For an organism to have offspring, it must not only acquire enough resources to reproduce, but also survive long enough to accumulate and use those resources. For many species, predation is a major risk to survival. However, this presents a trade-off because it is often difficult, if not impossible, to simultaneously avoid predators and forage for resources. As a result, predators not only reduce their prey’s fitness through consumptive effects - by killing and eating their prey - but also through non-consumptive effects - the costly defenses prey animals use to avoid predation. Costly defenses from predation not only include physiological defense such as shells and camouflage, but also changes in behavior, such as altering habitat use, time budgeting, and tolerating the presence of conspecifics (Lima 1998).

Natural selection should favor strategies that minimize both consumptive and non-consumptive costs of predation to maximize fitness in a given environment. Models have shown how animals can optimize their movement in space (e.g. Bracis et al. 2018) and their behavior over time. Standard models of signal detection theory suggest that animals should avoid foraging when predators are prevalent and only forage when it appears to be safe. However, more recent state-dependent models make the opposite prediction; that prey animals should be more likely to flee when predators are rare than when they are common (Trimmer et al. 2017). Similarly, the risk allocation hypothesis suggests that animals should handle the trade-off between foraging and predation by only foraging when predators are absent if predators are rare, incurring low consumptive costs and higher, but acceptable non-consumptive costs. But that if predators are common, their prey should forage whether predators are present or not, incurring higher consumptive costs, but low non-consumptive costs (Lima & Bednekoff 1999).

The decision of when to be vigilant and when to forage can be innate, but it can also be learned from experience. However, learning about predators is not an easy feat. Predators are necessarily uncommon relative to their prey, cues are not necessarily reliable, and each encounter with a predator may be an individual’s last. Despite the high cost of not attending to an accurate cue, animals cannot respond to every potential cue of a predator or else they would spend all of their time being vigilant and never forage. However, that makes it harder to learn to attend to valuable cues from necessarily limited learning opportunities. One way of increasing the amount of learning opportunities is through social learning. For many species, it is more likely that a conspecific will be present than a predator, so they can learn whether a cue is informative more efficiently based on how conspecifics respond to it instead of just relying on the presence of a predator.

Models have shown how animals can use the behavior of others to determine when to be vigilant (Jackson & Ruxton 2006). However, much of the work on social learning has been done from a cultural transmission perspective (e.g. Boyd & Richerson 1985), though it has been applied to more ecological contexts (for review see Kendall et al. 2004). In the broadest sense, social learning is expected to only evolve when there are enough individuals in the population that can learn on their own, to generate new information for social learners to acquire, resulting in an equilibrium population of a mix of social and individual learners (Rogers 1988). Models of changing environments suggest that social learning should evolve when the environment changes too rapidly for the optimal behavior to have time to become innate, but slowly enough for information received from other individuals to still be accurate (Boyd & Richerson 1985). Dewar (2003) proposed a simple model of whether social learning about predators should be favored based on the costs of responding to and ignoring a predator if it is present or absent.

In this paper, I use mathematical and agent-based models to predict what conditions should favor the evolution of social learning to recognize a particular cue indicating the presence of a predator; heterospecific alarm calls. Animals of many species use alarm calls to detect predators. Alarm calls are usually thought to be intended to scare away the predator or warn other members of the same species. However, they can also be heard by members of other species that happen to be present. Heterospecific alarm calls can contain valuable information, possibly at a reduced cost relative to conspecific alarm calls. Though some species have an innate capacity to recognize other species’ alarm calls, they can also be learned from experience (Magrath et al. 2014). For example, gray squirrels (*Sciurus carolinensis*) have been found to respond more strongly to the familiar alarm call of the American robin (*Turdus migratorius*) than to unfamiliar, but acoustically similar alarm calls made by the common blackbird (*Turdus merula*; Getschow et al. 2013). However, it is unknown whether individual learning is sufficient to recognize alarm calls, or if instead animals such as grey squirrels rely on the responses of others to determine which alarm calls to attend to and which to ignore. My model evaluates whether selection should favor individual learning or social learning in the context of learning to recognize heterospecific alarm calls.