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EE 522

Assisted Migration Paper

The idea of assisted migration is quite a controversial one in the conservation community. Some think it is a foolhardy notion without much nuance, while others believe that it is the future of conservation in the face of climate change. Assisted migration is the translocation of a species to a new habitat beyond its historical range. The reason why this topic is important is first because assisted migration is happening right now. Programs are currently ongoing and future programs are being debated about currently so knowing if this is even a beneficial strategy is crucial to those programs. Another reason why this is important is because of the rising effect of climate change. As carbon levels in the atmosphere continue to rise, warming the Earth, large amounts of species will need to find a new home, and may already need to (Sáenz-Romero et al. 2020). The problem is that many species, like many plant species, cannot disperse naturally to a more climate suitable area so they need assistance with their migration. As climate change grows as a problem it has raised the heat on assisted migration skeptics as to why the dangers of assisted migration outweigh the possible boon it could be towards fighting climate change and global warming. Many of the critics of assisted migration cite concerns with the unintended consequences of moving a species to a new place and the cost needed to do that since the project could easily fail, especially when the idea of assisted migration was first introduced (Hagerman et al. 2010). Some of those critics are more amenable to the idea of short term assisted migration with a critically endangered species. To protect it from imminent extinction, many scientists would let more things go. In response to the various environmental challenges that encumber our world, assisted migration may be an important solution, so with this paper we will stay in the solution space and analyze this conservation procedure.

Due to their stationary nature, species that fall under the plant kingdom have trouble dispersing when they need to. When their habitat is deteriorated it would be advantageous for them to move their range to a different place to avoid local extinction, but they can not always do that effectively. Therefore, humans may need to step in to assist in their colonization or migration to a new place. An example of this is a critically endangered wild orchid species in China, the *Paphiopedilum spicerianum*. This species had an extremely small population of just ten mature

individuals (Gao et al. 2020). A program was then set up to save the species which involved both a reintroduction and assisted migration effort. Ater the program was completed it was shown that the survival ratio of the reintroduced orchids was much less successful than the orchids under assisted migration (40% vs. 80%) after two years (Gao et al. 2020). The original orchid habitat worsened due to many reasons including habitat loss stemming from climate change and people over-collecting the pretty plant (Yang et al. 2020). For those reasons reintroducing the species to its original habitat has been difficult. Although the assisted migration program was more successful there are still problems, a main one being a lack of effective pollinators in the new area. This problem illustrates an overall issue with assisted migration programs. Outside of moving the endangered species, there is a litany of resources that a plant needs to survive which include both biotic and abiotic factors. Making sure every box is checked and all of the conditions are met is a complicated process that also increases the cost of the program. While the *Paphiopedilum spicerianum* population has recovered, there is still more work to be done to ensure the population can be self-sustaining, and not just fall back into being a major extinction risk after humans stop helping the species as much. Future research into pollination ecology and maybe even in vitro seed germination could be most helpful to ensure there is a future for the species in the decades to come.

One big issue people have with assisted migration that comes up in many critiques is the chance that moving a species to a new place could cause it to then become an invasive species that disrupts recipient ecological communities (Hewitt et al. 2011). As programs become more common and widespread there is a worry that it could get out of hand. In an interview with a multitude of governmental and industry experts on the subject, it was found that a common concern was the potential risk of migrated trees becoming invasive as assisted migration might trigger the introduction of harmful exotic species (Pelai et al. 2021). Since assisted migration moves a species to a place outside of their historical range, where they have not been before, it is understandable to have fear of it becoming an invasive species. In an assessment of the prevalence of this idea it was found that the risk of assisted migration to create novel invasive species is small (Mueller and Hellmann 2008, Brodie et al. 2021). The species that are chosen to be migrated in most circumstances are endangered species that are getting close to extinction. These types of species do not tend to be very successful or prolific wherever they go, therefore

the chance they become invasive is low. But, there is a caveat. If an assisted migration species were to become invasive, the consequences could be massive (Sáenz-Romero et al. 2021, Mueller and Hellman 2008). It is possible for a new species to come in and act like a classic invasive species that arrives without natural predators and takes advantage of an available niche to choke out any competition. The biological traits that promote a species becoming endangered are not just the opposite of those that favor invasiveness, necessarily. When evaluating assisted migration programs both the probability of invasion and severity need to be accounted for before going through with the project. It would be effective if the migrating species were evaluated for invasive characteristics such as early age of reproduction, high fecundity, or wide soil type tolerance (Sáenz-Romero et al. 2021). Also, concerning trees, nitrogen-fixers and clonal trees tend to be natural area invaders (Daehler 1998), so it would be useful to pay extra close attention to those types of tree species when moving them to a new location. Those types of trees share many characteristics with agricultural weeds who are prolific invaders. Maybe the biggest challenge to assisted migration is not that the program will work so well that the new species becomes invasive and spreads everywhere, but all the costs that come with a failed experiment, when a novel species never establishes itself in the new community and all of the effort and money put in, ended up producing nothing.

It is quite hard to successfully carry out an assisted migration project where the new species actually survives for a long period of time and can become somewhat self-sustaining in their new habitat. Because of this, there is an abundance of failed attempts (Novak et al. 2021) that cost a lot of time and money. Forestry-assisted migration can not only fail but can also incur enormous financial costs (Benito-Garzon et al. 2013). For this reason, many skeptics of assisted migration argue that the money could be used elsewhere that would help conserve nature in a better, more natural way. In Canadian forests, it was found that due to financial constraints, many assisted migration activities and features will not be feasible for many projects (Pedlar et al. 2011). In some circumstances, there is a spectrum for how much money you are given corresponding to how well you can do the assisted migration program with all the features necessary to do a really effective one. At times there may only be enough money to move a certain number of species, or that people can only stay and help the species for a certain amount of time, or there are fewer scientists working on the project. All of these limitations mitigate the

positive effect that assisted migration could have if there was more money. Another problem with assisted migration is a certain timeline that happens too often where scientists will carry out an assisted migration project, report their findings, leave the area, and then all of the species will die in their new habitat. No follow-up paper is published and no one knows that in actuality this enterprise was a failure. One of the harms of this is that other scientists read the paper, copy what they did, and then their program fails as well. There is a need for long-term monitoring and care for assisted migration species, but one big obstacle for that of course is the financial cost. Politically, there is a problem because "it may be politically perilous for policymakers to support assisted migration due to large financial costs" (Butt et al. 2020). Lawmakers and politicians might be worried that if an assisted migration project fails, which is not unlikely at all, then they will look really bad for approving something that yielded no positive results, and costed a ton of money to do. Instead, they may opt to fund proposals that have a lower chance of being really impactful, but a higher likelihood of not ending up as a perceived complete waste of money. Choosing the low risk, low reward path. The legal issues involved with assisted migration can prove to be tricky going into the future. With it being a relatively novel field, laws do not contemplate the extensive use of assisted migration as a broad strategy to manage climate change (Camacho 2010). There are laws in place in many places that support the more local movement of species to places they have not existed before though. In response to climate change, species, such as many tree species, might need to move across state and country lines, so working out the international politics is important. Nations need to create a system of assisted migration in order to move species most effectively. For assisted migration to scale up to the level of the problem that climate change is, laws need to be developed to allow for that scaling to be possible. There is also a lack of assisted migration regulation (Camacho 2010) to make sure that the people who are doing it are moving species in a safe way that does not disturb the recipient ecosystem too much. Assisted migration is still a relatively new field that needs a lot more research to be done. Current programs then have a fairly high failure rate, above fifty percent according to one assessment (Novak et al. 2021), and when people see that it could stop them from wanting future projects. It may be a useful idea to hold off on assisted migration programs right now, until we know more about how to do it, instead of failing many times until support vanishes before scientists become good at assisted migration.

Assisted migration in many cases that are happening currently, concerns itself with moving an endangered species in order to keep it from going extinct. Another, less common, but possibly more important type of assisted migration going into the future, is moving species to rehabilitate declining ecosystems and support biodiversity in recipient sites (Lunt et al. 2013). In the Minnesota Northwoods region assisted migration was recently used as a technique for forest restoration (Sullivan-Wiley et al. 2021). On public lands, trees were moved into declining forest ecosystems in order to replenish them. These trees were not native to the area but had an impressive 93 percent seedling survival rate (Sullivan-Wiley et al. 2021). The success of this program shows that assisted migration to rehabilitate and restore an ecosystem can work well and that this method is not just for saving an endangered species. This project stimulated enough interest that future ones were able to be introduced that increased the scope and impact of these types of assisted migration programs. Assisted migration of this type is not the classic method that restoration ecology tends to follow where the goal is to restore an ecosystem back to its original state and its original composition. Instead, a new ecosystem is made which attempts to fulfill the same role as the previous ecosystem did, before humans disrupted it, while containing a different composition of tree species. One more extreme form of this is to create a community of organisms where nothing of the sort was there previously. An example of this is seen is grassland restoration. North American temperate grasslands rank as being critically endangered (Hoekstra et al. 2005), as much vegetation has been lost due to agriculture conversion. Through assisted migration prairie communities can be constructed where none existed previously (McKone and Hernández 2021), with relatively low cost of time, money, expertise. Moving species into an area that has very low biodiversity and nature existing in it is a challenge. But to restore prairies and the beneficial services they provide, actions like these may need to be taken. Plant species that would be chosen to move would be ones that tend to already be abundant and prolific in other grassland ecosystems. Whether the restoration project is as adventurous as this one, or of a more manageable type, using assisted migration in this way could yield great results.

Protecting forests and the trees within them is a very important conservation problem. The Adaptive Silviculture for Climate Change (ASCC) program proposed that a solution to this issue could be assisted migration. They perform multiple assisted migration experiments to see how moving species to various places under different circumstances would work. In one recent

experiment, assisted migration was done with trees of the red pine forests in northern Minnesota (Wiechmann 2020). Trees were moved into four different treatments including one a "no action" control. The goal of moving these tree species was not only for them to survive in their new home, but to also develop into a tree population that was less vulnerable to the future effects of climate change. Successful migration of tree species is important to keep tree populations at a high enough level, but also very important to many other species, such as numerous animals, that rely on the trees and the forest as a habitat to live in. The treatment which had the lowest mortality, highest structural diversity, and better climate-adapted species composition was the "transition" treatment (Muller et al. 2021). This treatment, of the three experimental conditions, had the aim of having tree species that changed the most in composition from their original state. Other treatments opted to maintain the current tree types and attributes when moving them to a new location, accepting less change. Those treatments were dominated by red pine trees (Muller et al. 2021) and did not include many other tree species. The transition treatment, therefore, had greater biodiversity in their tree populations, making them more resilient to possible extinction-causing events and possessing all of the various other benefits that having greater biodiversity offers. This assisted migration example shows us that adapting more to the rapidly changing world around us may be the most effective option. Instead of just moving whatever trees exist in a forest into a new place, one can pick and choose the types of trees that would be most likely to survive in the face of future effects of climate change. This combats other people's ideals that we should be trying to return nature to a previous state before humans started disrupting the environment in major ways. A new normal though could be necessary to be established, as returning to the past could be an impossible feat to accomplish. Helping move but also change species could be the most effective way to do assisted migration.

The big driver of climate change now and into the future is global warming due to anthropogenic causes. One direction to move species is to move them towards the poles where it is colder to reach a habitat that is more suitable. Another strategy is to go up. The cloud forest tree species, *Magnolia vovidesii*, is native to Mexico and is an endangered species. One potential solution for this tree species to recover is to move them higher up elevation gradients to places that have lower temperatures (García-Hernández and Toledo-Aceves 2020), but that they have never lived before. To study this, saplings were planted at various elevations, including the

normal height that *Magnolia vovidesii* usually live at as well as eight other forest sites that were either higher or lower than their current elevation. It was found, with statistical significance, that the sapling survival rate increased with elevation (García-Hernández and Toledo-Aceves 2020). Although, at the very highest sites survival rate was poor. The best elevation was 600 meters above the current limit of their distribution and a move there could mitigate climate change effects. One of the problems associated with moving tree species and other species up elevation gradients is the lack of available space. In general, geographic features such as mountains decrease in overall surface area the higher one goes up the mountain. This makes it so that scientists can not just move all the tree species they want up the mountain, and some species are inevitably going to be lost. Moving species into higher elevation forests though could be very important as high elevation forests have a disproportionately large effect on their environment, as they, "regulate snowmelt and water quality" (Esser 2020) for the ecosystems below them. For this reason, it may be vital to move tree species to higher elevations not just to save the species at lower elevations. But also to make sure higher elevation forests are replenished with more trees. One does need to be careful though when introducing new trees into these higher elevated forests as disrupting the ecosystem services that they provide could be costly to all the ecosystems below them that rely on them.

Another example of a tree species moving to a higher elevation is the *Pinus psuedostrobus* conifer species which is native to central-western Mexico. This species has been decimated by the effects of climate change, specifically, the problem that drought stress has imposed on it, which is especially harmful because it is one of the most economically and ecologically important conifers in the area (Gómez-Pineda et al. 2021). Another tree species that has a naturally higher elevation is the *A. religiosa* which has been depleted in recent years due to climate change. The feasibility of upward assisted migration of *P. psuedostrobus* to fill the space left by many *A. religiosa* tree species dying was tested. It was found that moving the species did not decrease the survival rate or the tree population's average height (Gómez-Pineda et al. 2021). This would be crucial to protecting higher elevation forests that are so important to the ecological communities around them. There is also an unfortunate economic opportunity in that these trees may be cut down for their valuable lumber. Mountains, in general, get more rain than places at lower elevations (Crouch 2021), so moving *P. psuedostrobus* to a higher elevation could

really help them decrease the effect that droughts have on the species, helping rehabilitate their populations, now and into the future when droughts could become more prevalent. One important consideration when moving tree species in this manner, especially ones like *P. psuedostrobus*, which experience drought stress, is which side of the mountain one moves them too. Moving them up the windward side of the mountain or mountain range is important as that side receives much more precipitation than the leeward side of a mountain does (Crouch 2021). For tree species like *P. psuedostrobus* Moving tree species up in elevation is a very viable strategy of assisted migration and one that could help save many endangered species.

Douglas fir is a tree in the pine family that has been a very important source of timber for humans. Due in part to its great economic value (Lang 2021), the Douglas fir is one of the most common trees in North America. The problem is that studies have shown that Douglas-fir productivity generally will decline under climate change (Hashida et al., 2020). This is because of environmental degradation that is occurring due to anthropogenic climate change which destroys the Douglas fir's habitat. Douglas fir has a long history of humans deciding to plant them and the tree successfully growing. The reason humans did that was not for conservation reasons, but mostly to garner economic gain. The same types of methods and techniques can be used though to plant new Douglas fir in various areas. One big difference though is that the aim of assisted migration of Douglas fir is to move them towards an area away from their natural range. Elements of climate change such as global warming have made it so the Douglas fir's current habitat might not be suitable in the future for the tree and movement may be a needed course of action to save the species from rapidly declining in population. The question of how to most effectively move Douglas fir is an important one as some migration projects have fared better than others. Another way that Douglas fir are involved with climate change and assisted migration is across the pond in Europe. Douglas firs are not a native species in Europe but have become quite popular ever since their introduction in the 1800s (Spiecker 2019).

One example of assisted migration with Douglas fir is an experiment where various provenances of the tree species from a variety of origins were planted in Poland to test their ability to survive (Niemczyk et al. 2021). They found that in places that had been affected by the effects of climate change, specifically a decline in precipitation, certain Douglas fir provenances

performed quite well, and had high productivity (Niemczyk et al. 2021). The types of trees which performed the best were ones that come from North American areas which had low precipitation so they were well suited to survive well in this new area. Choosing Douglas fir trees for assisted migration specifically, in a way that their attributes align with the main problems occurring in the area they are moving to is important to do. This type of cross-continental assisted migration has people very worried about Douglas fir's impact on the local ecosystem in certain places. In this instance, Douglas fir species that had originated from the interior parts of North America, in places like interior British Columbia and interior Washington state performed the best. But in other circumstances, which is the norm, coastal species perform better as seen in other experiments (Smolnikar et al. 2021). In addition to coastal vs. inland, elevation also matters. In assisted migration experiments of Douglas fir, it was seen that the tree species did not perform well when being moved up in elevation (Sang et al. 2021). This is a problem with Douglas fir migration, where instead of moving trees northward or southward towards the pole, the scientists wish to move them higher up, Douglas fir might not be the most effective choice. This limits its versatility as an assisted migration tree that can come into a climate change deteriorated area, and replenish it with new trees. How native species will react to this new tree entering may be a problem. But many see the Douglas fir as a sustainable tree species for the future that can be migrated fairly easily and effectively while other tree species have more trouble doing so. As global warming-induced climate change increases organisms will have to move away from where they have lived for many years in order to keep surviving. Plants have great trouble doing that due to their dispersal limitations when compared to other species so they might need help in migrating to their new range. Douglas fir could be a prime candidate as an example of an important popular tree that makes a big move.

In recent years, the field of assisted migration is moving in a new direction towards a discussion of long-term assisted migration as a response to climate change. This is a gamble that some say is too big of a risk and takes attention away from the strategy of just reducing carbon emissions to cut off the problem at the source. But if the climate keeps changing at the rate that it is, drastic measures may need to be taken, and in order for those measures to be taken, they need to be researched and tested first, which is what some other scientists wish to do. The main problem in most assisted migration experiments is that the migration is unsuccessful and all the

species die while losing a lot of money and resources. An additional problem is the risk of a migrating species becoming invasive. Another problem is that the future of where the field of assisted migration is going is towards finding new long-term permanent homes for species, which introduces many complexities and unforeseen circumstances that are hard to plan for. Political and legal issues will also be an obstacle to overcome. There are numerous examples of assisted migration experiments and programs that have been effective, moving species all around, such as towards the poles or to places with a higher elevation, contributing to the idea that it is a viable strategy right now. Trees are a prime candidate for assisted migration due to their lack of dispersal capability, and also due to their great economic and ecological importance. Making sure trees are moved in the most effective way to save endangered trees and replenish declining forests will be very important. It is hard to build something that lasts for decades or centuries on end, especially when that thing is alive. The list of successful assisted migration experiments is not a very lengthy one, contributing to the idea that it is just too crazy of an idea to work in the real world. But finding a solution to that problem has the potential of being revolutionary in the field of conservation, opening up a new world of how to prevent species from going extinct and how to solve the issue of anthropogenic climate change. It is common for many scientists to adhere closely to a precautionary principle type of thought process with one expert saying “It is also necessary to justify why even relatively low risks should be taken” (Hewitt et al. 2011). The reason to do that is because there is a great risk of incredible environmental destruction due to climate change, which is bigger than the risks associated with the harms of solutions to climate change. Overall, weighing all of the benefits and harms outlined here and other factors that exist, I would say that assisted migration is a useful tool to save endangered species, especially trees, and that assisted migration will be very important in the fight against the effects of climate change.

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