The Gray Wolves (Canis lupus) of British Columbia's Coastal Rainforests

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RAINCOAST CONSERVATION SOCIETY

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- Findings from Year 2000 Pilot Study
- Conservation Assessment

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Chris has a BSc. in Biology and Environmental Studies from the University of Victoria. A professional biologist, he has studied other elusive wildlife species including Marbled Murrelets, Canada Lynx, and Northern Goshawks. Paul first introduced Chris to wolf research in 1998 when Chris worked for the Central Rockies Wolf Project. Chris plans to continue coastal wolf research as a graduate student. He operates Darimont Environmental.

Paul Paquet

Dr. Paul Paquet is an internationally recognized authority on mammalian carnivores, especially wolves, with research experience in several regions of the world. He worked as a biologist for the Canadian Wildlife Service for many years. Now, he is Senior Ecologist with Conservation Science, Inc., an international consultant and lecturer, and Director of the Central Rockies Wolf Project. Paul is a longtime fellow of World Wildlife Fund Canada and was the architect of the World Wide Fund for Nature's Large Carnivore Initiative for Europe. He is an Adjunct Associate Professor of Environmental Design at the University of Calgary, where he supervises graduate student research. He is also an Adjunct Professor at Brandon University, Manitoba and Faculty Associate at Guelph University, Ontario. He previously held academic appointments at University of Alberta in the Department of Biology and at University of Montana in the School of Forestry. He is a member of several government, industry, and NGO advisory committees concerned with the conservation of carnivores. Dr. Paquet has written more than 90 scientific articles and reports and was co-editor of the book *Wolves of the World.* His current research focuses on conservation of large carnivores and effects of human activities on their survival.

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The Raincoast Conservation Society

Raincoast is a non-profit organization promoting research and public education with the goal of protecting and restoring coastal rainforest ecosystems and all their interdependent life forms. Using the principles of Conservation Biology and on-the-ground field research, we strive to better understand the region's lands, seas, and wildlife to assist local communities, conservation planners, and government agencies design and implement sustainable land and marine use plans. We believe that vibrant sustainable economies and fully functioning ecosystems are not mutually exclusive but instead are interrelated.

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PREFACE

"Not everything that counts can be counted,
and not everything that can be counted counts."

Albert Einstein

Herein, we present the most comprehensive scientific report to date about the wolves of mainland coastal British Columbia. The report is intended for scientists and informed non-scientists alike, although most readers will have no difficulty understanding the content. We offer scientific information, our perspectives, and recommendations to First Nations, government, industry, conservation planners, and the global public. We hope these efforts will inform the decision-making processes that determine the future for wolves, deer, and all life along the central coast of British Columbia.

To formulate recommendations about a never-before-studied, low-density, and elusive animal that roams a remote area requires large investments of time and money. Consequently, this season marked the first and largely descriptive stage in a multi-year research project. Although we have invested considerable resources assembling information, carrying out literature reviews, and conducting fieldwork, our investigation to date is not long-term, comprehensive, or always scientifically rigorous. Accordingly, Dr. Ian McTaggart-Cowan, a member of the scientific panel that reviewed this report, cautioned that a lack of empirical knowledge compromises the certainty in which we can express our recommendations. We agree. We note, however, that even greater uncertainty faces the forest industry and the provincial government, which are proceeding with large-scale clearcut logging.

Although a paucity of information compels us to speculate on many biological issues, we do so using the best available information about coastal wolf-deer systems. Where necessary and appropriate we infer from published studies conducted elsewhere, our own experiences, and the experience of other researchers. Throughout the report, we are careful to distinguish fact from inference, speculation, and professional opinion.

Our concluding recommendations reflect our current knowledge and the fundamental principles of Conservation Biology. We adhere to the "precautionary principle" which recognizes the inherent uncertainty in managing natural systems and stresses the sound judgment in erring on the side of caution. In either business (Slywotsky 2000) or the ecological environment (Kareiva *et al.* 1999) and in the face of high uncertainty and poor information, the "precautionary principle" or "precautionary conservation" is required. The history of resource management shows that ignoring uncertainty results in failure to take needed conservation actions.

FOREWORD

The conservation of large mammalian predators such as wolves is one of the greatest challenges facing wildlife scientists, managers, and policy makers. Industrial society has left little room for these large animals and the space that remains is often fragmented, isolated, and too small. The people of British Columbia and southeast Alaska are fortunate stewards of some of the largest and most magnificent forests left in North America. Further, these coastal temperate rainforests represent one of the rarest ecotypes in the world. Indeed, the governments of Canada and the United States are trustees of a treasure that is of international importance. Unfortunately, these "trustees" usually are mired in the regnant paradigm of resource exploitation and short-term economic gain. The myopic focus of policy makers on logging, mining, and tourism likely will have severe consequences for wolves and other large mammalian predators.

We can only hope that reliable scientific knowledge concerning the ecology and conservation of wolves and other predators will help to enlighten policy makers and enable them to make sound, informed decisions (if only wolves could vote). To that end, the work of Chris Darimont and Dr. Paul Paquet described in this report is an excellent beginning. Their research is a natural complement to my own in southeast Alaska and it will help to shed light on the complex ecology of wolves in the coastal forests of Alaska and British Columbia. It is clear, too, that their work would not have been possible without the foresight and financial support of the Raincoast Conservation Society.

I cannot overemphasize the enormous difficulties that are faced when doing research on wolves in these temperate rainforests. One rarely has the opportunity to observe wolves in the thick forest cover. In addition, the scale of the endeavor, the logistic problems of living in remote places, and the irascible temper of the weather often make even the simplest of objectives a challenge. Chris and Paul have pioneered the use of DNA markers and noninvasive methods to study wolves, which will help to overcome some of those problems.

Wolves are what they eat, and this report emphasizes that deer are the most important food resource for wolves. The conservation of wolves requires the conservation of deer and their habitat. Forest management that eliminates habitat for deer will ultimately eliminate wolves. Although clearcut logging can create abundant forage for deer during snow-free months, the forage is of poorer quality because of the buildup of secondary chemical compounds in the plants such as tannins and phenols, and it generally senesces by early fall. In contrast, old-growth forest produces forage for deer that is available year round and is of much higher nutritional quality. Further, when clearcuts reach the pole or stem-exclusion stage after about 25-30 years, the dense forest canopy shades out understory vegetation and creates a biological desert for deer. In one of our study areas in Alaska, the density of deer was reduced from 27 deer/km^2 in productive old-growth forest to one deer/km^2 in second-growth forest greater than 40 years old. A reduction of this magnitude will have severe consequences for wolves and for the consumptive use of deer by people.

It is my hope that the work that Chris and Paul have begun will continue. I look forward to collaborating with them and sharing information and ideas. I believe that our work will contribute to the conservation of wolves and shed light on the complexities surrounding the interactions of wolves, their prey, and human beings.

David Person *Ph.D. candidate — University of Alaska (Fairbanks); Primary Investigator — Southeast Alaskan coastal wolf research, Alaska Department of Fish and Game.*

EXECUTIVE SUMMARY

Information about wolves is essential for current planning processes for the coast. To reduce complexity and increase efficiency, planners and managers often use focal species to develop conservation plans to preserve an area's biodiversity.

The mainland coast of British Columbia (BC) is a remote area that is comparatively free from human-caused disturbance. However, concerns about current and anticipated increases in industrial forestry activity have prompted conservation biologists to investigate the biota in this understudied region. We were commissioned by the Raincoast Conservation Society to study coastal wolves so that information could be incorporated into ongoing conservation planning and education efforts. The summer of 2000 marked the pilot season of a multi-year research project. Our team spent more than 240 person days in the field during the summer and fall seasons. We surveyed 18 mainland watersheds and 21 islands in an area greater than 29,000-km^2 (land and sea). We examined scats to describe wolf diet, collected genetic material, and noted other natural history observations. We also conducted an extensive review of scientific literature and made estimates of population size and human-caused mortality. Our key findings are as follows:

- **Natural History**
  Coastal wolves are morphologically distinct from their interior relatives. Den sites we located (n=2) were in low elevation old-growth forests. Late summer litter sizes averaged 3.3 (n=3). We estimate that human-caused mortality is approximately 2.3% annually of a total population of 406-473 wolves in the 19,300-km^2 study area (land base). We found abundant wolf sign in low elevation old-growth forests and in estuarine areas.

- **Distribution**
  We observed wolf sign on all islands and all mainland valleys surveyed, including islands separated by more than 5-km from other landmasses. Based on these surveys, we postulate that the potential for an island to support a persistent population of wolves depends on the presence of deer, density of deer, area, and isolation.

- **Diet**
  Deer constituted the dominant portion of wolf diet, which is similar to findings near our study area. We observed deer remains in about 83% of all scats, and in 93% of scats in summer. We also detected beaver, black bear, goat, bird, and garbage as food items. In addition, we noted marine foods in diet, especially spawning salmon in the fall.

- **Genetics**
  Although analysis is ongoing, genetic differentiation has been identified in mitochondrial DNA sequenced from scat samples (Conservation Genetics Laboratory, UCLA). A new haplotype, or version of mitochondria, which can be thought of as a unit of variation within the genetic profile of a species, has been discovered. We expected to observe morphological and genetic differentiation because of this population's evolutionary history and isolated habitat. From a conservation perspective, genetic diversity is an important element of biodiversity.

The second part of this document is a Conservation Assessment in which we identify and evaluate conservation concerns relevant to wolves and their prey in Pacific Northwest forests. Drawing from empirical evidence from adjacent southeast Alaska and Vancouver Island, as well as from our own observations, we contend that current forestry activities threaten the future of viable and well distributed populations of wolves and deer. Although clearcutting may provide initially abundant forage, available evidence suggests that it will likely reduce the forest's *long-term* carrying capacity for deer. Moreover, logging roads will provide access for increased legal and illegal killing of wildlife, including deer and wolves. Current BC Ministry of Environment and forest company management efforts are likely ineffective at comprehensively and effectively addressing the threats we have identified. In Part three we offer our summary conclusions and recommendations to First Nations, government, industry, conservation planners, and the global public.

PART I

YEAR 2000 PILOT STUDY

Den sites we located were in low elevation old-growth forests, and late summer litter sizes averaged 3.3. We estimated human-caused mortality to be approximately 2.3% annually of a total population of 406-473 wolves in the 19,300-km^2 land base of the study area. We found wolf sign on all islands and all mainland valleys we surveyed. Deer constituted the dominant portion of wolf diet. Although analysis is ongoing, our collaborators at UCLA have identified a new haplotype, or version of mitochondria, in DNA sequenced from scat.

1 INTRODUCTION

1.1 Background and Rationale

The wolf (*Canis lupus*) population of mainland coastal British Columbia (BC) has never been the focus of scientific inquiry. Government data are few and forestry companies have invested very limited resources to gather information. Museums and academic institutions have never carried out intensive research. The study of this apex predator provides an entry point to better understanding the complex terrestrial community on the coast. In addition to accumulating scientific knowledge, this study is important for several reasons:

- VULNERABILITY OF WOLVES TO INDUSTRIAL FORESTRY

  Conservation biologists, environmental organizations, and the public are expressing considerable concern about current logging practices in coastal BC. Substantial evidence suggests that coastal wolves are vulnerable to industrial forestry and the associated effects (Kirchhoff 1991; Person and Ingle 1995; Person *et al.* 1997; Person 2000). In adjacent southeast Alaska *(Map 1)*, a USDA Forest Service-sponsored interagency committee recently expressed concern about long-term wolf population viability and distribution due to extensive timber removal. Further, in 1993, the U.S. Fish and Wildlife Service was petitioned to list wolves in southeast Alaska as Threatened under the Endangered Species Act (Person *et al.* 1996; Person 2000).

- PHYLOGENETIC STATUS OF COASTAL WOLVES REQUIRED FOR MANAGEMENT

  The phylogenetic status of coastal wolves has yet to be resolved (Kirchhoff 1991; Shields 1995; Person *et al.* 1996; R. Wayne *pers. comm.*). This is a matter of considerable conservation importance. Formalized taxonomy can provide the basis for recognition and protection of unique, rare, or isolated populations. Modern and defensible designations of subspecies and management units now require the use of molecular data (O'Brien 1994). Our study is employing the biochemical analyses necessary for defining a genetics based "management unit" (Moritz 1994) to guide conservation planning.

- INFORMATION FOR LAND-USE PLANNING

  Information about wolves is essential for current planning processes for the coast. To reduce complexity and increase efficiency, planners and managers often use focal species to develop conservation plans to preserve an area's biodiversity (Wilcove 1993; Simberloff 1998). Wolves have been described as a keystone species (Power *et al.* 1996) and, owing to their large home-range requirements, can function as an umbrella species (Shrader-Frechette and McCoy 1993; Noss *et al.* 1999).

To date, the provincial government's Central Coast Land Resource and Management Plan (CCLRMP) (Lewis *et al.* 1997) has focused primarily on grizzly bear (*Ursus arctos*)-salmon (*Onchorynchus* spp.) systems. Wolf-black-tailed deer (*Odocoileus hemionus sitkensis*) systems have not been mentioned. However, two important distinctions between grizzly bears and wolves must be noted: 1) grizzly bears rarely occur on the coastal islands of BC and; 2) female home ranges on the coast (Hamilton *et al.* 1986; MacHutchon *et al.* 1993) are smaller than those of coastal wolves (Person *et al.* 1996; Person 2000). Woodroffe and Ginsberg (1998) warned that wider ranging animals are more likely to become extinct in a reserve of a given size, likely because ranging behaviour mediates contact with humans.

Considering the ecological, economic, and cultural importance (see below) of wolf-deer systems in this area, we believe this oversight compromised the primary goal of the planning process, which was to ensure *representation* in protected areas design. A recent non-governmental Conservation Areas Design for the coast (Jeo *et al.* 1999) identified the wolf as a species that should be included in a comprehensive design but one for which crucial distribution and demographic data were, at that time, lacking. Jeo *et al.* (1999) instead used grizzly bear and salmon as focal species. The Spirit Bear Conservancy Proposal *(Map 2)* (McCrory *et al*. 2000) recognized the need to protect wolf-deer predator-prey systems, but also cited the lack of data on coastal wolves. In addition, the Kitasoo Land Use Plan (Kitasoo Band Council 2000) places high cultural and ecological values on wolf-deer systems.

- Value of Comparative Information

  Although wolves have been studied intensively throughout the world, few data exist on populations that occupy pristine habitat and are immune from persecution. Few humans live in our study area and very little habitat degradation has occurred. Thus, information from this population may be interpreted as the "baseline" or "gold standard" against which many aspects of wolf research conducted elsewhere can be compared.

In this document we report our findings from the Year 2000 pilot study. We also summarize all available information about coastal wolves. In addition, the report serves as a Conservation Assessment as it reviews concerns relevant to wolves and deer in Pacific Northwest forests, for which there is considerable empirical support from adjacent southeast Alaska.

1.2 North American Distribution: Past and Present

The gray wolf is thought to have first colonized North America about 700,000 years ago (Nowak 1979; Kurten and Anderson 1980). Historically, wolves ranged in every habitat that supported their ungulate prey. During the last few hundred years, however, wolves have been the prey of humans. By the 1950s, habitat loss, the use of firearms, traps, and poisons dramatically reduced numbers of wolves and effectively isolated them in remote areas of Canada, Minnesota, and Alaska (Mech 1970, 1995).

The distribution of wolves was reduced by over 40% in North America. In the coterminous United States, wolves survived only in Minnesota and on Isle Royale (Thiel and Ream 1994). In Canada, wolves were extirpated in the Maritime Provinces, south of the St. Lawrence River in Quebec, southern Ontario, the prairies, and the lower mainland of BC (Theberge 1977, 1991; Carbyn 1983).

Habitat loss and persecution also greatly affected wolves that inhabited the temperate rainforests of North America's West Coast. These forests once stretched from California to southern Alaska (Schoonmaker *et al.* 1997). About half have been severely altered by clearcut logging and other human activities, especially in California, Oregon, and Washington (Jeo *et al*. 1999). Wolves were extirpated in these states.

Wolves of coastal rainforests are now restricted to British Columbia and southeast Alaska. Recently, however, the future of this remnant population has been in question. Biologists have predicted a decline in deer and wolf populations in southeast Alaska due to extensive timber removal (Kirchhoff 1991; USDA Forest Service 1991, 1996; Person *et al.* 1996; Person 2000). Wolves are also at risk of over-exploitation in this area, owing in large part to human access to wolf habitat provided by logging roads (Kirchhoff 1991; Person and Ingle 1995; Person *et al*. 1996; Person 2000).

Wolves of coastal BC are vestiges of the past, inhabiting a fraction of the former range of their species. They occupy some of the most pristine wolf habitat remaining on Earth and enjoy relative freedom from persecution by humans. Consequently, they form a globally significant population.

2 STUDY AREA

2.1 Physical and Ecological Landscape

The central coast of BC is extremely isolated. Boats and airplanes provide the only access to this largely roadless area. Deep fjords divide mainland valleys. Tidal waters separate islands that vary from <one-km^2 to >2200-km^2 (Princess Royal Island). Inter-island and mainland-island distances within the study area range from several metres to approximately 5.4-km.

The study area is roughly delineated by Gribbell Island (53° 32' north, 129° 00' west) in the north to Cape Caution (51° 10' north, 127° 47' west) in the south, and is oriented parallel to the coastline. The area of land is approximately 19,300-km^2 in the 29,700-km^2-study area *(Map 1)*. The Coast Mountains and the Pacific Ocean bound the study area to the east and west respectively. A small number of settlements, primarily of First Nations people, occur in the study area. Waglisla (Bella Bella) served as project headquarters during the field season.

Most of the low elevation forest falls within the Coastal Western Hemlock biogeoclimatic zone (*sensu* Krajina 1965), characterised by a wet and temperate climate. Annual precipitation exceeds 350-cm in most areas. Thirty-year average annual snowfall varies from 86-cm (Bella Bella) to 155-cm (Ocean

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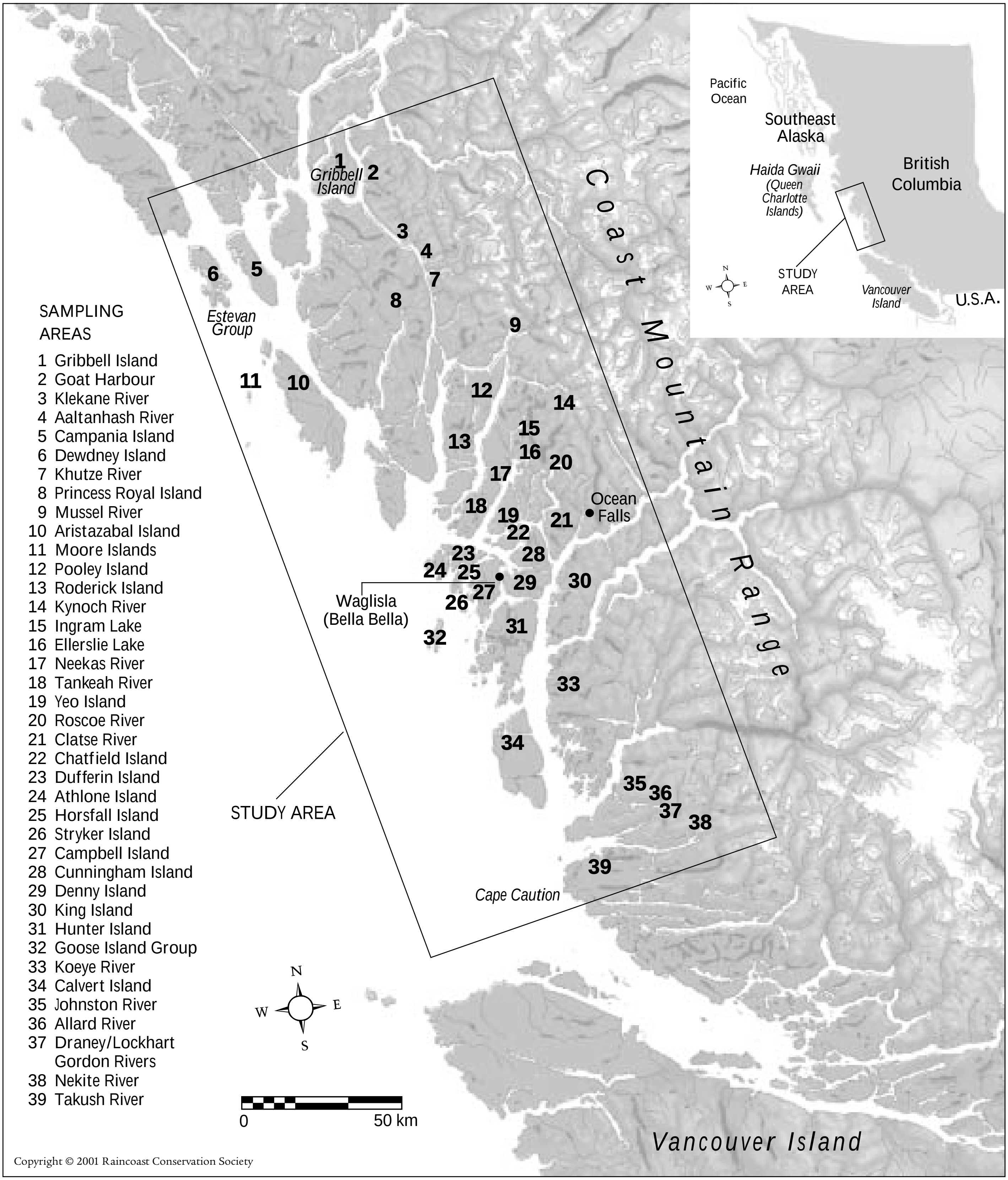
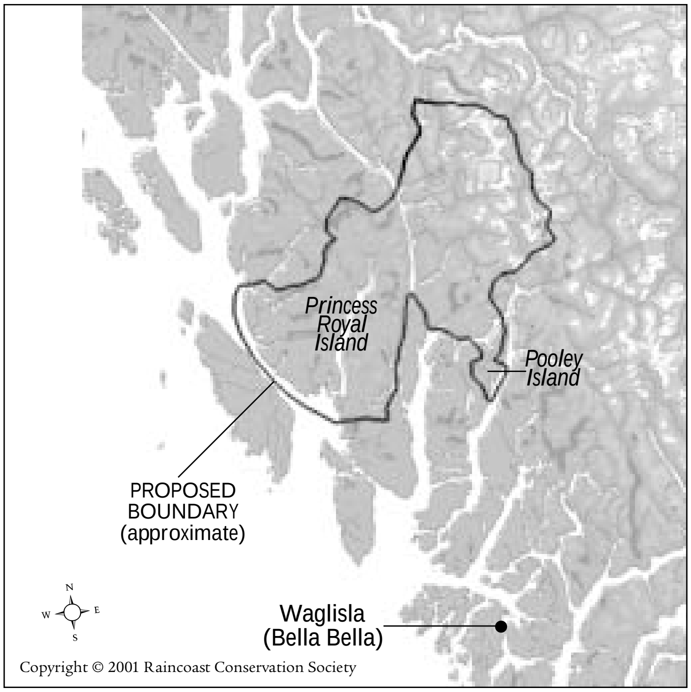
The central coast of BC is extremely isolated. Boats and airplanes provide the only access to this largely roadless area. The Coast Mountains and the Pacific Ocean bound the study area to the east and west respectively.

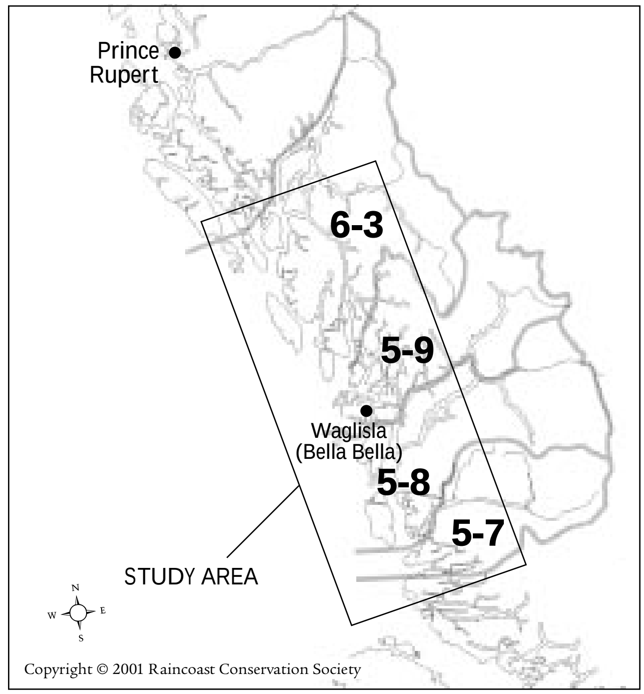
Troup (Deer) Passage, near Bella Bella, BC.



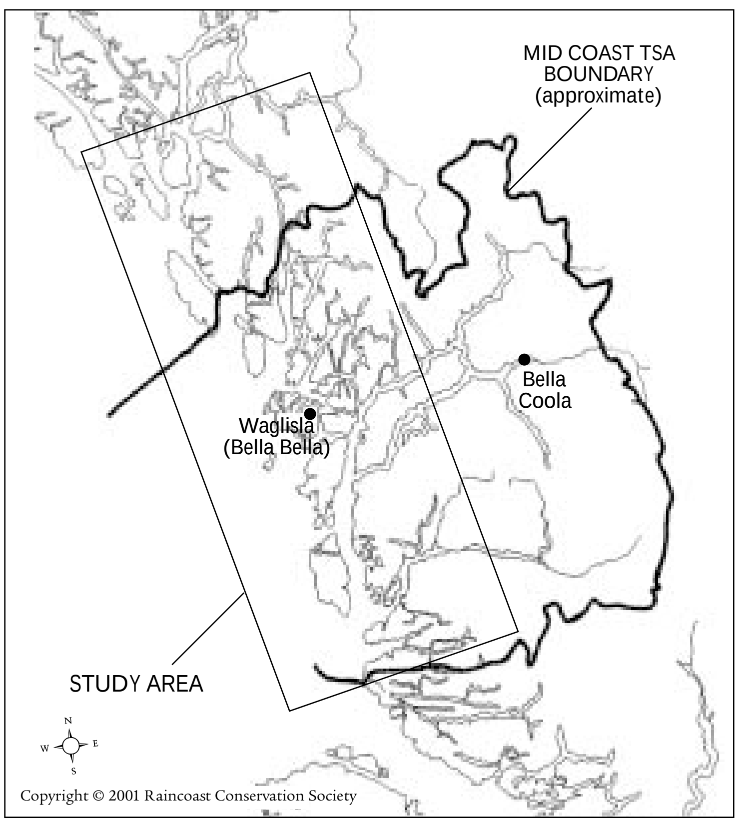
MAP 1 Study Area, sampling sites, and other important landmarks.



MAP 2 Spirit Bear Conservancy Proposal.



MAP 3 Ministry of Environment Management Units in study area.



MAP 4 Mid Coast Timber Supply Area.

Falls) (Environment Canada 1991). Snowfall is much greater in the inland portions of the study area but no weather data are available.

Western hemlock (*Tsuga heterophylla*), amabilis fir (*Abies amabilis*), western redcedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*) and yellow-cedar (*Chamaecyparis nootkatensis*) dominate the wetter maritime subzones common in the study area. A well-developed shrub layer of ericaceous species (Alaskan blueberry [*Vaccinium alaskaense*], red huckleberry [*V. parvifolium*], salal [*Gaultheria shallon*]) and hemlock/fir regeneration is typical. The herb layer is typified by deer fern (*Blechnum splicant*) and a well-developed moss layer dominated by *Rhytidiadelphus loreus, Hylocomium splendens,* and *Kindbergia oregana* is common (Pojar and Meidinger 1991).

Prey species available to wolves include Sitka black-tailed deer, beaver (*Castor canadensis),* river otter (*Lutra canadensis*), other mustelids, birds, and rodents. Moose (*Alces alces*) inhabit the eastern fringes of the study area. Mountain goat (*Oreamnos americanus*) are found in the rocky terrain of mainland valleys and are observed rarely on (some) islands (McCrory *et al.* 2000). Marine resources such as spawning salmonids and beached marine mammals are also available. Possible competitors are grizzly and black bear (*Ursus americanus)*, wolverine (*Gulo gulo*), coyote (*Canis latrans*), and cougar (*Felis concolor).*

Cultural Landscape

The study area included seven First Nations territories: the Heiltsuk, Kitasoo-Xaisxais, Nuxalk, Oweekeno, Hartley Bay, Haisla, and Gwa'Sala-'Nakwaxda'xw. Most sampling occurred in Heiltsuk Territory where the wolf is an important cultural symbol. In the creation story of one of the founding Heiltsuk tribes, a wolf fathers the first children of this group. One child remains a wolf and serves as a protector of the people. His siblings stay in their human form and create many of the gifts to the people including winter ceremonials, bighouses, and salmon. The mother marks the wolf father with ochre paint, giving him a reddish tinge that is still common to gray wolves of the area. Notably, the story takes place at a river system where wolves are frequently observed today.

3 KNOWLEDGE ABOUT COASTAL WOLVES

Although First Nations peoples have considerable knowledge about the natural history of BC's coastal wolves, comprehensive written information was absent before this study. Nevertheless, an extensive search of peer-reviewed and 'gray' literature yielded valuable information, which we have summarized.

3.1 Royal British Columbia Museum

The Royal British Columbia Museum has information regarding the presence of wolves on some islands in the study area. This information, however, is incomplete (D. Nagorsen *unpub. data*). Also, a museum mammal guide reported some morphological characteristics of a formerly acknowledged coastal subspecies, *C.l. fuscus* (Cowan and Guiguet 1975).

3.2 Government of British Columbia

The BC Ministry of Environment (MOE) has no field-collected data on wolves of the coastal mainland (M. Austin *pers. comm.*; S. Sharpe *pers. comm.*). The Ministry's estimates of human-caused mortality are tallied at a Management Unit (MU) level *(Map 3)*, which provides a poor degree of resolution. MOE collects information from guide outfitters regarding the location of killed animals but these data are unavailable to independent scientists.

The Ministry estimates a provincial population of 8,000 wolves, based primarily on hunting statistics (Archibald 1989). A separate coastal estimate has not been attempted. In 1978, relative density in coastal areas was classified as "moderate/plentiful", which is the highest category (MOE *unpub. data*).

3.3 Forestry Companies

Three large forestry companies operate in the study area: International Forest Products (Interfor), Western Forest Products (WFP), and Weyerhaeuser. Only WFP has published material that includes wolves (Henderson *et al.* 1996). The authors reported wolf sign on all larger islands and most mainland sites they surveyed.

3.4 Conservation Area Designers

McCrory *et al.* (2000) estimated densities of wolves and deer for the region encompassed by the Spirit Bear Conservancy Proposal, which is a subset of the study area and includes island and mainland locations *(Map 2)*. Densities of wolves on island portions were estimated to be 30–35 wolves/1000-km^2 based on data from Prince of Wales Island, southeast Alaska (Person 1997). Owing to less suitable habitat for deer, McCrory *et al.* (2000) applied half that density to mainland areas.

These authors also developed a GIS-based wolf-deer model. The model predicts seasonal presence of deer, and thus wolves, in different areas depending on habitat characteristics. The authors estimated that 11.5% of total reserve size provides suitable deer winter range based on criteria of elevation, slope, forest type, and stand volume class.

3.5 Universities

Friis (1985) investigated cranial differences among previously recognized subspecies in the Pacific Northwest. Multivariate analysis of skull measurements suggested that two groups of wolves were present in BC: a large northern type and a smaller coastal type. Statistical affinities among *ligoni* (southeast Alaska), *crassodon* (Vancouver Island), and *fuscus* (mainland coast from Oregon to Alaska) were found.

3.6 Model Systems

Although data are lacking for wolves of mainland coastal BC, wolf studies conducted elsewhere can provide insight into their ecology. The most comparable area is southeast Alaska *(Map 1)* where wolves have been studied extensively on the Alexander Archipelago (Kirchhoff 1991; Person and Ingle 1995; Person *et al.* 1996; Person 2000 and others). These islands are less than 300-km from our study area and are similar to coastal BC in climate, topography, and ecology (Pojar and MacKinnon 1994). The wolves show morphological affinity to wolves of coastal BC (Friis 1985; Nowak 1996) and the dominant prey is also Sitka black-tailed deer. In contrast, the human population is larger and logging and road building have been much more extensive in southeast Alaska. These important differences provide information about the ecological consequences to wolf-deer systems of large-scale logging in the Pacific Northwest.

The ecology of wolves on Vancouver Island *(Map 1)* has also been studied (Scott and Shackleton 1980; Hebert *et al.* 1982 and others). In contrast with the central coast of BC, Vancouver Island lacks water barriers and industrial forestry has severely altered the landscape. Moreover, some ecological studies of wolves were conducted concurrently with wolf control efforts by the Ministry of Environment (*see* Janz and Hatter 1986).

Although climate and ecology differ considerably, the long-term Isle Royale wolf study in Michigan can provide valuable insight into predator-prey dynamics on islands (Peterson *et al.* 1984a; Peterson and Page 1988) and the consequences of genetic isolation (Wayne *et al.* 1991).

4 KNOWLEDGE GAPS ADDRESSED IN THIS STUDY

4.1 Descriptive Natural History

Wildlife research requires an early descriptive stage. This is especially true for a low density and elusive study animal for which no previous data exist. One goal of this pilot study, therefore, was to observe and describe the natural history of this population of coastal wolves. This included gaining insight into morphology, population parameters, and habitat use.

4.2 Distribution

If local conservation planning is to incorporate wolves, information about their distribution is critical (Jeo *et al*. 1999). Herein, we provide the first report on the distribution of the central coast wolf population.

4.3 Diet

Wolves have evolved into efficient predators of ungulates and smaller prey. We hypothesized that black-tailed deer would be the principle food item based on data from nearby areas that show a high proportion of deer in the diet of wolves (Vancouver Island — Scott and Shackleton 1980; southeast Alaska — Kohira and Rextad 1997). Many wildlife scientists believe that clearcut logging can permanently reduce the capability of forests to support deer in the Pacific Northwest, especially in areas and years with deep snowfall (Wallmo and Schoen 1980; Alaback 1982; Schoen and Kirchhoff 1985, 1990; Schoen *et al.* 1988; Kirchhoff 1994). Wolf populations are known to decline as prey numbers decline (Gasaway *et al.* 1983; Peterson *et al*. 1984a; Fuller 1989).

Many wildlife scientists believe that clearcut logging can permanently reduce the capability of forests to support deer in the Pacific Northwest, especially in areas and years with deep snowfall. Wolf populations are known to decline as prey numbers decline.

Year 2000 logging, Gribbell Island, BC.

4.4 Genetics

Accurate taxonomy is crucial to conservation efforts because it can identify unique taxa, and in doing so can provide the basis for their protection. Modern and defensible designations of subspecies and management units now require the use of molecular data (Moritz 1994; O'Brien 1994). Our primary goal this season was to collect genetic material to resolve a long-standing phylogenetic debate.

Early taxonomic investigations, based on skull measurements, identified 24 subspecies of gray wolves in North America (Goldman 1944; Hall 1981). Three unique coastal subspecies were identified: *C.l. ligoni, fuscus* and *crassodon.* However, the most widely accepted systematics today, also based on skull measurements, designate wolves of coastal BC and Alaska as isolated members of *C. l. nubilis* — a group that includes populations from central Canada and Minnesota (Nowak 1996; *Figure 1).*

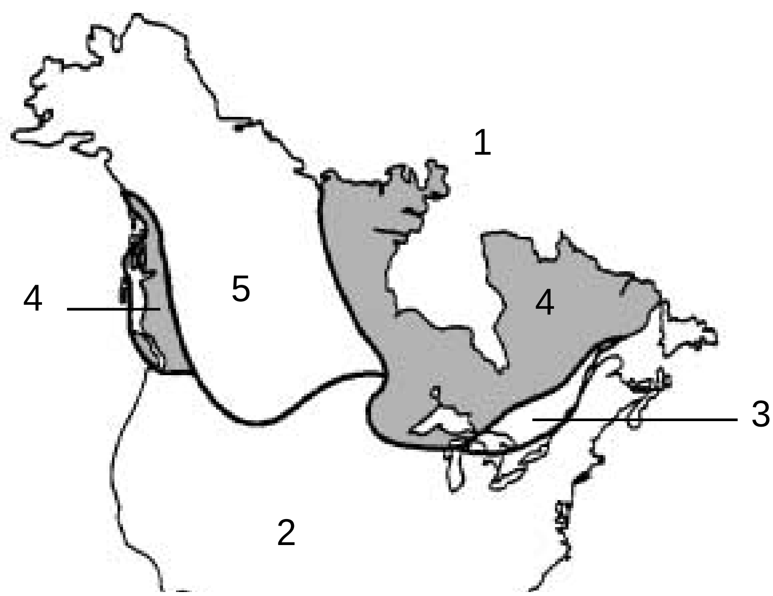


FIGURE I
Current distribution of North American wolves showing the five subspecies recognized by Nowak (1996):

1 *arctos*
2 *baileyi*
3 *lycaon*
4 *nubilus*
5 *occidentalis*

Note the disjunct nature of the subspecies currently recognized for wolves inhabiting the study area *(nubilis).*

Map adapted from Nowak (1996).

This classification is consistent with speculation that wolves re-colonized the Pacific Northwest from continental North America after the Wisconsin glaciers receded, following the northern expansion of deer (Klein 1965). Deer are thought to have re-colonized southeast Alaska (and thus coastal BC) approximately 8,000 years ago (Jull 1993). If this is the case, we expect the coastal population of wolves to be more closely related to southern (and extirpated) gray wolves. Although wolves are highly vagile, the Coast Mountain Range *(Map 1)* likely poses restriction on gene flow (Person *et al.* 1996; Person 2000), thus creating an isolated environment on the coast.

As an alternate hypothesis to Klein (1965), we speculate that wolves and ungulate prey may have persisted on a series of ice-free refugia on the coast during periods of glaciation. Analysis of mitochondrial DNA (mtDNA) identified distinct coastal and continental black bear lineages, which may have been isolated from each other for 360,000 years (Byun *et al.* 1997, 1999). The authors suggested this was likely the result of pre-glacial differentiation owing to geographic isolation and the preservation of distinct mtDNA lineages in coastal glacial refugia.

Wolves are more vagile than black bears and whether admixture among wolves would obscure any differentiation due to possible pre- or inter-glacial isolation is unknown. However, regardless of whether wolves recolonized BC's coast approximately 8,000 years ago or have persisted there longer, we expected some genetic differentiation given their morphological differentiation (Friis 1985; Nowak 1996), and their isolated and unique coastal habitat. In a preliminary investigation of mtDNA, Shields (1995) observed a fixed allelic substitution in southeast Alaskan wolves not found in wolves from interior Alaska and the Yukon. Moreover, genetic variation in coastal wolves was absent at eight other nucleotides within the 310 base pair mitochondrial region analysed. After evaluating these data, Shields (1995) recommended that the historical *ligoni* classification of coastal Alaskan wolves be restored and suggested acquiring corroborating data from wolves of coastal BC.

5 METHODS

5.1 A Non-invasive Approach

Wildlife research often employs radio telemetry: the subject animals are captured, immobilized, and fitted with a transmitter. This technique yields high quality data but can impose considerable stress on study animals (Cuthill 1991). Wolves occasionally die following capture and immobilization (*i.e.* Kreeger and Seal 1990). Radio telemetry studies are also expensive, logistically difficult to conduct in remote areas, and often hazardous to researchers. At this stage, we are committed to developing and using non-invasive investigative methods. The techniques pioneered in this study will contribute to assessing the efficacy of these new approaches (Cooper 1998).

One promising research method is the use of faecal material to identify and monitor the distribution of wolves. In the past, faecal material from wolves was used primarily to derive dietary information. Now, laboratory protocols are being developed so that microsatellite DNA derived from faeces can identify individual wolves. This information can be used with mark/recapture models to estimate population size and home range (*i.e.* Taberlet *et al.* 1997; Kohn *et al.* 1999).

5.2 Sampling

We spent 242 person days in the field. Our primary goal was to collect genetic material to investigate phylogeny on a continental scale. Survey design was not constrained by equal sampling of habitat types. Boats provided the only transportation in the mostly roadless study area. We selected locations from a subset of those where we considered moorage safe. At all locations, our surveys rarely extended greater than five-km inland. However, coastlines are dominant features in the archipelago study area.

Within each sampling location, we selected sandy beaches, estuaries, and forests of the beach fringe to begin our search for wolf sign. Wildlife trails, often next to watercourses, allowed us to travel inland. We also surveyed logging roads when encountered and often circumnavigated beaver ponds and other wetlands. Also, we walked forest ridgelines.

5.3 Descriptive Natural History

We classified all wolf sightings separated by >20-km as independent. Individual wolves were categorized into “gray” or “black” colour phases. We recorded all bedding, den, and rendezvous sites encountered. Although wolves scavenge, we classified areas with prey remains surrounded by wolf sign (tracks, hair, and/or scat) as kill sites. In addition, we made estimates of population size and human-caused mortality.

5.4 Distribution

Survey effort differed at each location from a few hours to several days. We determined presence of wolves by noting tracks, howling, and/or scat. To standardize water distances between islands, we calculated length as the shortest route between the outside edges of two landmasses, which often included small islands as intermediate "stepping stones".

5.5 Diet

Typically, dietary investigations of scat are conducted in a laboratory with a microscope, thus requiring large investments of time, labour, and money. We have initiated this process and results will be forthcoming. In the interim, we assessed diet by field examining all scat encountered (n=612) (Person and Ingle 1995). Although this method will not detect all prey items, we believe we met our primary goal, which was to estimate the percentage of scat that contained deer remains. Hair from deer has distinct diagnostic features (Mayer 1952) that allow identification in scats from cursory field examination. We also had voucher samples of hair from deer, beaver, and black bear. We identified salmon by presence of teeth, bone, and vertebrae. If uncertain, we classified items as "unknown" rather than inaccurately assigning them.

We divided our sampling effort into two seasons: summer (May 22 - July 31) and fall (September 12 - October 3). Because scat decomposes rapidly in the wet climate of our study area (Wallmo *et al.* 1962; D. Person *pers. comm.*), our sampling likely represents summer and fall diet respectively.

We used two indices to describe diet: an occurrence/faeces index (*i.e.* Dibello *et al.* 1990) and occurrence/item index (occurrence of a food item relative to total items in all scats — *i.e.* Theberge *et al*. 1978). Because occurrence/faeces index exceeds unity when grouped due to multiple prey species in some scats, we performed statistical analyses using the occurrence/item index (Kohira and Rextad 1997). We compared use of each food item between seasons using chi-square tests and applied a Yates correction for continuity (Zar 1984).

5.6 Genetic Analysis

Scat collection protocol followed a modified version of Wasser *et al*. (1997b). We collected a sub-sample of approximately 15-g and preserved it in a 1:3 ratio with 95% ethanol or Queen's buffer. We used rubber gloves as a precaution against the potential occurrence of *Echinococcus granulosus* and *E. multilocularis* in wolf scat — parasites that can cause serious health problems in humans (Meyer and Olsen 1971). We collected wolf hair in areas of recent wolf activity (bedding, rendezvous, kill, den, and trail sites) and stored it with silica desiccant until a freezer was available. We obtained a small number of hide samples from taxidermists. We collected three bone and teeth samples from animals found dead.

Collaborators at UCLA extracted mitochondrial DNA from faeces following Kohn *et al.* (1999). A 470-base pair fragment of the control region was amplified. Sequences generated were compared to those previously described in the literature and to unpublished data.

At this stage, we are committed to developing and using non-invasive investigative methods.

Heiltsuk wolf researcher Chester Starr collecting genetic material at a bedding site recently used by wolves.

6 RESULTS AND DISCUSSION

6.1 Descriptive Natural History

Colour Phases

Cowan and Guiguet (1975) commented that the black colour phase is "common" on BC's coast but provided no statistics. Sixteen of 64 (25%) wolves sighted on islands and the mainland of the study area were black. Proportionately more black animals were sighted on the mainland compared with islands, but this difference was not significant ($\chi^2_1 = 1.95$, $p = 0.163$). Black phases reported in hunting and trapping records from the islands of the Alexander Archipelago and coastal Alaskan mainland were 20% and 50% respectively (Morgan 1990).

Of the 48 grey animals, at least 19 had a conspicuous brownish red tinge, a feature responsible for the population's historic subspecific name *fuscus*. Coastal wolves are thought to have more brownish underfur than interior subspecies (Cowan and Guiguet 1975). This distinctive tone is relatively rare in North America. Red coloured wolves are common in Ontario and Quebec but debate continues whether these animals are gray wolves, red wolves (*C. rufus*), or coyote hybrids (P. Paquet *pers. comm.*). Wildlife Managers and Conservation Area Designers often assign high value to morphological differentiation of a wildlife population. For example, hunters are not allowed to kill white individuals of the Spirit Bear (*Ursus americanus kermodei*) (Ministry of Environment 1999), a subspecies in which roughly one in 10 bears is white (W. McCrory *pers. comm.*). The Spirit Bear is also the focal animal in a Conservation Areas Design for part of the central coast of BC (McCrory *et al.* 2000; *Map 2*).

Reproduction and Home Sites

Most wolves are sexually mature at 22 to 34 months. Person (2000) estimated that birth in nearby southeast Alaska occurs during the last two weeks of April. Average litter size is four (n=6) (Person 2000). We counted minimum litter sizes at one den site in early July, and at two rendezvous sites in late July and mid September (n=3). We noted two groups of four and another of two (mean=3.3).

All known den sites in southeast Alaska (n=22) were in low elevation old-growth forests within 100-m of fresh water and under the roots or fallen trunks of large diameter trees. Ten were next to beaver ponds or streams with active beaver colonies (Person 2000). We located two active den sites with the same characteristics, although we did not observe nearby activity of beaver. One den site was only two-m from a beach; both were below 50-m elevation.

We counted minimum litter sizes at one den site in early July, and at two rendezvous sites in late July and mid September (n=3). We noted two groups of four and another of two (mean=3.3).

Wolf pup at den site, coastal BC, July 2000.

We also visited a den site used in 1997 that was approximately 14-m from an estuary edge and 10-m in elevation.

Person (2000) noted high pup survivorship, possibly due to the availability of spawning salmon at weaning. We observed two rendezvous sites in the late summer in salmon-bearing estuaries. Open, grassy areas are common features of rendezvous sites and estuaries may often provide this habitat feature for coastal wolves.

Kill sites

We observed seven carcasses of prey killed by wolves. Four were deer; one of which was a fawn. We could not determine sexes. All kills occurred on or next to forest trails. In an estuary, we found an otter whose remains were separated by approximately 100-m. Credible witnesses observed two other instances of predation by wolves on otters.

In a forest/estuary transition zone, we encountered skeletal remains of a black bear surrounded by wolf scat containing bear hair. We observed porcupine (*Erethizon dorsatum*) remains in a boggy area, approximately 10-m from the closest tree where this rodent could have found refuge. Also, we noted the remains of a Sandhill crane (*Grus canadensis*) in an estuary.

Habitat Use

Wolves of southeast Alaska select low elevation forests throughout the year, especially during the pup-rearing season (Person 2000). The author reported that approximately 50% of radio relocations were below 84-m, 95% less than 396-m. Within this low elevation domain, there is evidence that wolves select old-growth forests near lakes and streams, and avoid seral forests and clearcuts. At elevations below 100-m, wolves strongly select old-growth forests and avoid clearcuts and roads (Person 2000). Although we did not systematically assess habitat use and thus cannot comment on habitat selection, we found abundant wolf sign (>500 scat) in low elevation (<300-m) old-growth forest, particularly near water bodies. Wolves also left scat and tracks on inactive logging roads. We found wolf sign in and next to many estuaries.

Bedding Sites

We found many hair samples in bedding sites, which typically were slight oval depressions of approximately 70 x 45-cm. They were often under large fallen trees or against the base of large standing trees. Many were next to forest trails that follow the beach or estuarine edge. We speculate that the views typically afforded through tree boughs may provide opportunity for wolves to remain concealed while watching for prey on the estuary or beach. Ballard and Dau (1983) also reported bedding sites that provided views but noted no selection for areas under evergreens. Coastal wolves may select canopy cover due to the study area's extremely wet climate. Substrate was exclusively in well-drained sites and of material that would offer thermodynamic value, such as conifer needle litter, squirrel middens, and sand. We often found scat in or next to the beds.

Population Estimate

Using these density figures, we estimate 406-473 wolves in our 19,300-km^2-study area during late winter.

We expanded on the work of Person (1997) and McCrory *et al.* (2000) by applying a 30-35 wolves/1000-km^2 density estimate to the islands (60% of total land base) and applying half that density to the mainland of our study area. Mainland areas have comparatively greater rock, ice, and other unproductive areas and have been described as less desirable habitat for deer (Klein 1965). Moreover, deer pellet-group surveys have suggested lower density of deer in mainland regions of southeast Alaska compared with adjacent islands (Kirchhoff 1996). Using these density figures, we estimate 406-473 wolves in the 19,300-km^2 study area during late winter. Wolves reach densities of >30/1000-km^2 in nearby southeast Alaska in areas of high density of deer (Person 2000).

The density estimate we applied is lower than other areas of North America where deer are the primary prey (*i.e.* Minnesota [39/1000-km^2] — Fuller 1989; Vancouver Island [44/1000-km^2] — Hatter and Janz 1994). Wolf densities, however, are strongly related to prey biomass (Fuller 1989), not the species of ungulate. Our study area likely contains less prey biomass because it includes large expanses of rock and ice, especially on the mainland.

The number of packs (reproductive units) is a function of the number of resident wolves and average pack size. In southeast Alaska, about 29% of wolves are non-residents (dispersing or extraterritorial) annually (Person 2000). Dispersal rates increase with high mortality when territories become vacant (Ballard *et al.* 1987; Fuller 1989). We estimate a 20% dispersal rate in our study area because mortality is comparatively lower (see below). Thus, we predict the presence of 325-378 resident animals in the total population. If average late winter pack size is 6.4 (Person 2000), this corresponds to 51-59 packs in our study area.

ESTIMATE AND SOURCES OF MORTALITY

Available data from the Ministry of Environment (MOE) indicate that resident hunters killed 182 wolves in Management Units (MUs) 5-7, 5-8, 5-9, and 6-3 between 1976 and 1999 *(Map 3)*. Guide outfitter clientele killed 41 wolves during this time (MOE *unpub. data*). Most wolves (76%) were killed in MU 6-3, which is closest to Prince Rupert, the most populous settlement on the coast *(Map 3)*.

We made the following assumptions to estimate total mortality in the study area:

1. The number of wolves killed in each MU is of average value in years when data are absent (34% of all "Management Unit years").
2. Unreported mortality is equal to estimates of resident hunter kills.[1]
3. The number of wolves killed is proportional to MU area represented in the study area (approximately 50% of each MU).

Based on these assumptions, we estimate that resident hunters have killed approximately 220 wolves in the study area during the last 24 years. Applying assumptions 1) and 3) to guide outfitter data, non-resident hunters killed 26 wolves in the study area during the same time. In addition, four wolves were trapped between 1985 and 2000 (MOE *unpub. data*). Thus, humans have killed at least 250 wolves in the study area in the last 24 years. This represents 10 wolves annually or roughly 2.1 to 2.5% of our population estimate (above). In contrast, Hayes and Gunson (1992) estimated that annual human-caused mortality was 11% for BC as a whole.

[1] The Ministry of Environment surveys licensed hunters to estimate mortality due to resident hunters. However, most people in the study area are First Nations people who are not required to purchased licenses (MOE 1999). Thus, they are not sampled. Consequently, we believe our doubling factor is conservative.

In both protected and exploited wolf populations, humans are responsible for a high percentage of mortality (Peterson *et al.* 1984b; Fuller 1989; Paquet 1993; Noss *et al*. 1996). Bella Bella residents reported that they typically do not target wolves, but take them opportunistically in deer hunting or fishing trips. However, there is current interest in restoring bounties for wolves in another coastal village (W. McCrory *pers. comm.*). The rationale is that they are helping deer populations and/or they are taking vengeance for putative wolf attacks on their ancestors. Guide outfitters in the study area advertise wolf hunts on the World Wide Web. Although the primary mode of transportation is by boat, hunters are starting to use logging roads.

We observed the remains of three wolves during the field season. We found the skull of a pup on Princess Royal Island. We found remains of another wolf near the Bella Bella garbage dump. Although the animal had severe leg damage, we could not identify the cause of death due to its severely decomposed state. Cranial characteristics and tooth wear indicated it was a young adult. Its proximity to the dump suggests humans played a role in its death. Local residents have stated that this occurs periodically at this site. At a remote outpost on Princess Royal Island, a person who alleged a wolf had previously attacked his dogs shot an adult wolf.

6.2 Distribution

We observed wolf sign at all mainland (n=18) and island (n=21) sampling sites *(Map 1)*. Our survey included large outer islands such as Dewdney, Aristazabal, and Calvert, which are among the most isolated in the study area. We hypothesize that wolves within the study area may inhabit all large islands that support deer, regardless of currents and open water distances.

This suggests that many island wolves function as nearly independent sub-populations between which migration is limited.

The most isolated location where we documented the presence of wolves was on the Moore Islands, 5.4-km from another landmass *(Map 1)*. Evidence from southeast Alaska suggests dispersal across large water bodies is possible but infrequent. Of 11 dispersing wolves collared on Prince of Wales Island, only one dispersed off Prince of Wales or adjacent islands (Person 2000). Person (*pers. comm.*) reported that a female wolf swam more than 10-km in open ocean, but suggested this is a rare event. Although low prey density can stimulate dispersal (Peterson and Page 1988; Fuller 1989), wolves that apparently were starving failed to swim 900-m to a nearby island (Klein 1995). This suggests that many island wolves function as nearly independent sub-populations between which migration is limited.

Once wolves reach an island, their persistence likely depends on the presence and abundance of deer and the island's effective area (island area and distance to other landmasses). Wolves have evolved to be obligate ungulate predators, which in Minnesota, need an estimated 3.2-kg of food per day per wolf for successful reproduction (Mech 1977). We believe that an island without deer would not support even one wolf. This seems to be the case on the Moore Islands *(Map 1)*, a very small (<5-km^2) and isolated (5.4-km) archipelago on which we failed to detect deer sign. We found one old scat with bird and other unidentified remains but observed no current sign, suggesting the wolf starved or left the island.

Wolves seem unable to persist on small and isolated islands, even if they do have deer. We collected old scat left by a wolf (only hair remained) from the Goose Group of islands *(Map 1)*. This is a small (~40-km^2) and isolated (3.75-km) archipelago that Guiguet (1953), after completing a four-month ecological inventory, reported having neither deer nor wolves. We observed extensive deer sign but failed to locate any fresh wolf sign. Furthermore, a sea lion carcass showed no evidence of having been scavenged by a large mammal. In the 1960's, four wolves were introduced to the 73-km^2 Coronation Island, southeast Alaska, to study the effects on resident deer (Klein 1995). After reaching a peak of 13 in four years, the wolf population, having severely reduced deer numbers, plummeted to one. Klein (1995) and Person *et al.* (1996) stated that small and isolated islands, such as Coronation, are unable to support populations of wolves. Person (2000) noted that islands as large as 180-km^2 with deer carrying capacities greater than 2,500 did not continuously support wolves between 1955 and 2000. However, packs may be sustained if their home ranges include a collection of such islands.

Deer constituted the dominant portion of wolf diet, which is similar to findings near our study area. We observed deer remains in roughly 83% of all scats, and in 93% of scats in summer.

6.3 Diet

Theberge (1991) classified prey-based ecotypes for wolves in Canada and included mainland coastal populations of BC in the "mule deer/moose-wolf" system. However, our study area and much of the immediate coast is better described as a "black-tailed deer-wolf" system, similar to that he identified on nearby Vancouver Island. Of 639 items detected in 612 faeces we examined, black-tailed deer constituted the largest portion of wolf diet during the summer and fall, although we detected diverse foods *(Figure 2)*. In both seasons combined, deer remains accounted for most of the occurrence/faeces and occurrence/item indices (83.8% and 80.3%, respectively), followed by salmon (8.7%, 8.3%), unknown items (8.2%, 7.8%), black bear (2.0%, 1.9%), beaver (1.1%, 1.1%), and goat (0.7%, 0.6%) *(Table 1)*. Presumably, hair in scats we classified as unknown were primarily from mustelids and rodents. We observed garbage in nine, intertidal foods in seven, and bird remains in three scats. We did not convert occurrence values to biomass consumed.

In the summer when salmon were not yet available, deer remains occurred in roughly 93% of scats, and beaver in less than one percent. In southeast Alaska, Kohira and Rextad (1997) reported a similar 92% occurrence of deer but an 18% occurrence of beaver in summer scats. A proportion comparable to ours (2.1%) was found on Vancouver Island (Scott and Shackleton 1980) throughout their study but no beaver remains were detected during summer months. However, on Vancouver Island, two ungulate species are available to

Figure 2

Combined occurrence per faeces (%) of food items in 612 wolf scats examined in the field in coastal British Columbia during the summer (May 22 - July 31; n=395) and fall (September 12 - October 3; n=217) 2000. Percentage represents numeric occurrence for each prey type and does not necessarily reflect biomass consumed.

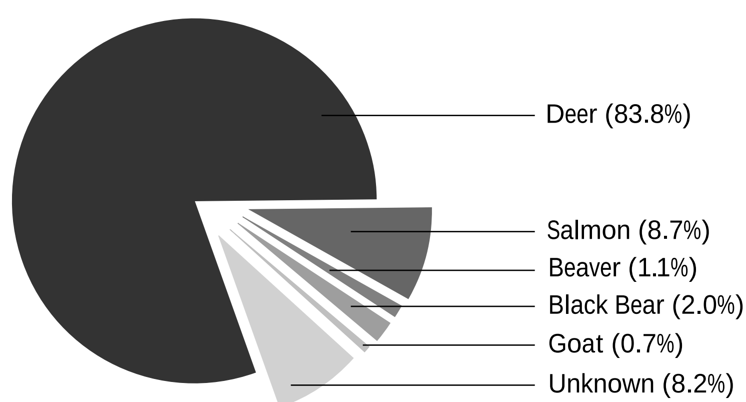


TABLE I Seasonal occurrence (%) of food items detected in 612 wolf scats examined in the field in coastal British Columbia during summer (May 22 - July 31; n=395) and fall (September 12 - October 03; n=217) 2000. OF is occurrence/faeces, and OI is occurrence/item indices.

Season	Number of scats	Number of items	Deer		Salmon		Black bear		Beaver		Goat		Unknown	
			% OF	% OI	% OF	% OI	% OF	% OI	% OF	% OI	% OF	% OI	% OF	% OI
Summer	395	401	92.7	91.3	0.0	0.0	1.0	1.0	0.5	0.5	1.0	1.0	6.3	6.2
Fall	217	238	67.7	61.7	24.4	22.3	3.7	3.4	2.3	2.1	0.0	0.0	11.5	10.5
Combined	612	639	83.8	80.3	8.7	8.3	2.0	1.9	1.1	1.1	0.7	0.6	8.2	7.8

wolves: Roosevelt elk (*Cervus elaphus roosevelti*) and deer. Our low estimate of beaver consumption may be due to a low density of beaver and/or a high density of deer. In other studies the inverse has been observed: high beaver consumption when density of beaver was high or density of deer was low (Voight *et al.* 1976; Theberge *et al.* 1978). We know of no data regarding beaver density on the coastal mainland of BC. However, Kohira and Rextad (1997) commented that beaver density may be low in conifer-dominated vegetation, such as that found in our study area. Moreover, deer density in coastal BC may be higher than in southeast Alaska. Second growth forest is near absent in our study area but is common in southeast Alaska (Person *et al.* 1996) and of much lower value for deer (Wallmo and Schoen 1980 and others).

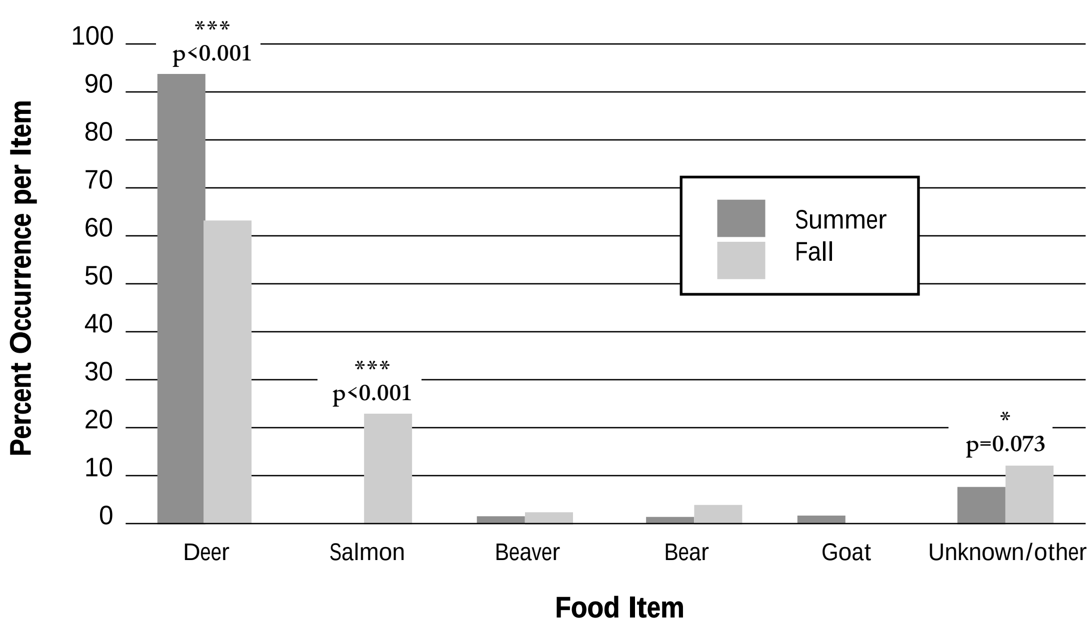
More likely, our low estimate of beaver consumption is primarily an artifact of our methodology. Person and Ingle (1995) used a similar approach in southeast Alaska and reported deer hair in 92% of 316 scats and beaver hair in less than 6%. A subsequent microscopic examination of a subset of the same scats (n=90) revealed that 97% contained deer and 36% contained beaver remains. This suggests that field examinations can underestimate the proportion of deer in diet and miss secondary items such as beaver.

We detected a shift from a nearly exclusive diet of deer in the summer to a considerable secondary use of spawning salmon in the fall *(Table 1; Figure 3)*. Compared with summer values, deer remains occurred significantly less in faeces in the fall than expected ($\chi^2_1 = 80.30$, p <0.001) and salmon remains occurred more than expected ($\chi^2_1 = 94.47$, p <0.001). In southeast Alaska, Kohira and Rextad (1997) also found a significant seasonal difference in diet due to use of fish in autumn. However, salmon was not detected in two studies of wolf diet on Vancouver Island (Scott and Shackleton 1980; Milne *et al.* 1989). We did not detect significant differences between seasons for any other food items *(Figure 3)*. However, although the difference was not significant, we classified more items as unknown in the fall (χ^2_1 =3.20, p=0.073). We suspect that many of these scats contained salmon remains. These are difficult to detect because we believe that wolves often eat only the brain or head of salmon (see below), portions which contain no diagnostic items such as hair or conspicuous bones.

The significant change in resource use we detected may reflect survey bias. In contrast to the summer season during which we traveled extensively (see range of survey sites in Map 1), in the fall we focused our effort by repeatedly sampling three packs to collect fresh genetic material. All groups appeared to remain localized near salmon bearing estuaries. Not all coastal wolves may demonstrate such affinity to salmon resources. Among collared packs in southeast Alaska with equal salmon availability, only a subset appears to use this resource (D. Person *pers. comm.*). Kohira and Rextad (1997) speculated that spatial differences in use of salmon may be the result of human activity at the most accessible salmon-bearing rivers.

Figure 3

Seasonal occurrence per item (%) of food items in 612 wolf scats examined in the field in coastal British Columbia during the summer (May 22 - July 31; n=395) and fall (September 12 - October 3; n=217) 2000. Note that salmon was not available to wolves during the summer. We did not observe goat in fall diet.



The dependence of wolves on deer in our study area was demonstrated clearly by this analysis. This is particularly relevant to the area's islands, where deer is typically the only ungulate species. Person *et al.* (1996) reviewed similar data for southeast Alaska and stated:

> These data strongly suggest that wolves occurring on the islands of southeast Alaska [where deer is the only ungulate prey] depend on the availability of deer and raise questions about the ability of alternative prey to sustain wolves in the absence of deer.

Preliminary Notes on Salmon Consumption by Wolves

Darimont (2000) used a stable isotope approach on taxidermy hair samples from fall- and winter-killed wolves from British Columbia to assess the use of salmon in diet. Isotope signatures in metabolically inert tissue such as hair, feathers, and nails reflect diet only during periods of growth. Wolves have one long annual moult beginning in late spring when the old coat sheds and a new coat of guard hair and underfur grows until late fall (Chapman and Feldhamer 1982; Young and Goldman 1944). Therefore, in animals that died in fall and winter, the base portion of guard hairs reflects most recent dietary assimilation (fall) whereas the tip portion reflects diet during earlier growth (summer). Isotope signals in the complete guard hair reflect average diet during the final moult.

Approximately half the samples of whole guard hairs had isotope signatures greater than those predicted for purely "terrestrial consumers" (Chisholm *et al.* 1982; Hobson 1987) which suggested that they had consumed (detectable quantities of) marine resources. Of the "marine consumer" samples, five of nine wolves showed a seasonal dietary shift that coincided with annual salmon availability. There was a coupling of enriched marine carbon and nitrogen isotope values in fall-grown hair (base) compared to summer-grown hair (tip) *(Figure 4)*. The differences between seasonal isotope values were greater than the standard deviation that Hobson *et al*. (1996) recorded along the length (5-mm segments) of whiskers from harp seals (*Pagophilus groenlandicus*) on a constant diet. In contrast, differential values for all "terrestrial consumers" were constrained by this value (approximately $0.5\ ^{0}/_{00}$ [parts per thousand]) for both isotopes. Together, this implies that the difference Darimont (2000) observed was due to diet and not to another effect. These results suggested that spawning salmon can provide a dietary contribution to some, but likely not all, coastal wolves. Moreover, this study presented biochemical

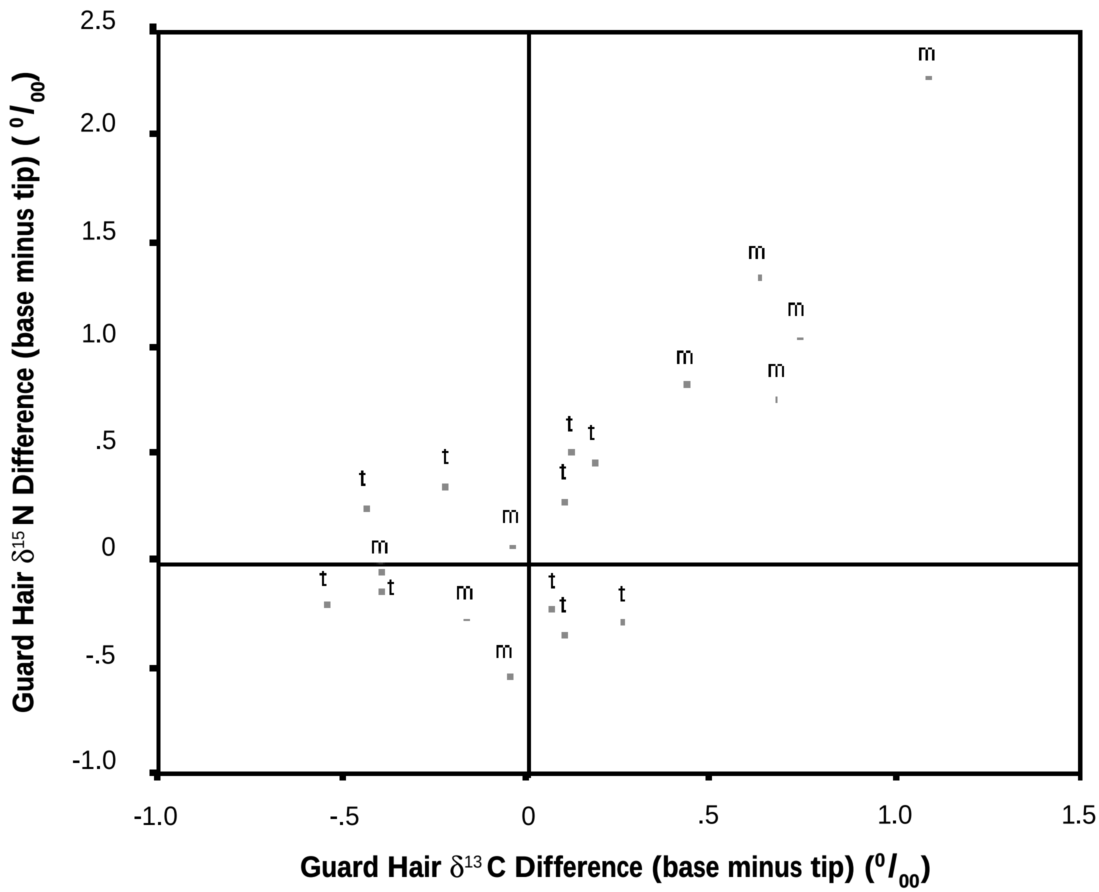
These results suggested that spawning salmon can provide a dietary contribution to some, but likely not all, coastal wolves.

corroboration to scat-based studies (Kohira and Rextad 1997; this study), and to numerous anecdotal observations about salmon-eating wolves on BC's coast.

Szepanski *et al.* (1999) measured stable isotope signals in bone collagen to assess the *lifetime* contribution of salmon in the diet of southeast Alaskan wolves. They estimated that salmon and other marine resources provided 18% of dietary protein. The authors stated that salmon may mitigate the predicted long-term declines in wolf populations caused by a reduced number of deer. We caution against this interpretation for coastal BC wolves. We believe that spawning salmon provide suitable alternate prey for such a functional response only during a few fall months and only to a portion of the coastal

Figure 4

Differential (base minus tip) guard hair $\delta^{13}C$ and $\delta^{15}N$ values of "marine consumer" (m) and "terrestrial consumer" (t) wolves from British Columbia. The five individuals clearly in the top right quadrant likely consumed salmon as the dominant source of marine diet; their position suggests increased assimilation of $\delta^{13}C$ and $\delta^{15}N$ (marine) isotopes during the fall (base of guard hair), corresponding to salmon availability. Adapted from Darimont (2000).



wolf population. Because of punctuated availability and selective use by wolves, the salmon intake is likely insufficient to compensate for widespread and long-term declines in deer populations. Moreover, many Pacific Northwest salmon stocks have declined dramatically and will likely continue to do so (National Resources Council 1996). During the last century of intense industrial fishing, salmon has become a resource for wildlife that once was highly predictable and abundant to one that is now often unpredictable and uncommon (T. Reimchen *pers. comm.*). In modern times, salmon may be seasonally important to some wolves but we believe that long-term persistence of BC's coastal wolves depends on abundant and well-distributed populations of deer.

Headless pink salmon (Oncorynchus gorbuscha), *Pooley Island, BC.*

Our limited observations suggest that wolves typically consume only the head (or brain) of salmon. Similarly, Young and Goldman (1944) stated that a biologist in southeast Alaska observed wolves that "had taken salmon... eating only their heads".

Other notable observations we made from field work and literature review include:

- **Transfer of Nutrients**

  Bears are the main vectors that transport salmon from streams to estuaries and forests. However, other large vertebrates also are known to do so (Cederholm *et al.* 1989; Willson *et al.* 1998; Reimchen 2000). Decomposed salmon remains and urinary/faecal deposition by consumers are important fertilizers that provide nitrogen and phosphorous nutrients that often limit plant growth in coastal forests (Willson *et al.* 1998). Our limited observations suggest that wolves typically consume only the head (or brain) of salmon. Similarly, Young and Goldman (1944) stated that a biologist in southeast Alaska observed wolves that "had taken salmon... eating only their heads". However, we suggest that due to a comparatively lower density and lower affinity for salmon as a food source, wolves have a minor role in nutrient transfer compared to bears. Although interference competition among black bears is thought to be responsible for considerable transfer distances (Reimchen 2000), wolves probably travel comparatively greater distances during salmon season. Thus, nutrient transfer via urinary and scat deposition may be distributed farther into the forest. Notably though, salmon (and the transfer of marine derived nutrients to forests primarily by bears) contribute to the carrying capacity of wolves by supporting the vegetation on which their main prey (deer) feed.

- **Fishing Behaviour**

  On only a few occasions our field crew observed wolves killing salmon or scavenging remains. However, anecdotal accounts from other credible witnesses are numerous. Bromely (1973) watched wolves that caught spawning whitefish (*Coregonus* spp.) in the Northwest Territories and

P. Paquet (*pers. obs.*) observed wolves fishing for white suckers (*Catostomus commersori*) in Riding Mountain National Park, Manitoba. After continuous observation of one wolf on several days, Bromely (1973) noted a 50% capture rate. The wolf used a "wait-and-lunge" method exclusively. During one hour of fishing, this animal caught 16 whitefish (Bromely 1973). In our study area, we suspect that most fishing behaviour occurs nocturnally because wolves are more active then (Asa and Mech 1992), and salmon show decreased evasive responses to shoreline disturbance during darkness (Reimchen 1998).

- **Interspecific Competition**

  Wolves are known to kill and consume black bears (Rogers and Mech 1981; Horesji *et al.* 1984; Paquet and Carbyn 1986; Kohira and Rextad 1997; this study). We theorize that wolf packs may be capable of competitively excluding black bears from portions of some salmon systems. In one of the three systems repetitively sampled, we failed to detect bears or bear sign. This area had a conspicuous and continuous presence of a wolf pack. We emphasize that this would occur only in rendezvous areas where reproducing (and comparatively large) packs remain relatively sedentary for long time periods.

6.4 Genetic Analysis

Jennifer Leonard, Ph.D. candidate in Dr. Robert Wayne's Conservation Genetics Lab at UCLA, is performing the DNA analysis and has shared preliminary results. DNA has been extracted from 30 faecal samples thus far. It has been possible to amplify a 470-base pair (bp) fragment of the control region of the mitochondria from 15 of these extracts. A 50% success rate, such as this, is what is expected from faecal samples. Because fragments of a large size (470-bp) have been amplified from these samples, it is likely that we will be able to amplify nuclear (microsatellite) markers as well. Nuclear markers can be used to sex the samples and often to identify individuals.

Four of the amplified control region fragments were sequenced. Two different haplotypes (versions of mitochondria) were identified in these samples. Both haplotypes are clearly of wolf origin. Three of the samples had a common North American wolf haplotype (reported in wolves from Montana, Alberta, and Labrador — Vila *et al.* 1999). The other sample had a haplotype that has not been previously reported in wolves. In a previous study of phylogenetic patterns in wolves worldwide, Vila *et al.* (1999) identified only 34 haplotypes (using the same 470-bp fragment). Due to the rarity of endemic haplotypes in wolves, this unique haplotype may have considerable importance.

Widespread extirpation by humans during the last two centuries caused a measurable reduction in the genetic diversity of wolves worldwide. Our study area, owing to its low population of humans, functioned as a refugium for wolves during this time. Genetic diversity was likely preserved when it was eroded elsewhere. Genetic diversity is an important component of biodiversity — an index that biologists, governments, conservation organizations, industry, and First Nations all contend requires preservation.

This interim report on genetic analysis has important implications:

- SCAT-BASED TECHNIQUES IN COASTAL RAINFORESTS

  A 50% success rate (if distributed randomly among samples) for amplification of a large DNA fragment is encouraging for future scat-based work in this area. As noted, the results suggest that this technique likely can be applied to identifying individuals, which permits the collection of spatial-ecological data such as home range information. Population estimates also may be supported.

- EVIDENCE OF GENETIC DIFFERENTIATION

  The discovery of a previously undescribed haplotype on BC's coast has considerable academic and conservation merit. Mexico and the Yukon Territory in Canada are the only North American areas in which endemic haplotypes have been identified (Vila *et al.* 1999).

  Clearly, we must continue analysis of previously collected samples and survey more coastal and interior BC locations to estimate the distribution and frequency of this newly described haplotype. However, subsequent analysis may provide sufficient support for defining BC's coastal wolves a genetic "management unit" (Moritz 1994). Groups of animals that have divergent allele frequencies are significant for conservation in that they represent populations connected by such low levels of gene flow that they are functionally independent (Moritz 1994).

  Vila *et al.* (1999) concluded that widespread extirpation by humans during the last two centuries caused a measurable reduction in the genetic diversity of wolves worldwide. Our study area, owing to its low population of humans, functioned as a refugium for wolves during this time. Genetic diversity was likely preserved when it was eroded elsewhere. Note that this newly documented genetic diversity is an important component of biodiversity — an index that biologists, governments, conservation organizations, industry, and First Nations all contend requires preservation.

PART II
CONSERVATION ASSESSMENT

In the following Conservation Assessment, we identify and evaluate conservation concerns relevant to wolves and their prey in Pacific Northwest forests. We contend that current forestry activities threaten the future of viable and well distributed populations of deer and wolves. Available evidence suggests that large-scale clearcutting will likely reduce the forest's *long-term* carrying capacity for deer. Moreover, logging roads will provide access for increased legal and illegal killing of wildlife, including deer and wolves. Current BC Ministry of Environment and forest company management efforts are likely ineffective at comprehensively and effectively addressing the threats we identify.

7 INDUSTRIAL CLEARCUT FORESTRY AND WOLF-DEER SYSTEMS

Industrial forestry targets the same low elevation old-growth forests on which wolves and deer depend. Of about 1,500 independent radio telemetry relocations of wolves in southeast Alaska, approximately 50% were below 84-m, and 95% below 396-m (Person 2000). Consequently, the potentially adverse impacts are disproportionately greater than those predicted by area affected by timber removal. Following are the potential consequences of this convergence *(see also Table 2)*:

TABLE 2
Possible effects of industrial clearcut forestry on wolf-deer systems in Pacific Northwest forests and the periods when they occur.

Impact	Short-term	Medium-term	Long-term
Physical loss of habitat	x	x	x
Disturbance/Area abandonment	x	x	x
Consumption of garbage	x	x	x
Direct mortality by resource workers	x	x	x
Decline in habitat carrying capacity for deer			x
Fragmentation/Edge effects	x	x	x
Access-related mortality	x	x	x

7.1 Physical Loss of Habitat

The most immediate and conspicuous impact is physical loss of habitat. Each clearcut removes part of a landscape with which deer and wolves of this area have evolved over millennia. We believe that this loss of structure and function can be considered permanent (see section 7.5 below). The impact may be instantaneous and severe for deer occupying cutblocks. Deer show considerable home range fidelity (Schoen and Kirchhoff 1985) and have been known to die of malnutrition rather than travel to an unknown area to search for forage (Dasmann and Taber 1956). Moreover, natural emigration is typically low (Schoen and Kirchhoff 1985), possibly due to the social behaviour of deer (Ozoga *et al.* 1982). Consequently, habitat loss in one watershed may not incite large-scale movements into adjacent watersheds (Schoen and Kirchhoff 1985).

7.2 Disturbance and Area Abandonment

Explosives and machinery used to build roads can cause considerable stress in wildlife (Wasser *et al.* 1997a), possibly leading to animals abandoning home ranges and territories. If core areas were disturbed, the effects on wolves would be most severe. Average core areas (50% adaptive kernel home ranges) are small for wolves in nearby southeast Alaska: 35-km^2 (Person 2000). Wolves have been shown to abandon areas after less than 100 disturbance events (Paquet *et al.* 1996). Person and Ingle (1995) reported that a pack in southeast Alaska abandoned a den area shortly after road building activity near the den began in July 1993. Moreover, the pack significantly reduced their year-round activity in the entire valley. Ballard *et al.* (1987) also reported den abandonment following human disturbance. In an unprecedented experiment, removal of physical structures and reduction of human activity allowed wolves to reoccupy previously abandoned habitats (Duke *et al.* in press).

Thiel *et al.* (1998) observed high levels of tolerance and even habituation to human disturbance among some packs in Denali National Park and areas within the lower 48 states. However, it is important to note that these packs all had a significant "ambient disturbance baseline", unlike the wolves in our study area that rarely encounter humans. Furthermore, this tolerance and habituation predisposes wildlife to legal and illegal hunting.

Explosives and machinery used to build roads can cause considerable stress in wildlife, possibly leading to animals abandoning home ranges and territories.

Wolves have been shown to abandon areas after less than 100 disturbance events.

Road building, Ingram-Mooto Lakes, coastal BC.

7.3 Consumption of Garbage

Wolves are known to consume garbage from humans. This summer we observed logging refuse, including dynamite cord, in nine scats. The consequences of this consumption are unknown. However, Gregory (1991) noted that plastic can cause harm to wildlife through blockages to the intestinal tract, possibly leading to starvation and death, or ulceration of delicate tissues by jagged fragments. In addition, the concentration of food at open garbage sites (*i.e.* at logging camps, towns) can distort wolf home ranges (Paquet *et al.* 1996) and may elevate the probability of persecution. Moreover, accumulating evidence suggests that wolves using dumps are more aggressive towards humans (P. Paquet *pers. comm.*).

7.4 Direct Mortality by Resource Workers

Industrial activities such as forestry can directly affect wildlife mortality and the frequency of wildlife law violations (Berger and Daneke 1988). Forestry workers spend their workday among wildlife and often carry firearms. Some have been observed shooting wolves while on the job (C. Darimont *pers. obs.*). This is legal conduct at least nine months a year in BC for anyone with a hunting license.

7.5 Decline in Habitat Carrying Capacity for Deer

Available evidence suggests that the most significant threat to viable wolf populations in the Pacific Northwest is clearcut logging, which is thought to reduce the forest's *long-term* carrying capacity for deer. Person (2000) described a "bottom-up" influence of clearcut logging on predator-prey dynamics. That is, reduced browse quantity and quality reduce the carrying capacity for deer, which in turn decreases wolf numbers. Many ecological factors contribute to, and magnify, this condition.

A temporary increase in forage production may follow clearcutting in some areas (Happe *et al.* 1990). Moreover, female deer have been shown to select clearcuts during mild winters in southeast Alaska (Yeo and Peek 1992). However, a more comprehensive perspective is required to evaluate the long-term influence of industrial forestry on deer populations.

Early successional browse in clearcuts may be abundant but can be of poorer nutritional quality than in old-growth stands because increased tannins reduce available digestible protein (Van Horne *et al.* 1988; Hanley *et al.* 1989; Happe *et al.* 1990). Moreover, the depth of logging slash can affect accessibility to and use of clearcuts by deer (Lyon and Jensen 1980). In Pacific Northwest forests, this residue can be considerable. Wallmo and Schoen (1980) reported 61 of 100 sample points unusable by deer in a nine-year-old clearcut.

More notably, available evidence suggests that clearcutting eventually changes productive old-growth forests into even-aged, second-growth stands of much

Available evidence suggests that clearcutting eventually changes productive old-growth forests *(left)* into even-aged, second-growth stands of much lower habitat value for deer *(right)*.

lower habitat value for deer. Starting in the mid-successional or "stem-exclusion stage" (15-35 years), the dense canopy severely limits forage available to deer. These conditions may persist for 150 to 200 years if no additional logging occurs. Under short-rotation, even-aged management, some understory plant species may never regenerate (Wallmo and Schoen 1980; Alaback 1982; Schoen *et al.* 1998). This loss in structure and function can be considered permanent. To this situation, Schoen *et al.* (1984) applied the term "nonrenewable old-growth habitat (for deer)".

Starting in the mid-successional or "stem-exclusion stage" (15-35 years), the dense canopy severely limits forage available to deer. These conditions may persist for 150 to 200 years if no additional logging occurs. However, under short-rotation, even-aged management, some understory plant species may never regenerate.

The ultimate factors of decreased habitat quantity and quality are responsible for reducing the long-term carrying capacity for deer. The proximate causes in declines are increased intraspecific competition for food and shelter that leads to decreased reproduction and increased chronic mortality (Caughley and Sinclair 1994; Person *et al.* 1996). Populations are then more susceptible to further declines due to stochastic events such as severe winters or disease outbreaks.

Person (*pers. comm.*) speculated that a reduced carrying capacity for deer would have disproportionately greater effect on populations of deer and wolves. Due to non-linear density dependent growth of deer populations, a decrease in deer carrying capacity introduces a proportionately greater decline in recruitment. Predation then may be more likely to remove more than the annual production of deer. This can lead to volatile wolf-deer equilibria. Moreover, in a landscape dominated by ocean and rock such as coastal BC, deer population crashes may be more frequent because immigration from other areas is likely limited. Peterson and Page (1988) provided empirical evidence for the effects of insularity even in undisturbed predator-prey systems on Isle Royale by documenting extreme amplitudes in wolf-moose populations.

Bergdahl *et al.* (2000), using company forest development plans and current logging rates, predicted the loss of approximately 23% of suitable deer winter range in the next 20 years and over 90% after 100 years.

All wolves generally selected for old-growth habitat while avoiding or showing neutral selection for clearcuts and seral forest (Person 2000).

In areas or years with heavy snowfall, the influence may be particularly severe. Forage in clearcuts may be unavailable or may require significant energy to access (Schoen and Kirchhoff 1985; Harestad *et al.* 1982). During periods of deep snow in southeast Alaska, high volume old-growth stands received disproportionately high use by deer (Schoen and Kirchhoff 1990), likely because this forest type is most effective at intercepting snowfall (Kirchhoff and Schoen 1987). Deer confined to isolated patches of old-growth during deep snow suffered higher mortality from malnutrition than deer in unfragmented forests (Kirchhoff 1994). Some may argue that this concern may not be valid because snowfall is typically low in (the western portion of) our study area. However, in southeast Alaska, Schoen and Kirchhoff (1990) showed that deer concentrated their activities in the highest volume old-growth within their home ranges when snow depth reached as little as 15-cm.

Although it is difficult to calculate the extent of deer declines in the long-term, scientists have made estimates of future impacts. Schoen *et al.* (1985) predicted the effect in Hawk Inlet on Admiralty Island, southeast Alaska, where logging was expected to remove more than 75% of commercially viable forests over 100 years. The investigators predicted that deer would be reduced to 20% of the 1985 level. Similarly, Bergdahl *et al.* (2000) assessed the impacts of road building and clearcutting within the Spirit Bear Conservancy Proposal *(Map 2)* using company forest development plans and current logging rates. These authors predicted the loss of approximately 23% of suitable deer winter range in the next 20 years and over 90% after 100 years.

Person (2000) developed a wolf-ungulate demographic model for southeast Alaska. Confirmed using empirical data from southeast Alaska and Isle Royale, the model predicted wolf and deer numbers under various management regimes between 1955 and 2045. Simulations predicted that, under current and future logging rates, wolves would decline from 340 in 1955 to 145 in 2045, and deer would decline from over 88,000 to 41,339 during the same period. Both species were predicted to decline to less than 50% of what likely existed before industrial logging in 1955 (Person 2000).

Person (2000) reported that effects of deer declines have already been expressed in the life histories of study animals in southeast Alaska. His study was the first to provide evidence of an inverse relationship between wolf home range and critical habitat for prey (after controlling for pack size). Of the seven packs studied, the two with the least logged habitat had the smallest home ranges. Conversely, the two with the greatest logged habitat had the largest home ranges. Moreover, all wolves generally selected for old-growth habitat while avoiding or showing neutral selection for clearcuts and seral forest.

The Annual Allowable Cut in the Mid Coast Timber Supply Area (overlaps considerably with and is roughly the same size as our study area — *Map 4)* is 1,000,000 cubic metres/year (Cuthbert 1994) and can be as high as 1,300,000 cubic metres/year (B. Corregan – Ministry of Forests *pers. comm).* Clearcutting is the dominant logging technique used in coastal BC and southeast Alaska. A significant difference is that the Alaskan Tongass Forest has a longer history of timber removal. Consequently, a greater absolute amount of timber has been removed. Under current management regimes, we believe that BC's coastal forests will become similar to those in the Tongass in which deer numbers have declined and continue to do so (Person *et al.* 1996).

7.6 Fragmentation/ Edge Effects

When fragmentation and the associated edge effects are considered, large-scale clearcutting again may be expected to have disproportionately greater impact on deer than predicted by volume removed. Fragmentation may result in increased predation by predators, including humans (see below). Predation efficiency is thought to be higher in landscapes fragmented by logging. Presumably, hunting is focused on specific sites where deer are concentrated and vulnerable, such as in remaining old-growth patches surrounded by clearcuts (Janz 1989; McNay and Voller 1995). This, in part, may create situations of unstable equilibria between wolf and deer populations in southeast Alaska with widely fluctuating populations of both species (Person *et al.* 1996).

7.7 Access-related Mortality

Forage along roads attracts deer (Romin and Bissonette 1996). Wolves use roads as travel routes, particularly when these thoroughfares become less active with vehicles (Thurber *et al.* 1994). It is thought that wolves use logging roads as efficient routes to access vulnerable prey (McNay and Voller 1995).

Humans also use logging roads to increase their hunting efficiency. Person *et al*. (1996) and Person (2000) showed that the number of wolves killed was significantly and positively correlated with the linear kilometres and density of roads in southeast Alaska. Wolves killed by hunters and trappers were located closer to roads and less often in productive old-growth. A large and growing proportion of wolves are killed directly from the road system (currently 44%) (Person *et al*. 1996; Person 2000).

Several other North American studies have suggested a strong relationship between road density and activity or survival of wolves. Wolves that re-colonized Wisconsin selected areas with low road density ($<0.45\text{-km/km}^2$) (Mladenoff *et al.* 1995). Moreover, wolves generally do not persist in areas with average road densities greater than 0.6-km/km^2 (Thiel 1985; Jensen *et al.* 1986; Fuller 1989). The absence of wolves in densely roaded areas is thought to be due to increased human-caused mortality (Van Ballenberghe *et al*. 1975; Mech 1977).

Mech (1989) reported wolves persisting where road density was comparatively high (0.76-km/km^2), but in a landscape next to a large, roadless area. The author speculated that dispersing animals from the adjacent roadless area compensated for high human-caused mortality in the roaded area. Notably, human-caused mortality was absent in the roadless area (Mech 1989).

Even in areas where wolves are protected from legal hunting and trapping, humans who use roads kill a considerable number of wolves. Similar road lethality applies to many other wildlife species, including deer.

Topography also influences the effects of road densities on wolves. For example, in mountainous landscapes such as many of the mainland watersheds of coastal BC, roads and habitat used by wolves converge in valley bottoms. Effective road densities calculated only for valley bottoms would be considerably greater than densities calculated for a pack's entire home range (Carroll *et al.* 1999).

Even in areas where wolves are protected from legal hunting and trapping, humans who use roads kill a considerable number of wolves (Fritts and Mech 1981; Fuller 1989; Paquet 1993). Similar road lethality applies to many other wildlife species, including deer (Trombulak and Frissell 2000). Note that road closures do not stop foot and all-terrain vehicle traffic.

Although many logging roads in our study area are not connected to human settlements, evidence suggests they are still a threat to wildlife. Mortality models have indicated linear kilometres and density of roads have a measurable impact on wolf mortality in watersheds of southeast Alaska accessible only by boat (Person 2000). Guide outfitters, hunters, and fishers often transport all-terrain vehicles by boat and motor vehicles are normally present at logging camps (Person 2000; C. Darimont and P. Paquet *pers. obs.*). This highlights the qualitative aspects of roads that must be considered. Regardless of road density, the associated lethality can be considered a function of frequency of use, speed of users, and the attitude/motivation of users (Merrill 2000). We have concern with the third variable in our study area.

Further, we believe that geography that includes water bodies predisposes wildlife to overexploitation. In essence, coastlines and river systems can be analogous to roads. Humans who gained access by boat were responsible for 53% of wolves killed in southeast Alaska (Person 2000). Guide outfitters in our study area commonly use jet boats for river access to otherwise remote wildlife (C. Darimont and P. Paquet *pers. obs.*).

8 TOP-DOWN EFFECTS OF A KEYSTONE PREDATOR

We have been asked, "What good are wolves to coastal forests?" and "How will preserving wolves help coastal forests?". The answers are revealed in the ecological importance of top predators. Modern theory of trophic dynamics predicts that predation by apex carnivores can exert a strong and controlling influence on species at lower trophic levels. This regulating influence is a key component in the maintenance of biodiversity (Terborgh *et al*. 1999). Top-down theory predicts that in the absence or reduction of predation, a prey species that is preferentially preyed on by a predator is capable of competitively excluding other species that depend on a limited resource. However, in an intermediate predation regime, common in systems undisturbed by humans, enhanced species diversity is predicted compared to when the predator is absent.

Modern theory of trophic dynamics predicts that predation by apex carnivores can exert a strong and controlling influence on species at lower trophic levels. This regulating influence is a key component in the maintenance of biodiversity.

Predator-prey systems are controlled by both top-down and bottom-up forces. For example, Person (*pers. comm.*) reasoned that clearcut logging in coastal temperate rainforests converts a productive habitat for deer into an unproductive habitat for deer, and thus also for wolves (bottom-up influence). In the same system, wolf predation on deer can exert a top-down effect on vegetation.

Top-down regulation is particularly apparent when predators are removed from ecosystems. In the consummate example, Pacific kelp forests were devastated when sea urchins were released from the controlling effect of predation after humans extirpated otter populations. Species richness drastically declined. Re-colonization of sea otters has restored many of these kelp forests and increased species diversity (Estes *et al*. 1978, 1989).

Long-term studies on Isle Royale wolf-moose-balsam fir systems provide compelling evidence of top-down regulation that wolves can exert. Changes in the abundance of wolves had community-wide consequences. There, wolves regulate moose populations whose effects on vegetation can be quantified in rings of young fir trees. During periods when wolf numbers were low, these dominant herbivores increased and collectively slowed tree growth through increased herbivory (McClaren and Peterson 1994; Messier 1994).

The keystone concept often is abused by its assignment to species for which there is little or no evidence of meeting the most accepted keystone species definition: a species that has an influence on the ecosystem disproportionately large compared to its abundance (Power *et al.* 1996). The top-down influence of wolves on Isle Royale exemplifies the wolf's role as a true keystone species. A few dozen wolves had a considerable effect on the 540-km^2 island's vegetation, the primary producers upon which all life depends.

Wolves on BC's coast undoubtedly exert top-down control through predation on deer. We observed a scenario that provided a microcosmic view of the potential consequences if coastal deer are released from predation by wolves. On the isolated Goose Group of islands, where wolves are absent but deer abound, we noted extreme over-browsing. Most *Vaccinium* shrubs, for example, were completely leafless below a very evident browse line. As most had not even flowered, we assumed that many would suffer reproductive failure. In coastal forests, huckleberry fruit provides nutrition for a host of species, from insects to birds to bears (to humans), each of which interacts with a myriad of other species. Goose Group deer, released from predation by wolves, likely severely limited this resource to many consumers. Declines in deer through density-dependent regulation may occur only after a potentially irreversible decline in biodiversity.

Terborgh *et al.* (1999) rang a somber warning bell by stating, "...it will be imperative to retain or restore [top predators] to as many parts of North America as practical. Failure to do so will result in distorted ecological interactions that, in the long run, will jeopardize biodiversity across the continent".

Biologists in nearby Haida Gwaii (Queen Charlotte Islands) *(Map 1)* have noted such declines in diversity in less than 100 years after the introduction of black-tailed deer onto the predator-free archipelago. Overbrowsing by deer was responsible for the local extirpation of shrub and herb species in some areas (Banner *et al.* 1989; Westland Resource Group 1994). Similarly, Decalesta (1994) reported the effects of ten years of overbrowsing by deer on inter-mediate canopy-nesting songbirds in Pennsylvania. Species richness declined 27% and abundance declined 37% between experimental enclosures of lowest and highest densities of deer.

Person (2000) reported that wolves were nearly exterminated twice by humans on Hecata Island, southeast Alaska. Had wolves been extirpated, re-colonization would be slow because of water barriers. Wolves are thought to be the only obligate ungulate predators on many of BC's islands (D. Nagorsen *unpub. data*). Terborgh *et al.* (1999) rang a somber warning bell by stating, "...it will be imperative to retain or restore [top predators] to as many parts of North America as practical. Failure to do so will result in distorted ecological interactions that, in the long run, will jeopardize biodiversity across the continent".

9 EVALUATION OF THE MANAGEMENT OF COASTAL BC WOLVES

9.1 British Columbia Ministry of Environment

Habitat/ Carrying Capacity for Deer

The Ministry of Environment (MOE), in concert with the Ministry of Forests (MOF), focuses its efforts on the creation of ungulate winter ranges (UWRs) to conserve deer populations (MOE and MOF 2000). Although the biological criteria (such as slope, aspect, elevation) used for designation of UWRs are sound, we question other aspects of this management system. Briefly, they are as follows:

- *Establishment Criteria*

  The strategy does not use biological criteria exclusively. Timber supply impacts are not to exceed levels stated in Timber Supply Reviews (MOE and MOF 2000).

- *Non-independent Process*

  The same forestry companies that remove timber from a given area are involved in the designation of the area's UWRs, creating a conflict of interest. Moreover, potential UWRs may be deleted and boundaries may be adjusted using input from companies (MOE and MOF 2000).

- *Efficacy of Management Strategy*

  To date, in the study area, there are very few designated UWRs (B. Nyberg — MOF *pers. comm.*). Although new ones are to be established "as quickly as possible" (MOE and MOF 2000), the final deadline is October 2003 — a date before which more than 3,000,000 cubic metres of wood may be removed from the Mid Coast Timber Supply Area *(Map 4)*. Moreover, previously identified UWR candidates not confirmed by this date cease to be UWRs. In addition, although a ceiling of total area has been identified (above), a minimum total area for preservation has not; no goal of UWR numbers or total size is apparent in MOE and MOF (2000).

- *Scope of Strategy*

  Winter survival is a crucial factor, but not the only one in maintaining viable and well-distributed ungulate numbers *in the long-term*. As stated above, available evidence suggests that large-scale clearcut logging will reduce both forage quality and effective quantity (Wallmo and Schoen 1980; Alaback 1982; Van Horne *et al.* 1988; Hanley *et al.* 1989; Happe *et al.* 1990;

Person *et al.* 1996; Schoen *et al.* 1998; Person 2000). We believe that piecemeal protection of a limited number of UWRs from 100 to 300 hectares each (B. Nyberg — MOF *pers. comm.*) will not sufficiently mitigate the anticipated long-term declines. In addition, UWR habitat "islands" may be subject to increased hunting efficiency by predators (Janz 1989; McNay and Voller 1995) contributing to volatile amplitudes in wolf-deer dynamics (Person *et al.* 1996; Person 2000).

Exploitation

Clearly, human-caused mortality in the study area is among the lowest where wolves still exist. However, we believe that human-caused mortality may grow considerably in the near future given the management regime coupled with increases in human population and hunter access via logging roads.

Clearly, the BC Ministry of Environment manages this population with limited information about how many animals exist and how many are killed annually. Management follows a laissez faire approach that relies on the reproductive potential of wolves.

The Ministry of Environment is charged with administering and enforcing the provincial Wildlife Act, which in part, governs the hunting activities within BC. Wolves are legally designated a "Big Game" and "Furbearer" animal. Low value is placed on the wolf; it is the only big game animal for which resident hunters do not require a species license, and it has the lowest license fee for non-resident hunters ($25). Although few wolves are currently trapped on the coast, the Ministry sets no bag limits (MOE 1999). In addition, the Ministry has designed and implemented wolf control programs as recently as 1987 for the purpose of increasing ungulate numbers on nearby Vancouver Island (see Janz and Hatter 1986).

Bag limits are set at three per resident hunter per season. Wolves are granted immunity only during part of the reproductive period. For example, in the northern portion of the study area (Management Unit 6-3; *Map 3*), hunting wolves is illegal only between June 16 and July 31 (MOE 1999).

Ministry of Environment estimates of the number of wolves killed are crude and must be interpreted with caution (P. Haley — MOE *pers. comm.*). Declarations from guide outfitters are assumed to reflect reality, but the estimate of mortality caused by resident hunters is an extrapolation based on generalized hunter surveys with small sample sizes. Moreover, the Ministry has no data for 33 of 96 (34%) "Management Unit years". Furthermore, the Ministry has never attempted a census of these wolves. Clearly, the BC Ministry of Environment manages this population with limited information about how many animals exist and how many are killed annually. Management follows a laissez faire approach that relies on the reproductive potential of wolves.

Similar hunting regulations, combined with a greater human population and considerable road access to habitat for wolves, have led to over-exploitation in southeast Alaska. The estimated number of wolves killed annually on some islands may exceed 45% during some years (Person and Ingle 1995). Depending on ungulate biomass and wolf population structure, wolves are thought to tolerate annual mortalities of 20-40% (Gasaway *et al*. 1983; Keith 1983; Peterson *et al*. 1984b; Fuller 1989).

Hunting pressure is a function not only of access to wolf and deer habitat and hunting policies but also of the number of hunters. Legal and illegal hunting will almost certainly increase as human population grows. The Central Coast Regional District grew by 11.6% between 1986-1991 and 12.6% between 1991-1996 (Statistics Canada 1999). Urban Eco Consultants Ltd. (2000)

Wolf den site under the root mass of a large diameter tree, coastal BC.

estimated that the Heiltsuk population (currently about 1,500) would grow to 3,435 by 2020, reach 5,398 members by 2050, and 11,461 by the turn of the next century. An increased human demand will be placed on deer populations that, under current forestry management, may simultaneously be declining. Inevitably, some will view the wolf as an unwanted competitor (as many do now), so legal and illegal hunting pressure may increase. Furthermore, the coast may be subject to a disproportionate increase in wolf and other big game hunting. The guide outfitting industry on BC's coast is growing and becoming globally well known (K. Belford — BC Guide Outfitters Association *pers. comm.*).

In wolves, we observe a suite of social traits only shared with primates: a social hierarchy, division of labour, year-round integration of age and sex classes, cooperation during hunting, and communal care of young. In Alaska and BC, there are no restrictions against killing adults with dependent young or the young themselves.

A strictly numerical analysis may underestimate the full extent of hunting on wolf populations. Haber (1996) speculated that qualitative aspects of the biology of this highly social species must be considered in their management. We agree. In wolves, we observe a suite of social traits only shared with primates: a social hierarchy, division of labour, year-round integration of age and sex classes, cooperation during hunting, and communal care of young. In Alaska and BC, there are no restrictions against killing adults with dependent young or the young themselves. Killing adults with dependent young — especially in a small pack or one with a large litter — may ultimately be the same as killing the young directly. This may also interrupt the social transfer of information between generations. Disruption in learning may result in fewer and simpler learned behavioural traditions, which are critical to adapt individual family groups to the specific resources and other unique features of each area (Haber 1996).

Wolves killed by humans are often dominant pack members as they are more likely to investigate baits at traps and howling simulations from hunters (P. Paquet and C. Darimont *pers. obs.*). With frequent replacement of key individuals, it may be difficult for wolves to maintain stable and well-defined dominance relationships. A potential result is more frequent and less selective breeding (Haber 1996) — a scenario not consistent with the evolutionary history of this species. The potentially negative consequences may not manifest for many generations.

Our analysis suggests that, numerically, a low incidence of human-caused mortality occurs in the study area. However, we believe the laissez faire management of wolves, elevated hunting pressure, increased human access to wilderness, and expanded forestry activity could combine to create conditions as adverse for wolves as those in southeast Alaska.

9.2 Forestry Companies

Habitat/Carrying Capacity for Deer

Interfor, Western Forest Products (WFP), and Weyerhaeuser do not officially incorporate deer or wolf populations into management plans, so no written material exists. However, Weyerhaeuser is currently working on Ungulate Winter Range establishment (Ron McLaughlin *pers. comm.*). Although a WFP-sponsored report acknowledged that mature forests are important in the selection of denning areas, that logging may increase predation efficiency on deer, and that wolves may avoid active logging roads, its authors suggested that logging will have a negligible effect on wolves (Henderson *et al.* 1996).

WFP's recent and official comment regarding the effects of industrial forestry is consistent with unofficial sentiment from Weyerhaeuser (Ron McLaughlin *pers. comm.*) and Interfor (W. Wahl *pers. comm.*) biologists:

> Forest management isn't expected to have a significant effect on wolf populations. Any changes in wolf populations will be related to changes in deer populations as more forage habitat is provided...We can expect that deer populations will, at most, climb modestly as forest harvesting provides some early seral habitat and forage. Wolf populations can be expected to follow. The extent to which these higher populations will be maintained will depend on the supply of new early seral habitat. If new early seral habitat is not provided, canopies will close and populations (of both deer and wolves) can be expected to return to their former abundance (Kerry McGourlick — WFP, email 2000/08/14 *pers. comm.*).

In our view, clearcuts award deer an ephemeral "severance package" of a potentially abundant but nutritionally questionable food supply that may not be readily accessible due to snow or logging residue.

We disagree with these predictions for reasons detailed above. In essence, when industrial forestry continually "supplies seral habitat", old forests and the associated ecological characteristics with which deer have evolved over millennia, are ostensibly lost forever (Wallmo and Schoen 1980; Alaback 1982; Schoen *et al.* 1998). In our view, deer are awarded an ephemeral "severance package" of a potentially abundant but nutritionally questionable (Van Horne *et al.* 1988; Hanley *et al.* 1989; Happe *et al.* 1990) food supply that may not be readily accessible due to snow or logging residue (Lyon and Jensen 1980; Wallmo and Schoen 1980; Harestad *et al.* 1982). Moreover, the resulting fragmented landscape may predispose deer to elevated levels of predation by wolves and other predators, including humans (Janz 1989; McNay and Voller 1995; Person *et al.* 1996; Trombulak and Frissell 2000). Owing to these factors, we believe a future landscape dominated by closed-canopy low-elevation forests will reduce the landscape's carrying capacity for deer, as do many other authors (Wallmo and Schoen 1980; Person *et al.* 1996; Schoen *et al.* 1998; Person 2000 and others).

Further, we emphasize our belief that clearcutting provides no net benefit to deer. We urge a more holistic evaluation from those who focus on the potential benefits from increased forage in new clearcuts. In one study, McNay and Voller (1995) concluded that "the risk of mortality [from predators] to adult deer at low elevations [in logged landscapes] likely outweighed potential benefits in habitat quality".

9.3 Local First Nations Land Management Plans

The Kitasoo-Xaisxais Land Management Plan (Kitasoo Band Council 2000) contains few specific management strategies. However, the plan recognized the ecological value of wolves and the importance of preserving habitat for wolves and their prey. The plan specifically forbids sport hunting in certain areas of Kitasoo-Xaisxais territory. A forthcoming Heiltsuk Land Management Plan may contain similar sentiment (L. Jorgensen *pers. comm.*).

PART III

SUMMARY CONCLUSIONS AND RECOMMENDATIONS

10 SUMMARY CONCLUSIONS

10.1 Year 2000 Pilot Study

To date, this project has exceeded its goals. We consider the descriptive natural history phase complete. Coastal wolves have a high incidence of the black colour phase, and a red tinge is common to grey animals. We estimate that approximately 403-476 wolves inhabit the study area and likely occupy all large islands and mainland areas where adequate numbers of deer exist. We believe that humans kill an average of 2.3% of the wolf population annually. Moreover, our dietary analysis revealed Sitka black-tailed deer is the primary prey of this population of wolves. Some packs showed a significant dietary shift to salmon in the fall. Our UCLA collaborators have discovered a previously unidentified haplotype in mitochondrial DNA from wolves of the study area. We remind readers of the importance of genetic diversity in the maintenance of biodiversity.

10.2 Conservation Assessment

We conclude that large-scale clearcut logging poses the greatest threat to this remnant and globally significant population of wolves. The effects of industrial forestry are well known in southeast Alaska where timber removal has been more extensive. Most importantly, considerable evidence indicates that the forest's carrying capacity for deer declines in the long-term. Moreover, logging roads provide access to humans who can over-exploit wolves, deer, and other wildlife. In 1991, a southeast Alaskan biologist warned, "substantial and potentially irreversible declines [in wolves] are anticipated in several biogeographic provinces" (Kirchhoff 1991). In our view, current management by the Ministry of Environment and forestry companies is not adequate to prevent similar declines in coastal BC. We believe, however, that a rare opportunity exists to preserve the ecological integrity of this wolf-deer system (see following recommendations).

11 RECOMMENDATIONS

The following recommendations reflect our current knowledge and the fundamental principles of Conservation Biology. As conservation biologists, we attempt to integrate the goals of economic development and nature conservation, as well as interject a biological framework into discourses of ethics. Accordingly, our recommendations address more than biology.

A rare, but diminishing, opportunity exists to preserve the wolves of coastal BC and the ecological systems that support them. Recognizing that this biological and spiritual legacy is of global importance, our suggestions reflect a sense of urgency and a need for immediate action. Until more information becomes available, however, our recommendations should be considered preliminary and cautionary. In the same regard, we urge industry and government, which are proceeding with large-scale timber removal, to adopt a more conservative and precautionary approach.

A rare, but diminishing, opportunity exists to preserve the wolves of coastal BC and the ecological systems that support them. Recognizing that this biological and spiritual legacy is of global importance, our suggestions reflect a sense of urgency and a need for immediate action.

1. **Continued Study**

   Intensive study should continue. Basic demographic, spatial-ecological, and behavioural data are urgently needed for land use plans. The forests are changing faster than scientists can measure the impact of these changes, let alone describe the most basic ecology of coastal wildlife.

2. **Comprehensive Perspective**

   We all must employ a broad spatial and temporal perspective when considering the status and management of this population. Regardless of the wide distribution and apparent ubiquity of wolves in the study area, this is a remnant and likely isolated population. Wolves in the region are descendants of those that first arrived in North America 700,000 years ago. In the last 200 years, these ancestors have had their distribution and numbers severely reduced by human beings. Conservation initiatives and management plans should develop long-term (*i.e.* 500 year) strategies to prevent the decline of this remnant and globally significant population.

3. **Source Population**

   Wolves of coastal BC should be considered a natural source population for wolves in nearby southeast Alaska, a population for which there is considerable conservation concern. Wolves are capable of dispersing over 900-km in continental North America (Fritts 1983). Person (*pers. comm.*) noted a minimum dispersal of 250-km in southeast Alaska.

As official stewards of habitat for wolves and deer, forestry companies and the Ministries of Environment and Forests should consider more active conservation measures. Conservation initiatives may include alternate timber removal prescriptions and preservation of large networks of low elevation old-growth forests.

4. GENETIC DIVERSITY

Wolves of coastal BC are morphologically distinct (Friis 1985; this study) and occupy a rare prey-based ecotype (black-tailed deer-wolf system — Theberge 1991; this study). Although preliminary data are encouraging, we cannot yet define this population as a distinct genetic "management unit". Regardless, we all must consider the importance of preserving diversity. This was eloquently pointed out by Friis (1985):

> In the interests of maintaining genetic diversity, wildlife managers should consider that the wolves of Vancouver Island and the mainland coast likely constitute the only surviving populations of the small southern wolf groups when designing their management plans for this species.

5. HABITAT STEWARDSHIP BY INDUSTRY AND GOVERNMENT

As official stewards of habitat for wolves and deer, forestry companies and the Ministries of Environment and Forests should consider more active conservation measures. This means more than protecting an undisclosed number and area of disjunct ungulate winter ranges. Conservation initiatives may include alternate timber removal prescriptions (*i.e.* Schoen and Kirchhoff 1985, 1990; Kirchhoff and Thomson 1998) and preservation of large networks of low elevation old-growth forests *(see below)*.

6. HOME SITE BUFFERS

Wolf home sites are important and comparatively small areas where reproductive activities take place. Pups are born, fed, raised, and protected in the den sites, a series of rendezvous sites, and surrounding areas. Wolves are sensitive to disturbance in home sites and are known to abandon them due to human activities (Chapman 1977; Ballard *et al.* 1987; Person and Ingle 1995; Paquet *et al.* 1996; Weaver *et al.* 1996). We know of current or historical homesites in Ingram Lake, Takush, and Lockhart Gordon watersheds on the mainland, and on Pooley, Roderick, and Yeo Islands *(Map 1)*. We believe current or imminent forestry activities (in some cases, roads already constructed) may adversely affect wolves in these six areas.

Forestry companies operating in these areas have an opportunity to incorporate this information into site plans for the upcoming breeding season (starting April 2001). In northern Alaska, wolves appeared intolerant of humans at 0.8-km (Chapman 1977). Regulations governing wolf reintroduction to Yellowstone National Park restrict human visitation to 1.6-km around active homesites (Fritts *et al.* 1994). Based on this information, and experience in Riding Mountain National Park (P. Paquet *unpub. data*) and

Banff National Park (Paquet *et al.* 1996), we recommend a precautionary buffer from all industrial activities of at least 2-km from the known or estimated den site.

7. Carnivore Conservation Areas

Wolves are known to be resilient to some human disturbances (Mech 1995). However, resiliency has limits and widespread historical declines attest the need for refugia (Weaver *et al.* 1996; Woodroffe and Ginsberg 1998). Given the scale and immediacy of timber removal and road building planned for the study area, we believe that opportunities to create intact reserves for wolf-deer systems are rapidly foreclosing.

The "umbrella species" concept states that protecting the habitat needs of wide ranging carnivores likely will provide the requirements of most other species (Shrader-Frechette and McCoy 1993; Noss *et al.* 1999). Conceptually, refuges function as "safety nets" from habitat loss and overexploitation elsewhere. Designing conservation areas is scientifically challenging and requires regional specificity. A starting point for coastal wolves is the widely agreed principle that viable populations require an adequate prey base and freedom from exploitation by humans (Fritts and Carbyn 1995; Mech 1995). We can proceed by examining the following general considerations regarding Carnivore Conservation Areas:

Given the scale and immediacy of timber removal and road building planned for the study area, we believe that opportunities to create intact reserves for wolf-deer systems are rapidly foreclosing.

Size

Critical reserve size is often based on population viability analysis that assesses the probability of a population's persistence over long time periods and various environmental conditions. A viable population size is large enough to permit its persistence despite genetic, demographic, and environmental uncertainties (Shaffer 1981) and their interactions (*i.e.* Mills and Smouse 1994). Depending on criteria used, landscape characteristics, and human influence in surrounding areas, scientists have estimated suitable reserve sizes for wolves that range from 3000-km^2 (Fritts and Carbyn 1995) to nearly 1,300,000-km^2 (Noss *et al.* 1996). Biological factors determine these vast spatial scales. For example, the amount of suitable or selected habitat in a landscape may be small (Noss *et al.* 1996). Consequently, home ranges are large (average 260-km^2 in southeast Alaska — Person 2000). Moreover, reproductive rates are constrained by the effective breeding population (typically only one pair breeds per pack — Noss *et al.* 1996; Weaver *et al.* 1996), and first-year survival is often low (Fuller 1989). These factors are partially mitigated by the species' considerable dispersal capabilities (*i.e.* Fritts 1983; Ballard *et al.* 1987), but less so in environments with barriers to dispersal such as water bodies.

In contrast to the spatial scales above, the Central Coast Land and Resource Management Plan (CCLRMP) (Lewis *et al.* 1997) identified 65 study areas *under consideration for protection*. These areas averaged only 4.8-km^2. Most were very small and would function to protect "key features" such as overwintering areas for waterfowl. The 14 (larger) areas selected for conservation, recreational, and cultural heritage representation averaged only 207-km^2. The largest is the Spirit Bear study area[2] at nearly 785-km^2; the largest composite area was 1,060-km^2 (above values calculated from Lewis *et al.* 1997). Clearly, given our current knowledge, the sizes (and disjunct nature) of these proposed protected areas are inadequate to ensure long term persistence of large carnivores on the coast.

[2] The original Spirit Bear Conservancy designers recommended a 2,470-km^2 reserve, which includes island and adjacent mainland areas (Bergdahl *et al.* 2000).

Configuration

Such large requirements of space may not be met under sociopolitical or habitat constraints. An option may be to consider population viability in a metapopulation framework that seems appropriate for wolves (Fritts and Carbyn 1995; Mech 1995; Mladenoff *et al.* 1995; Boyd *et al.* 1996). Critical reserve sizes may be met with configurations that include several areas linked by suitable dispersal routes. Reserve subdivision also may reduce the estimated viable population size because environmental stochasticity as an extinction force is decreased when populations are spread across space (Shaffer 1987).

Clearly, given our current knowledge, the sizes (and disjunct nature) of the proposed protected areas in the CCLRMP are inadequate to ensure long term persistence of large carnivores on the coast.

Importantly, if disjunct, these areas can be designed to encompass "hot–spots" of deer (biomass) distribution. In lieu of field data, planners can use GIS-based models that predict favourable deer (winter) habitat (Bergdahl *et al.* 2000) as a starting point. Finally, new protected areas can be linked to (and/or provide linkage among) the existing large protected areas (Kitlope Conservancy Area, Fiordland Recreation Area, and Tweedsmuir Provincial Park). We believe that there is an opportunity to create a fully representative, globally significant Carnivore Conservation Area if new and large coastal components are added.

Connectivity

A system of reserves must have appropriate connectivity to permit gene flow (Soule and Simberloff 1986) and demographic stability. As water bodies seem to be barriers to wolf dispersal (Person 2000), reserve matrices should include island and mainland areas. Moreover, because dispersing wolves suffer comparatively higher human-caused mortality (Peterson *et al.* 1984b; Person 2000), human access to dispersal routes must be limited. Finally, after conducting a literature review, Noss *et al.* (1996) suggested that "connectivity would be best provided by broad, heterogeneous linkages, not narrow, strictly defined corridors".

A Zoning Approach

Conservation-focused landscape design requires more than core reserve areas. Buffer zones may permit sensible industrial activity (*see* "Human Activities" discussion in Jeo *et al.* 1999) yet still provide supplemental habitat and shield sensitive species from human-caused mortality. Moreover, their value may be close to that of core reserves that alone may not be large and/or numerous enough to permit long-term viability (Noss *et al.* 1996).

In addition to providing refuge for wolves, deer, and other wildlife, large reserves can function as "natural laboratories". For example, "benchmark" demographic data from coastal wolves may lend insight into the persistence of other isolated or semi-isolated wolf populations. Genetic data may be exceptionally valuable. The information is relevant to concerns about inbreeding during wolf recovery and adds to knowledge of wolf dispersal (Forbes and Boyd 1996, 1997).

The BC Ministry of Environment's *unfulfilled* initiative advocated the creation of "preservation areas" that are "remote and of sufficient size to ensure the long-term viability of wolves". In these areas, wolves were not to be killed, and the primary objective was to "maintain viable populations of wolves in their natural state".

We encourage the implementation of planning by Bergdahl *et al.* (2000), Jeo *et al*. (2000), and McCrory *et al*. (2000). Together, our work advances considerably the BC Ministry of Environment's *unfulfilled* initiative that advocated the creation of "preservation areas" that are "remote and of sufficient size to ensure the long-term viability of wolves". In these areas, wolves were not to be killed, and the primary objective was to "maintain viable populations of wolves in their natural state" (Archibald 1989). Moreover, another Ministry publication noted, "the ecosystems that offer the best opportunities for the continued existence of these wolf-ungulate populations are those which have not yet been substantially altered by human development..." (Blower and Demarchi 1994).

This field season, we observed large-scale timber removal and road building in a minimum of five watersheds originally (and recently) classified as "core intact areas" (Jeo *et al.* 1999). We eagerly endorse large protected areas initiatives before such options are further compromised or lost.

8. Review of Sport Hunting Policy

The Ministry of Environment should review their sport hunting policy for wolves on the coast and throughout the province. Theberge (1991) estimated that less than 2.7% of the Canadian wolf population, on 1.2% of

Wolf shot by humans, coastal BC.

Management agencies should reconsider hunting regulations to reflect an improved understanding of wolf biology and changes in public ethics. Moreover, managers and the public should consider the extraordinary sentience and social nature of wolves as an ethical basis for prohibiting their killing.

total land base, is free from possible exploitation. Fritts and Carbyn (1995) estimated that fewer than six packs in North America live *exclusively* within parks where deliberate killing by humans is forbidden. Hayes and Gunson (1992) reasoned that management agencies should reconsider hunting regulations to reflect an improved understanding of wolf biology and changes in public ethics. Haber (1996) also argued that managers and the public should consider the extraordinary sentience and social nature of wolves as an ethical basis for prohibiting their killing. Moreover, a recent public opinion poll showed that the clear majority of British Columbians support a ban on the sport hunting of another carnivore, the grizzly bear (Kraft *et al.* 1999).

If trophy hunting of coastal wolves is permitted to continue, management that is more active must be implemented. For example, the Ministry should require all hunters to provide genetic samples from killed wolves. This would lead to a more accurate estimate of human-caused mortality and contribute to research efforts. Moreover, details of the hunt should be shared with interested scientists. Notably, precise kill-site information can support analysis of features in a landscape (roads/coastlines) that may predispose wolves to hunting pressure.

9. Wolves and Other Wildlife as a Non-consumptive Resource

Many people assume that protecting large areas for Nature carries significant costs in jobs lost and income foregone. Rasker and Hackman (1996) tested this assertion with case studies in the US Rocky Mountains. Although these authors identify no direct cause-and-effect relationship, employment and personal income levels in “wilderness” counties grew faster than in “resource-extraction” counties. Wilderness counties also showed higher degrees of economic diversification and lower unemployment rates. Rasker and Hackman (1996) offered an alternate hypothesis: the protection of wilderness habitat that sustains wild carnivores such as grizzly bears and wolves does not have a detrimental effect on local or regional economies. Clearly, however, some people would not benefit from a transition away from the current focus on resource extraction.

An opportunity exists on BC’s coast to expand wildlife-based ecotourism. Tourism is Canada’s fastest growing economic sector (Tourism BC 1996); nature and adventure tourism the fastest in the world (Ministry of Environment, Planning and Assessment 1989). It is clear that viewable wildlife has considerable financial value (Clayton and Mendelsohn 1993;

Barnes *et al.* 1999). Wolves have drawn thousands of tourists to Yellowstone and Algonquin Parks and surrounding areas. Even seeing sign or hearing howls of elusive wolves on BC's coast is a considerable draw for clients of ecotourism operators (B. Falconer — Maple Leaf Adventures *pers. comm.*; T. Ellison — Ocean Light Adventures *pers. comm.*).

We consider appropriate those operations that include and reward local involvement. Ecotourism has the potential to redirect an appreciable amount of revenue to local development and reinforce stewardship of wildlife and habitat (Bookbinder *et al.* 1998). First Nations tour operators may choose to integrate ecological and cultural education about wolves. Moreover, we advocate sensible and ethical practices that value education, safety, and have minimal influence on wildlife. We believe that viewing potential would be reduced in areas where wolves are killed or otherwise harassed by humans. Ecotourism operators also can aid in dispelling the common myths that contribute to the persecution of wolves in the area.

10. First Nations

Ecotrust (1998) noted that, in southeast Alaska, deer accounted for 20% of all wild foods consumed; an average of over 13,000 deer had an economic value of approximately US $6.4 million annually. Conflicts will almost certainly arise among user groups in the future when deer densities are reduced by industrial forestry.

We hope that continued collaboration and reciprocal learning can continue between researchers and local communities. This will be crucial in preserving viable wolf-deer systems on BC's coast. Reduced deer populations will have serious consequences for communities where jobs are scarce and many people rely to some extent on foods acquired by hunting, fishing, and gathering (Nelson 1997). Ecotrust (1998) noted that, in southeast Alaska, deer accounted for 20% of all wild foods consumed; an average of over 13,000 deer had an economic value of approximately US$ 6.4 million annually. Conflicts will almost certainly arise among user groups in the future when deer densities are reduced by industrial forestry (Person *et al.* 1996; Ecotrust 1998). Wolves may be incorrectly viewed as the cause. Thus, communicating the anticipated decrease in deer numbers due to forestry activities is extremely important.

11. Education

Education about coastal wolf-deer systems should continue to be extended to the provincial and global public. The value of charismatic large animals, such as wolves, cannot be understated in generating public awareness of wildlife and their habitat (Mech 1996). This can be accomplished by using print, photographic, and video media.

Year 2000 logging, Pooley Island, BC.

We believe that large-scale clearcutting of old-growth forests on BC's coast should discontinue until proponents can provide evidence that their actions will not imperil wolf-deer systems. Under the guidance of the precautionary principle, the burden of proof should be placed on advocates of resource extraction. We have presented convincing evidence that the volume and method by which timber is currently taken on the coast will irreparably harm deer and this remnant population of globally significant wolves.

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Communications

We are preparing a manuscript to summarize our findings in a scientific journal. Public communications have included a description of the project and research updates on the Raincoast Conservation Society's website (www.raincoast.org). This document will also be distributed to all interested parties in paper and compact disc formats, and is available on www.raincoast.org. CBC national radio featured this project in a documentary. Aspects of field research were videotaped for documentary broadcast on television.

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