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Predation by invasive mammals on an insular viviparous population of *Salamandra salamandra*

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Non-native, invasive species are considered to be the second greatest driver of human-caused species extinctions worldwide (Grosholz, 2005; Sax and Gaines, 2008). On islands, particularly invasive mammal species have caused population declines and extinctions of native species (Mooney and Cleland, 2001; Burbidge and Manly, 2002; Blackburn et al., 2004; Jones et al., 2008) and are often regarded as the most important threats to native biota.

Here we report the predation by invasive mammals on adults of an insular viviparous *Salamandra salamandra gallaica* population located near the Atlantic coast of Galicia (NW Iberia, Fig. 1). The island of San Martiño is included in the Atlantic Island National Park, which encompasses four small archipelagos located along the south-western Galician coast. These islands originated when sea levels arose after the last glacial period approximately 8000 years ago (Dias et al., 2000). Within this National Park, *S. salamandra* populations occur on two small continental islands: Ons Island (428 ha; length 5 km; width: 1.2 km) and San Martiño Island (146 ha; length 2.3 km; width: 1 km). These islands are separated 3.6 and 6 km from the mainland, respectively, and 12 km from each other.

The common reproductive mode in *S. salamandra* is ovoviviparity throughout its wide distribution range (from the Iberian Peninsula to Ukraine and Greece), although viviparity occurs in northern Iberian populations of *S. s. bernardezi* and *S. s. fastuosa* (Alcobendas, Dopazo and Alberch, 1996; García-París et al., 2003), and two island populations of *S. s. gallaica*. Within a phylogenetic study including viviparous and ovoviviparous populations Velo-Antón et al. (2007)

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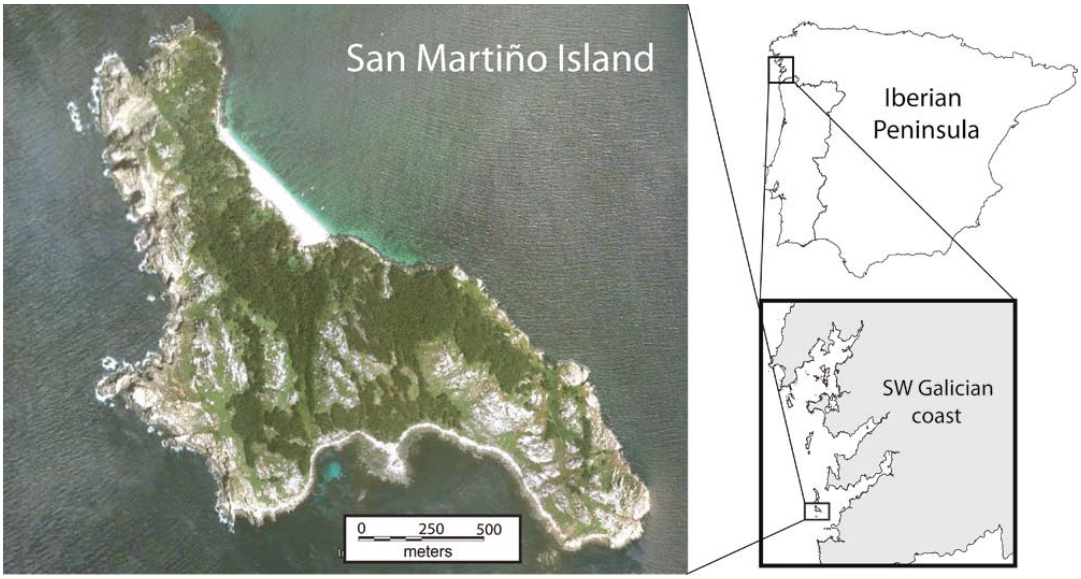


Figure 1. San Martiño island (146 ha) at the NW Iberian coast. This island harbours one of the two *S. salamandra* populations within the Galician Atlantic Island National Park. Picture taken from Google Earth.



Figure 2. Example of a salamander carcass found on San Martiño island. The carcass is half eaten (head and fore limbs) by predators, discarding tail and hind limbs. Note a mink excrement next to the carcass. (1B): Snail feeding on a salamander carcass. (1C): Example of a salamander plasticine model (above) next to a live salamander (below) in San Martiño island. Note that color morph in *S. s. gallaica* is highly variable and models were painted following that variability. (1D): Two rodent incisor marks on a salamander plasticine model.

showed that insular *S. s. gallaica* populations have independently evolved to viviparity. Consequently, these populations have a great conservation value and need to be protected from threats, such as invasive species.

Potential autochthonous predators of *S. salamandra* in San Martiño Island include the Northern goshawk (*Accipiter gentilis*), the Common buzzard (*Buteo buteo*) and the Viperine snake (*Natrix maura*). Furthermore, this small island harbours two non-native invasive mammal species: the Black rat (*Rattus rattus*) and the American mink (*Neovison vison*), which may be potential predators of *S. salamandra* similar to the European mink, *Mustela lutreola* (Montori and Herrero, 2004). The invasion of these mammals onto the islands of the National Park differs in time. Whereas *R. rattus* probably invaded these islands with sailors hundreds or few thousands of years ago and has occurred in sympatry with *S. salamandra* populations, *N. vison* has invaded the islands during the last decades due to accidental and intentional mink releases from mainland fur farms. The most recent and probably the most devastating event occurred in October 2009: approximately 14,000 minks were deliberately released from three fur farms in Abegondo, NW Iberia (ca. 100 km from the Atlantic Island National Park; Mouzo 2009). Subsequently, these minks spread throughout the mainland causing severe damage to general wildlife, while some managed to cross the 3-6 km sea barrier and colonised the islands along the NW Iberian coast. Predation by minks on seabirds, such as the European shag (*Phalacrocorax aristotelis*), was rapidly observed and documented within the Atlantic Island National Park (Álvarez, Munilla and Velando, 2009). Currently, the number of *R. rattus* in San Martiño Island is high, given the abundance of their excrements throughout the island and the easiness to observe active rats during our nocturnal field surveys, in addition to continuous observations by the only inhabitant on the island. *Neovison vison* however reached this island during the last years, and despite the fact that its population seems to increase and is spreading throughout the island, the population density is lower than observed in *R. rattus*.

We surveyed San Martiño Island since 2004 (March – April), and searched for salamanders during diurnal

and nocturnal sampling. During our last surveys (March 2010 and 2011) we found 4 and 1 carcasses of *S. salamandra* respectively. All carcasses were half eaten (head and fore limbs) by predators, discarding tail and hind limbs (Fig. 2A). Curiously, we also found a snail feeding on a salamander carcass (Fig. 2B). In order to assess which animals fed on salamanders carcasses found on this island, we made 50 salamander models by pouring melted, non toxic, black VanAken Modeling Clay in a silicone mold. We also made 30 round plasticine models to assess whether or not predators only attack salamander models. Salamander models were 120 mm total length and were painted to resemble *S. s. gallaica* (Fig. 2C). We spread these models across San Martiño Island in our 2010 and 2011 surveys (round models were used only in 2011).

All salamander models attacked had rodent incisor marks (Fig. 2D) and none had bird or mink marks, suggesting that only *R. rattus* attacked and likely prey on salamanders. None round models were attacked. However, it is not clear to us whether the salamander carcasses found in this island were attacked solely by rats. In fact, we found a mink excrement next to one of the salamander carcasses in our last visit to the island (Fig. 2A), which could also mean territorial marking. In addition, three minks captured on San Martiño Island were brought to a Recovery Center in the mainland and dissected searching for evidence of salamander predation by minks. None of them had salamander's bone or skin within the digestive tract. Clearly, video surveillance will allow determining whether rats and/or minks prey on *S. salamandra* so it will be performed in future visits to San Martiño Island.

Introduced rats and minks are now being eradicated from the island by researchers studying these invasive mammals and the staff of the National Park, by means of using traps. However, eradication remains challenging due to logistic problems regarding the accessibility to San Martiño Island in combination with steep topography, lack of paths and abundant spiny shrubs (*Ulex europeaus*, *Rubus fruticosus*) which form impenetrable thickets throughout most part of the island. Thus, many rats and minks still remain on the island.

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