

LATITUDINAL GRADIENTS IN VICTORIA LAND

SCAR WORKSHOP, AMSTERDAM

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Figure 1. Cape Hallett Campsite with penguin colony in the background. Cape Hallett is at $72^{\circ}15'S$, $170^{\circ}10'E$. Photo taken by E. J. Waterhouse, Antarctica New Zealand in November 2000.

INTRODUCTION

Over the past two years, there has been growing scientific interest in a latitudinal gradient approach to ecosystem and environmental studies along Victoria Land, Antarctica. The three national programmes, (Italian, New Zealand and USA) which have scientific bases in the region and constitute the majority of research done in Victoria Land have conducted separate workshops relating to the concept. The previous workshops have created reports ("*Victoria Land Coastal Program*" - Italy, "*The Latitudinal Gradient Project*" - New Zealand, and "*Latitudinal Ecosystem (LAT-ECO) Responses to Climate Across Victoria Land, Antarctica*" – USA) focusing on different aspects of an international project. The documents can be accessed over the Victoria Land web-site at <http://www-bprc.mps.ohio-state.edu/victorialand>.

This international workshop (*Latitudinal Gradients in Victoria Land*) was convened under the auspices of SCAR. This workshop has integrated the previous reports from the national workshops mentioned above and introduced the framework and concept to the broader Antarctic community. In addition, this international workshop created a consensus on the general strategies for studying terrestrial and marine ecosystem and environmental variability along Victoria Land from nearly 72°S to 86°S. This document summarises the discussions at the workshop and highlights the salient points from the previous reports. This report was written to provide a platform to stimulate discussions on this new interdisciplinary research approach and foster international collaboration in Victoria Land.

The interdisciplinary approach, which is central to this latitudinal-gradient research concept is a powerful tool for understanding the ecosystems and environments that exist along Victoria Land to interpret regional and perhaps global change impacts and responses. Interdisciplinary interest in the concept is represented by:

- Limnology and oceanography;
- Marine and terrestrial ecology;
- Physiology and genetics;
- Meteorology and climate modelling;
- Glaciology and geomorphology;
- Sediment- and ice-core paleoclimatology; and
- Geographic information system analyses and remote sensing analyses.

THE WORKSHOP

The international workshop on *Latitudinal Gradients in Victoria Land* was held in conjunction with the VIII SCAR Biology Symposium and chaired by Dr Paul Berkman from the Byrd Polar Research Center at the Ohio State University in the USA. Scientists and national representatives attended the workshop from Italy, New Zealand, UK, USA, Germany, Estonia and Japan. The workshop convenors, presenters and rapporteurs along with a list of participants is given in Appendix A.

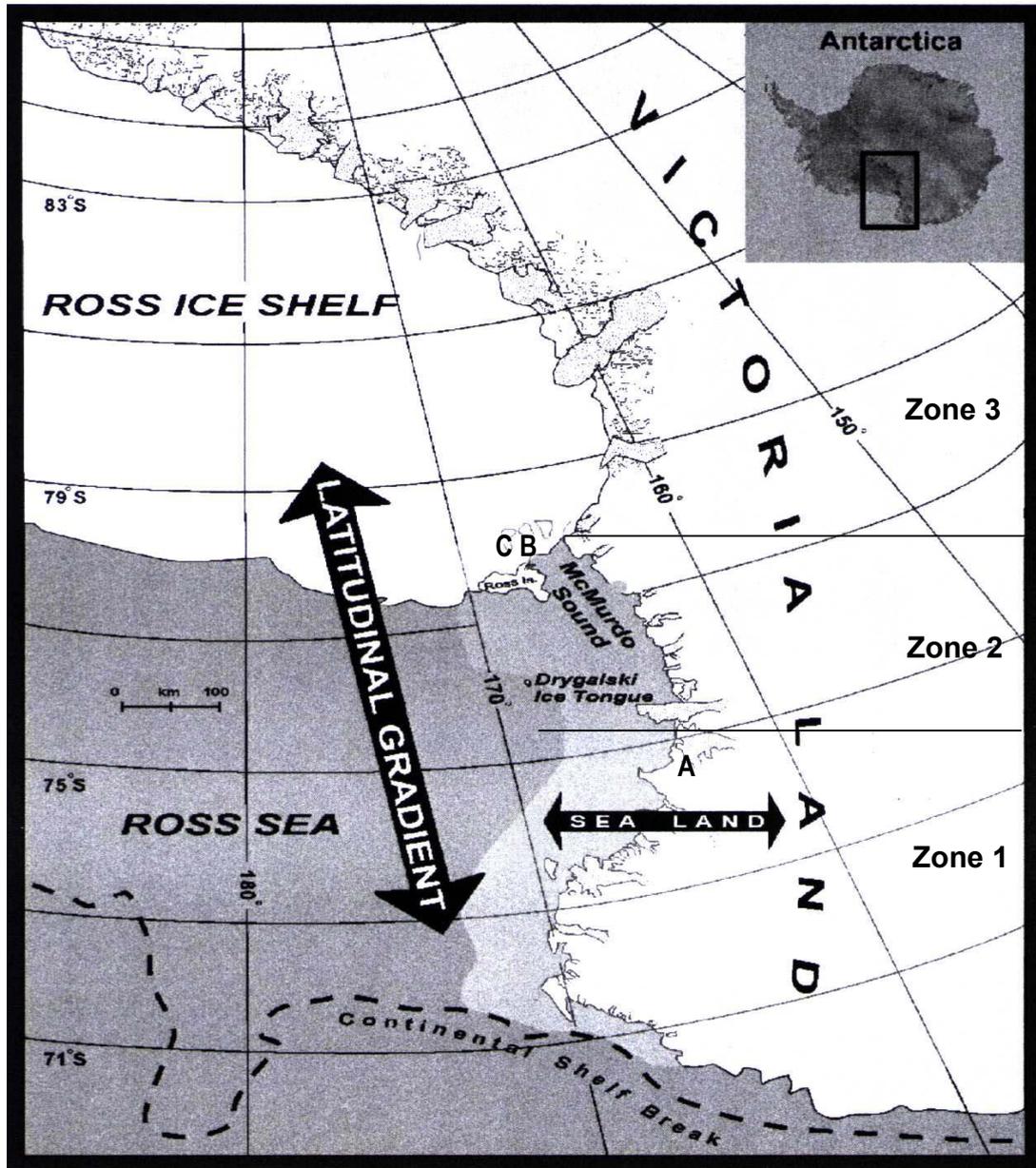


Figure 2. Map of Victoria Land, Antarctica (courtesy of LAT-ECO report from the April 2001 workshop).

The principal research zones are:

- Zone 1** (Open Water Zone) south of Cape Adare to the Drygalski Ice Tongue;
 - Zone 2** (Fast Ice Zone) south of the Drygalski Ice Tongue to McMurdo Sound and the edge of the Ross Ice Shelf; and
 - Zone 3** (Ice Shelf Zone) south of the Ross Ice Shelf edge along the Transantarctic Mountains to the southernmost terrestrial ecosystems on Earth.
- A.** Terra Nova Station (Italy, summer only)
 - B.** McMurdo Station (United States, year-round)
 - C.** Scott Base (New Zealand, year-round)

The workshop focused on identifying the information gained by a latitudinal study of the ecosystems in the region and on defining the physical conditions which control the composition of the ecosystems in Victoria Land. The workshop goals were to:

- Provide information about the project to researchers outside the three original countries involved in the project (Italy, New Zealand and USA);
- Reach agreement on the scientific concept of the project at an international level;
- Refine the working hypothesis of the project;
- Define key scientific questions the project could address; and
- Provide recommendations for the implementation of the project.

PHYSICAL FACTORS AND UNIQUE FEATURES OF VICTORIA LAND, ANTARCTICA

The distinct physical factors and features of Victoria Land make the area an “unique laboratory” for global change responses of Antarctica and the world in general. The following comments represent a distillation of the previous reports and workshop discussions. The comments provide the rationale for implementing an interdisciplinary latitudinal ecosystem research initiative along the Victoria Land coast.

- Southernmost ecosystems on Earth
- Relatively small anthropogenic influence (relatively pristine baseline)
- Extreme seasonality (24 hours of dark in winter / 24 hours of light in summer)
- Presence of ice shelves (largest in the world)
- Steep environmental gradient onshore/offshore
- Steep biological gradient onshore-offshore
- Antarctica has most limited terrestrial biodiversity of any continent (directly relates to ecosystem complexity, structure and function)
- Marine ecosystem dynamics "reset" when habitats opened after Last Glacial Maximum (~15,000 years ago)
- Excellent preservation in fossiliferous raised beaches and abandoned penguin colonies
- Circumpolar ecosystem (modern species distributions, Late Quaternary fossils in raised beaches) and environmental dynamics (polar vortex, Antarctic Circumpolar Current) provide basis for comparisons around the entire continent
- High latitude systems show greater sensitivity to climate change than mid or low latitudes particularly during the summer, because small temperature changes will influence phase transitions of water between a liquid and a solid
- Ability to integrate modern and historical records is unmatched elsewhere because of extant and fossil Holocene assemblages with the same species as well as marine, terrestrial and ice core records
- Extreme cold and aridity

- Ice core records - highest resolution, continuous long-term records of climate change and/or regional environmental change
- Bio-complexity is strongly ice-influenced / controlled (changes in ice-cover are related to climate)
- Seasonality of primary production - with its consequent effects on ecosystem structure and function - is extreme (on or off)
- Legacy influence of organic matter and habitat development is large, particularly in the terrestrial environment
- “Extreme” environmental and ecosystem conditions reduce experimental ambiguities for developing adequate controls to test various climate-response hypotheses
- Modern (species and environmental) analogs for experimentally interpreting the dynamics of paleo-systems
- 'Ozone hole' creates high ultraviolet radiation exposure in spring time
- Within demonstrated logistic capacity of United States, Italian and New Zealand programmes

GENERAL HYPOTHESIS

Ice-driven dynamics control the structure and function of biological systems (marine, terrestrial and freshwater) near the limits of life at high latitudes.

Independent Gradients and Ecosystem Influence

Three systematic environmental gradients that are significant to understanding Victoria Land ecosystem dynamics are latitude, altitude/depth and distance from the coast. The three gradients have different spatial scales, environmental variables and environmental constants. None of the gradients alone are simple surrogates for environmental change. However, combining these will result in a better understanding of our current ecosystems and an increased predictive knowledge of the future effects of environmental change. The importance of physical factors on the three geographically independent gradients: latitude, altitude/depth and distance from the coast can be represented in a matrix, shown in Table 1.

Victoria Land ecosystems can be separated into three types: marine, terrestrial and freshwater. Values for five factors that influence ecosystem function and structure are listed for each of these ecosystems in Table 2. The values given were reached through discussions during the workshop. By combining the matrix of environmental gradients with critical factors on ecosystems a picture of the dependencies of physical factors for Victoria Land ecosystems will begin to emerge.

Table 1. Terrestrial and Marine physical factors and how they relate to latitude, altitude/depth and distance from the coast variations.

Physical Factor	Latitude (per degree)	Altitude/ Depth (per 100 m)	Distance from Coast (per km)
Terrestrial Physical Factor			
Solar radiation	3	1	None
Temperature	3	2	2 – 1
Humidity	2	1	2
Wind	1	1	1
Precipitation (amount)	2	1	1
Precipitation (type)	2	1	1
Ablation (amount)	2	2	2
Ablation (type)	2	2	2
Terrestrial geochemistry	1	1	1
Seasonality	2	1	None
Marine Physical Factor			
Polynya	2	None	1
Current	2	2	2
Salinity	1	2	2
Sea Ice cover	2	None	1
Ice shelf cover	3	None	None

Key: 1 - Weak dependence; 2 - Medium dependence; and 3 - Strong dependence

Table 2. Influence of five critical factors on ecosystems in Victoria Land, Antarctica.

	Light	Nutrients	Liquid H ₂ O	Temperature	Gases
Marine	1	1	0	1	1
Terrestrial	1	2	2	2	0
Freshwater	2	1	1	2	2

Key: 2 = always limiting; 1 = sometimes limiting; and 0 = never limiting

General Strategies

The workshop participants reached agreement on four general strategies for the project:

1. An interdisciplinary approach to ecosystem research is the key to better understanding the ecosystem responses to variation in latitude.
2. Application of a transect approach (i.e. perpendicular to the coast), at the different latitudinal locations along the coastal zone, in order to separate altitude and depth dependence from latitudinal variation.
3. The project should be closely related to the SCAR Biology Programmes “Regional Sensitivity to Climate Change” (RiSCC) and “Evolution in Antarctica” (EVOLANTA).
4. Victoria Land can be separated into three distinct zones relating to the presence and persistence of ice (Figure 1: the oceanic zone, the fast ice zone, and the ice shelf zone).

Key Questions

The following key questions were formulated at the workshop. They were framed around the general hypothesis relating to ice-driven dynamics of coastal Victoria Land ecosystems.

1. How do ice dynamics (e.g. movement, melt, accumulation and ablation) influence the relationship between solar radiation and primary producers in the presence of available water?
2. What is the role of persistent ice structures in defining community composition along Victoria Land (e.g., Drygalski ice tongue)?
3. What is the extent of the availability of free water along the gradient, and how does this change in space and time?
4. How do elevational linkages in biodiversity change with latitude?
5. To what extent does soil carbon content change with latitude and therefore influence terrestrial systems?
6. How can biological/chemical records be used to interpret sea ice extent?
7. How are species energetics and timing influenced by ice extent?
8. What is the role of the meteorological forcing (e.g. katabatic winds) on the marine and terrestrial systems of Victoria Land?
9. What is the Victoria Land distribution of persistent organic trans-boundary pollutants?
10. To what extent does the biomass of benthic primary producers change with latitude?

CONCLUSION

The Latitudinal Gradients in Victoria Land Project will focus on the general hypothesis generated at the workshop by addressing the key questions raised and listed above. The unique environment of coastal Victoria Land may hold the key to understanding the Earth's response to global change.

Currently, logistic resources from the United States, New Zealand and Italian Antarctic programmes are being used to conduct research activities along the Victoria Land coast. These programmes provide helicopter and fixed-wing aircraft for deploying field teams that can be strategically staged from the different national research stations as well as remote sites with established fuel caches. Along with aircraft support each country has research vessel capability for marine research in the Ross Sea. It is anticipated that future research collaborations, information exchanges, database activities and logistic commitments among these programmes and other participating countries will involve a Science Plan and a Memorandum of Understanding, which is agreed to by participating countries.

The Latitudinal Gradients in Victoria Land Project should be implemented in an interdisciplinary context among the Italian, New Zealand, United States and other contributing national Antarctic programmes. The implementation plan for this international and interdisciplinary project should consider:

- operational and funding frameworks of the countries involved;
- proposal review process, which can align to the time constraints of the project; and
- overall practicality and cost-effectiveness of the co-ordination of the project.

The workshop participants suggested that the initiative be implemented in three phases.

Phase 1:

Informal networking and logistic co-ordination among funded scientists from the different national Antarctic programmes who share common research interests (e.g. near-shore marine benthic ecology; limnology and terrestrial ecology; meteorology; ice-core paleoclimatology; penguin ecology and paleoecology; and glacial geomorphology). Logistics capabilities to support such collaboration would need to involve discussions between national programme managers.

Phase 2:

The Creation of a Science Plan for the international project. The document would incorporate each nation's science and logistics capabilities for the international project to proceed. The Science Plan would include:

- general hypothesis and key questions;
- project structure;
- project timetable and logistics;
- scientific work at the sites;
- planned long term monitoring;
- environmental impact/management;
- data management plan and;
- reporting and publication of results.

Phase 3:

A Memorandum of Understanding that would elaborate on the Science Plan and identify additional commitments among national programmes for:

- ship-based logistics (e.g. RV-Italica (Italy), RV-Tangaroa (New Zealand) and RV-Nathaniel B. Palmer (US));
- data-storage facilities and data management strategies;
- scientific and field equipment and facilities;
- scientific and safety personnel;
- configuration and principal transport logistics (i.e. fixed-wing aircraft and helicopters);
- appropriate administrative infrastructure and co-ordination;
- environmental consideration consistent with the Madrid Protocol; and
- programme assessment procedures and stages.

Appendix A

Workshop Participants:

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Key to Activities: C – Convenor; P – Presenter; and R – Rapporteur