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RESPONSE

Response to concerns raised about the likelihood of protected areas serving as steppingstones for species responding to climate change

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Our recent contribution to Global Change Biology found that, globally, two-thirds of protected area units and over half of protected land area are unlikely to serve as steppingstones for many species under a warming climate (Parks et al., 2023). In response, Gillingham and Thomas (2023) point to previous evidence that protected areas have acted as steppingstones based on three studies from Great Britain that examined range shifts.

The first study found that 98% of the colonizing species analyzed ($n = 251$) were more reliant on protected areas than unprotected land (Thomas et al., 2012). The second study found that 62% of the butterfly and odonate (dragonflies and damselflies) species analyzed ($n = 99$) were more abundant in protected areas in newly colonized regions compared to the unprotected matrix (Gillingham et al., 2015). The third study found that bird species colonizing Great Britain usually established first in protected areas before expanding to unprotected lands (Hiley et al., 2014). Although these studies underscore the importance of PAs in helping species adapt to climate change—an importance we fully acknowledge—our research (Parks et al., 2023) provides nuance into factors that may impede successful range shifts among protected areas.

It is worth noting that a large proportion of the species in Thomas et al. (2012) and all species in Gillingham et al. (2015) and Hiley et al. (2014) have wings and can therefore fly, which means many of these species are highly mobile. As pointed out by Parks et al. (2023), such species are not likely limited by dispersal and, by inference, protected areas are more likely to serve as steppingstones for such species. Other species and lifeforms (such as plants) often have more restrictive dispersal abilities, so although "most species" in Gillingham and Thomas (2023) may have used protected areas for range shifts, this by no means equates to most species overall. Moreover, our study looks ahead to a period when temperatures are likely to rise at a greater rate than experienced by Great Britain during the period examined by Gillingham and Thomas (2023). Even in the absence of protected areas that harbor higher levels of biodiversity compared to the unprotected matrix (Brodie et al., 2023), others have concluded that climate change velocity exceeds the dispersal abilities of many species (Burrows et al., 2014) and human land use hinders the ability of many species to track climate change (Robillard et al., 2015).

Parks et al. (2023) clearly recognized that the biodiversity at a given site comprises innumerable taxa, with each species having variable dispersal abilities, sensitivities to human land uses, and climatic tolerances. As we did not claim that *all* protected areas were unlikely to serve as steppingstones for *all* species, we stand by our

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overall finding that protected areas are unlikely to serve as stepping-stones for *a large number of species* under a warming climate. We thank Gillingham and Thomas (2023) for an interesting debate.

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