Appendix 2 Global case studies of experimental assisted colonisations

Conservation translocations have been the subject of a number of reviews and Appendix 3 and 4 provide summary details for fauna and flora translocation reviews respectively. The majority of translocations have tended to be reintroductions with some augmentations, rather than conservation introductions, particularly for plants. Translocations that introduce species beyond their known range to avoid extinction due to climate change (assisted colonisation) did not feature in these reviews and very few cases have been documented. Whilst there is a paucity of empirical evidence (outside of forestry operations) to underpin policy on assisted colonisation, the effects of climate change are increasingly being considered in translocation and conservation guidelines. Table 1 in this report provides extracts and examples of recent documents that reference assisted colonisation for biological conservation purposes. However, some 'assisted colonisations' have been undertaken on an experimental basis and are detailed below.

Case study 1: Wild Orchids in southwest China

Liu H., Feng C.-L., Chen B.-S., Wang Z.-S., Xie X.-Q., Deng Z.-H., Wei X.-L., Liu S.-Y., Zhang Z.-B. & Luo Y.-B. (2012) Overcoming extreme weather challenges: Successful but variable assisted colonization of wild orchids in southwestern China. *Biological Conservation* **150**, 68-75.'

In southwestern China in 2006, 1000 endangered wild orchid plants were translocated to higher elevations to avoid inundation from human development. All of the species translocated were growing at 350 – 400 m above sea level and were translocated to ~ 1000 m above sea level. The largest elevation difference was approximately 3.6 °C cooler. Some of the species were translocated beyond their natural elevational range (i.e. only known to occur below 900m above sea level) whilst others are known to exist beyond 900 m above sea level. The study compared the impacts of multiple stressors (extreme cold spell, extreme drought, herbivory and initial translocation stress) of the out-of-range plants to the within range-species of 20 orchid species (462 individuals) for 5 years.
Results from individual stressors:

- An extreme cold spell accounted for < 10% of total plant mortality. All of the mortalities were from the out-of-range species but due to large variances, this was not significantly different to the within-range species. The majority of the species that recorded mortalities are not found above 700 m, with one species (350 – 500 m) suffering 90% mortality due to cold stress.
- No translocated plants died due to extreme drought conditions.
- Less than 10% of total plants died due to translocation stress. Interestingly, more within-range species failed to acclimatize than out-of-range species but variation was high and the result was not statistically significant.
- Herbivory from insects and mammals accounted for 21.6% of total plant mortality, causing higher mortality rates than the climate extremes (or transplantation stress). Mortality occurred in only three species, of which two were out-of-range species but difference between total individuals was not statistically significant between the two groups.

Overall, 60.4% of individual plants survived after five years. There was no survival difference between the within and out-of range species and the experiment was therefore considered an example of a successful assisted colonisation. All species flowered at least once one year after the translocation. No seedlings were observed within 0.5 m around the transplanted plants during the 2011 survey. The cost of project was 10 million RMB ($1.5m USD at the time of publication).

Case study 2: European forest herbs
Van der Veken S., De Frenne P., Baeten L., Van Beek E., Verheyen K. & Hermy M. (2012) Experimental assessment of the survival and performance of forest herbs transplanted beyond their range limit. *Basic and Applied Ecology* **13**, 10-9.

Four European herb species were transplanted in a northerly direction, beyond their known range to two transplant sites in Belgium. The minimum distance from the northern range edge of each species to the transplant site was different for each species: 50, 100, 200 and 500 km. After seven years, the species planted 50 and 200 km from their most northerly range edge had a high and intermediate success rate respectively. The success rate of species transplanted at 100 km was poor and no plants transplanted 500 km from their native range edge survived. The authors note that the poor results for two of the species are inconsistent with anecdotal evidence from European nurseries that sell many native species approximately 1000 km north of their current range edges. The inconsistency may be due to unqualified factors that could affect survivorship. For example, inappropriate seed origin and seed quality may contribute to low recruitment of the underperforming species. This experiment demonstrates that three of four species investigated can tolerate climate conditions outside of their native range and could be considered as candidates for assisted colonisation.

Case study 3: Seed germination beyond range limits in orchids
Keel B. G., Zettler L. W. & Kaplin B. A. (2011) Seed germination of *Habenaria repens* (Orchidaceae) in situ beyond its range, and its potential for assisted migration imposed by climate change. *Castanea* **76**, 43-54.

A 5.8°C increase in mean temperatures is expected over the next 50 – 100 years in the south east of the USA. Organisms with a requirement to stay within their current climatic envelope will need to shift 580 km north. Orchids are wind dispersed and considered to have good potential to range shift to stay within their climate envelope. However, orchids are thought to be particularly vulnerable to climate change because they are reliant on fungal associations. The aim of this study was to assess the ability of seeds from a southern provenance of a generalist orchid, *Habenaria repens*, to germinate *in situ* when buried at five sites at its northern limit and up to 850 km beyond its natural range. Seeds were buried without fungal inoculation and after five months the hyphal growth on the protocorms (leafless seedlings) was assessed. Only two of the five sites produced protocorms with active mycoflora (fungi). The authors conclude that it is possible for southern populations of *H. repens* to germinate up to 850 km beyond their natural range, provided active mycoflora is present.

Case study 4: Butterflies in the United Kingdom
Willis S. G., Hill J. K., Thomas C. D., Roy D. B., Fox R., Blakeley D. S. & Huntley B. (2009) Assisted colonization in a changing climate: a test-study using two U.K. butterflies. *Conservation Letters* **2**, 46-52.

Two butterfly species that are naturally expanding northward in the UK, but whose migration will possibly be interrupted by barriers, were used as test cases of assisted colonisation. Species distribution models calibrated with three climate variables were used to predict the potential habitats of *Melanargia galathea* and *Thymelicus sylvestris.* As a result of the modeling, the two species were introduced 65 and 35km respectively north, beyond their known range. This experiment was deemed to be successful, both from the modeling approach and from species' perspectives. After 6+ years, populations had established and expanded at a rate similar to other naturally-colonised sites of migrating butterflies. Furthermore, the pace at which the assisted migrants expanded their range was consistent with other naturally expanding butterfly species, < 1 km / year. However, the pace of their expansion is less than the current ~4.5 km / year northwards shift of the northern British isotherms. Therefore, the assisted migrants are not keeping pace with climate change and their introductions may need to be extended north to match or pre-empt changes in the suitable climate niche.

The use of assisted colonisation in the forestry industry

The forest industry has a long history of moving tree species and genotypes within and beyond their natural range to increase productivity. More recently, many high latitude foresters, particularly in Canada, have planted tree species beyond their current range as a climate change adaptation strategy to offset the expected decrease in productivity (see Table 1 in main document).

Case study 5: Hardiness and growth in trembling aspen

Schreiber S. G., Ding C., Hamann A., Hacke U. G., Thomas B. R. & Brouard J. S. (2013) Frost hardiness vs. growth performance in trembling aspen: an experimental test of assisted migration. *Journal of Applied Ecology* **50**, 939-49.

In a ten-year reciprocal transplant experiment in western Canada, seeds of *Populus tremuloides* were collected from and planted at five sites within its natural range. In addition, seeds were collected from Minnesota and planted at the five sites. The maximum distance between seed sources was 2300 km from Minnesota (north-east USA) to north-east British Columbia (western Canada); a difference of 11° latitude and ~5°C cooler in mean annual temperature (based on the 1961-1990 period). There were pronounced increases in height and biomass of non-local provenance plants compared to local provenance plants when moved in the direction of cooler climates. Whilst there were clear regional differences in phenological traits associated with frost tolerance, after ten years, this did not translate into inferior survival or growth by the plants sourced from warmer locations. The reciprocal transplant also demonstrated that where the northern provenances were planted into southern regions, their performance was inferior to the local provenance. These results suggest that genotypes of *Populus tremuloides* from warmer, southern locations should be planted at sites in a north-westerly direction to cooler climates. The authors conclude that failure to move genotypes of *Populus tremuloides* to cooler climates will have negative consequences for the forestry industry.

Forestry translocations have not always been successful. Translocations of *Pinus pinasta* from Spain/Portugal to France in the mid-1950s failed because the southern populations were maladjusted to the infrequent extreme frost events (Benito-Garzón *et al.* 2013). Consideration should be given to extreme weather events, not only averages, and adherence to an adaptive management strategy is recommended (Benito-Garzón *et al.* 2013).

REFERENCES

Benito-Garzón M., Ha-Duong M., Frascaria-Lacoste N. & Fernández-Manjarrés J. (2013) Habitat Restoration and Climate Change: Dealing with Climate Variability, Incomplete Data, and Management Decisions with Tree Translocations. *Restoration Ecology* 21, 530-6.