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REVIEW PAPER

Artificial cover objects as a tool for the survey and conservation of herpetofauna

Yan-Ronen Liberman[1] · Frida Ben-Ami[1] · Shai Meiri[1]

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Abstract

Artificial cover objects, made of various materials, have been used for decades for reptile and amphibian surveys, as well as in habitat restoration programs. Their low cost and maintenance demands make them a cost effective and efficient survey method. Since flipping covers does not require special skills, and covers can be uniform in size and material, they can be used as a standardized survey method to negate observer biases. We surveyed the literature in search of studies describing the use of artificial cover objects in situ as part of surveys or habitat restoration efforts of reptiles and amphibians in the twenty-first century. We found 490 studies conducted in 31 countries. Our results show that artificial cover objects are an effective method to sample reptiles and amphibians in terms of both labor and cost. Overall, artificial cover objects used in the studies we surveyed enabled the detection of 357 species belonging to 47 families. Only one study reported animal mortality caused by artificial covers and it also suggested a way to prevent it. No other studies reported direct or indirect injuries or deaths caused by artificial covers. We discuss the efficacy of artificial cover objects in surveying for reptiles and amphibians, and examine their effectiveness when used as part of habitat restoration programs.

Keywords Amphibian · Reptile · Artificial cover object · Conservation · Habitat restoration

Introduction

Reptiles and amphibians are highly threatened globally. At least 20–23% of all reptiles, and approximately 41% of amphibians, are currently threatened with extinction (Caetano et al. 2022; Cox et al. 2022). Historically, reptile extinctions were mostly driven by hunting by humans and invasive species (Slavenko et al. 2016), however, habitat destruction, degradation and fragmentation are now the major causes of faunal degradation, both generally

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✉ Yan-Ronen Liberman
yanronenl@mail.tau.ac.il

[1] School of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv-Yafo, Israel

(Todd et al. 2010), and for reptiles and amphibians in particular (Gardner et al. 2007; Cox et al. 2022). Conducting animal surveys allows researchers, for example, to create field inventories of the local fauna, monitor and observe how local populations are affected by natural or artificial phenomena, or collect specimens for field or lab experiments. Population monitoring is of great importance to restoration efforts, as part of assessing the progress and success of the restoration plans (Hale et al. 2019). Reptile and amphibian monitoring often consists of visual surveys as well as overturning rocks and other cover objects in search for individuals that use those covers for refuge (McDiarmid et al. 2012; Dodd 2016). Visual surveys take both time and expertise (Glorioso et al. 2022) and may also suffer from observer biases (Dodd 2016). Overturning natural objects can lead to the destruction of the refuge they provide, which often serve diverse target and non-target taxa, including various invertebrate species and even small mammals (Freedman et al. 1996). Thus, natural cover objects need to be handled with extra care (Nordberg and Schwarzkopf 2015; Moore et al. 2022).

A common method to monitor reptiles and amphibians, which takes advantage of their tendency to seek shelters, involves placing artificial cover objects in the study sites. Objects such as wooden boards, tin sheets, plywood, and roof tiles, are inexpensive, relatively lightweight, easy to transport and handle, and can be easily deployed in the field. This makes them a very cost-effective method for reptile and amphibian monitoring (Monti et al. 2000; Grillet et al. 2010; Dodd 2016). Once deployed, artificial cover objects require little maintenance (Grant et al. 1992; McDiarmid et al. 2012; Cassel et al. 2019), take less time to examine during visual surveys compared to natural objects (Hesed 2012; Michael et al. 2019), and require little training and expertise to properly use (Hesed 2012; Lettink and Monks 2016). Artificial cover objects can be, and have been, used as parts of reptiles and amphibians survey and conservation efforts for decades (Hesed 2012). The covers can be used as survey tools, by searching for animals taking shelter underneath them, or for habitat improvement and restorations (Webb and Shine 2000). The covers can provide reptiles and amphibians with shelter and refuge, and also with a microhabitat that can offer better temperature and moisture conditions for their physiological and behavioral processes (Lillywhite 1987; Macneil and Williams 2013). This is important because ectotherms that cannot reach their optimal temperature will suffer from reduced ability to forage, find mates or protect their territory (Downes and Shine 1998; Downes 2001), as well as from increased predation rates (Webb and Whiting 2005). Avoiding water loss and radiation is also important in many dry and open areas (Bickford et al. 2010). Reptiles and amphibians readily use artificial covers to the point that, for some species, their use became a primary survey technique (O'Shea 2005; Peterson and Rohr 2010; Howland et al. 2016; Scroggie et al. 2019). Artificial cover objects were successfully used to promote recolonization of previously occupied habitats by threatened species (Shoemaker et al. 2009; Grillet et al. 2010). That said, long-term placement of artificial covers may carry a risk. It has been suggested that covers could encourage individuals from nearby areas to relocate and settle under the covers, potentially driving them to low quality habitats or attracting predators to the area (Lettink and Monks 2016). No empirical data, however, has been offered to back this theory.

Some studies have tested how different artificial cover types and materials affect capture rates and examined if target species prefer one type of cover or another (Hampton 2007). Artificial covers were also used to enhance the quality of degraded habitats and encourage their repopulation (Márquez-Ferrando et al. 2009).

We review recent literature regarding the use of artificial cover objects in surveys and conservation practices of amphibians and reptiles, discuss their effectiveness, and test if they provide benefits compared to other common surveying methods. We discuss artificial cover safety, and whether covers benefit, harm or have no effect, on natural populations and individuals. Lastly, we examine artificial cover effectiveness as a tool for restoration projects of degraded habitats or declining populations.

Materials and methods

We searched Google Scholar and Web of Science using the keywords "Reptile OR amphibian AND artificial cover object", limiting the search to one year at a time, starting from 2022 and tracing backward to 2000. We continued to survey studies in each year until five consecutive Google pages (50 studies) yielded no additional results. Following the results of the initial search we then conducted a second search using each of the following terms: 'amphibian', 'reptile', 'Snake', 'Lizard', 'Salamander', 'Frog OR Toad', AND 'artificial refuge', 'artificial refugia', 'coverboard' (e.g., Snake AND artificial refuge) for the same period (2000–2022). We searched each term in turn until five consecutive pages yielded no new, relevant results. Lastly, based on the results of the aforementioned searchers, we searched for specific, commonly used materials that we might have missed when using more general terms for covers (e.g. refuge, cover, coverboard), combined with their relevant taxa. The terms used were 'tin', 'metal sheet' AND 'reptile', 'snake', 'lizard'; 'plywood' AND 'salamander', 'frog OR toad'; 'PVC' AND 'frog OR toad'. To qualify, a study needed to include the purposeful deployment, or use of, artificial covers to survey and detect reptiles or amphibians. We only included studies that were performed in situ, where the animals could move freely, were not limited by enclosures, and were not translocated directly into the artificial covers. We also included studies using artificial burrows, or artificial rocks, and treated them equally to cover object due to their similar purposes and ease of deployment and monitoring. From each publication we collected the following information:

The type or material used for the artificial cover object – materials were lumped into the following categories: 1. Wood; 2. Plywood; 3. Metal; 4. Onduline or bitumen; 5. Concrete; 6. Foam or sponge-like material; 7. Roof tile; 8. Felt; 9. PVC; 10. Unspecified. Materials that were used fewer than 10 times, such as plastic, rubber, carpet, etc. were grouped under an "other" category.

We recorded whether studies were targeting reptiles, amphibians, or both taxa. We also recorded the names of the species that were confirmed to be captured using artificial covers. We excluded species that appeared in studies utilizing multiple survey methods that did not report whether capture or sighting was specifically under artificial cover objects. We recorded the country studies were conducted in. Whenever possible, we recorded capture per unit of effort (specimens per single cover flip) and whether or not using artificial covers was effective compared to other survey methods.

Effectiveness—for the purpose of this study, we defined effectiveness as artificial covers detecting the highest number of specimens per unit of effort, detecting species that were not detected using other survey methods, or if the authors specifically mentioned effectiveness, or lack thereof, when no numerical data were available. We further classified the studies into one of three categories based on their overall purpose:

Conservation – any study the main purpose of which was restoring, enhancing or improving biodiversity by using artificial covers to provide animals with additional shelter, connecting fragmented habitats, or any other purpose where the covers were an active part of the restoration effort and not just a survey method.

Cover preference – all studies that utilized multiple types of materials, cover shape, size, or placement, and discussed differences in capture rates or use of the covers by the animals based on the material used. The comparison could have been between different artificial materials, or between artificial and natural covers.

Biodiversity, natural history, and ecological surveys – all studies that used artificial covers to survey amphibians and reptiles but did not fit into the previous two categories.

Results

We found 490 studies published between 2000 and 2022 that matched our search criteria (Appendix A). Most studies (444) were categorized as surveys, with cover preferences comparisons (47), and conservation studies (15), making up the remainder (Appendix A). One study (Webb and Shine 2000) was classified as both conservation and cover preference, and 15 studies tested cover preferences as a secondary goal and were classified as both cover preference and survey. Publications numbers increased over time ($R^2 = 0.523$, $P < 0.0001$, slope = 0.76X + 12.98 publications per year; Fig. 1).

More studies (222) were conducted on reptiles, than on amphibians (166), and on reptiles and amphibians combined (102). Most (281) studies surveyed for multiple species while 209 focused on a single species. Artificial cover surveys detected a total of 357 species belonging to 47 families. These included 77 frog (Anura) species, 66 salamanders (Caudata), 117 lizards (Sauria), 94 snakes (Serpentes), and 3 turtles (Testudines; Appendix B).

We identified 40 types of materials were used as artificial cover objects in these studies. In 42 studies the materials used were not specified. Wood (142), metal (140), and plywood (132) were the most commonly used materials (Fig. 2). The choice of materials researchers

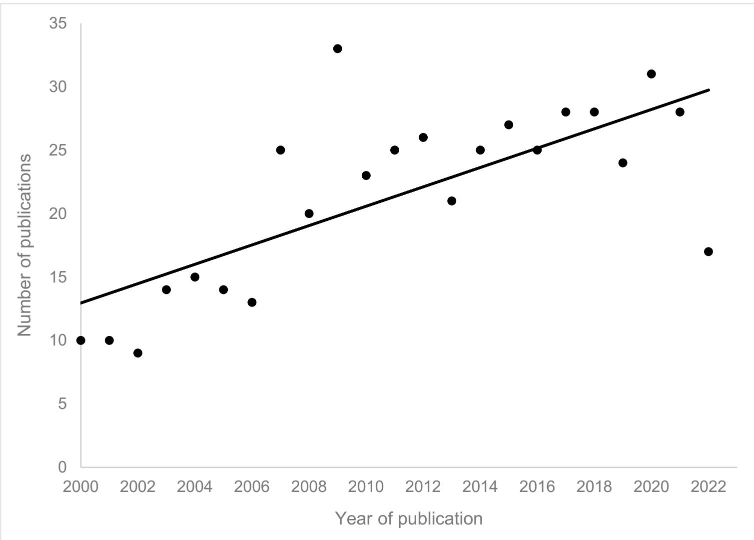

Fig. 1 Number of publications in our dataset, by year when they were published

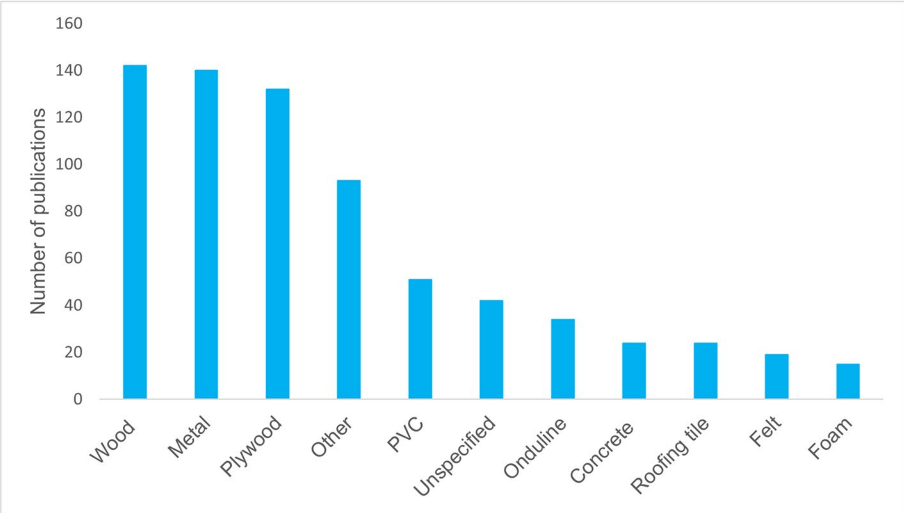

Fig. 2 Number of publications that used the specified material as an artificial cover object

chose to use for their study depended on the target taxa ($\chi^2=261.04$, df = 16, $P<0.0001$). In general, researchers were more likely to use wooden covers when sampling for salamanders, PVC pipes for frogs, plywood when sampling amphibians and reptiles simultaneously, and metal and the remaining materials when sampling reptiles alone. Studies were conducted in 31 countries, mostly in the USA (289), followed by (eastern) Australia (53), New Zealand (35), Canada (37), the UK (31) and France (11). The remaining countries had fewer than five studies each (Fig. 3). Very few studies were conducted in the tropics (except the Australian tropics): eight in central and south America (Ferreira et al. 2012, Whittaker et al. 2015; Brinkman et al. 2016; Atkinson et al. 2017; Pereira-Ribeiro et al. 2017; Curlis et al. 2020; Méndez-Galeano 2020; Caballero-Gini et al. 2021), two in the Caribbean (Simpson et al. 2012; Burrowes et al. 2021), one in Hong Kong (Sung et al. 2011), and one in Nigeria (Luiselli and Akani 2002). Only two other studies were conducted in continental Africa (both in South Africa, Forgus 2018; Tokota 2020), and only two in mainland Asia (one in Israel: Shacham 2004; one in Qatar: Cogălniceanu et al. 2014; Fig. 3).

Only one study (Shew et al. 2022) mentioned harm caused to animals because of artificial covers. In their study, PVC pipes used to sample frogs caused the death of mammals that got stuck inside. They found that attaching a rope to the inner side of the pipe allowed the mammals to escape and reduced mortality to zero. No other animal injuries or deaths related to artificial covers were reported, either direct or indirect. 104 of the 142 studies containing information that allowed us to check for effectiveness (73%) were considered to be effective according to our definition of effectiveness (see methods), compared to 38 (27%) that were not. Out of 40 studies that mentioned material, time, or labor costs, 34 studies (85%) found covers to be a cheap, fast and easy to use method compared to six (15%) that stated the opposite. The 104 studies that included information on captures per unit of effort averaged $0.25 \pm 0.32_{SD}$ captures per cover turned (median: 0.107) across all studies. Salamanders averaged $0.3 \pm 0.4_{SD}$ (median = 0.12), Frogs averaged $0.22 \pm 0.25_{SD}$ (Median = 0.1), lizards $0.27 \pm 0.31_{SD}$ (Median = 0.1), and snakes averaged $0.08 \pm 0.07_{SD}$ (Median = 0.06) detections per cover turned. Cover object surveys had a higher capture rate per unit of effort compared to

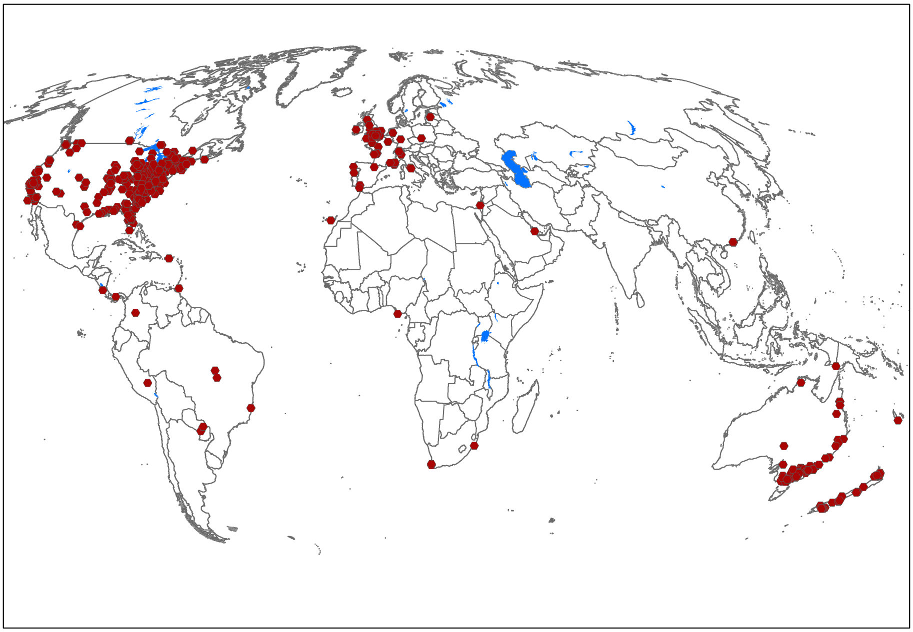

Fig. 3 Distribution of the study sites. A single study from Hawaii is not shown

other survey methods in 22 out of 37 studies that reported such data. The average increase in capture rate per unit of effort was $1.8 \pm 1.6_{SD}$ (median = 1.23) fold in favor of artificial cover surveys compared to visual surveys and pitfall trapping. Forty-six studies reported capture rates based on the material of cover type used. Their results were mixed, and often contradicting (see discussion), with no one material consistently performing better than others.

All studies focusing on conservation aspects, except Lettink et al. (2010), reported that the use of cover objects increased the number of individuals found (though it is not always clear if real abundance increased or only detectability) including those involving threatened species. Six studied found increased abundance of target species with a mean increase of 4.1 (±2.8) fold compared to surveys done prior to adding the covers. Three studies found that covers were mostly occupied by juveniles. Croak et al. (2013) showed an increase of 10% in juvenile survival of Lesueur's velvet gecko (*Amalosia lesueurii*) from 80 to 90% (based on mark – recapture). Milne et al. (2003) found that female pygmy blue tongued lizards (*Tiliqua adelaidensis*) living in artificial burrows had a significantly better body condition and larger offspring compared to those found in natural burrows. Three studies (Grillet et al. 2010; LeGros et al. 2014, 2017) suggested that artificial covers could be used to reconnect fragmented habitats. One study mentioned that there was no increase in predators seen after cover deployment (Grillet et al. 2010), and one study found increased predator abundance but no signs of increased predation (Souter et al. 2004).

Discussion

Our review suggests that the placement of artificial cover objects is an efficient, safe, cost-effective, and time-saving method to survey and conserve reptile and amphibian biodiversity. This makes them a valuable part of the field ecologist's toolbox. The vast array of materials used in the studies, including donated (Glorioso et al. 2022), or discarded items (Michael et al. 2004; Cox et al. 2009; Homan 2012; LeGros et al. 2017; Parry 2020), serves as proof of the versatility and cost-effectiveness of this method. The studies we surveyed, except that of Shew et al. (2022), reported virtually no negative effects of cover objects and only a few studies found cover objects to be ineffective. That said, the covers may damage sensitive vegetation underneath or attract the attention of people. Furthermore, our results could be biased if authors are unlikely to report any injuries or deaths they accidently caused during their surveys.

Artificial cover objects have proven to be effective in restoration projects with all conservation studies, except that of Lettink et al. (2010), who found neither positive nor negative effects. Other studies reported that over object use increased restoration effectiveness (Webb and Shine 2000; Davis and Theimer 2003; Souter et al. 2004; Márquez-Ferrando et al. 2009; Croak et al. 2010; Grillet et al. 2010 Croak et al. 2013; Manning et al. 2013; LeGros et al. 2014; Shoo et al. 2014; LeGros et al. 2017; Burrowes et al. 2021; Freeman et al. 2021; Suriyamongkol et al. 2021). Reptiles and amphibians use such objects for thermoregulation, hydroregulation, protection against predators, and extreme environmental conditions (Lillywhite 1987; Cowan et al. 2021). Covers can be used to supplement and enrich habitats that have been logged until natural wood can accumulate (Manning et al. 2013). In areas where non-renewable natural covers, such as rocks, have been depleted (For example, Webb and Shine 2000), artificial covers offer a good restoration option. Taking natural rocks and using them as artificial covers elsewhere may deprive one habitat of its rock covers and may even contribute to rock trade, resulting in a circle of buying rocks from the people who removed them (Webb and Shine 2000). Several studies deployed artificial 'rocks', made of concrete, to degraded habitats with a rock shortage (Webb and Shine 2000; Croak et al. 2010, 2013). All three studies showed that reptiles, including the endangered broad headed snake (*Hoplocephalus bungaroides*), and its prey gecko *A. lesueurii*, readily used these artificial 'rocks'. Furthermore, the survival rate of juvenile *A. lesueurii* in sites with artificial rocks was higher than in control areas, with no survival differences between adults in either plot type (Croak et al. 2013). These three studies emphasize the viability of artificial covers in restoration projects and their ability to replace degraded or missing natural covers. Artificial cover objects can also be used as steppingstones between fragmented habitats, serving as ecological corridors and providing animals with safe stops as they move across degraded or low-quality areas between two fragments (LeGros et al. 2014, 2017).

One of the potential risks to the use of artificial cover objects is that permanent placement could attract predators, or competitors, or alter the abundance and distribution of the focal species, by encouraging them to settle in the area where the covers were placed (Lettink and Monks 2016). This raises the risk that artificial cover objects will become an ecological trap – encouraging animals to settle in low quality habitats because of the cover provided. None of the studies we reviewed, however, found evidence of increased predation on the focal species or major changes in their spatial distribution. Several studies found an increase in abundance but did not mention impacts in the control sites (Márquez-Ferrando et al. 2009; Manning et al. 2013; Shoo et al. 2014 Freeman et al. 2021). Souter et al. (2004) discussed changes in abundance between sites with or without added covers. They reported that the abundance of a threatened lizard (*T. adelaidensis*) in control sites did not decrease despite an increase in abundance in treatment sites. Souter et al. (2004) therefore hypothesized that the increase in population size in treatment plots stemmed from either increased survival of juveniles and adults, who otherwise would have died during their search for a burrow, or from increased reproduction rate. These hypotheses are further supported by the high detection rate of juveniles under covers (Webb and Shine 2000; Grillet et al. 2010; Croak et al. 2013), and by the increased size and survival rate of juveniles in plots with added covers (Milne et al. 2003; Croak et al. 2013). Davis and Theimer (2003) detected a sixfold increase in the abundance of lesser earless lizards (*Holbrookia maculata*) 16 days after the construction of artificial burrows in test areas. Therefore, juvenile survival was unlikely to be the cause for the increased abundance. Davis and Theimer (2003) suggested that the burrows attracted lizards from nearby territories, although, they did not detect any changes in abundance in the nearby control plots. This suggests that perhaps the increase in abundance that was detected during surveys was not caused by an actual increase in the number of animals, but rather by an increase in their detectability. Croak et al. (2013) also suggested that increased detectability caused the increased abundance of animals under covers in their study, at least for adult lizards. Webb and Shine (2000) stated that they could not infer changes in abundance from their results only that lizards used their artificial covers. That said, added covers were shown to mitigate population declines and maintain abundance in logged areas, even when both control and treatment plots were surveyed using the same methods and intensity, thus preventing differences in detectability between plots (Ochs et al. 2022). Further studies, utilizing multiple survey methods, should be conducted in order to assess the effects of artificial covers on animal abundance and detectability.

Covers may serve as safe shelters in areas where the risk of predation are high (Grillet et al. 2010) and their benefits probably outweigh any potential loss caused by predation (Souter et al. 2004). Furthermore, we found no evidence to suggest that artificial cover objects lower the abundance, richness, survival or condition of populations where objects were placed, including in adjacent ones. In low quality habitats where refuge is scarce, artificial cover objects can be used to enhance the habitat's quality, by offering additional refuge.

Artificial cover objects were shown to aid in reptile and amphibian surveys, greatly increasing the number of sightings and/or species detected (Bell 2009; Engelstoft and Ovaska 2000; Sewell et al. 2012; Scroggie et al. 2019; Margenau et al. 2020; Rog et al. 2020). In the studies we surveyed, artificial covers, on average, doubled sighting and capture rates. Detection rates increase with the increase in cover density (Doré et al. 2011), even when corrected for search effort (Danielsen et al. 2014). Under optimal weather conditions, capture-recapture surveys utilizing artificial covers provided precise estimates of the actual population sizes (Lettink et al. 2011; Fleming et al. 2021). Since reptiles and amphibians use covers as refuge, it is possible to find inactive or cryptic reptiles underneath covers. For example, using artificial cover objects enables the detection of nocturnal species during the day (Michael et al. 2012), and of burrowing species where visual surveys only detected generalists (Michael et al. 2019). Covers also enable researchers to encounter and sample rare and cryptic species that are otherwise hard to detect, making their monitoring easier and more precise (Grant et al. 1992; Scroggie et al. 2019; Rog et al. 2020). Recent studies also revealed that cover objects can augment cryptic species detection using environmental DNA methods, by sampling the covers themselves (Ratsch et al. 2020; Matthias et al 2021; Kyle et al. 2022). This enabled the detection of targeted species

(*Clonophis kirtlandii*; *Contia tenuis,* and *Scincella lateralis* respectively) that used the covers even without encountering any individuals, with DNA detectable up to two weeks after the covers have been used (Kyle et al. 2022).

Another benefit of the use of artificial covers in surveys is that they cause little harm to the environment and to natural structures (Joppa et al. 2009). This may be especially important when sampling arboreal species. Arboreal lizards often take refuge underneath tree bark, and extracting the lizard often involves the breakage or removal of the bark, destroying the habitat in the process (Moore et al. 2022). Covering tree trunks with a piece of foam-based material proved to be a highly efficient method for capturing arboreal lizards (Michael et al. 2018), without causing harm to the tree bark (Nordberg and Schwarzkopf 2015; Moore et al. 2022).

Since flipping artificial covers takes no special skills or expertise, using them in surveys and experiments reduces observer bias to a minimum and enables standardized sampling (Hesed 2012; Baker and Allain 2020; Engelstoft et al. 2021). This in turn provides us with a viable and consistent comparison method for studies and surveys, using before-after-control-impact or similar designs (Cowan et al. 2021).

We found no consistent pattern with regards to the materials covers should be made of. Halliday and Blouin-Demers (2015), for example, found that the snakes they studied preferred tin over plywood, while Fitschen-Brown et al. (2021) found no preference between those materials. Similarly, MacNeil and Williams (2013) showed that the species they examined preferred vinyl and carpet over wood, but Scheffers et al. (2009) showed a preference of wood over carpet. Even within the same study, cover preference was shown to change based on current weather (Lange et al. 2020), species (Michael et al. 2012), land features near the cover (Croak et al. 2012), and time of day (Hoare et al. 2009; Lelièvre et al. 2010). It is likely that, rather than a direct preference for a type of material, animals choose indirectly based on the microclimate underneath the cover (Cox et al. 2009). Different materials will heat up at different rates, creating different microclimates underneath them (Hodges 2018). Therefore, even if the animal's choice is not based on the material used, the material itself is still a factor that needs to be taken into consideration when choosing the cover to use. Joppa et al. (2009), Scroggie et al. (2019), and Vanek et al. (2019), suggested that the best season for deploying artificial cover survey is spring, when temperatures are mild and covers provide slightly warmer than ambient temperatures when individuals are inactive. Cloudy days with ambient temperatures between 16°- 26 °C seemed to produce the best results when surveying covers (Thompson 2006; Joppa et al. 2009; Čeirāns and Nikolajeva 2017) – at least in temperate regions. Surveying cover arrays too frequently can deter animals from using them, potentially reducing detection rates (Reading 1997; Marsh and Goicochea 2003). We note, however, that almost no studies were conducted in deserts, or in the tropics, thus the best season and ambient temperature is likely to change based on geography and the focal species. In addition to temperature, moisture content underneath the covers plays an important role for amphibians (Lemm and Tobler 2021). Amphibians have a highly permeable skin, making them susceptible to water loss and dependent on substrate moisture for replenishment (Lillywhite 2006). As a result, amphibians were shown to prefer artificial covers with higher moisture content underneath them, even when the difference in moisture content was as low as 10% (Grant et al. 1992). Adding a layer of sawdust underneath the covers can increase moisture content with positive results on detection rates (Lange et al. 2020). For frogs, PVC pipes (typically with a drain hole on the side to prevent overflowing) placed perpendicular to the ground, or tied to tree trunks, and filled with water, seemed to produce good detection and capture rates (Suriyamongkol et al. 2021).

The success rate of surveys, and habitat or species restoration increased as the requirements of the focal species were better understood (Croak et al. 2010). We suggest that the focal species behavior, thermal, and physical needs, as well as the thermal and moisture conditions of the study site, and the thermal attributes of the covers themselves, need to be studied in order to optimize the use of artificial covers and to select the best cover type. For example, tin might be a good material for reptile surveys in temperate regions as it heats up fast and has a good heat retention, but it may overheat in warmer regions and deter animals from using it (Parmelee and Fitch 1995). For general surveys, with no particular species in mind, placing a variety of different covers to choose from may be the best option in hope that each species will be able to find a cover providing its preferred conditions. Capturing specimens, and attaching data loggers to them to measure the microclimate in their natural shelters, or offering them different choices of cover in the lab, can also allow better cover design and use rates (Arida and Bull 2008). Data loggers could then be placed under the covers in the field to validate that they produce the correct microclimate and adjust them accordingly (Thierry et al. 2009; Watchorn et al. 2022). Alternatively, surveyors could be equipped with temperature, moisture, solar radiation, air flow or other probes to measure the conditions on site and compare the conditions between occupied and unoccupied covers. Our review of cover preference studies suggest that amphibians and reptiles avoid covers that do not fit their needs, especially when better alternatives are available. Deploying covers is therefore a relatively risk-free sampling method, as covers that do not fit the animal's needs are unlikely to be used (i.e., Lettink et al. 2010).

It is possible that some of the results could be affected by biases caused by our choice to exclude several studies from the analysis. For example, we excluded studies in which researchers employed additional sampling methods (e.g., pitfall trapping) at the same site and at the same time as the cover objects were placed when measuring capture per unit of effort. Tom (2014), and Welbourne et al. (2020), placed artificial covers near pitfall traps, and counted individuals as captured in pitfalls even if they fell there while possibly being attracted to the covers. The omission of such studies may have artificially elevated the apparent efficacy of cover objects. Only a few studies were omitted based on such issues, and thus it is unlikely to have greatly affected our results. Choosing which category a material belongs to (e.g., wood vs. other) is sometimes subjective, especially when the study only gives a vague definition of the material used, and the size, shape and structure of covers may have as, or even more important, effects than cover material. This, together with the lack of overall effect of material we identify, suggest that further research is needed on the effect of types of cover on reptile and amphibian distribution and abundance, rather than just of cover presence.

Conclusions

The results of our review suggest that in general artificial cover objects greatly enhance both our ability to precisely survey reptiles and amphibians (e.g., by making individuals and even species that would otherwise be missed detectable), and evaluate the size and diversity of communities and populations, at least over short periods. Using artificial covers allowed animals in nearby areas to repopulate previously degraded habitats. Cover objects created ecological corridors, connected fragmented habitats, and potentially enhanced the carrying capacity of the surveyed areas. Further research still needs to be done on the long-term benefits, as well as risks of permanent cover placement and should include control areas to allow for a more accurate assessment of the effect of the covers on abundance and detection rate. As a survey tool, artificial covers emerge as a quick and efficient method to sample the local herpetofauna. Artificial cover surveys may not always yield the highest capture per unit of effort but, in several cases, they were found to be the only method capable of detecting certain species. This by itself is enough to justify their use, alongside other survey methods (visual surveys, pitfall traps, etc.), especially when the purpose of the study is to survey and identify multiple species within the study area.

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Author contributions Y.R.L: Literature review, writing: original manuscript, statistical analysis, prepared figures 1 & 2, conceived and designed the study. S.M: Supervision, prepared figure 3, conceived and designed the study, funding acquisition. F.B.A: Supervision, funding acquisition. All authors reviewed and edited the manuscript.

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Declarations

Competing interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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