USING ANIMAL BEHAVIOR TO GUIDE HABITAT RESTORATION

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Much of the world's biodiversity is threatened by human impacts to ecosystems. The World Wildlife Fund's "Living Planet Report" highlights that between 1970 and 2012 vertebrate populations have declined by 38, 81 and 36% respectively in terrestrial, freshwater and marine ecosystems (WWF 2016). Given that habitat loss and degradation are some of the main threats to biodiversity, the need to restore habitats is well-established, as highlighted by the recent announcement of the United Nations Decade on Ecosystem Restoration.

While restoration is urgently needed to preserve biodiversity, intended outcomes for wildlife in these projects, such as increasing abundance or re-establishing populations, often do not eventuate. There are several reasons restoration can fail wildlife, some of which are well understood, like the failure of plants to establish, and others that have historically received less attention. Restoration is often undertaken based on the assumption that if we alter structural habitat (e.g. replant vegetation, add structures to streams or into the ocean), then animals will colonize restored sites and be able to survive and reproduce, eventually creating self-sustaining populations. However, what happens if our fundamental assumptions about what constitutes suitable habitat for animals are incorrect? This is a potentially crucial reason why restoration can fail, but one that is not often considered.

Animals are continually making decisions about where to live, where to feed, and with which other animals to interact. By improving our knowledge of these decisions, particularly how and why animals make them, we can improve the chances that habitat restoration has the intended positive outcomes for biodiversity. In a recent paper (Hale et al. 2020), we highlighted two fundamental ways that unexpected behaviours of animals can cause intended restoration to fail, and how behavioural ecology can be incorporated into the planning and monitoring of restoration projects.


Willow flycatchers. Photo: Stock photo.

The first way animal behaviour impacts restoration relates to habitat selection (Hale and Swearer 2017). Many animals assess the potential suitability of a habitat based on environmental cues, which could come from the local environment (e.g. vegetation type, soil moisture), or from other animals (e.g. many marine fish are attracted to the smell of other fish; Coppock et al. 2013). When one of these cues is missing, animals may not colonize restored sites, even if habitat conditions are otherwise improved. For example, willow flycatchers (*Empidonax traillii*) may fail to recolonize

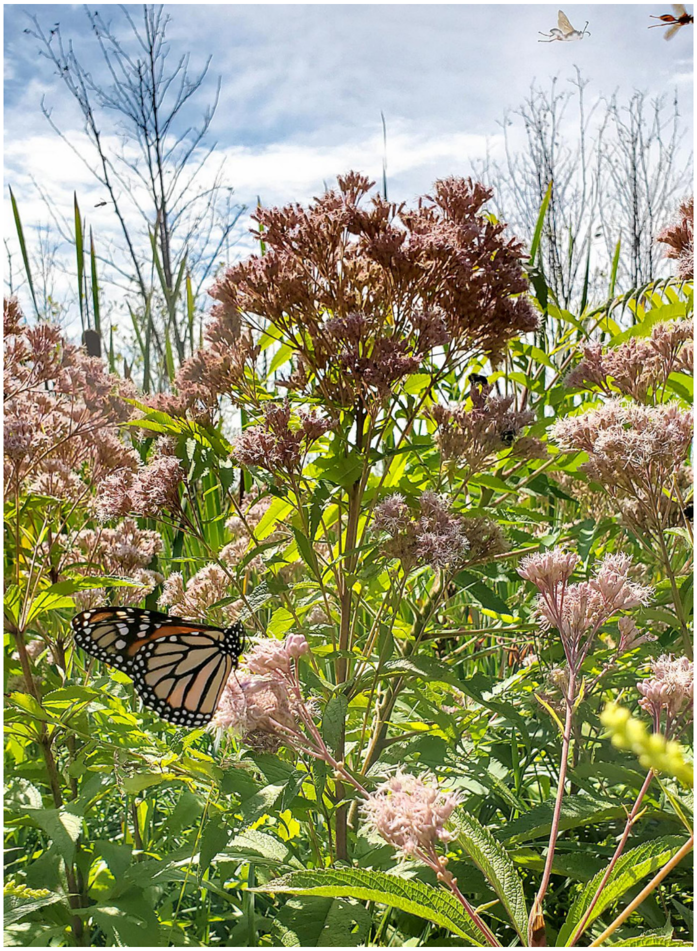


California ground squirrel and Western burrowing owl. Photos: Stock photo.

restored sites regardless of habitat suitability if these sites lack other calling flycatchers (Schofield et al. 2018). However, many restoration projects often assume that animals will colonize restored sites without considering the habitat-selection behaviour of animals (Hale et al. 2019).

The second way relates to whether habitat suitability in restored sites is simply driven by the presence of ecological resources (e.g. food and shelter), or whether there are more complex interactions that also need to be considered. We often understand the basic requirements for species and can ensure they are provided during restoration (Vesk et al. 2008a); however, complex behavioural interactions with other species can also be important drivers of habitat suitability. Like canaries acting as early-warning systems in coal mines, some species act as sentinels to warn others of the presence of predators. Birds like killdeer (*Charadrius vociferous*) have loud, distinct alarm calls that incidentally let other species of birds know that predators such as foxes are nearby. "Ecosystem engineers" are animals that can create, maintain, or destroy habitat for other species. Beavers (*Castor fiber* and *Castor canadensis*) have become an iconic example of an ecosystem engineer, but many other species have important impacts on habitat creation or maintenance; for example, the burrowing of California ground squirrels (*Otospermophilus beecheyi*) creates burrowes and maintains open vegetation habitat used by Western burrowing owls (*Athene cunicularia;* McCullough Hennessy et al. 2016). As these examples demonstrate, target animals that colonize restored sites may not be able to survive or reproduce if these kinds of components of habitat suitability are not present.

The phenomenon of "ecological traps" is a stark illustration of why we need to understand animal behaviour to improve restoration outcomes. We would expect animals to prefer habitats that provide the things they need to survive and reproduce. However, when the environment changes, some animals may make incorrect behavioural decisions, preferring lower quality habitats (a trap). Perhaps the most compelling example of an ecological trap is aquatic insects that mistakenly lay their eggs on artificial surfaces like roads rather than in water; the eggs subsequently cannot hatch and therefore die. These species have evolved to use polarized light as a reliable cue to locate water, but roads (along with other structures like smooth dark buildings) can reflect light in ways that make them even more attractive than water. Similarly, some marine turtles that use moonlight to navigate to the ocean after hatching are attracted inland by streetlights along the shoreline. Restoration can also cause traps: butterflies may breed in restored wetlands that subsequently flood, killing their offspring, while nearby wetlands do not flood (Severns 2011); trees and shrubs planted in savannah habitats might attract predatory birds, causing declines in lizard populations that are eaten by predators (Hawlena et al. 2010). If restoration inadvertently creates ecological traps, then it could mean animals are



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further threatened despite our best intentions.

How can we better incorporate knowledge of animal behaviour into restoration programs? The first step is to better understand these behaviours. For instance, which cues and senses do animals use to select habitats? Similarly, we need to understand all the factors that determine whether a habitat is suitable for animals – both in essential requirements such as shelter and food, but also for more complex behavioural interactions. In some cases, we may be able to source this information from published literature or through expert knowledge (including Traditional Ecological and Local Ecological Knowledge), whereas in other cases targeted research will be required. Once armed with this knowledge, we can use it to implement more fit-for-purpose restoration actions, or to better understand why some restoration actions fail. We may be able to modify habitats in cases of restoration failure, such as using song playbacks to attract birds to breed at restored sites (McCullough Hennessy et al. 2016). Our paper (Hale et al. 2020) outlines ways we can collect behavioural knowledge to guide the planning of restoration projects or to apply to help mitigate restoration failure. We also highlight situations when behavioural information is likely to be most important, and some of the practical considerations for its application in restoration.

Logistical constraints are important in almost all restoration projects, so several factors need to be considered when deciding to incorporate behavioural knowledge. First, it is likely to be most cost-effective to use behavioural knowledge to help plan restoration projects (e.g. making sure our actions immediately or eventually provide the things animals need; Vesk et al. 2008b). Some solutions to restoration failure, such as song playbacks, may be inexpensive. In comparison others may be labour- or resource-intensive or more complex, such as restoring habitats for both sentinels or ecosystem engineers and other interacting species. Second, collecting behavioural information at a wide variety of restoration sites in any system is likely to be logistically challenging; it may be better to include intensive research sites within a broad network of monitoring locations, with these sites used to collect information about animal behaviour, or to trial behaviour-informed solutions. We can also draw on precedents from the wider field of "conservation behaviour" (Blumstein and Fernandez-Juricic 2010) that shows using behaviour in applied situations is feasible. As examples, in situ predator training can improve the success of translocations to areas with predators (Ross et al. 2019) and knowledge of grizzly bear (*Ursus arctos*) learning is being used to developed warning systems in Canada to reduce train collisions (St. Clair et al. 2019).

Habitat restoration is urgently needed but often fails to have the intended benefits for animals. An improved understanding of the behaviour of target animals is an important component to improving these outcomes, and ultimately to ensure restoration helps to limit and reverse the impacts of habitat loss and degradation on biodiversity.

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