change become increasingly apparent, more managers are likely to seek guidance from scientists as to when assisted colonization might be an appropriate tool to use. Humans have historically moved organisms for a variety of purposes, and at least two species have already been moved under the aegis of assisted colonization [7,8]. Thus, we believe that an attempt to prohibit intentional translocations of species for conservation purpose is excessively restrictive and unrealistic. A better approach is to debate the relative (and subjective) merit of all possible courses of action given current information under an agreed-upon framework.

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Letters

Managed relocation: a nuanced evaluation is needed

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Managed relocation (aka 'assisted colonization' and 'assisted migration' [1,2]) aims to save species from the effects of climate change by purposefully transporting them to areas where they have not previously occurred, but where they are expected to survive as temperatures increase. In a recent Opinion article in *TREE* [3], Ricciardi and Simberloff suggest that 'assisted colonization is tantamount to ecological roulette and should probably be rejected as a sound conservation strategy by the precautionary principle.' We disagree for three primary reasons.

First, the precautionary principle is not a stand-alone reason to rule out managed relocation. It states that 'Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'[†] In the context of managed relocation, 'precaution' cuts both ways, as a motivation to avoid relocations that might cause unwanted harm and as a motivation to act before a species is driven extinct by climate change.

Second, we know more about the impacts of species invasions than Ricciardi and Simberloff suggest, particularly with respect to species extinction. For instance, extinctions facilitated by exotic species occur primarily on islands (>90%) as opposed to continents [4]. Also, extinctions are generally caused by predation as opposed to competition; there are no documented cases to our knowledge where competition from exotic species has been the sole causal factor for the extinction of any native species [4]. Indeed, over the past few hundred years, thousands of exotic plant species have been introduced to islands around the world, but few native plant species have become extinct as a result [5]. Given sufficient time, competition from plant species might eventually cause extinctions, but this has not yet occurred. Collectively, these findings suggest that relocated plant species are unlikely to cause extinctions, at least over the next few hundred years, and especially not within continents. Other findings (e.g. Ref. [6]) exist that can help inform the risks of relocating species, both with respect to species extinctions and ecosystem functioning.

Third, because extinctions are permanent and irreversible, using managed relocation to reduce extinctions at the cost of changing the composition and functioning of ecosystems is a tradeoff that some managers might be willing to make. This will be particularly true if most changes that result from relocations are small, and if those that are large are not necessarily detrimental. In considering these tradeoffs it is important to recognize that 'most invasions appear to have only minor impacts' [3] and that these impacts are not necessarily detrimental. Indeed, many exotic species provide important ecosystem services; for example, invasive aquatic plants can maintain water quality and provide habitat for native species [7].

Ultimately, the risk of species extinctions from climate change is too large to summarily discount managed relocation without first carefully evaluating its benefits and dangers in a nuanced way. Beginning this process now will better position us to make informed decisions in the years ahead, as threats of climate-mediated species extinctions become more common.

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Letters

Assisted migration: part of an integrated conservation strategy

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As part of a group of conservation biologists working to develop a framework for the appropriate use of assisted migration, we read with great interest the recent Opinion article in *TREE* by Ricciardi and Simberloff [1]. Although we agree with several of their points, we believe that assisted migration could become an important part of integrated conservation strategies. Ricciardi and Simberloff focus on extreme examples of species translocations, including the 're-wilding' of North America with African mammals and other examples of intercontinental and long distance transport of species. We do not condone these practices as legitimate conservation strategies because we also recognize the risk of biological invasions.

There is no 'one size fits all' strategy for assisted migration; each case requires independent consideration. We envisage assisted migration as having a role that mimics the natural dispersal of some species across landscapes, tracking the leading edge of their shifting bioclimatic envelopes, and it should be undertaken only if a species is not capable of natural migration, plastic response or adaptation *in situ*. Enhancing traditional conservation strategies will probably improve the rate of species survival in the absence of more extreme intervention and we recommend this as the first course of action. In many habitats that have become fragmented owing to human activity, assistance in the form of short distance jump dispersal or corridor creation might become necessary to ensure species survival. These types of dispersal pathway are less likely to result in enemy release and biological invasion than are long distance and mass dispersal [2].

Many of the most alarming examples cited by Ricciardi and Simberloff involve the movement of freshwater organisms between lakes. Natural migration of fish and other species between lakes would have been very rare historically; the ecological impacts of artificially increasing migration rates, especially over long distances, are demonstrably severe. By contrast, many of us who are considering assisted migration as a conservation strategy work in once geographically continuous ecosystems where there were historically few dispersal limitations. These ecosystems, such as the tallgrass prairie, are now highly fragmented, and dispersal limitation under these circumstances can affect both species richness and ecosystem productivity [3].

We also disagree with the assertion that species considered for assisted migration lack a documented invasion history. Many species that are likely to be considered have already had populations restored within their native range or have been grown in botanic gardens and other cultivated settings both in and outside of their native range [4]. The practice of habitat restoration has also led to on-the-ground experience with the aggressive nature of some native plant species, particularly clonal and/or rhizomatous forbs (e.g. grass-leaved goldenrod, *Euthamia graminifolia*) and these taxa are now used very judiciously, if at all [5]. This resident knowledge base can, and should, be tapped to determine the invasion potential of species before they are considered for assisted migration.

We concede that the authors' assertion regarding the appeal of assisted migration to those in a field filled with doom and gloom is probably correct. The realization that a conservation strategy could ameliorate the predicted loss of species under climate change is indeed appealing. However, we disagree with the assumption that proponents of assisted migration, or those willing to develop the idea into a realistic and well-designed strategy, are contemplating the ill-conceived, massive translocation of species. In a separate article, several of us outlined a decision framework specifically designed to prompt careful consideration of the logistic, biological, social and economic issues underpinning the assisted movement of species [6]; other authors have offered a balanced view of assisted migration [7] and have begun the process of evaluating its appropriate use [8]. We also assert that, rather than paying 'little attention to the evolutionary context,' we embody a deep

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