concentrations for these metals. In fact, Ni concentrations ranged from 5.6 to 40.0 µg.g^{-1} in renal appendages. Pericardial appendages concentrated Ag from 13.8 to 28.0 µg.g^{-1}, Al from 45 to 305 µg.g^{-1}, As from 155 to 412 µg.g^{-1} and Cr from 6.0 to 9.4 µg.g^{-1} (Figure 1).

Muscles exhibited generally the lowest concentration for all metals except for As which exhibited the highest concentration in this tissue (203-354 µg As.g^{-1} dry weight ; Figure 1).

Mn was present in high concentration in the gills and the renal appendages (i.e. 42-151 µg.g^{-1} and 16-152 µg.g^{-1}, respectively) while most tissues exhibited concentrations lower than 20 µg.g^{-1}. The highest Cu concentration was found in the hemolymph, with mean values of 1055 ± 12 µg.g^{-1}. Thus, it is not surprising to find relatively high Cu concentrations in the gills (i.e. 127 ± 38 µg.g^{-1}).

Percentage distribution of metals in soft tissues

With the exception of As and Mn which were mainly found in the body muscular remains (50 ± 12% and 42 ± 16%, respectively), the digestive gland contained the largest quantities of all metals : 75 ± 3% of Ag, 62 ± 11% of Al, 96 ± 3% of Cd, 95 ± 2% of Co, 57 ± 16% of Cu, 65 ± 5 % of Cr, 87 ± 4% of Fe, 84 ± 8 of Ni, 95 ± 3% of V and 88 ± 3% of Zn (Figure 2). Although the concentration of some metals was high in the renal and pericardial appendages, these tissues contain in fact low amounts of metals because of their small mass (Figure 2).

Discussion

The variability of metal concentration was relatively small among the four studied individuals. Low variation coefficients for toxic metals such as Ag, Cd or V (26%, 41% and 34%, respectively) are noteworthy. Nevertheless, coefficients of variation for Cd are similar to those found in two octopus species from the Southern Indian Ocean, *Benthoctopus thielei* and *Graneledone*, reported to have very high Cd levels in their tissues (Bustamante et al. 1998a). Such results suggest efficient regulation processes of toxic metals in Nautilidae even Cd levels were lower in *Nautilus macromphalus* than in these octopuses. Some other toxic elements, Ag, Co, Cr, Ni and V, were more concentrated in nautilus than in temperate cephalopods such as the cuttlefish *Sepia officinalis* and the octopuses *Eledone cirrhosa* and *Octopus vulgaris* (Miramand & Guary 1980, Miramand & Bentley 1992). This might be due to accumulation during nautilus life span (10-15 years), much longer than Coleoid’s (1-3 years). Moreover, several essential metals, such as Fe, Mn and Zn were also highly concentrated in *N. macromphalus*, but Cu concentrations almost the same as in Coleoidae species (Miramand & Guary 1980, Miramand & Bentley 1992, Bustamante et al. 1998a). High metal concentrations might reflect the ambient life conditions of nautilus. Mineral extraction activity, mainly Ni, is important in New Caledonia : Ni enrichment in the waters and food webs might thus account for high levels of Ni in *N. macromphalus*. Although the dissolved Ni have not been measured, large amounts in coastal sediments suggests that abnormal concentration may occur in sea water (Bryan 1976, Monniot et al. 1994). Indeed, Monniot et al. (1994) reported very high Ni concentrations in the body and the tunic of *Ascidia sydneiensis* from coastal waters, reaching 80.4 and 119.5 µg/g dry wt, respectively. Compared to other molluscs species, Ni concentrations in *N. macromphalus* were in the same order of magnitude than in several deposit feeder species such as *Scrobicularia plana* or *Macoma balthica* but are higher than in filter feeder species such as *Pecten maximus* or *Mytilus edulis* (Table 2). It was also the case for Co and Cr. High levels of Ni, Co and Cr in deposit feeder bivalves were related to direct exposure through contaminated sediments (Bryan & Hummerstone 1977). This strongly suggest that contamination is not only located on the New Caledonian coast but reach deeper waters where nautilus lives. This hypothesis is reinforced by the relatively high concentrations for these metals encountered in the hemolymph. Indeed, in circulatory fluid as hemolymph, turnover of metals is supposed to be rapid and by the way, metal concentrations relatively low, with the exception of Cu which is a main component of hemocyanin. It is the case for most of the trace elements analysed but not for Ni and Cr (Figure 1). This supposed a high exposure of nautilus to these metals.

Concerning Fe, *N. macromphalus* exhibit higher concentrations than in cephalopods from temperate waters that could also indicated contamination (Table 2). Nevertheless, Fe concentrations are lower than in bivalve and gastropod species from contaminated areas and were relatively low in hemolymph (Table 2).

Table 3 compares the trace element concentrations in the digestive gland of *Nautilus macromphalus* with those reported for other cephalopod species. The relative weight of the digestive gland in our samples is higher than in most of Coleoidae species. Indeed, the digestive gland consists of 20±5% of the fresh weight of the soft tissues of *N. macromphalus* while in Coleoidae, it represent 6 to 10% of the total body weight. Thus, when metals were highly concentrated in the digestive gland (e.g. Cd), metal concentrations in the whole individuals were proportionally higher than in other cephalopod species.

Ag, Cd, Co, Cr, Ni and V levels in the digestive gland of *N. macromphalus* are higher than those reported for *Eledone cirrhosa* and *Sepia officinalis* from the English Channel. Nevertheless, several squid species, i.e. *Loligo opalescens*, *Ommastrephes bartrami* and *Sthenoteuthis oualaniensis* from the Pacific Ocean, exhibit higher concentrations of Ag in their digestive gland (Martin & Flegal 1975). These authors explain these very high Ag concentrations by the release of the metal in the Californian waters. This suppose very high ability of cephalopods to concentrate Ag. For Cd, these squids and the octopuses from Kerguelen Islands (i.e. *Graneledone* sp. and *Benthoctopus thielei*) have far higher concentrations in the digestive gland than nautilus (Bustamante et al. 1998a). Although Cd concentrations in *N. macromphalus* were higher than in squids and cuttlefish from temperate waters (Table 3, Bustamante et al. 1998b), it doesn't indicate a contamination as they are in the same order of magnitude than in octopus species from these areas. Concentrations of Cu, Fe, Mn and Zn in the digestive gland of *N. macromphalus*, all essential elements, are in the same order of magnitude as those of other cephalopod species. Thus, these elements are properly regulated in the digestive gland of *N. macromphalus* as in the other cephalopod species. Results for As appear to be the first reported for the cephalopod digestive gland. For Al, concentrations can only be compared with those in the squid *Nototodarus gouldi* (Smith et al. 1984) which are ranged from 1.5 to 20 µg/g (Table 3).

Globally, concentrations of the toxic elements in the digestive gland of *Nautilus macromphalus* are generally higher than those reported for cephalopods from the French coasts, i.e. *Sepia officinalis, Eledone cirrhosa* and *Octopus vulgaris* (Table 3).

In the Coleoidae species, branchial hearts have been reported to concentrate essential elements such as Fe and Cu (Fox & Updegraff 1943, Ghiretti-Magaldi et al. 1958, Nardi & Steinberg 1974, Schipp & Hevert 1978, Miramand & Bentley 1992). These organs also concentrate toxic and radioactive elements such as ^{241}Am, Co, Ni, $^{239\text{-}240}$Pu and V (Ueda et al. 1979, Nakahara et al. 1979, Miramand & Guary 1980, Guary et al. 1981, Guary & Fowler 1982, Miramand & Bentley 1992). Moreover, kidneys of cephalopods have been shown to store Cd, Cu, Fe, Mn, Ni and Pb (Miramand & Guary 1980, Miramand & Bentley 1992).

High concentrations of trace elements (Ag, Al, As, Cr, Fe, Ni and Mn) were found in organs concerned with excretion, i.e. the pericardial and renal appendages (Figure 1). These results, and those concerning the digestive gland, suggest that these metals could follow another way of detoxification in nautilus than in the few Coleoidae species studied. The digestive gland would assume mainly the detoxification of metals such as Cd, V or Zn. The hypothesis is strengthened by the trace element levels in the circulatory fluid. Indeed, as the food can be considered as the main source of metals in cephalopods since they are carnivorous, the hemolymph would be a major vector for metal distribution among the different tissues. Metal levels in the hemolymph of *Nautilus macromphalus* showed relatively low concentrations for most elements, except for Cu which is present in hemocyanin. This is particularly clear for Cd, V and Zn which exhibited the lowest concentrations in the hemolymph (Figure 1).

The other tissues store trace element in much lower amounts than the digestive gland, the renal and the pericardial appendages. Nevertheless, muscles which generally exhibit the lowest metal concentrations, showed the highest As concentrations. This could be due to high consumption of crustaceans which are particularly rich in As.

Investigations on trace element concentrations in the tissues have highlighted the key role of the digestive gland of nautilus in the metabolism of metals, as is also the case in Coleoidae. This organ is indeed the major site of concentration of Cd, Co, Fe, V and Zn and, compared to other tissues, it shows also high levels of Ag, As, Cr, Cu and Ni (Figure 1). The digestive gland contains the highest percentage of metals, with the exception of As and Mn (Figure 2). Miramand & Bentley (1992) have classified some trace elements based on the ratio between the concentration in the digestive gland and in the muscle. Thus, in the digestive gland, three groups of elements can be evidenced in *Nautilus macromphalus* : poorly concentrated elements, i.e. Al, As, Cr, Cu and Mn (ratio <10), moderately concentrated elements, i.e. Fe, Ni and Zn (ratio >10 to <50) and highly concentrated elements, i.e. Ag, Cd, Co and V (ratio > 50). Similar ratios were found in Coleoidae (i.e. *Sepia officinalis* and *Eledone cirrhosa*) for Cr, Mn, Fe, Cd and Ag. On the contrary, V and Co are highly concentrated in the digestive gland of *Nautilus* whereas they are respectively poorly and moderately concentrated in Coleoidae. In the same way, Ni and Zn are moderately concentrated in the digestive gland of *Nautilus* but only poorly concentrated in *S. officinalis* and *E. cirrhosa*. High levels and storage of toxic metals in the digestive gland suggests efficient detoxification processes in this organ. Moreover, these high levels of toxic elements do not apparently disturb essential elements metabolism. Thus, it would be of particular interest to study detoxification processes in the digestive gland of nautilus.

5. Conclusion

Previous studies have demonstrated the ability of cephalopods to concentrate many trace elements. Data from nautilus species were particularly interesting on an evolutionary point of view. Indeed, as several elements are considered to be toxic for biota, marine animals would evolve to counteract their toxicity. It seems to be the case in cephalopods as they are able to growth and reproduce with very high metal concentrations. In their case, detoxification strategy involve storage mechanisms of these elements. This strategy appear to be efficient, and probably applied to minimise energetic cost, and is common among Nautilidae and Coleoidae cephalopods.

Enrichment of metals in New Caledonian waters appears to not be limited to coastal waters. Indeed, contamination by Co, Cr and Ni is supported 1) by high levels in whole animals which are in the same order of magnitude than in bivalves and gastropods from contaminated areas 2) by relatively high levels in excretory organs and in hemolymph that indicate a high exposure to these metals 3) by higher ratios between concentrations in the muscle and in the digestive gland that show an enrichment in this organ. Further studies are needed to evaluate the scale of the contamination by these metals and possible effects on the ecosystems.

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Table 1. Comparison of trace elements concentrations (μg/g dry wt) of dogfish liver DOLT-2 (NRCC), Orchard Leaves SRM 1571 (NBS) and fish-flesh homogenates MAA2 (IAEA) determined in the present study with certified values.

Standard	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	V	Zn
DOLT-2												
Present study	0.556±0.041	26.9±3.5	16.1±0.2	20.4±0.27	0.22±0.01	0.39±0.09	26.8±0.3	1072±17	6.26±0.11	0.24±0.04	-	86.3±1.2
Certified values	0.608±0.032	25.2±2.4	16.1± 1.1	20.8±0.05	0.24±0.05	0.37±0.08	25.8±1.1	1103±47	6.88±0.56	0.20±0.02	-	85.8±2.5
Orchard-Leaves												
Present study	-	-	-	0.13±0.02	(0.15)	(2.3)	12±1	290±15	85±6	1.5±0.1	(0.5)	25±1
Certified values	-	-	-	0.11±0.02	(0.2)	(2.3)	12±1	300±20	91±4	1.3±0.2	(0.6)	25±3
MA-A-2												
Present study	0.09±0.03	-	-	0.063±0.002	0.06±0.01	1.1±0.1	3.7±0.2	51±2	0.69±0.09	1.2±0.1	-	32±3
Certified values	0.10±0.01	-	-	0.066±0.004	0.08±0.01	1.3±0.1	4.0±0.1	54±1	0.81±0.04	1.1±0.2	-	33±1

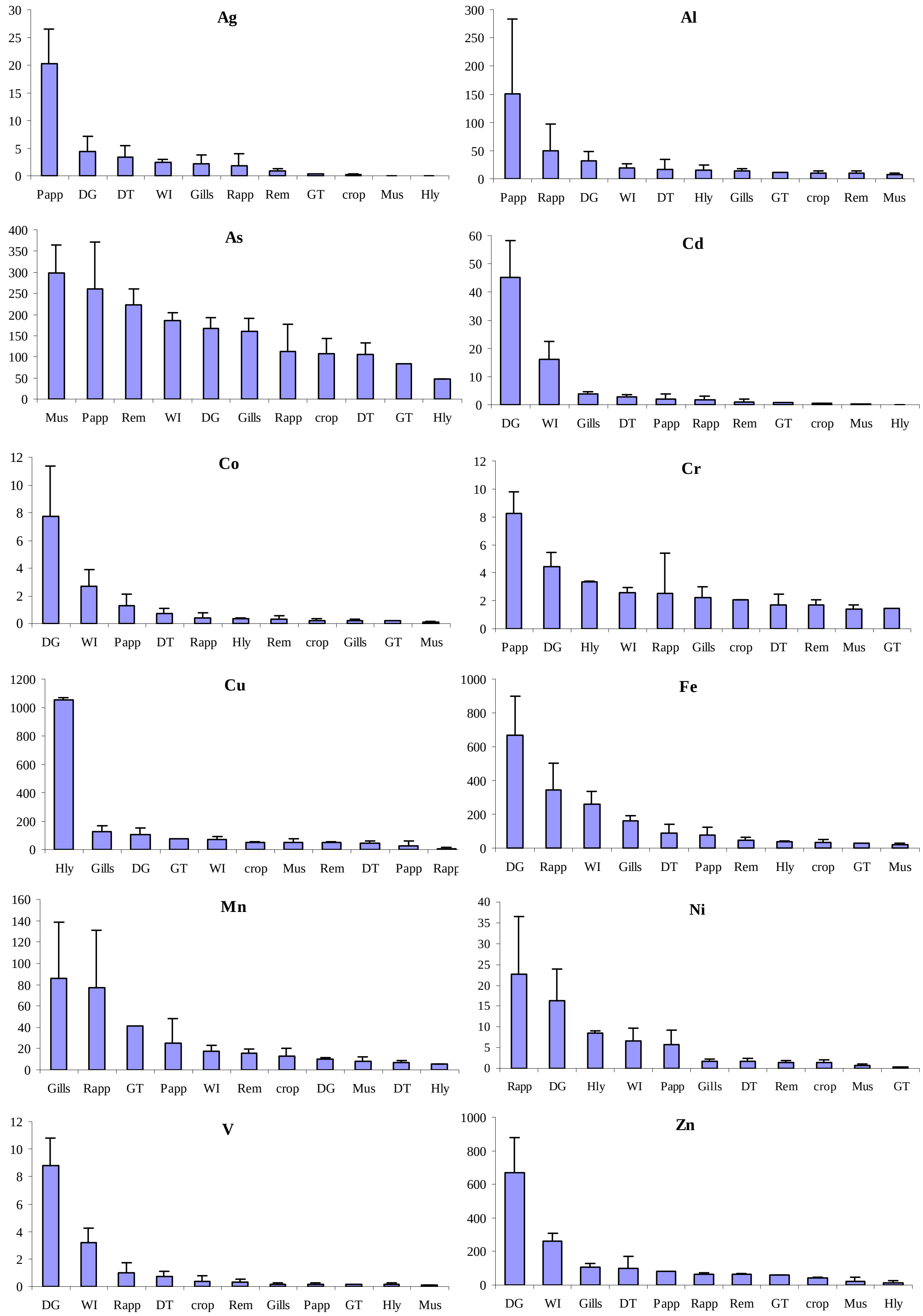

Figure 1. Trace elements concentrations (µg/g dry wt) in the tissues of *Nautilus macromphalus* from New Caledonia. Scale bars represent 1 standard deviation. DG: digestive gland; DT: digestive tract; GT: genital tract; Hly: hemolymph; Mus: muscle; Papp: pericardial appendages; Rapp: renal appendages; Rem: remainders; WI: whole individual.

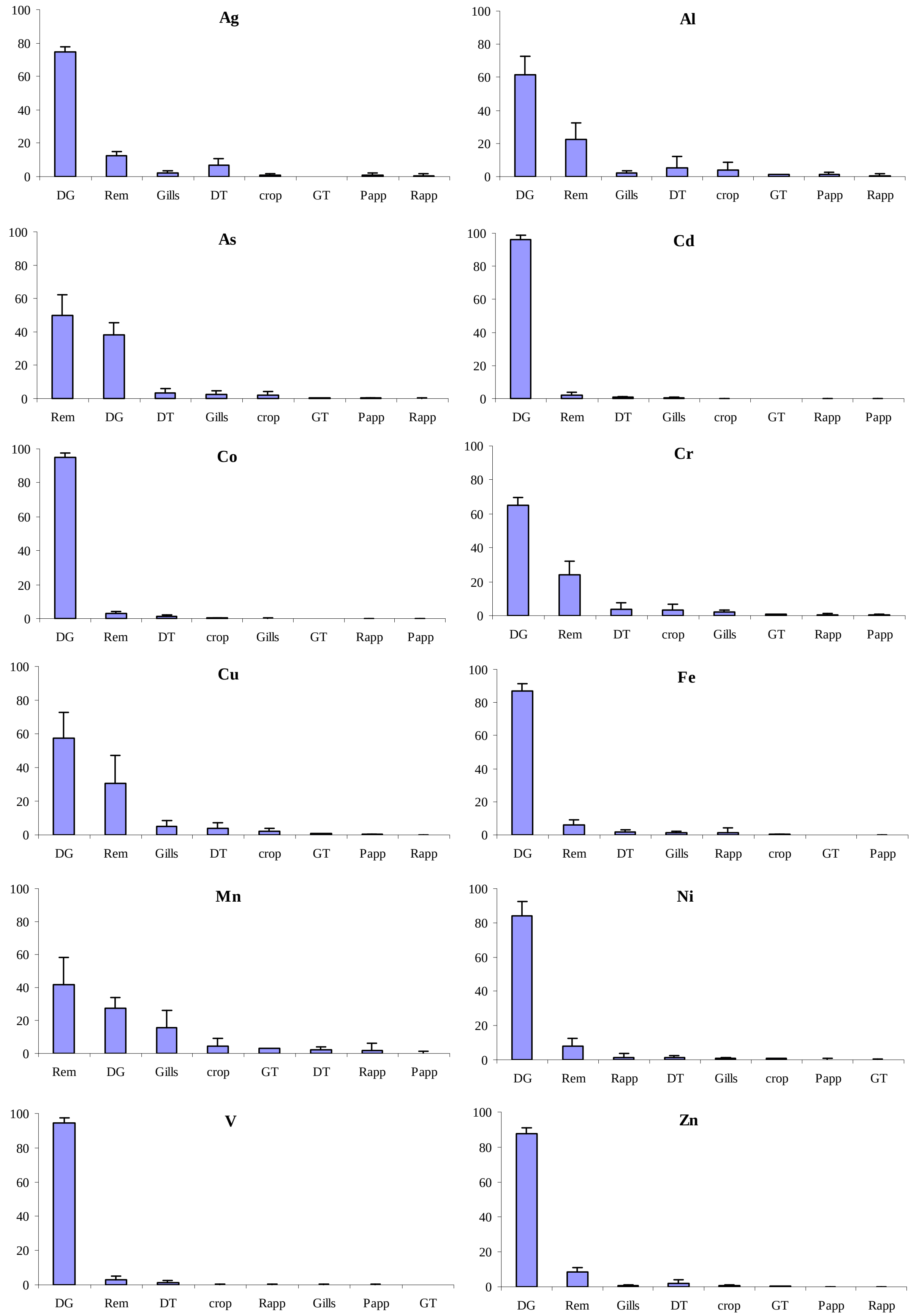

Figure 2. Percentages distribution of trace elements in the tissues of *Nautilus macromphalus* from New Caledonia. Scale bars represent 1 standard deviation. DG: digestive gland; DT: digestive tract; GT: genital tract; Hly: hemolymph; Papp: pericardial appendages; Rapp: renal appendages; Rem: remainders; WI: whole individual.

Table 2. Trace element concentrations (µg/g dry wt) in molluscs from this study and from the literature. Values are mean ± 1 SD, except from species marked * which are minimum and maximum values; * also indicates species from contaminated areas.

Class Species	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	V	Zn	Authors
Cephalopods													
Eledone cirrhosa	0.76 ± 0.48	-	-	5.36 ± 1.09	0.45 ± 0.09	0.6 ± 0.1	122 ± 11	81 ± 12	1.9 ± 0.5	0.8 ± 0.1	1.0 ± 0.2	234 ± 20	Miramand & Bentley (1992)
Nautilus macromphalus	2.4 ± 0.6	19 ± 7	186 ± 18	16.0 ± 6.5	2.7 ± 1.2	2.6 ± 0.3	73 ± 20	258 ± 79	17 ± 6	6.7 ± 3.0	3.2 ± 1.1	260 ± 49	Present study
Octopus vulgaris	-	-	-	1.2 ± 0.1	-	-	260 ± 70	140 ± 10	5 ± 0.5	-	0.7 ± 0.1	150 ± 50	Miramand & Guary (1980)
Sepia officinalis	0.66 ± 0.01	-	-	1.34 ± 0.03	0.39 ± 0.07	1.0 ± 0.1	59 ± 1	43 ± 4	1.6 ± 0.1	0.4 ± 0.1	0.7 ± 0.2	134 ± 6	Miramand & Bentley (1992)
Bivalves													
Cerastoderma edule *	0.11-6.5	-	-	0.48-1.04	1.28-2.93	1.34-2.46	5.2-27.2	406-991	6.2-44.6	34-62	-	46-66	Bryan & Hummerstone (1977)
Macoma balthica *	19-128	-	-	0.85-0.21	3.7-6.8	1.89-3.30	96-615	502-1540	19-24	6.9-7.9	-	510-1160	"
Mytilus edulis *	0.10-0.55	-	-	0.84-2.64	0.02-1.07	0.94-2.74	3.9-13.6	152-401	5.2-35.4	0.9-3.5	-	57-199	"
Pecten maximus	2.7	55	-	32.5	0.25 ± 0.09	1.3	8.9 ± 4.5	196 ± 83	107 ± 60	0.73 ± 0.25	-	273 ± 95	Bryan (1973)
Scrobicularia plana *	0.23-1.2	-	-	0.29-14.9	4.3-66	1.2-2.2	25-86	699-1240	19-87	3.4-11.9	-	353-2940	Bryan & Hummerstone (1978)
S. plana *	-	-	5-190	-	-	-	-	-	-	-	-	-	Langston (1980)
Gastropods													
Littorina littorea *	3.2-73	-	-	0.49-2.56	0.79-3.04	0.13-0.98	62-194	272-784	18-133	2.2-4.1	-	45-284	Bryan & Hummerstone (1977)
Patella vulgata *	1.5-6.0	-	-	3.3-21.5	0.24-1.56	0.48-2.62	10-27	891-2330	5.4-36.0	1.7-3.7	-	83-224	"

Table 3. Trace element concentrations (µg/g dry wt) determined in the digestive gland of cephalopods from this study and from the literature.

Species	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	V	Zn	Authors
Nautilus macromphalus	4.45±2.68	32.1±16.3	166±26	45.1±13.2	7.8±3.6	4.4±1.1	106±46	666±231	10.1±1.7	16.3±7.8	8.8±2.0	672±208	Present study
Sepia officinalis	6.15±1.75			12.67±0.35	3.27±0.6	1.1±0.1	315±3	244±28	3.3±0.1	1.3±0.4	5.0±1.3	571±47	Miramand & Bentley (1992)
Loligo opalescens	251.1±12.6			85.0±51.6			5350±3210	111±73				247±131	Martin & Flegal (1975)
L. opalescens	45.9±19.0			121.5±57.9			8370±3130	87±49				449±201	"
Nototodarus gouldi				33±30			363±238					830±355	Finger & Smith (1987)
N. gouldi	3.3±1.4	7.7±4.0		50±25			246±298	745±440	4.2±1.1			696±295	Smith et al. (1984)
Ommastrephes bartrami	12.1±8.6			287±202			195±212	399±204				163±55	Martin & Flegal (1975)
Stenoteuthis oualaniensis	24.1±10.9			782±255			1720±151	319±67				513±288	"
Eledone cirrhosa	3.20±1.74			24.00±1.75	2.06±0.0	0.8±0.1	456 ±11	287±13	4.2±1.6	2.5±0.1	3.3±0.5	646±86	Miramand & Bentley (1992)
Benthoctopus thielei				215			42					416	Bustamante et al. (1998a)
Graneledone sp.				369			1092					102	Bustamante et al. (1998a)
Octopus vulgaris							2550	1920					Ghiretti-Magaldi et al. (1958)
O. vulgaris				50±10			2500±700	700±130	7.0±0.5		4.5±1.0	1450±400	Miramand & Guary (1980)