ACCESS MANAGEMENT IN BRITISH COLUMBIA: A PROVINCIAL OVERVIEW

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BACKGROUND

In British Columbia, the proliferation of access over the past four decades has led to several public and resource related issues to which government must now contend. Rapid growth in the provincial forest road network and the growing popularity of four-wheel drive and off-road vehicle use has lead to a dramatic increase in public use of the forest roads and adjacent forest lands. This increase in public use has resulted in physical and human access related impacts on sensitive ecosystems, fish and wildlife populations and their habitats, and the diversity of traditional recreational experiences.

In partial response to this growing concern, resource agencies have attempted to address both the direct physical impacts of access as well as the growth in public demands on forest landscapes through a number of regional and district level access initiatives. The Ministry of Environment, Lands and Parks (MELP) and Ministry of Forests (MOF) have primarily led in this process, relying on current legislation and regulatory tools that were developed for agency-specific purposes and, consequently, have not been widely or consistently applied across the province.

Starting in the 1970s, Vehicular Access Hunting Closures (VAHC) were implemented under Section 110 of the *Wildlife Act*. This legislation prohibited the use of a motorized vehicle for the specific purpose of hunting within a defined area. The VAHCs were initiated in select areas to reduce hunting pressure and to maintain a diversity of recreational hunting opportunities. During this same period, a number of local MOF, MELP, and industry road closures were attempted. Unfortunately, these closures/restrictions were not legislatively supported and proved ineffective from an enforcement standpoint. During this same period, some public access closures were designated through the *Land Act*.

The legislative and management scope of access management was broadened in the 1980s. The *Wildlife Act* was expanded to provide MELP with authority to restrict the use of vehicles for the purpose of wildlife management on any defined road surface (Section 111(b.1)) or within a defined geographic area (Section 111(b)). Coinciding with this was the development of a local initiative that would later take on a provincial context. Co-ordinated Access Management Planning (CAMP) was developed jointly between Ministries of Forests and Environment, Cranbrook Forest District. It provided a planning framework in which all forest roads could be assigned a long-term management designation. These designations included:

Management Road	Full time forest roads open year around; however, management restrictions such as VAHCs or seasonal environmental restrictions may still apply.
Primitive Road	Maintenance is kept to minimum required to maintain vehicle accessibility, and prevent environmental damage.
Closed Road	Roads are maintained for defined period of time and then closed to all vehicle use once no longer required. Roads will be required for future use.
Reclaimed Road	Includes redundant or highly unstable access that can be fully reclaimed to other forest use.

The CAMP process was later applied extensively in Cranbrook, Invermere, and to some extent, the Golden Forest Districts. Modified versions of the CAMP process were also implemented in several other districts in the Province. Overall, the CAMP process proved to be a successful operational planning tool, but lacked proper strategic/land use direction, dedicated funding and legislative support. CAMP plans are presently outdated and no longer are being applied.

Although Section 66(1) of the *Land Act* can be applied to prohibit a specific use in a designated area (e.g., environmentally sensitive area), it is difficult to acquire and likely has no direct application to forest roads management. Sections 14(1) and 39 may limit the timeframe for occupation of Crown land by an applicant.

Recent amendments to the *Wildlife Act* (Sections 111(b) and 111(b.1) noted above) expands the authority of MELP to manage access for purposes related to wildlife management. Section 108(3)(d) allows MELP to make regulations under which boats, motor vehicles, aircraft or snowmobiles may be used for the purpose of trapping, hunting, angling or viewing wildlife. The regulation does not address non-hunting related habitat or vehicle issues and is a problem to enforce. Nonetheless, there are over 100 such designated areas across the province. Section 109(b) allows MELP to prohibit or restrict public access within areas designated for the purpose of wildlife management. To date, most of these closures have been in the Kootenay region. Section 109(c) allows MELP, with joint approval of the minister responsible for a road or highway, to temporarily close or restrict vehicular access to a given highway or road for the purpose of protecting wildlife. This regulation has not been widely used.

Currently, it is the opinion of many resource managers that the *Wildlife Act* should be used to restrict access to specific to protection of wildlife resources and the *Land Act* should be used to address the impacts of commercial recreation activities. Conversely, provincial Wildlife management staff feels that wildlife legislation is being used too often in a reactionary context to address specific issues that have been generated beyond the mandate of the Ministry of Environment, Lands and Parks. It is their shared view that access legislation should be integrated within a much broader inter-agency provincial access-planning framework.

The *Forest Practices Code* provides three new legislative components with respect to management of forest access. Section 105 allows the District Manager to protect recreational resources or manage public recreation related access issues. To date, this section has seen limited use and it has been determined by MOF that its application is limited to resolving conflicts between recreational users and for protection of a recreational resource. Sections 55 and 57 of the *Forest Practices Code* further allows the District Manager, or road permit holder, to close or restrict use of a road where there is potential for significant environmental damage to road or environment, or could endanger life or property. However, debate persists as to the definition and application as to what constitutes “environment” and “significant damage”. A further limitation of these sections is that they only apply to the road surface and thus allow for vehicular access to off road areas. Section 18(1)(n) of the Operational Planning Regulations of the *Forest*

Practices Code identifies provisions for road deactivation as a mandatory component of forest development planning.

Regional Land Use Plans and Local Resource Management Plans also direct access management and planning. The Vanderhoof Access Management Plan, for example, covers a broad range of access issues through a strategic planning approach similar to the early CAMP process. The Ft. St. James forest district Northern Long Term Roads Corridor Plan is LRMP directed while the Golden Forest District is currently developing a District Recreation Access Plan in association with Landscape Unit planning.

The above initiatives and legislative tools have had some success in addressing specific access issues in specific areas, however, the broad spectrum and range of access related issues and impacts (e.g., ecosystems, species, habitats, water and other resource and recreational values) still remains in many areas of the province. For example, the MELP Habitat Protection Branch on Access Briefing Note (February 5, 2001) identified the need for

- assessment of current legislative and regulatory tools available for management of roads and access created by forest development, with specific reference to managing impacts to fish, wildlife, their habitats and recreation values
- discussion of mining road access management has been tabled while forest road issues are discussed

In the above context, the provincial MELP Habitat Protection Branch retained the services of Nanuq Consulting to prepare a Problem Analysis around key management issues related to road access on provincial lands in British Columbia. The project involved the following components:

1. conducting an extensive literature review of to identify broad issues and concerns of road access on fish, wildlife, and habitat;
2. documenting the status, issues, and protocols pertaining to access management in each region; and,
3. reporting results including strategic and operational recommendations related to the issues and concerns identified.

This report presents these results.

METHODS

A comprehensive review of scientific and other literature pertaining to access and access related resource impacts on fish, wildlife, habitat and water resources was conducted. The geographic area considered was largely the Pacific Northwest.

Selected MOF and MELP district and regional staff from throughout the province were solicited for feedback on

a) provincial legislative and regulatory tools, and

b) regional/district access management strategies.

An access questionnaire was developed for response. The questionnaire was forwarded to a list of MELP and MOF regional and district staff identified by the project management team.

In concert with the direction of the MELP Habitat Protection Branch, mining road access management was not specifically considered.

RESULTS

A literature-derived assessment regarding the effects of forest road access on habitat, wildlife and fisheries was conducted. The tabular summary below (Table 1) outlines the general categories of habitat, wildlife and fisheries impacts associated with road access and human use identified through the literature review. The literature review results, including a comprehensive list of references, are presented in Attachment A.

Table 1: Access Categories Summary

	Road	Off-road	Water	Air
Access Related Activities	• industrial traffic • cars/trucks • off-road vehicles • non-motorized traffic	• ATVs • snowmachines • non-motorized • traffic	• motorized watercraft • non- motorized watercraft • traffic	• helicopters • fixed-wing aircraft
	Road	**Off-road**	**Water**	**Air**
Habitat Impacts	• direct habitat loss • habitat fragmentation • reduced habitat effectiveness • loss of forest interior habitat conditions • human-induced fire • invasion by non-native plants and animals • damage to soils and vegetation • spread of insects and disease	• invasion by non-native plants and animals • erosion • soil properties • human-induced fire • damage to soils and vegetation • spread of insects and disease	• biological invasions • riparian and wetland impacts • fuel deposits and spills	• industrial activities • fuel deposits and spills

	Road	Off-road	Water	Air
Wildlife Impacts	• species displacement • barriers to movement and dispersal • reduced habitat use • harassment/poaching • reduced reproductive success • sub-population fragmentation • hunting pressure • human/wildlife conflicts • problem wildlife control • habitat loss	• species displacement • barriers to movement and dispersal • reduced habitat use • harassment • poaching • reduced reproductive success • sub-population fragmentation • hunting pressure • human/wildlife conflicts • problem wildlife control	• harassment • habitat avoidance • hunting pressure • poaching • animal control	• harassment • poaching
Fisheries Impacts	• sedimentation and altered stream flows • debris flows and landslides • introduction of exotic species • restricted passages water quality • fishing pressure • riparian and wetland impacts	• sedimentation • fishing pressure • riparian and wetland impacts • stream bed and and stream channel disturbances • introduction of non-native species	• water quality • fishing pressure • disturbance • fuel deposits and spills	• fishing pressure • fuel deposits and spills

From a provincial perspective, assessment by MOF and MELP district and regional staff of current legislative and regulatory access management tools identified the following:

- All respondents considered access management to be of high to very high *management importance*.
- *Social and recreational access* issues need to be considered in access management planning. However, it was also noted that any current access management planning must necessarily consider social and recreational resource concerns.
- It was generally acknowledged that MoF should take the *lead role* in access management, with the caveat that other ministries such and Environment or Mines take responsibility if environment or mining related. An interagency or third party authority was also suggested.
- General agreement that legal objectives for access management be established through *landscape unit planning* and to a lesser extent the *Forest Practices Code*. Main advantages at the landscape level approach are greater potential for landscape-specific application, local public involvement and as a method for establishing legal objectives.
- The *primary obstacles* to access management, in order of the number of times reported by select respondents, are:

- a lack of clear across-ministries access management policy
- legislation, public participation, funding, staffing
- inventory, conflict resolution
- guidelines

The Table 2 summarizes access management strategies and operational planning initiatives, approaches, protocols and guidelines at the regional and district levels. Where needed, a brief description of the activity is provided and the issues and/or problems forwarded by reviewers are documented.

Table 2: Access Management Strategies

Access Management Strategies/Activities[3]	Description/Issue/Problems
Wildlife Act, Section 109 closures	• minimal compliance and enforcement (staff/funding constraints) • signage required
MOF and MELP Memorandum of Understandings on access	• appears to be working, but remain relatively untested
Forest Practices Code, Section 105	• development stages.
Forest Practices Code, Section 55 and Section 57	• current rationale does not meet legislative tests to impose FPC Sections 55 or 57 closures
LRMP approved with a number of areas targeted for access management planning	• staff and funds needed to complete process in a timely manner • uncertainty as to whether MOF or MELP lead?
Long Term Road Corridors Plan (Ft. St. James district)	• LRMP mandated and considers: • sensitive soils and terrain • timing of access related activities and specified wildlife and habitat concerns • 'loop' roads • access objectives for RMZs • dealt with new access – prior to development • road system inventories • identifies future main access corridors (2000) • rationalize access control points (2001) • rationalize existing road network and closure needs • did not stop native blockades
IRMP (Graham River)	• access timelines for forestry, oil and gas developments • early in process
Muskwa-Kechika Access Management Areas	• use of Wildlife Act to control recreation conflicts • not supported by non-hunting, fishing, recreation sectors/interests

[3] Existing strategic and operational planning initiatives, regional approaches, practices, protocols, guidelines

Access Management Strategies/Activities[3]	Description/Issue/Problems
Gated closures	• does not address across-region access connections • gates often left open • funding for maintenance and repairs • lack of commitment by industry and MOF to maintain closures (cost recovery through stumpage has been discussed) • people with keys accessing closed areas for hunting and fishing when general public is prohibited • often opposition by BC Wildlife Federation
Access - General	• helicopter and snowmachine access into alpine habitats (e.g., caribou, goats) • expectation that MELP should deal with fish and wildlife related access concerns • road rehabilitation to address stream sedimentation conflicts with public interests (e.g., remove bridge/culvert and/or deactivate road is least cost solution only) • deactivation standards may actually be creating unsafe situations (e.g., tank traps, berms, dirt piles across road and snowmachine use, unexpected barrier for vehicles) and related liability issues (court cases – Merrit forest district) • commercial and public recreation conficts • fish passage at existing (pre FPC) road structures • existing legislation of separate ministries does not adequately address collective access needs

RECOMMENDATIONS

Based on the literature review results (Attachment A) and feedback received from MOF and MELP regions and districts, the following recommendations are provided regarding access management in British Columbia.

1. A **provincial strategy** for access management is required.

   Comment*: Access management is a high to very high priority throughout the province. However, there currently exist varying interpretations within and between respective ministries regarding the regulatory and legislative mandates and participatory roles and responsibilities for access management. Use of some of the existing provisions has proven to be largely ineffective and limited in application. This uncertainty has reduced overall access management implementation and effectiveness with respect to wildlife, fisheries, recreation and other environmental and social values.*

2. The provincial strategy should consist of the following **components**:
   - Legislation clearly outlining *statutory obligations* of agencies (MOF, MELP, MEM) and industry

***Comment**: there are differences of opinion and interpretation regarding ultimate responsibility for management of forest road access. Management of access and associated impacts on other resource values is necessarily a joint partnership between agencies that must be defined in clear and concise terms.*

- *Policy direction* defining the provincial, regional and district roles and responsibilities for access management

  ***Comment**: policy direction for planning, implementation, public participation, funding, enforcement and follow-up 'implementation' and 'effectiveness' monitoring will be required to support the statutory obligations.*

3. Forest access **strategic and operational planning links** must be clearly defined throughout the hierarchy of planning processes.

   ***Comment**: access management coordination between planning levels needs to improve to take advantage of the planning direction provided at the strategic level (e.g., SLUP, Landscape Unit planning, public consultation, community-based decision making) thus ensuring efficient and effective connections to operational and implementation processes (e.g., forest development plans, restoration plans).*

4. Dedicated **funding** will be required for access-related planning (road inventories, public consultation), implementation (closures, signs, gates), maintenance and monitoring.

   ***Comment**: a political commitment to provide appropriate levels of funding and will be required if access management is to be effective and credible. A monitoring strategy that assesses the cost and environmental effectiveness of the access management planning process will be critical to providing feedback to the decision-makers in this context.*

ATTACHMENT A

Summary of Effects of Access Management on Fisheries, Wildlife and Habitat

There is a large body of scientific and management literature regarding the effects of access on habitat, wildlife, and fisheries. We summarize the broad issues and present a cross-section of available literature, including a number of review papers. We restrict references cited to papers that are widely available in scientific journals and in local management publications, where possible. *The End of the Road, The Adverse Ecological Impacts of Roads and Logging: A Compilation of Independently Reviewed Research* (Ercelawn 1999) is probably the most comprehensive annotated bibliography providing an overview of primary research, mostly from peer-reviewed journals, documenting the adverse ecological impacts of roads and logging on forest ecosystems. It can be located at the following website: (http://www.nrdc.org/land/forests/roads/eotrinx.asp).

ROAD ACCESS

Gucinski et al. (2000) conducted an extensive scientific literature review of the direct and indirect effects of forest roads on public lands in the United States. Trombulak and Frissel (2000) summarized the ecological effects of road systems in general. The physical nature of roads creates direct impacts on habitat, wildlife, and fisheries. Indirect effects are a result of encounters with people who travel into the backcountry on roads. In addition to the impacts discussed in this section, roads also increase the spatial extent of other activities by providing additional access to people exploring backcountry areas on off-road vehicles or with boats, bicycles, horses, skis, or on foot.

Habitat

Clearly, the greatest effect of roads on habitat is the industrial activity that usually accompanies the road building: forestry and mining. In addition, non-industrial uses can lead to extensive habitat changes. For example, firewood cutting can alter habitat available for forest-dwelling and cavity-nesting bird species (Aigner et al. 1998). Road building leads to a direct loss of habitat equal to the area of the road, as well as a "road effect zone" (Forman 2000) on either side, which is characterized by effects such as reduced productivity in areas disturbed by road-building and maintenance activities (Smith and Wass 1979, 1980, Forman 2000). Studies in eastern forests have consistently found that 4-5% of the land base is lost to roads (Gucinski et al. 2000). The effects of forestry and roads together extend to an area 2.5-3.5 times the actual area occupied by these land uses (Reed et al. 1996). Roads may also lead to an increase in areas dedicated to recreation, such as forest service campsites and park facilities.

Roads generate extensive impacts by altering geomorphic processes; that is, by altering erosion rates and flowpaths (Gucinski et al. 2000). Effects can range from increased sedimentation in streams (Megahan and Kidd 1972, Bilby et al. 1989) to higher peak flows and catastrophic events like landslides (Reid and Dunne 1984, Jones and Grant

1996, Larsen and Parks 1997). Traffic volumes influence the ecological effects of roads; for example, sedimentation rates in streams are correlated with traffic rates (Bilby et al. 1989).

Soil disturbance caused by road building and maintenance plays a major role in the dispersal of invasive and/or exotic plants (Hobbs and Huenneke 1992, Zink et al. 1996, Kotanen 1997). Also, roads serve as corridors of dispersal by either natural (*e.g.* wind, water) or human-related agents (*e.g.* vehicles), allowing invasive species to penetrate farther into areas than otherwise possible (Lonsdale and Lane 1994, Greenberg et al. 1997). Soil disturbance tends to favour exotic species over native plants (Kotanen 1997), and invasions may be enhanced where roadside and native soil characteristics differ the most (Greenberg et al. 1997).

Roads constitute distinct habitats (Baker and Knight 2000), and their interface with other ecosystems creates extensive edge habitats that extend the ecological influence of roads beyond that of the road width (Forman 2000, Forman, *in press*). Roads increase edge and reduce interior habitat conditions, fragmenting previously contiguous patches of habitat (Mader 1984, Reed et al. 1996, Baker and Knight 2000). Roads create 1.5-2 times more edge habitat than forest clearcuts of similar area (Reed et al. 1996).

Road networks change the pattern of fire on a landscape, allowing access for better fire suppression and providing a network of firebreaks (Salazar and Gonzales-Caban 1987, Swanson et al. 1990). Ultimately, this can lead to different biotic communities in roaded versus unroaded areas (Hann et al. 1997). Rates of human-related ignitions have been associated with high recreational use in areas with high road densities (Hann et al. 1997).

Wildlife

Effects of roads on wildlife can be classified into 2 categories: direct effects caused by the physical presence of a road (i.e., habitat loss, habitat fragmentation, barriers to movement), and indirect effects, caused by interactions with people travelling on roads (i.e., collisions, hunting, poaching, animal control measures, harassment). Wisdom et al. (2000) documented the negative effects of roads on 65 terrestrial vertebrate species in the interior Columbia basin. In fact, few species appear to be immune to the effects of roads (Trombulak and Frissell 2000).

Species such as grizzly bears (*Ursus arctos*) are particularly susceptible to road effects because of their low reproductive rates and the mortalities that inevitably result from confrontations with humans who travel into bear habitat on backcountry roads. Mortalities can be the result of legal hunting, collisions with vehicles, poaching, or animal control kills resulting from chronic interactions with humans (Knight et al. 1988, Horejsi 1989, Mattson et al. 1992, Mattson et al. 1996). Roads and access management are consistently cited as major factors influencing human-caused grizzly bear deaths (McLellan and Shackleton 1988, Mace et al. 1996). Similarly, gray wolves (*Canis lupus*) suffer from the increase in human contact that accompanies road access (Mech 1970, 1995, Van Ballenberghe et al. 1975, Thurber et al. 1994, Fritts and Carbyn 1995). Most wolf mortalities are caused by humans, and most occur near roads (Boyd and Pletscher

1999). Increasing road densities are correlated with declining wolf populations (Thiel 1985, Jensen et al. 1986, Mech et al. 1988).

Cole et al. (1993) found that severely limiting access to roads reduced harassment and poaching of elk (*Cervus canadensis*). Roads are an important source of direct mortality for other ungulates (Groot Bruinderink and Hazebroek 1996), including mountain caribou (*Rangifer tarandus caribou*; Hamilton et al. 2000), mountain goats (*Oreamnos americanus*; Singer 1978), bighorn sheep (*Ovis canadensis*; Chapman 1999), moose (*Alces alces*; Bangs et al. 1989), and deer species (*Odocoileus* spp.; Trombulak and Frissel 2000).

Smaller animals such as reptiles and amphibians typically suffer high rates of mortality as a result of roads, particularly those that actively use roads for heating and cooling, or species that commonly move between wetland and upland habitats (Trombulak and Frissell 2000). Declines in the abundance of amphibians have been linked to road densities and traffic rates (Fahrig et al. 1995).

Roads affect the availability of habitat for wildlife not only because of the physical space they occupy, but also because many species avoid road corridors. Elk and deer avoid areas near roads (Rost and Bailey 1979, Lyon 1983, Rowland et al. 2000), and avoidance increases with increasing traffic volumes (Johnson et al., 2000). Degree of avoidance can depend on the availability of nearby suitable habitats (Rost and Bailey 1979). Black bears (*Ursus americanus*), grizzly bears, and wolverines (*Gulo luscus*) can also be displaced from areas near roads (Mattson et al. 1987, McLellan and Shackleton 1988, Kasworm and Manley 1990, Mace et al. 1996, Forman et al. 1997, *c.f.* Hornocker and Hash 1981). A large number of bird species avoid nesting, or suffer lower reproductive success, near roads (Trombulak and Frissell 2000).

Roads fragment wildlife habitat, affecting movements and dispersal of several species. These barriers can lead to genetic changes in populations (Mader 1984, Reh and Seitz 1990, Forman et al. 1997, 1998). Black bears avoid crossing roads with high traffic volumes, and may alter the location of their home ranges in response to high road densities (Brody and Pelton 1989) Road crossings of bobcats (*Lynx rufus*) are also inversely related to traffic volumes (Lovallo and Anderson 1996). Cougars (*Puma concolor*) may avoid crossing improved dirt and hard surface roads (Van Dyke et al. 1996). Wolves are generally restricted to landscapes with low road densities (Thiel 1985, Jensen et al. 1986, Mech et al. 1988, Mladenoff et al. 1995). Roads can serve as movement barriers for small mammals (Mader 1984, Merriam et al. 1988); the smaller the mammal and the larger the road, the more effective the barrier (Oxley et al. 1974), although even minor roads can inhibit movements (Mader 1984, Swihart and Slade 1984, Merriam et al. 1988).

Habitat fragmentation can isolate herpetofauna populations; persistence in the remaining matrix of habitat patches depends on species-specific relationships with patch size, shape, isolation, and habitat patch quality (Maxell and Hokit 1999). Forest-dwelling songbirds are also adversely affected by forest fragmentation. So-called interior species are less

common in smaller forest fragments (Keller and Anderson 1992) and breeding success of forest-dwelling species is correlated with patch size (Paton 1994). Breeding success is lower and the rate of brood parasitism higher along edges than in the interior of forest patches (Paton 1994).

The increase in edge habitat that is related to habitat fragmentation leads to changes in faunal communities. Some bird species specialize in edge habitats and become more abundant along road right-of-ways (Hanowski and Niemi 1995); however, high rates of mortality can result from collisions with vehicles (Vestjens 1973). Small mammal communities are more diverse and many species occur at higher densities near roads (Adams and Geis 1983).

Fisheries

Impacts of roads on fisheries are primarily a result of changes in channel morphology caused by the physical presence of roads (Harr and Nichols 1993), and secondarily by increases in fishing pressure that result from the human access afforded by the roads. The result is that road density at a landscape scale has been correlated with the declines of non-anadromous salmonids (Lee et al. 1997).

Roads directly alter the hydrology of stream channels and slopes, resulting in several changes that can ultimately affect the quality of the aquatic environment for fishes. Changes include: increasing sediment loads, changes to channel widths, depths, and local gradients, changes in habitat features (*e.g.* pools and riffles), and higher water temperatures (Alexander and Hansen 1986, Furniss et al. 1991, Harr and Nichols 1993, Lee et al. 1997, Gucinski et al. 2000). Unpaved roads create sediments that can reduce the productivity, growth, and survival of fishes (Alexander and Hansen 1986, Newcombe and Jensen 1996). Increases in fine sediments in stream gravel have been linked to decreases in fry emergence (Everest et al. 1987, Chapman 1988, Scrivener and Brownlee 1989, Young et al. 1991, Weaver and Fraley 1993). Densities of juvenile salmonids in rearing areas decrease as fine sediment concentrations increase (Alexander and Hansen 1986, Everest et al. 1987). Fine sediments can also reduce the winter carrying capacity of streams (Thurow 1997). Sediment loads are correlated with the number of culverts and stream crossings in a forest, and trout populations are inversely correlated with the abundance of these structures (Eaglin and Hubert (1993). Removal of canopy cover can increase stream temperatures, resulting in a variety of negative effects, including poor fecundity, migratory disruptions, and increased disease susceptibility (Beschta et al. 1987, Hicks et al. 1991). Road densities are also related to low frequency but catastrophic events such as large floods, landslides, and fires that can have profound effects on streams (Lee et al. 1997).

Roads commonly create barriers to movement and migration of fishes (Clancy and Reichmuth 1990, Furniss et al. 1991). The failure to accommodate fish passage in road construction and other developments has fragmented and isolated many previously migratory salmonid populations (Kershner et al. 1997, Rieman et al. 1997). Poorly engineered stream crossings and culverts that result in high water velocities can impair

fish passage (Belford and Gould 1989) and result in widespread habitat losses (Beechie et al. 1994).

Roads also increase the likelihood of invasions by exotic species into the aquatic environment (Lee et al. 1997). These invasions may be accidental (*i.e.* transmission of Eurasian milfoil, *Myriophyllum spicatum*, on boats and trailers), or purposeful (*i.e.* introduction of exotic fish species to increase fishing opportunities). In addition to impacts on native fisheries, these changes can also affect water-dependent terrestrial species, such as amphibians and reptiles (Maxell and Hokit 1999).

Road building practices have improved in recent years, but many older roads remain and continue to affect fish habitats (Furniss et al. 1991, Lee et al. 1997).

OFF-ROAD ACCESS

Off-road access can be categorized as non-motorized (*e.g.* hiking, skiing, biking, horseback riding), all terrain vehicles (ATV's; including motorcycles), and snowmobiles. Most of the concern about off-road access has been related to motorized traffic (Webb and Wilshire 1983); however, non-motorized impacts can be similar where traffic volumes are large (Youmans 1999).

In general, the impacts of off-road access are much less than those created by a road network because roads create a greater (and often permanent) physical disturbance that conveys greater numbers of people engaged in a wider range of activities into the backcountry. However, off-road access can create extensive impacts that are spread widely on the landscape (Knight and Gutzwiller 1995). Many of the impacts discussed in previous sections related to soil erosion, stream sedimentation, and wildlife harassment also apply to this category of access activities.

Habitat

Off-road access results in habitat modifications through disturbances to vegetation and soil, and through changes to microclimates (Boyle and Samson 1985, Knight and Cole 1991). Impacts are greatest in alpine (Willard and Marr 1970, Bell and Bliss 1973), bog, and arid areas (Douglass et al. 1999). Wet-soil areas are at greatest risk of trampling by human foot traffic (Willard and Marr 1970). Trampling can lead to plant community changes and can create favourable environments for invasion by exotic species (Douglass et al. 1999).

Horses are more destructive to trails than humans on foot, and motorcycles are more destructive than horses on upslopes (Weaver and Dale 1978). The soil compaction, vegetation damage, and changes in community structure associated with ATV use can last decades or centuries (Blackburn and Davis 1994). The habitat changes associated with off-road access create favourable environments for weed invasions, the seeds for which are carried by ATV's or in hay for horses (Blackburn and Davis 1994, Douglass et al. 1999).

Snowmobiling in wetland areas can affect the distribution and abundance of wetland vegetation (Sojda 1978). Compacting of snow by snowmobiles in any habitat lowers subnivian temperatures and reduces the over-winter survival of plants and soil microbes (Douglass et al. 1999). In addition, compacting reduces the water-holding capacity of snow, leading to greater peak flows in spring. Compacting also increases melt times and creates a partial gas seal over vegetation (Neumann and Merriam 1972). Mechanical disturbance associated with snowmobiles damages plants above the snow line (Neumann and Merriam 1972).

Wildlife

Hunting is an obvious impact on wildlife that is facilitated by off-road access to the backcountry. Poaching usually follows hunting; for example, hunters shoot wolves misidentified as dogs or coyotes, or they intentionally kill wolves (Claar et al. 1999). Boyle and Samson (1985) reviewed the effects of non-consumptive outdoor recreation on wildlife and found them to be overwhelmingly negative. Many of the impacts are indirect; for example, domestic dogs accompanying humans into the backcountry can be significant vectors of disease for gray wolves (Boyd et al. 1993).

Human intrusions can negatively affect the species richness, abundance, reproductive success, survival, and habitat use of birds near trails (Riffell et al. 1996). Generalist bird species are more common and specialist species rarer near trails than in areas away from human intrusion (Gutzwiller et al. 1998, Miller et al. 1998). The zone of influence of a trail may extend up to 100 m (Miller et al. 1998). Non-motorized recreation activities have also been linked to declines in herpetofauna (Garber and Burger 1995).

Hikers can disrupt the normal behaviour of a variety of other wildlife species (Boyle and Samson 1985). Harassment of ungulates can lead to increased metabolism, resulting in illness, reproductive costs, and death (Geist 1978). Many studies have documented the displacement of ungulates from preferred habitat by recreation-related activities (Boyle and Samson 1985, Freddy et al. 1986, Canfield et al. 1999). Deer, moose, and elk react to cross-country skiers (Ferguson and Keith 1982, Freddy et al. 1986, Cassirer et al. 1992). Wolves and black bears may abandon dens disturbed by humans (Lindzey and Meslow 1977, Claar et al. 1999). In addition, habituation can be a serious problem with many wildlife species near hiking trails, particularly species that are dangerous to humans such as grizzly bears (Jope 1985). Grizzly bears respond more strongly to humans on foot than to regular motorized traffic to which they have habituated (McLellan and Shackleton 1989).

Faunal changes that occur with increased human presence (*e.g.* domestic dogs and cats, ravens, *Corvus corax*, racoons *Procyon lotor*, coyotes, *Canis latrans*) may adversely affect native wildlife populations. For example, many amphibians and reptiles suffer high rates of mortality because of the presence of these opportunistic predators (Maxell and Hokit 1999).

Additional impacts occur when humans are on ATV's. Numerous studies have documented negative effects of ATV's on ungulates (Canfield et al. 1999). ATV use

along riparian banks and through wetlands may impact semi-aquatic mammals such as beavers (*Castor canadensis*), mink (*Mustela vison*), river otters (*Lutra canadensis*), and muskrats (*Ondatra zibethica*; Waller et al. 1999). Studies have directly linked the use of ATV's with vegetation changes and associated declines in herpetofaunal and small mammals (Busack and Bury 1974, Bury et al. 1977).

The effects of snowmobiles on wildlife depend on how machines are operated and on the characteristics of snow cover and underlying habitats (Bury 1978). Snowmobiles pack snow and reduce its insulating value, thus affecting the subnivian environment for small mammal (Jarvinen and Schmid 1971, Neumann and Merriam 1972, Bury 1978). Effects include disruptions of movements and higher over-winter mortality. Neumann and Merriam (1972) found that changes in snow structures caused changes in the mobility of snowshoe hares (*Lepus americanus*) and red foxes (*Vulpes fulva*). Snowmobile use on ice in winter may affect semi-aquatic mammals (Waller et al. 1999).

Snowmobile trails can enhance the winter mobility of deer (Richens and Lavigne 1978); however, they also increase the mobility of predators such as wolves (Paquet et al. 1996). Deer avoid trails frequented by snowmobiles, and increase their movements in response to relatively light traffic, but there is little evidence of longer-term effects (Dorrance et al. 1975, Eckstein et al. 1979). Hear rates of white-tailed deer (*Odocoileus virginianus*) increase when exposed to snowmobile noise (Moen et al. 1982).

Fisheries

Off-road traffic near waterways can affect fish-bearing habitat. Trails along streams affect riparian vegetation and increase sedimentation rates in streams, ultimately affecting the quality of the aquatic environment for fishes (Murphy et al. 1981; see above). Snowmobiles affect water quality by introducing contaminants associated with the inefficient burning of gasoline in two-stroke engines. Lead and hydrocarbon pollution generated by two-stroke engines is known to affect fish populations (Bury 1978, Waller 1999). In addition, human consumption of fish from contaminated lakes and streams poses a public health risk (Bury 1978).

WATER ACCESS

Water access involves both motorized (*e.g.* propeller-driven and jet boats) and non-motorized (*e.g.* canoes, kayaks) activities. Very few studies have addressed the effects of water access activities on habitats common in British Columbia; however, results of some studies from other jurisdictions are relevant.

Habitat

Motorboats are associated with a number of impacts on aquatic habitats, including: shoreline erosion, water pollution, sediment resuspension, increased turbulence and turbidity, and damage to aquatic plants (Waller et al. 1999). Non-motorized boating can also be associated with high levels of aquatic pollution, mostly from related human activities (King and Mace 1974). Boating and angling are significant vectors of exotic weed distribution (Johnstone et al. 1985).

Wildlife

The general effect of water access on wildlife is related to the increase in human activity in backcountry areas that comes with the access opportunities. These effects range from increases in hunting pressure and harassment of wildlife, to vegetation changes (Boyle and Samson 1985). These impacts are outlined in other sections. In addition, there are some wildlife species that are particularly susceptible to disturbances from boating activities. One example is the harlequin duck (*Histrionicus histrionicus*), which nests in low densities on fast-flowing wilderness streams and rivers (Campbell et al. 1990). Studies have repeatedly shown that nesting harlequin ducks are disturbed by the presence of humans, and that breeding densities decline with increases in recreational activities such as whitewater rafting (Hamann et al. 1999). Common loons (*Gavia immer*; Hamann et al. 1999) and ospreys (*Pandion haliaetus*; Levenson and Koplin 1984) are also considered to be sensitive to disturbance on and near water.

Fisheries

The most obvious effect of water access on fish is an increase in mortality associated with increased fishing pressure. In addition, boats or wading anglers may cause areas to be abandoned by fish or may reduce the breeding success of fish populations by driving guarding males off nests (Waller et al. 1999). Effects in shallow water are more severe than in deeper water (Mueller 1980). Garrad and Hey (1988) demonstrated a relationship between boat traffic, increased turbidity, decreased macrophyte abundance, and decreased fish abundance and species diversity.

Up to 30% of fuel used in two-stroke marine engines is discharged unburned into water (Douglass et al. 1999). The effect of these discharges on aquatic organisms is poorly understood (Cole and Landres 1995); however, there is compelling evidence that fish populations are affected by pollution associated with two-stroke engines (Bury 1978, Waller 1999).

AIR ACCESS

Access to the backcountry by helicopter or fixed wing aircraft falls into 2 categories: overflights and flights involving landings. Obviously, the potential for impacts is greater when aircraft land. Impacts of overflights are generally restricted to harassment of wildlife.

Habitat

We assume that the effects of helicopter and floatplane landings on terrestrial and aquatic habitats are minimal.

Wildlife

Hunting pressure increases in remote areas where aircraft are used to discharge hunters. Impacts of landings and overflights on wildlife are otherwise restricted to harassment. Landings generate more harassment events than overflights because aircraft make closer approaches to animals.

The response of ungulates to aircraft has been widely studied. Of particular management concern in British Columbia is the effect of overflights on mountain caribou (Simpson and Terry 2000) and mountain goats (Wilson and Shackleton, *in press*). Overflights of caribou in Labrador by military aircraft have been shown to reduce calving success (Harrington and Veitch 1992). No studies have linked demographic declines of mountain goats with aircraft overflights; rather, most studies have measured short-term behavioural reactions (Foster and Rahs 1983, Côté 1996). Other ungulates have demonstrated varying responses to overflights by different aircraft, including: bighorn sheep (Krausman and Hervert 1983, Bleich et al 1994), mule deer (*Odocolieus hemionus*; Krausman et al. 1986), and white-tailed deer (Hood and Inglis 1974). Effects of overflights on other wildlife species occurring in British Columbia are poorly documented.

Fisheries

The effect of air access on fisheries is generally restricted to the effect of increased fishing pressure that accompanies access into otherwise inaccessible areas. In British Columbia, these areas include high elevation lakes that have low natural productivity and are sensitive to fishing pressure.

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