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SUBMISSION TO STANDING COMMITTEE ON CLIMATE CHANGE, ENVIRONMENT AND THE ARTS

NEW INQUIRY INTO AUSTRALIA'S BIODIVERSITY IN A CHANGING CLIMATE

Maintaining biodiversity under climate change is going to be challenging. This submission is aimed at highlighting 5 key issues that have not received much attention in discussions so far. The submission also highlights some major knowledge gaps where additional research is required. The material is based on recent publications from our group reviewing some of the issues involved (see bottom of submission).

1. Species, communities and ecosystems are not static entities and this needs to be considered in natural resource management

Much of biodiversity management treats species, ecological communities and ecosystems as static entities incapable of adapting to climate change. This leads to predicted high rates of extinction in animals and plants from some local regions in Australia and elsewhere.

Yet natural populations are responding to global climate change both through altered timing of life history traits, geographical shifts in species ranges and potentially altered ecosystem interactions. If populations change genetically and can evolve and adapt to these predicted environmental changes, then species extinction risks because of climate change might be substantially reduced.

Recent studies have highlighted that evolutionary change can be rapid, including in species that have invaded new areas and in native species responding to biotic invasions. This indicates that evolutionary adaptation can be an important way for natural populations to counter rapid climate change, and that predicted colonization patterns and distribution shifts will almost certainly be affected by the inclusion of evolution into models.

There is already evidence for rapid evolution in response to climate change in several short-lived species (including in our own work with Drosophila flies and work with birds by a group from the ANU), suggesting that organisms have the capacity to respond to climate change within a time frame of tens of years.

Because some species will adapt and others will not, natural communities are expected to shift in composition under rapid climate change. This means that natural communities and ecosystems should not be seen as static entities, but rather as collections of species changing dynamically through time. Attempts to conserve vegetation and fauna based on the notion of stable communities may therefore be misplaced.

Actions

- Develop ways of reclassifying communities based on climate change resilience, and recognizing the dynamic nature of communities and ecosystems.
- Identify species likely to increase and decrease under climate change based on resilience and adaptability (below).

2. **Species adaptability and resilience is poorly understood and species distribution modelling is an inadequate predictive tool.**

Rapid climate change is likely to produce a range of new selection pressures on populations. Species will persist if they can adapt to deal with these selection pressures. Increasing periods of thermal stress and drought will produce selection for resistance, particularly in species close to physiological limits. An inability to adapt will create losers and drive species to extinction.

Climate change will also favour species that can adapt to take advantage of favourable conditions. Warmer conditions may select for earlier emergence from winter diapause and for dispersal to new environments as species take advantage of conditions that become newly favourable. The species that can adapt may well become winners.

The challenge for biodiversity management is to pick winners and losers so that outcomes can be managed. Some species will be capable of adapting to the effects of climate change through evolution and plastic changes, whereas others will not.

There is emerging evidence that particular characteristics of species groups can help predict whether species are winners or losers. For instance, overseas work indicates that plants that rapidly shift their flowering times under changing thermal conditions appear to have a high potential to adapt, whereas plants whose flowering time responds mostly to photoperiod have a substantially higher rate of local extinction. Unfortunately we don't know a lot about environmental cues affecting flowering time in many Australian native species. A recent study by my group of alpine plants suggests that some alpine species are not particularly plastic in their flowering time, but there are exceptions. This type of information can often only be collected through long term ecological research, which has been poorly funded in this country.

Local research in our group also suggests that invertebrate species from different environments are likely to vary in their adaptability. Species from moist rainforest environments are appear to have a low potential to adapt to dry conditions through evolutionary change, unlike more widespread endemics. Susceptible species with a low evolutionary potential (low adaptive capacity) can be identified if genetic variation has been characterized for key traits limiting distributions. Where genetic variation is very low, there is likely to be limited evolutionary potential to adapt, as in the case of the response of rainforest Drosophila to low humidity conditions. Evidence for limited abilities to adapt to climate change also comes from vertebrates. For instance, some tropical lizards existing close to upper thermal thresholds that are likely to be exceeded in the next few decades may also show a low level of adaptability.

Species distribution models are often used to predict where species will go in the landscape as climate change occurs. At present, correlative distribution models are particularly popular for predicting distribution shifts, because these models require little biological information of the target species and tend to only consider correlations between species distributions and climatic variables.

However, these models have serious limitations and do not explicitly consider species adaptability. Their performance has often been poor when predicting the geographical ranges of introduced species. These ranges often cover climate space outside areas in the native ranges of the species, pointing to the importance of factors such as rapid evolution and species interactions in driving range expansion.

Evolutionary changes in traits and other aspects of adaptability could be incorporated into other classes of models for predicting species distributions. For instance, mechanistic models of energy and mass transfer for organisms and their microclimates start from first principles to identify the traits that limit distributions, which can then be allowed to evolve. Such models are not available for the majority of Australian species but could be developed for key threatened and threatening species. For instance, they have already been developed to predict the distribution of disease transmitting *Aedes mosquitoes* in Australia (Kearney et al, Functional Ecology 2009).

Actions

- Develop predictive models for key representative species that allow aspects of adaptability to be included in the models. Species to be considered include those that are highly threatened as well as others that drive ecological processes in ecosystems.
- Assess the adaptability both in terms of evolution and plastic changes of representative species from key Australian plant and animal groups. This might include testing their ability to survive stressful extremes of temperature and drought. (particularly for vulnerable life stages, such as tree seedlings and juvenile animals). It is important to include invertebrates like butterflies, as well as vertebrates in this exercise.

3. Threatened species recovery programs need to incorporate climate change considerations (but have not generally done so).

Our threatened species are particularly vulnerable to climate change because of their small population size (which limits adaptive capacity and increases susceptibility to stochastic events like environmental catastrophes), (often) localised distribution, and (often) low competitive ability/proneness to predation. Species recovery programs currently rarely consider adaptive capacity in response to climate change when developing management options. Yet management options are available for threatened species that could increase their resilience under climate change. Management plans should aim to develop resilient populations where the adaptive capacity of species can be conserved. This can be achieved by considering ways of enhancing genetic diversity and the evolutionary processes that generate and sustain biodiversity.

Genetic diversity is typically divided into two categories. Adaptive genetic diversity underpins the way an organism adapts to a new environment. In contrast, neutral genetic diversity involves parts of the genome that are not under natural selection, and it does not directly reflect or measure the adaptive capacity of organisms. Yet conservation biologists working on threatened species have largely focussed on neutral genetic diversity, even though adaptive genetic diversity is needed for organisms to evolve and persist in rapidly changing environments.

Population size also directly contributes to adaptive capacity. We know that rates of adaptive evolution increase with population size up to at least a few thousand individuals. So how well do conservation efforts currently preserve adaptive genetic diversity and adaptive capacity? The answer to this question would seem to be ‘not very well’. When dealing with highly threatened species, there is often little opportunity to increase population size although breeding programs can maximize effective size. In addition, there is also adaptation to conditions of captivity resulting in reduced fitness of populations for eventual release into the wild. The current focus on maintaining neutral genetic diversity, rather than ways of maximising adaptive genetic diversity and thus adaptive capacity is a serious limitation of current conservation programs.

Moving individuals from one population to another (genetic translocation or assisted migration) within a species' current range is a way of conserving or enhancing the adaptive potential of species. This represents a potentially powerful, but largely neglected, conservation tool. More attention should be given to the strategic mixing of populations as a practical and cost-effective method of establishing viable populations that are capable of persisting in the face of environmental change. This approach has recently been implemented for a threatened Victorian population of mountain pygmy possum.

Actions

- Develop recovery programs that explicitly consider adaptive genetic diversity and likely effects of climate change.
- Consider the possibility of genetic translocation to increase the adaptability of threatened species. This may involve mixing gene pools across wide geographic areas.

4. **Revegetation programs with biodiversity targets need to take a precautionary approach.**

Revegetation is widely carried out to restore degraded landscapes. Because local adaptation is recognized as being commonplace, the focus has been on local provenance when making decisions about which seed to source for restoration and reintroduction programmes. A 'local is best' sourcing practice misses two important points, which may seriously impact restoration or reintroduction outcomes in the face of future climatic changes.

The first potential problem with 'local is best' recommendations is that there is a risk of encouraging the establishment of populations that do not harbour sufficient genetic variation and evolutionary potential (i.e., establish genetic ghettos).

The second issue is that particular environmental conditions driving local adaptation can change very rapidly, so local may not be best. In many regions of Australia, climate modelling indicates that conditions under which a 200-year-old tree established are likely to be quite different to those existing today. Source material from more distant (geographically and ecologically) populations will often harbour adaptations that more closely match the environment of the focal restoration site today.

From an evolutionary perspective and to build future adaptive capacity, it makes sense to mix seed across regions, with the source population being dictated by current and historic patterns of pollination and seed dispersal as well as fragmentation in the landscape. When revegetation is carried out for Landcare projects and other projects, guidelines need to be developed for key tree and understory species. Ideally, revegetation should allow for sufficient numbers of individuals so that natural selection can ensure high quality material into the future.

The development of connectedness in landscapes can help ensure the movement of individuals and genes along corridors linking environments and can increase evolutionary resilience. When populations are interconnected along climatic gradients, there is the potential for ongoing adaptive evolution. This will help to secure biodiversity into the future.

Actions

- Develop guidelines for revegetation programs that allow for ongoing selection and ensures that genotypes in the landscape match future climate conditions.
- Focus reserve development and revegetation efforts on areas where there are sharp climatic gradients to allow for ongoing adaptation in Australia's biodiversity.

Sources

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