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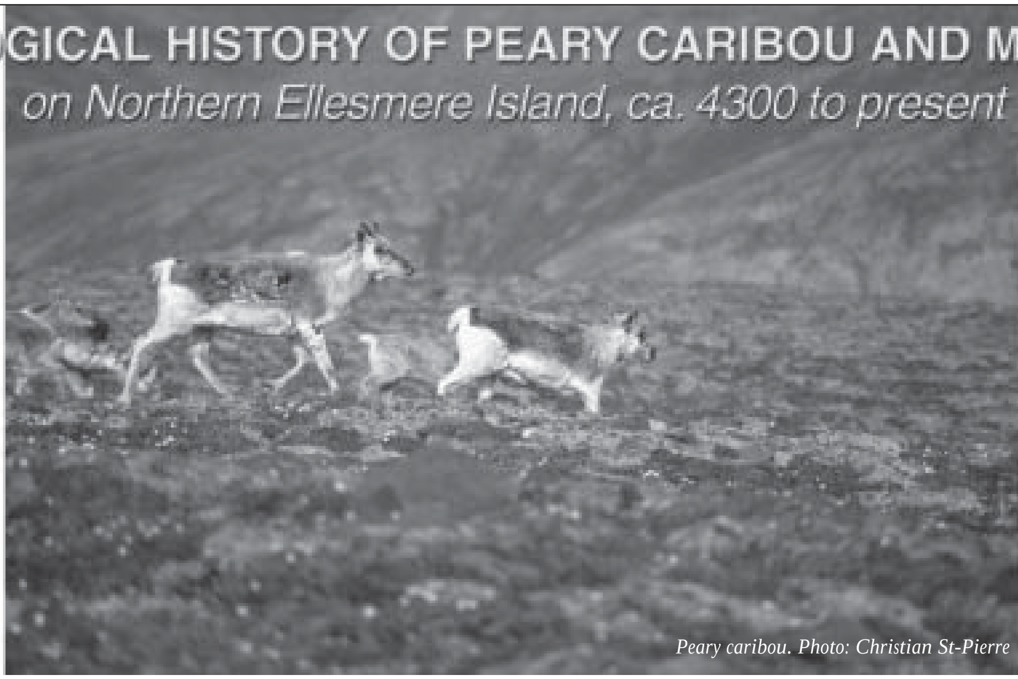
Research Links

A Forum for Natural, Cultural and Social Studies

ECOLOGICAL HISTORY OF PEARY CARIBOU AND MUSKOX
on Northern Ellesmere Island, ca. 4300 to present



Peary caribou. Photo: Christian St-Pierre

*Micheline Manseau, Lyle Dick, N***** Lyons, Christian St.-Pierre and Jennifer Wood*

Peary caribou (*Rangifer tarandus pearyi*) occur throughout the Arctic islands, except for the islands of the Baffin Island region, and on Boothia Peninsula. They live exclusively in arctic tundra, in environments that range from relatively flat and featureless in the south and west to mountainous in the north and east. Four distinct populations have been identified and all have suffered severe declines over the past decades. The Queen Elizabeth Islands population (High Arctic Islands) has declined by more than 90%; from a population of 24 000 in 1961 to as few as 2000 animals in 1987 (Miller 1991). These declines can be attributed to a number of factors, and the intensity and interrelatedness of these factors vary among different caribou populations. Factors known to have contributed to population declines include: 1) inaccessibility of forage caused by irregular winter events such as heavy snow and freezing rain; and 2) hunting at unsustainable rates. Since limited information is available on distribution and movement of Peary caribou, undetected movements of caribou or distribution shifts may also be misinterpreted as population declines. Peary caribou of the Queen Elizabeth Islands are listed as "endangered" by the Committee on Status of Wildlife in Canada (1991) and the World Conservation Union (1996).

Most of the information for the Queen Elizabeth Islands is based on survey of the western islands. Only one survey of the eastern Queen Elizabeth Islands was done in 1961 and estimated the number of animals at 1482 (Tener 1963). In order to contribute to the recovery effort and to provide insights into the distribution and status of Peary caribou in the northern part of Ellesmere Island (most northern of the Queen Elizabeth Islands), we decided to compile all information available for the area. To this end, we assembled archeological and historical records and further analyzed Peary caribou population data collected by biologists of Quttinirpaaq National Park over the last decades. We also compiled information available on muskoxen (*Ovibos moschatus*), a more abundant and resilient species, to gain comparative insights into the population ecology of the species. We seeked to identify critical areas for Peary caribou and past population sizes from these complementary sources of information and

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Research Links is a publication that highlights research from the natural, cultural and social sciences, and is published by the Western Canada Service Centre (Calgary).

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FRANCOPHONES

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Editorial

Noteworthy Items...

PARKS CANADA HISTORIAN AWARDED HAROLD ADAMS INNES PRIZE

Harold Adams Innes (1894-1952) was one of Canada's most distinguished interdisciplinary scholars. His concern for problems associated with the development of Canadian society and the course of Western civilization led him to examine an enormously diverse array of materials from History, Philosophy, Science, Literature and the Arts. His understanding of Canada's Economic History, his grasp of the issues which beset his generation and his perceptions set him apart from his contemporaries. Events of the past decade have made his writings even more relevent today.

Please join us in congratulating Lyle Dick, Historian, Parks Canada Western Canada Service Centre in Vancouver, for receiving the Harold Adams Innes prize as author of the vest English-language book in the Social Sciences. His book, "Muskox Land: Ellesmere Island in the Age of Contact," was published by the University of Calgary Press, and has received outstanding reviews. This year the book was among 150 entries and live finalists. Below you will find information from the website of the Canadian Federation for the Humanities and Social Sciences.

Lyle was presented with the award this past November at the National Library in Ottawa. He will donate this $1000 prize money to the school at Grise Fiord.

Find out more about Lyle's research in our feature article on page 1.

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in collaboration with Inuit of Grise Fiord and Resolute Bay.

AREA OF INTEREST

This project focused on the northern part of Ellesmere Island, within the area of Quttinirpaaq National Park of Canada. "Quttinirpaaq" means "top of the world" in Inuktitut, the Inuit language. At 37,775 km^2, Quttinirpaaq is the second largest national park in Canada. It's massive ice caps and glaciers, jagged mountains, dissected Hazen plateau, and many lakes and rivers create a large diversity of landscapes and ecological conditions, including the Ward Hunt Ice Shelf, a vast polar desert, and the Lake Hazen Oasis. The nearest communities are Grise fiord, 640 km to the south of the Park, and Resolute Bay, 260 km further south. Parks Canada has summer installations at Tanquary fiord and Lake Hazen. The Department of National Defence has year-round military and research facilities to the south and north of the Park, in Eureka and Alert.

METHODS AND RESULTS

Archeological Evidence

The archaeological data reconstruct land and resource use patterns for the succession of cultural groups to have occupied Ellesmere Island and adjacent small islands over the past four millennia. Information from nearly 600 site components (each representing a cultural occupation) were obtained from the Archaeological Survey of Canada (ASC) and Parks Canada site records and mapped to reflect the distribution of different cultural groups in the study region (Figure 1, see Table 1 for a chronology of human occupation on Ellesmere Island and vicinity). The Arctic Stone Tool tradition represents the first group of cultures to occupy the area, including Independence I and II, Pre-Dorset, Early and Late Dorset, and the Sarqaq people of West Greenland. Neoeskimo groups include the Thule and historic Inuit cultures. Non-Inuit groups include the Norse of Greenland and the historic European-based cultures (see History section below for account of the latter). The distribution of fauna, or animal remains utilized by humans, was also mapped by cultural affiliation (figure not shown). Fauna was divided into three categories for analysis: a marine category, incorporating all sea mammal elements (including whale bone used in houses and polar bears); a terrestrial category, including caribou and muskox, and; an 'other' category, capturing bone and antler artifacts and other terrestrial species.

The distribution of site components on Ellesmere, if they are reflective of actual habitation on the island, provides a number of land and resource use patterns over four millennia

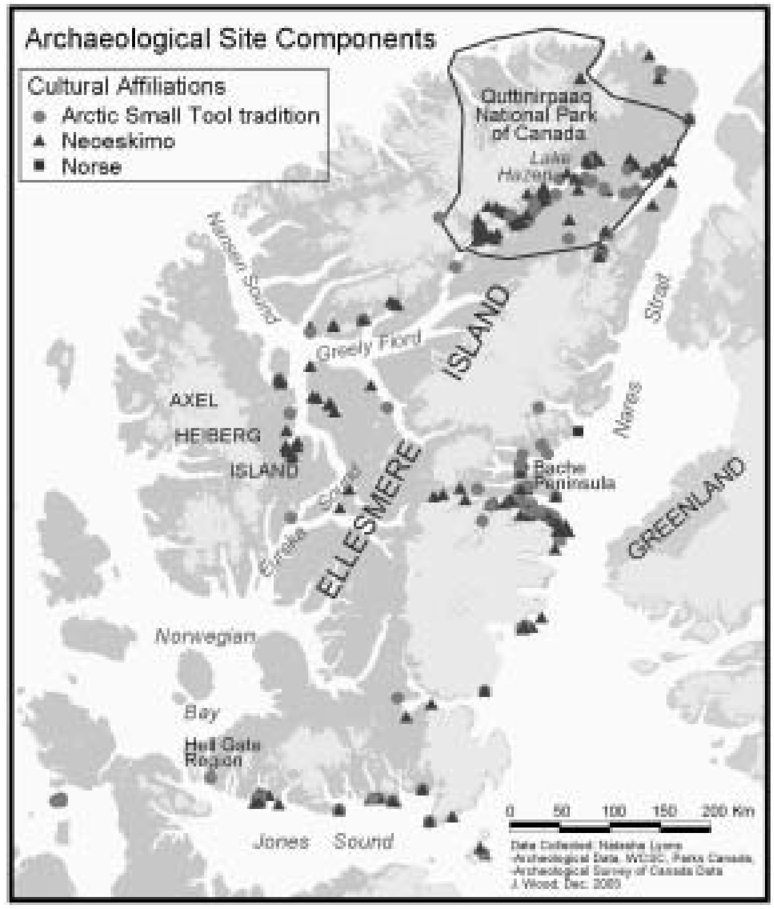

Figure 1. Distribution of archaeological site components on Ellesmere Island by major cultural traditions.

Table 1. Cultural chronology for Ellesmere Island

	Cultural Group	Occupation Time (BC/AD)*	Extent of Cultural Occupation
Arctic Small Tool Tradition	Independence I	2000-1700 BC	High Arctic
	Saqqaq	1800/1900 to 800/900 BC	West Greenland, east coast Ellesmere Island
	Pre-Dorset	c. 1200-800 BC	Low Arctic and areas of High Arctic
	Independence II	1000-500 BC	High Arctic
	Early Dorset	c. 700-500 BC	Pan-Arctic
	High Arctic Abandonment		
	Late Dorset AD	700- 1150	Pan-Arctic
Neoeskimo & Historic Cultures	Thule	c. AD 1100-1700	Pan-Arctic
	Norse	c. AD 1100(?)	Greenland, parts of eastern Canadian Arctic
	Historic Inuit	c. AD 1875	Pan-Arctic
	Non-Inuit	c. AD 1875	Pan-Arctic

* The dates presented above and in the following text follow the relevant literature (Maxwell 1985; Schledermann 1990; Schledermann and McCullough 2003, pers. comm.; Sutherland 1989).

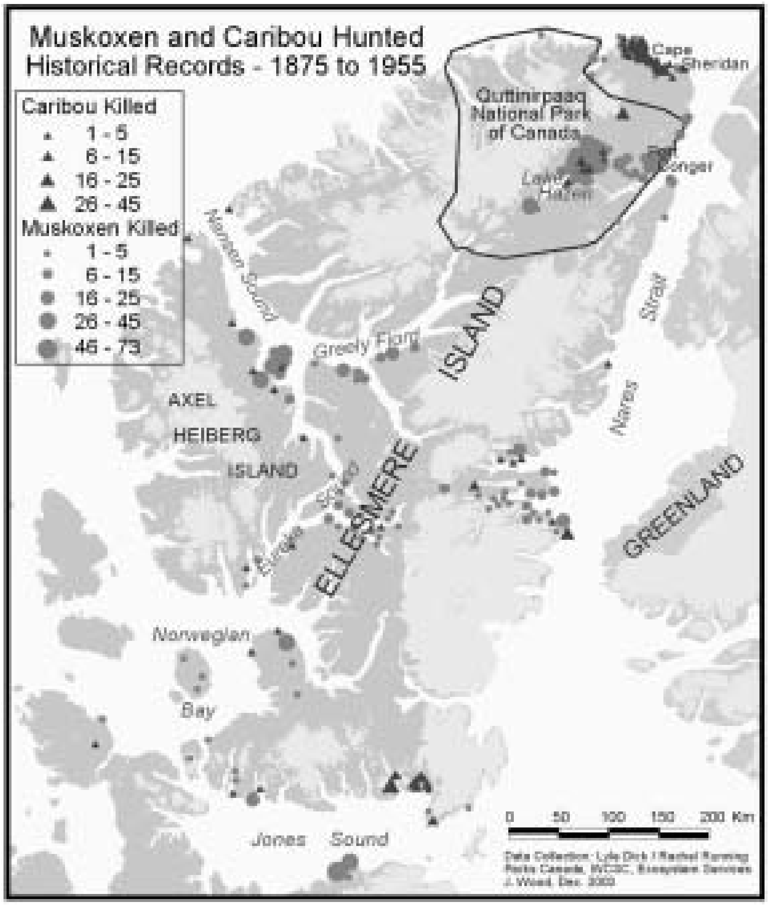

Figure 2. Kill sites for Peary caribou and muskox between 1875-1955.

of occupation (Figure 1). The relative proportion of sites per region reflects the relative intensity of occupation across space. We see that the Bache Peninsula region, adjacent to areas of open water (polynyas) with a high diversity and abundance of sea mammals, contains nearly half the site components of the AST period, and is home to just about forty percent of components for the succeeding Thule and Inuit cultures. Northern Ellesmere, and primarily the Hazen Plateau of Quttinirpaaq National Park, was used by about a third of Ellesmere's cultural inhabitants through time. The northwest, southeast, and south follow in descending order. No sites have been recorded in the Hell Gate region of the southwestern Ellesmere shoreline, and very few along the far north coastline. Sverdrup (1904: 115-116) assessed the Hell Gate and Bjorne Peninsula region of southwestern Ellesmere to be hostile and uninhabitable in his exploration of the area. The North Coast, also a relatively rugged, icebound area, was little used until European explorers began to frequent the region in their quest for the North Pole (cf. Dick 2001).

Faunal patterns show a developing focus through time on sea mammal hunting in open water polynyas, such as the large North Water that borders east and southeast Ellesmere and multiple secondary polynyas near the east and south shores of the island (Schledermann 1980). For the most part, terrestrial resources have been considered too vulnerable to have provided a dietary mainstay for Arctic cultural groups (Maxwell 1985:33). Certainly, by Thule times, terrestrial resources were a secondary resource in most Arctic regions, sought in large part for the raw materials as much as for consumption (McCartney 1989:299-300). However, an interesting departure from this subsistence pattern arises in the available data from northern Ellesmere Island, which reflects long-term use of the area for terrestrial hunting. The faunal data from Quttinirpaaq indicate a clear emphasis on caribou and muskox hunting, along with substantial supplements of other terrestrial resources (Sutherland 1989). Though coarse-grained, the combined faunal and settlement data suggest that hunting and consumption of caribou and muskox occurred throughout all pre-contact cultural periods across the Hazen Plateau, in a sustainable though likely sporadic fashion.

Historical Evidence, 1875-1955

For the post-contact era, evidence of sighting or hunting of muskoxen and Peary caribou on Ellesmere Island and adjacent land masses is contained in the unpublished and published writings of European explorers and RCMP officers in the 100 years between 1875 and 1975. Research in these records has generated more than 550 references to the presence of these animals in various areas of the island, especially the northern interior and coastal regions, the southern and southwestern coasts, and the east-central coastal areas (Figure 2). The locations where animals were hunted was partly determined by the siting of base camps or settlements as well as the itineraries of exploring parties. However, the base camps were also often sited at particular locations because of the presence of game animals nearby.

For the muskox, the historical evidence suggests that intensive hunting in northern Ellesmere Island in the late nineteenth and early twentieth centuries placed severe stress on resident animals. During Peary's 1898-1902 expedition, his parties killed a minimum of 435 muskoxen on Ellesmere Island and during his 1905-06 North Pole expedition, they took 502 muskoxen, but in 1908-09, excepting the animals taken in northern Greenland, his parties were able to secure only 41 muskoxen on the island, mostly in the north. In 1908-09, Peary's parties hunted in many of the same areas visited on previous forays, so it is highly possible that muskox in northern Ellesmere Island were significantly depleted by hunting in the first decade of the twentieth century. For Peary caribou, the records tell a

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story of increasing kills through the Peary period. In 1898-1902 Peary's parties killed 27 caribou, increased the kill to 84 in 1905-06, and peaked at a kill of at least 149 caribou taken during his last North Pole expedition of 1908-09. The increasing emphasis on caribou apparently derived from Peary's inability to find muskoxen on the island by 1908 and the explorer's need to substitute other large game animals to feed his large expedition party. Following Peary's last North Pole expedition, very few explorers reached northern Ellesmere Island. The only reported sightings or kills occurred in 1935, when a member of the Oxford University Ellesmere Land expedition killed three caribou near the Gilman Glacier. The comparative absence of sightings suggests that Peary caribou in the north may have been seriously compromised by Peary's hunting activities.

The hunting of both species continued during subsequent exploration forays but hunting of muskoxen in the arctic archipelago was prohibited by an amendment to the Northwest Territories Game Art in 1917. Hunting of caribou was carried out by members of the RCMP during its occupations of detachments on Ellesmere Island at Craig Harbour (1922-25; 1933-40) and Bache Peninsula (1926-32). The numbers of animals taken increased significantly in the 1950s following the re-opening of the Craig Harbour detachment and the relocation of Inuit from Quebec and Baffin Island to Ellesmere Island. Between 1953 and 1955, Inuit at Craig Harbour killed 73 caribou. Relocating to Grise Fiord in 1956, members of the community killed a number of caribou and muskoxen between 1956-57 and 1978-79. They hunted these animals at various locations in the southern or southwestern areas of Ellesmere Island or adjacent land masses. Areas of particular focus included the Bjorne Peninsula and Graham Island, both comparatively abundant sites of caribou habitat, as well as sites adjacent to various fiords along the south coast.

CURRENT BIOLOGICAL INFORMATION

Identification of the most productive regions is crucial to determine potential habitats for large ungulates. To achieve this, remote sensing images (AVHRR and LANDSAT TM) were ground truthed in the Lake Hazen and Tanquary Fiord areas and indices of productivity (Normalized Difference Vegetation Index or NDVI) were derived based on green plant biomass (Figure 3) (St-Pierre 2002). A series of 10-day composite maps were produced for Ellesmere Island using AVHRR images and a July peak productivity map was produced for the Park area using LANDSAT images. Three classes of productivity were used to stratify the June wildlife surveys; NDVI values lower than 0.05 corresponding to non-vegetated (and non-glaciated) areas; 0.05 and 0.1 corresponding to less than 20 g/m^2 (dry biomass); 0.1 to 0.3 corresponding to 25-50 g/m^2. In the Park, plant productivity was higher in the Lake Hazen area; plant productivity increased to a maximum in mid-July and declined thereafter. Dominant plant communities included dryas barrens and sedge (willow) meadows.

Muskox densities were 10 times higher in the high productivity class compared to the non vegetated areas; their distribution being strongly correlated with the productivity index obtained from the

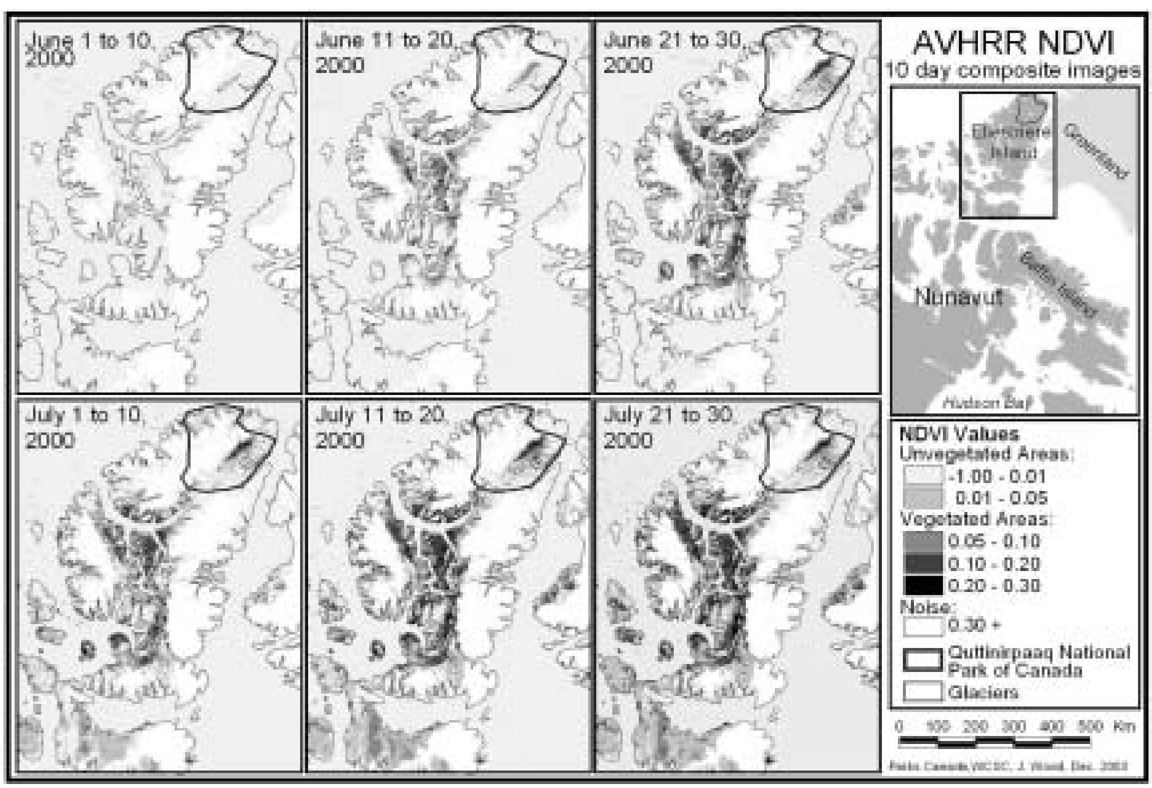

Figure 3. Vegetation productivity indices based on AVHRR-NDVI (0.05- 0.1<20 g plant/m^2; 0.1-0.2=20-35 g plant/m^2; 0.2-0.3=35-50 g plant/m^2).

Landsat images. Muskox surveys estimated the number of animals for the Park area as 1787 ± 371 in 2000 and 1754 ± 454 2001 (flight transect width estimated at 1.5km) and posteriori stratification of 12 years of surveys indicate a stable trend over time. Peary caribou were less abundant and their distribution was not correlated with the productivity index. This may be explained by a different habitat selection use pattern or simply, by the small number of observations. The best estimate of Peary caribou in the Park area is based on wildlife surveys conducted between 1988-2002, casual observations by Park wardens during annual patrols, and the satellite collaring work between 1994 and 1997. These observations account for a minimum of 45 animals which is significantly lower than what Peary encountered at the turn of the century.

DISCUSSION AND CONCLUSION

Archeological evidence confirms that Inuit people and their ancestors used the marine and terrestrial resources of Ellesmere Island over four millennia of occupation. Periodic abandonments of the area seem to stem from climatic changes, felt particularly acutely in High Arctic regions. Yet, the continuity of resource and land use by humans through time speaks to the sustainability of their subsistence and settlement strategies. While the use of marine resources and adjacent areas occurred in a predictable fashion, as established settlements within proximity of large and secondary polynyas, the exact nature of the pre-contact use of the Hazen Plateau has not been fully clarified by the archaeological record. Nevertheless, faunal and settlement data from northern Ellesmere Island, though coarse-grained, suggest that hunting and consumption of caribou and muskox occurred throughout all pre-contact cultural periods.

Muskox and caribou were also hunted during the historical period for the purpose of supplying the different polar expeditions and for local consumption following the establishment of a Canadian Inuit community on Ellesmere Island, based since 1956 at Grise Fiord. In northern Ellesmere, a minimum of 233 caribou and 1091 muskox were killed between 1875 and 1909 and there is clear indication that by 1908, the muskox had been severely depleted in these areas. Regarding the Peary caribou, the only significant hunting of terrestrial mammals in northern Ellesmere Island after the Peary era was carried out by a Walter Ekblaw, leader of a party of Donald MacMillan's Crocker Land Expedition in 1915. The fact that Ekblaw's party encountered no caribou may be evidence that this species had been largely depleted by Peary's last North Pole expedition. Areas traveled by the different explorers corresponded to most but not all areas of high habitat productivity for caribou and muskox; small refugia that were not visited possibly protecting the species from extinction. Based on current population estimates, these preliminary results suggest that the number of muskox is comparable to pre-contact level but the number of Peary caribou is much lower. Research activities are continuing to further investigate the impact of the explorers on Peary caribou in northern Ellesmere Island.

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Table 2. Number of Peary caribou and muskoxen harvested between 1875-1955 on Ellesmere Island.

		No. Peary caribou killed		No. Muskox killed	
Expedition	Years	*Northern Ellesmere*	*South/Central Ellesmere*	*Northern Ellesmere*	*South/Central Ellesmere*
Nares	1875-76			62	
Greely	1881-84			103	
Sverdrup	1898-1902	2	1		66
Peary	1898-1902		27	356	79
Peary	1905-06	84		499	3
Peary	1908-09	149		41	
Cook	1907-08				6
Whitney	1909				27
MacMillan	1913-17			30	93
MacMillan	1923				23
MacMillan	1924				10
RCMP, Craig Hbr.	1922-25		4		5
RCMP, Bache Pens.	1926-32		28		16
RCMP, Craig Hbr.	1933-40		25		
Shackleton	1935	3	3		
Inuit, Craig Hbr.	1953-55		83		

Note: These are minimum numbers. Explorers also reported other kills but numbers and specific locations were not provided so these records could not be included in these tallies.

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In collaboration with the community of Grise Fiord and the Nunavut Government, future work will use Inuit knowledge along with scientific knowledge to begin reconstruction of the historic genetic composition of Peary caribou in Northern Ellesmere Island (we have located the pelts of most Peary caribou killed in northern Ellesmere Island at the American Museum of Natural History), to understand landscape use and movement patterns of Peary caribou in the High Arctic and to identify the source population(s) that re-colonized Quttinirpaaq National Park and northern Ellesmere. This work will provide us with necessary information to understand the status of the species in the northern part of Ellesmere Island, their recovery rates and recovery patterns.

FUNDING

This project was funded by the Western Canada Service Centre of Parks Canada, the Nunavut Field Unit of Parks Canada, Quttinirpaaq National Park of Canada and Parks Canada Species at Risk Recovery Action and Education Fund, a program supported by the National Strategy for the Protection of Species at Risk.

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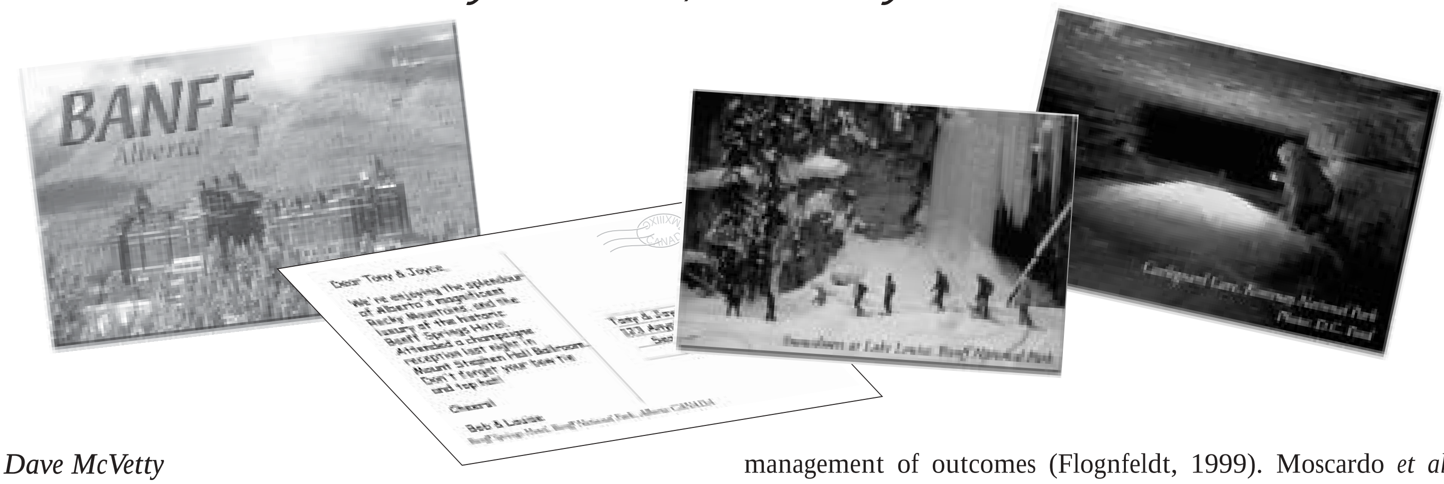
SKETCH COMING BY MONDAY

Understanding Patterns of Visitor Use in Our National Parks:

The 2000 POVU Study for Banff, Kootenay and Yoho National Parks



Dave McVetty

Parks Canada Agency is the steward of Canada's system of national parks: protecting the parks' heritage for this and future generations in ways that allow visitors from Canada and abroad to discover, learn, reflect, and recreate. The challenge for managers to offer high quality visitor experiences and expand the audience for learning opportunities in ways that leave the ecosystem's key processes and elements unimpaired. However, decisions to improve conditions in one area (greater public engagement; regional economic growth) may threaten conditions in another (threats to ecological integrity). To address this dilemma, managers seek tools to explain the relationships between visitor volumes, visitor behaviour, and the social and environmental impacts of visitor use.

Social science can reveal patterns in visitors' behaviour, which is the foundation of a park's visitor use system. Parks Canada developed the (POVU) approach in 2000 to enable managers to understand the system of visitor use and then manipulate that system to achieve desired outcomes (Bellinger *et al*, [n.d.]). In so doing, Parks Canada aims to manage the range of impacts related to visitor use more effectively.

The POVU approach reduces the range of behaviour from thousands or millions of visits to a few valid and meaningful visit types. When visit types correlate to visitors' use of facilities or services, managers can develop science-based hypotheses about the range of impacts for a decision based on changes to the visit type scenario. Monitoring the impacts of those decisions over time can enable social scientists and managers to predict the range of outcomes from changes to the visitor use system (Consulting and Audit Canada, 1994; McArthur, 1996). The POVU approach is included in Parks Canada's Science Strategy (2001), a framework for natural, social, and cultural sciences to work together in support of the mandate.

So why is a new approach needed? Recent social science literature discusses the relative value of describing visitor behaviour with demographic, geographic, psychological, and behavioural segments (Moscardo, Pearce, and Morrison, 2001), but few studies describe visitor behaviour in ways that relate directly to management of outcomes (Flognfeldt, 1999). Moscardo *et al* surveyed visitors to Australia's Wet Tropics region to compare the management value of visitor origin segments to behavioural segments. They suggest that behavioural segments have more value, but their sample size was too small to make clear conclusions (n=549).

The POVU approach attempts to describe aggregate visitor behaviour in terms that relate directly to management decisions. It is based on the premise that visit type segmentation better explains visitor behaviour than other traditional means of describing differences between visitors. To test this premise, this paper uses data from the original study (Parks Canada Agency 2000). If true, the POVU approach has potential value throughout the Parks Canada Agency. Otherwise, the Agency will need to explore new options to help managers understand the visitor use system in Canada's national parks.

RESEARCH METHODS

In 2000, Parks Canada, Alberta Economic Development, and the Banff Lake Louise Hotel Motel Association joined together to study visitor use. The study collected data from visitors to Banff, Kootenay, and Yoho National Parks between June 12 and October 13, 2000. Brief personal interviews with a randomly selected sample of group leaders established population parameters. Interviews were in English and French. Park residents, employees, and commuting workers were excluded from the sample. A mail-back questionnaire (available in English, French, German, and Japanese) collected more detailed information from selected respondents.

This paper focuses only on independent visitors to Banff National Park. These results are based 5,405 personal interviews and 1,127 returned questionnaires (a 41% return rate).

Results were weighted to correct for response bias by origin (local residents were under-represented in the questionnaire) and to reflect the number of visitor party entries by gate and date. Thus, all results are presented as the actual number of independent visitors (or visit parties, where noted).

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This study compares the value of two ways to predict visitor behaviour:

1. Visitor Origin Segmentation: Visitors' origins were collapsed into seven categories that correspond with previous studies. Note that some visit parties represent several origins (e.g.: an Alberta resident with visiting friends or relatives), so the origin of respondents was compared to the origins for all visitors to determine whether using respondent origin would introduce a bias. The two analyses produce similar results (see Table 1), so this paper uses respondent origin as to describe visitor origin.

Table 1. Origins of visitors and respondents.

	*Origin of all Visitors***		*Origin of Respondents++*	
Visitor Origin	**Estimated Number of Independent Visitors**	**Pct. of Visitors**	**Estimated Number of Independent Visit Parties**	**Pct. of Visit Parties**
Alberta	336,774	21.4%	112,300	20.6%
Other Canada	275,064	17.4%	93,260	17.1%
U.S.A.	523,669	33.2%	195,024	35.7%
U.K.	94,063	6.0%	38,376	7.0%
Germany	115,573	7.3%	40,005	7.3%
Other Europe	85,729	5.4%	18,288	3.3%
Other International	57,970	3.7%	34,239	6.3%
Unreported	88,400	5.6%	14,841	2.7%
Total	**1,577,242**	**100.0%**	**546,333**	**100.0%**

** The survey asked for the origin of each visitor in the party. The first two columns illustrate the origin of all visitors in the surveyed parties, weighted up to the estimated number of parties.

++ One respondent (over the age of 16) was randomly selected from each visit party to answer on behalf of the group to minimize response bias on the basis of origin, age, and sex.

2. Visit Type Segmentation: The visit type segmentation used three types of information:
   - the importance of 16 visit opportunities to respondents' visit decision;
   - the parties' activities in each of the parks' visitor nodes; and
   - the parties' spending in Banff National Park.

The comparison was a multi-step process. First, a principal component analysis was applied to the respondents' reported importance scores. It used a varimax rotation and calculated component scores for the rotated components. Then, a hierarchical cluster analysis was applied to the components score using Ward's clustering method with squared Euclidean distances. A three-cluster solution was selected based on the agglomeration schedule. Finally, the cluster centres from this solution were used as initial clusters for a 3-cluster, k-means cluster analysis. The results are presented in Table 2.

Table 2. Visit types

Visit Type	**Est. No. of Independent Visit Parties**	**Pct. of Independent Visit Parties**
Getaway Visit	241,462	44.2%
Comfort Visit	188,656	34.5%
Camping Visit	116,215	21.3%
Total	**546,333**	**100.0%**

The visit type segmentation produced three types of visit[1]:

Getaway Visits (44%): day visits or 2-3 day visits during which visitors often focus on a specific activity or area;

Comfort Visits (35%): visits that make use of the parks' hotels and restaurants, and during which visitors tend to spend the most money; and

Camping Visits (21%): visits that include camping and touring, during which visitors often use campgrounds, but may use a range of accommodation and restaurant opportunities.

COMPARISON 1: DETERMINING THE MERIT OF EACH APPROACH

Do both approaches explain significant variance in visitor behaviour? If they explain simialr degrees of variance, they will be assessed for their value as management tools.

To conduct this assessment, we selected three variables for their relevance to the study's funding partners (who represent the interests of many of the stakeholders in the parks' operations). The variables were:

- party-visit spending in Banff National Park;
- importance of opportunities to learn about Canada's natural and historic heritage to a party's visit; and
- propensity to stay in a hotel, motel, or bed and breakfast facility while in Banff National Park.

Table 3 summarises the overall results.

[1] Chi-square analysis suggests that visit type and respondent origin are strongly related ($p<0.001$), Goodman Kruskal tau = .209; see Table 3). *Getaway* visit type parties are mainly from the host Province of Alberta, neighbouring British Columbia, and bordering American states. Half of the *Comfort* parties are from the U.S.A., with almost no parties from the Province of Alberta. Finally, the *Camping* visit type is about one-third American (34%) but features a disproportionately large number of German visitors (21%).

Table 3. Summary of Comparison #1: Determining the merit of the two approaches. The left hand side is data from visitor origin segmentation and the right hand side is data from visit-type segmentation.

Mean Party Visit Spending
Overall Mean = $698; Standard Deviation = $1,122

	Mean	S.D.		Mean	S.D.
Alberta	$164	$424			
Other Canada	$411	$578			
U.S.A.	$992	$1,300	Getaway Visit	$290	$474
U.K.	$903	$651	Comfort Visit	$1,308	$1,557
Germany	$296	$173	Camping Visit	$434	$469
Other Europe	$674	$863			
Other International	$1,037	$1,338			
Sig. < 0.001	ETA squared: 0.112		Sig. < 0.001	ETA squared: 0.176	

Importance of Opportunities to Learn about Canada's Historic Heritage to Visit Decision
1 = Not at all Important, 5 = Very Important
Overall Mean = 2.7 Standard Deviation = 1.2

	Mean	S.D.		Mean	S.D.
Alberta	2.7	1.4			
Other Canada	2.8	1.3			
U.S.A.	2.6	1.2	Getaway Visit	2.7	1.3
U.K.	3.2	1.2	Comfort Visit	2.8	1.1
Germany	2.8	0.9	Camping Visit	2.8	1.2
Other Europe	3.1	0.9			
Other International	2.7	0.9			
Sig. < 0.001	ETA squared: 0.018		Sig. < 0.001	ETA squared: 0.001	

Importance of Opportunities to Learn about Canada's Natural Heritage to Visit Decision
1 = Not at all Important, 5 = Very Important
Overall Mean = 3.2 Standard Deviation = 1.3

	Mean	S.D.		Mean	S.D.
Alberta	2.8	1.5			
Other Canada	2.9	1.4			
U.S.A.	2.9	1.3	Getaway Visit	3.0	1.4
U.K.	3.6	1.0	Comfort Visit	3.3	1.2
Germany	4.4	0.8	Camping Visit	3.5	1.4
Other Europe	4.2	0.9			
Other International	3.9	1.0			
Sig. < 0.001	ETA squared: 0.135		Sig. < 0.001	ETA squared: 0.015	

Propensity to Stay in a Hotel or Motel During This Visit
Overall Propensity = 37%

	Propensity		Propensity
Alberta	12%		
Other Canada	22%		
U.S.A.	48%	Getaway Visit	23%
U.K.	66%	Comfort Visit	74%
Germany	27%	Camping Visit	6%
Other Europe	41%		
Other International	57%		
Sig. < 0.001; Goodman & Kruskal tau = .108		Sig. < 0.001; Goodman & Kruskal tau = .245	

COMPARISON 1A: PARTY VISIT SPENDING IN BANFF NATIONAL PARK

Respondents indicated how much (in Canadian dollars) their party spent in Banff National Park during their visit, including taxes, tips, and prepaid expenses, using cash, credit card, and debit card. They then indicated the proportion of this total that was spent in each of nine categories. Note that only the aggregate total is used in this analysis.

Visitor spending is the basis for analysing the economic impact of tourism and visitor use. This is essential information for stakeholders who wish to understand the economic dimension of visitor use.

Origin segmentation approach: International respondents spend most, except for those from Germany. Albertan respondents spend the least. The differences are statistically significant, and ETA squared results suggest that visitor origin explains 11.2% of the variance in spending.

Visit type segmentation approach: Comfort Visit parties report the highest party spending. Albertan respondents report the lowest amount. The differences are statistically significant, and ETA squared results suggest that visitor origin explains 17.6% of the variance in spending.

Conclusion: Visit type segmentation has more value for explaining differences in visitor spending.

COMPARISON 1B: IMPORTANCE OF OPPORTUNITIES TO LEARN ABOUT CANADA'S NATURAL AND HISTORIC HERITAGE

Respondents indicated how important 16 different opportunities were to their visit decision. They used five-point scales, where 1 was "Not at all important" and 5 was "Very important." Two of the opportunities relate directly to the Parks Canada mandate: opportunities to learn about Canada's natural and historic heritage. Some items not included in this analysis include: to enjoy time with friends and/or family; to see wildlife in its natural environment; or to mix outdoor experiences with modern comforts.

Origin segmentation approach: Results show a significant relationship between respondent origin and importance of heritage learning opportunities. Europeans (from outside Germany) report the highest importance scores for historic heritage, while all others report similar levels of

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RESEARCH

Recreation vs. Ecological Integrity at Long Beach, Pacific Rim National Park Reserve

The Long Beach Unit of Pacific Rim National Park Reserve (PRNPR) offers recreational space for more than 700,000 Canadian and international visitors a year. People come to Canada's most westerly national park to take part in wildlife viewing activities, to walk and play on the beach and to see the ocean or go surfing. Long Beach has established itself as a surfing hotspot in Canada. Dog-owners like to come to the beach to let their dogs run and play, but PRNPR is also an important staging area for migrating small shorebirds and nesting territory for bald eagles (*Haliaeetus leucocephalus*). High population densities of these species may be indicative of ecological integrity in this community. Shorebirds use the beach habitat for a two or three day feeding and resting break on their way from South America to their nesting grounds in the Arctic in the spring and when they return South in the early fall.

Naturalists living adjacent to the park have noticed a decline in shorebirds and a rise in recreational use. Members of the local Tofino community often blame dog-owners for letting dogs disturb shorebirds by chasing flocks. Park managers also receive frequent complaints about dogs running loose at Long Beach and disturbing visitors. Some of these dogs run in a pack and belong to the growing Esowista First Nation community in the park. Although, First Nation people also have to comply with leashing their dogs off reserve grounds the process of giving an official warning is more complicated than with other visitors. Local papers, as well as signs on the beaches, urge visitors to keep their dogs on a leash, although my observations suggest that 62% (in August) to 80% (in April and May) of dog-owners do not comply with the on-leash rule at PRNPR.

REGULATIONS POSTED ON SIGNS AT LONG BEACH:

1) Dogs must be kept on a leash at all times
2) Attention: Shorebirds Ahead

Be on the lookout for flocks of shorebirds. They have migrated thousands of kilometres to arrive on local beaches and mudflats where they feed and rest. This stop-over is critical to their survival and breeding success.

Do not disturb them. Give shorebirds plenty of space and do not allow dogs to give chase.

This is one of just a handful of migration "pit-stops" in western North America. Please enjoy this natural wonder from a distance.

The sign includes drawings of a Western sandpiper, semipalmated plover, short-billed dowitcher, whimbrel and greater yellowlegs.

One of my first objectives with this research was to determine whether off-leash dogs are really the main cause of shorebird disturbance. I began with a series of beach surveys to determine the abundance and distribution of shorebirds in the area. Initial results from the beach surveys showed that small shorebirds, such as semipalmated plover (*Charadrius semipalmatus*), dunlin (*Calidris alpina*), sanderling (*Calidris alba*) and Western sandpiper (*Calidris mauri*) were using the beach most commonly for feeding. Observation showed that these small birds are highly mobile, even in the absence of obvious disturbances, and did not show any clear preference for feeding areas during the off-peak season in April and May.

Given that the shorebirds scatter easily even without the presence of humans, I conducted experiments to find out whether a leashed dog, or even a lone human is enough of a factor to disturb the birds. These experiments test whether the on-leash regulations posted at the beach are effective in protecting shorebirds from disturbance and how the presence of a dog would affect shorebird escape behaviour. I found that the shorebirds were more likely to flush as a result of a human moving through the birds, with or without a dog, than walking or jogging past shorebirds at a distance of about 10 metres; again the dog made no difference.

A secondary goal of this research is to identify reasons for non-compliance with on-leash laws, and thereby identify areas where the park might improve and/or enforce the regulations. Visitor awareness of the shorebird population at Long Beach was very poor despite information signs in the parking areas. When I asked visitors, with and without a dog, if they had seen any wildlife on the beach, very few respondents had taken note of the shorebirds. Instead, they associated "wildlife" with larger, charismatic species such as bears and cougars. Therefore the public's perception that shorebirds are not "wildlife" may be a factor in their non-compliance.

The findings of this research are only preliminary. However, based on the results to date, it is possible that even if the current on-leash regulations are followed, they may not be enough to prevent shorebird disturbance during their crucial feeding and resting stop on Long Beach. Conservation efforts should not only address dogs off leash, but also humans, who are walking through shorebird flocks without realizing that they are imposing stress on these birds. In contrast to the unpredictable distribution of shorebirds, human distribution was very predictable (decreasing proportionately with

HIGHLIGHTS

distance from parking areas), and it may be that access to the beach needs to be restricted during the shorebirds' stopover to prevent disturbance from humans and dogs. In addition, dog-owners, who do comply with the on-leash rule want to see that others are reminded more vigorously by park staff to do the same.

In my research, the initial concerns about the Esowista dog pack have not proven to be a major factor for the local shorebird population compared to any other visitor, dog or human. Instead, the conflict between the Esowista community, parks staff and visitors itself needs to be addressed. Efforts to recognize dogs as part of the native community have not been evident. This may be due to the fact, that visitors pay user fees and their satisfaction may therefore be more important to park managers than the privacy of the local First Nation community. The problem of visitor complaints about the reserve dogs has been addressed by proposing a dog kennel at the warden office to confine free ranging dogs and passing them on to dog shelters if not claimed by their owners.

My intention is that more effort into conflict management, more presence of park staff on the beach and visitor education will enable PRNPR to increase visitor compliance with current regulations reduce shorebird disturbance on Long Beach.

Thanks to my supervisory committee Paul F. Wilkinson, Nigel Waltho and Dawn Bazely, and the Parks Canada team of the Long Beach Unit at PRNPR. This project was funded in part by Parks Canada.

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G8 Legacy Project Underway near Banff National Park

A wildlife bridge has been constructed over the Rundle hydroelectric canal in Canmore, near Banff National Park, as part of the Kananaskis Summit Environmental Legacy. The Government of Canada established the Legacy after the G8 Summit was held in Kananaskis in 2002, committing $3 million in seed money to wildlife crossing structures and $2 million to the creation of a Wildlife Ecology Chair at the University of Calgary. Over the past decade, Parks Canada, adjacent land managers and the private sector have collaborated to develop a regional network of wildlife corridors in the heavily developed Bow Valley. The new 25m wide bridge is an important piece of the network, allowing wildlife to bypass the town of Canmore when moving between habitat in Banff National Park and Kananaskis Country. The structure was completed in December 2003 and monitoring has already begun. Ownership and long-term management will be the responsibility of the Province of Alberta.

The project team is now planning for a wildlife underpass to be constructed in the spring of 2004 at a location where a primary wildlife corridor crosses the Trans-Canada Highway. The underpass and associated highway fencing near Dead Man's Flats will reduce the high wildlife mortality and human injury that occurs along this stretch of the highway east of Canmore. The crossing structure projects have garnered wide community support, and the Alberta Ecotrust Foundation has established a Legacy fund to accept private and corporate donations.

The Kananaskis Environmental Legacy wildlife crossing structures are modeled after those in Banff National Park and the resulting knowledge gained from the long-term monitoring program of the 22 structures within the park.

The Legacy program illustrates the benefits to protected area managers of developing collaborative working relationships with other land managers and community stakeholders to expedite the delivery of regional scale initiatives that contribute to the environmental, economic and social sustainability of a region.

For more information see www.g8legacy.gc.ca or www.albertaecotrust.com

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importance. The ETA squared results suggest that origin explains only 1.8% of the variance. International visitors – especially those from Germany – report the highest scores for opportunities to learn about Canada's natural heritage, whereas North Americans report relatively low scores. In this case, origin explains 13.5% of the variance.

Visit type segmentation approach: The visit type segments report similar levels of interest in opportunities to learn about Canada's historic heritage. The differences are statistically significant, but visit types explain less than 1% of the variance. There is a more pronounced result when we look at the importance of learning about Canada's natural heritage, but the segments explain only 1.5% of the variance.

Conclusion: Origin segmentation has more value for explaining the differences in the importance of learning opportunities.

COMPARISON 1C: PROPENSITY TO STAY IN COMMERCIAL ACCOMMODATION

Respondents indicated what type(s) of accommodation they used in the parks, including hotels, motels, bed and breakfast facilities, campgrounds, backcountry camping, hostels, and homes of friends or relatives. The first three options are grouped collectively as commercial accommodation.

Origin segmentation approach: International respondents report the highest propensity to use commercial accommodation, although German respondents are only slightly higher than Canadians. The differences are statistically significant and the segments explain 10.8% of the variance.

Visit type segmentation approach: Not surprisingly, Comfort Visit parties report the highest propensity to use commercial accommodation and Camping Visit parties report the lowest. The differences are statistically significant and ETA squared results suggest that visitor origin explains 24.5% of the variance.

Conclusion: Visit type segmentation has more value for explaining the differences in visitors' propensity to use commercial accommodation.

COMPARISON #2: ASSESSING THE MANAGEMENT VALUE OF EACH APPROACH

This study uses the same methods as Moscardo *et al* to compare the management value of these two approaches. Each type of segmentation is compared against the eight criteria for effectiveness to evaluate the two segmentation approaches. To have value, segmentation should be:

- homogeneous (unique from each other, but internally consistent);
- durable (over an extended period of time);
- measurable (can be identified and counted with reasonable accuracy);
- responsive (a unique marketing approach required);
- relevant (to the organisation commissioning the research);
- accessible (easily reached via one or more media);
- substantial (large enough to warrant attention); and
- compatible (with existing markets) (Moscardo *et al*, 2001).

Homogeneous: Both approaches develop distinct segments with little internal variation. The origin approach was more effective for visit motives, but neither approach explained much variation. The visit type approach explained more variance for spending and hotel use.

Durable and Measurable: The visitor origin approach seems more durable and measurable on the surface, as most people change residence infrequently and residence data are captured and reported objectively. But note that the same visit types emerged independently in both the summer and autumn samples, suggesting some durability. And the durability of the visitor origin approach may be questioned, since Calgary is one of Canada's fastest-growing cities (changing in size and composition); the proportion of international visitors to the park has grown significantly in the past decade; and recent trends in the tourism industry can quickly change a market's composition. Visitor origin has an advantage, but not by a wide margin.

Responsive: The visit type segments explain much more behavioural variance and origin segments may possibly respond better to messages based on visit motives (although neither approach explained more than 10% of the variance). Findings suggest that pre-trip information could be targeted at geographic segments with messages that reflect their unique interests patterns, but that activity information is best targeted to on-site visit type segments. This differs from the findings of Moscardo et al, who found that activity-based segments explained more motive variance.

Relevance is in the eye of the beholder. Those who wish to appeal to visitors' interests may be best to pursue origin segments, but those interested in visitors' activities in the park – and their movements through it – would find more value in the visit type approach. Strategies to influence the tourism system may investigate similar approaches. Moscardo et al came to a similar conclusion, but for different reasons. In that study, activity segments were better predictors of visit motives.

Accessible: Without these findings, visitor origin segments seem more practical for pre-trip and en route information and for building awareness. But with the results, it is clear that visit type segments are accessible – and more useful – for targeting on-site activity information. Results suggest where to find each segment, and which activities to target. Moscardo et al suggested that visitor origin segments were generally more accessible.

Substantial: Both approaches provide segments that are large enough to warrant attention. In recent years, data miners and proponents of 1:1 marketing have suggested that new models may render this criterion obsolete. Many successful enterprises cater to individuals or to very small niches, or create new segments when the opportunity is truly unique (Behrens, 1987). But, when faced with a need to describe the outcomes of visitor use, market segmentation is still an appropriate activity. This supports the findings of Moscardo *et al*.

Assessing compatibility is beyond the scope of the variables used for this paper, although the survey did include items to help assess this criterion (e.g.: desire for solitude versus desire for companionship). Moscardo et al did find support for their activity-based segments on this criterion.

CONCLUSIONS

Visit type segmentation was more useful for predicting variables of relevance to the development of park tourism and management of its facilities. They should be more useful to managers who wish to assess the size, competitiveness, and compatibility of segments within the market. Visit-type segments were also relatively stable and reasonably accurately measured.

Visitor origin segmentation produced good results on accuracy of measurement and pre-trip accessibility. This approach was also related to participation in specific activities, but less so than visit types.

The results suggest that visit type segmentation explains visitor behaviour better than other traditional means of describing differences between visitors. Thus, the POVU approach has potential value throughout Parks Canada Agency, and it may improve the analysis and interpretation of data collected in future visitor surveys to provide more conclusive results for managers.

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Digital Cameras for Monitoring Plant Biomass in Grasslands National Park

Mryka Hall-Beyer, Nancy A. Lee, John F. Wilmshurst

We used a Kodak DC260 digital camera to see whether consumer-type digital camera images can be used to collect information that could be converted to biomass and live/dead grass ratios for environmental monitoring in a grasslands ecosystem. The objectives of this experiment were to compare accuracies of various operational image classification techniques, especially for live vegetation; to relate live vegetation statistics derived from classified images to biomass weights; and to test the significance of such relationships.

Photography with a digital camera has a number of potential advantages for monitoring vegetation, both when acquiring data strictly on the ground, and when ground data will be used as a control for aerial and satellite imagery. Many digital cameras are small, easy to obtain and use, inexpensive and versatile. Many cameras produce separate image layers (bands) for the different wavelengths sensed (King 1995), and record a wider range of intensities than film. Digital images are compatible with computer systems, enabling analysis with remote sensing software. Ground- obtained images do not suffer from atmospheric interference nor cloud cover as do satellite and many aerial images. Digital images are quickly and easily acquired, and may be automated.

Consumer-type digital cameras also have some drawbacks. Digital resolution is usually lower than film. Technical specifications documenting precise wavelength sensitivity are unavailable for most inexpensive cameras. Commonly available cameras do not record a separate band for near infrared (nir) wavelengths (780-1300 nm), which potentially contain a great deal of vegetation information. Some, but not all, digital cameras may be sensitive to nir radiation within the band recorded as red. Specialized cameras exist for which information is available, or which have these capacities, but these are quite expensive and do not have the other advantages we sought.

Plants show a distinctive spectral reflectance pattern depending on cell contents and intercellular air spaces (Ray 1994). Healthy green vegetation reflects highest in the nir. Within the visible wavelengths (vis), chemical composition of cell contents dominates the spectral signal. Many plants have characteristic absorption due to additional pigments, but these do not dominate the spectrum when chlorophyll is present. Imagery that simultaneously contains information for the nir and several discrete vis wavelengths yields maximum plant information. Where atmosphere (which scatters blue) is not a factor, as is the case with ground-level images, both red and blue yield appreciable information.

Senesced vegetation and soil are usually present in a grassland images, and are needed to create accurate canopy models used to estimate phytomass production, evapotranspiration and surface energy balance (Nagler *et al*. 2000). The three components (live vegetation, seneced vegetation and soil) are theoretically differentiable in the red band. Incompletely

Table 1. Vegetation composition of plot types.

	Grazed cow pasture	Ungrazed cow pasture	Horse grazed	Horse ungrazed
Grasses	Prairie junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schultes.) blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths) needle-and-thread grass (*Hesperostipa* (formerly *Stipa*) comata ssp. comata (Trin. & Rupr.) Barkworth (ITIS 2001))	Same as grazed, but smaller amounts and greater proportion dead material	Only occur in very small patches of live and dead.	
Forbs	Pasture sage, *Artemisia ludoviciana* Nutt.)	Pasture sage prairie crocus (*Anemone patens* L.) present but not in photos, vetch (*Vicia spp.*) goatsbeard (*Tragopogon dubius* Scop.)	Pasture sage and prairie crocus	Pasture sage only identifiable forb
Other	Dead grass		Exposed bare soil. Large patches of lichen and spikemoss (*Selaginella densa* Rydb.)	Dead vegetation (mulch) covers most of ground

senesced vegetation has parts that resemble the green vegetation curve; other parts resemble the soil curve. Complete discrimination of senesced vegetation is possible only by observing lignin spectra at 2000-2500 nm (Nagler *et al*. 2000). However, ordinary digital cameras do not use these wavelengths.

Even with these potential drawbacks, recent work has used digital cameras successfully to obtain biophysical parameters. Bennett *et al*. (2000) estimated total biomass in a structurally simple area containing only grass and soil, and Paruelo *et al*. (2000) did so in an area of grama grass, sedge and minor forbs. Neither work considers partly senesced vegetation, various forbs of different growth habit, or shadows .

MATERIALS AND METHODS

We gathered the images from grazed and ungrazed northern mid-grass (*Stipa - Bouteloua*) prairie in Grasslands National Park (GNP), SK. Plots 0.5x1 m were photographed vertically from about 1.5 m elevation, between 29 June and 2 July 1999, from 9:30 AM - 3:00 PM. We used a Kodak DC260 digital camera with CCD resolution of 1548x1032 pixels and image resolution of 1536x 1024 pixels (Eastman Kodak 2000). With the exception of resolution and convenience features, this model is not greatly different from more recent consumer models. The manufacturer would not provide information about band width and location (for the model used or for more-recent consumer models). However, King (1995), and Lynch and Livingston (1995) state that most three-band beam-splitting cameras have 100 nm bandwidths centred at the human visual maxima, 440 nm (blue), 530 nm (green) and 570 nm (red). Files were transferred in JPG format. Images analysis used PCIWorks software v.7.0.0 (PCI 2001).

We photographed four plot types: grazed cow pasture (G1: 5 sites); ungrazed cow pasture (U1: 5 sites); horse grazed pasture (HG: 3 sites); and ungrazed horse pasture (HU: 3 sites). Table 1 lists vegetation composition of each type. After imaging, we clipped, separated and weighed the vegetation components, yielding total biomass and total green biomass (g-m^{-2}). For each plot we recorded a single radiance value in three vis and one nir band by positioning an Exotech 100BX spectroradiometer (Exotech Incorporated, Gaithersburg, MD, USA) at 1.5 m height, yielding a target 35 cm across.

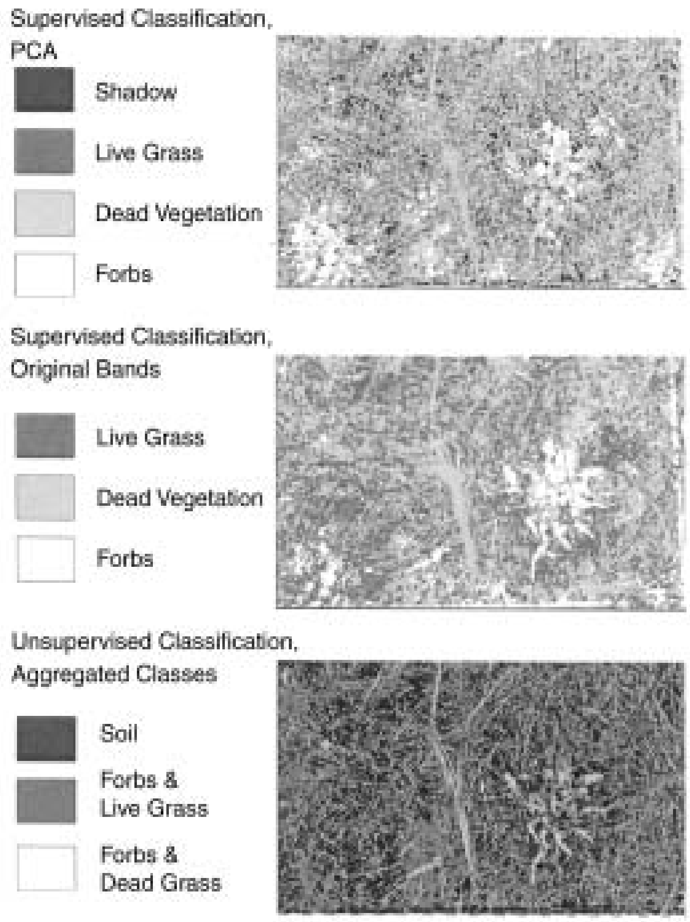

Fig. 1 Comparison of class definitions.

In all classifications, the trained classes were: live grass, live pale coloured forbs, live dark coloured forbs, dead vegetation, flowers, lichen, rocks, spikemoss and soil. These were aggregated after classification into live grass; dead vegetation including lichen and spikemoss, soil (all nonliving material), and live forbs (where identifiable). Live vegetation classes included only the greenest material; partially senesced vegetation was included in "dead."

In the absence of nir data, the difference between the chlorophyll absorption in either the red or blue band, and the relative lack of it in the green band, provides the best single measure of live vegetation. Therefore we created a vegetation index, the NBVI, to highlight the difference between green and blue pixel reflectance. It is defined as:

$$(DN_{green}-DN_{blue}) / (DN_{green} + DN_{blue})$$

where DN is the digital number. A red-green index did not provide good differentiation between soil and vegeta-

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tion. The first two Principal Component (PC) channels served to create shadow and dead vegetation masks.

We carried out supervised, unsupervised and neural net classifications. The classification yielding the highest accuracy was used to calculate the percent image area occupied by live grass and live forbs. We calculated mean and standard deviation of the blue DN values for all pixels in these classes, compared mean NBVI with the NDVI value for each image. We then compared NBVI and percent live grass and forbs to the actual percent live biomass values measured from clippings. We then evaluated the coefficient of determination (r^2).

RESULTS AND DISCUSSION

Red vegetation DNs were greater than expected. The larger values could result from camera red sensitivity including some nir. This possibility remains hypothetical because typical colour films (developed for the same purposes as digital cameras) almost duplicate satellite band visible sensitivities that are optimized for vegetation analysis (Kodak 2001).

PC1 shows the variation in brightness (shadow) of all bands and accounts for more than 90 per cent of total image variance. Contrast between blue and the other two bands occurs in PC2. The darkest PC2 values correspond to dead vegetation and the brightest to pasture sage. PC2 did not discriminate effectively among green grass, soil, rocks and spikemoss. Visual inspection shows that PC3 bears little relation to the desired classes, although it does show the contrast between red and the other two bands. Red spectral camera sensitivity to longer wavelengths may account for this problem.

Figure 1 compares class definition by the various methods described above. All of the classifications result in the same class assignment of the prominent features, such as the large shock of dead grass at image centre, and much of the live vegetation.

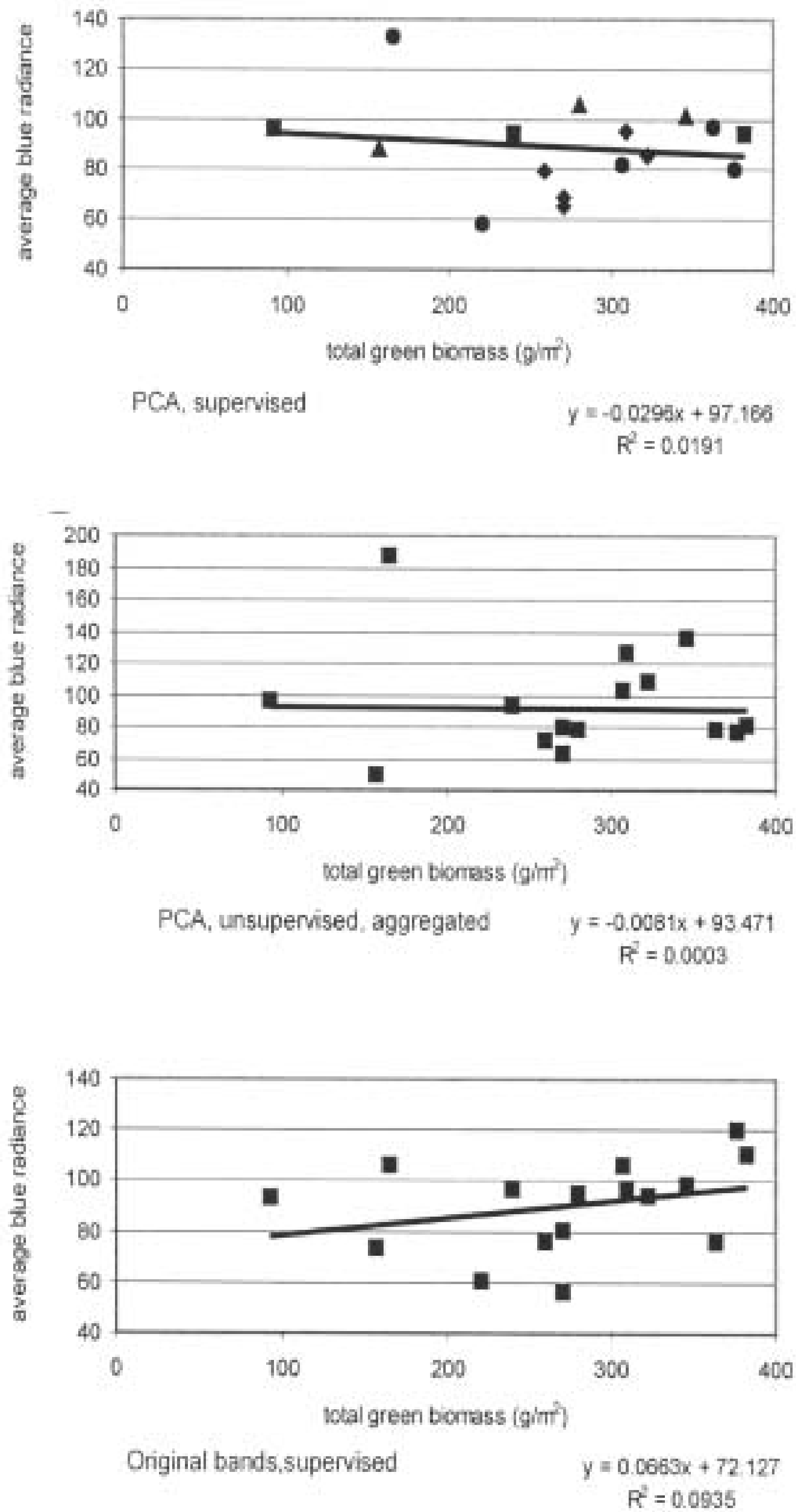

Figure 2. Regression of plot mean blue radiance vs. green biomass, g/m^2

Table 2. Representative accuracy calculations. 6 statistic (range 0-1.00) represents the degree to which classification is better than random pixel assignment. N=16.

Method	Class	User's (%) (mean:max-min)	Producer's (%) (mean:max-min)	Overall (%)	6
PCA/sup				67.93: 9.0 - 83.3	0.31: 0.003 - 0.64
	dead	79.27: 43.87 - 97.14	88.11: 62.35 - 97.83		
	forbs	58.30: 50.00 - 75.00	35.20: 30.77 - 9.13		
	live	51.07: 18.75 - 77.78	44.52: 15.00 - 81.82		
	shadow	74.78: 49.75 - 100.00	42.79: 20.93 - 97.44		
Supervised				44.40: 28.7 - 59.30	0.18: 007 - 0.36
	dead	63.08: 33.95 - 97.44	51.82: 25.44 - 90.24		
	forbs	19.31: 0.00 - 46.94	39.36: 0.00 - 100.00		
	live	43.63: 7.69 - 86.21	33.03: 5.36 - 81.82		
Unsupervised				60.90: 36.00 - 61.30	0.28: 0.00 - 0.46
	dead	74.48: 42.86 - 89.04	63.40: 16.90 - 95.56		
	live	32.94: 16.28 - 59.26	48.54: 29.17 - 92.11		
	soil	79.22: 51.90 - 92.31	63.09: 53.66 - 77.36		

Treatment of forbs by the different methods varies.

Different results for different methods occur partly because the classes at this small area represent a set of continua (live to dead vegetation and full illumination to deep shadow), whereas landscape scale classification from satellite images uses spectrally and conceptually distinct classes. We selected spectral extremes of each vegetation class as training pixels. Intermediate pixels fall on one side or the other of the class divide, depending upon the precise location of the dividing line. With continua the dividing line does not necessarily fall where few pixels occur, rather it depends on how much brightness variability occurs within the training sites as compared to brightness variability within the class as a whole[1]. It is not surprising that different classifications show similar core areas, but different total image areas, for given class. We did not train for "shadow" as a distinct class because its type of variability in these images violates the assumption of multivariate normal DN distributions. Instead, shadow was estimated from the PC1 image.

Table 2 provides data on the several of the most successful trials. Supervised classification with PCA shadow mask had slightly higher overall accuracy than unsupervised or supervised classification without PCA. (There are only 16 images in total, so significance of differences between methods was not determinable.)

High class accuracies, (generally 80% or better) were obtained for the "dead" class using supervised classification with PCA shadow input, and corroborated by visual observation. The "live grass" class, is 20 40% accurate. Highest accuracy values are found using supervised classification and user's accuracy (avoidance of errors of commission). Thus live grass area was consistently underestimated. Forb accuracy was less than that for live grass, occasionally 0%.

Error sources include difficulty defining classes (as discussed above), and pronounced bidirectional reflectance effects. For close-up images, leaves oriented at many angles cause specular reflection, which creates confusion similar to that between illuminated and shadowed objects. In addition, light can be reflected and transmitted by the lower layers and through upper leaves, altering their spectral characteristics. Recorded images therefore represent primarily the upper layer, rather than the total biomass in denser grass canopies. These problems are analogous to those

- continued on page 20 -

[1] A simple analogy is converting percent grades to letter grades. The ideal situation, non-continuous classes, is to divide A from B at a grade few students have earned: thus most grades fall clearly into one or the other class. The continua situation is where equal numbers of students earn each percent grade, so placing the line dividing A from B is arbitrary – and complaints (inaccuracies) can be expected from those with a grade very close to the division point.

- continued from page 19 -

encountered when deriving biophysical parameters from forest scenes at a coarser image resolution (cf. Myneni *et al*. 1995).

Shadow caused confusions among the classes. Live vegetation absorbs more vis light than other scene objects, and so when brightly illuminated appears darker than other objects. So, shadowed objects may be incorrectly placed in the live vegetation class (creating errors of commission). NBVI minimized the effect of slight shadow, but could not completely solve this problem. The shadowing effect creates more difficulty in a vis-only image, as compared to an image with a separate nir band, because vegetation reflectance is low in all vis bands. Furthermore, shadow mutes more of the spectral differences among the objects than would be the case were the bright nir band present.

We plotted mean blue radiance of the area classified as live grass for each plot, against the total green biomass normalized by image area (grams-m^{-2}). Figure 2 shows the results, one for each classification method. R^2 values range from 0.0003 to 0.0988, none of which is significant. Indeed, the slope of some regression lines is positive and of others negative. Similarly poor correlations exist when regressing area occupied by live vegetation classes (grass + forbs) against biomass. Given the generally poor accuracy of the live vegetation classes, good correlation would not be expected. There is no apparent correlation problem introduced by one particular plot type, because point scatter is equally broad in all four types.

Regressing green biomass vs. image mean NBVI produces slightly better results ($r^2 = 0.1223$). As a control, green biomass was regressed against NDVI (the normalized nir-red contrast index) derived from spectroradiometer readings, obtaining $r^2 = 0.1872$. Neither is significant at $\alpha = 0.05$, but NDVI is significant at $\alpha = 0.10$. Thus even the well-documented NDVI does not accurately estimate biomass at this scale.

Forbs, with visible colours quite different from those of grass (and so presumably with different spectral reflectance curves), are difficult to treat as a single unit. At the same time they are difficult to analyze as separate classes due to their diversity. Spikemoss also covered part of the ground. Spikemoss was not counted as live biomass because it does not appear green and grazers do not generally eat it. Nevertheless, its spectral reflectance (even when dry) is closer to that of live vegetation than to that of non-live background (Hall-Beyer and Gwyn 1996). Although spikemoss should have been considered live, it was aggregated into the dead category in the image classification. Its spectral characteristics might have induced classification errors, but the degree to which this affected results is unknown.

RECOMMENDATIONS

Our objective for this study was to use consumer model digital camera images to perform vegetation analysis. The lack of information about spectral sensitivity was one main problem we encountered. Digital cameras exist with the three bands we desire (nir, red and green), produce false-colour images (Forest Health Technology Report 1996; House *et al*. 1998), but do not appeal to a mass market, and are therefore not as accessible or affordable as standard models. Since completion of the research described here, the authors have acquired an inexpensive vis-blocking filter usable with consumer model digital cameras (Hoya 72 or RM90, Wratten 87 or 89). For cameras with red-band nir-sensitivity it should be possible to add a separate nir band by taking two images of each sample, one recording vis and one recording only nir. An effective vegetation sensing system would require filtering all nir radiation out of the red band using a nir-blocking filter that excludes all wavelengths longer than the vegetation “red edge.” To date we have not found any such filters, although colour separation red-pass filters for printing might be effective. We therefore recommend continuing experimentation to enable the camera to meet our requirements without resorting to expensive specialized equipment.

Some of the problems we encountered can be overcome for a given camera and filter system by determining wavelength ranges passed and excluded using a continuous-field spectroradiometer. Requiring such calibration diminishes the advantages of using a commercial digital camera (i.e., affordability and availability). Spectroradiometers cost tens of thousands of dollars, and provide information with much greater precision than required for our purposes. An alternative way of obtaining the same information is from the camera and filter manufacturers. However they have little incentive to provide data on the spectral sensitivity of their various camera models and filters as most consumers of these cameras do not require this information.

CONCLUSION

Digital imagery using an ordinary consumer digital camera as currently configured can give neither an adequate vegetation classification nor a significant quantitative measurement of grassland vegetation in a complex grass and forb plot.

None of the techniques we employed using an ordinary consumer digital camera yielded sufficiently high accuracies to justify their operational adoption. We suspect the inaccuracy is a result, in part, of the complexity of vegetation structure at plot scales, but most importantly it is related to a lack of technical information about the camera and the absence of a separate nir band.

Simple, inexpensive filters exist that may be able to eliminate some problems with consumer-type digital cameras . Experimentation is required to explore this possibility. Release of spectral response data by digital camera manufacturers would greatly aid in this process.

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Publications and Updates

The Science of Bird Songs

All bird species innately recognize calls of their own kind, such as alarm calls that signal danger and location calls that keep flocks intact. Increasing day length in the spring stimulates the production of hormones that drive male birds to sing. They sing until early summer to establish territories and to attract mates. A female bird evaluates a male's desirability as a partner by a careful examination of his vigour, usually expressed by the make as bright plumage or the quality of his song. Brightly feathered male birds use appearance to intimidate rivals or catch the attention of females. In contrast, males with elaborate songs generally belong to some of the least conspicuous species.

The most spectacular group in this regard is the "songbirds" – warblers, thrushes, wrens, robins, vireos, finches, sparrows, etc. Most songbirds are only temporary visitors to Canada, making the long journey from the tropics to nest and raise chicks during our season of abundant insects. Most birds cease the effort of singing by mid-July, once the young of the year have fledged.

Humans vocalize using our larynx, which uses about 2% of exhaled air. The corresponding structure in birds is the syrinx. It's vastly more efficient using nearly all the air that passes through it. And because it has two tubes, each with its own set of sound producing membranes, birds can express two sounds at once, in effect singing along with themselves. Or they can catch small breaths through one tube while singing.

Complex vocalizations also require sufficient mental capacity. Relative to their body size, birds have larger brains than any other vertebrates except mammals. Male white-crowned sparrows learn songs from their father and from other males in the vicinity. They try to match the other songs in their neighbourhood but slight variations emerge to create regional dialects. Some species, like song sparrows, have extensive individual repertoires, that is, they have multiple versions of the song they use to show off to females and to impress less capable males. What with 31 subspecies of song sparrow in North America, each with a slightly different repertoire of songs, bird song recognition is a challenging pastime.

SOUNDS LIKE SPRING!

New Bird Song CD Recorded in Mount Revelstoke and Glacier National Parks

As spring arrives once again, streams of bird species return to the Columbia Mountains and the morning soundscape grows in volume and variety. Bird songs distinguish species better than any other trait. Park interpreters are frequently approached by visitors who are curious to know the species of birds they hear, but have difficulty understanding visitors' descriptions of the sounds. We simply lack vocabulary to discuss what we hear.

The Friends of Mt. Revelstoke and Glacier sponsored the production of a CD entitled, "Discovering Birds and Their Songs in Mount Revelstoke and Glacier National Parks," that helps visitors and staff to tune into the audio landscape. It points listeners to where and when to listen to the key birds of our wetlands and forests, using local recordings. The recordings were collected using an omni-directional microphone mounted in a parabolic disk, or with a directional microphone and a Minidisk, then edited with computer softwear.

The collection of sounds is based largely upon the work of John Woods, an off shoot of his efforts to find less invasive techniques to monitor ecological integrity. The CD is sold by the Friends of Mt. Revelstoke and Glacier for $15. Contact them at 250-837-2010 or frmg@telus.net.

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Canadian Intermountain Joint Venture (CIJV)

UPDATE

Bird species in British Columbia and Alberta are benefiting from the efforts of a diverse group of people. Landowners, conservation organizations, governments, First Nations, universities and industry groups from forestry, mining, hydro and the cattle ranching sectors are working together for the birds through the CIJV. Aimed at bird species in the south and central interior of BC and the Rocky Mountains of Alberta, the Joint Venture is taking a landscape approach – addressing the stresses on the habitats that support birds and other wildlife. They are working toward a landscape that supports healthy populations of birds, maintains biodiversity, and fosters sustainable resource use for communities within the region, This kind of stewardship is a key component of the newly proclaimed Species at Risk Act, and was recently endorsed by the North American Bird Conservation Initiative.

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"CONSERVING WORKING LANDSCAPES - A FRAMEWORK FOR CONSERVATION ON PRIVATE LAND"

A New Publication from the East Kootenay Conservation Program (EKCP)

The EKCP is a coalition of over 30 groups and agencies who have joined forces to develop a home-grown strategy that promotes private land stewardship to help conserve critical habitat in the region. Over 11% of East Kootenay is privately owned and concentrated in the rich valley bottoms. These same valley bottoms are also critical terrestrial and aquatic habitat to the diversity of animal, bird and plant species. The increased demand on this biologically rich landscape is resulting in more species being pushed to the limit of their existence. Currently, there are 199 species of plants and animals, and 16 plant communities that are threatened, endangered or have disappeared from East Kootenay.

The EKCP has just published a document entitled, "Conserving Working Landscapes – A Framework for Conservation on Private Land." The publication is designed to encourage private landowners to work together with EKCP in a mutually beneficial way to conserve key habitats. A key component of the document is setting habitat conservation goals, which provide a focus to be more efficient and create synergies with partners and private landowners. Many private landowners are already doing various stewardship activities on their properties that are benefiting fish, wildlife and water resources.

Copies of "Conserving Working Landscapes – A Framework for Conservation on Private Land," can be downloaded from www.wingsovertherockies.org

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Recently In Print

Chruszcz, B., A.P. Clevenger, K.E. Gunson and M.L. Gibeau. 2003. Relationships among grizzly bears, highways ad habitat in the Banff-Bow Valley, Alberta, Canada. Canadian Journal of Zoology 81:1378-1391

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