THE LATITUDINAL GRADIENT PROJECT

"A DISCUSSION PAPER"

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INTRODUCTION

Life in Extreme Environments is one of the five themes of the 1998 Antarctica New Zealand Science Strategy (1). A number of existing projects fall into this theme and in the past work related to extreme environments has often been conducted as a series of small scale and disparate projects. There are clearly significant advantages to be gained in drawing together New Zealand's expertise in this area and linking this with our science partners in the Ross Dependency. Antarctica New Zealand is keen to see the theme approach to our science being used as a means of focusing our efforts. This proposal is a suggestion for bringing together the thoughts and energies of New Zealand scientists while maintaining a degree of individual research direction. It is based on the concept that if we place our work related to extreme environments within a single broad theoretical base (key issue) we can maximise the transfer of information and ideas, utilise large environmental datasets and utilise joint logistic facilities with our partners the USA and Italy.

We believe the key issue that needs to be addressed by our biologists is the response (biochemical, physiological, organism, community or ecosystem level) to a changing environment. To do this effectively will require information from other disciplines such as climate research, soil science, glaciology and oceanography to provide the environmental framework that is needed to fully understand the ecosystems under study.

The Ross Sea region contains a number of environmental (ecological) spectra relating to cold, aridity, solar radiation, UV and light/dark conditions. Some of these systems are unique to the Antarctic. Within the Ross Sea region the Victoria Land mountains and coast contains the most extensive coastal latitudinal gradient in Antarctica, from 68°S (Cape Adare) to 86°S at the southern end of the Ross Ice Shelf (18º of latitude along a narrow longitudinal band).

Environmental changes over a wide latitudinal range at one point in time can be used to mimic environmental changes at one point in space over a long time span. A latitudinal gradient can therefore be used to study the effects of potential changes in regional climate that may be associated with global change, as well as providing a range of environmental conditions for more fundamental studies.

RECOMMENDATION

We recommend that New Zealand scientists working under the theme of Life in Extreme Environments take advantage of the natural "laboratory" in the latitudinal gradients offered by the Ross Sea sector and take advantage of the extensive combined logistics pool of the US, Italy and New Zealand to:

- Combine our thinking to address the issue of biological responses to a changing environment.

- Link with physical scientists to define the environmental characteristics of the latitudinal gradient.

- Jointly work on coastal marine ecosystems, inland aquatic ecosystems, and terrestrial ecosystems.

- Join colleagues in the US and Italian programmes who are currently interested in this approach.

- Provide agreement between ourselves on the method of pursuing these goals.

There are a number of existing New Zealand programmes that could contribute to the project. Examples in the area of physical sciences include: glacial studies of ice dynamics; climate monitoring, looking at micro-climates; geological research; Antarctic soil research; bathimetric measurements; and tidal studies. The area of Biological research would include: terrestrial biodiversity studies; penguin research; UVB effects; Antarctic aquatic ecosystem research; fish biology; marine ecosystem studies; and seal research. The research topics mentioned would greatly contribute to a better understanding of the coastal ecosystems. The latitudinal variation would begin to give us a predictive knowledge of future impacts to the environment.

GRADIENTS IN THE ROSS SEA SECTOR ANTARCTICA: THE EFFECT OF LATITUDE

A number of separate proposals from the international science community as well as individual proposals from within New Zealand have been formulated over the last few years which are now converging on a major environmental initiative using the latitudinal gradient in the Ross Sea sector. The principal proposals which are being formulated at present are:

1. Microbial consortia in polar regions (international proposal generated at the VII SCAR Biology Symposium in Christchurch 1998)

2. Regional Sensitivity to Climate Change on Antarctic terrestrial and freshwater ecosystems (RiSCC) (SCAR Biology Working Group initiative to replace BIOTAS)

3. Victoria Land coastal transect (US direction with interest from New Zealand and Italy)

The land within the Ross Dependency spans a wide latitudinal range (66-90ºS) and includes a variety of marine, terrestrial and freshwater habitats unmatched in Antarctica. This latitudinal span is accompanied by major north-south gradients in environmental properties (e.g. annual radiation, UV radiation, duration of melt, air temperature, day length) which are likely to exert a large influence on ecological processes.

This proposal is aimed at increasing our understanding of coastal marine and freshwater and terrestrial organisms and ecosystems, their controlling variables and sensitivity to environmental change along this north-south continuum.

Climatic extremes within the Ross Sea sector vary from almost no precipitation in the Dry Valleys to relatively high snowfalls on the coast at Ross Island, from low altitude to adjacent high altitudes in the Transantarctic Mountains which stretch the length of the Dependency, and from relatively warm temperatures (coastal sites north of the McMurdo Ice Shelf) to cold temperatures (southern inland sites, or those adjacent to the Ross Ice Shelf). Along the coast itself there are varying degrees of ice cover, culminating in this the Ross Ice Shelf. There is a large polyna in the centre of the gradient to the Ross Sea.

South of McMurdo Sound the Ross Ice Shelf exerts a much colder influence on the adjacent landmass than the sea from McMurdo northwards.

Two major zones can thus be defined: north and south of the seaward edge of the Ross Ice shelf. Within each of these, variations in climate and habitat for living organisms are likely to be significant with a discontinuous shift in physiological and ecological responses across the boundary of the Ross Ice Shelf and perhaps other, as yet unknown boundaries. For instance unpublished evidence from coastal marine bivalves indicates that significant changes occur around Terra Nova Bay which may allow us to partition the Victoria Land coastal environment at this point also (2).

Summer meltwaters are common from the McMurdo Sound area and northwards but are less frequent south of this area. We may therefore expect that the types of terrestrial organisms, their abundance and their adaptations to Antarctic conditions would be very different at Cape Hallett and the Beardmore Glacier. For instance (3) and (4) recorded a few species of algae and bacteria from frozen ponds at latitude 83ºS where freshwater existed only under a cover of ice. In contrast, at Moubray Bay (Cape Hallett) extensive areas of moss flush fed by seeping waters form a large “wetland” across the inner reaches of the Bay, and algae are common in the meltstreams of the area (5).

We may expect that ambient temperatures and the period of free water may decrease from Northern Victoria Land to the southern latitude of Southern Victoria Land. For instance, seasonal variability in solar radiation is at its most extreme at latitude 60-90ºS (Table 1). At say, Cape Adare, 68ºS, there may be two months of the year when less than 1MJ m^{-}_ day of radiation reaches the atmosphere, but at the Beardmore Glacier (85ºS) there are 6-7 months of the year with less than 1 MJ m^{-}_ day. This latitude-directed study may allow an analysis of N-S gradients in enhanced UV radiation effects resulting from spring ozone depletion in the aquatic biota.

In these conditions we may also expect that species composition will change and species diversity may fall as latitude increases with the few remaining species adapted to extreme southern conditions.

Table 1 (adapted from Vincent 1988). Radiation at the top of the atmosphere as a function of latitude and time of year for the zone 60-90ºS. Data as 1MJ m^{-}_ day^{-}_.

	Month												Total
Latitude	J	F	M	A	M	J	J	A	S	O	N	D	(MJ y^{-}_)
60ºS	42	31	19	11	4	2	3	8	18	27	38	44	7417
70ºS	42	28	13	5	1	-[a]	-	3	13	22	37	45	6174
80ºS	44	26	6	-	-	-	-	-	6	18	38	47	5592
90ºS	44	26	-	-	-	-	-	-	-	18	39	48	5411

CURRENT INTERNATIONAL RESEARCH DIRECTIONS THAT LINK WITH THE LATITUDINAL GRADIENT APPROACH

1 Microbial consortia in polar regions

When initially discussed this concept was endorsed as a bi-polar concept with contrasting latitudinal gradients in the Arctic and Antarctic. There was general agreement that many science questions can best be approached by comparative bi-polar studies along gradients, particularly in areas such as the influence of biogeography and species *vs.* functional complexity.

A range of sites over a latitudinal gradient studied over short time periods (1-2 years each) with one set of sites near the centre of the gradient to be studied over a long time period. In the latter case the US Dry Valleys Long Term Ecological Research Project (LTER) could be used to provide a "calibration" for the short term studies and conversely the short term studies will extend (both north and south) the dynamics of the LTER type of approach.

This was initially seen as a microbial research initiative with key questions such as:

- How do microbial consortia respond to change and what is the nature of intra- and inter-annual variability?
- How do small changes in temperature affect processes?
- What is the effect of sub zero temperatures?
- What is the influence of liquid water duration and how does it interact with photoperiod?
- How is nutrient cycling affected by small changes in micro climate?
- What are the limits on biodiversity (e.g. Arctic regions are not isolated)?
- What are the effects of trophic complexity (compare maritime Antarctic and lower Arctic *vs* continental Antarctic and high Arctic)?

These questions could equally apply to non microbial communities, e.g. coastal benthos.

At present scientists from various countries are offering support for each other in their internal national funding rounds. No new meeting or structure has been formally proposed at this time but Spanish and Canadian researchers will be joining the New Zealand programme at Bratina Island this year to initiate some of the work proposed at the SCAR meeting.

2 Regional sensitivity to climate change in Antarctic terrestrial ecosystems (RiSCC)

The SCAR Biology Working Group has identified the need for a terrestrial/freshwater component to GLOCHANT to complement the marine studies.

Understanding structure and function of ecosystems in a changing environment. This proposal was first proposed at the SCAR VII Biology Symposium in Christchurch in 1998, with two circumpolar transects and one latitudinal transect. The latitudinal transect would address the issue of regional differences in climate and therefore provide an insight into potential regional climate change on ecosystem processes.

RiSCC will involve an ecosystem approach addressing processes such as carbon fluxes, nutrient cycling and utilisation, genotypic plasticity, biodiversity responses.

An interactive workshop in Madrid in May of this year has been proposed to set up a science plan so that this programme could be in operation before the SCAR 2001 Biology Symposium.

3 Victoria Land coastal transect

Victoria Land has the most extensive latitudinal zonal gradient along the Antarctic coast that can be studied within existing logistic frameworks.

Co-ordinated research activities in a number of disciplines with shared logistic support from three nations. Suggested disciplines include:

glaciology, geomorphology, limnology/inland aquatic ecology, coastal marine ecology, geochemistry, coastal physics, coastal terrestrial ecology.

Hypotheses are being addressed at present and will cover examples such as: “Ecological responses to latitudinal gradients are not continuous but are revealed in series of steps”.

This transect has been discussed with the Office of Polar Programmes in the US who have suggested a steering group be set up consisting of Dr Paul Berkman (US), Dr Riccardo Cattaneo-Vietti (Italy) and Dr Clive Howard-Williams (New Zealand) to pursue this concept further.

The transect concept has been identified as a discussion topic at the next meeting of the West Antarctic ice sheet (WAIS) and has also been discussed with the co-ordinator of GLOCHANT and with the Japanese National Institute of Polar Research.

We recommend here that the Victoria Land Coastal Transect be extended to cover the full latitudinal gradient of Victoria Land from Cape Adare to the southern extremity of the Ross Ice Shelf.

4 US Long term Ecological Research Programme in the Taylor Valley (LTER)

Discussions have been held with Dr Berry Lyons, PI of the LTER who has offered support for the latitudinal gradient approach. This will be followed up with the US NSF. The basis of the discussions can be summarised in the following way: The Taylor Valley LTER sits in the centre of the proposed latitudinal gradient. Thus, a continuous long term data set is potentially available against which to compare shorter studies at various points along the gradient. The gradient approach will strengthen the LTER by providing a regional perspective to the LTER and the LTER in turn will act as a "standard" environmental data set for the gradient.

RECOMMENDATIONS

1 The New Zealand's Antarctic science community be invited to consider the usefulness of placing their research within a latitudinal gradient framework. Even if the research is to be conducted in one place, how useful would ancillary data be from other studies over a wider range of sites (e.g. ocean currents, climate data, etc.).

2 If there is support for this concept then Antarctica New Zealand should begin to explore the logistics capability with the US and Italy of moving scientists and equipment north and south of the McMurdo Sound.

3 If agreement in principle can be reached between the three national programmes to share logistics, the science providers in each country (US, Italy, New Zealand) will be asked to:

- provide information on how can currently funded projects might be altered or on ideas for future projects
- attend a national or international workshop to develop the ideas, concepts and hypothesis
- define priority logistic requirements for a five year period.

4 The logistic requirements will be fed back to national programmes for feasibility studies and co-ordination.

5 An overview (loose!) steering group be appointed to ensure that maximum benefit to science is obtained and that maximum transfer of information between these studies and other Antarctic programmes (e.g. SCAR programmes) occurs.

References

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