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Original Articles

Mustelids as bioindicators of the environmental contamination by heavy metals

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ABSTRACT

Cadmium (Cd), lead (Pb), zinc (Zn) and copper (Cu) concentrations in the liver and the quadriceps muscle of adult stone marten (9 specimens) and pine marten (11 specimens) from Central Italy were assessed. No significant difference in the heavy metal values for each of the two selected tissues was detected for the two mustelid species. The measured heavy metal values were generally below the contamination level ranges from other areas of Central Italy and Croatia, except for the Cd in this latter area. Toxic Contamination Index (TCI) values for Cd showed high contamination levels both in the stone marten (most synanthropic species, colonizing mainly suburban environments) and in pine marten (species less adaptable to the anthropic environments, colonizing mainly rural and forest environments). High TCI values for Pb were detected only in stone marten. This fact indicates a higher Pb contamination in suburban habitats, probably due to the past use of leaded gasoline and still currently released by several anthropogenic activities, as the industrial emissions of mineral processing and incinerators, making Pb one of the most common heavy metal contaminant in soils. The present study suggests that stone marten and pine marten can be good bioindicators with a complementary role regarding the evaluation of the heavy metal contamination in a given territory. When high levels of TCI (in our case for Cd) are detectable in selected tissues of both stone marten and pine marten, it means that we are in the presence of widespread pollution. On the other hand, when this condition is observed only for stone marten (in our case for Pb), it means that we are in the presence of a local contamination mainly localized in areas with high anthropization.

1. Introduction

The heavy metal contamination is one of the significant environmental issues that affect the ecosystems health and consequently the human health (Järup, 2003; Wuana and Okieimen, 2011; Gall et al., 2015). The heavy metals sources are due both to natural sources and anthropogenic emission activities of industrial, agricultural and zootechnical origin. Some metals, such as copper (Cu) and zinc (Zn) are essential elements with metabolic functions (i.e., micronutrients) resulting toxic only at high doses. Other metals, such as mercury (Hg), cadmium (Cd) and lead (Pb), are considered non-essential elements, being toxic even in traces (Keil et al., 2011; Ferrari, 2012; Boyd and Rajakaruna, 2013; ATSDR, 2017). Hg in the form of methylmercury (biomethylation processes), differently from Pb and Cd, shows biomagnification processes; however, all the metals are bioaccumulated in selected tissues of the biota (Gall et al., 2015).

Studies on the relationship between biota and heavy metal contamination in freshwater environments are many more (De Jonge et al., 2008; Zhou et al., 2008; Liu et al., 2009; Di Veroli et al., 2012a, 2014; Pallottini et al., 2015, 2017a,b) if compared to terrestrial environments. Furthermore, the choice of suitable terrestrial indicators is more problematic; since many species occupy vast territories and peculiar terrestrial habitats as forests it is difficult to relate them with pollution sources that are usually present in anthropized environments (Dip et al., 2001).

The heavy metal food chain contamination leads to a significant impact on the terrestrial ecosystems wildlife, in particular on the wild animal populations health. This condition reflects especially on the carnivorous mammals that are at the top of the food web, and therefore they are more subject to the metal bioaccumulation processes (Bilandžić et al., 2010; Garcia et al., 2011).

Different mustelids have been used in various biomonitoring studies

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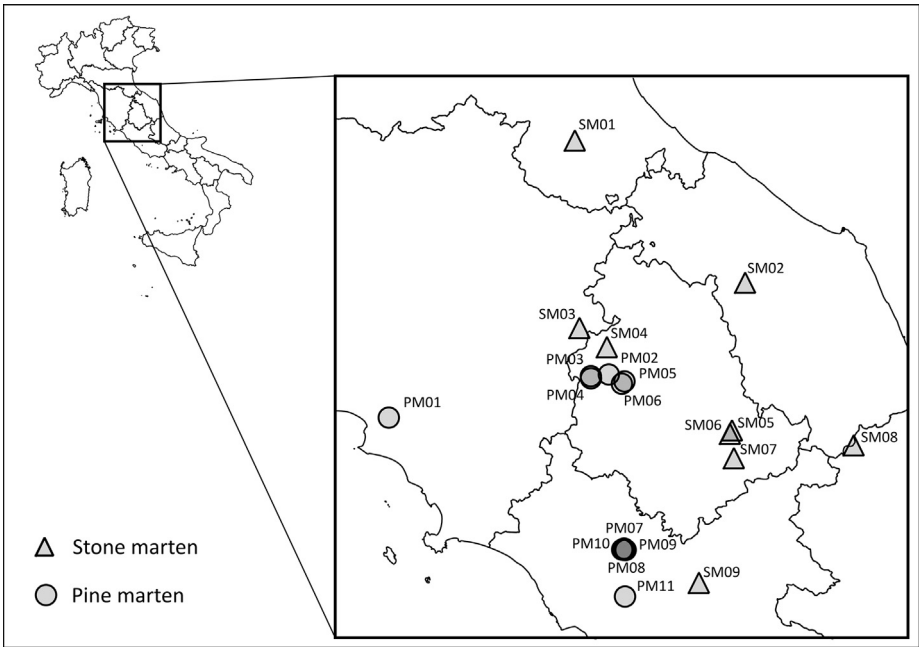

Fig. 1. Location of the nine stone marten *(Martes foina*) and eleven pine marten (*Martes martes*) adult specimens from Central Italy.

on the heavy metal pollution in terrestrial ecosystems, including suburban, rural and forestal habitats (Alleva et al., 2006; Millàn et al., 2008; Kalisińska et al., 2009, 2016; Bilandžić et al., 2010, 2012; Lodenius et al., 2014). In aquatic ecosystem, in particular piscivorous carnivores as Eurasian otter and American mink were used (Gutleb et al., 1998; Mason and Stephenson, 2001; Harding, 2004; Lake et al., 2007; Strom, 2008; Lanszki et al., 2009; Lemarchand et al., 2010; Mayack, 2012; Ramos-Rosas et al., 2013; Kang et al., 2015; Kalisińska et al., 2016).

The current study considered as bioindicators of heavy metal bioaccumulation two of the most used mustelid species of terrestrial habitat: stone marten, *Martes foina* (Erxleben, 1777) and pine marten, *Martes martes* (Linnaeus, 1758). The diet of both species depends on local conditions and seasonality, but it consists primarily of small mammals (mainly rodents), birds, invertebrates (mostly insects) and berries (Jędrzejewski and Jędrzejewska, 1993; Pulliainen and Ollinmäki 1996; Helldin, 2000; Sidorovich et al., 2010).

Martes martes has a wide range related to areas with mature forests. It is an uncommon species, very elusive, nocturnal, territorial and it is less adaptable to anthropogenic environmental modifications respect to the stone marten; it tends to avoid human settlements (Genovesi and De Marinis, 2003). *Martes foina* has a wide range and frequents a wide variety of habitats, from forest to rural areas up to anthropized environments. Among the carnivores, it is one of the most ecologically adaptable and flexible species (Serafini and Lovari, 1993; Genovesi and De Marinis, 2003; Bakaloudis et al., 2012; Balestrieri et al., 2013; Papakosta et al., 2014). Both species are evaluated by the International Union for Conservation of Nature (IUCN) at the level of Least Concern (LC).

The use of these two mustelid species for biomonitoring purposes is motivated by different reasons. They occupy small territories (daily ranges and annual home range are on average about 0.5 km^2 and 2 km^2, respectively) (López-Martín et al., 1992; Zalewski et al., 2004) and have a long biological cycle (about 10 years) (Genovesi and De Marinis, 2003). Moreover, they are relatively abundant in the area they hold (Vercillo, 2005). Therefore their populations are influenced by local pollution (Alleva et al., 2006; Bilandžić et al., 2010, 2012; Kalisińska et al., 2016). Heavy metals bioaccumulation tends to reflect the different eating habits of the considered species, and the colonization of more or less anthropized environments shows a close relationship between contaminants and trophic levels (Mann et al., 2011). The metabolic capacity is species-specific and, within each population, is also influenced by sex, age and seasonality (Hyvärinen et al., 2003; Lanszki et al., 2009; Garcia et al., 2011). In short, stone marten adapts to a variety of environmental conditions, also living in urbanized areas (more ubiquitous species), while pine marten instead prefers rural habitats (more specialist species).

The present study aims to characterize the heavy metals bioaccumulation in selected tissues (liver and quadriceps muscle) of two mustelid species, stone marten and pine marten, used as bioindicators of the heavy metal contamination of a territory through the application of a toxic contamination index. In the present study we apply the Toxic Contamination Index (TCI), firstly developed for freshwater environments through the use of crayfish (Goretti et al., 2016), adapting it to terrestrial environments through the use of mustelid species.

2. Materials and methods

2.1. Sampling campaign

Nine stone marten and eleven pine marten adult specimens were collected between 2001 and 2016, from six regions of Central Italy (Abruzzo, Emilia-Romagna, Lazio, Marches, Tuscany, and Umbria). All pine marten specimens came from the central-western sector of this geographic area; this is related to this species range in Central Italy. Quite surprisingly, all the stone marten specimens came from the central-eastern sector of this area, although their range is supposed to cover the whole Central Italy. However, it is known that in Italy stone marten prefers to colonize territories where the competition with pine marten is low (Vercillo, 2005).

All the animals were found dead, road killed. Stone marten specimens were coded as SM, from 01 to 09; pine martens were coded as PM, from 01 to 11 (Fig. 1). For each specimen sex, weight, region and year of the collection were recorded (Table 1). The corpses were preserved frozen at -20° C. During the necropsy liver and part of the quadriceps muscle tissue were collected, preserved in 90% alcohol and frozen at -20° C for heavy metals analysis; the gastrointestinal content was obtained to define the alimentary behavior.