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EDITORIAL NOTES

Conserving narrow range endemic insects in the face of climate change: options for some Australian butterflies

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Many insects in the southern hemisphere are regarded as 'point endemics' or 'narrow range endemics', known from single sites or small, strictly circumscribed areas. Failure to find them elsewhere during extensive targeted searches suggests strongly that such distributions are initially 'real' (reflecting long isolation and speciation) rather than the remnant consequences of extensive anthropogenic changes. The latter may further fragment the already small range. Not unexpectedly, such species commonly arouse conservation attention. However, recovery plans or less focused conservation management agendas commonly can pay little constructive heed to ramifications of future climate changes, not least because those ramifications can only be inferred within rather broad limits and require a certain amount of 'crystal ball-gazing'. In addition, the factors causing the current narrow distributions of the insects can usually only be suggested, most commonly in terms of supply of critical resources as a key component of suitable habitat. In practice, conservation of narrow range species has concentrated almost wholly on urgent short-term issues of site and resource security with—should it be considered at all—little heed to the changing suitability of the site(s) as climates change. This approach alone may prove inadequate and is based on the largely unproven presumption that the species may still be able to persist on those sites.

Alternatives may be possible for some taxa, in helping to cater for likely future range changes by (1) acknowledging and plotting environmental gradients and preparing new sites to support those species within the species' dispersal capability, and (2) securing sites within more distant but potentially suitable areas to receive translocations in the future. Any change in distribution of the species necessitates change of both scope and detail of management, as the spatial and temporal distributions of its resources change. There is at least suggestion that the entire present range of some such taxa may be rendered unsuitable, predominantly by changes in temperature and precipitation patterns, and possibly within only a few decades. Additionally, increasing CO_2 levels may influence plant metabolism and affect food availability. Whereas increasing connectivity between occupied sites is a common recommendation in insect species management, it is not as frequently acknowledged that this may not always serve for the longer term. It is, nevertheless, a valid 'insurance tactic' to guard against increased risk of destructive fires, already recognized as a threat to many such taxa in Australia and likely to increase in the future with projected global warming.

As Dennis (1993) discussed, three aspects of climate change relate strongly to butterfly biology: the absolute rise in regional temperatures and consequent changes in other attributes, particularly precipitation; the rate at which such changes occur; and the frequency and magnitude of 'extreme weather events'. Consequences to species are extinction, adaptation in situ, or movement elsewhere, with the last of these gaining particular attention for conservation. However, the options available to plan for the future of narrow range endemic insects in the face of range alterations imposed by climate change will vary with the kind of distribution, as well as the level of ecological specialization, with extreme specialization curtailing the alternative 'outlets of escape' (Dennis 1993) within an occupied site. Several different scenarios or distribution patterns are evident in narrowly distributed Australian butterflies. They manifest one of about five basic patterns,

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as follows, revealed when we plot the species' distribution against its possible one along an altitudinal or latitudinal gradient. Other gradients, such as coastal to inland or of aridity, also occur in particular cases, and limitation within each may reflect either or both of climate and resource suitability. Thus, a species may already be known only at an extreme of such a gradient (category 1, exemplified by some alpine taxa: (New and Sands 2002), such as the satyrine *Oreixenica latialis theddora*, known from a single isolated plateau, Mount Buffalo, in Victoria). Indeed, the entire parent species' range spans only about 4° of latitude within the montane area of south eastern Australia.

Perhaps more commonly, a species is known from a single population or site in a presumed intermediate part of the possible range (category 2), so may have opportunity (but not, necessarily, the physical or physiological capability) to 'move' in either or both directions from its present range. Third, a species may be found with populations or sites separated but loosely grouped within a broad range (perhaps of up to several hundred kilometres of latitude, or several hundred metres of altitude and sometimes with some ecological amplitude such as having different food plants, associated ants, voltinism or phenology in different places: category 3). This distribution may represent further fragmentation of a formerly wider occupancy (as for the Eltham copper, *Paralucia pyrodiscus lucida*, in Victoria) but, nevertheless, one still formerly highly circumscribed. In contrast, populations or sites may be grouped much more tightly (category 4) to constitute a more distinctive local endemic with a strongly concentrated and well-defined range within which all known populations occur. One example is the Bathurst copper (*Paralucia spinifera*) in New South Wales. Last (category 5), a species may be known only from isolated populations at or near both extremes of its possible range. This scenario is perhaps the most difficult to interpret, and may commonly be assumed to be associated with either (1) extensive loss of intermediate populations to leave these remote remnants or (2) need for taxonomic clarification, so that the two entities may in fact be different taxa, or the ends of a cline, and each parallel the first category noted above. In either case, their high separation may accord them status as 'significant populations'. However, it is possible that the vacated intermediate range could be reoccupied

It is commonly presumed that category 1 taxa would have 'nowhere to go' if their present sites become unsuitable, because they already occupy extreme environments that reflect the narrow tolerances of the insect and may be eliminated as conditions change, so that current site-focused conservation may be futile for longer-term sustainability. Alpine species may already be on the highest land available, for example. Commonly, conservation is directed at the site(s) in the hope that the species may indeed be capable of adapting to a changed climate regime when its resource needs are assured. The assumption depends on the taxon being restricted due to intolerance of less extreme or different regimes (for example, of temperature) and, in almost every case, this remains unproven. Studies on British butterflies by Menendez et al. (2006, 2007) implied that generalist and specialist species are constrained by different combinations of factors, with the richness of resources being, perhaps, more important than climate responses alone for the latter group.

Wider options may be open for category 2 and category 3 species. Unless they are extremely specialized in relation to an optimal climate regime (with a narrow 'climate envelope'), a category 2 species may have capability to expand along the gradient in either direction from the central distribution, so that acquiring, safeguarding and rehabilitating/restoring additional sites within a relatively broad range, either for translocation or natural colonization, may be a viable conservation action. A similar approach may be adopted for category 3 species, perhaps with potential to expand beyond one or both current range extremes. Category 4 species may prove to be climatically limited, as reflected in a 'tight' concentration, but the options noted for category 2 species merit consideration for these. Any such suggestions presuppose that the reasons for the current distribution of the species are understood: in most cases that understanding is based on presence or quality of biological resources, rather than of optimal climate regimes. Unlike the situation in much of Europe, for example, historical data on butterfly distributions and their changes is relatively sparse in Australia and, indeed, for most of the southern hemisphere.

Modelling studies that imply future range changes through poleward movements are often based on the presumption that climate change will both present opportunity to expand, naturally or by transfer, from the current range, and render parts of the current range unsuitable for continued occupancy. These inferences are perhaps best interpreted in the context of a comment by Beaumont and Hughes (2002, p. 969). 'Bioclimatic models do not represent forecasts of future distribution, but rather provide an indication of the potential magnitude of the impact climate change may have on these species distributions'.

Some of the butterflies we need to consider for conservation in Australia have distributions coinciding with that of their equally restricted food plants: the skipper *Ocybadistes knightorum* in coastal New South Wales is one such example (Sands 1997). Others are markedly less widely distributed than their larval food plants and (for some Lycaenidae) their mutualistic ants. They thereby give an initial impression that there is plenty of 'unused space' that appears to be suitable. Reasons for this disparity are largely unknown, but are sometimes attributed to differences in topography (slope, aspect) so implying possibility of microclimate limitations and, hence, possible sensitivity to climate change, with the likelihood that the different players in a community module may be affected differently by any change. Maintenance of close ecological associations or mutualisms under climate change poses complex practical problems. For all such species, most of which are in categories 2–4 above, realistic options for conservation can include consideration of sites outside the current range. Distribution of a category 3 species already demonstrates considerable amplitude, likely to include climatic variety, and unless changes exceed that amplitude it may persist. However, for all species, 'new' sites should be considered, perhaps most usefully poleward (or upward) from the current range, and conservation planning can include selection and preparation of such sites to receive insects either by dispersal or by translocation. This approach diverges from the more traditional advocacy to make transfers of specimens only within the documented historical range, replacing this with the express purpose of changing that range to include regions never occupied previously. Translocations to climatically suitable areas beyond the current ranges have been made in Britain (Menendez et al. 2006), but the effect of climate was stronger for generalists than for specialist species.

A possible emphasis for us now is to consider the values of sites which are at present not climatically suitable, and if these can be selected and secured for the future, as a component of a current conservation plan. A major concern is whether, and how, such sites can be selected and prepared for reception, and the major tool available remains 'climate modelling', with the uncertainties of how any particular species may adapt. Experimental translocations now (such as those undertaken for the North American hesperiid *Atalopedes campestris* by Crozier 2004) may provide intriguing clues to future success, and also indicate probable 'stumbling blocks'. However, they are inevitably made to different environments, on sites perhaps realistic in space, but which will later change in condition and climate regime to resemble more closely sites that are currently occupied. Crozier's study is, nevertheless, important in demonstrating the differential effects on the skipper's biology of changes along a temperature gradient of only 3°C. Likewise, studies such as that by Merrill et al. (2008) apply to current circumstances but may not apply in the same way in the future.

Modelling studies on Australian butterfly distributions (Beaumont and Hughes 2002) have not specifically noted different distributions of narrowly endemic taxa. However, that study included basic documentation of the regimes occupied by 77 species, and projected range changes for 24 taxa to 2050 from four possible climate change scenarios.

Life history information was integrated with those models to identify species that might be expected to be especially vulnerable to climate change. Seven such species were indeed identified. Five had very narrow climatic envelopes (with mean annual temperature range spanning less than 4°C), with scenarios revealing that mean seasonal temperatures by 2050 may exceed the values to which the species are exposed at present. The other two species lost large proportions of their distribution range under all climate change scenarios projected. These species included specialists, mutualists and poor dispersers, and all have narrow current distributions, much of which is predicted to be lost as climate changes. They were considered unlikely to be able to change distributions to track either a changing climate or changing distribution of the host plant. Four of the seven are myrmecophilous Lycaenidae, with the additional complication that they must track also their mutualistic ant species. Further studies (Beaumont et al. 2005, 2007) help to project the possible consequences for butterfly range changes, but reveal also the considerable uncertainties and inconsistencies in simulating species responses by modeling. The major inference was that 'several climate models, each represented by multiple realizations, are required … to capture the reality of projecting species distribution in the future' (Beaumont et al. 2007). The practical implication is that more immediate conservation planning must accept this uncertainty but, as far as possible, anticipate the most likely trends, namely for poleward and upward range shifts. As Wilson et al. (2007) discussed for Spanish butterflies, this is leading progressively to increased species richness at higher latitudes and altitudes, with expectations also of decreased richness at currently occupied lower sites. Temperature changes appear to be the major driver of such shifts. Wilson et al. also implied increasing domination of lower altitude communities by widespread species as the more ecologically specialised species were displaced. The latter are those of primary interest here, and their often already low capability for natural dispersal may be thwarted already by isolation imposed by landscape changes that have reduced 'connectivity' (see Warren et al. 2001, for Britain).

Elevational gradients may effectively compress needs for natural dispersal by necessitating movement only over rather short distances to track environmental changes. Much of Australia is rather flat, and much of the limited alpine area of the southeast is forecast realistically to decline substantially within a few decades, so that specialised alpine species may indeed be on the road to extinction, perhaps particularly if temperature is the limiting factor to their wellbeing. However, many range changes for butterflies may involve negotiating the greater distances of latitudinal rather than elevational changes to track suitable climate regimes. Site preparations for their future may thus commonly need to consider poleward localities at similar or higher elevations to those already in use. Sites at lower altitudes or latitudes will be much lower priority. Conditions needed for future sites can be modeled in terms of future climatic analogues to the 'best' current sites, with due attention also to threat abatement measures based on major current threats.

For natural dispersal, in essence 'invasion' (Ward and Masters 2007), most narrow range butterfly species of concern in Australia lack the more obvious features facilitating their likely success. They are highly specialized feeders, often with restricted resource and other requirements and, at least by implication, tend to disperse little—even to nearby sites that appear to be suitable. Ecological considerations may therefore need to encompass the concept of the 'Grinnelian niche', but with the corollary that species with low dispersal rates tend to occur only or predominantly in the most suitable habitat patches (see Pulliam 2000, for background). This idea is at least partially implicit in metapopulation dynamics in relation to patterns of patch occupancy with resource suitability, and whereby a species may be absent (at least temporarily) from parts of its potential range. However, many narrow range species occur in very few populations, and these probably often are truly 'closed' rather than representing the surviving segregates of former functional metapopulations, with their dispersal potential very low.

Returning to our five categories of narrow range butterflies, it may be possible to suggest options for practical conservation or to indicate other possibilities.

Category 1 species remain problematical. Their environments may become more crowded and competitive as other species invade from elsewhere (these possibly including ecologically similar taxa from 'nearby'), and resource enrichment on current sites is the only obvious partial counter to this. At the other end of a gradient, as indicated in one extreme of category 5, massive range expansion may be possible as conditions change—in parallel with a number of tropical Australian butterflies moving southward, but with possibility of the more equatorial parts of the range being vacated. Category 2 species will need additional poleward sites, probably to be prepared several years (or even decades) in advance for translocations, with the proviso that even host plants intolerant of current conditions there may need to be introduced only as near as possible to the planned translocation dates of a decade or more into the future.

Category 3 species provide for more flexibility. An interim plan may include translocations to increase the number of independent populations within the most suitable parts (poleward, highest altitude) of the current range, perhaps using the most vulnerable (equatorward or lowest altitude) populations as the donors for this. A possible disadvantage of this approach is translocating from one range extreme to the other, rather than using closer (and, possibly, more climatically compatible) sources within the range. More tightly grouped species (category 4) do not permit this approach, and the major option for these (as well as being a second phase for category 3 species) will be for translocations into new areas. For most species the option of landscape restoration to enable full natural connectivity and natural dispersal will be low (although this is a current priority for the Richmond birdwing, *Ornithoptera richmondia*, most Australian species of concern are not such strong fliers) and translocations planned to occur at a sequence of sites and time intervals will be needed. The main immediate need will be to select and designate the sites on which those operations will occur, assure their security and progressively render them suitable as a gradient sequence from the existing range, with the closer sites accorded priority for earlier action. In some cases, it may be possible to use reserves that already exist or that are planned as part of Australia's increasingly representative reserves network, but original selections will also be needed. At the same time, source stocks for food plants must be selected if they are not already present on the proposed sites and, if necessary, propagation and transfer methods designed and tested. The methods available for insect translocation also need review with, for example, consideration of whether establishment of captive stock is needed, from where this should be derived (with likelihood of increasing numbers of 'salvage operations' in the future), what stages and numbers may be needed for any more direct transfer (with attention to relevant genetic issues), and when translocations should occur. It is highly likely that additional biological study of the subject species and its key resource species (which are likely to be at least as poorly known) will be needed to determine this. Should mutualisms be involved, for example with specific ants, their presence at the receptor sites, or transfer to them, is also a consideration. The latter may prove at least as complex an exercise as transferring the butterfly itself.

Any operation of this complexity is obviously an expensive and long-term commitment and, idealistically, could be projected along the entire modelled range of the insect. Clearly, it cannot become a universal strategy for insect species conservation. More proximal ramifications include that it might not be wise to emphasise species conservation on the 'trailing edge' of their current range—a matter of considerable relevance in Australia where individual state or territory legislations may give high conservation status to range edge insects that extend narrowly into their jurisdictions but be less vulnerable elsewhere. Nevertheless, any such strategy must be anticipated well in advance. Preparation may take decades, together with considerable study of the optimal timing and methods. Both 'range edge creep' and 'saltatorial' translocations may be needed. An additional regulatory 'novelty' (as noted by Nowicki et al. 2007, for *Maculinea* in Europe) is that such early site selection may become an important component of a species conservation plan but will necessitate protection and investment in sites which are not currently inhabited, or habitable, by the species.

In conjunction with a wider trend to area-wide management, the topic of what Hunter (2007) termed 'assisted colonisation' (see also McLachlan et al. 2007, as 'assisted migration') extends clearly beyond the more usual initiative of facilitating normal dispersal by improving connectivity. Hunter considered the characteristics of suitable candidate species (based on probability of extinction due to climate change, vagility, ecological role), candidate sites (isolation, levels of disturbance, species richness) and, importantly, feasibility (costs, technology, public support). The last is of particular concern for insects. Whereas a strong scientific case to counter extinction proneness can be made, few butterflies or others are likely to garner sufficient public support to become realistic candidates for such unproven and long-term exercises, particularly in competition with likely wider conservation benefits accruing from deploying equivalent support elsewhere. One alternative option then becomes to specifically consider a selection of narrow range endemic insects in more comprehensive long-term plans for biotopes (or, in Australia, 'Ecological Vegetation Classes') for the future. However, selecting the few most deserving candidates for highly expensive exercises of this sort will be difficult, and disputes likely to arise over their selection could cause delays (McLachlan et al. 2007).

At present, such futuristic planned translocations for narrow range insects are unlikely to appear on most conservation agendas. The major emphasis will continue to be on short-term operations based in crisis management. However, the forthcoming and potentially widespread inevitability of climate change necessitates broader considerations and these should indeed be debated more extensively as a matter of urgency, and as investment in the future of many notable taxa and ecosystems. In common with vast numbers of insects in many parts of the world, range changes in many Australian butterflies appear certain to occur and, in the current 'climate of uncertainty' of how best to proceed, short-term efforts alone may herald the eventual demise of numerous narrow range endemic species unless specific visionary plans for their future are adopted. At the least, wider landscape considerations of future range composition merit inclusion in planning their conservation. Both temporal and spatial dimensions of a butterfly's distribution are fundamental aspects of its long-term wellbeing.

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