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Research Links

A Forum for Natural, Cultural and Social Studies

Monitoring Plant Community Diversity and Regeneration in the Vermilion Pass Burn

Kootenay and Banff National Parks

Greg Chernoff

Fire is an essential force that shapes the ecological landscape in the subalpine ecoregions of the Canadian Rocky Mountains. The constant evolution of plant communities from a newly burned area, through the regenerative process, to a mature forest that will eventually burn again, is a cycle that is essential to the promotion and maintenance of ecological health and diversity. Only relatively recently have popular attitudes begun to change, in recognition of the importance of fire to the maintenance of ecological balance. It is, perhaps, due to this fact that the regeneration of natural plant communities from fire is a process that is not well documented or understood, and that further exploration into the nature of this process is required (Bailey 1996, Achuff *et al.* 1984, Harris 1976). Canada's National Parks provide the ideal environment in which to seek a deeper understanding of such natural processes.

This article provides an overview of the present (1999) distribution and composition of plant communities in Vermilion Pass – the result of natural regeneration in an area that burned in July 1968. The current state of regeneration in the burn will be compared to patterns that were identified immediately after the 1968 fire (Harris 1976), to provide some insight as to how the vegetation of the Vermilion burn is changing over time. Longitudinal studies of this nature may be useful for predicting the effects of prescribed burning, the landscape-dependent variability of regeneration patterns, and the impact of anthropogenic factors on regeneration.

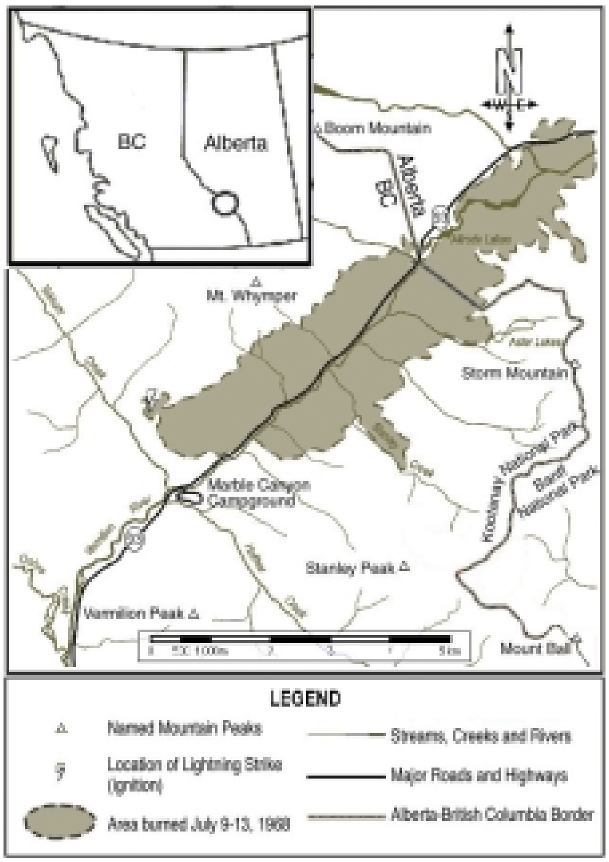

Figure 1. Vermilion Pass Canadian Rockies. Map showing relative location of Vermilion Pass and ignition point/spatial extent of burn.

THE VERMILION PASS BURN

Vermilion Pass straddles the continental divide, and the border between Kootenay and Banff National Parks (Figure 1). It is situated among the high peaks of the Eastern Main Ranges of the Rocky Mountains, and experiences high precipitation, low temperatures, and a short growing season (Achuff *et al.* 1984).

The Vermilion Pass Fire was ignited on July 9, 1968 by a dry lightning strike in the Tokkum Creek Valley, on the shoulder of Mount Whymper. Extremely dry fuel conditions coupled with steady wind from the west caused the fire to spread quickly and burn intensely (Personal Communication, Parks Canada Staff, Marble Canyon Campground, 1999). By the time the fire was brought under control on July 13, it had consumed a total of 2,430ha, ranging in elevation from just over 1,500m to just under 2,400m (Figure 1). The Vermilion burn was the largest recorded in the subalpine ecoregions of Kootenay, Yoho, and Banff National Parks between 1961 and 1985 (Johnson & Miyanishi 1991). Its location within the mountain parks assures that the regenerative process has been allowed to run its natural course, free from human intervention.

METHODS

During the summer of 1999, vegetation cover was assessed and recorded for 217 randomly selected 10X10m sample plots. This percent cover data was entered into SPSS for hierarchical cluster analysis (after La Roi *et al.* 1988), which grouped the data set into 10 distinct plant communities (Figure 2, see page 6).

A 1:20,000 scale digital elevation model (DEM) and Satellite Imagery of the study area were used to delineate the burn boundary and to identify other physical

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Research Links

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FEATURE ARTICLES

DEPARTMENTS

FRANCOPHONES

Le texte de cette publication est offert en français. Vous pouvez l'obtenixr en écrivant a l'adresse dans la p. 24

UPCOMING DEADLINES

July 26, 2002 — Winter 2002
November 29, 2002 — Spring 2003

EDITORIAL

Ecosystems are incredibly complex and diverse. I recall as a student, a supervisor once told me that he could have spent his entire life studying the dynamics of a very small, montane meadow, and still know very little about the ecology of that particular meadow. His remarks take on a significance, as resource managers attemmpt not only to understand the ecology of much larger and more complex systems, but also to manage these systems to maintain ecological integrity.

Two thoughts struck me after Dianne gave me the draft layout of this issue of *Research Links.* First, this issue underscores the complexity and diversity of ecosystems by showing the breadth of research ongoing in national parks and national historic sites. Articles in this issue span the gamut of ecology, from terrestrial vegetation mapping to aquatic vertebrate sampling to air-quality testing.

Second, this issue deals with ecologically significant themes of global warming, long-term monitoring, air quality and modeling. Several of the articles in this issue struck a chord with me. After reading Natalie McMaster's article on using alpine ponds as indicators of global warming, I remembered a recent quotation from David Suzuki. A reporter asked him how he responds to the regular charges made against him that he is an alarmist and cries "wolf" much too often. Suzuki's response was that in the parable of The Boy Who Cried Wolf, the wolf eventually came.

When I sat on Greg Chernoff's graduate examining-committee several months ago, one of his recommendations was to continue long-term monitoring in the Vermillion Pass burn. Consistent, long-term monitoring continues to be a challenge for Parks Canada. In this issue, John Wilmhurst comments on the future of monitoring in national parks and recommends asking the right questions a priori. From these examples it is clear that research conducted in our national parks is often at the leading edge of resource management issues.

However, the challenge remains on how to integrate such large volumes of complex information into decision-making. Demonstrated by this year's theme for the Ecological Monitoring and Assessment Network (EMAN) science meeting "Enhancing the Effectiveness of Ecological Monitoring." The plenary symposium will discuss linking ecosystem monitoring, research and assessment to decision-making.

Causal links between science and decision-making are cornerstones of ecosystem management. In order to address our ecological integrity mandate, park managers must know baseline conditions and how ecosystems change over time. Parks Canada requires long-term vision to collect this kind of information consistently. I hope projects like those featured in this issue of *Research Links* can foster the necessary commitment and vision.

Sal Rasheed
Editor of Research Links and Ecosystem Conservation Specialist, WCSC Calgary

Alpine Ponds:

Canaries of climate change?

Natalie McMaster

Over the last century the climate of the eastern front ranges of the Canadian Rocky Mountains has become warmer and drier (Slaymaker 1990, Fyfe & Flato 1999). Climate models predict that this trend will continue due to increased greenhouse gas emissions (Hengeveld 2000). Alpine areas are expected to experience greater temperature increases than lower elevation regions due to snow depletion, which will lead to reduced reflection of incoming radiation and increased heat absorption by the ground (Fyfe & Flato 1999).

Among the first alpine ecosystems to respond to climate change will be alpine ponds. Alpine ponds are typically small, shallow, closed basins. Their size, depth and lifespan is variable and depends on their morphology and drainage area, and climate variables such as air temperature and the frequency and amount of precipitation. Their dependence on temperature and precipitation makes their existence and physical environment very responsive to climate change. The organisms in alpine ponds are generally ectothermic, meaning that their body temperatures are determined primarily by the ambient water temperature; they will respond quickly to environmental temperature change. Furthermore, because of the small size, short life spans, and high reproductive rates of the organisms, time lags are minimized between environmental changes and population adjustments to new conditions. Thus, both the physical environment and the organisms in alpine ponds should respond quickly to climate change.

BACKGROUND

Although alpine ponds are the most numerous (there are over 3000 in BNP) and extreme aquatic ecosystems in Banff National Park of Canada (BNP), much less is known about their ecology than larger waterbodies. Alpine ponds are also among the most extreme aquatic environments on earth. Temperatures in alpine ponds can fluctuate from 0.2 to 28°C in a single summer day; some dry every summer and many freeze solid every winter. Despite their extreme physical environment alpine ponds are teeming with life. Pond organisms must be adapted to physical extremes and drying (Jefferies 1994). But it is unknown how much stress they can handle and how robust populations will be to climate change given that little is known of their ecology. Only occasional surveys of zooplankton (Anderson 1971, Anderson 1974) and algal communities (Vinebrooke & Leavitt 1999) have been conducted in the last 3 decades.

Climate change, by increasing the frequency of warm and dry years, should make alpine ponds even more extreme environments in the future. A warmer and drier climate will lead to increased evaporation (Schindler 1997) and an increased frequency of dry periods. Although communities in temporary ponds should be resilient to drying because they do dry seasonally, deviation from the typical drying regime may cause changes in community structure. Furthermore, the communities in historically permanent ponds will be highly sensitive to decreased water levels and possible seasonal drying. Declining water levels should lead to decreased levels of dissolved oxygen, increased concentrations of dissolved salts and increased water temperature (Mackay 1984).

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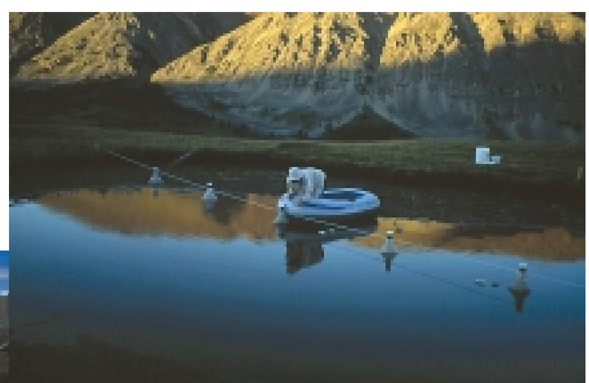

(Left and above) Sampling alpine ponds in Banff National Park

Notes of Interest

Human Use Management in Mountain Areas
- June 2001 Conference -
The Banff Centre for Mountain Culture, Banff, AB

Proceedings from this conference, edited by Leslie Taylor and Anne Ryall, are now available from The Banff Centre and can be ordered online: https://secure.banffcentre.ca/mountain culture/order_form.htm

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Alpine Ponds: Canaries of Climate Change?

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These changes may create conditions that exceed the biological limits of some species, thereby decreasing pond species richness and diversity. Non-lethal effects of increased water temperatures may include accelerating the development of some invertebrates (Hogg & Williams 1996). The result of these drought effects may be a radical reorganization of pond ecosystems.

Investigating the effects of drought on aquatic systems and organisms is increasingly important as climate change increases the frequency of warm and dry years in many areas of the world. Since alpine ponds are located in an area that is expected to have enhanced warming, they may act as "canaries in the coalmine" by giving an early indicator of climate change and of the effects that climate change will have on aquatic ecosystems. Furthermore, without immediate research, these unique ecosystems may be forever altered with no knowledge of their natural ecology.

METHODS

From 1998 to 2000, I studied 5 alpine ponds ranging in size (160-5000 m^2), depth (0.3-0.9 m), and hydroperiod (temporary to permanent) in BNP. I measured water temperature, water loss, and water chemistry, and sampled zooplankton, and insect communities once a week during the ice-free season (approx. June 1- September 30). In the winter and spring of 2000, I used snow fencing to trap snow and increase water recharge to one pond, to simulate a wet year. I slowly drained three temporary ponds to simulate a dry year. I used the remaining pond, a historically permanent pond, as a reference system, with no water manipulation. To put the climate of the study years into a historical context, I analyzed 113 years of climate data for Banff Town Site.

RESULTS AND DISCUSSION

Of the last 113 years, the summer of 1998 was the 4th warmest, 1999 was the 15th coolest, and 2000 was the 23rd coolest. Of the three years, the summer of 1998 was the warmest and 1999 was the coolest and wettest. Although 2000 had the driest summer based on the amount of precipitation, the warm temperatures in 1998 led to intense evaporation that year and as a result, in 1998 ponds were the driest of the three years.

The three temporary ponds dried at least three weeks earlier during the natural (1998) and experimental (2000) dry years than during the wet year. The pond that had the simulated wet year in 2000 dried only during the natural dry year and contained water at freeze-up during both wet years. The reference pond did not completely dry during the study. Accelerated water loss from the ponds during dry years characterized by reduced precipitation and increased temperature and evaporation, demonstrates that the persistence of alpine ponds is directly controlled by climate.

Physical and Chemical Response

The physical and chemical environment of the ponds also changed due to accelerated water loss during the dry years. Water temperatures of 0.2°C and 28°C were recorded in the same day in one pond in the dry year. This large diurnal water temperature variation occurs because during the day the dark pond bottom absorbs solar radiation, thus warming the water, then at night evaporation and heat loss to the air, cools the water. Diurnal water temperature ranges typically increased throughout the summer as water levels declined. The increase was greatest during dry years (Figure 1).

Since the main source of water loss in these ponds was evaporation, dissolved salt concentration increased with declining water levels ($r^2 = 0.11$, $p<0.001$). The increase in dissolved salts should not significantly affect pond organisms because the small change (conductivity increased from 12 to 134μScm^{-2}) was insufficient to overwhelm most organisms' osmoregulatory mechanisms.

There may be a nutrient response to decreasing water volumes. Total dissolved phosphorus (TDP) concentrations increased as water levels declined ($r^2 = 0.18$, $p<0.001$). Increased anoxic phosphorus release from the warmed sediment probably explains increased TDP levels. Dissolved inorganic nitrogen (DIN) concentrations were not correlated with water loss. Low N:P ratios and a significant ($r^2 = 0.06$, $p<0.05$) relationship between nitrogen and algal biomass suggests the algal community is N-limited. High algal demand for N prevents DIN from increasing with water loss.

Biological Response

Temperature, because of its influence on the rate of biochemical reactions, affects nearly all functions of an ecosystem. For instance, a dominant zooplankter, the calanoid copepod *Diaptomus nudus*, required two to three weeks less time to grow to maturity in warm-dry years. Also, in dry years, development time of emerging insects was accelerated, leading to earlier insect emergence and shortened emergence events (Figure 2). Earlier and shortened emergence could decrease overall survival of

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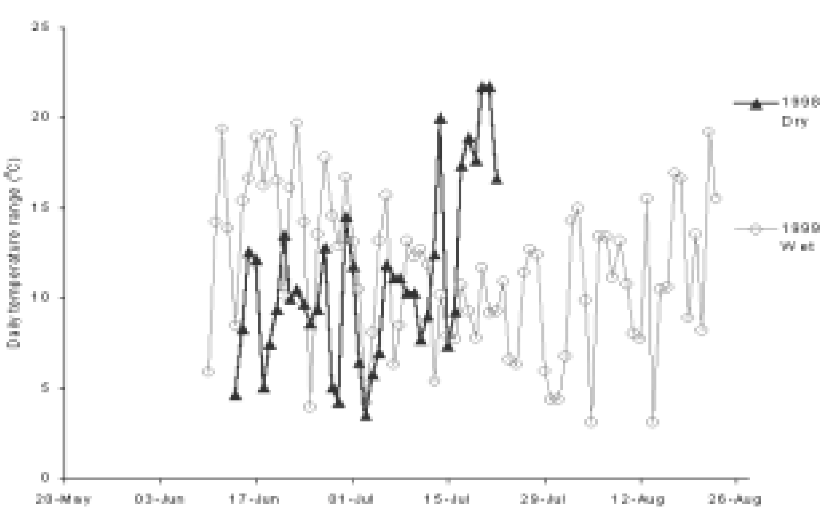

Figure 1. Trends in daily water temperature range (difference between daily maximum and minumum temperatures) for P3, a temporary pond. 1998 (black triangle) was a dry year and 1999 (grey circle) was a wet year.

Alpine Ponds: Canaries of Climate Change?

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emerged insects because of the increased probability of snow and below freezing air temperatures early in the season. Species richness of emerging insects decreased after the dry year in the three ponds with the longest hydroperiod. This suggests that some species were lost, at least temporarily, due to the deviation from the typical drying regime.

The results of this study demonstrate that the physical environment in alpine ponds will become more extreme in response to possible future climate change and the composition and dynamics of the biological community will change as a result.

MANAGEMENT IMPLICATIONS

Although alpine ponds are the most common aquatic ecosystem in BNP and they are relatively species rich in an otherwise species-poor ecoregion, there is little known about them. This study, although informative, included less than 0.2% of the alpine ponds in BNP. As climate change continues, thousands of temporary alpine ponds in the Canadian Rockies may permanently dry and now permanent ponds will become temporary. Many aquatic invertebrates that inhabit only permanent ponds or that can not complete their life cycles in the shorter wet phase in temporary ponds may be eliminated from the alpine ecoregion. It is essential for managers to support detailed biological surveys of alpine ponds throughout the Canadian Rocky Mountains before they are forever altered.

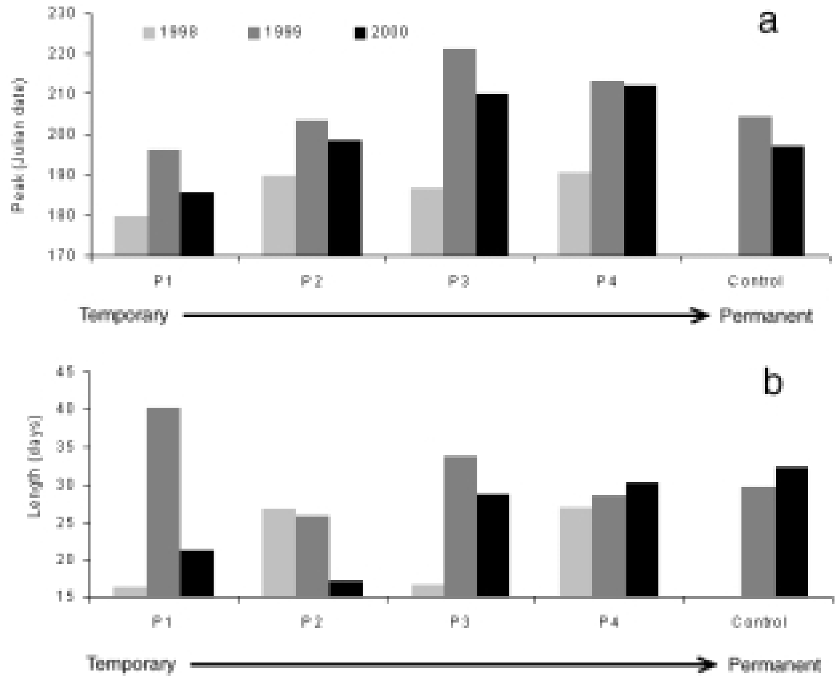

Figure 2. Trends in: a) date of peak insect emergence; and b) length of the average insect emergence event in each study pond. 1998 was a wet year, and 2000 was a dry year for the first three ponds, a wet year for P4, and an average of the three years for the control pond. The ponds are in order of increasing permanence.

Because alpine areas will see enhanced warming, alpine ponds could be considered "the canaries of climate change" or indicators of future changes in other systems. Although climate change is a global problem caused by factors largely outside park boundaries, this study demonstrates that climate change potentially has biologically significant effects on ecosystems inside these boundaries. As a result, National Parks should continue to be managed as a smaller part of the greater functioning ecosystem, as opposed to discrete ecosystems defined by boundaries. In addition, park management strategies should be adaptive to the changing stresses inside and outside the park.

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Monitoring Plant Community Diversity and Regeneration in the Vermilion Pass Burn

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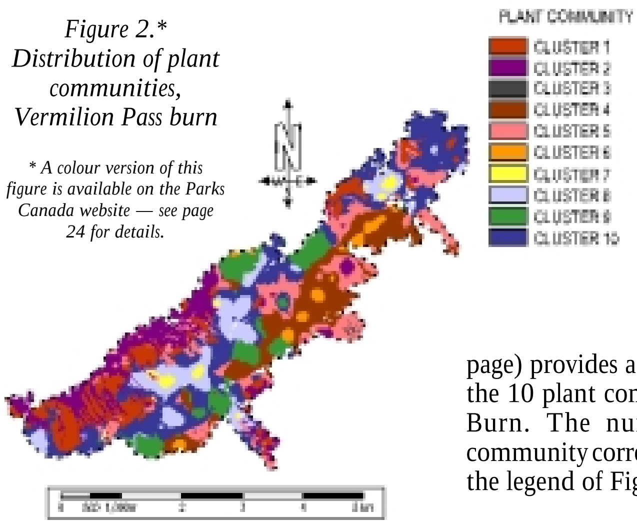
Figure 2. Distribution of plant communities, Vermilion Pass burn*

** A colour version of this figure is available on the Parks Canada website — see page 24 for details.*



features. The DEM was also used to derive a set of ancillary topographic variables (i.e. slope, aspect, cross-slope and down-slope curvatures), which would be used to model vegetation distributions (after Peddle & Duguay 1995, and Eyton 1991). A point coverage consisting of sample plot locations was created, and ancillary variable values were identified for each sample plot.

Three "diagnostic species" – lodgepole pine (*Pinus contorta* Dougl. ex Loud.), rusty menziesia (*Menziesia ferruginea* Sm.), and grouseberry (*Vaccinium scoparium* Leib. ex Coville) – were determined to be most useful in deciding plant community membership. Diagnostic species were selected according to the three criteria of ubiquity, high correlation to ancillary topographic variables, and improved community differentiation. The distribution of each diagnostic species was modeled using a three-stage process (after Lister *et al.* 2000). First, the species' percent cover values were regressed against highly correlated ancillary variables to get a general regression surface. Next, ordinary kriging interpolation was performed on regression residuals at sample plot locations to generate a continuous residual surface. Finally, the regression surface and the kriged residual surface were combined in an additive overlay.

The final stage of the modeling process was the mapping of the ten plant communities' spatial distributions. This was achieved through a maximum likelihood classification of the study area, using diagnostic species' percent cover distributions as input channels. Figure 2 is a map of the modeled distribution of the plant communities of the Vermilion burn.

PLANT COMMUNITIES OF THE VERMILION BURN

Table 1 (opposite page) provides a brief description of each of the 10 plant communities of the Vermilion Burn. The numbers beside each plant community correspond to cluster numbers in the legend of Figure 2 (above left).

LONGITUDINAL MONITORING OF THE VERMILION BURN

The research described here provides the second "time slice" in what is envisioned as a longitudinal monitoring project which records the vegetative conditions within the Vermilion burn at regular intervals throughout a complete fire cycle, thereby providing a foundation for the improved understanding of the spatial and temporal dynamics of vegetation communities regenerating from fire. The current distribution and composition of plant communities in Vermilion Pass is compared to that found in 1972, as reported by Harris (1976).

The areas of highest lodgepole pine seedling recruitment in 1972 have become some of the most densely covered areas. Some new high-density areas have appeared, particularly on the slopes of Mount Whymper, at the mouth of the Stanley Glacier hanging valley, and at the far southwest end of the burn. Spruce and Fir seedlings were scarce in 1972, and confined to areas immediately adjacent to the burn boundary or to patches of mature forest. These tree species are now nearly ubiquitous within the burn. The densest concentrations of spruce and fir are currently located east and just west of the divide.

In 1972, most of the Vermilion burn was dominated in the shrub layer by rusty menziesia, with the exceptions of the "avalanche complex" on the slopes of Mount Whymper, some unvegetated areas at high altitudes, and a diverse assemblage of shrubs at the northeast end of the burn. Since then, shrubs have re-established in all areas, and species richness has increased (there were 2 more shrub species identified in 1999 than in 1972 – 17 species in total). Dominance patterns have also changed – while rusty menziesia is still dominant over large areas (especially on the southeast side of the Vermilion valley), russet buffaloberry is now dominant over much of the northwest side of the valley, and co-dominant with rusty menziesia in the valley bottom.

Avalanche tracks are co-dominated by russet buffaloberry and willow species, and the Storm Mountain grouseberry plant community is dominated by juvenile or krummholz limber pine (*Pinus flexilis* James)[1] and subalpine larch (*Larix lyallii* Parl.).

Figures 3 and 4 (page 8) are included to illustrate the change in dominance patterns in the herbaceous layer over the past three decades, and also provide an example of the technological and scientific progress that has occurred in the fields of biogeography and vegetation mapping.

In 1972, Harris (1976) refers to a "major battle for dominance" in the herbaceous layer between fireweed (*Epilobium angustifolium*) and heartleaf arnica. Other dominant herbs include an assemblage of "grasses", and in small areas at the northeast end of the burn, aspen fleabane (*Erigeron speciosus* (Lindl.) DC.) and hawkweed (*Hieracium* L.) (Figure 3).

By 1999, the "battle" has subsided, and species richness has increased by 7 (a total of 62 herbaceous plant species were identified). Grouseberry is by far the most dominant herbaceous plant, sharing dominance with fireweed (sub-dominant on the southeast side of the valley), and most commonly with twinflower and Canadian bunchberry (at low to middle elevations and in valley bottoms). Downy ryegrass and twinflower are co-dominant in the open pine forests on the northwest side of the valley, and the subalpine meadows and avalanche tracks are too heterogeneous to declare any species as dominant.

RECOMMENDATIONS FOR FUTURE MONITORING AND CONCLUSIONS

The description of the plant communities of the Vermilion burn and the mapping of their distributions is biogeography. The

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[1] Achuff et al. [1984] identify the most common tree species in this area as whitebark pine (Pinus albicaulis Englm.).

Monitoring Plant Community Diversity and Regeneration in the Vermilion Pass Burn

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Table 1. Plant Communities of the Vermilion Burn

Name (Cluster #)	General Remarks	Avg. Elev. (Range)	Avg. Slope (Range)	Dominant Vegetation by Stratum* A	B	C
Mount Whymper Open Pine/ Buffaloberry (#1)	Open pine forest, found mostly on NW side of Vermilion valley, adjacent to avalanche tracks.	1,760m (1,554-2,068)	25° (7-35)	lodgepole pine	russet buffaloberry	downy ryegrass, twinflower
Subalpine Meadows & Avalanche Tracks (#2)	Sparsely vegetated areas, mostly on slopes of Mt. Whymper - likely a combination of 2 distinct plant communities.	1,930m (1,586-2,246)	31° (8-51)	very few trees	heterogeneous assemblage of low-lying, resilient herbs and shrubs	
Storm Mountain Grouseberry (#3)	Anomalous and highly localized, found exclusively on S-SE-facing shoulder of Mt. Whymper.	2,208m (2,196-2,232)	19° (16-20)	very few trees	juvenile or krummholz conifers	grouseberry**
South Side Open Pine/Menziesia (#4)	Open pine-spruce forest, side of Vermilion valley, most common on the SE near Continental Divide.	1,767m (1,590-2,066)	18° (5-34)	lodgepole pine, Engelmann spruce	rusty menziesia	grouseberry, fireweed
Open Pine/Menziesia/ Bunchberry-Grouseberry (#5)	Very open pine forest, distributed throughout burn in small patches, frequently at avalanche track termini and in valley bottoms.	1,789m (1,565-2,170)	19° (7-30)	lodgepole pine	rusty menziesia, willow species	heterogeneous assemblage of species
Ribbon of Menziesia (#6)	Highly localized and anomalous, confined to a narrow band along SE side of Vermilion valley. May be related to localized groundwater resurgence.	1,788m (1,659-1,898)	21° (10-38)	lodgepole pine, Engelmann spruce	rusty menziesia**	grouseberry, fireweed
Dog Hair Pine (#7)	Impenetrably dense pine forest, found only in a few isolated patches within the burn.	1,656m (1,570-1,849)	18° (3-28)	lodgepole pine**	russet buffaloberry	twinflower, grouseberry
Bottomlands Dense Pine (#8)	Stereotypical regenerating closed pine forest, widespread at lower elevations and in valley bottoms.	1,696m (1,537-1,942)	16° (3-42)	lodgepole pine	rusty menziesia, russet buffaloberry, juvenile Engelmann spruce	grouseberry, twinflower, Canadian bunchberry, fireweed, heartleaf arnica
Midslope Closed Pine/Menziesia (#9)	Closed pine forest with a very homogeneous understory, found at middle elevations throughout the burn.	1,735m (1,673-1,847)	15° (10-19)	lodgepole pine	rusty menziesia	grouseberry
Closed Pine/ Buffaloberry/ Grouse-berry-Twinflower (#10)	Closed pine forest, most common of all plant communities, widespread at middle elevations throughout the burn.	1,678m (1,549-1,903)	15° (1-34)	lodgepole pine	russet buffaloberry	grouseberry, twinflower

** plant species' common names from Integrated Taxonomic Information System (ITIS*[ca]). Scientific names have been omitted to conserve space.*
*** denotes plant species that are overwhelmingly dominant in a given plant community.*

Monitoring Plant Community Diversity and Regeneration in the Vermilion Pass Burn

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vegetation maps produced by this reaearch are perhaps best used as baseline data to be interpreted by ecologists, wildlife biologists, land managers, and Parks staff.

It is recommended that a similar vegetation study be performed not more than 25 years from now, and that the regeneration of the Vermilion burn continue to be monitored regularly throughout the remainder of the current fire cycle. Also, similar studies should be undertaken in other burn areas, prescribed and natural, both in and out of National Parks, to determine the variability in regeneration patterns that may be attributed to management strategies, climate, size of burned area, and other locally sensitive natural and anthropogenic factors.

Some suggestions for improving the modeling process include incorporation of data on precipitation, soils, wildlife, and other topography-related variables that may influence the distribution of plant communities.

An important part of Parks Canada's mission statement is a commitment to preserve ecological integrity, and to ensure that "[Kootenay National] park's ecosystems and their component native species and natural processes are free to function and evolve" (Parks Canada 2000, p.13). While there is inherent value in preserving these natural processes for their own sakes, we can gain further and perhaps greater benefits from understanding and learning from natural processes. To understand processes that function and evolve over time scales that exceed human lifespans, researchers require patience, humility, and vision.

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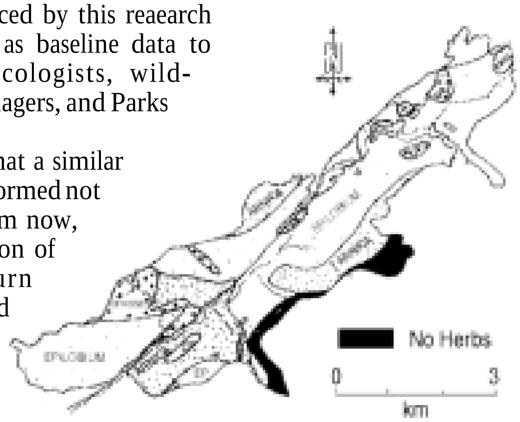

Figure 3. 1972 map showing post-fire distribution of dominant herb species in the Vermilion burn. Source: Harris, 1976.

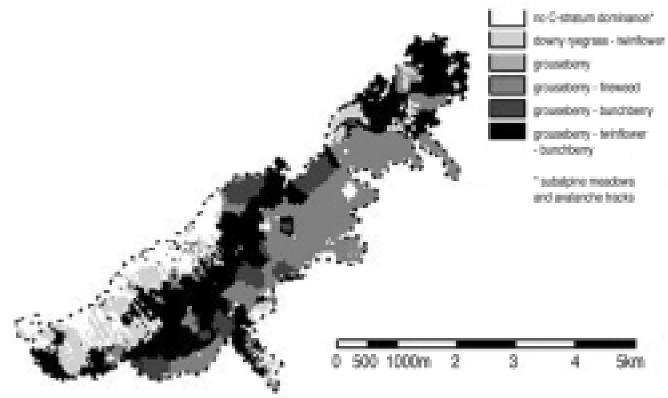

Figure 4. Generalized 1999 distribution of dominant C-stratum (herb) species in the Vermilion burn.

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Predicting Vegetation Patterns at the Landscape Level
in Prince Albert National Park

S.R.J. Bridge and E.A. Johnson

One of the goals of ecology has been to predict the distribution and composition of species over the landscape. Clearly, with today's limited resources and need for ecosystem management, understanding and accurately predicting vegetation patters over the landscape has taken on a new significance. Plant ecologists have been successful at defining changes in the abundance of species along abstract environmental gradients (e.g. moisture) (Whittaker & Gauch 1973). However, the challenge has been to relate these environmental gradients to the terrain and to the physical processes of hillslope and basin geomorphology. This study links the vegetation change down a hillslope to geomorphic principles that govern the development of a drainage basin. This linkage may provide a general explanation for landscape scale (10^1 to 10^3 km) spatial vegetation patterns. If the relationship between vegetation and geomorphology is string, and this modelling approach accurate, then landscape vegetation patterns can be modeled similarly in other areas.

Relationship between vegetation gradient and hillslope position

Moisture and nutrients are two common gradients governing vegetation distribution and abundance in a variety of vegetation types (e.g. Chabot & Mooney 1985, Barbour & Billings 1988). On slopes, both moisture and nutrient status are controlled principally by topography (e.g. Anderson & Burt 1977~~)~~, Harr 1977, Sinai *et al.* 1981 and others). Top slopes tend to be dry and nutrient poor while bottom slopes tend to be wet and nutrient rich. Vegetation often reflects this topographic control over moisture and nutrient gradients (e.g. Johnson 1981, Marks & Harcombe 1981, Allen & Peet 1990, Bridge & Johnson 2000). Divergent erosive processes such as rain splash, soil creep and mass wasting form hillslopes in such a way that slopes on the same substrate tend to have similar hillslope profiles across the landscape. Moreover, similar hillslope profiles have quantifiable and predictable moisture and nutrient gradients down the slope. Vegetation composition can therefore be related to a characteristic of the slope, such as distance from the ridgeline (Bridge & Johnson 2000) (Figure 1).

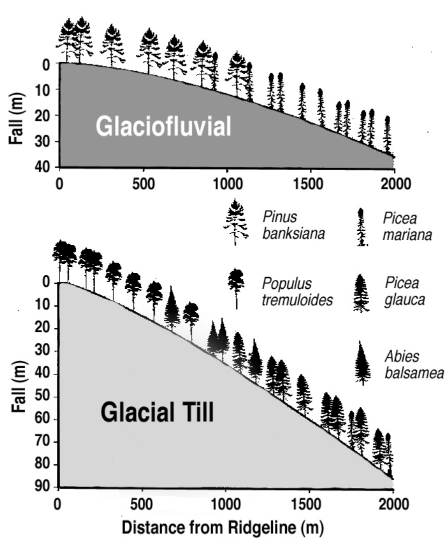

Figure 1. General landscape patterns of vegetation composition in Prince Albert National Park. The shape of the slopes in the figure depicts the slope profile of most slopes in the Park. The tree symbols depict the general change in dominant canopy species down the slope, which is based on the relationship between the stand positions on the abstract moisture and nutrient gradients and the stand distances from the ridgeline (Bridge & Johnson 2000).

In this study, we predict the distribution of vegetation composition over the landscape of Prince Albert National Park (PANP). Accurate predictions of current and future vegetation patterns down hillslopes will facilitate the development of sound management strategies. For example, accurate predictions regarding vegetation patterns could provide valuable clues to landscape-level requirements, such as biodiversity (Chipman & Johnson 2002).

METHODS

Study Area

The study was conducted in PANP. This 4000 km^2 park has gently rolling topography with an elevation range from 500-800 m a.s.l. Surficial materials consist primarily of glacial till deposited directly by glacial ice, with significant amounts of glaciofluvial and small amounts of glaciolacustrine deposits left behind by glacial meltwaters. The study area is part of the mixedwood boreal forest (Rowe 1972) and the main disturbance is large, lightning-caused fires that kill most of the canopy trees (Weir *et al.* 2000).

Methodology

We linked spatial vegetation patterns to geomorphic principles that govern the formation of drainage basins in the following 4 steps. For brevity, we restrict our discussions here to vegetation distributions in glacial till basins, although the vegetation patterns in glaciofluvial basins were similar.

1. Describing drainage basin shape in PANP using allometry:

We produced a map of drainage basins by delineating basins from a digital elevation model (DEM) of the park using image analysis software (PCI™ version 5.2, PCI inc. West Wilmot St. Richmond Hill, ON). The software successfully delineated drainage basins that were similar in size and location to several first order drainage basins delineated visually from 1:50 000 topographic maps of the study area.

Drainage basins can be thought of as ~~four~~a system of hillslopes assembled around a framework of channel networks. In many basins around the world, in many diverse environments, the basin length is related to the basin area by the allometric relationship:

$$\text{Basin Length} = 1.4\ (\text{Basin Area})^{0.6}$$

(e.g. Hack 1957, Shreve 1974, Newton 1978). Since the exponent is greater than 0.5, basin length increases at a disproportionately greater rate than basin area. In other words, larger basins tend to be longer and narrower than smaller basins (Figure 2, page 10). However, the average hillslope length remains constant. Since hillslopes on the same substrate have the same profile and roughly constant length, the average proportions of different vegetation types should remain constant within basins regardless of size. Furthermore, this should be a common pattern of landscape vegetation assembly, since basins develop in the same fashion in many different environments.

Eighty-nine basins dominated by glacial till materials were picked using a surficial geology map of the park (Padbury 1978). We calculated the basin area and the basin length (the shortest distance from the point where

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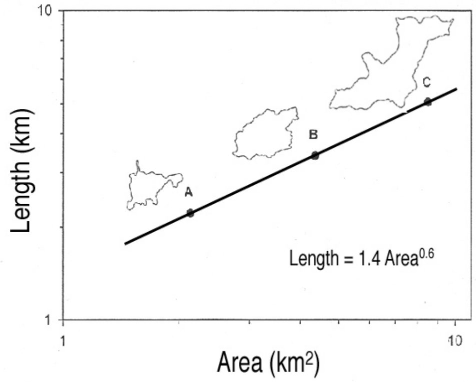

Figure 2. Hack's (1957) allometric relationship between drainage basin length and area with 3 examples of drainage basins at PANP that confirm to the relationship.

Predicting Vegetation Patterns at the Landscape Level

- continued from page 9 -

the stream flowed out of the basin to the most distant point in the basin (cf. Morisawa 1958) for these basins. Allometric relationships between basin length and area were derived by regressing the log basin length onto the log basin area using a geometric mean regression.

2. Mapping the actual landscape vegetation distribution

To determine the actual vegetation distribution across the landscape, we classified a Landsat TM (Thematic Mapper) image of the park. We mapped the upland vegetation on the landscape via a supervised classification of a Landsat TM image acquired under cloud free conditions on July 12, 1990. In addition to TM bands 1-7, a digitized version of the time-since-fire map of the park (Weir *et al.* 2000) provided ancillary information in the classification. A maximum likelihood classification was performed on the first 4 eigen channels of a principal components analysis of TM bands 1-7 and the time-since-fire image using PCI™. Ground surveys of 101 upland forest plots showed that with the exception of stands dominated in the canopy by both white spruce *(Picea glauca)* and aspen *(Populus tremuloides)*, most stands were dominated by just one of the 5 major boreal forest tree species in the park. This allowed us to classify the upland forest vegetation into 6 mutually exclusive classes based on the main canopy species having an abundance >40% (Table 1). Half of the ground plots were used to train the classification and the other half were retained to assess the accuracy of the map.

Table 1. Six mutually exclusive upland forest classes used to classify the Landsat TM imagery

Surficial Material	Upland Forest Vegetation Class
Glacial Till	Aspen
Glacial Till	Aspen/White Spruce complex
Glacial Till	Balsam Fir
Glacial Till	Black Spruce
Glaciofluvial	Jack Pine
Glaciofluvial	Black Spruce

3. Predicting the landscape vegetation distribution

We predicted the vegetation distribution within the park using the quantitative relationships between vegetation composition and topographic position on slope derived by Bridge & Johnson (2000) (see also Figure 1) and the DEM of the park. The upland forest vegetation distribution was predicted by first producing a raster map of ridgelines from the map of drainage basins. Ridgelines were defined as the boundary between basins. For each pixel on the map, we calculated the distance to the nearest ridgeline using PCI™. Pixels were classified into upland forest types based on the underlying surficial material and the distance from the ridgeline (Table 2) (Bridge & Johnson 2000). Reference values for the different vegetation classes were derived by first defining the moisture and nutrient gradients via a gradient analysis of vegetation in the park. Since the vegetation composition is correlated to the gradients and the gradients are correlated to distance from the ridgeline, critical points along these gradients where canopy species composition changes can be derived relative to distance from the ridgeline. The point along the gradients where the main canopy species abundance dropped below 40% was taken to be the dividing point between vegetation classes. A time-since-fire map (Weir *et al.* 2000) was also used to help separate balsam fir from aspen/white spruce complexes.

Table 2. Reference distances from the ridgeline used to predict vegetation class for glacial till hillslopes.

Distance from Ridgeline (m)	Vegetation Class
0-108	Aspen *(Populus tremuloides)*
108-400	Aspen/ White Spruce complex *(P. tremuloides/Picea glauca)*
400-800	Balsam fir *(Abies balsamea)*
>800	Black Spruce *(Picea mariana)*

4. Testing the model results

Finally, we calculated both the actual proportion and the predicted proportion of different upland forest vegetation classes in the 89 drainage basins used to determine the allometric relation ship between basin area and length. We compared the actual proportion and the predicted proportion to assess how well our model captured the relationship between topography and vegetation distribution down the hillslope.

RESULTS

Eighty-nine basins dominated by glacial till materials were picked using a surficial geology map of the park (Padbury 1978). We plotted log basin length onto log basin area and estimated the allometric relationship using a Geometric Mean Regression (GMR). The exponent of the allometric equation fitted to the data was greater than 0.5, and was similar to Hack's (1957) equation (Figure 3).

The supervised classification of the Landsat TM image with the time-since-fire information had an overall accuracy of 74.1%. In upland forest areas, most of the misclassification occurred in pixels where 2 or more canopy species had similar abundances. Thus, most of the confusion occurred between canopy species that overlap in moisture and nutrient requirements.

We divided the study area into northern and southern portions based on differences in European settlement history and subsequent disturbance regimes (Weir & Johnson 1998, Weir *et al.* 2000). European settlement around the southern boundary of the park resulted in many settlement

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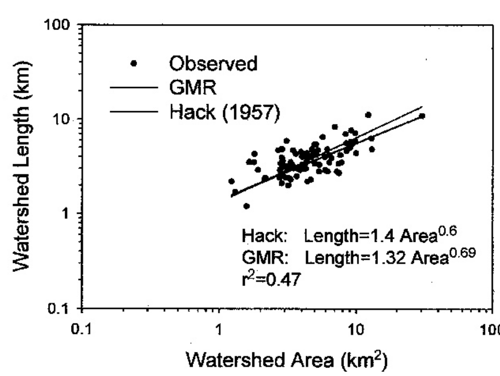

Figure 3. The relationship between drainage basin length and area for glacial till basins. Also shown is the geometric mean regression (GMR) for the data and Hack's (1957) relationship. The GMR is a least squares fit that assumes both length and area are subject to error.

Predicting Vegetation Patterns at the Landscape Level

- continued from page 10 -

fires spreading north into the park from 1890-1945. In addition, the southern portion was characterized by a shorter fire cycle (the time required to burn an area equal in size to the study area). The southern portion was also selectively logged for white spruce. The northern portion, however, is still surrounded by mostly continuous forest and has never been logged.

In the north, the average predicted proportion of upland forest vegetation classes in glacial till basins was, in most cases, identical to the actual proportions of these vegetation classes (Figure 4a). In the south, there was less white spruce and more aspen than predicted (Figure 4b).

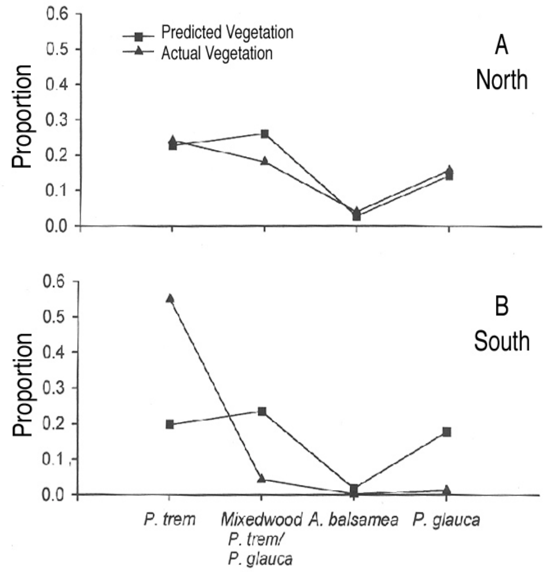

Figure 4. The average proportion of actual vegetation and predicted vegetation for upland forest classes in glacial till watersheds for (a) the northern portion of the park and (b) the southern portion of the park. Standard error bars are too small to be shown.

DISCUSSION

It appears that a large proportion of the variance in landscape vegetation distribution can be explained with a relatively simple understanding of geomorphic principles of hillslope shape, moisture and nutrient subsurface flow, and the spatial arrangement of hillslopes around channel networks into drainage basins. Given that these processes occur similarly across most ecosystems, this modelling approach may be applied elsewhere, in similar or different terrain.

In the southern mixedwood boreal forest, geomorphic processes operate on vegetation patterns at 2 scales: the hillslope scale and the drainage basin scale. At the hillslope scale, divergent erosive processes (e.g., soil creep) modify the surficial material to produce slopes with the same profile on the same surficial material. Since topography governs available moisture and nutrients, vegetation composition depends on distance from the ridgeline. At the drainage basin scale, overland flow governs the length of slope and the formation of channels. Consistency in slope shape (e.g., convex) and surficial material ensure that surface saturation and overland flow occur at a roughly constant distance from the divide.

Thus, these 2 sets of processes, operating at different scales, produce characteristic distributions of moisture and nutrients across the landscape. Any attempt to understand the landscape patterns of vegetation must therefore address these geomorphic processes. By linking the patterns of vegetation within drainage basins to geomorphic principles of space filling by basins, it may be possible to predict further landscape scale patterns of vegetation distribution and abundance.

A good understanding of the processes controlling the vegetation patterns puts us in a much better position to make predictions about vegetation change due to such things as climate change than does a statistical description of the past trends. It also allows us to see the impact of other processes, such as human disturbance, on specific systems.

By dividing the study area into a northern and southern portion, we were able to understand how human disturbances have impacted vegetation in PANP. The southern portion of the park, has a higher proportion of aspen than predicted due to past logging and settlement fires outside the park burning into the park at the turn of the 20th century (Weir & Johnson 1998). Selective logging of white spruce removed much of the white spruce seed source from the southern portion of the park and frequent settlement fires prevented new white spruce from reaching sexual maturity. The net result was a massive reduction in white spruce. Conversely, aspen, which reproduces vegetatively from suckers, has dominated where white spruce used to be, which is evident in the actual vegetation distribution.

Technology (e.g. GIS, remote sensing) and the modelling approach applied in this study can be applied to other parks, with both similar and more complex relief. This approach provides managers and ecologists with a cost-effective method to accurately predict and understand vegetation distribution at the landscape scale.

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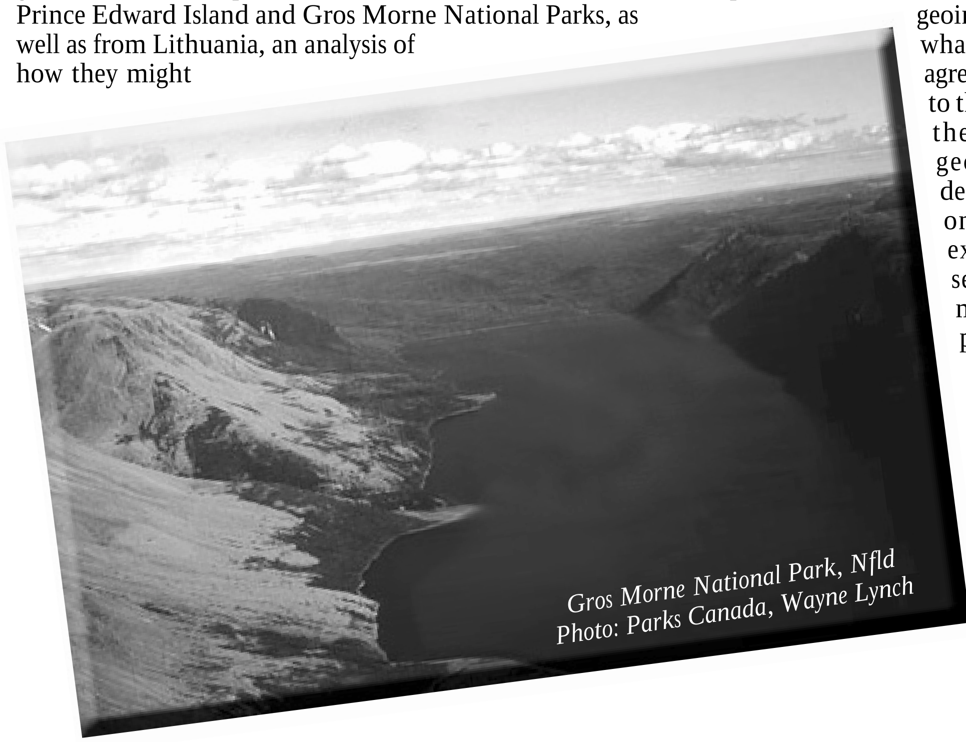
Workshop Report:

GEOINDICATORS FOR ECOSYSTEM MONITORING IN PARKS AND PROTECTED AREAS

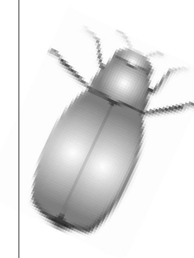
10-14 September 2001, Gros Morne National Park

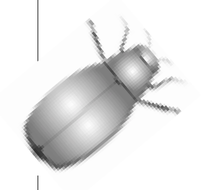
Twenty-five specialists interested in monitoring the effects of rapid geological change on protected ecosystems met to discuss how geoindicators can be applied in a wide range of natural settings, and to provide guidelines for the establishment of new monitoring efforts, including field and laboratory protocols and procedures. The meeting was chaired by Tony Berger on behalf of the International Union of Geological Sciences (IUGS) and attracted Canadian delegates from Parks Canada, the Geological Survey of Canada, the Ecological Monitoring and Assessment Network coordinating office, the Canadian Forestry Service, the Newfoundland Geological Survey, and Memorial and Brock Universities. United States delegates came from the National Park Service (US.NPS), Geological Survey, Geological Society of America and the Newkirk, Engler and May Foundation. European interests were represented by the Deputy Director of the Geological Survey of Lithuania and co-director with Tony Berger of the IUGS geoindicators initiative. IUGS defines geoindicators as measures of geological processes and phenomena occurring at or near the Earth's surface and subject to changes that are significant in understanding environmental change over periods of 100 years or less. You can read more about geoindicators at the web site of the US Global Change Research Information Office, http://www.gcrio.org/geo/intro.html.

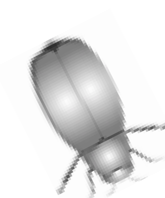
Workshop presentations gave an overview of geoindicators, examples from Mount Revelstoke, Glacier, Prince Edward Island and Gros Morne National Parks, as well as from Lithuania, an analysis of how they might fit to Parks Canada's ecological integrity monitoring framework, and how they might come to be integrated into the Gros Morne National Park ecosystem management framework. US.NPS speakers explained how they have adopted the geoindicators framework to help develop monitoring programs under the Parks Vital Signs program, and how geoindicators have helped to test climate change models. US and Canadian presenters explained how students and volunteers can participate in environmental monitoring programs. Two days of the workshop were devoted to field excursions within Gros Morne to examine sites of geological interest and how process monitoring in each case may or may not be of practical interest to the park and to the wider community. Regrettably, the excursion of 11th September was curtailed out of respect for the tragic events in New York.



Gros Morne National Park, Nfld
Photo: Parks Canada, Wayne Lynch







The US.NPS is developing geoindicator monitoring plans in each park with a geological resource inventory. In 2002 it will do this for Glacier National Park, Montana. The workshop recommended that the Parks Canada national office and Waterton Lakes National Park be invited to join this exercise, at least with observer status, to appraise the merits of the geoindicator checklist for park ecosystem management purposes. Guided by the US.NPS experience, the workshop simulated a geoindicators selection exercise for Gros Morne. There was enough convergence of opinion to recommend that the park consider a workshop to determine what geoindicators to monitor, and by what means. Participants also agreed to several recommendations to the IUGS, including: to extend the scope of some of the geoindicators as presently described; to add several new ones; to adopt the US.NPS experience for geoindicator selection for protected area monitoring; and to develop protocols.

Proceedings will be posted on http://www.lgt.lt/geoin/ They may also be published by Parks Canada.

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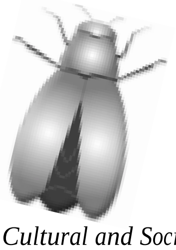
ARCH HIGHLIGHTS

ARE MOUNTAIN PINE BEETLES ATTRACTED TO FIRE-DAMAGED LODGEPOLE PINE TREES?

Mountain pine beetles, *Dendroctonus ponderosae*, attack mature pines, overcoming the trees' defenses through mass-attack. When beetle populations are dense, they can kill millions of trees.

Controlled burning has been proposed as a method for disturbing natural systems to modify the risk and magnitude of beetle infestation. High intensity fires are known to kill adult and larval beetles, but it is unclear how mountain pine beetles respond to trees damaged by low intensity fire, as may occur at the periphery of a prescribed burn. Previous research suggests that mountain pine beetle are attracted to fire-damaged trees because the trees possess a weakened defense system. During 2001, we conducted experiments in Banff and Kootenay National Parks in 2001 to determine whether mountain pine beetles attack fire-damaged trees preferentially. Sites were selected to encompass a range of beetle population densities, allowing us to test whether beetle response to fire damaged trees is density dependent.

We investigated the effect of fire damage by burning 0/3, 1/3, 2/3, and 3/3 of the circumference of a tree's bole. Beetles did not attack fire-weakened trees preferentially. Beetle attack density, and rate of attack, were also independent of fire damage. We noted that beetle attacks on fire damaged trees were more likely to produce successful egg galleries, but only in low-density beetle populations. In high density beetle populations there were enough beetles to overwhelm the trees' defenses in all burn treatments. Therefore, we conclude that in low-density beetle populations, increased attack success on fire-damaged trees may maintain the beetle population or facilitate the transition from an endemic to an outbreak population.



During the summer of 2002 we will measure the reproductive success of beetles in fire damaged trees. By measuring reproductive success we will get a direct measure of whether fire damaged trees favour larval development. If beetles have increased reproductive success in fire-weakened trees, the effectiveness of prescribed burns as a tool to decrease beetle numbers may be reduced. Our results will help forest and park mangers better assess when and how fire may be used as a method for reducing the risk of beetle infestations, and how beetles respond to natural fires.

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AMPHIBIAN MONITORING IN ELK ISLAND NATIONAL PARK

Researchers at the University of Alberta and Elk Island National Park (EINP) recently completed a 3rd year of monitoring the 5 species of amphibians that occur in EINP and the larger Beaver Hills area. Amphibians within EINP were monitored over 3 years in upland habitats associated with long-term biomonitoring plots; in 2001, a number of breeding ponds within EINP were sampled as part of a M.Sc. project. Breeding pond data can be used to track long-term changes in amphibian abundance relative to regional patterns, while upland data provides information about shifts in amphibian habitat use in response to management tools such as fire.

Most of the sampling effort was devoted to pitfall trapping (which effectively samples adults and newly metamorphosed juveniles) using arrays constructed of buried pails and plastic fencing. Amphibians captured in pitfall traps were measured, weighed, marked, checked for deformities and then released at the same site. For the

Photo: Andrew Dickinson

Western Toad in EINP

upland sampling, 9 sets of fences and traps were scattered over 5 sites within EINP in 2001. Spring call surveys were also used in EINP in 2001; this method, although inexpensive and quick, excludes females and non-calling species such as the tiger salamander.

Monitoring efforts in the future will be tied into a broader park monitoring program and help researchers understand the apparent replacement of the Canadian toad by the western toad within the park over the past 15 years. The data will also be assessed for linkages to large scale initiatives (e.g. EMAN) and future Parks Canada requirements from a national perspective.

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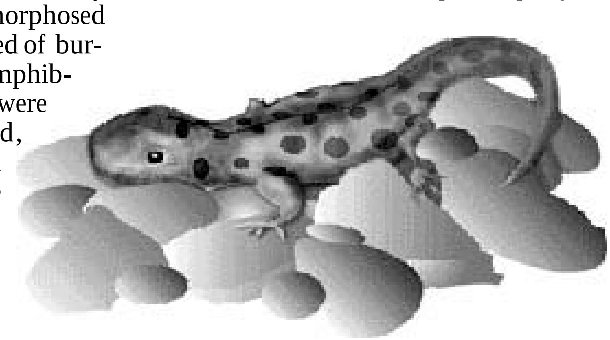

The Answer, My Friend, is *Blowing in the Wind*

Assessing Sources of Particulate Matter in Elk Island National Park

Laurie Bates, Angela Treble and Ross Chapman

Particles less than 2.5 microns in diameter ($PM_{2.5}$) can be emitted into the air during natural events like forest fires and dust storms, or result from vehicular exhaust, road dust, agricultural activities and industrial emissions. Coagulation of smaller particles and/or chemical reactions of precursor gases such as sulphur dioxide, nitrogen oxides and ammonia can also lead to $PM_{2.5}$ formation. This fine particulate matter has the potential to scatter light and so can significantly reduce visibility (US EPA 1995, Pryor 1996). It has also been linked to various respiratory problems in humans as it is small enough to penetrate deeply into the lungs (HC and EC 1999, US EPA 1996a, US EPA 1996b, NRDC 1996). The chemicals within these fine particles may also adversely affect natural vegetation and change the acidity of water bodies, both of which can make Parks Canada's mandate of maintaining ecosystem integrity difficult to uphold. Recent studies regarding the transport of human-made pollutants to pristine areas (Welch 1998; Schindler 1999; Köchy and Wilson 2001) prompted Environment Canada and Elk Island National Park (EINP) to initiate a study to determine the major sources of $PM_{2.5}$ entering EINP. Eventually, researchers hope to determine whether particulate levels are correlated with changes in vascular and non-vascular plants in the park.

Figure 1. Elk Island National Park Air Pollutant Source Sectors

METHODS

EINP is located 40 km east of the city of Edmonton, 37 km east of the Strathcona Industrial Area, and 20 km southeast of numerous industrial complexes including chemical, petrochemical, and fertilizer plants near Fort Saskatchewan. EINP is also surrounded by numerous prairie agricultural operations.

Fine particulate matter concentrations were measured using a standard Taped Element Oscillating Microbalance (TEOM) fitted with a $PM_{2.5}$ sampling inlet. This instrument continuously sampled ambient air yielding an instantaneous measurement of particulate concentration. This instrument was installed on the roof of EINP's warden office in July 1998. Wind speed and directional data from the Alberta Environment's Edmonton East station were used during this study instead of those measured at Elk Island, as it was determined that the wind vane at the park was not calibrated correctly with respect to the influence of local vegetation. Based on current source inventories, 4 source sectors surrounding EINP were identified: agriculture (0° - 140°), clean (141° - 230°), urban (231° - 270°), and industry (271° - 360°) (Figure 1).

It must be noted that the "clean" sector is in fact a misnomer. Although it contains the south portion of EINP, agricultural and small oil and gas sources are also scattered throughout the parkland area to the south of the park. Activities within EINP are also sources of fine particulate, including prescribed burning activities, vehicular traffic and road dust. Contributions from local sources were measured during periods with calm winds (less than 1 km/hr) and stable atmospheric conditions.

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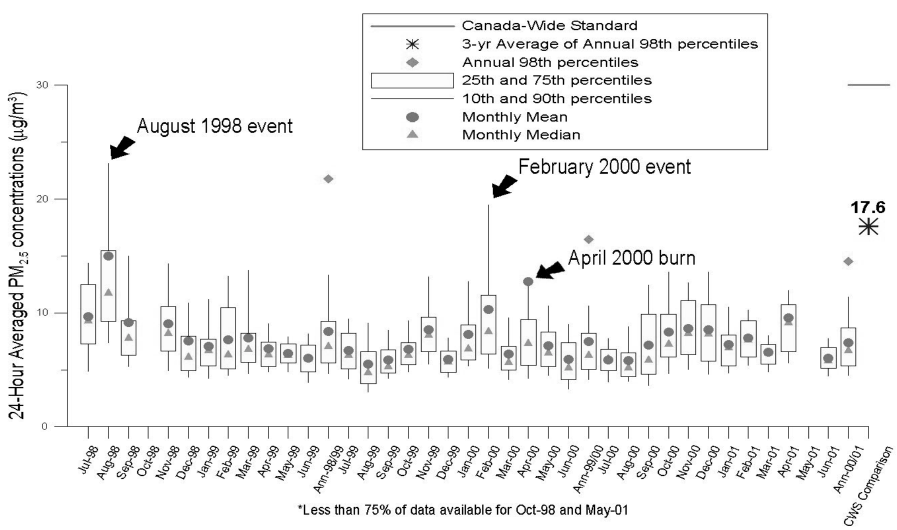

Figure 2. Daily-Averaged $PM_{2.5}$ Mass Statistics for Elk Island National Park (July 1998 to June 2001)

Assessing Sources of Particulate Matter in Elk Island National Park

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Table 1. $PM_{2.5}$ Daily Averaged Statistics for Three Sites in Alberta: Edmonton Northwest (Urban), Elk Island National Park (Rural-Influenced) and Esther (Remote)

Time Period	Edmonton Northwest				EINP				Esther			
	Median	Mean	Stdev	98th %ile	Median	Mean	Stdev	98th %ile	Median	Mean	Stdev	98th %ile
July 98-June 99	13.0	14.6	8.7	35.0	7.1	8.4	5.1	21.8	3.7	4.7	3.1	12.1
July 99-June 00	10.6	11.6	5.0	25.1	6.3	7.5	8.5	16.5	N/A	N/A	N/A	N/A
July 00-June 01	10.5	11.6	5.9	26.6	6.7	7.4	3.0	14.5	4.6	5.0	3.0	11.5
3-year Comparison to 30 mg/m³ CWS				28.9				17.6				11.8

RESULTS AND DISCUSSION

$PM_{2.5}$ concentration statistics at EINP are presented monthly and annually in Figure 2. In general, the lower quartile of the data can be considered typical of regional background levels while concentrations above the upper quartile are related to various episodes. The sizable concentrations observed in August 1998 can be attributed to long-range transport of particulate matter from forest fires in northern Alberta. The relatively high values observed in February 2000 coincide with very calm winds. Fine particulate matter episodes during the winter season may result from a combination of increased anthropogenic emissions and conducive meteorological conditions (i.e. calm winds and low mixing heights). In April 2000, the site experienced a daily maximum of 222.7 mg/m^3 during a prescribed burning episode within the park. As a result the mean concentration for April 2000 was skewed toward higher values.

The results can be compared with national standards. In 1999, the Canadian Council of the Ministers of Environment (CCME) ratified an ambient Canada-wide Standard (CWS) for $PM_{2.5}$ based on the health, social and economic considerations. This CWS of 30mg/m^3 is based on a daily averaging time. According to this standard acceptable levels are based on the 98th percentile of daily-averaged measurements, which are averaged annually over three consecutive years (CCME 1999). From July 1998 to June 2001 the 98th percentile daily-averaged $PM_{2.5}$ concentration at Elk Island National Park was 17.6 mg/m^3, which is compliant with the CWS. This concentration is typical of rural-"influenced" sites, which tend to be lower than city centers, but higher than remote rural areas that are far from large sources. Table 1 compares $PM_{2.5}$ statistics from Alberta Environment's Edmonton Northwest site, EINP and the remote rural site at Esther, located in southern Alberta. Edmonton Northwest experienced a 98th percentile daily-averaged $PM_{2.5}$ concentration of 28.9 mg/m^3 from July 1998 to 2001 while Esther only observed 11.8 mg/m^3. These statistics suggest that EINP was significantly influenced by regional sources, however all three sites were compliant with the CWS (Table 1).

So where is this $PM_{2.5}$ coming from? An understanding of the possible regional sources provides us with a starting ground, but by plotting the frequency and strength of winds from a certain direction we can qualitatively determine how often and fast the wind will carry these fine particulates towards the park (Figure 3). During the summers of 1998-2001, winds originated most frequently from the west-north-west (the "industry" sector) and south (the "clean" sector), but the west-north-west (the "industry" sector) component was significantly reduced during the winter. From this analyses we can determine that with an *average* wind speed of 3 m/s, PM from Edmonton would have taken approximately four hours to reach the park.

The wind and $PM_{2.5}$ mass data can be combined into seasonal plots, which allow for the resolution of PM concentrations originating from each direction (Figure 4). Each hourly-averaged $PM_{2.5}$ concentration was designated as originating from a particular direction by establishing the hour's average wind direction and confirming the consistency of that wind vector for the previous four hours. Although not infallible, this criterion reduced the possibility of cross-sector influences. In Figure 4 median $PM_{2.5}$ concentrations (dark gray) are surrounded by the 98th percentile $PM_{2.5}$ concentrations (light gray) from each direction in 45-degree intervals. Concentrations at EINP during calm winds (less than 1 km/hr) are also presented in the lower left-hand corner of each plot. Although PM concentrations may periodically be elevated from a given direction, that sector's overall contribution may not be significant due to rare winds. Therefore, in Figure 5 concentrations are

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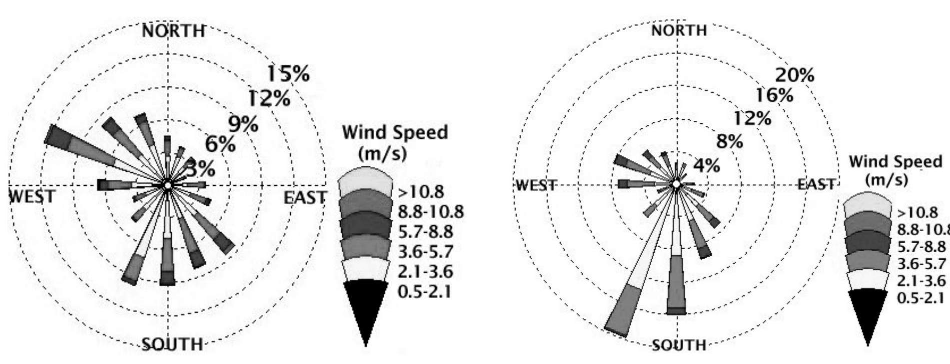

Figure 3. Seasonal Wind Roses for Edmonton East Station:
Direction = blowing from, Percentages = frequencies, Gray shades = Wind speed intervals (m/s) as noted
a) Summer = April to September, 1998-01 ; Calm winds = 2.6%; Average Wind Speed = 3.2 m/s
b) Winter = October to March, 1998-01; Calm winds = 3.4%; Average Wind Speed = 3.1 m/s

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multiplied by directional frequency to weight the relative contributions from each direction.

A number of conclusions can be drawn from these plots:

- As shown in Figure 4, median concentrations from each sector were relatively similar, although the 98th percentiles were slightly more pronounced from the "clean" and "industry" sectors.
- Figures 5a and 5b reinforce the influence of the greater frequency winds from the north-west and south on the overall contribution towards the particulate loading in the park. In winter (Figure 5b), a distinct spike originated from the "clean" sector. Although there are several small sources of PM within the clean sector, preliminary back-trajectory analyses showed that more than 4 hours prior to the highest concentration winter events, winds frequently originated from the "urban" and "industry" sectors. During these events, stagnant atmospheric conditions (i.e., light winds and reduced mixing heights) would have trapped the emissions associated with increased heating from Edmonton and Fort Saskatchewan.
- As noted in Figure 4, the highest 98th percentiles were observed during periods of calm winds (less than 1 km/hr) when dispersion was also inhibited. In April 2000, the highest values were observed during EINP prescribed burning activities concurrent with periods of calm winds. However, calm conditions only occurred less than 2% of the time and therefore, as noted on Figure 5, the comparative contribution to the total PM loading at EINP was relatively small.

CONCLUSIONS

This preliminary study has allowed us to obtain a better understanding of the source sectors and their potential contributions to the $PM_{2.5}$ mass measured at EINP. It is clear that the park's proximity to external anthropogenic sources has significantly influenced the ambient $PM_{2.5}$ concentrations. EINP experienced relatively high concentrations of fine particulate matter from the "clean" and "industry" sectors, however the daily averages remained well below the Canada-wide Standard for $PM_{2.5}$. Local park sources, such as prescribed burning activities, have also impacted air quality within the park.

Environment Canada and Elk Island National Park staff have initiated the second phase of the particulate matter study presented here, which entailed the chemical analysis of $PM_{2.5}$ samples collected during the winter and summer of 2001. If these chemical analyses yield concentrations above analytical detection limits, back-trajectory analyses and source apportionment models will be used to isolate individual source types within the identified source sectors. Currently discussions are underway with researchers to see if correlations can be drawn between air quality and potential effects on non-vascular and vascular plants in the park. This research could ultimately identify potential impacts on the ecological integrity of the park.

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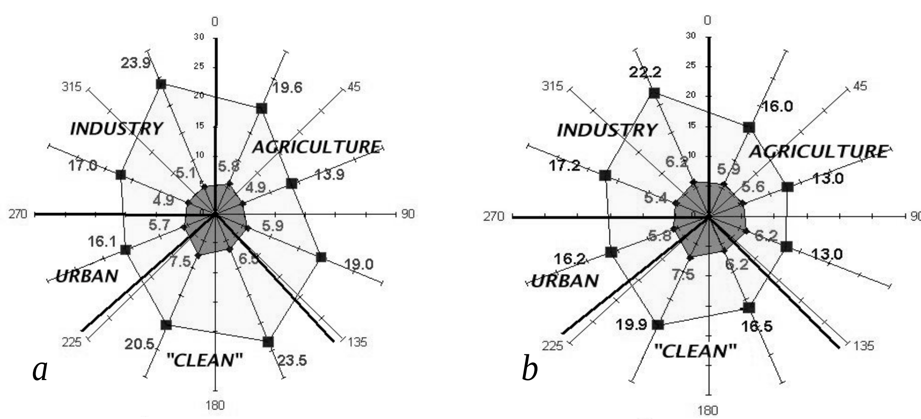

Figure 4. EINP Seasonal Pollution Wind Roses:

a) Summer = April to September, 1998-01
Median CALM = 7.5 μg/m³
98th percentile = 72.7 μg/m³

b) Winter = October to March, 1998-01
Median CALM = 7.3 μg/m³
98th percentile = 75.8 μg/m³

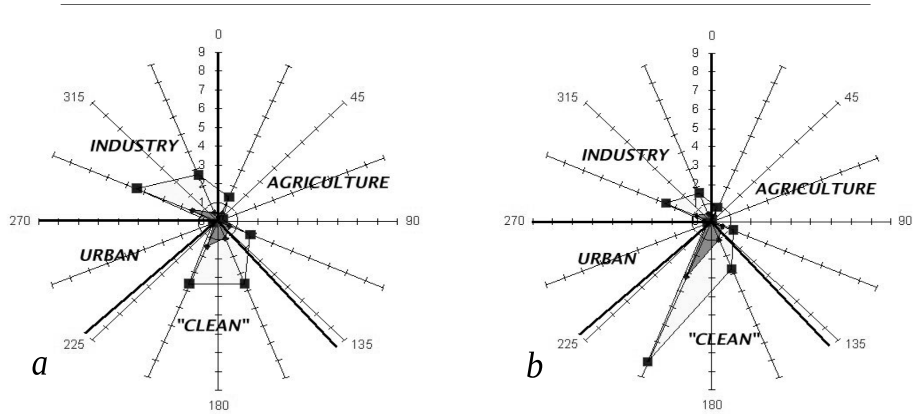

Figure 5. EINP Frequency-Adjusted Pollution Wind Roses:

a) Summer = April to September, 1998-01
Median CALM = 0.05 μg/m³
98th percentile = 0.24 μg.m³

b) Winter = October to March, 1998-01
Median CALM - 0.04 μg/m³
98th percentile - 0.43 μg/m³

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Ventilation Index Forecasts Available

To reduce the likelihood of poor air quality events during prescribed burns, Environment Canada recommends the incorporation of ventilation index forecasts into burn management plans. The ventilation index provides a measure of how effectively the atmosphere will disperse or dilute a pollutant released into the air.

The Prairie and Northern Region of Environment Canada is currently distributing ventilation index forecast bulletins for Alberta, Saskatchewan, Manitoba, the Northwest Territories and Nunavut.

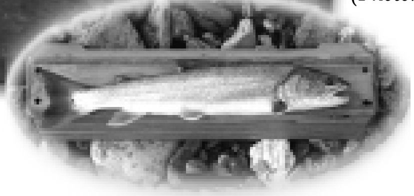
To be added to the list server that issues these daily bulletins, please send an e-mail message to:

majordomo@cmc.ec.gc.ca

with the message body containing:
subscribe pnr_vi your.email@goes.here

Bull trout (*Salvelinus confluentus*) distribution, life history, & habitat use

in the South Nahanni watershed



Left: N. Mochnacz and K. Bourassa sampling at Marengo Falls (Photo: D.P. Tate)

Below: Bull trout from S. Nahanni River (Photo: N. Mochnacz)

Neil J. Mochnacz, James D. Reist and Douglas P. Tate

Bull trout (*Salvelinus confluentus*), a native char of North America, is currently listed as "threatened" within the coterminous United States and "sensitive" in Alberta, British Columbia, and the Yukon Territory (U.S. Fish and Wildlife Service 1999; Canadian Endangered Species Conservation Council (CESCC) 2001). Bull trout is considered a species that could be at risk of extinction or extirpation in the Northwest Territories (NWT) and is a candidate for a detailed risk assessment in this region (Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development 2000). Dolly Varden (*Salvelinus malma*), which is closely related to bull trout, is also found in the northwestern portion of the NWT. Dolly Varden has frequently been confused with bull trout in the past because of the similar appearance of the two species (Reist *et al.* 1997, Reist *et al.* 2002 in press). Despite confirmation of self-sustaining bull trout populations in the NWT (Reist *et al.* 2002 in press, Mochnacz *et al.* submitted), the distribution, life history and habitat requirements for this species are poorly understood in the region.

Such uncertainty is problematic for fisheries managers in the NWT, as bull trout populations found in the south have demonstrated an inherent vulnerability to perturbation from human activities. Many populations found in the southern portion of the species' range have experienced significant declines and in some cases, local extirpation (McPhail and Baxter 1996, McCart 1997, Baxter *et al.* 1999). Impacts contributing to the decline of southern bull trout populations include: fragmentation and isolation of populations by man-made structures such as dams; over-fishing; habitat disturbance from activities such as forestry, mining, oil and gas exploration and development; and interaction with exotic species (Goetz 1989, McPhail and Baxter 1996, McCart 1997; Baxter *et al.* 1999).

Since bull trout are considered by many to be an indicator species for water quality (Goetz 1989, McPhail and Baxter 1996, Baxter *et al.* 1999), understanding and monitoring the populations found in and around Nahanni National Park Reserve (NNPR) contributes directly to Parks Canada's mandate of maintaining ecological integrity in Canada's National Parks. The ecology of a park is greatly affected by the environment outside the park's boundaries, particularly in fluvial (river) systems where headwaters are not protected, which is the case for the South Nahanni River. Furthermore, the possibility of using bull trout to monitor water quality in and around NNPR should be examined as it could prove to be an excellent ecosystem management tool for park managers in the future. In this paper we report on the distribution, biology, life history, and habitat use of bull trout populations found in the lower South Nahanni watershed.

METHODS

During the summer and fall of 2001, fisheries surveys were conducted at selected sites in NNPR and adjacent portions of the South Nahanni watershed (Figure 1). Angling and backpack electrofishing were used to sample fish at various locations in the lower portion of the watershed. The presence of bull trout and associated species at each habitat type (pools, runs, and riffles) was documented throughout the sampled reaches. Captured char were identified to species in the field before being released. Fork length and weight were recorded for all bull trout caught and Floy-tags were placed below the dorsal fin on all fish greater than 150 mm for future identification. Part of the adipose fin and the first two pelvic fin rays were taken for genetic studies and non-lethal ageing. Nineteen char were retained for biological sampling, ageing, and confirmation of species identity. A linear discriminant function proven to be 100% effective in distinguishing bull trout from Dolly Varden was used to confirm the identity of char that were captured (Haas and McPhail 1991).

Habitat assessments were conducted at Funeral, Jorgenson, and Marengo creeks (Figure 1). Habitat assessments were done in reaches (200 – 400 m) from the lower and upper sections of each stream after the reach was fished. In each stream reach, habitat was partitioned into pools, runs, and riffles similar to the procedure described by Arend (1999). Once habitat was categorized, depth, water velocity, substrate, temperature, and cover were recorded at nine equally spaced points throughout each habitat type.

RESULTS AND DISCUSSION

Distribution

Bull trout were captured at seven different locations in the lower South Nahanni watershed (Figure 1). The largest number of bull trout were captured from Funeral Creek. However, fishing effort was focused in this area as this stream was identified as a likely spawning and rearing site. Furthermore, proposed mining developments in the local area have the potential to impact water quality and fish habitat. The frequency of bull trout captures in other

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Bull trout (*Salvelinus confluentus*) distribution, life history, & habitat use

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locations throughout the area was relatively low and may indicate that small, widely dispersed populations occur in the lower South Nahanni watershed.

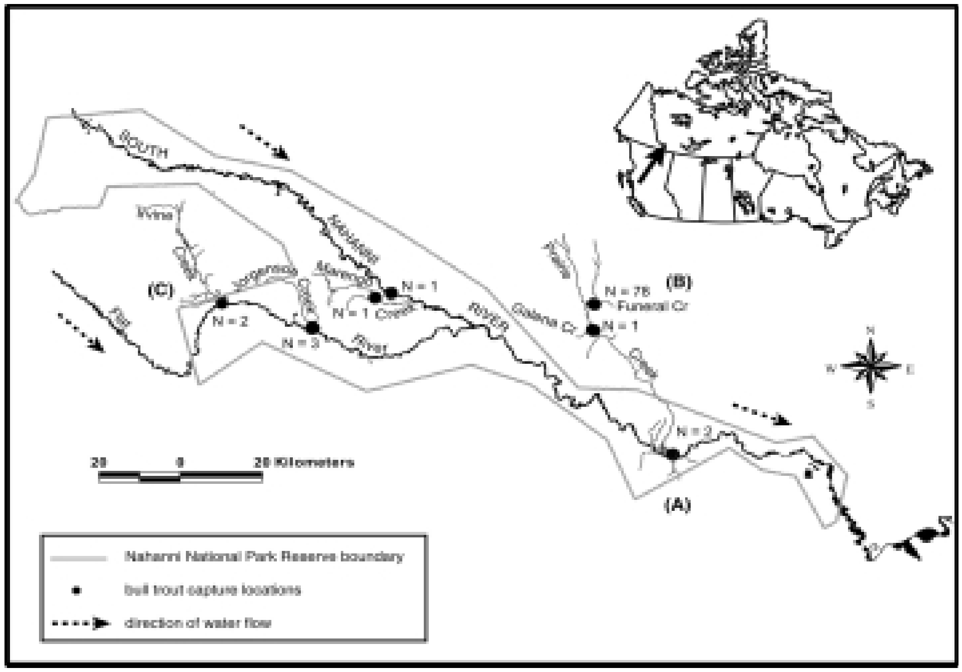

Figure 1. Location of bull trout captures in the South Nahanni Watershed, Northwest Territories during summer and fall sampling in 2001. Note that some fish from these locations (letters A - C, Table 1) were sacrificed to provide critical biological data; the remainder were released live.

Biology

The bull trout captured in Funeral Creek represented a number of different age classes (Table 1). Many small fish (e.g., 35–80 mm) were captured in Funeral Creek upstream of barriers that are impassable for juveniles but not adults. The capture of juveniles above impassable barriers indicates that these fish were hatched in this stream, as juvenile bull trout remain in their natal streams for 3–5 years before joining adults from the spawning population. The adults captured in the summer were either sexually mature fish preparing to spawn or resting adults that will spawn in subsequent years. Spawning in non-consecutive years is common for most bull trout populations found throughout the species' range (McPhail and Baxter 1996). Eight adult bull trout were captured from Funeral Creek during the summer and tagged with individually numbered Floy-tags. Three of these eight fish were recaptured from Funeral Creek during the fall after spawning. These individuals may make annual migrations in the fall to spawn in Funeral Creek or remain in the stream year round and spawn in the fall.

Bull trout populations that occupy the South Nahanni watershed may exhibit fluvial or stream-resident life history strategies. Fluvial populations spawn and rear in small tributary streams and overwinter in larger rivers. Stream-resident populations spend their entire lives within their natal stream despite having access to larger tributaries with suitable habitat. Adults from stream-resident populations are usually slow growing and attain a smaller size at sexual maturity than do individuals from fluvial populations (Goetz 1989, McPhail and Baxter 1996). The small size exhibited by adults caught in Funeral Creek and the habitat potentially available in this stream year round suggests that these individuals are part of a stream-resident population. Bull trout captured in the South Nahanni and Flat rivers in the past and during this study are considerably larger than individuals of the same age from Funeral Creek, which suggests that these individuals may be part of a fluvial population(s) found in the watershed (Table 1). Such size differences between stream-resident and fluvial or adfluvial (lake-dwelling) bull trout are common (Goetz 1989, McPhail and Baxter 1996).

Habitat

Funeral Creek, which was identified as a likely spawning tributary, provides year-round habitat for bull trout in the watershed. Funeral Creek is a relatively small creek that flows into Prairie Creek. The creek has an average wetted width of 2.5 meters and is composed of numerous intermediate sized (0.5-1 m) plunge pools followed by cascading riffle habitats and runs. Many of the larger plunge pools (approximately 1-2 m) are impassable for small juveniles (35-80 mm) but not for larger adults. Large boulders, intermediate cobble, undercut banks and turbulence provides sufficient cover for juveniles and adults. The stream has an average velocity of 0.42 m/s, which is relatively fast given its size. However, instream cover provides ample opportunity for smaller fish to seek refuge during high flow periods in the spring. The substrate in the creek is dominated by cobble (16-65 mm diameter) and appears to have groundwater infiltration throughout the year. Bull trout spawning populations have demonstrated a distinct preference to areas that have groundwater infiltration, as these sites provide an ideal incubation environment for eggs throughout the winter, which typically increases egg to juvenile survival (Baxter and McPhail 1999). Funeral Creek possesses many of the physical habitat requirements that typically characterize high quality bull trout spawning and rearing habitat (Baxter and McPhail 1996).

Despite the low frequency of bull trout captures in the South Nahanni and Flat rivers, as well as Prairie, Marengo, and Jorgenson creeks, all of these watercourses possess a large proportion of habitat suitable for bull trout. Furthermore, because the South Nahanni River, Flat River, and Prairie Creek do not freeze to the bottom and continue to flow during winter, they can be considered year-round fish habitat. Consequently, bull trout populations likely use these watercourses for either or all of the following: 1) migratory corridors to spawning sites, 2) seasonal feeding habitat, and 3) overwintering habitat.

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Bull trout (*Salvelinus confluentus*) distribution, life history, & habitat use

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Table 1. Collection and biological data for bull trout that were caught and sacrificed for this study

Fish Number	Date D/M/Y	Location and Map Code for Figure 1 (A,B,C)	Fork Length (mm)	Weight (g)	Sex[1]	Maturity[2]	Age[3] (years)
47325	17/08/01	South Nahanni River (A) (61° 14' 57.8"N, 124° 24' 29.3"W)	281.0	236.0	M	resting	11
47263	14/08/01	Funeral Creek (B) (61° 36' 37.5"N, 124° 44' 12.3"W)	72.0	2.8	UK	immature	1
47264			65.0	2.3	UK	immature	1
47265			323.0	397.0	M	mature	11
47266			289.0	297.0	M	mature	9
47267	13/08/01	Funeral Creek (B)	168.0	56.0	M	immature	4
47268			266.0	204.0	F	resting	7
47269			354.0	506.0	F	resting	---
47270			185.0	72.0	M	immature	5
47330	11/09/01	Funeral Creek (B)	272.0	246.0	F	resting	11
47331			101.0	10.0	UK	immature	2
47332			67.0	3.0	UK	immature	1
47333			61.0	2.0	F	immature	1
47334			35.0	1.0	F	yoy	0
47335			38.0	1.0	UK	yoy	0
47336			99.0	14.0	F	immature	2
47337			139.0	28.0	F	immature	3
47338	15/09/01	Flat River at Irvine Creek (C)	456.0	934.0	F	resting	10
47596		(61° 18' 08.7"N, 124° 25' 24.1"W)	626.0	2870.0	F	resting	12

1 Key: M=male; F=female; UK=unknown

2 Key: resting=sexually mature fish that will not spawn this year; mature=sexually mature fish that will spawn this year; immature=fish that have not completely developed sexual organs; yoy=fish hatched this year

3 Ages are based on otoliths

Management

Given that bull trout populations generally spawn in non-consecutive years, mature late and are vulnerable to impacts on their habitat (McPhail and Baxter 1996, Baxter *et al.* 1999), any development that may occur in or around water bodies containing bull trout should be avoided if possible. Small impacts on habitat (e.g., improper winter road construction) could significantly impact spawning sites by decreasing egg to juvenile survival rates rendering small slow-growing populations, such as the Funeral Creek population, at risk of extirpation. Impacts to fish habitat will be an important consideration in the environmental assessment of potential on-site and downstream impacts of industrial activities currently proposed in the upper reaches of Funeral and Prairie creeks.

It is also critical to recognize that bull trout populations are typically small and widely dispersed in local areas throughout the species' range (Goetz 1989, McPhail and Baxter 1996). However, the apparent isolation of small populations in individual tributaries, such as Funeral Creek, is frequently the result of straying, a common behavior in salmonid populations. Straying is when a certain proportion of adults from local breeding populations move into and spawn in non-natal streams. Such wandering creates meta-populations, which are small local populations in individual tributaries that are connected to larger individual breeding populations by the exchange of individuals. Meta-populations are a product of incomplete isolation and local adaptation and maintain genetic variability through straying from other breeding populations. Straying strengthens regional populations by refounding and protecting the genetic diversity that is necessary for survival under constantly changing environments, thus it facilitates the replenishment and long-term persistence of such populations (Quinn *et al.* 1991, NRC 1996, Policansky and Magnuson 1998).

Since small numbers of bull trout have been observed throughout the lower South Nahanni watershed during this study as well as in the past and no impassable barriers are present from the South Nahanni River at Virginia Falls to Funeral Creek, it is likely that meta-populations occupy the watershed. The potential connectivity between bull trout populations in the South Nahanni watershed must be considered during management decisions because fragmentation could create a group of increasingly isolated and dwindling populations that are subject to increased susceptibility of extirpation. Future bull trout studies in the South Nahanni watershed should focus on habitat use, connectivity, and population size to ensure that populations are managed appropriately. Periodic, non-lethal sampling using standardized fishing effort (e.g., backpack electrofishing, fish fences) in specific areas, such as spawning sites, could be used to monitor populations throughout the watershed over time. The possibility of utilizing bull trout as an indicator species for water quality in and around NNPR should also be considered. Managers could associate the presence of abundant, well-structured year classes from bull trout populations (i.e., healthy population) with excellent water quality. Conversely, year class losses and/or declines within populations would be an indication of marginal water quality reflecting an impact to the watershed. The use of bull trout in this capacity could improve Parks Canada's ability to detect impacts to ecosystems and facilitate more effective ecosystem management.

ACKNOWLEDGEMENTS

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Parks Canada and Ecological Monitoring:

Looking out for the future

In January 2002 the Prairie Parks Biologist working group convened in Elk Island National Park to discuss challenges related to ecological monitoring. We focused on long term ecological monitoring; bringing together participants from Riding Mountain (Doug Bergeson), Waterton Lakes (Cyndi Smith), Grasslands (Adrian Sturch, Rob Sissons), Prince Albert (Norm Stolle, Dan Frandsen, Jeff Weir), Elk Island (Steve Otway, Ross Chapman, Norm Cool, Kalya Brunner) National Parks,as well as from the Western Canada Service Centre (David Poll, John Wilmshurst) and the Ecological Integrity office in Ottawa (Steve McCanny), with a guest speaker from the Alberta Research Council (Garry Scrimgeour). Here, I distill the ideas we discussed collectively at the workshop and present potential solutions.

John Wilmshurst

The theoretical foundation for ecological monitoring is clear. Noss (1990), in his now seminal work, described how to design monitoring programs, Woodley (e.g., 1994 and references therein) developed an extensive framework for monitoring in Parks Canada and ecological monitoring has been a focal point of discussion by Parks Canada (Skibicki *et al.* 1994, Parks Canada Agency 2000). Together with an extensive literature on potential indicators, there should be no confusion as to why, how, or (for the most part) what we should monitor.

Why do we continue to monitor so poorly (Auditor General of Canada 1998)? Perhaps it is due to inadequate funding, staff turnover and staff shortages, and the lack of a long-term vision or peer review. Or is it that we continue to implement monitoring programs that do not have clear foci or research questions? The absence of clear questions cannot be because they are lacking (Noss 1990), nor because we do not recognize questions as being central to ecological monitoring.

Parks as a Baseline

Many people argue that National parks are ecological baselines against which to compare changes arising from human development. This notion provides parks with a clear hypothesis upon which to frame otherwise rudderless monitoring programs:

Differences observed across the park boundary are due to different management practices.

More importantly, this hypothesis transforms simplistic monitoring questions such as “Are exotic species densities increasing in parks?" to which the answer is almost undoubtedly “yes,” into “Are exotic species densities increasing in parks at a different rate than elsewhere?” — a far more thought-provoking question. Additionally, monitoring and mitigating visitor impacts can only be achieved by understanding what visitors expect from parks relative to similar recreational opportunities elsewhere. Such comparisons spawn clear, essential questions that can guide monitoring programs.

The Large Scale

The majority of our working group agreed that monitoring needs to extend beyond park boundaries if it is to be effective, and that by its very nature, monitoring is a long-term and comparative exercise. By explicitly identifying areas outside parks, the questions that drive monitoring become clear. In fact, many parks monitor in part to contribute to larger national or international endeavors, including breeding bird surveys, air quality and climate monitoring. One of the challenges of investing in these programs is that sampling is *often* not replicated within the park, leaving little scope for questions that can be answered at the park level. At the national and international scale, the questions are clear and data from protected areas act as ecological baselines that allow evaluations of anthropogenic effects.

The Long Term

Despite being difficult to maintain, long-term monitoring projects represent a remarkable and unprecedented contribution by Parks Canada to ecological research. The magnitude of the contribution increases with the full weight of time and when the program extends beyond park boundaries. The slow accumulation of data by parks, when combined with that from external organizations, can answer short-term (often interim) questions, while laying the foundation to answer long-term questions. Indeed, even local, within-ecosystem comparisons of simple data trends across management regimes can be enormously valuable. Our immediate challenge may be to create and maintain monitoring programs that formalize links to ecological integrity statements, park management plans, and that benefit from linkages with external organizations.

Monitoring for Ecological Integrity

Parks Canada defines ecological integrity using the ecological characteristics of each park's natural region. Thus, we may not be able to evaluate our success or failure in achieving ecological integrity by comparing conditions just within park boundaries. Rather, it is clear that we need to understand ecological patterns and processes across an ecologically-meaningful region. Additionally, because activities around parks will affect the ecological integrity in parks, we will not be able to quantify changes in ecological integrity without monitoring both inside and outside our boundaries. Attaining ecological integrity within parks means that future initiatives need to promote and *measure* ecological integrity in the greater park ecosystem. This approach has alreay been adopted by several parks. In fact, monitoring programs that both declare precise measures and involve outside partners will stand a higher chance of recognition in management plans: a necessary step for implementation.

Partnerships

It is likely that Parks Canada will never receive sufficient funding to carry out its monitoring mandate, and it could be argued that establishing partnerships may be a pre-requisite to successful long-term monitoring. To some extent, parks have been establishing partnerships (e.g., McCanny and Henry 1995), but we need to increase these efforts. Elk Island and Prince Albert National Parks have also benefitted from establishing science advisory committees whereas others, such as Waterton Lakes and Grasslands National Parks, have established relationships with United States parks and other organizations, to effectively monitor invasive species. Strong ties to industry and provincial departments have helped Prince Albert and Riding Mountain National Parks to develop integrated forest monitoring programs.

However, parks are ultimately responsible for reporting the actions outlined in park management plans, and we must ensure that monitoring projects are designed to do this. As well, monitoring implies a long-term commitment to data gathering and reporting. Often monitoring programs are designed to be dependent upon a substantial time-series of data, with minimal annual replication. When establishing partnerships, we should be careful to ensure that the loss of the partner does not compromise the essential components of the monitoring program.

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Parks Canada and Ecological Monitoring

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Conclusion

To be effective, ecological monitoring has to be based on core scientific principles including hypothesis testing. During our discussions, it emerged that partnerships and cross-boundary projects can help us clarify these issues. This argument also supports effective zoning within park boundaries. Monitoring programs often founder due to a lack of clear direction and we implore others to identify the core question before embarking on ecological monitoring programs. This is by no means easy, but it is essential.

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"Lyle Dick has been a historian with Parks Canada for many years. He lives in Vancouver, BC, where he is currently the West Coast Historian for Parks Canada's Western Canada Service Centre. Her has written, researched and published extensively in the fields of Arctic history, western Canadian history and historiography... Muskox Land is a comprehensive study of European-Inuit contact in the High Arctic, including the roles played by the natural environment, culture, circumstance, and historical change arising during the era of exploitation."
- University of Calgary Press, Press Release, November 2001.

"[This book]... definitely makes a significant contribution to Arctic history and anthropology. I am sure that the Inuit of Canada and the Inughuit of Greenland will be pleased to see that their voices are finally being heard! There is no other work which delves with such depth into the subject matter."
- Rick Riewe, Department of Zoology, University of Manitoba

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MEETINGS OF INTEREST

April 3-6, 2002

GORGEous WILDLIFE: Society for Northwestern Vertebrate Biology (SNVB) Annual Meeting. Hood River, Oregon. Speakers for this conference include Jim Agee, College of Foreest resources, University of Washington; Edmund Brodie, Department of Zoology, Utah State University; and Charlie Crisafulli, USDA Forest Service, Pacific Northwest Research Station, Olympia, WA. Session topics include habitat use and conservation, threats to amphibians in the Pacific Northwest, bats, bull trout, forest carnivores, invertebrates and shrub-steppe birds. Contact: Kelley Jorgensen, Treasurer, SNVB: Tel: (503) 621-9785; jorgenk@wsdot.wa.gov; http://www.cou.edu/snvb

April 9-13, 2002

Ecological Monitoring and Assessment Network (EMAN) National Science Meeting. Gatineau. PQ. The theme of this year's conference is Enhancing the Effectiveness of Ecological Monitoring. Among the topics for discussion are: knowledge management (metadata training/symposia), internet mapping, standardization and coordination of ecosystem monitoring protocols, the role of biodiversity networks in decision/management support, and the plenary symposium — linking ecosystem monitoring, research and assessment to decision-making. Contact: EMAN, Environment Canada, tel: (905) 336-4414; fax: (905) 336-4499; eman@ec.gc.ca; http://www.eman-rese.ca/eman/events/intro.html

May 8-11, 2002

Canadian Society of Zoologists Annual Meeting. University of Lethbridge. This conference will include the following symposia: Prairie Biodiversity - Processes, Patterns and Practice; Comparative Physiology and Biochemistry - Geonomics as a Tool for Assessment; Parasitism - Evolution and Ecology of Arthropod/Host Interactions; and Ecology, Evolution and Ethology - Predicting the Effects of Enviro Canadian Animal Populations. Information and onliine registration are available: C.P. Goater, tel: (403) 329-2752; fax: (403) 329-2082; http://home.uleth.ca/-goatcp/csz/english/index.html

July 7-12, 2002

International Society of Behaviour Ecology. Université du Québec à Montréal (UQÀM). The 9th Anual Meeting of the International Society for Behavioural Ecology will involve formal and informal scientific exchange as well as field trips in Montreal and the surrounding countryside. In addition to several plenary talks, the conference will feature a symposium on Ecology and the Central Nervous System, afternoon paper presentations and evening poster sessions. For information and on-line registration: isbe2002@uquam.ca; tel: (514) 398-6466; fax: (514) 398-5069; http://www.isbe2002.uqam.ca

July 11-14, 2002

Society of American Naturalists (ASN) Conference. Banff, AB. Symposia planned to date include: ASN Young Investigators, Spatial Ecology, and plenary lectures on Research Frontiers by new or past winners of Sewall Wright and E.O. Wilson Awards. Field trips include a hike to the Burgess Shale, and a guided bus trip on an ecological transect in the Bow and Kananaskis River Valleys. Contact: Patricia Williams, pat@zoo.utoronto.ca

August 9-14, 2002

4th International Workshop on Disturbance Dynamics in Boreal Forests: Disturbance Processes and Their Ecological Effects in Boreal Forests. University of Northern British Columbia, Prince George, BC.. This workshop will focus on understanding disturbance processes and their ecological effects. We seek to develop a better understanding of how disturbance operates, the effects of different types of disturbance, and the mechanisms by which disturbance influences boreal forests. The workshop includes 4 full days of presentations and 1 mid-workshop field day. Contact: S. Ellen Macdonald, tel: (780) 492-3070, fax: (780) 492-1767, BorealDist@afhe.ualberta.ca for conferrence information or Jennifer Studney, tel: (250) 960-5520, fax: (250) 960-6432, studney@unbc.ca to register. Also see: www.res.unbc.ca/borealdisturbance

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