Ecological interactions and climate change

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PLEASE NOTE: THIS IS THE ORIGINBAL ABSTRACT BUT I HAVE EXPANDED THE TOPIC SOMEWHAT IN THE MAIN TEXT, AND PARTS OF THE ABSTRACT SHOULD PROBABLY BE RE-WRITTEN

Abstract

The effect of climate change on wildlife is not likely to be simple, as ecological interactions and wildlife behaviour are often far from simple. This is a major problem for conservation of biodiversity, and also for tourism operators wanting to predict where various species will be reliably seen. A wompoo fruitdove may be well able to withstand some temperature increases, but will its food sources increase or decrease in particular local areas? If they decrease due to altered rainfall patterns, are there sufficient regions of appropriate reserved habitat for it to occupy in lean times? If resources increase in the highlands to the south of its range because of increased temperatures there, will they and the bowerbirds cease their altitudinal movements and compete more with species that cannot move downhill for winter? Will they and others fail to reach areas where seeds of trees, vines and shrubs need to be dispersed by them at certain times of year for the natural long-term replenishment of forest ecosystems? Will currawongs over-winter in places they have not been able to before, and cause serious declines in populations of small birds, as has been caused in the past by food provision during winter in high-altitude areas? Sometimes there is a chain of interactions not at all obvious until closely studied. For instance the Richmond birdwing butterfly, already a threatened species, relies on vines which in turn rely on pollinating midges which in turn rely on clear mountain streams for larval development. How many more such chains do we not yet know about that may be in peril with so-far unknown effects on each of the links? There have been serious suggestions of releasing northern rainforest species into more southern rainforest areas to conserve them as their original haunts become unsuitable, but what would the effects of such releases be on the animals and plants already occupying these regions? What are the most relevant and urgent questions we should be asking while there is still time to do something useful?

PLEASE NOTE: I HAVE RUN OUT OF TIME BEFORE THE CONFERENCE TO COMPLETE ALL RELEVANT ABSTRACTS ETC., AND CAN DO THIS ON MY RETURN TO QLD

Introduction

The effect of climate change on wildlife is not likely to be simple, because not only are there a lot of species, each with its own physiological needs and behavioural adaptations (which may not be capable of changing as rapidly as the climate), but also there is a multitude of ecological interactions between species which are often far from simple. Extensive information is available on the ecology and behaviour of some species, but even for these we may not know everything necessary to predict effects of climate change. Then there are many more, especially amongst the invertebrates, about which we know very little. How then do we even begin to predict the effects on important interactions between species within natural and other ecosystems, interactions which if disrupted could cause the loss of species locally and globally? This is a major problem for the conservation of biodiversity, and could also become a problem for ecotourism operators wanting to predict where various wildlife species will continue to be reliably seen.

An example. There is a midge, a small insect related to flies, living in the subtropical forests of the Qld/NSW border. In its larval stage it needs clear mountain streams, and as an adult needs to lay its eggs in clear mountain streams. Little else appears to be known about its ecology and behaviour, it hasn't even been formally named yet, and we simply don't know how it is likely to be affected by climate change. If it is at risk, I can imagine a lot of people saying 'So what? One little midge species gone' But this little midge pollinates the flowers of a few species of the *Aristocochlea* vine which are the essential food plants for the caterpillar stage of Australia's third largest butterfly, the very beautiful Richmond birdwing (Sands 2008). Lose the midge, in time we lose the vine, since it will no longer reproduce, and very soon after that we lose the birdwing. We know about this ecological link because the butterfly is beautiful, large, endangered and well-publicized, but we still don't know enough to predict what exactly will happen. How many other strings of dependency are there that we know far less about in our rainforests, outback deserts, coral reefs, even the habitat we are most familiar with, the typical Aussie bushland (open sclerophyll forests and woodlands)?

Possible effects of climate change on single species

To predict the effects of climate change on interactions between species, we first need some understanding of possible effects on individual species. Climate change involves many factors that could affect wildlife, and these will vary in particular local areas:

- Temperature increase
- Temperature decrease (e.g. where warm currents are deflected)
- Increased rainfall
- Decreased rainfall

- Rising sea level
- Increases in extreme weather
- Increased fire frequency
- Other local effects (e.g. increase in physical damage to riparian communities by massive floods or to forests by cyclones)

Effects of the above on single species could include:

- Physiological reactions to temperature changes
    - A 3°C change in mean annual temperature (middle of the predicted temperature range over the next 70 years) corresponds to a shift of approximately 300 – 400 km in latitude (in the temperate zone globally) or 500 metres in elevation (Hughes 2000). Animals that can't take the heat will have to move
    - Pockets of high-altitude habitats such as alpine heath or cool temperate rainforest on mountain tops are predicted to eventually disappear, and the microclimates will probably become unsuitable to many animal species that now live there even before the vegetation has gone, animals that will not be able to move, as they have nowhere to go (Green and Pickering 2002)
    - Coral polyps have already been dying for some years now in response to higher than normal temperatures and changes in CO2 levels, resulting in dead, bleached coral on many reefs throughout the world (Hoegh-Guldberg 1999, 2005).
    - Black flying foxes seem unable to take sudden extremes of heat, sometimes dying in large numbers during heat-waves. Climate change could restrict or change their distribution (Welbergen *et al* 2007)
    - Climate modeling by the Australian Greenhouse Office in Canberra for the habitats of several Western Australian frog species predicts that the white-bellied frog (*Geocrinia alba*) and sunset frog (*Spicospina flammocaerulea*) are likely to disappear with an increase in average annual temperatures of just 0.5°C. (http://www.cosmosmagazine.com/news/1908/australian-species-increasing-climate-threat)
    - A study of captive Gouldian finches (Burton *et al* 2003) demonstrated heat stress at normal daily temperatures. These birds tend to forage early in the morning and late in the afternoon to avoid such heat stress. WWF is concerned that temperature increases could reach a point where these birds, already endangered in the wild, are incapable of foraging for long enough to satisfy their dietary needs.
    - Marine turtle tend to return to the same sites year after year for egg-laying but their eggs will not be able to withstand predicted sand temperature increases if they continue to breed on the beaches they have traditionally used (http://www.cosmosmagazine.com/news/1908/australian-species-

increasing-climate-threat).
    - One area of research in The School of Physiology at the University of the Witwatersrand, South Africa, is Wildlife Environmental Physiology focusing on the ecophysiology and thermoregulation of African, Australian and Arabian mammals including the possible physiological responses of wild mammals to global climate change.

- Changing breeding patterns
    - Birds that are geared to moult, migrate or breed by day-length, irrespective of whether temperature is now inappropriate (s.g. Beaumont *et al* 2006)
    - Some birds are starting to breed at higher latitudes
    - Turtles that have been breeding for decades in designated reserves may have to start breeding in more southerly, unprotected areas (Col Limpus, personal communication)

- Altered rainfall patterns: more water, less water, physical damage
    - About 10,000 turtles are estimated to have died when the lakes of Currawynia National Park dried out a few years ago (Peter McRae, EPA, personal communication), for the third time since white settlement in Australia. What will be the long term picture for these and other wildlife of the area if such droughts become more common?
    - Kangaroos are reasonably mobile, but their habitats aren't, and are predicted to shrink. Euan Ritchie and Elizabeth Bolitho of James Cook University estimate that the ranges of kangaroos will shrink due to drought rather than temperature increase, perhaps as much as 48% with a 2^{o} rise, and that the anitpoline wallaroo of the wet tropics could have its range reduced by 89% with the same rise.
    - Platypus have been in the upper reaches of Running Creek, in and near Lamington NP for decades of human memory, probably millennia, but have not been seen since the devastating floods in January 2008, which hurled large boulders around, felled over 90% of the trees in the creekbed (personal observation) and probably crushed the platypus burrows. If such extremes become more frequent, will they ever return to the local area?
    - Offshore islands have sometimes been hailed as a solution for animals that will not be able to cope with increased competition and other problems on the mainland, but neither these nor the animals already there can easily move from one island to another more suitable one, and what of the islands that diminish in size or disappear with rising sea levels or are battered by frequent severe storms? Albatross have been literally blown off their nests in stormy weather, and eggs and nestlings destroyed. Will this kind of scenario increase in frequency (and not just for albatrosses) with climate

change? There are many breeding colonies of marine birds in exposed areas throughout the world.
- Tree kangaroos and other arboreal rainforest mammals are very susceptible to direct injury and death when trees are knocked down by tropical cyclones, and affected also by the diminishing of their local food supplies.

Possible effects of climate change on interactions between species

Even predicting the effects on single species is difficult when there are so many variables we know so little about and so many species we've yet to discover and describe, let alone understand their ecology, behaviour or physiology. Every time Professor Roger Kitching's crew head into the rainforest canopies collecting insects ror BATH (see below) or other projects, they uncover many species that have never been named or described. Their ecology and behaviour is mostly unknown, apart from what can be guessed at from their anatomy and what is known of closely-related species. There is still much that remains unknown about the ecology and life cycles even about very common insects such as the scribbly gum moth and the granny's cloak moth: with climate change already starting to show its effects, there is no time available to collect information on all species or even a substantial proportion of them, but we need to find what we can, and prioritize our searches to maximize relevant information per unit effort. However, there are always surprising discoveries, so there is a danger also in sticking exclusively to the prioritized items.

BATH (Biodiversity At The Heights) is an ambitious two-year joint project of Griffith University and the Smithsonian Institute, the fieldwork for which has recently been completed, collecting invertebrates of various taxa at varying altitudes from 300m to 1100m above sea level in a subtropical rainforest. One if the aims is to find indicator species for the effects of climate change. If a taxon usually restricted to a lower altitude is found in future years to be occupying a higher altitude, or if a taxon restricted to the higher altitude becomes locally (and possibly globally) extinct, this will sound a warning that other, possibly very serious, changes could be imminent.

The complicating effect of interactions between species

Species do not live in isolation. There are very many processes involving two or more species, and the links will not always be obvious. There is great potential for disengagement of some of these links with climate change.

Species interactions may involve

- Predator/prey, herbivore/plant or parasite/host (i.e. one species feeding on

another, whether it is an animal or plant or part thereof being eaten)
- Mutualisms (especially pollination, seed dispersal and the miccorhizae fungi that help forest trees and other plants derive nutrients from the soil)
- Competition between species that have coexisted for a long time within a site, when one species is disadvantaged more than another by climate change
- Competition between species after migration brings new competitors into contact with each other
- Other interactions – e.g. physical damage to burrows, nests or general habitat by large or numerous invaders

Predator/prey, herbivore/plant or parasite/host

From the point of view of the predator or herbivore:

- The Arrow-head violet is already shrinking in is range through habitat loss, and may be further reduced by a drying climate, as it needs moist places to survive. Apart from being a very attractive little flower, it is the only known food plant of the Australian fritillary butterfly, a highly-endangered species
- An increase of carbon in the atmosphere causes some eucalypt leaves to create different levels of chemicals in their tissues. Big deal? We'll still have trees looking much the same. But some of the chemicals that increase are toxic to koalas and may be also to greater gliders, and some of the nutrients koalas need will decrease. Koalas are known to be very fussy about what leaves they'll eat, even within a eucalypt species How much of an effect will the changes in leaf chemistry have on koala populations? Well that's under study at present, but if no one had studied it in the first place we wouldn't even know that much until possibly too late.
- Drought conditions mean plants stop producing young tender leaves. This can mean starvation for anything dependent on soft, digestible leaves, from caterpillars and leaf-eating beetles through to greater gliders and koalas. It may not happen all year round, but how do we tell the larvae of the Richmond birdwing in September 'it;'' be ok, you can eat something in January.' Tropical rainforests of northern Australia are expected to become unsuitable for rainforest vertebrates, with fewer young tender leaves of the right food species (Williams *et al* 2003)
- Matthew Fitzpatrick, Aaron Gove, Nathan Sanders and Robert Dunn have been modellimg the effects of climate chane scenarios on banksias species in a biodiversity hotspot in southwestern Western Australia, assuming that the plants can travel via their wind-dispersed seeds about 5 km each decade. 55% of species are predicted to reduce their ranges across all nine scenarios modeled, and 89% reduce under 7 of the 9. Extinctions began in the year 2030 for all scenarios, but range reductions would be occurring well before this. Many birds depend on banksias for nectar and pollen, especially during the winter months. The honey possum is unique. For starters it is not really a possum but belongs to a family of its own. It is also the world's only

mammal totally dependent on nectar and pollen. Banksias are an important part of its diet. Can't it just switch to something else? Sarah Jennings of the University of Western Australia found that *Acacia* species could provide the protein it needs, but acacias don't provide much nectar, and in a harsh climate this little marsupial finds it more efficient to forage in plants which offer the combination of protein-rich pollen and energy-giving nectar in the same spot. Will banksias decrease within the honey possum's range? What about the eastern banksias that are fed on by the endangered regent honeyeater in some seasons, and also extensively used by other honeyeaters and blossom bats? Can they switch to other foods or are there some periods when not much else is flowering?

- An unacceptable prey item is moving into ever-increasing areas of Australia – the cane toad. Rangers used to be able to confidently take visitors to places where they could see the northern quoll, but these are now being poisoned by feeding on cane toads and now rarely seen. Redbellied black snakes and other predators have declined elsewhere after cane toads have moved in. A warmer climate in the southern parts of Australia and at higher altitudes may see the range of the toad extending further into areas currently too cold and bringing it into contact with other native predators.
- Increased fire frequency and intensity is likely to directly kill a lot of animals that may escape relatively low-intensity fires. Intense fires can also destroy the understorey and sheltering logs that animals such as the quoll, the potoroo and many smaller ground-dwelling creatures depend on, as well as the foods of low-foraging mammals such as potoroos and bettongs, birds such as gouldian finches and bristlebirds, and even large stands of trees such as the sheoaks (*Allocasuarina torulosa*) needed by the glossy black cockatoo (the tree itself may not become locally extinct, but massive numbers of mature fruits with the much-needed seeds can be unavailable for long periods after a fire). WWF considers that changes in fire regimes may increase invasion of introduced grasses into areas of native grasses favoured by bilbies. Bilbies, gouldian finches, emu wrens and ground parrots appear at least in some regions to have benefited by the kind of mosaic burning practiced by Aboriginals, but intense fires in large areas could eliminate their food supply.
- Air temperatures over the Southern Ocean have been increasing steadily since the 1960s, coinciding with a decrease in the abundance of both wandering and black-browed albatross, which breed in Australian waters. Warmer waters are more nutrient poor than cooler waters and the success of seabird feeding has been correlated with instances where a high degree of mixing between colder deeper nutrient rich water and warmer nutrient poor surface water occurs. In 2002, there were unusually high sea surface temperatures (SSTs), associated with reductions in food availability.

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From the point of view of the prey

- Crocodiles may move southwards. The optimal temperature for digestion is 30-32^{o}C, which currently limits their geographical range
- Some years ago, bird-loving residents of the cool hilly regions of Canberra and New England innocently planted lots of winter-fruiting plants such as hawthorn and cotoneaster in their gardens. The currawongs no longer had to move down to coastal areas in winter, and so remained in large numbers, ready to raid nests in early spring. Harry Recher (personal communication) recorded 100% mortality of nestlings in some remnant forest patches near Armidale. Higher temperatures in high altitudes could have similar effect of increasing food supply in winter. This could be bad for biodiversity, and won't do the bird-watching tourism industry in Australia much good either
- Some parasites may be favoured – one that will trouble humans is the malaria virus which will reach higher altitudes and higher latitudes. A parasite known as the French heartworm, normally restricted to southern areas in the UK has been found for the first time in a dog in Scotland. An oyster parasite once found only south of Washington is now infecting oysters in Maine. Researchers at Murdoch University are currently studying whether climate change will promote rage extensions and longer seasons of activity for parasites of marsupials, and what management plans may be appropriate.

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Mutualisms

Mutualisms are a common and important feature of ecosystems. There are many ways in which the partners involved in these ecological interactions could get out of phase with one another. The animal may move to higher latitudes or altitudes within one or a few generations, while the plant is unable to follow fast enough able to follow only by short-distance seed dispersal over many generations. One species may respond to changing day-length and another to change in temperature or rainfall - e.g. a flower producing pollen at a time of year when no pollinators are available, fruits ripening and then rotting before fruit eating birds and bats arrive from the north…

Wompoo fruitdoves are important seed dispersers in subtropical Australian rainforests (Green 1993), being one of the largest-gaped species, thus able to swallow large-seeded fruits most other birds can't manage, and being present throughout the year with only short-distance altitudinal movements (as opposed to the more nomadic topknot pigeon and the migratory rose-crowned and superb fruitdoves that head north for winter). Wompoos may be well able to withstand some temperature increases, but will its food sources increase or decrease in particular local areas? If they decrease due to altered rainfall patterns, are there sufficient regions of appropriate reserved habitat for it to

occupy in lean times, and will it be able to find all essential nutrients in the available fruits? If resources instead increase in the highlands in winter because of increased temperatures, will wompoos and other frugivores such as the bowerbirds cease their altitudinal movements, competing with other weaker-flying or more highly territorial birds that cannot move downhill for winter, and neglecting the dispersal of seeds in the valleys? There are too many variables to predict the outcomes, but the potential for problems in this and other mutualisms is real.

Diminishing of rainforests by storm damage and by drought, including the loss of low-lying clouds will diminish habitat for many species such as cassowaries and musky rat kangaroos which in turn are important dispersers of seeds of trees and vines which in turn provide important resources for other wildlife

There are some very specialized pollination systems, such as that involving the black lily (*Typhonium brownii*), the primitive *Eupomatia,* the 'birdwing vine' (*Aristolochia* spp.), figs and many orchids (Geoff Monteath, Queensland Museum, personal communication), plus many more that must exist that we as yet know little or nothing about. There is tremendous scope here ofr disruption of ecosystems. For a while, the forest may look unchanging, until we realize that some of the trees, vines and shrubs just aren't producing seeds any more.

Competition between species within a site

Black-eared miners at Gluepot Reserve were disadvantaged in the past when the construction of farm dams allowed the Yellow throated miners that benefited from extra water to move in and crossbreed with them (http://www.riverland.net.au/gluepot/birds.html). The elimination of most of those dams has now benefited the black-eared miner, which is better able to withstand drought that to withstand the onslaught of its yellow-throated relatives. What other effects will we see as climate changes benefit one species at the expense of the other (as the introduction of dams did)?

Competition between species after migration

Some species that cannot cope with the change will be forced out of their home ranges, but may not be able to compete with animals that are already there.

Others will be able to expand their ranges, either seasonally or year-round, possibly to the detriment of others that never before had to compete with them

Will nonflying or weakly-flying animals on islands suddenly find themselves competing with flying animals that are moving to higher latitudes, eating the same insects, nectar or fruits?

Will the same happen in habitat "islands", with less mobile species or those that cannot travel through intervening habitats being disadvantaged by newcomers that can do so?

Again, there is a huge scope for changes within ecosystems, with new plants competing with one another and new animals competing with one another.

Some ecologists have suggested bringing tree kangaroos and other tropical vertebrates into southern, subtropical rainforests before climate change eliminates them. The effect on the existing residents of the subtropical forests however, could be disastrous. Where could they be taken, if this process was to be followed? Tasmania? It has even been suggested that Tasmanian species be taken across to New Zealand, but this is hardly likely to be taken as a serious suggestion after the devastation caused there by just one Australian species, the brushtailed possum.

Other interactions

A WWF reporter, speaking of MacQuarie Island, states that "[c]ruise passengers heading south this season will be in for a shock when they see what rabbits, rats and mice have done to one of Australia's World Heritage islands in the Southern Ocean" (http://www.wwfindia.org/news_facts/index.cfm?uNewsID=1480).Dy Kenny Scott of the University of Tasmania has suggested global warming to be partly responsible for the recent increase in rabbit populations (www.publish.csiro.au/?act=view_file&file_id=EC136p20.pdf).

Will there be a shortage of specialized nesting materials such as lichens for some forest birds? Will hollow-forming invertebrates be disadvantaged, in turn providing less hollows for possums and owls? It is impossible to predict all possible changes.

So what should we be asking?

We know a lot of the general problems, but the actual problems happen in each particular, local area. Local conservation managers, and tourism operators who depend on showing wildlife and natural ecosystems to travelers, need to think about the following:

- What are the seed dispersers and pollinators, especially for vulnerable plants?
- What do these pollinators and dispersers need?
- What species are likely to be vulnerable because of their physiology?
- What plant species might be especially important to particular animals during lean times or raising young?
- Is breeding (of bird, tree etc triggered solely by day-length. If so, is it so locked into this it will start when the weather is too hot/wet/dry in future years?

- If triggered by a cold spell, will the weather still get cold enough to provide the right cues?

- How can we best get amateur naturalists working in with scientists to collect and disseminate information in the shortest possible time?

- Are there particular stages in life history of animals or plants that may be affected? (e.g. germination and early growth of tree or vine, early larval sage of insect, newly metamorphosed frog – effects could be direct temp or rainfall changes or lack of an essential resource)

- What potential problem species are likely to move in or stay longer? (cane toads, crocodiles, and over-wintering currawongs could all profit by rising temperatures)

- What barriers of movement might there be to species that have to move seasonally or in lean seasons, in response to climate change?

- What competitors of rare species might move in?

- \is the weather likely to get hotter, cooler, wetter, drier, more extreme in all directions? Are there vulnerable species which will fare worse than their competitors

- is there anywhere for shore nesting birds and other coastal creatures to move to unflooded ground? If not, can we provide something for them?

What else can we do?

We can buffer some effects by increasing the amount of habitat preserved in conservation areas and on private land, both by conserving what is there and restoring habitat, and also increase connectivity between fragments and reduce edge effects

We could also start recreating some habitats in places now very degraded but which would appear to support particular species and communities in the climates of the future

We can increase efforts at conservation breeding in captivity ready to restock wild areas as opportunity permits

We can learn all we possibly can from what remains of the world's wild places and their resident species so we know what to aim for. There are not enough scientists to do this alone - amateur naturalists, concerned landowners, volunteer conservation-minded travelers and others are needed.

Conclusion

When we were children, we thought the North Pole would always be covered in ice and the world would always have wild polar bears. It is uncomfortable to realize this is not necessarily so. It is frightening to think of the other, very great changes that may be happening within our lifetimes. But that is what we must do – think about them, and the many complexities involved, if we are to find any solutions within the very little time we have available.

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