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Effectiveness of Two Artificial Cover Objects in Sampling Terrestrial Salamanders

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***Abstract.*—Artificial cover objects (ACOs) provide a nondestructive, efficient method of monitoring cryptic herpetofauna, yet few studies conduct side-by-side comparisons of novel ACO materials. We monitored 930 pairs of ACOs, one made of solid wood and the other made of plastic vinyl and carpet padding, and tested for the effect of ACO type, season, and slope orientation on ACO use by terrestrial salamanders. During two seasons of sampling, we recorded 2,917 salamander encounters representing five species under ACOs. Overall, salamander encounters were three times greater under wood ACOs than under plastic ACOs, and encounters with Eastern Red-backed Salamanders (*Plethodon cinereus*) and Northern Zigzag Salamanders (*P. dorsalis*) were significantly greater under wood ACOs (*P* < 0.01). Salamander encounters were greater in the spring than in the fall and were also greater on northeast and northwest facing slopes than on southwest facing slopes, regardless of ACO type. Precipitation was not correlated with salamander encounters, while air temperature was negatively correlated with encounters for smaller species. We suspect that the difference in the success of the two ACO types is due to greater moisture retention and temperature buffering of wood objects compared to that of plastic objects.**

Key Words.—amphibians; coverboard; detection; downed woody debris; *Plethodon cinereus*; *Plethodon dorsalis*

Introduction

The cryptic nature of many amphibian and reptile species makes them difficult to monitor. Herpetofauna often require multiple sampling techniques to assess the diversity of forms and life histories in this group (Heyer et al. 1994). While drift fences, pitfall traps, and funnel traps work well to capture species that make regular movements or migrations (Dodd and Scott 1994; Ryan et al. 2002; Todd et al. 2007), fossorial species and species that do not annually aggregate at breeding sites are often better sampled with searches of natural and artificial cover objects (Willson and Gibbons 2010). Artificial cover objects (ACOs) are considered a relatively low cost and effective method of sampling terrestrial herpetofauna (DeGraaf and Yamasaki 1992; Fellers and Drost 1994). Such objects simulate natural cover such as logs and rocks which provide a favorable microclimate and protection from predators. Relative to other sampling techniques, ACOs minimize habitat disturbance, minimize observer bias, and require little money and effort to install and maintain (Fellers and Drost 1994; Monti et al. 2000; Willson and Gibbons 2010).

Although various types of ACOs have been employed to monitor herpetofauna, including plywood, solid wood (of various tree species), carpet, corrugated tin, and asphalt roofing (DeGraaf and Yamasaki 1992; Engelstoft and Ovaska 2000; Houze and Chandler 2002; Scheffers et al. 2009), few studies have conducted direct, within-study comparisons of the effectiveness of different types of materials (exceptions include Engelstoft and Ovaska 2000; Lettink and Cree 2007; Scheffers et al. 2009). Assessment of the relative success of ACO types across multiple studies is hindered by vast discrepancies in study design and duration. Furthermore, differences in habitat and regional climate among study areas may yield dissimilar results from the same type of ACO (Grant et al. 1992; Davis 1997; Willson and Gibbons 2010). Moreover, many previous studies of ACOs do not assess abiotic factors such as slope aspect, natural cover, precipitation, and temperature, which may influence ACO success (Monti et al. 2000; Ryan et al. 2002; Marsh and Goicochea 2003; Moore 2005; Carlson and Szuch 2007; Hampton 2007). While use of ACOs is now a common and accepted technique for sampling herpetofauna, refining this method to optimize capture effectiveness and sampling costs (time and money) requires research that directly compares construction materials, and especially research that tests novel materials and dimensions (Grant et al. 1992; Moore 2005) and incorporates interactions of environmental factors.

As part of a study examining the effects of timber harvests on terrestrial salamanders, we compared the effectiveness of two types of ACOs in sampling salamanders in deciduous hardwood forests. We compared solid pine boards to objects composed of vinyl carpet runner and carpet padding (‘plastic’ objects) which, to our knowledge, have not previously been tested as potential ACOs. Wood objects have been used with success in past herpetofaunal research (DeGraaf and Yamasaki 1992; Fellers and Drost 1994), but are typically heavy and inconvenient to install. Thus, we tested new objects made with light-weight materials, including carpet padding to absorb and retain moisture and a plastic covering to provide structure and potentially prevent evaporation of moisture. The advantage of lighter-weight objects is easier installation in remote field sites. In addition to ACO type, we tested for the effects of slope aspect, season, and volume of downed woody debris on salamander encounters, and for correlations between salamander counts, temperature, and precipitation. Our results lend to the understanding of salamander use of ACOs and will aid in design of future monitoring programs of herpetofauna in forested habitats.

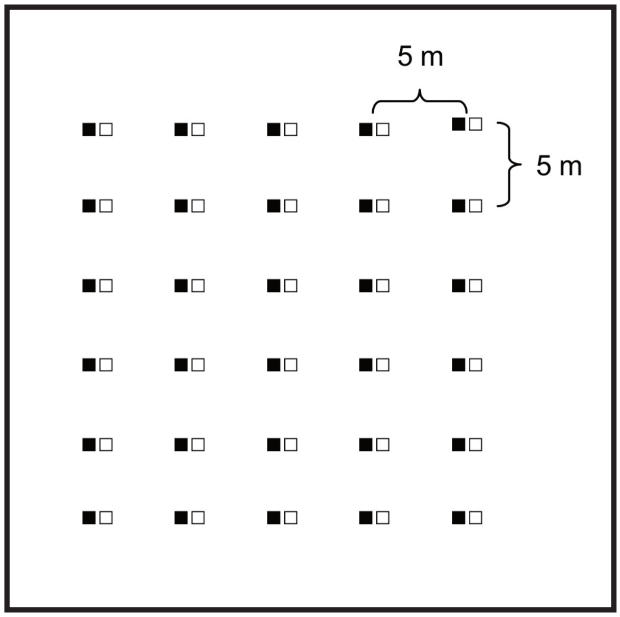

Figure 1. Diagram of artificial cover object (ACO) grid consisting of 30 wood ACOs (black squares; untreated pine boards, 30 × 30 × 5 cm) and 30 plastic ACOs (hollow squares; vinyl carpet runner stapled to carpet padding, 34 × 51 × 1 cm) with 5 m spacing between each pair.

Materials and Methods

Study area and target species.—Sampling occurred within the approximately 19,100 ha of Morgan-Monroe and Yellowwood State Forests in Morgan, Monroe, and Brown Counties in south-central Indiana, USA. The forest type is a mixture of oak-hickory and beech-maple with a canopy dominated by Sugar Maple (*Acer saccharum*), oak species (*Quercus* spp.), Tulip Poplar (*Liriodendron tulipifera*), and American Beech (*Fagus grandifolia*). The topography consists of steep ridges and valleys. Both state forests are managed for hunting, recreation, research, and timber production.

Twelve species of salamander occur in the study area and inhabit the litter and soil on the forest floor (Minton 2001; Williams et al. 2006). Of these, nine species (*Notophthalmus viridescens*, *Desmognathus fuscus*, *Ambystoma* spp., and *Eurycea* spp.) breed at ponds or streams. The remaining three species, the Eastern Red-backed Salamander (*Plethodon cinereus*), Northern Zigzag Salamander, (*P. dorsalis*), and Northern Slimy Salamander (*P. glutinosus*) are terrestrial breeders and thus are more likely to be encountered in the upland habitat sampled in this study (Petranka 1998). Additional litter-dwelling herpetofauna in the study area include four lizard species, 13 snake species, and nine anuran species (Minton 2001; MacGowan and Williams 2013).

Field methods.—In April and May of 2007, we established grids of ACOs at 31 sites across the study area. Each grid consisted of 30 pairs of ACOs arranged 5 × 6 with 5-m spacing (Fellers and Drost 1994; Fig. 1). Each pair consisted of one solid wood board (30 × 30 × 5 cm) made of untreated pine and one plastic object (34 × 51 × 1 cm) made of clear vinyl carpet runner stapled to carpet padding. We placed paired wood and plastic ACOs approximately 20 cm apart, in direct contact with the soil, with leaf litter and debris scraped away from beneath the object. We set plastic objects with the carpet padding down. We attempted to place an equal number of grids on northeast and southwest facing slopes (in the northern hemisphere, north and east facing slopes tend to receive less solar energy and retain more moisture than south and west facing slopes; Chen et al. 1999), however, the natural topography of the study area sometimes prevented ideal grid placement. The result was nine grids placed on northeast facing slopes (azimuth 0–90), eight grids placed on northwest facing slopes (azimuth 271–359), two grids placed on southeast facing slopes (azimuth 91–179), and twelve grids placed on southwest facing slopes (azimuth 180–270). The average distance between grids was 223 m (distance to nearest grid ranged from 90 m to 1.6 km; median 119 m). The entire range of grids spanned approximately 26 km from north to south.

We allowed ACOs to weather on site for four to five months. We then sampled each grid four to six times during September to November 2007 and four times during March to April 2008, with one to two week intervals between each sampling occasion to minimize disturbance to sites (Marsh and Goicochea 2003). On each sampling occasion (i.e., a single check of a single grid) observers lifted all wood and plastic ACOs at the grid and recorded the number and species of any vertebrates detected. Across both seasons, five grids were sampled eight times, 17 grids were sampled nine times, and nine grids were sampled ten times, resulting in 283 total sampling occasions at paired ACO grids. For each sampling day, we obtained precipitation and temperature records from National Oceanic and Atmospheric Administration (NOAA) cooperative stations (Martinsville 2SW, ID#125407 for Morgan and Monroe Counties; Nashville 2NNE, ID#126056 for Brown County). The distance between ACO grids and NOAA stations ranged from 7.3–18.2 km (mean 13.1 km).

Detection of herpetofauna by ACOs may vary depending on the amount of natural cover available (Fellers and Drost 1994; Hyde and Simons 2001); thus, we measured volume of downed woody debris (DWD) at each grid using a line intercept method (Van Wagner 1968). During March to April 2008, observers walked two parallel 20 m transects, one 5 m upslope and one 5 m downslope of each ACO grid, and recorded the diameter at the point of intersection of each piece of DWD ≥ 10 cm in diameter. Volume of DWD per grid (cm^3/m^2) was then calculated as in Van Wagner (1968).

Statistical analyses.—In fall 2007, some grids were checked as few as four times while others were checked as many as six times, so we rarefied the fall data by removing those sampling occasions that fell farthest outside the range of sampling dates for the majority of grids. This resulted in the removal of 35 of 283 total sampling occasions. The resulting dataset included four checks for every grid in the fall and four checks the following spring. The count data could not be normalized through transformation, nor examined under a Poisson or negative binomial distribution due to problems with overdispersion. Therefore, following rarefaction we pooled salamander counts across sampling occasions within each season for each grid and ACO type, resulting in lognormal distributions for the two most common species, *P. cinereus* and *P. dorsalis* (no other species were encountered in numbers sufficient to achieve normal distributions). For each of these two species, we compared mean encounter rates with a mixed model analysis of covariance (ANCOVA). We tested for the fixed effects of ACO type, slope aspect, season, and interactions among these terms, with volume of DWD as a covariate. To account for potential correlations between the wood and plastic ACOs placed at the same grid location, we included 'grid' as a random effect. Following each ANCOVA, we conducted post hoc Tukey adjusted pairwise comparison tests to identify specific differences within significant effects and interactions.

Given the geographical breadth of the study area and a limited number of technicians, it was logistically impossible to sample all grids in a single day. To account for variation in weather on different sampling days we computed Spearman partial correlation coefficients to quantify associations between salamander encounters, average daily air temperature, and amount of precipitation 48 hrs before each sampling occasion. For these correlation tests, we did not rarefy the data or pool counts across sampling occasions, since temperature and precipitation were specific to the day of sampling. We used partial correlations to account for potential multicollinearity among the independent variables (Zar 1999). The Spearman rank test is nonparametric, which allowed us to repeat this test for salamander counts under each ACO type for *P. cinereus*, *P. dorsalis*, and *P. glutinosus*, despite non-normality of these distributions. We conducted all statistical tests in SAS version 9.2 (Statistical Analysis Systems, Cary, North Carolina, USA) and accepted significance of tests at $\alpha = 0.05$.

Results

During 283 sampling occasions we recorded a total of 2,917 encounters with salamanders (Table 1). These included five species, the most common of which were *P. cinereus*, *P. dorsalis*, and *P. glutinosus*. We also recorded 35 encounters with reptiles, 26 of which were under plastic objects. On a per object basis, wood and

Table 1. Total and mean[a] (with standard error in parentheses) amphibian and reptile encounters under wood and plastic artificial cover objects (ACOs) in fall 2007 and spring 2008 at 31 sites in south-central Indiana.

	Wood		Plastic		Both
Taxon	Total	Mean (SE)	Total	Mean (SE)	Total
Caudata					
Plethodon cinereus	1501	5.3 (0.30)	424	1.5 (0.13)	1925
P. dorsalis	642	2.3 (0.18)	193	0.7 (0.08)	835
P. glutinosus	99	0.3 (0.05)	16	0.1 (0.02)	115
Eurycea cirrigera	35		6		41
Ambystoma maculatum	1		0		1
Total	2278		639		2917
Encounter rate per ACO[b]	27%		7.5%		
Squamata					
Diadophis punctatus edwardsii	7		17		24
Carphophis amoenus helenae	0		4		4
Storeria o.occipitomaculata	1		3		4
Plestiodon spp.	1		2		3
Total	9		26		35

[a]Mean encounters per sampling occasion, N = 283.
[b]Salamander encounter rates per ACO were determined by dividing total counts by the total number of ACO checks during the study (i.e., 283 sampling occasions × 30 ACOs per grid = 8,490 ACO checks).

plastic ACOs had salamander encounter rates of 27% and 7.5%, respectively (Table 1).

Cover object type, slope aspect, season, and the interaction of cover type and season all had significant effects on mean encounters of *P. cinereus* and *P. dorsalis* (Table 2). Using post hoc pairwise comparisons, we found mean encounters for both species were greater under wood ACOs than under plastic ACOs ($P < 0.001$), and this held true in both the fall and the spring. Mean encounters for both species were also greater on northeast and northwest slopes than on southwest slopes ($P < 0.05$). Overall, mean encounters for both species were greater in the spring than in the fall (*P. cinereus*, $P = 0.019$; *P. dorsalis*, $P < 0.001$). With post-hoc tests we found this seasonal pattern was consistent for *P. dorsalis* under both wood and plastic ACOs (despite the overall significance of the ACO type by season interaction in the ANCOVA, Table 2), but was only significant for *P. cinereus* under wood ACOs.

Table 2. Analysis of covariance results for fixed effects and interactions on mean encounters of *Plethodon cinereus* and *P. dorsalis* under wood and plastic artificial cover objects (ACOs).

			P. cinereus		*P. dorsalis*	
Effect	ndf[a]	ddf[b]	*F*	*P*	*F*	*P*
ACO type	1	87	115.66	<0.001	46.91	<0.001
Aspect	3	26	4.17	0.016	6.34	0.002
Season	1	87	5.76	0.019	83.34	<0.001
ACO type*aspect	3	87	2.46	0.068	0.13	0.943
ACO type*season	1	87	6.16	0.015	5.09	0.027
DWD	1	87	0.57	0.452	0.15	0.698

[a]Numerator degrees of freedom
[b]Denominator degrees of freedom

Mean daily air temperature on sampling days was 13.5° C (-0.6–23.6° C) in the fall and 7.5° C (0.0–8.6° C) in the spring. Mean precipitation during the 48 hrs prior to sampling was 0.84 cm (0.0–6.6 cm) in the fall and 1.39 cm (0.0–8.7 cm) in the spring. We found negative correlations between air temperature and counts of *P. cinereus* and *P. dorsalis* under both wood and plastic ACOs (Table 3). Counts of *P. glutinosus* under wood but not plastic ACOs were positively correlated with temperature. Only counts of *P. cinereus* were correlated with precipitation 48 hrs before sampling; this relationship was negative and occurred only for encounters under plastic ACOs (Table 3).

Discussion

The ACOs in our study detected five of 12 salamander species in our study area (Minton 2001; Williams et al. 2006). As expected, the salamander species with life histories least tied to ponds and streams (i.e., terrestrial breeders) were the most commonly encountered under ACOs. We observed a strong tendency for salamanders to use wood ACOs rather than plastic ACOs. In contrast, counts of reptiles, though low overall, were consistently higher under plastic objects (Table 1). These results agree with previous findings that the effectiveness of ACO material depends on the species of interest (Grant et al. 1992; Hampton 2007; Willson and Gibbons 2010).

We hypothesized that the cool, wet conditions of northeasterly slope aspects (Matlack 1993; Xu et al. 1997; Chen et al. 1999) would mitigate differences in microhabitats created by the two ACO materials. However, we did not detect a significant interaction among slope aspect and ACO type. Our findings of greater salamander encounters on northeastern and northwestern slope aspects compared to southwestern slope aspects are congruent with results of Moseley et al. (2009), sampling terrestrial salamanders under natural cover objects. Although our results suggest slope aspect should not be ignored in field studies of salamanders, we found wood ACOs outperform plastic ACOs regardless of slope aspect.

Downed woody debris was not a significant covariate in our mixed model analysis (Table 2). Positive associations between salamander abundance and DWD volume have been documented in various regions of North America (Bury and Corn 1988; Maidens et al. 1998; Brooks 1999; Butts and McComb 2000; Moore et al. 2001), although no such relationship was found in the southeastern Coastal Plain (Owens et al. 2008). The lack of correlation in this study could be due in part to our relatively narrow range and high variability of volumes (volume of DWD ranged from 0.00 to 262.88 cm^3/m^2; mean ± 1SE = 66.22 ± 67.99 cm^3/m^2) or our pooling of all DWD regardless of decay class (Bury and Corn 1988; Herbeck and Larsen 1999). Most previous investigations into links between salamanders and DWD used pitfall traps or time or area constrained searches rather than ACOs (Bury and Corn 1988; Maidens et al. 1998; Butts and McComb 2000; Moore et al. 2001; Owens et al. 2008), so further research into the relationship between ACO use and DWD is warranted.

Many ACO studies agree that herpetofaunal use of different cover objects is likely driven by temperature (Grant et al. 1992; Engelstoft and

Table 3. Spearman partial correlation coefficients[a] for associations between salamander counts, average daily air temperature, and precipitation 48 hrs before sampling based on 248 observations (31 grids × 8 sampling occasions = 248).

Species	ACO type	Temperature	Precipitation
P. cinereus	Wood	-0.40***	ns
	Plastic	-0.42***	-0.23***
P. dorsalis	Wood	-0.35***	ns
	Plastic	-0.39***	ns
P. glutinosus	Wood	0.16*	ns
	Plastic	ns	ns

[a]Significance levels: *, $P < 0.05$; ***, $P < 0.001$; ns, not significant.

Ovaska 2000; Hampton 2007; Lelievre et al. 2010). The negative correlation between counts of *P. cinereus* and *P. dorsalis* with average daily air temperature is likely explained by the lungless and ectothermic nature of these species, which restricts them to cool and moist microhabitats (Petranka 1998). The positive relationship between temperature and *Plethodon glutinosus* is likely due to its larger adult size and thus lower rate of dehydration compared to smaller salamanders (Spotila 1972; Feder 1983). Future studies using ACOs would benefit from directly measuring temperature under cover materials with digital temperature loggers to better understand how microhabitats differ by material and change over time and space (Grant et al. 1992; Engelstoft and Ovaska 2000). In contrast to temperature, we did not find strong or consistent correlations between salamander counts and amount of precipitation during the 48 hrs before sampling. Other measures, such as humidity or soil moisture, may be more useful than recent precipitation in predicting amphibian use of ACOs (Cohen and Alford 1996).

Although plastic and wood ACOs differed in surface area, we do not believe this had any great effect on our results. The plastic ACOs covered nearly twice as much surface area (1,734 cm^2) as the wood ACOs (900 cm^2). If ACO size did strongly influence salamander use, we would expect the bias to favor the larger objects (as observed by Richmond and Trombulack 2009), yet our results show exactly the opposite (i.e., despite their smaller size, the wood objects were superior in sampling salamanders).

It is also important to emphasize that the salamander counts reported here do not reflect numbers of individual salamanders. We did not mark individuals, and it is likely we observed the same individuals multiple times during the study, especially given the small home ranges and reported territorial behavior of Plethodontid salamanders (Petranka 1998). However, given that the two ACO types were arranged in side-by-side arrays, the counts provide a useful measure of the relative effectiveness of each type.

Conclusions.—Wood ACOs were more effective in sampling salamanders than plastic ACOs. The encounter rate per wood ACO for all salamander species pooled was 27%, a rate among the highest reported in the literature (see Table 1 in Moore 2005), whereas the rate for plastic ACOs was only 7.5% (Table 1). While plastic was more effective than wood at sampling reptile species, reptile encounter rates under plastic were much lower than those found by other studies using ACOs made of tin (e.g., Grant et al. 1992), asphalt roofing (Engelstoft and Ovaska 2000), Onduline corrugated roofing material, corrugated iron, or concrete (Lettink and Cree 2007). The plastic ACOs were designed with the expectation that the carpet padding below would absorb and retain moisture, while the plastic covering above would provide structure and potentially prevent evaporation. The lighter weight of the construction materials, compared to solid wood, allows for easier installation. However, plastic ACOs were more often blown or washed away by wind and heavy runoff than wood ACOs, and over the winter some plastic objects froze in bent shapes and were difficult to keep flush with the soil the following spring. The carpet padding portion of plastic ACOs degraded more quickly than wood boards, so the long term costs of plastic ACOs could be greater than initial costs. We do not recommend the use of plastic ACOs in sampling herpetofauna in relatively dry habitats such as that of our study area (i.e., hardwood forest, steep slopes, and dry ridge tops). It is possible plastic objects would be more effective in consistently wet habitats such as marshes and swamps, although such environments might speed degradation of materials. Our results support the use of thick wood ACOs in sampling terrestrial salamanders in hardwood forests, but there remain innumerable combinations of habitat types, target species, construction materials, and dimensions of ACOs that might yet be tested to optimize capture efficiency.

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