Impact Assessment of ATVs on Bogs and Options for Management

James B. Ross

A Manuscript Report Prepared for the
Canadian Environmental Assessment
Research Council
May 1991

CONTENTS

ABSTRACT

This study was undertaken to determine the nature and scope of environmental damage, caused by the uncontrolled use of all-terrain vehicles, to the bogs of the Cape Breton Highlands.

Using vertical aerial photography, topographical and orthophoto maps, and oblique aerial photographs, the areal extent of ATV use was determined. Changes in vegetative cover and soil structure attributable to ATV impact were determined by field testing and a controlled impact experiment was conducted to relate impact damage to impact frequency.

It was determined that the ATV trail network had grown both in intensity of impact and in area1 extent from 1975 to 1990. Impact tests showed that, after only 10 ATV passes, 50% of the vegetative cover of the impacted trails on the bogs had been destroyed and, after 40 passes, virtually 100% of the vegetative cover had been destroyed. It was further determined that the threat posed by ATVs has greater potential, at present, for ongoing impact than does mineral exploration or intensive forestry practices within the study area.

It was concluded that bogs and wetlands are unsuitable for ATV use and they should be banned from such areas. An integrated management program incorporating education and

training, recreation planning, alternative institutional arrangements, and limited legislative control is the best option for controlling ATV use in the Cape Breton Highlands.

ACKNOWLEDGEMENTS

Funding for this research was provided by a Canadian Environmental Assessment Research Council (CEARC) Contract Award KA171-0-5729. Thanks to L. Ross who drew the hand-drafted figures and provided the computer and cartographic expertise to digitize the maps, A. Hanam and D. Banks of the Nova Scotia Department of Natural Resources in Baddeck who provided invaluable advice and logistical support, and N. Hill who helped immeasurable in the field. Also I wish to thank Dr. B. Freedman, Dr. Martin Willison, and Prof. Ray Cote for their assistance as members of my committee.

1. LITERATURE REVIEW

The largest body of literature on off-road vehicles and their impacts on the natural environment has originated in the United States. One may follow the growth of the off-road phenomenon beginning in the deserts of the southwestern United States in the late 1960's with 4-wheel drive trucks and dune buggies. This grew, in the mid 1970's, to encompass winter off-road activities with the popularity of snowmobiles. With this a new body of literature devoted to snowmobile impacts emerged from the northern U.S. and Canada.

The following is a review of the impacts of ATVs on bog and tundra ecosystems especially on the substrate and vegetation. It takes an ecosystem approach, concentrating primarily on the ecosystem components of soil and vegetation, and to a lesser degree, wildlife. There are few studies concerning the effects of all-terrain vehicles. Most address impacts attributable to other off-road vehicles such as trail bikes, snowmobiles, dune buggies, and 4-wheel drive vehicles. In many instances it is possible to apply these impacts to the case of ATVs; for instance ATVs travelling on snowmobile trails produce impacts that were similar to-those of snowmobiles and there is more difference in impact between ATV types than between ATVs and snowmobiles (Wells 1984).

1.1 EFFECTS OF ATVs on BOG ECOSYSTEMS

The effects of ATVs on bogs and barrens is essentially undocumented (Johnson 1987; Eaton 1990; Wilmshurst 1990). There is no specific primary literature on the subject; any references addressing the problems of ATVs and bogs exist as secondary items contained in literature concerning the operational capability of these vehicles (Yong 1990).

Three specific sources were identified describing in general detail the impacts of ATVs and the general susceptibility of bogs to impacts (Singleton 1973; National Wetlands Working Group (NWWG) 1988; Johnson 1987).

Off-road vehicle problems arise from two sources: biological damage, and conflict with other user groups. Primary consideration must be given to the biological aspects of the problem. (Singleton 1973)

Off-road vehicles crush vegetation on bogs where even minor depressions, that may be created by a single pass, are capable of changing the drainage pattern on the bog leading to the possible death of large areas of vegetation (Singleton, 1973). This is especially important in raised bogs that receive their nutrient input solely from precipitation and the atmosphere (NWWG, 1988). These small depressions provide channels for collecting water which leads eventually to the development of a quagmire. ATV drivers avoid these areas by driving around them thus creating more wet areas and so the quagmire grows (Johnson, 1987).

Off-road vehicles directly alter the soil in continuous belts leading to erosion and changes in slopes (Singleton

1973). Bog substrate is of low-strength and therefore the depth of peat, degree of decomposition, and depth to the water-table determine the bog's sensitivity (NWWG 1988). Sites with a high water-table, deep and moderate-to-well decomposed organic matter are more sensitive to impacts than are those bogs with a low water-table and poorly decomposed organic material. Bog sites dominated by black spruce and *Ledum* shrubs are less sensitive than those dominated by black spruce and *Alnus* shrubs (Jeglum et al. 1974; Scott and Virgo 1977; Gemell 1979).

1.2 EFFECTS OF ATVs on TUNDRA ECOSYSTEMS

Even slight damage in tundra ecosystems must be regarded as serious because disruptive processes which are initiated in tundra areas may move down slope and eventually impact larger areas (Willard and Marr 1971).

Wet or moist tundra is more susceptible to damage than is dryer tundra because ground features are more easily modified when the tundra is wet. ORVs leave conspicuous trails in the tundra when it was wet; when the tundra was dry only minor damage occurred leading to the development of quagmires (Willard and Marr 1971; Wooding and Sparrow 1978). Poorly drained soils are the most damaged soils in the trails tested. The warming and tilling common to ORV traffic causes an increase in the decomposition of organic matter. This combined with the resulting compaction leads to a reduction in soil porosity with the consequence that the absorptive organic layer breaks down and water accumulates in the area causing a quagmire to develop (Wooding and Sparrow 1978). ORV drivers tend to avoid these wet areas which results in further distributing the impact to the surrounding area thus increasing the size of the quagmire (Brodhead and Godfrey 1979).

A comparison of various ecosystem components shows that the most easily damaged vegetation were those with a high moisture content, as witnessed by the development of quagmires on moist tundra. Tall herbaceous vegetation was the next most susceptible to damage and sedges are the most resistant to numerous vehicle passes (Willard and Marr 1971; Wooding and Sparrow 1978).

The degree and type of impact is a function of:
(1) soil and terrain characteristics such as depth, texture, and drainage, (2) plant habitat type, (3) vegetation type and its ability to recover, and (4) time of year and the amount of use (Wooding and Sparrow 1978).

Some tundra ecosystems such as fellfields can recover in one to two growing seasons from one season of trampling but damage over a longer period necessitates a longer recovery period. The one year recovery for one year damage scenario does not apply in the case of more prolonged damage (Willard and Marr 1971). Uniformly vegetated fellfields sustain less plant damage than do sparsely vegetated meadows, and plants small in stature having little woodiness or those with buds that are protected at, or beneath, the surface are the best survivors of ORV impacts (Greller et al. (1974).

Once turfs are broken by impacts and erosion takes place natural recovery can be "tediously slow" and recovery from this type of damage may take several hundred to a thousand years (Griggs 1956; Osburn 1958; Willard 1960, 1963; Willard and Marr 1971).

1.3 EFFECTS OF ATVs on WILDLIFE

1.3.1 Effects on White-tailed Deer

All-terrain vehicles have difficulty with deep snow but are capable of winter travel once snowmobiles have opened a trail through the snow (Wells 1984).

Sound-level tests have been conducted on snowmobiles, and ATVs on snowmobile trails and the average noise levels for both types of vehicle were calculated. All-terrain vehicles emit an uphill and downhill combined average of 67.9 decibels, at trail side, all test speeds considered; snowmobiles were slightly noisier at 74.5 decibels (Wells 1984).

Deer disturbance tests were conducted during the winter months, a time when deer are most stressed by their environment. Excessive energy loss during this time, as would be required to avoid snowmobiles and ATVs, has the potential of effecting winter survival and fawn production (Moen 1976; Eckstein et al. 1979). All studies were concerned with casual contacts; no studies dealt with deliberate harassment.

A significant negative correlation was found between the number of snowmobiles and the number of deer sightings. On weekends when snowmobiles were plentiful deer were not; the reverse held true for the weekdays when the number of snowmobiles was low. It was typical for the lead snowmobiler to encounter 20-25 deer and only 6-7 on subsequent trips (Dorrance et al. 1975).

Casual encounters did not have a negative impact on deer. Deer movements have been monitored and it was found that the activity patterns and habitat of the deer were not seriously altered by the presence of snowmobiles. They did not move to thicker cover during periods of snowmobile use (Eckstein et al. 1979). Deer become inured to snowmobile traffic, at least in parks it is hypothesized that deer which are hunted annually would not be sensitized to accept traffic as readily as are deer in parks (Dorrance et al. 1975).

Deer have developed several coping strategies, designed to ease travel in deep snow, which utilize these trails. They use snowmobile trails because these snow packed trails are better able to support their weight thereby reducing energy expenditure and as the severity of winter increases so does their use of these trails. This behaviour is not common to all deer but all deer use trails at least for short distances. However, deer would not use snowmobile trails on wide logging roads due to their wariness to wander into a large cleared area (Richens and Lavigne 1978).

Although snowmobile trails may be utilised by deer, these trails also provide an easy means of access to the deer for unsupervised dogs (Doherty 1971).

1.3.2 Effects on Moose

Moose tend to concentrate in good forage areas in the winter; these moose yards may contain as many as thirty-five animals (CWS 1977). Therefore, the incidence of human encounter increases in winter (Denniston 1956). During the winter moose are severely stressed by their environment and quite susceptible to the effects of disturbance.

A study conducted with the aid of aerial moose census and browse surveys determined that the disturbance effect on moose extends between one to two kilometres from the edge of the disturbed area. Moose may tolerate a quiet observer but be seriously startled by a failed attempt to stalk. Often a disturbed moose may give no initial show of alarm but move slowly until it reaches cover and then run (McMillan 1954; Denniston1956; deVos 1958; Geist1963; LeResche 1966; Hancock 1976).

1.3.3 Effects on Birds

Until 1980 there were only five published papers that dealt specifically with the impact of off-road vehicles on birds (Berry 1980). All of these focused on areas in and around the Mojave Desert. These findings may be generalized to the avian population in ATV-impacted areas in more temperate habitats.

Virtually all habitat types show similar results. ORV use has a significant negative impact on the number of breeding pairs and bird density. In desert scrub habitats there were 1.7 to 5 times fewer breeding pairs on ORV impacted sites than on control plots. Twenty three times fewer breeding pairs were counted in impacted areas of desert washes. Similar results were found in riparian habitats (Bury ~~et al~~. 1976; Luckenbach 1978; Weinstein 1978). On high ORV use days the areas with fewer ORVs contained more birds Weinstein 1978).

Noise was another parameter considered. There was an increase in flushing and fleeing with the sound of ORVs even at great distances. Fleeing birds would often travel 0.8 to 3.2 km or more to escape the noise. This could result in disruption of territories, a decreased ability to feed young and defend the nest, and an increase in the vulnerability of the adult to predation. It is possible that prolonged or numerous periods off the nest could result in a lower hatching rate (Weinstein 1978).

ORV activity significantly decreased the number of small mammals in the area which could have a significant negative impact on amount of raptor forage which is available and effect their productivity (Byrne 1973; Busack and Bury 1974; Bury et al. 1976).

1.4 IMPLICATIONS for MANAGEMENT

1.4.1 Implications for Management in Bog Ecosystems

Singleton (1973) poses three questions about the impacts of off-road vehicles on bogs:

* What will be the effects?
* What is the magnitude of these effects?
* What significance is the resulting change?

If the impact is considered to be serious a regulatory approach is warranted according to Singleton (1973). If the impact is negligible, or regulable, the user group conflicts may then be considered.

In Singleton's view, much of the environmental damage is the result of a lack of operator knowledge about the potential impacts on bogs of off-road vehicle use.

1.4.2 **Implications for Management** in **Tundra Ecosystems**

Wooding and Sparrow (1978) contend that it is almost impossible to eliminate ORV travel from tundra ecosystems. This has several implications for ORV management in these ecosystems. Greller et al. (1974) recommends a program of restricting ORV traffic to specifically selected trails, closing those in problem areas and re-routing trails to avoid these areas. In some cases, they suggest, it may be necessary to improve existing trails through the use of gravel or corduroy construction to make them more attractive to ORV use. Tundra ecosystems, say Willard and Marr (1971), deserve "far more care than they are now receiving" (p 189).

1.4.3 **Implications for Management near Wildlife**

Eckstein et al. (1979) conclude that the responsible use of snowmobiles has little effect on the winter habitat and movement of white-tailed deer. They say that deer are more likely to be disturbed by the relatively silent approach of hikers and cross-country skiers than they are by snowmobilers.

Doan (1970) considers that snowmobile trails, if properly managed, could be a good method of reducing malnutrition and winter mortality in deer. This, he says, could be accomplished by situating trails in clearings that would provide good browse, and by establishing trails that induce deer to explore previously unexploited winter areas.

In general, Dorrance et al. (1975) and Eckstein et al. (1979) believe that it is more appropriate to situate snowmobile trails to avoid deer wintering yards. This would confine these trails to upland deciduous forests (Eckstein et al., 1979).

Most moose encounters occur in the winter (Denniston, 1956) a time when they are already critically stressed. Hancock (1976) has shown that human disturbance may effect moose up to two kilometres from the area of the disturbance. In planning projects in areas of moose habitat it is therefore necessary to identify and avoid moose yards especially if no alternate winter habitat exists.

No literature on the effects of off-road vehicles on avian populations directly addresses the question of ORV management in these areas. Berry (1980) advocates "stringent precaution and restrictions" (p 461) in this regard in designating areas for ORV use.

2. THE STUDY AREA

The study area (Figure XXX) is on the Cape Breton Highlands Plateau west of the Park Spur Extension Road at an elevation of 425 to 450 metres above mean sea level. It is on Provincial Crown Land which is under the jurisdiction of the Department of Lands and Forests and administered under the Crown Lands Act (1987).

Access to the study area is by way of the Park Spur Extension Road, the Pembrook Lake Road, Bell Cote Road, and the Highland Road. - Snowmobiles and ATV trails from the Cheticamp area provide unofficial, off-road, access to what may be considered as one of the most remote areas in the Province.

The upland slopes of this **area** are the highlands and the upper surface, where the study area is located, is the Highlands Plateau. The distinction of uplands, highlands, and lowlands is useful for general application, but because of the varied nature of topography in this area "the terms have little meaning" (Roland 1982, p54). Common usage has designated the entire area as "the Highlands? This is the use adopted in this report; the terms plateau and highlands plateau have been used in the description of the study area; however, "Highlands" has been used elsewhere.

2.1 GEOLOGY

After the Cretaceous period the east coast of Canada rose and subsided a number of times resulting in an uplifted planation surface sloping towards the Atlantic. Ensuing rapid erosion developed deeply incised south and east-flowing rivers. This was followed by a period of complex and intensive glaciations which left a Plateau surface dominated by compacted basal moraine material derived from igneous rock (Keppie 1979; Roland 1982)).

The Plateau is generally well-drained with a radial pattern of slow-moving streams (Simmons et al. 1984; Department of Development 1986).

2.2 VEGETATION

The Plateau forest consists of even-aged boreal species of balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), and white birch (*Betula papyrifera*). Windthrow and insect damage are the major natural successional agents in these forests. Spruce budworm *(Choristoneura fumiferana)* is responsible for the major insect damage with the most recent outbreak beginning in 1973. Although some old burned areas have been found, forest fire is not a major successional agent on the Plateau (Lands and Forests 1983; Simmons et al. 1984).

Five to ten percent of the total surface of the Plateau is *Sphagnum* bog, much of which is raised bog (Simmons et al. 1984).

2.3 WILDLIFE

The area does not contain a large diversity of small mammals. However, due to spruce budworm damage, birds such as woodpeckers are common (Simmons et al. 1984). Moose (*Alces alces*) exist in abundance with approximately 2000 on the

Plateau and another 1500 in Cape Breton Highlands National Park (Banks 1990).

Snowshoe hare (*Lepus americana*) are plentiful and the area contains some of the last remaining habitat in the province for lynx. Deer (*Odocoileus virginianus*) use the Plateau in the summer but congregate in yards on the Highland slopes in the winter (Simmons et al. 1984).

2.4 RECREATION

In the winter, snowmobilers use the Plateau area extensively and local snowmobilers have organized into clubs. Many people travel from as far as Halifax to enjoy the excellent snowmobiling conditions. There are now three cabins operated by clubs in or near the study area. One of these was constructed with the aid of a federal government grant (Hanam 1990).

As the use of ATVs grew in popularity, year round access to the Highlands and Plateau became a reality. Since 1979 the network of ATV trails has grown and concern has been voiced by Lands and Forests over the possibility of long-term environmental damage to bogs.

Hunting and fishing is popular and rewarding on the Highlands and Plateau. However, previously unexploited lakes are in danger of being over-fished because of the increased access provided by ATVs. Fished-out lakes on the Plateau which flow into the lakes and streams in the National Park will not be re-stocked, at the insistence of Canada Parks

Service (Forsythe 1990).

In 1988 the native and non-native moose hunt netted 223 animals. Mostly were taken along the roads south of the National Park (Patton 1989). In 1990, 222 moose were shot during the two-week hunting season (Banks 1990).

2.5 FOREST HARVESTING

The most recent outbreak of spruce budworm on the Highlands and Plateau began in 1973. The Province did not permit spraying to control the infestation until 1979, by which time 67% of the merchantable balsam fir had succumbed. In 1979 spraying with *Baccillus thuringiensis kurstaki* (Btk) was sanctioned on a trial basis for 6000 hectares.

By 1981 the infestation of budworm had peaked. A survey that same year concluded that an average of 73% of the softwood had survived on the sprayed areas, and only 22% in the unsprayed areas. The trial spray program was terminated in 1982 (Lands and Forests 1983).

The Province appointed a Task Force of Wood Allocations and Forest Management in 1977, specifically to address the problem created by the spruce budworm. By this time the pulp and paper markets were depressed and pulpwood inventories were high. The Task Force recommended a salvage program that called for the cutting and storage of 1.44 million cubic metres of softwood pulpwood. The Province decided to store 1.19 million cubic metres of salvagewood but by the end of 1981 only 1.1 million cubic metres had been salvaged (Lands and Forests 1983). In the ATV study area clear-cutting, although not extensive, was completedby 1980-81 (Hanam 1990).

2.6 MINERAL EXPLORATION

Within the general study area mineral occurrences of copper, potassium, nickel, and lead have been recorded (Keppie 1979). At present Inco, Noranda, and Seabright Explorations are exploring for gold. Some of these operations involve digging exploration trenches in the bedrock and drilling test holes.

Although small-scale mining for various metals has occurred sporadically in the Cheticamp area since the late 1800's, there have been no mining operations conducted in the Plateau area of the Highlands (McLeod 1903).

2.7 HYDRO POWER

In the mid 1970's the Nova Scotia Power Corporation began construction of the Wreck Cove Hydro Electric Project. This involved diverting water from 22,015 hectares of the Plateau, 65% of which was covered by forest (Simms 1974) creating approximately 2,072 hectares of reservoir in the form of several large lakes linked by canals and tunnels to a 200 megawatt Peak Demand Station (Cape Breton's Magazine 1974).

Controversy over the project centred on the environmental aspects of the development and the fact that it would be "opening to human activity the last inaccessible wilderness in Nova Scotia" (Cape Breton's Magazine 1974, p3).

2.8 CANADIAN HERITAGE RIVER SYSTEM

In October 1988 the Province and the Canadian Parks Service initiated a study to determine the feasibility of designating the Margaree River as a Heritage River under the Canadian Heritage River System (CHRS) (Rutherford and Assoc. 1988, 1989). Public consultations were held early in 1990 (CHRS 1984, 1990). A recommendation was made by the Margaree River Advisory Committee (MRAC) in June for nomination as a Heritage River (Chronicle-Herald 1990; MRAC 1990). In February, 1991, the Minister of Lands and Forests approved the nomination of the Margaree-Lake Ainslie river system to the Canadian Heritage Rivers program (Chronicle-Herald 1991).

The objective of CHRS is to conserve and protect the natural and human heritage of rivers and the opportunities they possess. Because the integrity of a river must be protected in order to gain and maintain its designation, a designation as a Heritage River could have far-reaching consequences for the Highlands and Plateau. Any damage of consequence in the Highlands could effect the ecological status of the Margaree River system which in turn could place the Heritage River designation in jeopardy.

2.9 TROUT LAKES STUDY AREA

An in-depth examination of the impact of ATVs was conducted in the Trout Lakes area. Four bogs and 1525 metres of ATV impacted trail were surveyed. Bogs were classified in the field by their visual characteristics according to the Canadian Wetland Classification System (NWWG 1988).

Bog 4 is a small raised, or domed, bog of 5.4 hectares, approximately 2 to 3 metres above the surrounding landscape. Drainage is mainly to the north but it slopes also to the south near the southern end.

The lake trail passes through a mixed stand of stunted black spruce (*Picea mariana*) and balsam fir with some small, poorly developed, tamarack and a small pocket of white birch. It ends at bog 3, a slope bog of 0.2 hectares, which slopes gently towards the lake. Bog 3 receives the drainage from a lagg area at the northeast end of bog 2. This lagg area has a grade of 10/1 and is dominated by poorly developed-tamarack (*Larix laricina*) and alders (*Alnus*).

Bog 2 is a long narrow raised bog, 0.9 hectares, edged with poor tamarack and black spruce. It contains several ponds, or flarks, which lie parallel to the contour of the bog. The forest stand between bog 2 and bog 1 has been attacked by spruce' budworm, and has not been removed by salvage cutting; many dead snags remain. A natural regeneration of fir and black spruce is growing in this area.

Bog 1 is a horizontal fen of 1.2 hectares. It was chosen for the ATV impact study site for several reasons, Preliminary investigation determined the vegetation present on this bog is representative of that on other bogs in the area. It is easily accessible by ATV from the Park Spur Extension Road, relatively free from previous impact by ATVs, and relatively protected from further impact by virtue of its proximity to the road and the main ATV trail.

3. METHODS

3.1 RESEARCH DESIGN

Four research approaches were used to understand the effects of ATVs on bogs. First, a review of the relevant literature provided an examination of the impacts on soil and vegetation caused by recreational vehicles. To a limited extent the impact on wildlife was also addressed. Second, an analysis of aerial_. photography and topographical maps determined the extent of the various impacts; the nature of the impacts was validated by a ground survey. Third, soil and vegetation surveys were conducted to ascertain the significance of ATV impact. Fourth, experimental passages with an ATV were carried out on a bog to relate damage to impact frequency.

3.1.1 Aerial Photography and Map Analysis

This analysis determined the spatial and temporal extent of impacts from ATVs, mineral exploration, and salvage cutting on the Cape Breton Highlands. A three-step process was used. National Topographic System maps, compiled from 1978 aerial photography, and orthophotographic maps, compiled from aerial photography flown 'in 1975, provided a baseline from which to determine the development of ATV trails. Next, vertical aerial photography, flown in 1984, was analyzed to ascertain the expansion of the ATV trail network, and the area1 extent of salvage cutting and mineral exploration. Finally, field observations and oblique aerial photography from'1990 provided an understanding of the present extent of the ATV network and mineral exploration activities within the study area.

The result of this three-step process was digitized on an AutoCAD system as Figure 1.

3.1.2 Soil and Vegetation Surveys

Soil moisture concentration and soil compaction measurements are the two most widely used methods with which to quantify soil changes caused by ATVs (Wilshire et al. 1978).

Soil moisture content is the percentage of a field sample that is composed of water. Soil moisture is a key factor controlling plant growth, weathering rate, and the susceptibility of soil to downslope movement. Loss of moisture reflects a change in the structure and composition of the soil by compaction and erosion (Wilshire et al. 1978). t is calculated by:

$$[(W_f - W_d) / W_d] * 100$$

where W_f is the field weight of the sample and W_d is the dry weight of the same sample.

Bulk density measures the soil water percentage by volume; it is the ratio of the mass of the dry sample to the volume of the field sample. Bulk density varies with soil structure, compaction, and organic matter concentration.

A bulk density sampler of 450 cm^3 volume was used to obtain volumetric samples **from which bulk density was***

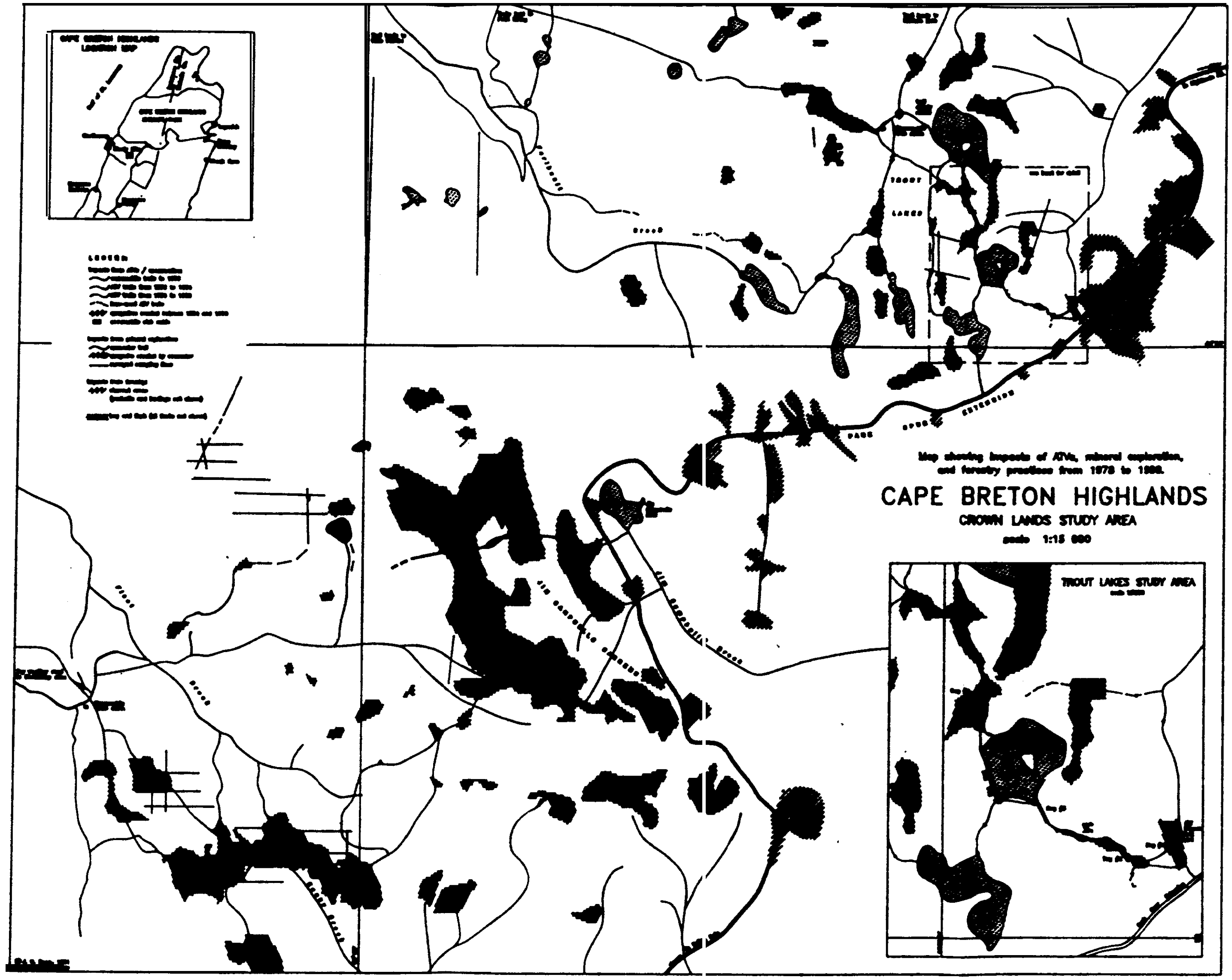

CAPE BRETON HIGHLANDS
CROWN LANDS STUDY AREA
TROUT LAKES STUDY AREA

FIGURE 1

calculated by:

$$W_d / 450$$

Samples for soil moisture and bulk density were dried at 90°C for 48 hours. Defining the dry state of porous material is difficult in these tests (Gardner 1986); however, the drying method used in this instance is thought to be sufficient for the purpose.

Soil compaction increases the resistance of soil to penetration by roots and seedlings (Goudie 1984). Compaction also reduces the rate of water infiltration and changes the soil moisture status (Chancellor 1977). Compaction was measured directly in the field using a Proctor penetrometer to measure resistance. A 2.54 cm diameter needle was used as it gave the most consistent results on the bogs. The penetrometer was pushed into the substrate to a depth of 5 cm and the resistance reading was noted. The average of three similar readings was used to determine the resistance measurement for each site. The penetrometer was calibrated in imperialunits of lb/in^2, which was converted to pascals (Pa) by multiplying by 6.9×10^3.

Loss of weight on ignition tests were conducted on the soil of the "lake trail" to determine the loss of organic content due to ATV trampling. These samples were oxidized in a kiln at 500°C for 26 hours. The percent of oxidizable organic matter was then calculated by:

$$[(W_i - W_f) / W_i] * 100$$

where W_i is the initial sample weight and W_f is the weight of the sample after oxidization.

A 0.25 metre sampling quadrat was used to measure vegetative cover. An inventory of plants **was** conducted and an **estimation was made** of their cover within the quadrat. The *Flora and Fauna of Nova Scotia* by Roland and Smith **(1969) was** used to identify plants in the field. Those plants unable to be positively identified were collected, pressed and later identified with the assistance of Dr. B. Freedman of Dalhousie University. A 35 mm slide photographic record was made of each quadrat and reviewed, with Dr. Freedman's assistance, to validate the field observations.

Soil and vegetation sampling was conducted at intervals along the bogs and **the lake trail.** At each sample location the impacted trail and a reference site were sampled.

3.1.3 ATV Test Plot

The ATV test **plot was established on bog number** 1 (Figure ~~XXX~~ 1). Five lanes each 3 metres wide and 20 metres long were staked out on the bog. A reference lane was established adjacent to these. The first lane received one ATV pass; the second lane received five passes; the third, ten; the fourth, twenty'; and the fifth, forty passes with the ATV. The ATV operator was given the following instructions:

* drive at a consistent speed.
* maintain the same track in each lane.
* make half the passes in one direction and half in

the opposite direction in each lane.

* turn well past the ends of the lanes to avoid creating quagmires and ditches near the test plot.

* do not drive or walk in the control lane.

A Honda "Big Red" three wheel ATV was used for this test, and driven by an experienced operator. This machine had a weight, exclusive of fuel and driver, of 170 kg, a wheelbase of 1,230 mm, and 25 X 12.0-9 low-pressure tubeless tires (Honda 1983).

On completion of the ATV runs, samples were obtained for soil moisture content and bulk density, penetrometer measurements were taken, and a vegetation survey was conducted in each lane.

3.2 RESEARCH LIMITATIONS

The data collected generated sufficient information to enable conclusions to be drawn concerning the effects of ATVs and to establish baseline data from which to gauge ongoing impacts and vegetation recovery rates. The number of sample sites, although sufficient to indicate trends, is not adequate for an in-depth soil or vegetation survey. The vegetation survey did not inventory all of the vegetation at each site. Species inventoried were the major taxa, and were adequate to indicate important trends. The study does not address the recovery of bogs after the cessation of ATV impact. A number of years of observation of the test plot will be required to obtain such information.

4. RESULTS

4.1 MAP AND AERIAL PHOTOGRAPHY ANALYSIS

Until 1978 there was evidence of only one trail in the study area (Figure 1). It had its origin at the end of a dry-weather road which follows the Cheticamp River valley from Petit Etang.

By 1984 a snowmobile clubhouse had been constructed which became a focus for snowmobile activity and a network of trails, in excess of 7 kms., with the clubhouse as the centre, had spread to all lakes in the Trout Lakes system. There are two centres of focus for these trails: they have been used to provide access to the lakes and as a means of access to the Park Spur Extension road, where 1200 km. of well-maintained woods roads are available.

These trails cross the bogs longitudinally in almost all cases because the bogs provide an attractive alternative to cutting trails through the woods.

There were few obvious ATV trail links between Trout Lakes and Jim Campbells Barrens in 1984. As with Trout Lakes, trail activity in the Jim Campbells Barrens area centred around a snowmobile club cabin, located west of the barrens near the end of a dry weather road leading from the Plateau and Cross Point area. This cabin is on topographical map 11K/10 edition 3 which was updated from 1978 aerial photographs.

In 1978 there were no trails indicated on the topographical maps in the vicinity of Jim Campbells Barrens. By 1984 a network of more than 8 km had developed in this area. Here too, the bogs have been used as a convenient alternative to cutting trails through the woods. These trails have no specific destination other than the Park Spur Extension and Pembrooke Lake roads.

From 1990 field observations and oblique aerial photographs it was noted that few new trails have been established in the study area since 1984. The presence of ATVs has been most strongly felt in this area through their impacts on the bogs. Quagmires have grown both in number and in size since 1984, and the bogs have suffered more traffic as a result of the all-season availability provided by ATVs.

These machines have affected the bogs both intensely and extensively since 1984. Bog 4, which in 1984 had a single track through it, has been 25% impacted by ATVs since that time. Bog 2 also had a single track through it in 1984, at present about 75% of the bog has been impacted and deep channels: have been cut parallel to the contour of the slope. These provide a path for drainage. Many areas have been turned into quagmires. This has led to the cutting of alders and small black spruce in some areas to provide a way around. the quagmires.

Salvage cutting began in 1973; by 1978 clear cutting had still not taken place within the study area (Lands and Forests 1983). Between then and 1984 a major woods road with pushoffs and landings, the Park Spur Extension, had been constructed. Thirty hectares of forest had been cut in the area at present this is regenerating naturally. Logging ceased here by 1981 and there is no commercially viable timber remaining (Hanam 1990).

There are numerous survey lines which were established by the mining companies for exploration sampling. Although the companies are reluctant to disclose any information about their activities, some information has been obtained from 1984 aerial photographs. At that time there had been no obvious exploration activity such as trenching, except for an area to the west beyond the study area. This is in a well-drained and wooded area away from bogs. Trenching activities are still confined to well-drained, fir-forested areas (Hanam '1990).

Field observations and 1990 oblique aerial photographs revealed that one of the mining companies had recently used a section of Jim Campbells Barrens through which to transport its excavator. A number of trips had been made which resulted in a wide (4 m) track which has turned into a quagmire in a number of places. In one place the tracked vehicle had become mired and a considerable section of the bog, to a depth in excess of 1.5 m, was destroyed while extricating the machine. In another instance it crossed a small stream which flowed into Jim Campbells Brook and the North East Margaree River. The stream course was, as a result, altered for a short distance. When this damage was noted by Lands and Forests the mining company was instructed to stay off the bogs, and to confine their activities to the woods or the alders at the edge of the bogs.

4.2 SOIL STRUCTURE MEASUREMENTS

4.2.1 Moisture Content and Bulk Density

Table 1 (a,b) contains a summary of the measures of central tendency for the various substrate parameters. Bulk density for all sites, both on the bogs and on the wooded trail, was greater on-the impacted trails than it was on the reference sites.

Moisture content varied negatively with bulk density. This association followed the model:

$$Y = a - bX$$

where Y equals the log of moisture content and X equals bulk density. This is useful in describing the relationship between moisture and bulk density on the wooded trail (R^2 = 95.3%, $p < .001$, $r = -.976$). However, on the bogs it is only marginally predictive (bog 4: R^2 = 40.9%, $p < .001$, $r = -.640$; bog 2: R^2 = 43.4%, $p < .001$, $r = -.659$). This association will be addressed further in the discussion.

4.2.2 Penetration Resistance

Penetration resistance was slightly greater on the bog reference sites than it was on the impacted bog sites. The trail through the woods had a higher resistance on the impacted track than on the reference sites.

BOG 4 (n=3)

ln Penetration	**on track**	**off track**
median	2.2	2.3
mean	2.4	2.4
range	1.9 - 3.6	2.0 - 3.0
Bulk Density	**on track**	**off track**
median	.08	.05*
mean	.07	.05*
range	.05 - .10	*
Soil Moisture	**on track**	**off track**
median	89.8	93.3
mean	90.3	91.7
range	86.8-94.3	88.4-93.4

* differences are not significant

BOG 2 (n=5)

ln Penetration	**on track**	**off track**
median	2.1	3.1
mean	2.2	3.1
range	1.9 - 2.8	2.3 - 4.1
Bulk Density	**on track**	**off track**
median	.06	.04
mean	.06	.05
range	.04 - .07	.04 - .06
Soil Moisture	**on track**	**off track**
median	92.7	92.7
mean	92.9	92.6
range	91.4-94.7	92.6-95.1

TABLE 1(a): Summary of the measures of central tendency (mean and median) of penetration resistance (Pa X 10^5), bulk density (g/cm^3), and soil moisture content (%).

LAKE TRAIL (n=6)

ln Penetration	**on track**	**off track**
median	16.6	**12.4**
mean	17.3	**12.9**
ranse	8.3 - 27.9	8.0 - 22.9
***Bulk* Density**	**on track**	**off track**
median	.22	.11
mean	.43	.24
range	.14 - .96	.07 - .89
Soil **Moisture**	**on track**	**off track**
median	68.6	72.1
mean	58.4	66.7
range	22.4-82.5	27.2-86.9

TABLE **1** (b) : **Summary** of the measures of central tendency (mean and median) of penetration resistance (Pa X 10^5), bulk density (g/cm^3), and soil moisture content (%).

Penetration results were deceiving, especially on the bogs. On bog 4 there was virtually no difference between the median and mean on the track and the median and mean on the reference sites adjacent to the track. However, a flat-blade shovel was easily shoved into the bog on the impacted track in most instances but it had to be driven in by foot to the same depth in the reference site immediately adjacent to the impacted track. This demonstrated that, while penetration resistance remained relatively constant, ATV impact caused a loss of cohesion which accounts for the ease with which the shovel could be driven into the impacted site.

4.2.3 Soil Structure Change

Table 2 presents the changes in structure from on-trail to off-trail sites. In the case of each bog and trail there was an overall change in the substrate structure as a result of ATV impact.

4.2.4 Loss of Weight on Ignition

Figure 2 shows the results of the loss of weight on ignitiontests for the lake trail. There was a higher percent of oxidizable organic matter in the substrate on the reference sites than there was on the impacted trail. This indicates that there was more mineral soil present in on-track samples. In forest habitats and in grasslands it has been noted that the exposure of mineral soil increased significantly as the number of ATV passes increased (Chappell et al.; Cole 1985).

BOG 4

Site	Bulk Density	% Moisture	Penetration
1	**60%**	1.7%	73.3%
2	0%	1.1%	9.1%
3	100%	7.1%	12.1%

BOG 2

Site	Bulk Density	% Moisture	Penetration
1	**20%**	1.9%	17.1%
2	0%	0.2%	35.6%
3	25%	1.1%	44.1%
4	75%	1.4%	13.2%
5	0%	0.4%	49.1%

LAKETRAIL

Site	Bulk Density	% Moisture	Penetration
1	87.5%	4.9%	9.1%
2	**55.5%**	8.5%	93.3%
3	**736.4%**	**64.3%**	100.0%
4	128.6%	28.8%	51.7%
5	2.3%	6.4%	77.7%
6	64.7%	4.1%	4.0%

TABLE 2: Change in soil structure from reference to impacted sites; increase or decrease is not specified.reference sites to the impacted trails, both on the bogs and on the trail in the woods.

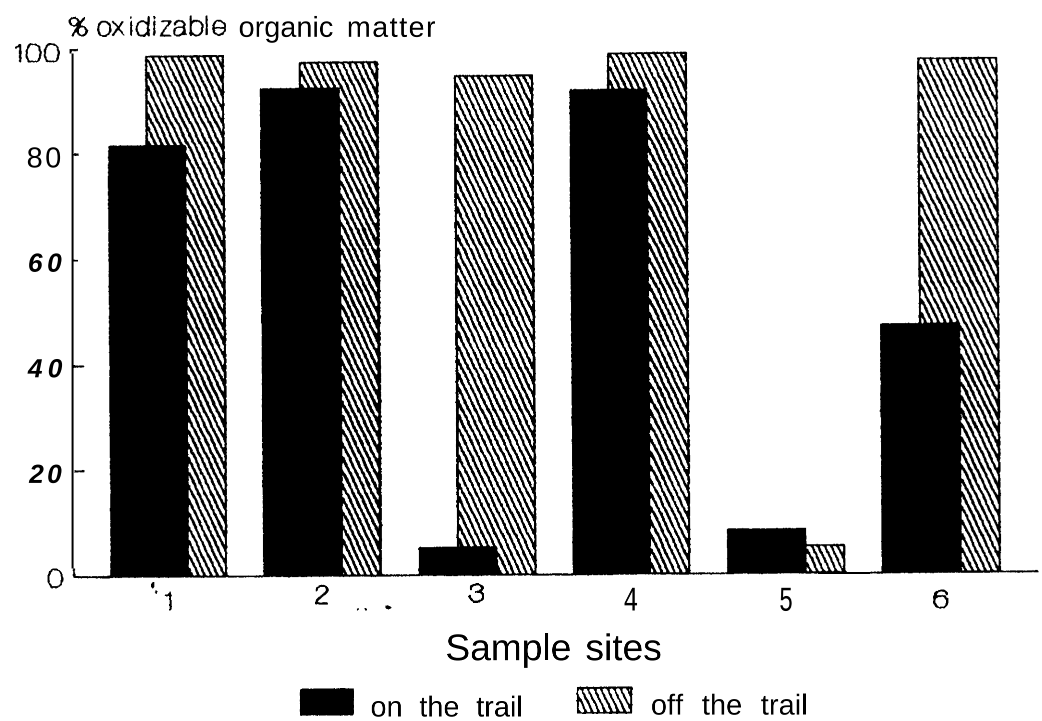


FIGURE 2: Results of loss of weight on ignition tests on the lake trail.

4.3 VEGETATION SURVEY

Table 3 contains the measures of central tendency for species richness. In general about 50% of the species had succumbed to the impact of ATVs. In all cases the total plant cover for all species on the trails was considerably less than the total cover in the reference vegetation. The more abundant the species, the more extreme the decrease in cover as a result of vehicular impact.

Table 4 shows the relative cover of some of the abundant species. Although the bogs and the wooded trail had some species unique to their environments, the most abundant species were common to both ecosystems.

Sphagnum moss was the dominant species both on and off the trail with an average of 6% and 59% cover respectively. *Scirpus cespitosus* was the next most abundant with 9.4% cover on the trail and 26.3% in reference vegetation.

On the bogs the average impacted site showed 76.1% unvegetated ground and the reference sites had only 2.5% bare ground (Table 5). The wooded trail had 88.2% on impacted sites compared to only a trace of unvegetated ground in reference vegetation.

4.4 ATV IMPACT EXPERIMENT

A vegetation survey was conducted on the lanes immediately after ATV impact was complete (Plate 1). With one pass vegetation was bent and the machine tracks were easily discernable. In the lane with five passes the substrate was impacted to a greater degree. The ATV operator reported that after 3-4 passes the machine appeared to "float" on the bog.

	Bog 4		Bog 2		Lake Trail	
	on	off	on	off	on	off
median	4	8	6	8	3	10
mean	3.7	7.7	5.8	8	3.2	9.3
range	2 - 5	5 - 10	4 - 8	5 - 12	2 - 8	5 - 12
n	3		5		6	

TABLE 3: Central tendencies (mean and median) for species richness. Quadrat size was 0.5 X 0.5 metres.

Sphagnum spp.:

	Bog 4		Bog 2		Lake Trail	
	on	off	on	off	on	off
median	tr	50	tr	50	tr	50
mean	0.4	63.3	1.1	51	a.4	63.3
range	tr - 25	40-100	0 - 5	0 - 90	0 - 25	40-100
n	3		5		6	

Scirpus cespitosus:

	Bog 4		Bog 2		Lake Trail	
	on	off	on	off	on	off
median	tr	20	15	50	N/A	N/A
mean	1.8	28.3	26.2	48	N/A	N/A
range	tr - 5	15 - 50	1 - 70	10 - 80	N/A	N/A
n	3		5			

Andromeda glaucophylla:

	Bog 4		Bog 2		Lake Trail	
	on	off	on	off	on	off
median	0	2	0	0	N/A	N/A
mean	tr	2.4	tr	tr	N/A	N/A
range	0 - tr	tr - 5	0 - tr	0 - tr	N/A	N/A
n	3		5			

Aster nemoralis:

	Bog 4		Bog 2		Lake Trail	
	on	off	on	off	on	off
median	0	2	2	5	N/A	N/A
mean	tr	2.4	3.5	4.4	N/A	N/A
range	0 - tr	tr - 5	tr - 10	2 - 5	N/A	N/A
n	3		5			

TABLE 4: Central tendencies (mean and median) of the relative vegetative cover for some of the abundant species. Quadrat was .5 X .5 metres. Tr < 0.1%.

Unvegetated ground:

	Bog 4		Bog 2		Lake Trail	
	on	off	on	off	on	off
median	99.0	0	**75.0**	**0**	**95.0**	**0'**
mean	82.7	0	69.6	5	88.2	tr
ranse	50 - 90	0	40 - 98	0 - 15	50-100	0 - 2
n	3		5		6	

TABLE 5: Central tendencies (mean and median) of unvegetated ground. Quadrat was .5 X .5 metres. Tr < 0.1%.

PLATE 1: Aerial view of the test plot, Oct. 5, 1990; photo by A. Hanam, Lands and Forests..

A faster speed caused the tires to spin. Ten passes resulted in still deeper (7.6 cm) ruts. After 7-8 passes the machine began to till the sphagnum. Very deep wheel ruts, tilling of the substrate, and the beginning of a quagmire were the results of 20 passes, and 40 passes led to very deep ruts (17.8 cm) which contained standing water. This run was completely tilled and the ATV sank to it's axle in a number of places. The driver reported that in other circumstances he would have avoided this track thereby causing the quagmire to grow in size.

4.4.1 Experimental Plot Vegetation

On the experimental plot a strong negative association (r = -.960) was observed between the number of ATV passes and the log of species richness (Figure 3). The model that best predicts this relationship is Y = a - bX, where Y is the predicted log of species richness and X is the number of ATV passes (R^2 = 92.2%, p<.001, DF = 1).

Figure 4(a,b) shows the response of the major species to ATV trampling. Cover loss was compared to the number of ATV passes, a more accurate picture of vegetation loss (Cole 1985). Generally, vegetative cover had been reduced to 50% between 10 to 20 passes.

The number of passes is only a fair predictor of the amount of bare ground and is predicted by the model: Y = -a + bX where Y is the percent of bare ground and X is the number of ATV passes (R^2 = 89.9%, p = .471, DF = 1) (Figure. 5).

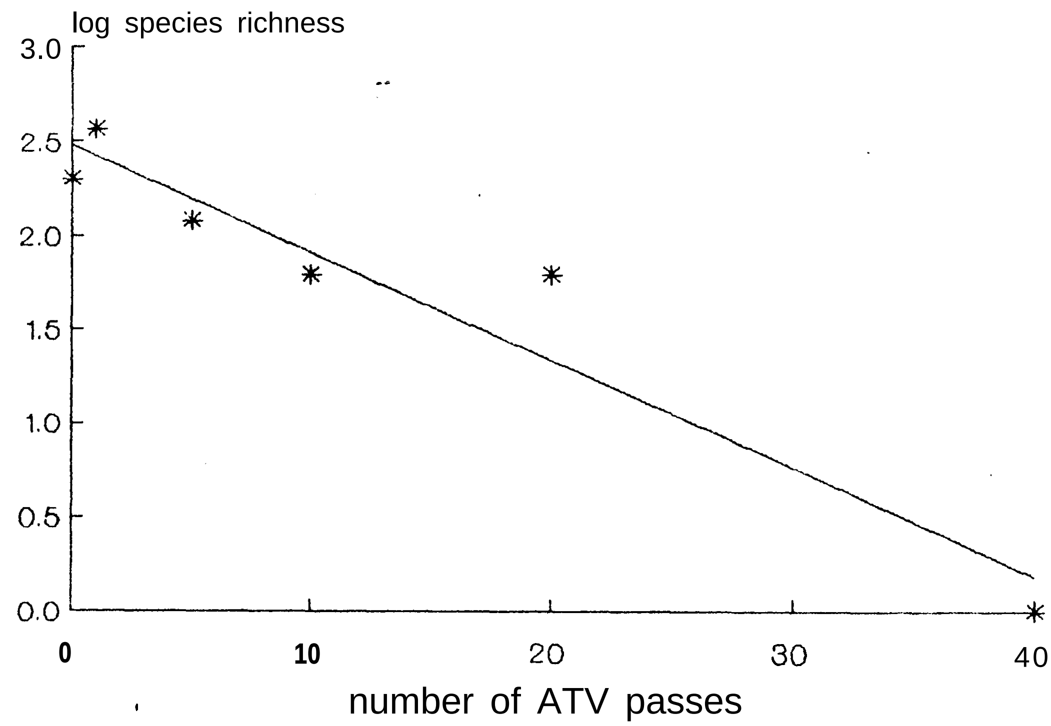
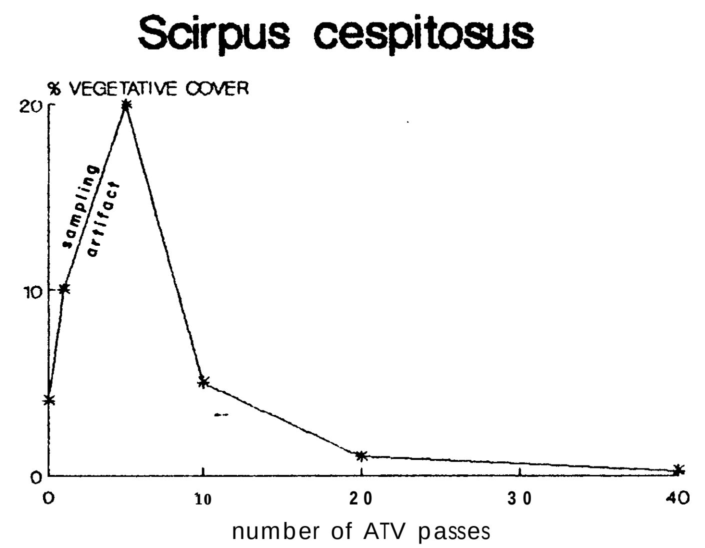


FIGURE 3: Regression plot of log of species richness and the number of ATV passes for the test plot.



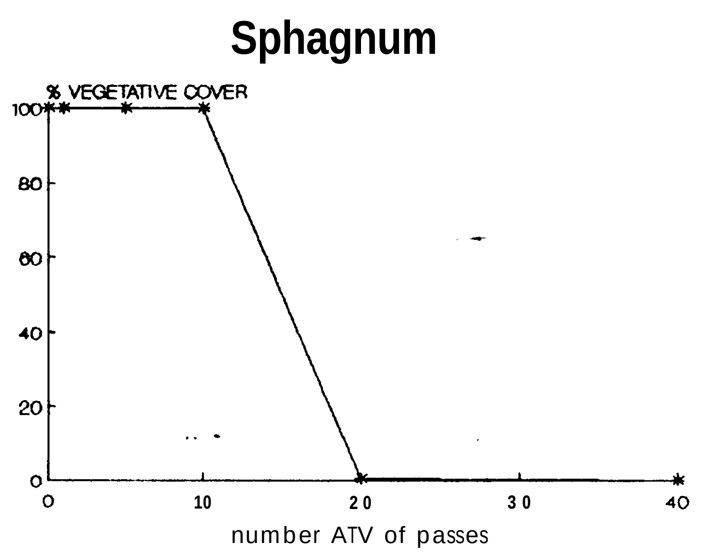
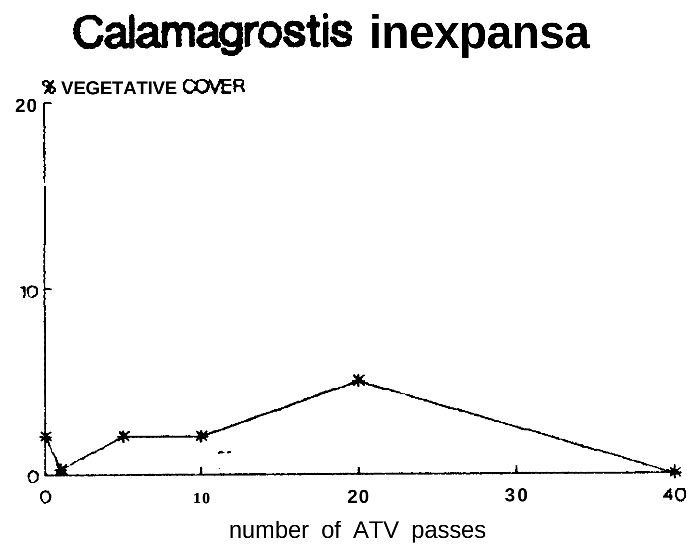


FIGURE 4(a): Response of major species to ATV trampling.



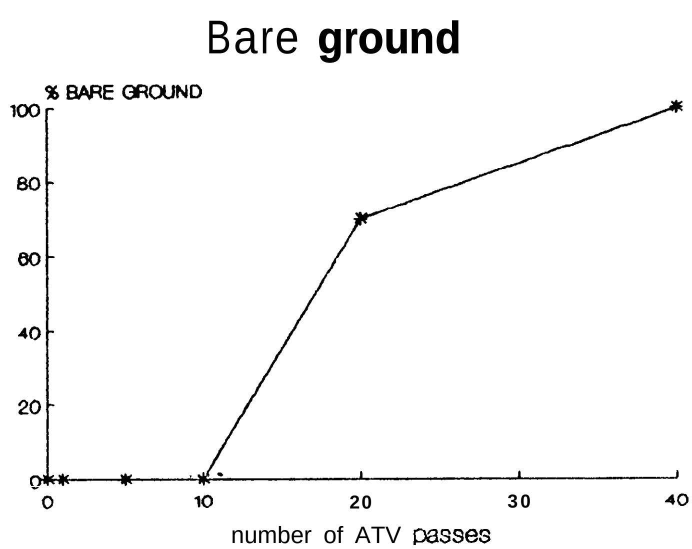


FIGURE 4(b): Response of major species to ATV trampling.

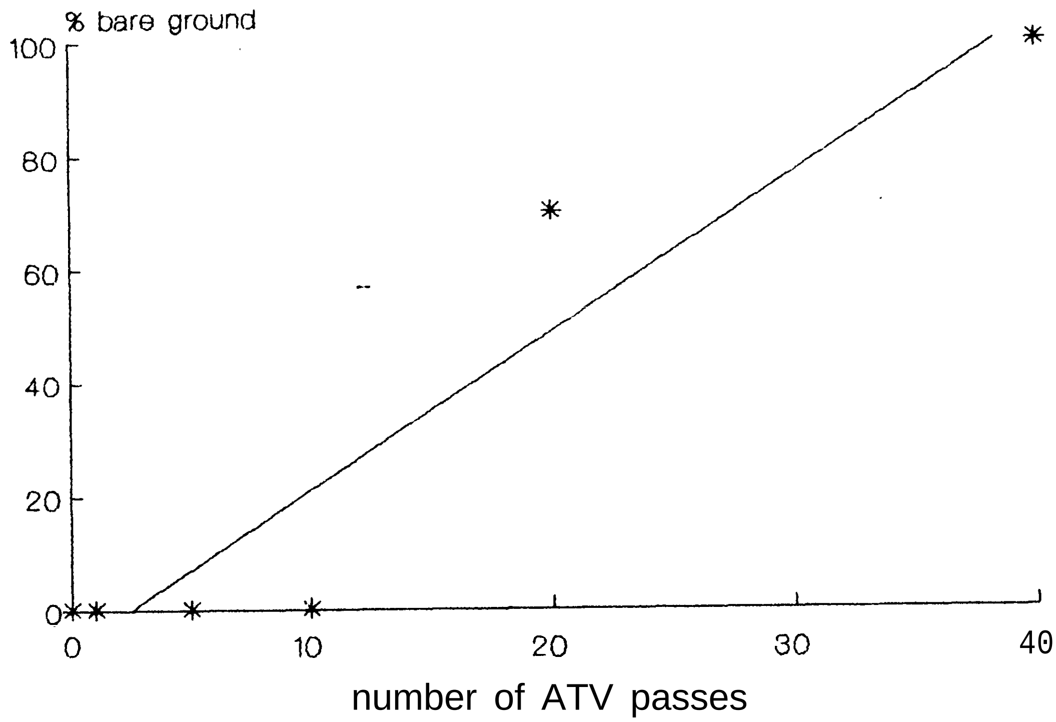


FIGURE 5: Regression plot of amount of bare ground and the number of ATV passes for the test plot.

A sensitivity index adapted from Cole was applied to the major species on the test plot based on the following criteria **(Cole** 1985):

very resistant	if relative cover greater than 50% after 40 passes
resistant	if relative cover greater than 50% after 20 passes
neither resistant nor sensitive	if relative cover greater than 50% after 10 passes
sensitive	if relative cover greater than 50% after 5 passes
very sensitive	if relative cover greater than 50% after 1 pass

The following results were obtained:

very resistant	none
resistant	**Calamagrostis *inexpansa*** ***Drosera rotundifolia*** ***Vaccinium oxycoccus***
neither resistant nor sensitive	*Andromeda* ***glaucophylla*** ***Sphagnum spp.***
sensitive	***Chamaedaphne calyculata*** ***Sarracenia purpurea*** ***Scirpus cespitosus***
very sensitive	***Clintonia borealis***

No species were classified as very resistant to ATV impacts. ***Calamagrostis inexpansa, Drosera rotundifolia,*** and ***Vaccinium*** *angustifolia* all had been decimated between 30 and ***40*** passes. ***Andromeda glaucophylla*** and ***Sphagnuzn*** moss species were classified as neither resistant nor sensitive, and both were reduced to 0% cover by 20 passes. ***Chamaedaphne calyculata,*** ***Sarracenia purpurea,*** and ***Scirpus cespitosus*** were sensitive to the passage of ATVs. ***Chamaedaphne calyculata*** and ***Sarracenia purpurea*** were eliminated by 10 passes, but ***Scirpus cespitosus,*** although reduced to less than 50% by 20 passes, still retained a trace presence after 40 passes. ***Clintonia borealis*** was the only very sensitive species, and had been reduced to 0% cover-before 10 passes. The anomaly that appears in the graph for ***Scirpus cespitosus*** (Figure 4a) is a sampling artifact, and not the result of ATV trampling.

4.4.2 Soil structure measurements

Penetration resistance varied negatively, but not significantly, with increased trampling on the test plot ($r = -.468$, $p = .063$). This was true also for bulk density. However, after 10 passes it was impossible to obtain further bulk density samples because the substrate had lost its cohesion. Moisture content increased with trampling ($r = ,790$, $R = 62.4\%$, $p = .063$) conforming to the predictive model $Y = -1987 + 20.8X$ where Y equals the number of ATV passes and X equals the moisture content.

These results, although not conclusive in themselves, do indicate general trends that increasing impact does have an effect on structure and the substrate's ability to retain moisture.

5. DISCUSSION

Discussion of the results examines three questions. 1) How susceptible to impact are the bogs on the Cape Breton Highlands plateau? 2) Is the impact from ATVs significant, and what is the extent of the effect? 3) How does ATV impact compare to the impacts from logging and mineral exploration in the study area?

5.1 SUSCEPTIBILITY OF BOGS TO IMPACTS

Bogs that are the most sensitive to impacts are those with a high water table, deep and moderate-to-well decomposed organic material, and dominated by *Ledum* shrubs; these types of bogs are very slow to regenerate from impacts (Jeglum et al. 1974; Scott and Virgo 1977; Gemmell 1979; National Wetlands Working Group (NWWG) 1988).

The bogs examined in the Highlands all had high water tables within 3 to 4 cm from the surface.

No determination was made of the degree of organic decomposition. The waterlogged nature of new peat restricts air circulation, causing the soil to become anaerobic thus slowing the decomposition process (Comeau 1971). Therefore, it may be hypothesized that on non-impacted areas of the bog peat decomposition is slow. However, on areas subject to ATV use, especially where soil tilling has taken place, aerobic conditions occur thus accelerating decomposition

Peat accumulates at a rate of 1 to 2 mm per year on North American bogs (NWWG 1988). From the results of pollen carbon dating, it appears that organic sedimentation began on the

Cape Breton plateau about 9000 years BP (Livingston and Estes 1967). Therefore, a peat depth between 9 and 18 metres would be expected. Peat depths of up to 20 metres were reported by the mining companies as determined in their exploration drilling (Hanam 1990).

As previously stated, bogs most sensitive to impacts are dominated by *Ledum* shrubs. It was observed that *Ledum* shrubs are more abundant on the main part of the bogs. Near the bog edges the *Alnus* shrubs were predominant.

These factors contribute to make the bogs in the Cape Breton Highlands sensitive to impacts.

5.2 SIGNIFICANCE OF ATV IMPACT

5.2.1 Definition of Significance

The definition developed by Beanlands and Duinker (1983) provides the basis for the discussion of the significance of ATV impact:

> Within specified time and space boundaries, a significant impact is a predicted or measured change in an environmental attribute that should be considered in project decisions, depending on the reliability and accuracy of the prediction and the magnitude of the change. (p45)

5.2.2 Spatial Boundaries

It is necessary to define-spatial boundaries to provide a context within which to ascertain impact significance.

Physically, the problem presented by ATVs on the bogs of the Highlands is not confined to a single bog or bog system. The consequences are more far-reaching. The cumulative ATV impact initiated in such ecosystems move downslope, eventually impacting larger areas (Willard and Marr 1971). On a regional scale, serious impact to the bogs could eventually affect the drainage systems of the area with consequences for major rivers such as the Cheticamp, Margaree, and North East Margaree Rivers.

The Cheticamp River is within the National Park and almost the entire study area drains into it, except for a portion of Jim Campbells Barrens which drains east toward the North East Margaree and Margaree Rivers. These also draw from the bogs on Big Barrens and Western Barrens.

Bogs act in a water storage and regulation capacity. During periods of high precipitation the amount of water stored in bogs increases with a gradual release during periods of low precipitation. This reduces the hazards posed by flooding and sustains the supply of water during dry spells. Bogs also act as water filters and purifiers. The organic matter traps metal ions, pathogens, and other toxins that deposit with precipitation (NWWG 1988).

Bogs in the Highlands have an economic as well as an ecological function. They provide flood protection, ensure a constant water supply, and protect the valuable recreational fishery of the area. Therefore, in determining a spatial reference, the system must be regarded as a whole, because the cumulative impacts of all activities of sufficient significance and magnitude which occur in the Highlands bogs will have consequences for the economy of the larger area.

5.2.3 Significance of Ecological Change

A significant impact is a predicted or measured change of an environmental attribute that should be considered in project decisions (Beanlands and Duinker 1983). Soil structure and vegetation change were the components measured in the study.

When the change in bulk density and soil moisture content is greater than 5%, and bearing capacity changes by more than 10%, significant alteration has been done to the soil structure (Crozier <u>et al</u>. 1978).

Continual ATV impact such as that received by the bogs and woods trails has significantly altered the bulk density and penetration resistance of the impacted soil (Table 3, p58). Soil moisture content varied little with impact on the bogs but changed significantly on the wooded trail. This may be attributed to the tilling action of ATVs which produces a loss of cohesion on the impacted areas of bogs. The moss is rendered into finer particles which in turn are tightly compressed to provide a similar resistance but less cohesion than on the reference sites.

The changes in the structural measurements of the test plot were inconclusive likely due to the short time between impact and measurements. If time had been allowed for the impacted area to reach a new equilibrium, **more meaningful results would have been obtained.**

In all cases vegetative cover was greatly reduced by ATV

impact. Overall cover reduction varied between 56 to 100%, both on the bogs and trail surveyed. This compares favourably with tests conducted in tundra ecosystems (Wooding and Sparrow 1979). All trails examined in the Highlands had a higher soil mineral composition on the impacted trails than on the reference sites. This indicates prolonged trampling or a very high level of trail use (Cole 1985). There was less unvegetated ground on the impacted areas of the bogs than there was on impactedareas of the trail. This may be due to ATVs not being restricted to a single trail on the bogs, thus causing impact to be felt over a wider area.

Although some bog species may be classified as resistant to ATV impact, most were found to have some degree of sensitivity when a sensitivity index was applied to the test plot vegetation. No bog species were very resistant; that is having 50% of the relative cover survive 40 passes of an ATV.

Test plot results show that 50% of the vegetation had been destroyed between 10 to 20 passes of the ATV. Because there are no other studies of this nature on the impact of ATVs on bogs, there is no basis for direct comparison. However, all researchers who have used this 50% reduction criteria agree that is a useful threshold from which to determine susceptibility to trampling. After only 40 passes, hikers had achieved a 50% cover reduction in forest and grassland ecosystems and the most damage in these ecosystems occurred with the initial impact (Cole 1985, 1988; Leonard at al. 1985).

5.2.4 Magnitude of ATV Impact

The magnitude of an impact affects its significance (Beanlands and Duinker 1983).

Between 1957 and 1984 two clubhouses and 15 km of ATV trails had been developed. The most popular destination is the Trout Lakes and the woods road system. From an analysis of the maps and aerial photography it is clear that the bogs have been used as a convenient means of travel to these two areas.

Between 1984 and 1990 few new trails had been developed in the wooded areas. ATV use has been marked by a more extensive and intensive use of already impacted bogs. ATV drivers have unrestricted freedom on the bogs and avoid driving through wet areas and quagmires. This distributes the vegetation and soil damage more widely, causing the quagmire to grow. This practice is unique to bogs. Corduroys, which are road or trail beds of logs crossing muddy areas, were constructed in similar situations in the wooded areas.

On more steep, restricted, areas of the bogs extensive quagmires have developed with deep longitudinal ruts containing more than 50 cm of standing water. These are areas where accelerated bog drainage occurs. Natural drainage takes place also and it appears to have been accelerated by ATV activity between bogs 2 and 3. On impacted areas of a bog frost enters the ground earlier in the fall, penetrates deeper, and remains in the ground longer, This creates ice dams which hold back water and in time contributes to vegetation differences between impacted and undisturbed sites (Anderson 1990).

Standing water was observed in the ruts which were created after only 20 ATV passes on the test plot. Ruts such as these which run parallel to the contour of the bog provide channels for drainage to take place. Because sphagnum requires in excess of 80% moisture to survive (Fuchsman 1986) the potential to destroy large quantities of bog is very real if drainage of the bog is accelerated.

5.3 IMPACT OF SALVAGE CUTTING

The study area has been impacted from other sources. A major woods road has been constructed and 30 hectares of forest have been removed from the study area by salvage cutting.

The salvage cutting was accomplished by clear-cutting. Although there are no studies on the specific effects of the clear-cutting operation in the Highlands, several general impacts to the soil as a result of this harvesting method have been identified (Freedman 1982).

Clear-cutting contributes to accelerated nutrient removal from the site than would less-intensive methods such as shelterwood cutting or strip and patch cutting. Within the study area, these woods operations were confined to plots of 0.6 to 13.9 hectares in size which may be considered patch cutting.

The rate of nutrient export from a clear-cut site increases due to groundwater flow and surface runoff. However, in general, these are short term **losses** of relatively small quantities of nutrient (Freedman 1982).

Soil erosion is accelerated with indirect effects such as siltation of aquatic habitats and destruction of wildlife habitat. In the study area the hanresting operation ended in 1981. No observable evidence of ongoing erosion could be attributed to clear-cutting, although, elsewhere in the Highlands, erosion due to woods road construction is an ongoing problem and road maintenance is required to upgrade and replace culverts and repair washouts. This long-term control of road erosion seems to be a project to which Stora Forest Industries is committed (Hanam 1990).

Finally, an increase in stream water yields due to the loss of evapotranspiration opportunities has been identified with clear-cutting. This declines markedly after the first year after harvest (Freedman 1982).

Numerous studies have shown that clear-cutting has many impacts, both positive and negative, on the avian and mammal populations of the forest. Studies have also demonstrated that through the proper management of harvesting operations these effects can be minimized and in many instances they can be turned to the advantage of certain animals (Telfer 1970; Freedman et al. 1981; Freedman 1982; Jordan 1986; Walters

1987). Because of the infestation of spruce budworm, the habitat structure in the study area would have changed in time and may have produced effects similar to those of clear-cutting.

At present there is no commercially viable timber remaining within the study area.

5.4 IMPACT FROM MINERAL EXPLORATION

Exploration for gold has impacted the study area. Exploration trenching is confined, by the nature of the geology, to well-drained wooded areas where its direct impact on bogs should not be felt (Hanam 1990). However, exploration activities have caused negative impacts on the bogs in other ways. Some of the bogs in the Jim Campbells Barrens have been used to transport heavy excavators and to move people and other equipment to the trenching sites. This has created an obvious scar across Jim Campbells Barrens. The exploration company employees had not realized they were damaging such a fragile ecosystem, and have avoided the bogs since being so instructed by Lands and Forests.

Although there is a requirement for the trenches to be filled in once they are no longer needed, there is no requirement for the sites themselves to be revegetated.

5.5 COMPARISON OF IMPACTS

Of the three major activities affecting the bog system in the study area, the use by ATVs is of most concern. Although an in-depth assessment of the effects of ATVs was undertaken only a preliminary assessment of the effects of clear-cutting and mineral exploration was conducted. Clear-cutting was, at the time, a major alteration of the forest ecosystem, though the spruce budworm infestation would have produced similar results. Within the study area the degree of environmental change and the magnitude of the change are small. Because it is not ongoing in this area mitigation is not a consideration. Elsewhere in the Highlands, where logging operations are ongoing, the habitat__ requirements of the wildlife are now routinely considered (Hanam 1990).

Most of the damage attributable to mineral exploration has been confined to wooded areas, a less sensitive ecosystem than that of the bogs. Any damage done to bogs in this regard has been through lack of knowledge and was halted once the situation became known. The degree of change and the magnitude of the change is less than it is with logging. Trenching operations are considerably smaller and more localized than are clear-cut sites.

In terms of spatial boundaries, change to the environment, and the magnitude of impact, ATVs pose a more significant threat to the bogs of the study area than do mineral exploration or logging. Because tile impact of ATVs is significant and will become more so in the future, management of this activity is required.

6. IMPLICATIONS FOR MANAGEMENT

The uncontrolled use of wetlands by recreational vehicles must not continue on the Highlands. Several management options are available to address this problem; this chapter presents a number of possible management scenarios and recommendations. It is not intended to present a comprehensive action plan. This would be contingent on fostering a level of commitment from Lands and Forest management to protect the bogs, a better understanding of the composition of ORV user groups, and further investigation into the ability of the impacted wetlands to recover.

6.1 THE STATUS QUO OPTION

Opting to maintain the status quo in terms of ATV use will lead to continued degradation of the bog system in the Highlands. Doing nothing implies that the bogs have no inherent value, and with zero value this resource is in danger of overuse. The problem of ATV damage will intensify in the bogs which are presently under attack. In addition, the bog system will become more extensively impacted and new bogs will likely be explored by ATV recreationalists.

This study has demonstrated that 50% of the bog vegetative cover is destroyed after only 10 passes and by 40 passes of an ATV virtually 100% of the vegetation is destroyed. As ATV rallies become popular it is possible that a trail of destroyed vegetation could result from one such event of fewer than 20 participants. Ruts resulting from this activity may accelerate bog drainage. In time there will be a differential shift in plant species to those that are more tolerant to these conditions. With an increase in ATV activity of this type quagmires will quickly spread and the ecological integrity of large areas of the bogs may be compromised.

ATV damage to the bogs has increased intensively and extensively with time. There is no evidence that this type of recreational activity will decrease. It may increase in the Highlands as other areas of the Province, where closures may be more easily enforced, become off limits to ORV use.

The impact from a four wheel ATV would likely be marginally less than that of a three wheel machine because the actual area impacted by four wheel machine is smaller. It is unlikely that a heavier machine of the same size as the standard ATV would have a substantially increased impact on the bog. During the impact tests the driver reported that after four passes the machine began to "float" with its undercarriage on the bog. This would probably be the case also for heavier machines. From this study it appears that the factors, other than repeated passage, that contributes to the impact on the bogs are the physical dimensions of the machine and the tire design.

6.2 LEGISLATED CONTROL OPTION

Lands and Forests, under the Crown Lands Act (1987) and the Off-road Vehicle Act (1987), is empowered to take the legislated control approach to managing the ATV problem in the Highlands. Although this option may be effective in a small discrete area, a number of factors militate against its effectiveness in the Highlands.

The usefulness of legislated control as an option may be seen as a function of enforcement and the size of the fine imposed. Enforcement requires costly inputs of manpower, support vehicles, and judicial personnel. This must be considered in light of the great size of the area involved in the Highlands and the likelihood of apprehension. The use of a fine as a deterrent also must be considered. A fine that would act as an example to others could possibly be seen as disproportionate to the magnitude of the individual crime. It is unlikely that this would be acceptable within the judicial system.

A consideration of the practicality and economic realities of apprehension leads one to conclude that the application of legislated controls provides at best only an "illusion of control" (Sheridan 1979, p79).

6.3 INTEGRATED MANAGEMENT OPTION

Conclusions reached by this study, and on-site observations of ATV damage, indicate that an integrated management approach is the preferred option. Such a plan would incorporate education and training, recreational planning, and consideration of alternative institutional arrangements, combined with limited legislated control (Johnson 1987).

During the summer and fall of 1990, in response to numerous complaints of illegal ATV and trail bike use, the Halifax Police Department, in combination with Honda Canada and the provincial Registry of Motor Vehicles, conducted an educational/training program in junior and senior high schools on the city outskirts. This program, in combination with enforcement, reduced the number of complaints received by 90-95% (Martin 1990). Many parents on learning, through this program, of the environmental damage done by these machines returned their kids' trail bikes and ATVs to the dealers and the kids reported that they "didn't realize the (environmental) damage" the machines could do (Martin 1990).

This program demonstrates the need for recreational planning which would consider the requirements of ATV recreationalists. The lack of ORV facilities in the Halifax area has been voiced by the Halifax Police Department and also provincially (Johnson 1987; Freedman and Willison 1989). Opportunities exist under the Trails Act (1988) to designate ATV trails and also to close specific areas to these vehicles. Opportunities also exist for private operators.

When alternative institutions are actively involved in the program the quality and effectiveness of the program is enhanced with alternative ideas. The credibility and acceptance of the program is also increased. The potential for confrontation is reduced, and the skills, knowledge, commitment, and interest of these institutions will help further the goals of the program. Local area snowmobile/ATV clubs, that already have an investment in the Highlands by virtue of their cabins, could be utilized in this regard.

An integrated management approach has several advantages over the status quo and legislated control options. Unlike the status quo option, the integrated management approach demonstrates that the environment is a resource worth protecting. The integrated approach attempts to address the causes of the problem. Finally, the application of limited legislated control in an integrated approach would act as a deterrent to those who choose to disregard the management objectives.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

ATVs should be prohibited from all bogs and wetlands in the Cape Breton Highlands. This study has demonstrated that these ecosystems are unsuitable for ATV travel as they are very susceptible to damage from recreational vehicles. Trails should be situated through wooded areas or developed in upland forests to avoid sensitive areas. Alternative trails should be closed to ATV use to permit natural regrowth to occur. Opportunities exist to include the snowmobile clubs in this exercise of rationalizing the trail systems. These trails should be constructed in such a manner as to provide an attractive alternative to the trails through the wetland areas.

Significant damage to the bogs, in terms of vegetation and soil structure damage, has resulted from ATV use of these areas. This impact has been characterized by its growth both in intensity and area1 extent.

Impact from ATVs has been determined, by this study, to be the most serious ongoing threat to bog ecosystems in the Highlands. At present this use has more potential for environmental damage than does either mineral exploration or intensive forest harvesting.

Unless a management plan is initiated, ATV use in the Highlands will increase. This relatively isolated area is attractive to ATV and snowmobile enthusiasts from as far away as Halifax. As prohibitions on ATV use are imposed in other areas of the province the pressure of ATV use in the Highlands will increase.

The results of this study, in terms of the impact of ATVs on bog, have application to bog ecosystems in general. It is equally important that all bogs and wetlands be protected from the pressures of recreational impacts such as those of ATVs.

7.2 RECOMMENDATIONS

Recommendation 1

An integrated management program, encompassing the components of education and training, recreation planning, use of alternative institutional arrangements, and limited legislated control, should be developed and instituted to control ATV use in the Cape Breton Highlands. Such a program must incorporate a commitment, by the Provincial Government, to the preservation of bogs and other wetlands.

Recommendation 2

A review of the literature and personal observations indicates that snowmobiles also have impacts on these ecosystems. Therefore, it is important that snowmobiles, trail bikes, and other off-road vehicles, be included in any management plans.

Recommendation 3

Further study is required to determine the effects of **ATVs** and other recreational vehicles on bogs during other seasons and to provide an indication of the recovery rates of bog substrate and vegetation. This will provide a better understanding of the impacts of recreational vehicles and assist in the evolution of an integrated management program.

Further study of the consequences of snowmobile impact on bog ecosystems is warranted. This subject, like that of the effects of **ATVs** on bogs, has not been widely investigated.

Recommendation 4

Damage to Jim Campbells Barrens, caused by the improper use of the bog for transportation by a mineral exploration company was noted during the field investigation. This damage resulted from a lack of understanding by the exploration crews of the importance and fragility of these ecosystems. Information courses designed to foster awareness and appreciation of these ecosystems should be a requirement for those working commercially in, or near, fragile ecosystems such as bogs or wetlands. Such courses should be made a condition of licensing agreements.

BIBLIOGRAPHY

Anderson, A.R. 1990. Telephone conversation . Lands and Forests, Truro. Nov. 21, 1990.

Banks, D. 1990. Personal communications with D. Banks, Wildlife Biologist, Dept. of Lands and Forests, Baddeck, N.S.

Beanlands, G.E. and Duinker, P.N. 1983. An ecological ***framework for environmental impact assessment in Canada.*** Institute for Resource and Environmental Studies, Dalhousie Univ. Halifax, N.S.

Berry, K.H. 1980. A review of the effects of off-road vehicles on birds and other vertebrates. In: ***Management of Western forests and grasslands for nongame birds Workshop Proceedings.*** U.S. For. Serv. Gen. Tech. Rep. INT-86 (pp 451-467).

Brodhead, J.M. and Godfrey, P.J. 1979. ***Effects of off-road vehicles on plants of a northern marsh.*** Nat. Park Serv. Boston, Mass., contract no. CX-1600-5-0001.

Bury, R.L.; Wending, R.C. and McCool, S.F. 1976. ***Off-road recreation vehicles: a research summary, 19694975.*** Texas Agr. Stn. Texas A&M Univ.

Busack, S.C. and Bury, R.B. 1974. Some effects of off-road vehicles on sheep grazing on lizard populations in the Mojave Desert: ***Biol. Conserv.*** 6(3):179-183. Relied on Berry (1980) for information.

Byrne, S. 1973. The effects of off-road vehicle use in the Mojave Desert on small mammal populations. In: Berry, K.H. (ed.) Preliminary studies on the effects of off-road vehicles on the northwestern Mojave Desert: a collection of papers. Privately Published. Ridgecrest, Calif. Relied on Berry (1980) for information.

Canadian Wildlife Service (CWS). 1977. ***Moose.*** Fisheries and Oceans and Environment Canada, Cat. No. CW69-4/1.

Cape Breton's Magazine. 1974. Wreck Cove hydro-electric investigation. ***Cape Breton's Magazine.*** **9:3-11.**

Chancellor, W.J. 1977. Compaction of soil by agricultural* equipment. ***Univ. of Cal. Bull.*** **1881.** Relied on Goudie, 1981 for information.

Chappell, H.G.; Ainsworth, J.F,; Cameron, R.A.D.; and Redfern, M. 1971. The effect of trampling on a chalk grassland ecosystem. *J. Appl. Ecol.* 8:869-882.

Chronicle-Herald. 1990. Margaree River nominated for heritage program. ***The Chronicle-Herald.*** June 27, 1990. p C11.

Chronicle-Herald. 1991. Margaree nomination OK'd. ***The Chronicle-Herald.*** Feb. 7, 1991. p12.

CHRS. 1984, The Canadian Heritage Rivers System objectives, Principles and procedures.

____. 1990. Canadian Heritage Rivers System Annual Report 1989-1990.

Cole, D. 1985. Recreational trampling effects on six habitat types in western Montana, ***Research Paper*** *INT-350.* USDA Forest Service.

Comeau, P.L. 1971. A study of five raised bogs on the Cape Breton Plateau. MSc thesis, Acadia Univ. N.S. unpublished.

Crown Lands Act. 1987. An Act Respecting Crown Lands. 1987.

Crozier, M.J.; Marx, S.L. and Grant,I.J. 1987. Off-road recreation: the impact of off-road motorcycles on soil and vegetation conditions. ***Proc. of the ninth New Zealand geography conf.*** Dunedin. Aug. 1977.

Denniston, R.H. 1956. Ecology, behaviour and population dynamics of the Wyoming or Rocky Mountain moose. ***Zoologica.*** 41:105-118.

Dept. of Development. 1986. ***The resource atlas of Nova Scotia.*** Halifax, N.S.

deVos, A. 1958. Summer observations on moose behaviour in Ontario. ***J. Mammaml. 39*** (1):128-139.

Doan, K.H. 1970. Effects of snowmobiles on fish and wildlife resources. Sixteenth Conf. of International Assn. of Game, Fish, and Conservation Commissioners. Relied on Reichens and Lavigne (1978) for information.

Doherty, P. 1971. Effects on fish and game management. In: Butler, et al. (eds.) Conf. on snowmobiles and all-terrain vehicles. Univ. of West. Ont., London, Ont. Relied on Halls (1984) for information.

Dorrance, M.J., Savage, P.J., and Huff, E. 1975. Effects of snowmobiles on white-tailed deer. ***J. Wildl. Manage.*** 39(3):563-569.

Eaton, P. 1990. Personal communications with P. Eaton, Environment

Canada, Dartmouth, N.S.

Eckstein, R.G. et al. 1979. Snowmobile effects on movements of white-tailed deer: a case study. Env. ***Cons.*** 6(1):45-51.

Forsythe, L. 1990. Personal communications with L. Forsythe, Manager fish hatchery, Fisheries and Oceans Canada, North East Margaree, N.S. Sept. 10, 1990.

Freedman, B. 1982. An overview of the environmental impacts of forestry, with particular reference to the Atlantic Provinces. Halifax: SRES.

Freedman, B.; Beauchamp, C.; McLaren, I. A.; Tingley, S. I. 1981. Forestrymanagementpractices **and** populations of breeding birds in a hardwood forest in Nova Scotia. ***Canadian Field-Naturalist. 95*** (3):307-311.

Freedman, B, and Willison, M. 1990. Unrestricted ATV use threatens environment. ***The Mail-Star. Nov. 25, 1989.***

Gardner, W.H. 1986. Water content. In Klute. ed. 1986.

Geist, V. 1963. On the behaviour and the North American moose (Alces alces andersoni Peterson 1950) in British Columbia. ***Behaviour.*** 20:377-416.

Gemell, J.R. 1979. The identification of forest sites in the Clay Belt. In Proc. 2nd. Ontario Conf. on Forest Regeneration. Ont. Ministry of Natl. Res. March 6-8, 1979, Kapuskasing. pp 42-54. Relied on NWWG 1988 for information..

Goudie, A.' 1981. ***The human impact: man's role in environmental change.*** Blackwell. Oxford, England.

Greller, A.M., Goldstein, M., and Marcus, L. 1974. Snowmobile impact on three alpine tundra plant communities. ***Environ. Conserv.*** 1(2):101-110.

Griggs, R.F. 1956. Competition and succession on a Rocky Mountain fellfield. *Ecol.* 37(1):8-20. Relied on Willard and Marr, 1971 for information.

Hancock, J.A. 1976. Human disturbance as a factor in managing moose populations. In: ***Proc of the 12th. North American Moose Conference and Workshop.*** Hancock and Mercer (eds.) St. John's, Nfld. Mar. 1976. pp 155-172.

Hanam, A. 1990. Personal communications with A. Hanam, Crown Lands Forester, Dept. of Lands and Forests, Baddeck.

Honda. 1983. ***1984 Honda ATC Big Red owner's manual.*** Honda Motor Co. Ltd.

Jeglum, J.K., Boissonneau, A.N., and Haavisto. 1974. Toward a wetland classification for Ontario. CFS, Environment Canada. Info Rep. O-X-215. Relied on NWWG, 1988 for information.

Johnson, P.W. 1987. Recreational off-road vehicle use in Nova Scotia: an investigation of the environmental impact, land-use conflicts, and management options. M.E.S. thesis, Dalhousie Univ., Halifax, N.S. unpublished.

Jordan, C. F. 1986. Ecological effects of forest clearcutting.

Keppie, J.D. 1979. Geological map of the Province of Nova Scotia. Dept. of Mines and Energy. Nova Scotia.

Lands and Forests. 1983. A submission to the Nova Scotia royal commission on forestry. Lands and Forests. Halifax, N.S.

Leonard, R.E.; McMahon, J.L.; Kehoe, K.M. 1985. Hiker trampling impacts on eastern forests. Research Paper NE-555. USDA Forest Service.

LeResche,R.E. 1966. Behaviour and calf survival in Alaska moose. M.S. thesis. Univ. Alaska, Fairbanks. Relied on Ream, C.H. 1980 for information.

Liddle, M.J. 1975. A selective review of the ecological effects of human trampling on natural ecosystems. *Biol. Conserv.* 7: 17-36.

Livingston, D.A. and Estes, A.H. 1967. A Carbon-dated pollen diagram from the Cape Bretonplateau. Can. Jour. *Bot.* 45:339-359. Relied on Comeau (1971) for information.

Luchenbach, R.A. 1978. An analysis of off-road vehicle use on desert avifaunas. Trans. Forty-third No. Am. Wildl. and Nat. Resour. Conf. Wildl. Manage Instit., Wash., D.C. Relied on Berry (1980) for information.

Martin, G. 1990. Personal communications with Const. Gary Martin, Halifax Police Dept., Nov. 22, 1990.

McLeod. R.R. 1903. ***Markland or Nova Scotia: .its history, natural resources and native beauties.*** Markland Pub. ***Co.***

McMillan, J.F. 1954. Some observations on moose in Yellowstone Park. Am. *Midl. Nat.* 52(2):392-399.

Moen, A.N. 1976. Energy conservation in White-tailed deer. Ecology. 57:192-198.

NWWG. 1988. ***Wetlands of Canada.*** National Wetlands Working Group CWS, Environment Canada.

MRAC. 1990. The Nomination of the Margaree-Lake Ainslie River System to the CHRS Program. Report of the MRAC.

Off-highway Vehicles Act. 1987. An Act to Regulate Off-highway Vehicles. ***1987.***

Osburn, W.S. 1958. Ecology of winter snowfree areas of the alpine tundra of Niwot Ridge Boulder County, Colorado. PhD thesis, Univ. of Colorado. Relied on Willard and Griggs 1971 for information.

Patton, A. 1990. Moose harvest report, 1989. *N.S.* Conservation. 13(4):8-10.

Richens, V.B. and Lavigne, G.R. 1978. Response of white-tailed deer to snowmobile trails in Maine. *Cdn.* ***Field Nat.*** 92(4):334-344.

Roland, A.E. 1982. ***Geological background and physiography of Nova Scotia.*** The N.S. Inst. of Sci. Halifax, N.S.

Roland, A.E. and Smith, E.C. 1969. ***The flora of Nova Scotia.*** The Nova Scotia Museum. Halifax, N.S.

Rutherford, L.A. and Associates. 1988. Background study Margaree River System. Prepared for Lands and Forests and Environment Canada.

Rutherford, L.A. and Associates. ***1989.*** A management framework for Canadian Heritage Rivers in Nova Scotia: Margaree River system case study. Prepared for Lands and Forests and Environment Canada.

Scott, R.D. and Virgo, K.D. 1977. A site classification system for clearcut areas in the Clay Belt. Ont. Min. Nat. Res. Kapuskasing. Unpublished. Relied on NWWG (1988) for information.

Sheridan, D. 1979. Off-road vehicles on public land. Council of Environmental Quality. Washington, D.C. Relied on Johnson (1987) for information.

Simmons, M., Davis, D., Griffiths, L., and Muecke, A. 1984. ***Natural history of Nova Scotia. N.S.*** Dept of Ed. and Dept. of Lands and Forests. Halifax, N.S.

Simms T.J.G. 1974. Information (in letter of file at SRES) from T.J.G. Simms VP and GM MacLaren Altantic Ltd. to NSPC. Nov. 5, 1974.

Singleton, M. 1973. A submission to the Select Committee on Motorized

Snow Vehicles and All Terrain Vehicles concerning snowmobiles, hovercraft, and other off-road vehicles. prepared on behalf of The Federation of Ontario Naturalists. Aug. 31, 1973.

Telfer, ES. 1970. Relationship between logging and big game in eastern Canada. ***Pulp and Paper Mag. of Canada.*** Oct. ***2.*** pp 3-7.

Trails Act. ***1988. An*** Act to Provide for Trails over Land and Water in Nova Scotia. 1988.

Walters, B. 1987. Small mammals and forestry management. Dalhousie Univ. unpub.

Wells, C. 1984. ***All-terrain vehicles on groomed snowmobile trails.*** Idaho Dept. of Parks and Recreation. Boise, ID.

Weinstein, M. 1978. Impact of off-road vehicles on the avifauna of Afton Canyon, California. U.S. Bureau of Land Manag., Calif. Desert Prog., Riverside, Calif. Rep.onCantr. CA-060-CT7-2734. Relied on Berry (1980) for information.

Willard, B.E. 1960. Ecology and Phytosociology of the Tundra Curves area, Trail Ridge, Colorado. MSc thesis, Univ. of Colorado.

____________, ***1963.*** Phytosociology of the alpine tundra of Trail Ridge, Rocky **Mountain** National Park, Colorado. PhD thesis, Univ. of Colorado.

Willard, B.E. and Marr, J.W. 1970. Effects of human activities on alpine tundra ecosystems in Rocky Mountain National Park, Colorado. ***Biol. Conserv.*** 2(4):257-265.

______________________ 1971. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. ***Biol. Conver.*** 3(3):181-190.

Wilmshurst, B. 1990. Personal communications with B. Wilmshurst, Dept. of Lands and Forests, Dartmouth, N.S.

Wilshire, H.G., Nakata, J.K., Shiply, S., and Prestegaard, K. 1978. Impacts of vehicles on natural terrain at seven sites in the San Francisco Bay area. ***Env. Geol.*** 2(5):295-319.

Wooding, F.J. and Sparrow, S.D. 1978. An assessment of damage caused by off-road vehicle traffic on subarctic tundra in the Denali Highway area of Alaska. ***Recreational impact on wildlands.*** Conf. Proceedings Seattle. U.S. For. Serv. R-6-001.

Yong, R.N. 1990. Personal communication from R.N. Yong, Director

Geotechnical Research Centre, McGill Univ. Mont. P.Q.
July 4, 1990.