Integrating consequences of climate change on biogeography, macroecology, evolution and ecophysiology of terrestrial biota

Climate change is a major environmental disturbance, affecting biology at all levels from cells, through organisms and communities, to ecosystems and the entire life support system of the planet. Major challenges today lie in understanding the links between these levels – tolerances and responses of organisms to stresses they already face, what dictates where they can live, how they get there, what they interact with, and how all of these will be affected by environmental change. These questions are fundamental in the emerging field of macroecology – understanding what controls biology at a global scale, and biological feedbacks into the Earth's Life Support System.

The polar regions provide ideal opportunities to address such questions, with simple ecosystems, tractable food webs, and are facing the most rapid rates of environmental change worldwide. In these regions, with chronically low temperatures and often restricted water availability, even relatively small changes represent biologically extreme events that can have disproportionately large consequences. Such extreme events are a focus of selection on an evolutionary timescale yet, worldwide, there is little knowledge or consistent view of how they will affect individuals, communities and ecosystems (Gutschick & BassiriRad 2003).

The responses of communities and ecosystems to stress and climate change are, ultimately, an integration of the responses of individual organisms. However, the impacts of climate change for individual organisms are likely to be subtle, with alterations in physiological resource allocation 'traded-off' against other life history features. These changes, whilst individually small, can combine to produce much greater effects within the life cycle, and in interactions with other species, and progression through the ecosystem (Day 2001).

There is considerable concern worldwide about the likely invasion of alien organisms under contemporary and predicted climate change, including the polar regions. Invasions can have wide and important impacts in fields ranging from biodiversity and conservation management through to agriculture, human economics and sociobiology. There is therefore an urgent need to identify and understand the 'climate envelope' within which indigenous and potential alien species can exist, and hence to predict more accurately the consequences of climate change for these biota. Alien colonisation of high latitudes may occur via aerial, terrestrial or marine routes. Increased immigration, enhanced by a more favourable climate, will alter the trajectory of community development, however the relative importance of abiotic variables and interspecific interactions as influences on invasions are debated.

Understanding current patterns of biodiversity and biogeography, both in the historical context of the controls on their evolution and in their linkages with ecology and physiology (macroecology), is fundamental for improving Man's ability to predict and, possibly, mitigate the consequences of environmental change. Despite the obvious parallels in location, the two polar regions differ in important respects, particularly in their levels of isolation, patterns of environmental stress and change experienced, and evolutionary and colonisation histories. Some elements of Antarctic terrestrial and marine faunas pre-date the break-up of Gondwana, while more recent Pleistocene refugia exist in the Arctic, and contemporary colonisation occurs at the timescale of days to months. Importantly in this context, knowledge is lacking on polar biodiversity and biogeography, community structure and colonisation processes. These are key to the understanding of historical and contemporary processes controlling dispersal and colonisation, and how these may be altered under climate change.

With this background, we propose developing a number of interrelated areas of active scientific interest that could advantageously utilise the opportunities for collaborative, integrative research

that exist in the context of IPY, while building on international linkages that already exist (e.g. the SCAR RiSCC grouping, Frenot *et al*., in press). These could each be linked within a single integrated programme or, alternatively, form the nuclei of separate specific projects.

A) The evolution of current patterns of polar diversity

This requires an approach combining classical biogeographical and biodiversity survey, and the use of modern molecular taxonomic techniques. IPY provides the opportunity to coordinate surveys across a wide geographical range, encompassing both polar regions. International collaborative effort (*e.g.* through the SCAR RiSCC grouping) would be extremely advantageous, as would be the involvement of taxonomic experts in a range of plant, animal and microbial groups. The uncertainties inherent in the study of taxonomically poorly known groups (especially microbiota) can be much reduced by the incorporation of 'molecular fingerprinting' techniques, which can also be advantageously applied to better known groups (*e.g.* bryophytes, arthropods, nematodes) in order to describe evolutionary patterns and linkages.

B) Quantifying the risks associated with alien invasion under climate change scenarios

This should be addressed using comparative ecophysiological approaches applied to a wide range of indigenous and potentially invasive species, in order to define their environmental tolerances, combined with ecological studies (*e.g.* across wide northern and southern environmental gradients) of communities at varying stages of development or complexity, and of specific communities already known to contain established alien species. This approach has been successful in predicting the establishment potential of non-native insects and mites in the UK (Bale, 2002) and could usefully incorporate modelling techniques that identify 'preferred' strategies under different climate scenarios (Voituron *et al*., 2002).

C) Comparative studies of adaptation and evolutionary rates across major environmental gradients

The combination of geographical isolation (at a range of temporal and physical scales) and the wide environmental gradients available at high latitudes provide great potential for the study of local adaptation, metapopulation and evolutionary processes, particularly in the context of climate change (Convey, 2003). A range of approaches are appropriate, focussing on describing the ecophysiological envelopes characteristic at metapopulation level across, for example, latitudinal or altitudinal gradients, and linking these with genomic/proteomic approaches and intraspecific study of molecular evolutionary rates.

Wider linkages

The proposal is at the heart of the UK NERC's "Science for a sustainable future 2002-2007" strategy, addressing:

1. Earth's life-support system: What previously unexplored sources of biodiversity can we find within the deep ocean, ice, soils, rocks and clouds?
2. Climate change - predicting and mitigating the impacts
3. Sustainable economies: What are the impacts of alternative land management scenarios (transport infrastructure, waste disposal, leisure and tourism) on biodiversity?

The proposal contributes directly to the UK's responsibilities under the Antarctic Act and international biodiversity treaties and initiatives, and to the research priorities identified by SCAR (through the RiSCC, EASIZ and EBA Programmes).

References: **Bale JS** (2002) *Proc. Roy. Soc*. B 357: 849-862; **Convey P** (2003) *Antarct. Res. Ser.* 78: ; **Day TA** (2001) *New Phytol*. 152: 183-186; **Frenot Y. *et al.*** (in press) *Biol. Rev.*; **Gutschick VP, BassiriRad H** (2003) *New Phytol*. 160: 21-42; **Voituron Y *et al.*** (2002) *Amer. Nat.* 160: 255-270.