Trace metals intake of *Nacella (P) magellanica* from the Beagle Channel, Tierra del Fuego (Patagonia, Argentina)

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Abstract: *Nacella* species and *Mytilus* species constitute a popular food in the Beagle Channel zone as both of them are well distributed in the area. With the aim to infer the daily intake of heavy metals through the consumption of these gastropod molluscs in the diet, more than one hundred individuals of *Nacella (P) magellanica* were sampled, separated in viscera and muscle, and then

examined with respect to the accumulation of different transition metals. Collection was performed in seven strategic locations along 170 km of the coastal area of the Beagle Channel (Tierra del Fuego, Argentina) in two campaigns during 2005 and 2007. In this study, the intake of the trace metals Cd, Cr, Cu, Ni, Pb and Zn by molluscs was calculated and evaluated in terms of the potential risks to human health derived from their consumption. Particularly, cadmium and lead presented more interest as they are non-essential and very well known toxic metals. Generally, the integrated evaluation of the results evidence that risks for humans seem unlikely for the regular consumption in the area. Further discussion will be provided on this issue.

Keywords: limpets; trace metal intake; Beagle Channel; Patagonia.

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1 Introduction

Gastropod mollusks (i.e. *Nacella* species) and bivalves (i.e. *Mytilus* species) are a popular food in the Beagle Channel (Tierra del Fuego, Argentina) zone as both of them are well distributed in the area. These species are also well established as biological monitors of seawater metal pollution at ecosystem level (Ahn et al., 2002; Conti et al., 2002; Conti et al., 2007). In fact, they meet the requisites for a good biomonitor that are: to be sedentary, easy identifiable, ubiquitous and they must have high concentration factors (CFs) (Conti et al., 2005; Deudero et al., 2009; Conti et al., 2010). These species are relevant to the economy of the Beagle Channel and they can contribute to dietary daily intake of several essential trace metals (i.e. Cu and Zn). Much attention has been paid on the safety of foods and in order to improve public health is necessary to control the content of toxic or potentially toxic trace elements such as Cd, Cr, Ni and Pb.

Cadmium is a non-essential element and it is highly toxic. The effects of acute poisoning in humans are of high significance and can affect blood pressure, kidney damage, destruction of red blood cells and testicular tissue (Manahan, 2000). Cadmium was classified as carcinogenic, Group I by IARC (IARC, 1993) and its half-life in contaminated renal cells is 15–30 years. Moreover, Cd and Zn are chemically similar. Thus, Cd can replace Zn in some enzymes altering their stereostructure and then its catalytic activity, causing some diseases (Manahan, 2000).

Gastropod molluscs have recently contributed to the more complete comprehension of bioaccumulation and ingestion by humans in Antarctic and marine Mediterranean areas (Ahn et al., 1999; Conti et al., 2007; Conti and Finoia, 2010). Bioaccumulation may not be toxic to one (or more) species, but may be an index of human exposure mostly when the species is known to be indigenous food as above reported. The limpet *Nacella (Patinigera) magellanica* (Gmelin, 1971) is well distributed in the Beagle Channel, it inhabits the middle and the upper intertidal zones and lives on rocky substrata of tidelands and tolerates fairly long periods of time outside of water. It eats algae and vegetable deposits that it scratches from the rocks. Moreover, it is important to underline that this herbivorous gastropod takes metals generally from the diet (Ahn et al., 2002; Conti et al., 2012b).

Thus, with the aim to infer the daily intake of heavy metals through the consumption of these gastropod molluscs in the diet, individuals of *Nacella (P) magellanica* were sampled, separated in viscera and muscle, and then examined with respect to the accumulation of different transition metals.

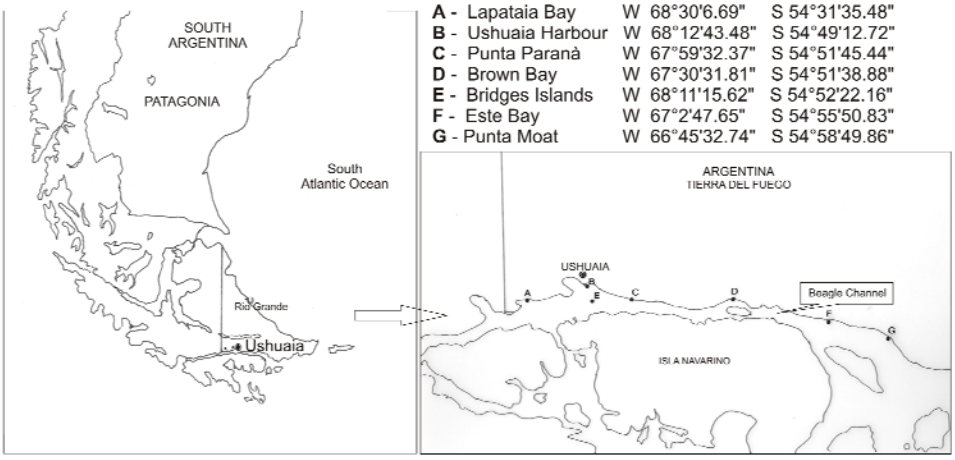
This study follows the first one recently published (Conti et al., 2012b) and conducted in the same area by using the same biomonitor in order to test its aptitude as biomonitor for baseline trace metals in the Beagle Channel.

2 Materials and methods

Tierra del Fuego has a typical ecosystem and it is characterised by a wide variety of wildlife and biodiversity (Conti et al., 2009; Conti et al., 2012a). Beagle Channel is a strait in Tierra del Fuego, near the southern tip of South America. The channel has high ecological relevance and is about 240 km long and between 5 km and 14 km wide. It

separates Isla Grande de Tierra del Fuego from several smaller islands in the south. The main urban settlement in Tierra del Fuego is the city of Ushuaia that is the southernmost city of the world with ca. 60,000 inhabitants. Ushuaia is the most important port for the Antarctic tourism and maritime traffic. Except for the case of Ushuaia Harbour, the six remaining sampling sites were carefully selected as examples of supposedly unpolluted areas along the Beagle Channel (Conti et al., 2011; Conti et al., 2012b). Collection was performed in seven strategic locations along 170 km of the coastal area of the Beagle Channel (Tierra del Fuego, Argentina) in two campaigns during 2005 and 2007 (Figure 1).

Figure 1 The Beagle Channel



Individuals of *Nacella (P) magellanica* (n = 175) were collected in the tidal zone at the same depth and distance from the shoreline in 2005 (n = 105) and 2007 (n = 70) sampling campaigns. The sampling campaign in 2005 was 15 individuals each site (15 × 7 = 105); and ten individuals each site (10 × 7 = 70) in 2007. Afterwards, they were depurated (t = 24 h) with filtered seawater from the same site of collection of samples. Shell lengths and weights of the samples were kept fairly constant in order to reduce variability due to size (Conti et al., 2012b). All individual samples were separated in muscle and viscera, placed in polyethylene bags, deep-frozen and transported to the laboratory. Soft parts were taken out of the shell using plastic tools (hammer and spatula) to prevent metal contamination, and then they were rinsed with deionised MilliQ water (DIW) to remove residues of shell (Conti et al., 2012b).

The meaning of the MW digestion methods in biological and environmental matrices was discussed elsewhere (Bocca et al., 2007; Pino et al., 2007). Samples of muscle and viscera (400–800 mg) were previously dried, homogenised and treated with 8 mL of 70% (w/w) nitric acid Suprapur (Merck) and 2 mL of 30% (w/w) hydrogen peroxide Suprapur (Merck) in PTFE vessels. A complete description of mineralisation, heavy metals' determination, results' traceability, limits of detection (LODs) and dry weight determination is reported elsewhere (Conti et al., 2012b).

3 Results and discussion

Table 1 shows mean metal concentrations in the two sampling campaigns (2005 and 2007) (μg g^{-1} dry weight) in muscle and viscera of *Nacella (P) magellanica*. From these results we can observe clearly higher metal bioaccumulation levels in viscera than muscle samples. This result agrees with previous studies conducted on *Nacella* species collected in Antarctic sites (De Moreno et al., 1997; Ahn et al., 2002). The mean metal concentrations determined in viscera samples in the two sampling campaigns decreased in the order: Zn > Cu > Cd > Ni > Cr > Pb. The higher metal levels determined in viscera than those in muscle indicate that accumulated metals are taken up mostly from diet (Ahn et al., 2002; Conti et al., 2012b).

Table 1 Mean metal concentrations in the two sampling campaigns (2005 and 2007) (μg g^{-1} d.w.) in muscle and viscera samples of *Nacella (P) magellanica* (mean ± SD) (Conti et al., 2012a)

	Cd	*Cr*	*Cu*	*Ni*	*Pb*	*Zn*
Muscle (n = 175)	3.97±2.45	0.20±0.28	<4.00	<0.30	<0.10	30.7±5.9
Viscera (n = 175)	8.22±4.01	3.16±2.29	15.16±8.45	7.63±4.07	1.23±1.57	96.2±25.4

Notes: Detection limits (LODs) (3σb, n = 10) were: Cd: 0.0001 mg L^{-1}; Cr: 0.0002 mg L^{-1}; Cu: 0.020 mg L^{-1}; Ni: 0.005 mg L^{-1}; Pb: 0.001 mg L^{-1} and Zn: 0.010 mg L^{-1}.

Cu, Ni and Pb were below detection limits in all the analysed muscle samples (Table 1). These findings agree with our preceding study which considered the Beagle Channel as a baseline ecosystem for these pollutants (Conti et al., 2011).

For the study of intake, all data were properly standardised by using 66% and 34% of mean weight for muscle and viscera in the whole tissue respectively (n = 70).

The established Cd weekly intake is 7 μg g^{-1} body weight (WHO/FAO, 1993). Thus, for an average adult (i.e. 65 kg) no more than 455 μg per week is recommended.

Considering the average concentration of Cd found in the Beagle Channel for *N. magellanica* samples (i.e. 5.42 μg g^{-1} whole tissue), the consumption of about 409 g (wet weight) of molluscs should be enough to reach the safety level. However, and taking into account the current consumption of *N. magellanica* in the zone, this quantity is hardly attainable.

For lead, the weekly intake level is 25 μg g^{-1} body weight (WHO/FAO, 1999), which means a weekly intake limit of 1625 μg for an average adult. The average standardised concentration of Pb in *N. magellanica* is 0.48 μg g^{-1} (whole tissue). By considering this value, it would be necessary to consume about 16.5 kg (w.w.) in order to reach the WHO/FAO limit (1999). Then, presently, for Cd and Pb, the health risks of *N. magellanica* consumers can be excluded.

Copper is essential for the development of connective tissue, nerve coverings, and skin pigment. The Recommended Dietary Allowances (RDAs) for copper is 0.90 mg/day for both men and women (Food and Nutrition Board, 2001). Considering that the standardised mean Cu levels obtained in *N. magellanica* in the Beagle Channel were 38.0 μg g^{-1} (wet weight), we can assume that eating a normal portion of 50 g (wet weight) of molluscs implies an intake of 1.90 mg of Cu that exceeds the RDAs.

Zinc is linked with more than 100 specific enzymes and has high relevance in protein function and gene expression. The Recommended Daily Intake (RDI) (FAO/WHO, 2002) for Zn in the adult population with moderate bioavailability of Zn in the diet is 7.0 mg/day and 4.9 mg/day for men and women, respectively. Considering that the standardised mean Zn levels found in this study were 258.4 μg g^{-1} w.w., we can infer that eating 50 g w.w. of molluscs implies an intake of 12.9 mg of Zn that is much higher than the RDI level established by FAO/WHO. These results confirm the nutritional relevance of these molluscs for the intake of essential metals such as Cu and Zn.

Chromium stimulates insulin action in the body. Due to a lack of information about the dose response relationship between Cr and insulin response it was not possible, at present, to establish its daily intake (Food and Nutrition Board, 2001). However, for comparison, our mean standardised Cr levels (5.90 μg g^{-1} w.w.) found in this study were much lower than the threshold tolerance limit established by USFDA (1993) (i.e. 13.0 μg g^{-1} dry weight) for shellfish.

Dietary nickel seems not to be toxic to man, even cancer of the respiratory tract and dermatitis were observed in nickel refineries' workers (Reilly, 1991). Presently, based on adverse effects observed in animal studies, tolerable upper intake levels (ULs) were set at 1 milligram per day (Food and Nutrition Board, 2001). Since the mean Ni levels in *N. magellanica* found here were 13.6 μg g^{-1} wet weight, it can be inferred that the contribution of gastropods to Ni intake is quite low (i.e. 0.68 mg) for a 50 g consumption.

4 Conclusions

Our studies revealed that Cd and Pb levels are below the tolerance levels for human consumption assuming a daily intake of 50 g (wet weight). Regarding chromium, the mean standardised levels found in this study were much lower than the threshold tolerance limit established for shellfish by USFDA. For Cu, eating a normal portion of 50 g (w.w.) of molluscs implies an intake of Cu that barely exceeds the Recommended Dietary Allowance (RDA); for Zn eating 50 g (w.w.) of molluscs implies an intake that exceeds the Recommended Daily Intake (RDI) level established by FAO/WHO (2002). No harm was noticed regarding nickel intake as it resulted quite below according to the tolerable upper intake levels (ULs) established by the Food and Nutrition Board (2001).

Eventually, the integrated evaluation of the results indicates that risks for humans seem unlikely for the regular consumption in the area.

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