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Forest management and conservation of an elusive amphibian in the Alps: Habitat selection by the Golden Alpine Salamander reveals the importance of fine woody debris

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This paper is dedicated to the memory of Enrico Romanazzi, beloved friend and colleague who contributed greatly to the pioneering studies on this salamander.

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ABSTRACT

Amphibians are declining worldwide and one of the major causes of such decline is habitat loss. Forestry practices have a primary role in causing habitat loss and fragmentation, detrimental to amphibians. We studied the ecological requirements of a fully terrestrial and threatened amphibian, the Golden Alpine Salamander *Salamandra atra aurorae,* which is endemic to a small portion of the Italian Alps. This rare and elusive salamander lives exclusively in forest environments and forestry practices are considered among its major threats. We employed both a capture-mark-recapture (CMR) and an occupancy approach in fifty 400 m^2 plots, within a managed mixed forest dominated by Norway spruce and to a lesser extent beech, and silver fir. Modelling salamander occupancy as a function of site-specific habitat features allowed us to understand the ecological requirements of this salamander and provide precise guidelines for forest management. The application of hierarchical models (occupancy) for evaluating forest management plans is highly effective, requires less effort and is a less impacting methodology than CMR performed by searching for salamanders under shelters also in non-optimal weather conditions. Distance from open pasture edges significantly affects the distribution of salamanders while, at a smaller scale, brushwood piles, classified as fine woody debris (FWD, diameter from 1 to 10 cm), play a key role in providing suitable habitat for this endangered amphibian. The importance of FWD in the conservation of small vertebrates is generally poorly studied and probably underestimated. However, our results show that FWD should be considered as an additional element that has to be managed to enhance habitat suitability for this and, intuitively, for other small forest vertebrates.

1. Introduction

Anthropogenic causes, especially habitat change and degradation, are the main factors resulting in global biodiversity loss (Newbold et al., 2015). Populations trends and species extinction in amphibians suggest their systematic and dramatic decline worldwide, making them the most endangered class of vertebrates (Stuart et al. 2004; Leung et al., 2017). Amphibian populations are declining, even in temperate regions, such as North America and Europe where stringent environmental regulations are usually implemented (Leung et al., 2017). Among the human activities resulting in habitat fragmentation, modification and loss, unsustainable forestry may alter the habitats both at a global (Carlson & Groot, 1997) and fine scale level (Riffell et al., 2011). Although most amphibian species have biphasic lifestyles (i.e., aquatic larvae and terrestrial adults), several of them are completely terrestrial and associated to forest environments. Therefore, protection and sustainable management of woodlands is the only way to preserve amphibian populations of these fully terrestrial species.

In particular, terrestrial salamanders are highly constrained to a narrow range of environmental conditions due to their physiological requirements (Feder, 1983; Peterman & Semlitsch, 2014). Moreover, they exhibit limited spatial movements (see Table 8.1 and related references in Vitt & Caldwell, 2013) and they are highly sensitive to small-scale variation in soil moisture and shelter availability (deMaynadier, 1995; Popescu & Hunter, 2011; Peterman & Semlitsch, 2013). However, many management plans with multiple aims (e.g.

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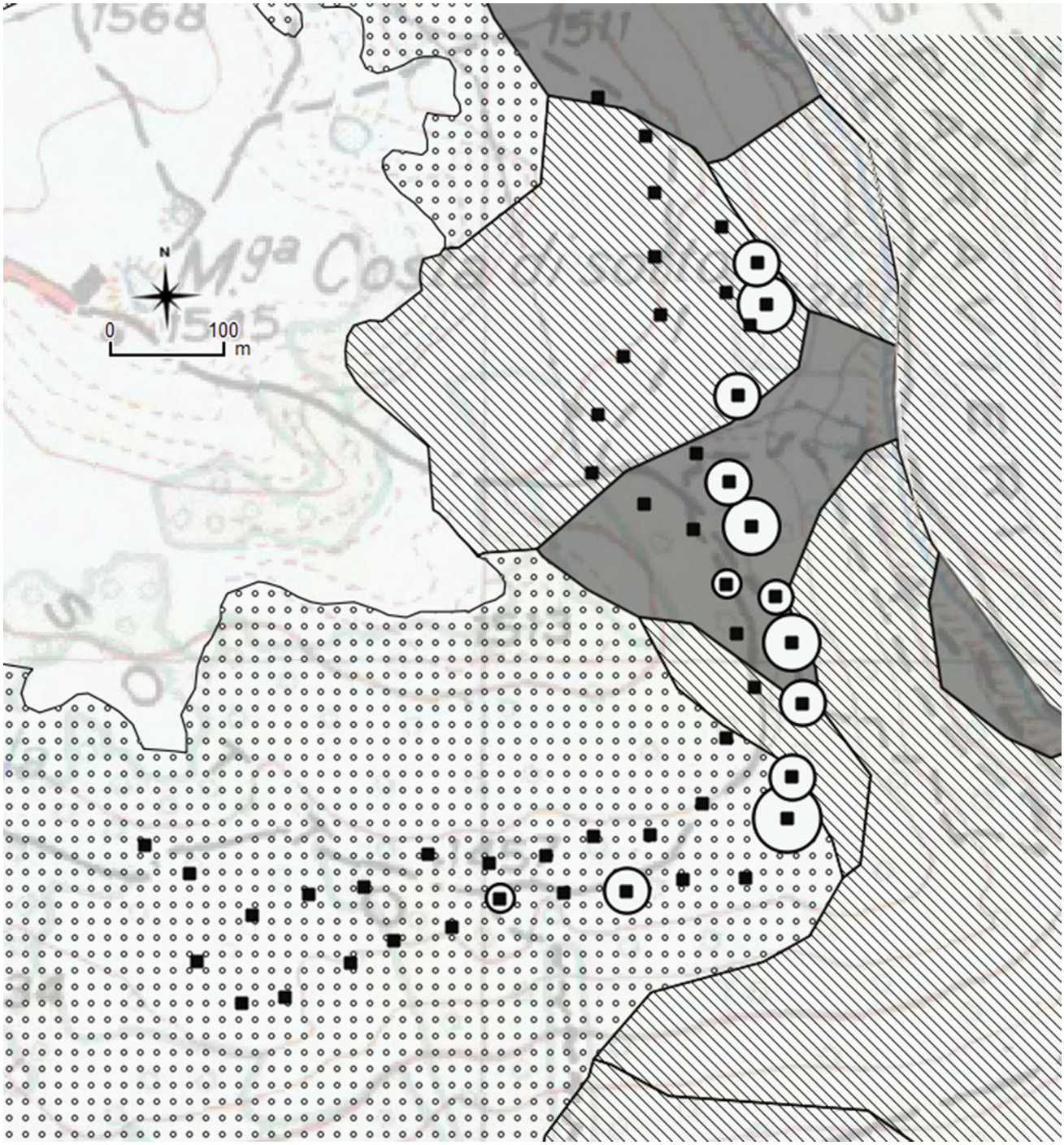

Fig. 1. Spatial distribution of sampling sites (black squares) of Golden Alpine Salamander on the Vezzena plateau (Northern Italy). Abundance of salamanders (from 1 to 6 records) in each plot is proportional to the size of white circles. Dotted area: Norway spruce; grey area: Silver fir; shaded area: Beech and Silver fir; blank area: open pasture.

forest productivity and biodiversity conservation) provide information and guidelines only at the landscape level (Trombulak & Baldwin, 2010; Connette & Semlitsch, 2013; Clauzel et al., 2014). At smaller scales, the best studied aspect linking herpetofauna conservation and forest management is the retention of deadwood in harvested areas (see Otto et al., 2013 and references therein). When appropriate forest management strategies are set up to target terrestrial amphibians, knowledge of their ecological features is a prerequisite. A common issue with such species is that they are often difficult to detect. Detection plays a key role in determining the presence or (supposed) absence of a species at a site. However, site occupancy models accounting for imperfect detection (MacKenzie et al., 2017) allow estimates of the occupancy parameter (i.e. the probability that a species is present at a site).

Recently, site occupancy models applied at small spatial scales have provided useful information for conservation and management of forest salamanders (Basile et al., 2017; Romano et al., 2017). We applied this approach to a fully terrestrial and endangered salamander strictly associated to alpine forest habitats, the Golden Alpine salamander *Salamandra atra aurorae* Trevisan, 1982. The study area has been subject in recent decades to forestry exploitation. Our aim was to gain insight into the ecological requirements of this endangered salamander, in order to provide the first practical guidelines for its conservation in managed