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# EFFECTS OF COVER BOARD AGE, SEASON, AND HABITAT ON THE OBSERVED ABUNDANCE OF EASTERN RED-BACKED SALAMANDERS (*PLETHODON CINEREUS*)

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*ABSTRACT:* Plethodontid salamanders are potentially good ecological indicator species in woodland habitats due to their abundance and sensitivity to changes in the environment. The use of terrestrial salamanders as ecological indicators depends on effective means of surveying their abundance and distribution. Our study examined the use of old and new artificial cover boards by Eastern Red-backed Salamanders (*Plethodon cinereus*). We also considered the effects of season (spring vs. fall) and habitat type (deciduous vs. coniferous vs. mixed) on cover board use by *P. cinereus*. Our results indicated that *P. cinereus* abundance was greater under old cover boards compared to new cover boards. However, the difference between the use of old and new cover boards was greater during the spring than the fall, suggesting that the effect of cover board age became weaker over time. *Plethodon cinereus* showed strong seasonal variation in observed abundance, with peaks during the spring and fall seasons and very low surface activity during the summer. *Plethodon cinereus* had higher observed abundance in deciduous habitats than in coniferous and mixed habitats. Our results suggested that care should be taken to account for cover board age in long-term monitoring programs, especially if cover boards are replaced during a study.

## INRODUCTION

Plethodontid salamanders are potentially good ecological indicator species in woodland habitats due to their abundance and heightened sensitivity to fine-scale changes in the environment (Welsh and Droege, 2001; Welsh and Hodgson, 2013). The effective use of terrestrial salamanders as ecological indicators depends on whether or not the data being collected is accurate and repeatable. Some of the more common methods of monitoring terrestrial salamanders have been the use of transect counts, quadrat searches, funnel traps, pitfall traps, searches of natural cover objects, and searches of artificial cover objects (Bailey et al., 2004; Strain et al., 2009; Otto and Roloff, 2011).

The use of artificial cover objects has been suggested as a simple and efficient means of monitoring populations of plethodontid salamanders, particularly those of small-bodied terrestrial species such as the Eastern Red-backed Salamander (*Plethodon cinereus*) (Moore, 2005, 2009; Grover, 2006). Several factors influence the use of artificial cover objects by salamanders (see Miller Hesed, 2012 for review) including: the proximity of the artificial cover objects to natural cover objects (Ciul et al., 2010), cover object size (Carfioli et al., 2000; Moore, 2005), the frequency cover objects are checked (Marsh and Goicochea, 2003), and the construction material (Hampton, 2007).

Given the common use of artificial cover objects in the study of salamanders, it is surprising how little is known about the effect of cover board age on their effectiveness (see Miller Hesed, 2012). Understanding the effects of cover board age on observed abundances of *P. cinereus* (or other salamanders) is potentially important since any change in the use of cover boards by salamanders as boards age would introduce bias into estimates of population trends or studies of habitat use or temporal change if boards of differing ages were used in different habitats or at different times. Over time the physical structure of the artificial cover board likely will change as it starts to decay and be affected by moisture and insects, and the microclimate under the cover board will change as the cover board settles into the soil and the board fits into the soil more closely (G.R. Smith, pers. observ.). It is thus likely that soil moisture and temperature under cover boards change as they age. The microclimate under older cover boards (e.g., more moist) is likely better

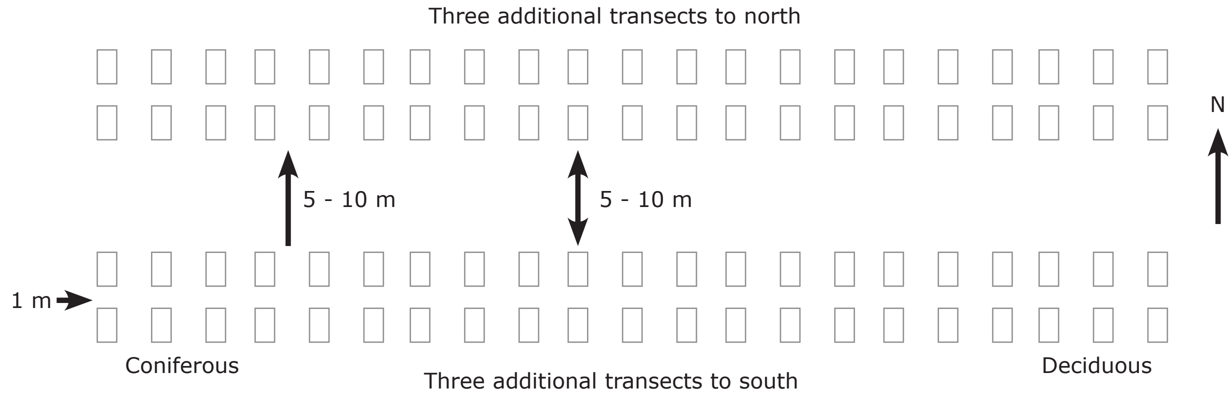


Figure 1. Schematic diagram of two transects. There were a total of eight transects on the study site. Note that the diagram is not drawn to scale.

for *P. cinereus* than the microclimate under newly placed cover boards, since cover boards provide a moist soil environment and it probably takes time for such conditions to develop under cover boards (Willson and Gibbons, 2010). Our study examined the use of old versus new cover boards as artificial cover objects by *P. cinereus.* Given the likely differences in microclimate, we predicted that more *P. cinereus* would be observed under old cover boards than new boards. We also considered the effects of season and habitat type (deciduous woods versus abandoned pine plantation) on observed abundances of *P. cinereus*.

## MATERIALS AND METHODS

We conducted this study within the Denison University Biological Reserve, Granville, Licking Co., Ohio, USA (40.085367°, -82.509422°; Elevation 340.8 m). The study area was a southward-facing slope with two forest types, a mixed mesophytic forest (dominant species = Sugar Maple, *Acer saccharum*) and an abandoned pine plantation (dominant species = White Pine, *Pinus strobus*), which we subsequently refer to as deciduous and coniferous habitats, respectively. We collected data along transects running along a gradient from deciduous to coniferous habitat including a mixed deciduous-coniferous habitat where the two habitats met (Figure 1).

We collected data using pine lumber cover boards (30.5 x 61.0 cm, 4 cm thick). We placed each board on the forest floor after first clearing all leaf litter and debris from the soil surface. Half of the boards used in this study were well established in the environment 6 -7 years prior to the beginning of this study; these boards are collectively referred to as the old boards. These old boards were well weathered and settled into the environment. We placed new boards that were of identical size and shape as the old boards on 23 March 2008, one week prior to the onset of data collection. We placed one new board 1 m from each of the old boards, so that we had 168 pairs of old and new boards. We arranged cover board pairs in eight transects of 21 pairs each, distributed across the edge of deciduous and coniferous habitats (Figure 1). Each transect was spaced 5-10 m apart, and each pair of cover boards within a transect was 5–10 m from the next pair in the transect. We classified a cover board as being in deciduous habitat if at least four of the five closest canopy trees were deciduous, as in coniferous habitat if at least four of the five closest canopy trees were pine trees, and in mixed habitat in all other cases.

We recorded the number of *P. cinereus* under each cover board weekly. We used weekly intervals because Marsh and Goicochea (2003) found that checking cover boards more frequently than once a week creates too much disturbance and affects observed salamander abundance, whereas lower frequencies do not appear to affect observed salamander abundances. We checked cover boards for 32 consecutive weeks from 29 March 2008 through17 November 2008. We checked the transects between 0900 h and 1200 h.

We used a repeated measures ANOVA on the observed abundance of *P. cinereus* with habitat type (deciduous versus coniferous versus mixed) and artificial cover board age as the independent variables, and time (i.e., sampling date) as the repeated measure. We used StatView 5.0.1 for Windows (SAS Institute Inc., Cary, NC) to conduct all statistical analyses.

## RESULTS

There was a clear bimodal seasonal pattern in the observed abundance of *P. cinereus* in our study, with peaks in the spring and fall and very low observed abundances in the summer (Figure 2A; Table 1). Cover board age significantly affected the observed abundance of *P. cinereus*; old boards had more *P. cinereus* under them than new boards (Figure 2B; Table 1). However, the difference between new and old boards was greater in the spring than in the fall, especially after the beginning of October (Figure 2B; Table 1).

Cover boards in the deciduous habitat had higher observed abundances of *P. cinereus* under them than either the coniferous or mixed habitats (Figure 2C; Table 1). There was a significant interaction between time and habitat type, with no difference in observed abundance between habitat types during the period of very low observed abundances from early June to early September, and differences among habitat types at other times (Figure 2C; Table 1). There was a significant interaction between cover board age and habitat type with significant differences among different combinations of habitat type ad cover board age during the periods of high observed abundances and no differences during the period of very low observed abundances (Figure 23; Table 1). We also found a significant three-way interaction between cover board age, habitat type, and time (Figure 3; Table 1). Again, differences were observed during the periods of relatively high observed abundances and none were observed during periods of low observed abundances.

## DISCUSSION

*Cover Board Age* — We observed higher abundances of *P. cinereus* under old cover boards than under new cover

Table 1. Results of repeated measures ANOVA of *Plethodon cinereus* activity with time, cover board age (new vs. old), and habitat type (deciduous, coniferous, and mixed) as independent variables.

| Variable | df | F | P |
|---|---|---|---|
| Between Subject Effects | | | |
| Age | 1 | 17.159 | <0.0001 |
| Habitat Type | 2 | 31.184 | <0.0001 |
| Age*Habitat Type | 2 | 5.603 | 0.0040 |
| Error | 329 | | |
| Within Subject Effects | | | |
| Time | 31 | 59.193 | <0.0001 |
| Time*Age | 31 | 4.717 | <0.0001 |
| Time*Habitat Type | 62 | 4.180 | <0.0001 |
| Time*Age*Habitat Type | 62 | 2.397 | <0.0001 |
| Error | 10199 | | |

boards. Our study did not allow us to differentiate between the effects of a change in the physical characteristics or integrity of the cover board itself and the effects of a change in the microenvironment and microclimate under the cover boards as they age, such as increased soil moisture or changes in soil temperature (see Willson and Gibbons, 2010). We think it is very likely that both of these changes are responsible for the differences in the use of old and new cover boards by *P. cinereus*.

Previous studies examining the effects of age on the effectiveness of cover boards are relatively few and with mixed results. For example, Monti et al. (2000) and Grant et al. (1992) both observed a difference in artificial cover object use with the age of the cover object and suggested that salamanders, including *P. cinereus*, do not readily inhabit new cover objects and that cover board age should be considered in data collection. Other studies have found no effect of cover board age/weathering in counts of *P. cinereus* between new boards and weathered boards; however, in these studies both "new" and "old" boards were placed in the habitat at the same time, thus both types of boards were not weathered in situ (Monti et al. 2000; Carlson and Szuch 2007). Houze and Chandler (2002) found no difference in the number of *Plethodon ocmulgee* observed under coverboards that had been aged in situ one week, 14 weeks, and 27 weeks.

One alternative explanation for the difference in observed numbers of *P. cinereus* under the new cover boards compared to the old cover boards is that the P. *cinereus* did not have time to find and occupy the new cover boards early in the study. We do not believe this is a likely explanation for our observed results. The distance between the new and old cover boards was only 1 m. This distance falls within the dimensions of *P. cinereus* home ranges (Kleeberger and Werner, 1982; Liebgold and Jaeger, 2007) or distance moved (Gergits and Jaeger, 1990; Ousterhout and Liebgold, 2010) found in other studies. In addition, Schieltz et al. (2010) observed that *P. cinereus* frequently move between cover boards placed 1 m apart. *Plethodon cinereus* can disperse or move over much greater distances and across more restrictive habitats than the 1 m between cover boards in our study (e.g., Marsh et al., 2004, 2005, 2007). Thus, we conclude that *P. cinereus* were likely to have been able to find and occupy the new cover boards at the start of our study and that other explanations, such as those outlined above, are more likely to explain our results. Another factor that might affect the difference in the use of new and old cover boards by *P. cinereus* in our study is if cover boards were used and defended as territories. We do not believe this is likely to have affected our observations since individual *P. cinereus* in our population exhibit virtually no evidence of territoriality in the field or in laboratory experiments (Hurst and Smith, 2006; Burgett and Smith, 2012). A mark-recapture study would permit us to examine how easily individual salamanders move between old and new cover boards.

*Seasonal Activity* — We observed strong seasonal variability in observed abundances of *P. cinereus*, with peaks during the spring and fall seasons and very low observed abundances during the summer. The vast majority of *P. cinereus* we found were adults (C. Grasser, pers. observ.), thus the observed pattern does not appear to be greatly influenced by recruitment patterns. This bimodal seasonal pattern of observed abundance of *P. cinereus* has been seen for the 8+ years that this population has been monitored, including the exceptionally high peaks in mid-April (G.R. Smith, unpubl. data), and is consistent with other studies of *P. cinereus* activity in northern parts of its range (e.g., DeGraaf and Yamasaki, 2002; Leclair et al., 2008; Otto and Roloff, 2011). Nagel (1977) showed that *P. cinereus* populations in the southernmost part of the species' range are active for most of the year

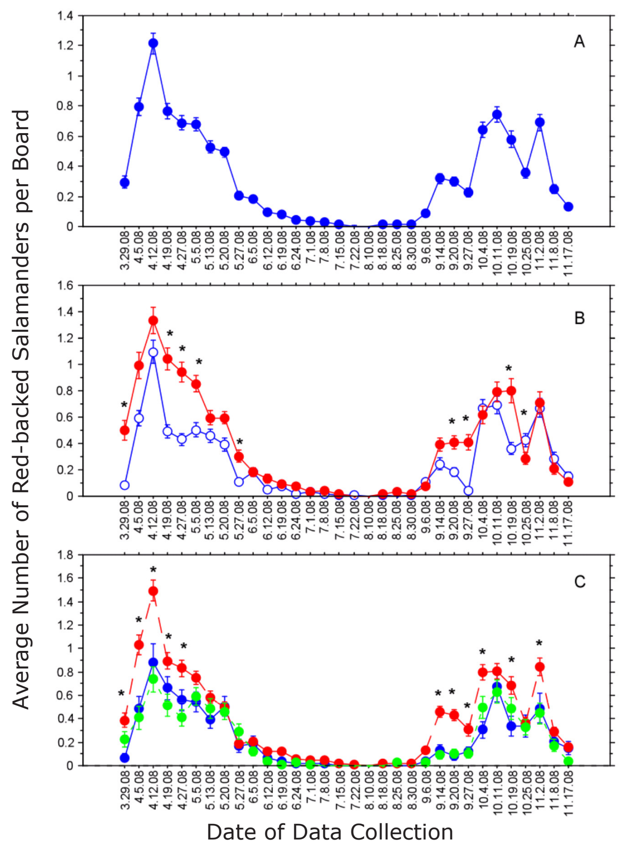


Figure 2. (A) Mean number of *Plethodon cinereus* found underneath all cover boards (i.e., includes both new and old cover boards) throughout the course of our study (B) Mean number of *P. cinereus* found underneath old cover boards (closed circles) and new cover boards (open circles) throughout the course of our study. (C) Mean number of *P. cinereus* found underneath cover boards classified as being in coniferous (blue solid line), deciduous (red long-dash line), and mixed habitats (green short-dash line) throughout the course of our study. * indicates significant differences among means for a sampling date. Means are given ±1 SE.

with only a short inactive period during the summer, suggesting a single extended activity period rather than a bimodal pattern each year. In particular, it is likely that surface activity declines during summer months due to an increase in desiccation and heat stress risk during this time of the year. The activity pattern of *P. cinereus* thus appears to vary with latitude and so probably reflects the local climate and the duration and timing of temperatures and precipitation conducive to surface activity (e.g., Leclair et al., 2008;Willson and Gibbons, 2010).

*Habitat type* — While the main focus of this study was to examine the use of new and old cover boards by *P. cinereus* we were able to begin to examine the effects of habitat type (coniferous vs. deciduous vs. mixed) on their observed abundance. A more complete analysis of more than eight years of data awaits, but the results from this study indicated that *P. cinereus* had higher observed abundances under cover boards in deciduous habitat than in coniferous and mixed habitats. Our results were consistent with previous studies comparing *P. cinereus* abundance in deciduous habitats and coniferous habitats or pine plantations. In general, observed abundances of *P. cinereus* were lower in coniferous habitats than in deciduous habitats (e.g., Pough et al., 1987; DeGraaf and Rudis, 1990; Waldick et al., 1999). However, Mathewson (2009) found more *P. cinereus* in eastern hemlock stands than mixed deciduous stands. The differences in the abundance of *P. cinereus* in deciduous and coniferous habitats are likely a consequence of the effects of these habitats on environmental conditions. Pine plantations and coniferous habitats tend to alter soil characteristics, such as lowering pH and moisture, as well as other potentially important habitat characteristics, such as increased temperature (e.g., Augusto et al., 2003; Cunnington et al., 2008; Scott and Messina, 2010; see review in Scholes and Nowicki, 1998). Pine plantations can also have more bare soil than deciduous forests (e.g., Amo et al., 2007). Such differences in soil and habitat characteristics are likely to affect the abundance and distribution of *P. cinereus* between these habitats since these same characteristics are known to affect the abundance and distribution of *P. cinereus* in other studies, both in the field and laboratory (Wyman, 1988; Sugalski and Claussen, 1997; Harper and Guynn, 1999). The difference in observed abundance between the deciduous, mixed, and coniferous habitats in our study could also arise if cover board use or detectability of *P. cinereus* differs between habitat types (see Bailey et al., 2004).

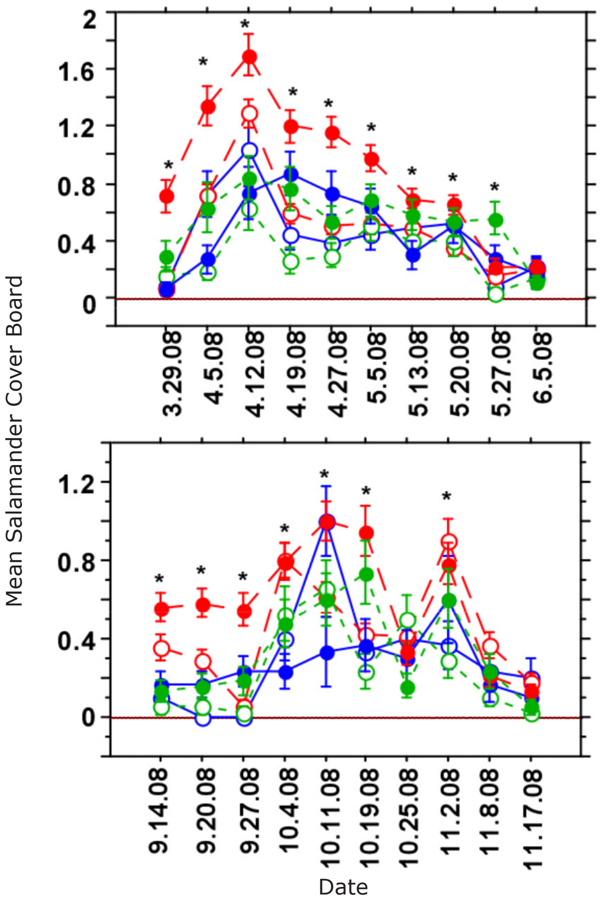


Figure 3. Mean number of *Plethodon cinereus* found underneath cover boards throughout the course of our study as a function of habitat type (coniferous = solid line, deciduous = long-dash line, and mixed habitats = short-dash line) and cover board age (old = solid circles, new = open circles). For increased clarity, we only show the results for those sampling dates with relatively high observed abundances of *P. cinereus* (see Figure 2). * indicates significant differences among means for a sampling date.Means are given ± 1 SE.

However, we feel this explanation is not likely to play a major role in explaining our results since other studies found that *P. cinereus* abundances are higher in deciduous habitats compared to coniferous habitats using a variety of techniques (nighttime visual surveys: Pough et al., 1987; drift fence with pitfall traps: DeGraaf and Rudis, 1990; pitfall traps, natural cover object survey, Waldick et al., 1999; leaf litter sampling, Harper and Guynn, 1999).

In addition, laboratory studies show that *P. cinereus* prefer deciduous leaves over pine needles as a substrate, and that soil from each habitat type had relatively little effect on salamander behavior (Renaldo et al., 2011). Regardless of the underlying cause, our results suggested that coniferous and mixed habitats likely supported fewer *P. cinereus* than deciduous habitats.

*Monitoring Implications* — Our results suggest that cover board age should be accounted for in long-term monitoring programs, especially if cover boards are replaced during the study. For example, many of the old boards in our study were beginning to lose some of their integrity during 2008. Indeed, recent observations from the fall of 2012 suggest that many of the old boards would no longer be viable as standardized survey tools due to deterioration and loss of structural integrity. The length of time an artificial cover board is viable will likely depend on the composition of the board and different types of wood used for cover boards might result in different effects of cover board age on observed abundances of *P. cinereus*. We recommend that for long-term monitoring programs that use cover boards to monitor terrestrial salamander populations that new, replacement cover boards be placed and monitored in the environment paired with existing cover boards at least a year, but perhaps more, before the end of the old boards' effective life.

*Future Directions* — Our results have raised several questions that need further research. First, what is the exact mechanism that drives the use of new vs. old cover boards in *P. cinereus*? In addition, further study is needed to assess how long individual cover boards can serve effectively. Do the patterns of observed abundances we found match patterns in absolute abundances of *P. cinereus* in these habitats? What habitat or microclimate factors are responsible for such patterns of habitat use.

Mark-recapture studies along with long-term monitoring of both salamander abundances and abiotic factors will be needed to answer these questions, as will field and laboratory experiments.

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