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THE SCIENTIFIC CHALLENGE OF OUR CHANGING ENVIRONMENT

A conference addressing environmental change in Newfoundland and Labrador and similar regions

March 3-5, 1993
Memorial University of Newfoundland

This conference was the Annual Technical Meeting of the Newfoundland Section of the Geological Association of Canada, organized in conjunction with TERRAMON, and supported by the Canadian Global Change Program and the St. John's-88 Fund.

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Legume-*Rhizobium* symbiosis in the shorelines of Newfoundland: nitrogen fixation activity in beach pea root nodules

(Poster)

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Lathyrus maritimus (L) Bigel, commonly known as beach pea, grows along the shorelines of arctic and subarctic regions from Greenland to Siberia and Japan. In Canada it is found in Newfoundland, Nova Scotia and Quebec. The roots of the plants are found to be nodulated by the nitrogen-fixing bacterium *Rhizobium* under naturally growing conditions. In Newfoundland this plant occurs on sandy and gravel beaches. Besides being a sandbinder due to the horizontally growing underground stems and roots, it is often used as fodder for grazing cattle. In this paper a study of beach pea nodules and its nitrogen-fixing activity are presented. Maximum values for nitrogen fixation, measured by the acetylene reduction assay, were obtained at 20°C, and the Q_{10} between 5 to 20°C was found to be ~2. The nodule anatomy revealed its indeterminate perennial form. Oleosomes (lipid bodies) were present in the nodule tissues. Morphometric analysis showed their presence in the cortical cells throughout all developmental stages, but the infected cells were marked by temporal presence only during the early stages of infection and symbiosis. The rhizobia were isolated, cultured and characterized in the laboratory. The plants could be grown under laboratory conditions and infected effectively with the isolated rhizobia. Beach pea and its symbiotic rhizobia offer a system, the study of which will provide insights into the nature of our shorelines.

An analysis of snow conditions and winter climate over the Grand Lake catchment and other Newfoundland locations

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Late-winter snow cover over the Grand Lake catchment was analysed for the period 1934 to 1990, with the objective of examining its sensitivity to winter temperature and precipitation. Snow depth and water equivalent were obtained from annual snow survey records and compared with corresponding temperature and precipitation series from nearby climatological stations. Mean winter temperature exhibited an overall increasing trend until the mid-1950s followed by shorter oscillations through to the present. Winter snowfall and the snowfall/rainfall ratio showed considerable short-term variability throughout. Over the period as a whole the depth and water content of the late-winter snow blanket over this catchment show significant correlation with mean winter temperature and winter rainfall, but not with winter snowfall. Within the basin, variations in snow conditions are influenced by site elevation, distance inland and the overall character of winter weather. The historical relation between snowfall and mean temperature is also compared for other locations on the island and in Labrador over the past 40 to 50 years.

Multistakeholder attitudes toward and knowledge about water pollution in St. John's Harbour, Newfoundland

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St. John's Harbour is one of 12 sites identified in Atlantic Canada under the Atlantic Coastal Program (ACAP). Under ACAP water quality is to be addressed by the local community through a comprehensive resource management and planning process. In St. John's this process began in February 1992 with the identification of various stakeholders.

Data were collected from multistakeholders (n=70) through a personal interview and mail-back survey administered in the summer of 1992. The personal interview contained open-ended items focusing upon concerns about the harbour, main pollutants and polluters, attitudes toward the planning process and attitudes toward the development of a management plan. The mail-back instrument consisted of 67 closed-ended items addressing attitudes toward and knowledge about water pollution in St. John's Harbour.

Descriptions of the harbour varied considerably among stakeholders. While some respondents saw the harbour as an overloaded cesspool with a noxious aroma, others saw the area as a small active harbour in a scenic setting. Most respondents believed that the pollution needed to be addressed quickly. Of the top five concerns (sewage, smell and aesthetics, importance of environmental awareness, tourism

potential and current visitor use, and health problems), most were more human than biological, suggesting again the importance of understanding the human dimension to resources management issues. Although all respondents knew raw sewage was dumped into the harbour, knowledge about potential health problems was considerably less. Understanding multistakeholder attitudes and knowledge can aid resource managers in focusing environmental awareness programs and identifying concerns during the planning process, thus ensuring successful implementation of management plans.

East coast marine fog chemistry

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Recent data indicates that fog and cloud water can be ten times more acidic than rain in eastern North America. In coastal regions with relatively high fog frequencies, fog water can be an important pathway for the transport and deposition of acidic substances. Cape Race, Newfoundland, is exposed to 164 days/year of fog on average. Fog chemistry monitored near Cape Race, indicated that fog is acidic (median 4.0). Excess sulphate and nitrate account for most of the acidity, with sulphate being the more important contributor. Comparison with other monitoring sites indicated that land use and distance from source regions were important factors in determining fog acidity. Trace metal concentrations were low in fog samples. Deposition estimates indicate that fog is an important pathway for hydrologic and chemical input to coastal ecosystems.

The need for standard geological indicators of environmental change

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Many agencies are now seeking clear, simple and quantifiable scientific parameters to measure changes in the biosphere, hydrosphere, atmosphere and lithosphere--changes that take place on a time scale of years or decades, and which may be gradual and linear or chaotic and catastrophic. Much effort is now being focused upon ecological, hydrological, chemical and climatic indicators. Geological parameters and processes affecting surface and near-surface environments appear to be commonly ignored, especially in non-urban settings. IUGS is now compiling a standard checklist of geological indicators needed to assess the health and integrity of natural environments, for example, through repeated baseline surveys and biophysical inventories. The goal is to contribute essential tools necessary to measure actual environmental change, for use both by geoscientists and others. The results should help to build linkages between geoscience on the one hand and biology, botany, climatology, ecology, forestry, hydrology, etc., on the other.

The geo-indicators will deal with erosion and deposition, neotectonics, slope stability, weathering and soil development, geochemical and geophysical parameters, and other dynamic aspects of the landscape. Ideally, the indicators will assist in differentiating between changes that are naturally occurring and those induced, accelerated or retarded by human activity. Even if this distinction is not readily attainable, it is still important to understand in what ways the environment may actually be changing.

Recent coastal evolution of gravel barachoix, Placentia Bay, Newfoundland

(Poster)

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Detailed study of gravel barachoix beaches at Ship Cove and Big Barasway, Placentia Bay, has revealed significant differences in morphology, sediment texture, and structures between the beaches, in addition to lateral variability within each of these systems. The individual shoreline assemblages reflect differences in source material volume and characteristics, in the amount and seasonal variability of local sediment supply from fluvial discharge and bluff erosion, and in the hydrodynamic settings of the barachoix. Differences in orientation with respect to the prevailing southwesterly winds, and in the nearshore bathymetry, also contribute to the characters of the shorelines. Anthropogenic modification of the beach systems has been extensive. The Ship Cove system is currently unstable as a result of aggregate removal during highway construction in the early 1960s and a forced northerly relocation of the outlet. At Big Barasway, sediment depletion and limited re-supply has resulted in extensive erosion throughout 1992. The outlet has widened more than 5 m between May and December 1992. Overwashing and ice-foot development also act to modify both shorelines to differ-

ent degrees. Radiocarbon dates and sedimentological data indicate that transgression is currently occurring along the southeast Placentia Bay shore, and further modification of the coastline is anticipated in the subsequent century.

Implications of environmental changes on rare plant distribution patterns in Newfoundland

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The island of Newfoundland has about 275 species of plants that are rare. They represent 30% of the total native vascular flora of the island. The west coast, particularly the Corner Brook and the Strait of Belle Isle regions, has the highest concentrations of rare species due mainly to the climatic gradient and diverse bedrock geology.

From a physiogeographical perspective, many of these rare plants are peripheral or disjunct species whose populations are restricted in their distribution to specialized marginal habitats such as limestone barrens/talus, serpentine barrens and late-lying snowbeds.

These "refugial" habitats are unique and represent fragile ecosystems that are vulnerable to degradation by human impact (land-use practices, resource depletion, pollution). They are also sensitive to more long-term ecological changes in regional environmental conditions. Some of the very restricted rare plant populations that are near the limits of their range of tolerance in these habitats may have predictive value as indicator species of changing patterns in climate and vegetation cover. Biogeographical or spatial analyses of the important environmental and biophysical controls that are maintaining these rare plant populations is a basic step towards explaining their present distribution patterns and ensuring their conservation.

Environmental change since deglaciation: the evidence of pollen and other data from lake and marine sediments

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Lake and marine sediments in Newfoundland and Labrador provide proxy data from which environmental change can be reconstructed for the 13 to 6 millennia since the last deglaciation. The data considered include microfossil pollen, algae and charcoal, sediment geochemistry and radiocarbon dates, interpretation of which permits the recognition of such terrestrial events as:

(1) accelerated soil erosion in the European period in anthropogenically disturbed catchments;
(2) changes in forest composition, treeline, species range and fire frequency during the 6 to 4 ka B.P. interval, with inferred summer temperatures up to 1°C warmer than present, followed by cooler, moister conditions with development of wetland;
(3) slow initial development of forest in S and SE Newfoundland until 8.5 ka B.P. following late deglaciation (after 10.5 ka B.P.), possibly related to low ocean temperatures (Laurentide Ice Sheet melt); and
(4) a cold period interrupting earlier deglacial warming elsewhere on the island, correlated with the amphiatlantic Younger Dryas oscillation (11-10 ka B.P.).

Marine events identified include:

(1) sea level change: e.g., flooding of St. John's Harbour basin ca. 10 ka B.P. as sea level rose above the -14 m threshold;
(2) hiatuses within and disturbances of the late-Pleistocene - Holocene sedimentary record on the northeastern Newfoundland Shelf.

Pollen, paleotemperatures and the next ice age

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Temperature profiles, usually for less than 100 years, are linked with CO_2 records to predict greenhouse warming. Holocene pollen profiles, usually for 10,000 years, show a much more complicated pattern of vegetation change which reflects climate. In many parts of North America the palynomorph records show a consistent pattern wherein glacial environments are replaced by forest stands and prairie. This culminated in the mid-post-glacial Hypsithermal when climate was as much as 1.5°C warmer than today. The last 5000 years have witnessed several significant fluctuations in vegetation and climate. The last major climate swing started about 600 years ago with the beginning of the Little Ice Age; pine became established as a significant component of the temperate forests of eastern North America. Recovery from the

Little Ice Age to "normal" conditions has taken more than 100 years. More than half the temperature change following the Little Ice Age took place in the early part of this century when our production of CO_2 and other greenhouse gases was low. A further increase to re-establish Hypsithermal conditions is not outside post-glacial norms. Given that the record of temperature change through the Holocene shows fluctuations that are not obviously linked to greenhouse gases and the present record of climate change is part of a larger cycle, is it fair to implicate atmospheric pollutants as the sole cause of things to come?

A role for exploration geology in environmental monitoring in urban developments and wetlands in Newfoundland and Labrador

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Three projects utilizing techniques for Pb, As and U exploration are summarized to show how geologists can help with urban development strategies and to help preserve wetlands. (1) In Newfoundland, exploration geochemistry has played a significant role in the search for ore deposits. There now exists a data set of 33 element analyses examined from 16,300 sites. In rural areas, Pb anomalies in sediment and water are thought to reflect the natural environment; nevertheless, some ponds have significantly more than 20 ppm Pb in the sediment. As towns and cities in the province develop new water and sewer systems, planners must take into account the role of bedrock geology in modifying lake sediment chemistry and the flux of naturally occurring Pb into city reservoirs and water systems. (2) Pb and As can also be incorporated into sediments from anthropogenic sources. In places such as northern Ontario, where "smokestack industry" has been active for nearly a century, exploration geologists look for chemical anomalies that are not only high but are also persistent at depth in lake sediments. Viewed from another perspective, anomalies present in shallow sediments might be very useful indicators of the areal extent and intensity of pollutants from point sources. (3) Naturally occurring U has the potential for creating environmental problems. U is a very mobile element having a strong affinity for organic material. Commonly, it occurs as a dispersed trace metal in granitic rocks such as those in Newfoundland and Labrador. Weathering releases U that can next become concentrated in reduced sediments of wetlands and lakes. For example, in places along the Rocky Mountains of Nevada and Colorado, any proposal to drain wetlands containing stable, reduced U may cause extensive pollution to municipal water systems as U is oxidized and released. Given that the igneous terranes of Newfoundland and Labrador contain radioactive granite bodies, there is no doubt that data provided by exploration geologists will be useful for protecting the urban environment.

Sedimentological, palynological and diatom evidence of the Younger Dryas, Pine Hill Pond, Terra Nova National Park, eastern Newfoundland

(Poster)

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The basal 150 cm of lacustrine sediment in a core from Pine Hill Pond, Newfoundland, includes the late-glacial and early Holocene and contains strong sedimentological and paleoecological evidence for a climatic oscillation equivalent to the Younger Dryas. Basal late-glacial minerogenic sediments are overlain by a silty gyttja marking the onset of organic sedimentation, but an overlying unit comprising 7 cm of silty clay marks a brief reversion to mineral sedimentation, prior to subsequent uninterrupted deposition of organic sediments. During this phase, the reversion from shrub tundra to a sparser herb-shrub tundra pollen assemblage (*Oxyria digyna, Artemisia*) is a strong indicator of climatic deterioration at the site. The paleolimnological expression of the Younger Dryas at this site is manifested by a sharp decrease of diatom concentrations followed by decreases in the relative frequencies of *Fragilaria* spp., which are largely replaced by a stratigraphically restricted group of unusual benthic forms, a rise in the relative frequency of chrysophyte cysts, and a crash in *Pediastrum* concentrations.

Sea level variation in Newfoundland and Labrador - glacio-isostatic, climatic and anthropogenic

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Sea level history throughout Newfoundland and Labrador reflects the complex interaction of glacio-isostatic, climatic, and anthropogenic factors. Understanding of past sea-level variations, and of recent coastal evolution, is critical both to assessment of previous climatic change and to prediction of future change. Subsequent to deglaciation, marine limits were largely controlled by the former position of the Laurentide Inlandsis margin, both in Labrador and Newfoundland. Marine limits locally exceeded 100 m asl in the interior reaches of Labrador fjords, and on the Northern Peninsula. Limits show a gradually declining pattern of elevations along the west and northeast coasts of the island. All areas of the province, including the Avalon and Burin peninsulas and the south coast, were subjected to postglacial sea levels above the present level. The pattern of limits suggests that isobases trended in a northeasterly-southwesterly orientation across the island. Subsequent isostatic recovery, combined with punctuated additions of meltwater from ablating continental glaciers, resulted in declining sea level through the early Holocene. Sea levels were below the present value along the southeastern and southern coasts during parts of the mid- and late Holocene. In the past 1000 years, transgressions have occurred along extensive segments of the Newfoundland coast. These ongoing changes in sea level are attributed to anthropogenically-driven climate changes, combined with ongoing isostatic adjustments.

The effect of urban and industrial development on the geochemistry of the watersheds in the St. John's area: preliminary results

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A lake sediment geochemical survey conducted during 1990 revealed that the watersheds in St. John's have been chemically affected, with Pb values in the urban core 10 to 15 times higher than in the surrounding area. To define more precisely the effect of man upon these watersheds a lake sediment coring project was conducted during the winter of 1992.

This current study takes a multi-disciplinary approach to document the chemical, physical, and biological history, and if possible, identify sources of the contaminates added to the watersheds. Sediment cores, 1 to 2 m long, were collected from four lakes in St. John's and a background pond overlying similar geology 30 km south of the city. This study examines a 49 element suite, pollen, diatoms, soot, charcoal, oil droplets, stable $^{206/207}$Pb isotopic ratios, and ^{210}Pb and ^{14}C dates.

Preliminary results depict three periods of widespread pollution from farming, coal burning, and urbanization in the St. John's area. All cores in the study have been affected with the background pond showing the smallest chemical increase and Quidi Vidi Lake the largest. Sediment Pb levels in Quidi Vidi Lake have increased 20 to 30 fold over background from 15 to 20 ppm at the base to 612 ppm near the top. The pollen, diatoms, soot, charcoal, oil droplets, isotopic ratios, and age dates all complement the chemical profiles providing an in-depth account of anthropogenic activity in the St. John's area.

Analysis of Mn and Fe coatings on stream pebbles by laser ablation microprobe-inductively coupled plasma-mass spectrometer (LAM-ICP-MS): a tool for environmental monitoring and geochemical exploration

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Pebbles from fluvial systems are commonly coated with Fe and/or Mn oxide coatings. These oxide-coatings absorb and concentrate metals from solution and hence provide a gauge of metal abundances in water integrated over time. Many elements of interest in both environmental monitoring and mineral exploration are below the limits of detection in water for most analytical methods; both types of research require delineation of anomalous concentrations vs. background. LAM-ICP-MS is a method of multi-element analysis of very small amounts of sample such as thin oxide coatings on pebbles. In order to test the potential of LAM-ICP-MS for the analysis of Fe-Mn oxide coating, a series of stream pebbles were collected from two fluvial systems; one flowing through a metropolitan area and the other draining a relatively undisturbed natural environment with known base metal geochemical anomalies.

Based on analytical response, a suite of 17 elements (including Pb, Zn, Cu, Co, As, Be, Ba, S, Sb, I, Fe, Mn, Ti,

Mo, B, Sn and Ce) could be adequately determined in coatings from the city stream, and this suite together with U, Hg and Ag were determined from the undisturbed stream. Signals for most elements appear to better correlate with Fe, except Zn which shows a much closer relationship with Mn. Ratios of heavy metals for Fe and Mn in coatings from the city stream increase downstream. The technique is fast and relatively inexpensive for both environmental monitoring and mineral exploration.

Aquatic insects as environmental indicators

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All life forms on the planet have a set of requirements for their existence. The existence of a taxa at a site indicates that the basic requirements are being met, at least for the stage observed, although they may not be optimal. Each taxa will have different requirements and varying optimal conditions, so that as environmental conditions change so will the populations of the taxa in a habitat. Even though the fauna of Newfoundland are impoverished, there are several hundred species of aquatic insects. These insects live in all types of aquatic habitats and are herbivores, carnivores, detritivores, and omnivores. They obtain this food by shredding, scraping, collecting and predation and have a range of substrate, water movement and chemical requirements. Thus by knowing the impact(s) on a taxa of a gradient of an environmental variable(s) it is possible to predict the conditions in a habitat by whether a taxon is absent or present plus its condition. Examples of the use of aquatic insects to indicate environmental condition will be given and how biotic indices have been developed.

Private sector marine geoscience in Newfoundland and Labrador
(Poster)

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Terraquest Associates is a Newfoundland-based firm offering marine geoscience consulting services to private industry and government agencies. We specialize in innovative approaches to the acquisition, processing, interpretation and dissemination of geoscience data, with emphasis on an improved understanding of the seabed and related marine environmental issues. Our expertise is in the acquisition and interpretation of high resolution single-channel seismic and sidescan sonar data, as well as sedimentary analysis, from offshore and coastal zones.

IKB Technologies was incorporated in 1975 as a Newfoundland company committed to designing and improving instruments for use in the marine geophysical survey industry. The company has produced and sold (internationally) a wide range of equipment; with perhaps the most successful being the IKB SEISTEC™ high resolution seismic profiler. This surface-towed system is capable of resolving sedimentary layers as thin as 0.25 m and operating in water depths from 1 to 100 m.

Acoustic remote sensing devices, including high resolution single-channel seismic and side-scan sonar systems, are widely used to gather data concerning the seabed. Single-channel seismic systems generate a profile of the sub-bottom geology, while side-scan sonars yield a plan view of the seafloor. Careful interpretation of these data can yield a wealth of information about sediment thickness, type and distribution, plus the location and identity of seabed features such as shell beds, iceberg scours, shipwrecks, sewer outfalls, wellheads, pipelines and telecommunication cables. Bottom sediment samples and photographs may be used locally to confirm interpretations made from geophysical data. Potential applications of these technologies include harbour surveys for construction and pollution monitoring purposes, pipeline or cable route surveys, offshore resource inventories, wellsite surveys, lake studies and environmental monitoring programs.

The initiation and development of boreal peatlands in Atlantic Canada and their response to global warming

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Peatlands cover about 120 x 10^6 ha, or about 12% of Canada. Most, about 75%, are classified as boreal. Peat accumulates via terrestrialization, the infilling of topographic lows, and by paludification, often defined as the swamping of forests, a process largely independent of topography. The latter dominates in the eastern part of the boreal zone where it produces physiognomically and behaviourally distinctive mire forms. This paper focusses on paludification; the proc-

esses that initiate and sustain it, and on the potential responses of ombrotrophic mires to global warming.

Paludification is not exclusive to the boreal zone, but is clearly a dominant process there. The general distribution of its products suggests climatic forcing working directly through energy availability and water balance, and indirectly through climatically-mitigated disturbance, particularly fire. The well-defined regional geography of mire forms implies that even small differences in the climatic template induce distinctive responses. Stratigraphic data attest to the sensitivity of mire systems to climatic shifts. However, behaviour and hence, development, are determined ultimately by the ecologies of the various peat formers which may induce quasi-cyclic responses largely independent of macroclimate. The responses of these systems to global warming at least in Atlantic Canada are likely to be slow and muted with none of the large-scale 'depaludification' predicted by Russian researchers.

Are we managing the environment yet? The manager's dilemma and the first whiff of a solution

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This paper explores one problem we face in manipulating the natural systems that are our sustenance. We articulate the Manager's Dilemma in managing ecosystems (often in crisis) for diverse human uses, sustainably. Then, we examine selected models to see if solutions to the Dilemma might be beginning to emerge.

The latest scientific response to environments in crisis is ecosystem management. The objective is usually defined as something like "ecosystem health." The scientific challenge is to define and understand, restore, and finally, sustain the health of the ecosystem. One horn of the Manager's Dilemma is here, in the technical and scientific: the first step of the program (define and understand the ecosystem) could easily consume all the available resources well into the next millennium. An intriguing theoretical possibility is that much of the ecosystem management will be required in areas of "irreducible ignorance," in any case. That is, we can *never* understand enough to predict around such ignorance. The taxonomy of ignorance explains this.

A second horn of the Manager's Dilemma is social or political: the various groups of human users of the ecosystem in question make dramatically divergent, often conflicting, demands of the system. Some are subsistence needs; others are commercial; still others are recreational; yet others are aesthetic, or even ethical. How to accommodate this diversity in a single management scheme? The manager is charged, then, with managing the unknown and to some extent unknowable ecosystem for the use of a collection of human subpopulations with essentially irreconcilable goals for that single environment: the Manager's Dilemma. The political ("values") and scientific ("indicators") paradigms diverge.

The whiff of a solution to the Dilemma may be emerging from a number of Canadian case studies that are reviewed in detail. All meld the scientific with the political in striving to manage healthy ecosystems, sustainably.

Can we provide resources for ten billion humans?

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Perhaps the greatest question facing human society today is "can we provide the resources for a high quality of life for the ten billion humans who will be on Earth next century when we cannot do this for the five billion present now?"

The basic factors of life support are well known (air quality, water quality, soil quality...) and we must understand climate and all the fluctuations driven by Sun and Earth.

The carrying capacity of Earth is complex and today largely controlled by modern technologies and particularly energy. It is clear that if we continue on the same track as for the past two centuries, our life support systems may fail. Earth scientists must become more involved in the decisions that will be made concerning the necessary and vast developments which will occur next century.

Finally, all who live with Earth must be educated to understand the life support systems. Education, male = female, is the key to population control. Education requires absolute freedom of information and access to information.

Defining the hydrogeological framework for environmental studies in Newfoundland and Labrador

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Most of Newfoundland and Labrador is underlain by fractured bedrock, characterized by low matrix porosity and permeability, with a thin veneer of overburden. In most places, this overburden consists of a thin soil cover over glacial till and/or glacial-fluvial material with moderate porosities and permeabilities. Peat bogs and wetland areas are common. Significant deposits of alluvium with high porosity and high permeability are restricted to a few areas of the province. In contrast to many other parts of North America, the overburden in Newfoundland generally has a very low clay content. In addition, except for the western part of the island of Newfoundland and the southern coast of Labrador, the bedrock and the locally derived overburden generally have low buffering capacities.

Coupling these hydraulic properties with the high precipitation and relatively high relief of most areas of the province, produces complex groundwater flow systems with strong interactions between surface water and groundwater flow systems. This presentation reviews the use of three-dimensional groundwater flow and transport models to determine the configuration of two regional flow systems, one in fractured granitic rocks and the second in fractured sedimentary rocks. The configuration of the flow system and the predicted travel times determined using these three-dimensional flow and transport models provide a tool for evaluating changes in the isotopic and chemical composition of surface and ground waters between different parts of the flow systems and a basis for distinguishing between changes that reflect natural groundwater evolution and anthropogenic effects. The complex flow system configuration and short residence times in the shallow part of the groundwater flow system, predicted by these models and confirmed by the groundwater isotopes, show the need to carefully define the configuration and dynamics of the groundwater flow system as an integral part of most environmental studies and, given the low natural attenuation capacity of the natural system, when siting hazardous waste facilities.

Long-term salmonid research near Cape Race, Newfoundland

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The Department of Fisheries and Oceans, in collaboration with investigators from Memorial University, is undertaking long-term salmonid research in rivers on the southeastern part of the Avalon Peninsula, Newfoundland. Management of Atlantic salmon is based on allowing sufficient 'escapement' of adult fish returning to rivers for adequate deposition of eggs to maximize output of smolts, the juvenile stage migrating to sea. Both biotic and abiotic factors determine relative production and survival between rivers. Competitive effects, and hydrological and climatic factors, cause annual fluctuations, which are presently being analysed.

Monitoring the environment using an airborne imaging spectrometer - applications and Newfoundland examples

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Imaging spectrometers allow for simultaneous acquisition of images in contiguous, narrow bands such that full reflectance spectra can be constructed for each pixel in the scene. There are a host of biogeophysical parameters which can be measured using such data, including water quality (phytoplankton concentration and genera, dissolved organic carbon, suspended particulate matter); vegetation canopy biochemistry (and, by corollary, ecosystem processes such as net primary productivity); rock/mineral determination and geobotanical phenomena; and soil characteristics. The Compact Airborne Spectrographic Imager (CASI) is a Canadian designed and built imaging spectrometer which can acquire data in either (i) spatial (image) mode (maximum of 15 bands) or (ii) spectral mode (288 contiguous bands) and therefore satisfies the demand for high spectral resolution data in the visible to near IR region of the spectrum. CASI data sets collected in Newfoundland and Labrador over the past three years will be presented to illustrate various terrestrial and marine applications for this technology.

The international toxics monitoring project - a status report

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Scientific literature has shown a high level of mercury and other metal contamination in fish in New England and Canada. Very recent data have indicated an alarmingly high concentration of mercury in the feathers of American Bald Eagle chicks in Maine. These data, when viewed in conjunction with air emissions data available through the U.S. Environmental Protection Agency, focus our need to gather information to assist in the explanation of the sources of toxic materials.

The following study was designed to obtain first year regional data, gathered on atmospheric deposition of toxic materials within lake basins. The study area includes all of eastern North America, north of the State of Pennsylvania, in an attempt to investigate the impact of as many atmospheric patterns as possible. Fish species and snow melt data will be gathered and analyzed. Control sites in northern Canada were selected to investigate sample locations previously selected by the Canadian Department of Fisheries and the Environment in 1977-78. Available results will be presented at the conference.

Variability in Newfoundland's marine environment

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Variability, how to measure it, what it means, and the relationship between physics and biology in the marine environment have been central concerns of ocean scientists for more than a century. Significant variability in the ocean occurs at many time and space scales, a point made graphic in the familiar Stommel diagram. Over the time and space scales of the marine environment in which our fisheries are played out, much physical and biological data relating to the ocean exist for the Newfoundland area, Changes over time and space can be traced in both, but patterns are not clear and variation in one cannot readily be related to changes in the other. This may stem from inattention to matters of scale. The question of appropriate scales of analysis in the fisheries is only beginning to be addressed.

The Newfoundland environmental assessment process

(Poster)

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The Newfoundland Environmental Assessment Act and Regulations are designed to facilitate the wise management of our natural resources and to protect the environment and the quality of life of its residents. Through environmental assessment, it is intended that projects are planned taking into account the needs, constraints and benefits of the bio-physical and socio-economic environment--a multi-disciplinary approach. The process applies to developments proposed by individuals, groups, companies, civic bodies, and government departments. Relatively few developments must undergo further assessment (only 5%) beyond an initial review (registration) but until the Minister releases the undertaking from the process, other permits and authorizations cannot be obtained and no part of the project can proceed.

The poster display describes the assessment process in further detail.

An approach to monitoring and mapping mesoscale change in remote areas

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The detection and understanding of climate-driven local and regional environmental change can be approached through a combination of observational and analytical methods involving conventional and special climatic and other biophysical data, proxy data, remote sensing, and geographical information systems. In remote arctic and subarctic areas, coverage by permanent observing networks is generally inadequate to support the interpretation of field evidence in areas of particular interest on the scale of 10^2 to 10^4 km^2. Automated climate stations and remote sensing provide a means of filling these observational gaps, while physical and geostatistical models permit objective interpolation over the area. Using a digital elevation model as the base, mapping of variables is done by layering within a GIS, which permits further analysis of spatial relationships. Mesoscale environments being investigated using these methods include (1) a

high arctic, ice cap marginal area, (2) a low arctic interior lowland area, and (3) a maritime subarctic location. The approach has proven useful in updating the results of intensive field studies made 20 to 30 years ago, for purposes of change detection.

Reconstruction of sapwood: a dynamic measure of foliage biomass
(Poster)

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As part of a larger study with environmental implications, sapwood and heartwood relations were examined in trees. The estimation of foliage biomass based on current sapwood cross-sectional area is static and of limited use in stand dynamics. If sapwood cross-sectional area in the functional fraction of the crown (where all branches contribute to stem sapwood growth) were to be reconstructed over time, it could provide a dynamic measure of foliage biomass. Such estimates are needed to support the development of biologically based growth and yield models to monitor changes in foliage accumulation. Also, with estimates of past foliage accumulation, it may be possible to examine various indices of growth efficiency; defined as the ratio of stem volume increment to sapwood area. The theoretical basis for reconstructing sapwood area in tree stems was established because of a strong relationship between the number of sapwood rings and the age of the total stem section. Based on this relationship a sapwood reconstruction methodology was developed using growth layer analysis techniques. This approach applied to the reconstruction of sapwood cross-sectional area and sapwood volume is new. The reconstruction methodology was applied to jack pine in the northern Ontario boreal forest but should have wider applicability to the boreal forests of Newfoundland and Labrador.

Monitoring activities of the water resources management division
(Poster)

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The Newfoundland Department of Environment and Lands has a mandate to monitor and manage the water resources of Newfoundland and Labrador. Much of this mandate is the responsibility of the Water Resources Management Division, which began operating in 1975 with a staff of two and currently has a staff of 22 in six sections: Surface Water, Hydrologic Modelling, Water Investigations, Water Quality, Groundwater, and Water Rights.

The Surface Water Section is responsible for monitoring protected water supplies; 50% of the province's population obtain their water from 220 protected basins. This section also operates federal-provincial and provincial hydrometric networks, providing data to the Hydrologic Modelling Section and various users across the province. The Modelling and Investigation Sections monitor hydrologic, climatic, and ice processes in several major watersheds. These computerized monitoring systems generate very useful databases and also provide near-real-time monitoring of stage and flow via data collection platforms and satellites; such data is used in flood forecasting, by the hydroelectric power industry, and even by the tourism industry and canoe clubs. The Water Quality Section operates a federal-provincial Water Quality Monitoring Agreement and analyzes provincial network data collected during the past 15 years. The Groundwater Section monitors eight observation wells for groundwater quality, temperature, and piezometric levels; several landfill sites for groundwater contamination; and the effects of road salt on groundwater quality.

Much of the Division's work involves collaboration with federal agencies, and both collaborative and provincial reports are produced. Major recent publications include the **Water Resources Atlas of Newfoundland** and the Main Report of the Urban Hydrology Study of the Waterford River Basin.

Water quality monitoring in Newfoundland and Labrador

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Water quality studies have been undertaken in the province by both the federal and provincial governments for over 20 years, but it was not until 1977 that a provincial Water Quality Network Plan was implemented to provide continuous reliable data. Specific objectives at the time were to provide baseline water quality data at representative sites

throughout the province, to specifically study known water quality problems, to assess relationships between competing land and water uses, and to provide a basis for water quality management through development of water quality guidelines and site objectives. Most monitoring was restricted to stations in the eastern portion of the Island of Newfoundland until the mid-1980s. A comprehensive multidisciplinary study of the hydrology and water quality of the Waterford River basin was conducted from 1980 to 1985. By early 1986, the Canada-Newfoundland Water Quality Monitoring Agreement was signed, and this cost-shared and work-shared agreement now provides for regular sampling of over 60 index stations, including two stations in Labrador.

Most waterbodies in the province are drainage systems, and water quality is characterized by low conductivity and acid neutralizing capacity and relatively high concentrations of organic carbon. A comparison of remote rivers to urban rivers on the eastern part of the island shows that major ion concentrations are elevated in urban runoff, often more than an order of magnitude above background. Many trace metals are positively correlated to major ions and to each other, and they often exhibit strong seasonal variation correlated to temperature or to acidity. Total concentrations of trace metals can become elevated in response to erosional events caused by high water flow or by ice scour of sediments. In general, correlations between water quality parameter concentrations and daily mean flow are weaker than those related to seasonal temperature variation.

Post-glacial sea level change in Newfoundland as deduced from the distribution of radiocarbon dated marine shells

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Previous reconstructions of post-glacial sea level change in Newfoundland have mostly relied on a careful examination of data from a single site. Recent compilations of radiocarbon dates has allowed regional patterns of sea-level change to be deduced. A coast that has shown consistently falling sea-level since deglaciation (a type-A sea level curve) should allow collection of marine shells from above current sea level, showing a range of ages up to the present. A coastline that had sea level initially higher than present but subsequently falling below present (a type-B sea level curve) will provide shell dates ranging from deglaciation to the point at which sea-levels fell below present. One hundred ten radiocarbon dates on marine shells found above current sea levels are available for the island of Newfoundland. The chronological distribution of these dates shows a strong bias towards older ages, with dates <7000 B.P. found only at the northern extreme of the island. The dates show a strong trend with latitude, with the range of dates progressively increasing towards the north. These distributions are best explained by most of the island having a type-B sea-level curve, with the age of transition to sea levels below present increasing to the south. The tip of the Northern Peninsula may show a type-A or modified type-B curve. Examination of geomorphological evidence of raised sea levels corroborates these results. The data allows a prediction of the time of emergence-submergence transition over the island, and these results compare well with those from well-defined sea level curves from specific sites. These patterns suggest that most of Newfoundland is experiencing rising sea-levels at present, making low elevation coastal sites particularly susceptible to any rise in global sea-levels.

Elemental analysis of water, biological, and rock samples

(Poster)

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Since 1984, our laboratories have been active in the development of analytical methodology for the routine determination of trace elements in a variety of sample types including drinking water, pond water, wine, mussels, fish, milk, blood, other biological tissues, rocks, soils, and sediments. Increasingly, it is important that fundamental studies monitor a large number of elements, and hence multi-elemental techniques are required which offer limits of detections which are below natural concentrations in uncontaminated samples. An Inductively Coupled Plasma-Mass Spectrometer is used for the analysis of water and biological samples, which have been prepared using various methods. The instrumental protocol quantitatively determines 39 elements (Li, Be, B, Mg, Al, Si, P, S, Cl, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Br, Rb, Sr, Mo, Ag, Cd, Sn, Sb, I, Cs, Ba, La, Ce, Hg, Tl, Pb, Bi, and U) with limits of detection, for waters, which vary from a low of 0.01 ppb up to 5 ppm, depending upon the element being determined. For digested biological samples, typically prepared at dilutions of 1:100 solid limits of detection are 100 fold higher.

For solid samples including rocks, soils, and sediments, a procedure using X-Ray Fluorescence (XRF) offers the

economical determination of 30 elements (Na, Mg, Al, Si, P, S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Nb, Ba, Ce, Pb, Th, and U) with limits of detection which vary from 0.6 ppm to 100 ppm.

Examples of the application of elemental analysis in various studies will be shown.

Sea level change during the Late Quaternary in the Botwood (NTS 2E/03) map area

(Poster)

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Isostatic depression in the Botwood map area was influenced by both local Newfoundland ice and Laurentide (mainland) ice, with the larger Laurentide ice mass exerting the greater influence. As the Newfoundland ice mass decayed and retreated isostatic rebound occurred at a much slower rate. This resulted in higher sea levels as the sea invaded isostatically depressed terrain. As the ice decayed large quantities of meltwater were produced. Deltas formed as the meltwater reached the sea. Deltaic deposits within the study area consist of interbedded, stratified sands to cobbles, with the beds dipping steeply northeastwards towards the Bay of Exploits.

In the Botwood map area the marine limit has been estimated at 58 m asl, based on the height of the raised marine delta at Laurenceton. As isostatic recovery continued and relative sea level fell subsequent stands were recorded at 42, 35, and 11 m asl producing either deltas or marine terraces. The occurrence of small, isolated marine terraces and raised gravel beach bars at elevations between 7 and 1 m asl suggest that isostatic deformation is ongoing at the present.

Origin and successional status of heath in Newfoundland

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Heathlands cover approximately half a million hectares or 25% of the land surface in eastern Newfoundland. However, only a very small proportion of these heaths represents climax vegetation. Alpine heaths are localized on the highest inland ridges and the most wind-exposed coastal areas. Moss heaths dominated by *Rhacomitrium lanuginosum* occur in areas experiencing extreme fog frequency. These latter heaths have close floristic affinity to similar oceanic heaths in the European-north Atlantic region.

Other heath types in this region originated on sites that once supported productive forests dominated by *Abies balsamea* and *Picea mariana*. Repeated cutting and burning during nearly four centuries of European settlement are considered to be the primary causes of extensive heathland development. The Empetrum Heaths and Kalmia Heaths are anthropogenic vegetation types each of which has a distinct physiognomy and history of development. Analysis of relic trees preserved in the humus of the Empetrum Heath, clearly demonstrates that forests, comparable in productivity to extant trees in lowland valleys, occupied these upland sites in the last century. It appears that the widespread destruction of the forest landscape by European settlers has caused a 100 m depression in the natural forest treeline.

The Kalmia Heaths are an ericaceous dwarf-shrub thicket dominated by *Kalmia angustifolia*. These heaths occupy the lowland in close association with continuous tracts of boreal forest. This study tested the hypothesis that the Kalmia Heath could naturally reforest by a mechanism of seed relay from surrounding forest stands. The experimental design incorporated a small black spruce forest island in a heath landscape and a small island of heath in a forest landscape to test the stability of the forest-heath ecotone. Results from the study clearly demonstrate that after 20 years of succession the levels of tree recruitment, total establishment and regeneration growth were extremely low. Therefore, it was concluded that the Kalmia Heath, although at one time forested, now represents a stable vegetation.

Trends in mean monthly temperature for St. John's 1874-1991

(Poster)

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Temperature data have been collected at various sites in the St. John's area on a regular basis since 1874. Using periods of overlapping observations for various older observatories and the continuous records since 1942 from Torbay Airport, a time series of mean monthly temperatures has been assembled for the period 1874-1991. This data set was then analysed to determine (i) the trend and (ii) the existence of cycles having periods up to 50 years.

The trend extracted indicates a warming of approximately 1°C/ century based on both the complete record and

two 50 year sections of the record, one prior to 1942 and the other for the period 1942 to 1991. This suggests the warming trend has been consistent and persistent over the total observational period.

There is evidence in the records for the presence of several cycles having periods in the 7 to 8, 12 to 15, 20 to 24 and 40 to 45 year ranges. These cycles were determined using simple autocorrelation techniques on each of the monthly data sets and corroborate earlier evidence from the full data set for their existence.

Birds as bio-indicators in marine and terrestrial ecosystems

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Birds are the most wide-ranging and highly visible components of terrestrial and marine ecosystems. They are also vulnerable to anthropogenic and natural perturbation, and importantly, they are relatively easily accessible to scientific investigation. Seabird studies have been critical in bringing to light the extensiveness and significance of the deliberate discharge of bilge and tank oil from ships in the northwest Atlantic and in monitoring this pollution problem, which cannot be remotely sensed through technical means. Marine birds are also useful in assaying the movements and conditions of capelin and other pelagic fish and squid in the Newfoundland region. Recent studies with landbirds are revealing that different avian communities are associated with different forest habitats and how bird abundance and biodiversity can be preserved in the face of forestry, land-use and protected areas practices and policies.

Sea level change in the Carmanville area in northeast Newfoundland

(Poster)

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Northeast Newfoundland was ice covered during the last glaciation. Since the onset of deglaciation the area has been subjected to complex changes in sea level as a result of isostatic recovery.

Elevations of marine terraces and erosional platforms have been measured in the Carmanville area (NTS 2E/8), with three locations providing an excellent opportunity for observing and measuring the marine platforms and correlating the results. Sea level reached a maximum elevation of 67 m asl which is 27 m higher than the previously established marine limit for the area. Thereafter there were at least seven major still-stands of sea level between the onset of deglaciation and the present at 52 m, 38 m, 34 m, 17 m, 11 m, 5 m, and 2 m asl. Substantial thicknesses of marine gravels are present at each of the elevations (e.g., over 4 m of sediment at 11 m asl). Raised marine sediment is exposed at several localities throughout the area. At Wing's Point (34 m asl) several stages of beach development can be observed in section as a series of stacked bars with differing clast and grain size.

The area is characterized by fluctuating sea levels. Sea level has dropped from 67 m asl to below present and has then risen slowly to its present value. Undercutting and erosion at the modern coast at Wing's Point, Carmanville, Ladle Cove and Victoria Cove may be evidence that sea level is still rising. These results may be a reflection of sea level change elsewhere along the coast in northeast Newfoundland.

Compound-specific carbon isotope analysis of PAH compounds isolated from shallow sediments from St. John's Harbour and Conception Bay (Newfoundland)

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Organic pollution in marine and estuarine environments has generated great concern over the last few decades. Polycyclic (or polynuclear) aromatic hydrocarbons (PAH) which contain two or more fused benzene rings represent an important class of contaminants deposited in sediments. These compounds are ubiquitous environmental pollutants that have toxic characteristics and represent the largest class of suspected chemical carcinogens. PAH can enter into aquatic systems via a number of natural and anthropogenic pathways. Past studies of fluxes and deposition of PAH in sediments have relied on a number of molecular criteria for distinguishing such inputs.

Compound-specific isotope analysis (CSIA) of carbon is a technique that is currently being investigated as a complementary tool for studying sources of PAH in these environments. The $^{13}C/^{12}C$ ratios of individual compounds are determined using a modified conventional isotope ratio mass spectrometer following initial separation by gas chromatog-

raphy (GC) and quantitative conversion to carbon dioxide in a combustion interface.

The presentation will outline the procedures employed for isotopically analyzing individual PAH compounds extracted from two very different environmental systems. The applicability of CSIA for characterizing PAH sources and fate in these environments is also explored.

Ecology of landscapes with serpentinized rocks

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Serpentinized ultramafic rocks occur throughout the world and are conspicuous for their impoverished but botanically interesting floras. There is often a sharp contrast with the floras of adjacent areas, and serpentinized ultramafic soils in places contain endemic, rare and unusual races of plants, as well as species which accumulate, exclude or tolerate various elements.

Serpentinized areas cover about 3% of the 106,000 km^2 of the island of Newfoundland. These areas contrast strongly with the adjacent Boreal Forest vegetation and stand out as reddish-brown rock deserts. The prominent serpentinized areas in Newfoundland are part of the Appalachian Orogen and are mainly transported ophiolitic rocks, peridotite, dunite, and minor pyroxenite of 200 to 540 million years of age. Geologists, for example, have hailed them as 'the eighth wonder of the world' because of their spectacular geology and physiography, and active geological and botanical investigations have taken place since the turn of the century. In Newfoundland's serpentinized landscapes, soil horizon development is restricted by cryoturbation which in turn is related to sparse vegetation because of toxic quantities of Mg, possibly Ni, Cr, Co, and low essential nutrients, especially Ca. These potential element deficiencies, imbalances and excesses have been the focus of research globally.

This paper presents a review of the ecology of serpentinized landscapes from Newfoundland. The location, geology, glacial history, soils, flora and vegetation are related to the major stress factors associated with these habitats, and reference is made to other similar sites throughout the world.

State of the environment reporting and anticipating environmental change

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The State of the Environment Reporting (SOER) organisation is an agency of Environment Canada charged with providing Canadians with regular, timely, authoritative and credible information on the state of Canada's environment. Under Canada's Green Plan a number of initiatives are underway to deliver on this charge. A comprehensive national report on The State of Canada's Environment, containing 27 chapters on all aspects was released in April 1992. Four specialized reports and three facts sheets on specific topics have been published. The first of a forthcoming comprehensive series of Environmental Indicator Bulletins was released in November and another will be forthcoming in March.

The organisation is fostering the creation of a network of EcoScience Centres which will carry out comprehensive and intensive ecological monitoring and research. The objective is to establish at least one centre in each of Canada's major ecozones. By focusing on cross-disciplinary research and the linkages between processes and issues, the hope is to improve our understanding of how ecosystems function, how they are being affected by human activity, both local and global, to devise suitable indicators of ecosystem functioning, to enable anticipation of undesirable ecosystem damage and, ultimately, to be able to take action to prevent it.

Evidence and forcing mechanisms of past climatic changes

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In the last few years, outstanding proxy records relating to the interpretation of Quaternary paleoclimates and paleoenvironments have become available. The principle sources are from relatively long continuous continental sequences, better and more deep sea cores, and more and higher resolution data from Greenland and Antarctic ice cores. This has led to a better understanding of the climatic forcing mechanisms involved. Highlights supporting orbital induced variations of insolation (Milankovitch forcing) are long loess-paleosol records from China and pollen records from South America and other areas. At least 37 major climatic events have been identified over the last 2.5 m years. Antarctic ice cores, and new, high resolution ice cores from Greenland have allowed us to understand conditions and identify changes during the last glacial-interglacial period (last 125 k years) much better. For example, various proxy data (i.e., ^{18}O, deuterium, Al)

suggests major climatic changes took place world-wide at about the same time. During the last deglaciation, several abrupt climatic changes spanning short-time intervals are now able to be identified. For example, we can identify the so-called "Heinrich" events, and now believe the "Younger Dryas" event was initiated in less than 50 years. Forcing mechanisms, other than orbital variations, must be found to explain these changes. Over about the past 1000 years there have been many short-term climatic variations such as the "Medieval Warm Period" and "Little Ice Age", explained by such mechanisms as solar variations and explosive volcanism. Much more dramatic of course, is the rise of anthropogenically induced atmospheric greenhouse gases since the last 19th century. The consequences of this for humanity and the earth in general, is an on-going debate.

Fifteen years of freshwater biological monitoring at the Experimental Ponds Area and other places in Newfoundland - experiences and suggestions

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The Experimental Ponds Area is eight small lakes and their watershed at the headwaters of the northwest Gander River. Limnological data have been collected from the Area by Department of Fisheries and Oceans since 1977 for the purpose of documenting chemical, physical, and biological changes. In 1987 and 1989, similar monitoring programs were started at Stevenson's Pond on Grandy Brook (north of Burgeo) and at Harding Pond (on the Humber River in Gros Morne Park). Participating agencies include Forestry Canada, Conservation and Protection Branch, Canadian Wildlife Service, Memorial University, and Parks Canada. Examples of seasonal, annual, and between-lake variations in water quality and the abundances of zooplankton, benthic invertebrates, and fishes are shown. Long-term anthropogenic (i.e., acid rain) and natural (i.e., stream flow and temperature) correlates of habitat quality are compared to biotic changes. Data are presented which show that short-term (5 years) trends may not be indicative of longer-term (15 years) trends and that frequency of observations and sampling interval are major determinants of long-term biotic trend indications.

Monitoring the vegetation of Terra Nova National Park

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National Parks are representatives of our natural heritage which have been set aside for protection and preservation. An indirect consequence is that these areas are available for long-term monitoring.

Vegetation responds to the multifaceted aspects of environmental changes by shifts in the structure and composition of the plant communities of which it consists. Terra Nova National Park is an example of a typical boreal forest. While it has no significant features with respect to its vegetation, it is a sample of the vegetation which covers the rest of the island and will serve well as a monitoring site.

An initial study of the vegetation was undertaken in 1976 and a map was produced on the basis of forest type. In the present study, three years of field work and a detailed phytosociological analysis have been completed. In addition to the field studies, infrared analysis of satellite images has been evaluated as a tool for classifying vegetation.

Using remote sensing to monitor *Kalmia angustifolia* encroachment on disturbed forest sites in central Newfoundland

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Kalmia angustifolia (sheep laurel, "Kalmia") is an ericaceous shrub which occurs naturally throughout central Newfoundland, often as a low-density understorey species associated with black spruce. However, Kalmia can spread rapidly following disturbances such as logging or fire and impede subsequent regeneration of spruce. Once established, Kalmia is difficult to eradicate. Priority is presently given to regenerating disturbed sites with a Kalmia density of <50%, as spruce planted on sites with a Kalmia cover greater than this often perform very poorly. Spaceborne multispectral sensor systems potentially offer the most cost-effective means of detecting and mapping Kalmia over large areas, and for monitoring the spread of this species. Work using an airborne multispectral scanner (CASI) has shown that Kalmia is spectrally distinct from other commonly associated species. However, it is not clear whether the relatively large GRE of

spaceborne systems would be able to discriminate this species where its distribution is patchy (a common occurrence) or at what point the "background" reflectance of soil and other species would contaminate the spectral response to such a degree that Kalmia is no longer recognizable. Work is on-going to develop techniques and methodologies to map the distribution of Kalmia using several operational classes. This will assist foresters to make more informed decisions when setting priorities for reforestation efforts. Future work will focus on the wider project objective of using high spectral resolution remote sensing as a means of detecting and quantifying differences in site quality (mainly fertility) as indicated by differences in canopy chemistry, as this would further assist both in planning silvicultural activities as well as in predicting future wood supply from these "problem" sites.

Tracing atmospheric sulphates using sulphur and oxygen isotopes

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The global sulphur cycle has undergone unprecedented changes as a result of anthropogenic activities. Human perturbation has roughly doubled the annual mobilization of sulphur from the lithosphere. While the masses of various sulphur reservoirs have remained essentially unaffected, these activities have resulted in a large increase in the annual flux of sulphur through the atmosphere as well as a net transfer of sulphur from the continental to the oceanic atmosphere. The atmosphere with its small mass and low concentration is a sensitive environmental indicator of such changes. Many refinements have been made to flux estimates within the sulphur cycle including recent estimates for biogenic contributions from the oceans. With these improvements has come the realization that anthropogenic emissions are now comparable in magnitude to natural emissions to the atmosphere on a global scale. The importance of atmospheric sulphur in terms of acidification and climate modification can only be evaluated if the various sources of sulphur are specifically and quantitatively characterized.

Atmospheric sulphates contain sulphur and oxygen isotope signatures which reflect their sources and mechanisms of formation. These signatures can be used in conjunction with meterological and chemical information to deduce their complex histories. Most workers have focussed on only S or 0 isotopes resulting in frustration in interpretation, however, recent work on the Atlantic coast using a combined isotope approach successfully distinguished sources of anthropogenic, marine and biogenic sulphur to the atmosphere. Similar work is now underway in Newfoundland and will be commencing in Ontario this summer.