



Short-term effect of forest liming on eastern red-backed salamander (*Plethodon cinereus*)



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ABSTRACT

Liming, the application of calcitic materials to soil, is increasingly used in acidic, base-poor sugar maple stands of eastern North America to restore nutritional status and vigor of sugar maple trees. However, few studies have evaluated the effect of base cation addition on other components of these ecosystems. The eastern red-backed salamander (*Plethodon cinereus*) is one of the most abundant vertebrates in forests of eastern North America, and is commonly used as an indicator of forest disturbances. So, it is important to know how it might be affected by soil liming. This is the first study dealing with the potential direct and short-term effect of liming on amphibians of North America.

Lime, in the form of CaCO_3 (3 Mg ha^{-1}), was added at the surface of microcosms containing a low buffered soil and forest floor from a sugar maple stand to evaluate the short-term effect of this treatment on this amphibian species. Two grades of lime were used in this study: finely ground and sandy CaCO_3 . Finely powdered lime was included to verify if it could clog salamander skin pores, since this could negatively affect health and growth, and consequently induce mortality. The results suggest that, even when applied in finely ground form, direct contact with lime had no short-term effect on the species' health and survival rate. Given this, and the fact that it can be found in a wide range of soil pH conditions, the red-backed salamander is thus unlikely to be affected by the use of liming to restore acidic, base-poor sugar maple bushes. Some old liming trials carried out in forests of eastern North America could be used in the next years to verify the long-term effects of liming on this species. This should help foresters decide whether or not liming treatments are compatible with conservation, ecological and management objectives.

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1. Introduction

Base cation addition, such as liming, is increasingly used in acidic, base-poor sugar maple (*Acer saccharum* Marsh.) stands of eastern North America to restore nutritional status and vigor of sugar maple trees (Long et al., 2011; Moore et al., 2012). However, few studies have evaluated the effect of base cation addition on faunal components of these ecosystems (Seagle and Curd, 1995; Pabian and Brittingham, 2007; Skeldon et al., 2007; Pabian et al., 2012). Such studies are important to evaluate liming treatments with respect to forest sustainability objectives. Catchment liming has also been used in many European countries to mitigate the effect of acid deposition on aquatic and terrestrial ecosystems (Smallidge et al., 1993; Clair and Hindar, 2005). However, very few studies in Europe have evaluated the effect of this treatment on amphibians (Bellemakers and van Dam, 1992; Beattie and

Tyler-Jones, 1992; Beattie et al., 1993), and none have done so on salamanders.

The eastern red-backed salamander (*Plethodon cinereus*) is one of the most widely distributed and abundant vertebrate species in forests of eastern North America (Burton and Likens, 1975; Petranka, 1998). The ecological importance of this species has been extensively studied over the years (e.g.: Burton and Likens, 1975; Wyman, 1998; Maerz et al., 2005). The red-backed salamander is terrestrial, ectothermic and lungless, relying mainly on its skin for respiration and hydration. As a result, it may be affected by changes in microhabitat (Feder and Pough, 1975; Bobka et al., 1981; Homyack et al., 2011). In Maryland, Seagle and Curd (1995) reported no negative effect of liming on the eastern red-backed salamander, 2 years after limestone application. However, their work should be considered as an exploratory investigation, given the few specimens sampled ($n = 46$) and the absence of replication of limed watersheds. Moreover, they did not document the possible effects of lime coming directly in contact with the animals' skin.

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The objective of this study was to evaluate the short-term and direct effect on the red-backed salamander of two grades of lime commonly used in sugarbushes, in the form of finely ground or sandy CaCO_3 . Finely powdered lime was used in one of the treatments to verify if it could clog salamander skin pores, since this could negatively affect health and growth, and consequently induce mortality.

2. Materials and methods

2.1. Site description

The experiment was performed at the Lake Clair Watershed Experimental Forest (46°57'N, 71°40'W), located approximately 50 km northwest of Quebec City (Quebec, Canada). In this area, elevation ranges from 270 to 390 m, average slope is approximately 10%, and mean annual temperature and annual precipitation (1971–2000) are 4.3 °C and 1200 mm, respectively. During the study period, monthly mean temperatures (11 °C from May 21 to 31, and 15, 18, 17 and 12 °C from June to September, respectively) and precipitations (131 mm from May 21 to 31, and 137, 105, 123 and 112 mm from June to September, respectively) generally compared well with monthly averages observed from 2000 to 2013, except in May 2013 where precipitations were higher than normal.

Forest stands are mainly uneven-aged and dominated by sugar maple in association with yellow birch (*Betula alleghaniensis* Britt.) and American beech (*Fagus grandifolia* Ehrh.). According to the Canadian System of Soil Classification (Soil Classification Working Group, 1998), the soil is a well-drained, stony, sandy loam Orthic Ferro-Humic Podzol. The humus is 8 cm thick and of a mor to moder type. The humus and soil are extremely acid, with pH ranging from 3.0 to 3.2 in the forest floor and from 3.8 to 4.1 in the upper 15 cm of the mineral soil (Houle et al., 2002). The parent material is a stony glacial till, originating from the regional bedrock consisting of granite, gneiss and syenite.

2.2. Experimental design

The experimental design was a completely randomized experiment consisting of 50 microcosms distributed under the closed canopy over an area of approximately 300 m². Three treatments were tested: a control ($N = 16$), powdered lime ($N = 17$), and sandy lime ($N = 17$). Each microcosm consisted of a simple plastic pail (29 cm inside diameter, 45 cm depth, 20 L capacity) fitted with a tight cover. Holes were made at the base of the pail and in the cover to permit heat, water, and gas exchange with the surrounding soil, and a 0.5-mm mesh plastic screen was glued at the base of the pail and placed on its cover to preclude predation and salamander escape.

In early May 2013, soil was excavated down to 40 cm and reconstituted in each microcosm. Coarse roots and stones were removed from the soil. The soil in the microcosm was placed at the same height as before the excavation, but the top 8 cm of the pail exceeded the forest floor surface. Uniformly-sized pieces of sugar maple bark were placed in each microcosm to mimic natural shelter for salamanders in this area (Moore, 2010) and to facilitate their observation.

On May 21, 50 salamanders (adults and juveniles) were collected in the vicinity of the experiment. To avoid affecting salamanders by too many manipulations, salamanders were only weighed (with a digital balance) at the beginning and at the end of the experiment, 5 months later. Mean initial weight of *P. cinereus* was 0.7 g (± 0.2 g; total range 0.3–1.2 g), which is similar to values observed by Moore and Wyman (2010) who observed this species over a 5-year period in the same area. This suggests that the

salamanders used were representative of the population in this area. One salamander was placed in each microcosm a few minutes after its capture.

One week after introducing salamanders, the two CaCO_3 treatments were randomly applied by hand at the surface of the microcosms, at a rate of 3 Mg ha⁻¹ (Fig. 1). CaCO_3 is known to dissolve relatively rapidly under acid conditions, particularly for small particle sizes like those used in this experiment (Warfvinge and Sverdrup, 1989). The dose used in this study is considered as an optimal value for sugar maple in Québec (Moore et al., 2012) and is currently applied at an operational scale on acidic, base-poor sugar maple stands. Untreated microcosms served as controls. The screened plastic cover was tightly placed on the top of each pail. Throughfall precipitation could freely enter the pails. Salamanders were checked (presence/absence) and fed with 8 live ants every two weeks. They were released in the forest at the end of the experiment.

All protocols for this experiment were approved by provincial authorities (Minister of Sustainable Development, Environment, Wildlife and Parks, permit no. 2013040500703SF).

2.3. Statistical analyses

An ANCOVA was performed on final body weight of salamanders, with initial weight as a covariate. No random effects were included in the model. The analysis was performed using the SAS MIXED procedure (SAS Software Inc., 2000).

3. Results and discussion

Nearly 5 months after the start of the experiment, all salamanders introduced initially were still alive. However, salamander weight decreased in all treatments (Fig. 2). This is likely due to an insufficient food intake, given the absence of harsh weather conditions during the study (see Section 2). Ants added during the study were intended to complement existing preys in the soil of microcosms, rather than to serve as the main food source. For example, springtails were often observed, both during soil manipulations at the time of microcosm establishment and under bark pieces, when checking for salamanders during the study. Although ants may not be an optimal food source for salamanders (Burton and Likens, 1975), they are relatively easy to capture in the quantities required for such an experiment, as compared to other preys. Also, salamanders were observed at the surface of the microcosms on only 69–78% of the observation dates, with no differences



Fig. 1. Limed pail.

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