

Noninvasive Approaches to Reduce Human-Cougar Conflict in Protected Areas
on the West Coast of Vancouver Island

by

Danielle M. Thompson
B.Sc. (Wildlife Management),
University of Northern British Columbia, 2001

A Thesis Submitted in Partial Fulfilment of the
Requirements for the Degree of

MASTER OF SCIENCE

In the Department of Biology

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Supervisory Committee

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Abstract

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Cougars (*Puma concolor*) are a growing concern for managers of Pacific Rim National Park Reserve and Clayoquot Sound UNESCO Biosphere Reserve on the west coast of Vancouver Island, British Columbia. Since the mid-1990s, the frequency and intensity of human-cougar interactions have dramatically increased. Concurrently, these areas have become increasingly popular for human activities. The primary goal of my study was to recommend ways to reduce the potential risk of human-cougar interactions to ensure long-term conservation of cougars while minimizing risks to visitor safety. To achieve this goal, I examined the use of two noninvasive approaches. Firstly, during 2005-2006, I compared the rate of detection, cost and time required for a detector dog, sign surveys, scented rub pads and remotely triggered cameras to detect cougars in coastal temperate rainforests. Sign surveys were the most effective method due to the availability of good tracking substrate throughout the study areas. Cameras were also practical because they could be used by less skilled personnel and had the capacity to detect several species of wildlife. Secondly, I demonstrated the utility of pre-existing data by analysing the spatiotemporal trends of human-cougar interactions on the West Coast Trail from 1993-2006. My results showed a moderate increase of reported human-cougar interactions ($n = 157$) despite a steady decline in hiker numbers across these years. Additionally, I

identified four areas where activities of people and cougars repeatedly overlapped (hotspots). In general, interaction locations were primarily associated with high human activity: near campsites and landscape characteristics that were associated with campsites (i.e., beaches and freshwater drainages >20 m wide). However, the distribution of hotspots suggests that the co-occurrence of human-use areas (e.g., campsites) and important travel routes (e.g., freshwater drainages and logging roads) used by cougars may increase the likelihood of interactions. These findings will allow protected area managers to proactively mitigate human-cougar conflict through visitor education and protocols that reduce people and cougars from intersecting in space and time.

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Dedication

To my grandfather, *James M. Devine*, whose smile and laughter will forever light my way, and to my mentor, *Bob Hansen*, for his unwavering support and his determination to reduce human-wildlife conflict.

Chapter 1: General Introduction

Overview

Conflicts between humans and wildlife are a global concern, particularly as they affect populations of large carnivores. The expansion of human activity throughout the world has caused widespread habitat loss and fragmentation (Saunders et al. 1991; Noss and Cooperrider 1994; Smallwood and Fitzhugh 1995; Logan et al. 1996; Rodiek and Bolen 1997), and increasing spatiotemporal overlap between people and wildlife. Human impacts and movements extend well beyond urban settlements into wilderness areas, and modern society dominates most terrestrial landscapes. This influx of people into wildlife habitats, combined with human-habituated wildlife (e.g., Whittaker and Knight 1998; Smith et al. 2005) has resulted in an ever-expanding interface between people and wildlife, and a greater frequency of escalated conflicts (Treves and Karanth 2003; Quigley and Herrero 2008). Defined by the World Conservation Union (IUCN, World Park Congress 2003), human-wildlife conflict occurs when the lives and livelihoods of people and wild animals, in search of similar life requisites, are negatively impacted by each other. Crop-raiding, predation of livestock or game, and attacks on people are among the most serious and ubiquitous forms of human-wildlife conflict. These conflicts involve a taxonomically diverse range of species, but those involving species of large carnivores have a tendency to evoke controversy (Woodroffe 2002; Graham et al. 2005; Thirgood et al. 2005).

The controversy over human-carnivore conflict likely stems from the important role large carnivores play in the consciousness of people and in human culture (Kellert et al. 1996),

and a deeply rooted fear of being attacked or killed (Quigley and Herrero 2005). It is widely recognized that large carnivores can cause tremendous economic losses through predation of livestock and can pose threats to human safety. In both developing and developed nations, rates of livestock predation by large carnivores have steadily grown, especially in areas where animal husbandry impinges on wilderness, and livestock compete with wild herbivores for range (Torres et al. 1996; Jackson and Wangchuk 2001; Mazolli et al. 2002; Wilson et al. 2005). Incidences of large carnivore attacks on people are relatively less common than attacks on livestock, yet are considerably more emotive (Beier 1991; Saberwal et al. 1994; McNay 2002; Nyhus and Tilson 2004; Smith et al. 2005). The risk of attack on humans by large carnivores is generally not tolerated and this intolerance greatly influences the way in which modern societies respond to the presence of large carnivores (Kellert 1996; Conforti and Cascelli de Azevedo 2003; Carrow 2005; Hemson et al. 2009).

The typical response of human beings is to kill problem animals when they are perceived to harm people and threaten their economic security – a time-honoured practice that has resulted in widespread persecution of carnivores (Kellert et al. 1996; Weber and Rabinowitz 1996; Woodroffe et al. 2005). Indeed, intentional killing of large carnivores, combined with other human-caused mortality (e.g., hunting, poaching, and vehicle collisions), has been identified as a major and rising threat to the vitality of many carnivore populations (Woodroffe and Ginsberg 1998; Woodroffe 2000; Ogada et al. 2003).

Human-mediated declines of large carnivore populations also have broad implications to ecosystems. Extirpation of large carnivores can trigger trophic cascades, thereby increasing herbivore density with consequent negative impacts on plant species distribution and abundance and, indirectly, overall reductions in biological diversity (Terborgh et al. 2001; Soulé et al. 2003; Hebblewhite et al. 2005; Knight et al. 2005). Despite such conservation concerns, people who experience damage by large carnivores often harbour resentment about carnivore presence and, consequently, can undermine reintroduction and conservation efforts (Löe and Røeskaft 2004; Sillero-Zubiri et al. 2006). Hence, human-carnivore conflict is more than simple competition for resources; it is a *mélange* of opposing human values relating to the ethics, politics, and economics of animal welfare and the protection of nature (Decker and Chase 1997; Treves and Karanth 2003; Sillero-Zubiri et al. 2007).

The conflict between humans and large carnivores is especially problematic inside and adjacent to protected areas, where densities of large carnivores are often high and use by humans continues to grow (Udaya Sekhar 1998; Woodroffe and Ginsberg 1998; Gibeau et al. 2002; Weladji and Tchamba 2003). Protected areas, including parks, reserves, and wildlife sanctuaries, are credited with saving many species of large carnivores from regional extirpation and range-wide extinction, and remain an effective tool for conservation (Noss et al. 1996; Soulé and Terborgh 1999; Soulé et al. 2003). Yet, many protected areas have become multi-use landscapes, increasingly popular for residential, recreational and other tourist-related activities, and consequently, areas where human-carnivore conflicts are concentrated (Naughton-Treves 1998; Gibeau et al. 2002; Weladji and Tchamba 2003; Nyhus and Tilson 2004). Best expressed by Treves (2008:215),

protected areas requiring the coexistence of people and large carnivores “reveal the fundamental dilemma posed by global concerns for biodiversity conservation on the one hand and individual and economic motivations to safeguard human life and livelihood on the other hand”.

This dilemma is faced by managers of Canadian National Parks. Managers must uphold concurrent mandates of: 1) safeguarding ecological integrity, 2) providing visitor experiences for the enjoyment of future generations, and 3) ensuring public safety within National Parks (e.g., National Parks System Plan, Parks Canada 2009). Achieving this balance therefore requires managers to maintain sufficient carnivore populations for preserving ecosystems and visitor viewing opportunities, while simultaneously reducing the potential risk of human-carnivore conflict.

The policies of ‘protection’ further complicate the challenges of protected area management by effectively reducing the number of viable options with which to mitigate human-carnivore conflicts. Lethal methods of control (e.g., shooting and poisoning) are most directly opposed to large carnivore protection because they can potentially result in the loss of large numbers of nontarget animals, and thus produce a population sink (Treves and Karanth 2003; Woodroffe et al. 2005). Conversely, nonlethal methods (e.g., sterilization, translocation and rehabilitation) are generally complex and require personnel, time and logistical resources that are often unavailable (Treves and Karanth 2003). Moreover, although nonlethal methods seem more acceptable to the public, they can have negative impacts on individuals and social networks, such as interspecific competition, infanticide, and higher mortality from reduced competency for hunting and

survival (Treves and Karanth 2003; Woodroffe et al. 2005). However, both types of control address the consequences, not the causes, of conflict between people and large carnivores. Attempts to proactively mitigate human-carnivore conflict should be based on an explicit understanding of where the activities of human and carnivores overlap spatially and temporally, and on an understanding of which social and ecological factors are associated with conflict areas. Based on these understandings, managers should be able to formulate policies and procedures that successfully eliminate or reduce these conflicts.

Several factors have been associated with human-carnivore conflict. Nyhus and Tilson (2004), for example, demonstrated that conflicts between Indonesians and tigers (*Pantheras tigris*) are more likely to occur during daylight hours near forest edges where resources are easily accessible, and where human settlements are surrounded by extensive tiger habitat. Similarly, the risk of conflict between people and grizzly bears (*Ursus arctos*) in north-central Montana was higher in areas where concentrations of human-related attractants (e.g., bee hives, bird feeders, garbage) overlapped with bear habitat (Wilson et al. 2005). Other research showed that lion (*Leo panthera*) attacks on people increased significantly along the fringes of the Gir Forest protected area in northwest India during the monsoon as a result of cooler weather and increased activity of lions during the day when people were also active (Saberwal et al. 1994). Thus, conflict arose in situations where human activities occurred close to or within carnivore habitat.

Background

Cougars (*Puma concolor*) once occupied the widest distribution of any terrestrial mammal in the western hemisphere (Banfield 1974). By the turn of the twentieth century, cougars had been extirpated from much of their North American range due to direct persecution and by exponential increases in human populations and resultant human activities that reduced habitat in addition to the number and types of prey (Cougar Management Guidelines Working Group 2005). Cougar range is now reduced to portions of Florida, Mexico, and areas within the mountains, foothills and rainforests of western Canada and the United States (Sweaner et al. 2000).

In British Columbia (BC), cougars were perceived as major threats to livestock, game, and human safety, and were heavily persecuted through government-sponsored bounties until 1957, by which time regional populations had been significantly reduced (BC Ministry of Environment 1980). Today, cougars are provincially managed as a yellow-listed species subject to hunting as 'big game' (Province of BC 1996), and they are federally protected within National Parks (Government of Canada 2000). The estimated number of cougars in BC is 4,000-6,000, and that number is thought to be stable (Austin 2005). Although cougars are not considered to be at risk, growing numbers of human-cougar interactions, including attacks on people, are presenting new management challenges and conservation concerns.

Cougars are a growing management and conservation concern in Pacific Rim National Park Reserve and Clayoquot Sound UNESCO Biosphere reserve, located on the outer west coast of Vancouver Island. As one of three large terrestrial carnivores (i.e., cougar,

grey wolf (*Canis lupus*) and black bear (*Ursus americanus*) inhabiting this area, cougars play a key role in maintaining natural ecosystem processes (Terborgh et al. 2001; Soulé et al. 2003). However, since the mid-1990s, reports of interactions between people and cougars have increased in frequency and intensity (Figure 1.1). Concomitantly, these protected areas have become increasingly popular to tourists and outdoor enthusiasts, with recent visitor use numbers exceeding 1 million annually (LEAD International 2004; Edwards 2005). Cougars appear to be habituating to human-use areas by continuing to travel, hunt, and den in these areas; however, the cumulative impacts of human activity and land alteration may be compromising the ecological integrity of reserve areas and placing extant cougar populations at risk of decline (B. Hansen, Parks Canada, pers. comm. 2006). Recent conflict events corroborate such a supposition – in 2003 a cougar was destroyed in response to predatory attacks on people and domestic pets, and necropsy results from a cougar known to be involved in numerous incidents of conflict revealed starvation as the cause of death.

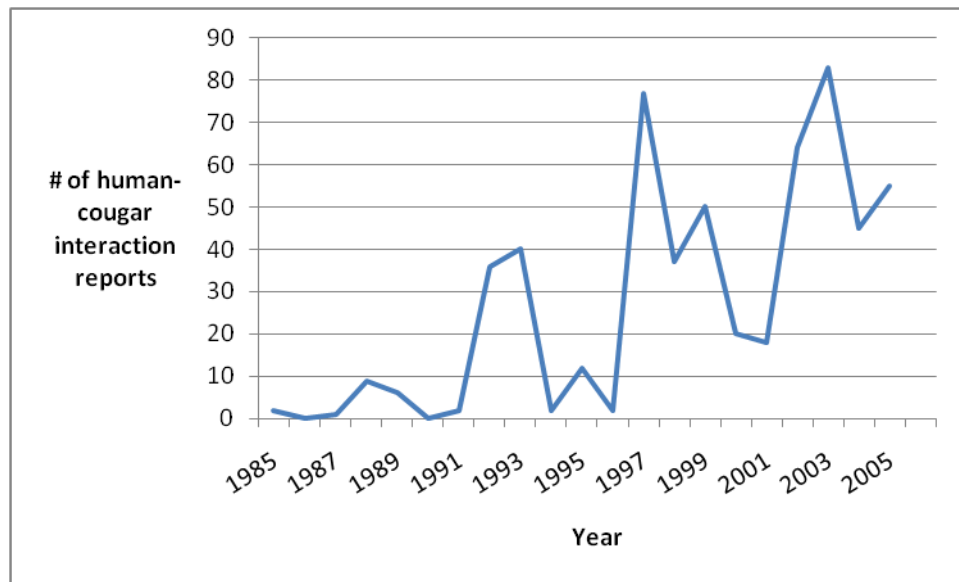


Figure 1.1 Reports of human-cougar interactions ($n = 621$) in Pacific Rim National Park Reserve and Clayoquot Sound UNESCO Biosphere Reserve, 1985 – 2005. Human use in these protected areas also increased over this period.

Faced with budgetary constraints and a paucity of baseline information about local cougar populations, protected area managers are challenged to ensure long-term conservation of cougars while minimizing risks to visitor safety. Thus far, attempts to manage human-cougar conflict have been primarily reactionary, and based on anecdotal reports and intra-agency experiences. There is a critical need to develop a cost-effective monitoring program to identify where the activities of cougars overlap those of people, and to identify the underlying factors that influence the occurrence of human-cougar conflicts.

Rationale

Obtaining information about cougars has been a long-standing logistical challenge due to their highly cryptic, mobile and solitary nature. Cougars are among the most difficult

terrestrial mammals to census (Lindzey 1987; Cougar Management Guidelines Working Group 2005), and cougar detection and monitoring requires extraordinarily intensive field efforts (Smallwood and Fitzhugh 1995). Customarily, cougar research is conducted using radio-telemetry (e.g., Ackerman et al. 1984; Iriarte et al. 1991; Ross and Jalkotzy 1992; Sweanor et al. 2000; Dickson and Beier 2002), a technique that is widely recognized as well suited for obtaining detailed spatial and ecological information about difficult-to-detect species (Dunn and Gipson 1977; Douglass 1989; Samuel and Kenow 1992; Choate et al. 2006).

Radio-telemetry was employed in previous studies of cougars on eastern Vancouver Island (Gladders 2000; Goh 2000; Hahn 2001). However, I chose to use noninvasive approaches to study cougars for the following three reasons. First, the cost of collars and receivers, tracking vehicles and aircraft, and on-the-ground workers required to monitor cougars in the remote and densely-vegetated terrain of the west coast of Vancouver Island was too high (BC Ministry of Environment, Lands and Park 1998; Wilson et al. 2004) for use in this study. Second, capture-based methods are invasive; that is, they involve inherent risk and contentious handling of individuals in the target population (Beier and Cunningham 1996; Gompper et al. 2006). Moral principles aside, few would argue the benefits of minimizing disturbance to study animals. Lastly, new detection methods and types of analysis have made noninvasive methods more applicable to studying large carnivores, given their ecology and behaviour (MacKay et al. 2008).

The term ‘noninvasive’ has become a standard term used in the wildlife literature to describe survey methods that “do not require target animals to be directly observed or

handled by the surveyor” (MacKay et al. 2008:1). Large carnivores typically exhibit territorial behaviours that include conspicuous placement of sign (e.g., tracks, scat, and territorial markings) along focal movement paths (Beier 1995; Murphy 1998; Whittington 2002); and such sign have morphological and ecological distinctiveness that facilitates sign identification and species discernment – characteristics that allow the indirect ‘capture’ of elusive species through the detection of sign (Smallwood and Fitzhugh 1995).

In much the same way, anecdotal sighting reports are increasingly being used to develop baseline detection/non-detection and abundance data for rare and difficult-to-detect species, particularly in the absence of empirical data – a consequence of insufficient funding, monitoring, and detection capacity (Stoms et al. 1993; Merrill et al. 1999). Despite the inherent limitations and biases of such data, repeated sightings of a target species can reveal important spatial and temporal patterns of distribution and help identify priorities for better allocation of management activities. Wilson et al. (2005), for example, conducted a spatial analysis of sighting reports of grizzly bear in human use areas using a geographical information system (GIS) to determine which social and ecological factors were associated with human-grizzly conflict hotspots. Similar methods were used to identify habitat variables associated with occurrence of grizzly bear in North Cascades National Park, Washington (Agee et al. 1989), Iberian lynx (*Lynx pardinus*) in southwest Portugal (Palma et al. 1999), bobcat (*Lynx rufus*) in Illinois (Woolf et al. 2002), and wolf (*Canis lupus*) in northern Poland (Jędrzejewski et al. 2004).

Goal and Objectives

This study was designed as a noninvasive approach to address the growing concerns about cougars in the human-dominated protected areas on the west coast of Vancouver Island. The overarching goal of my project was to contribute to the development of long-term conservation strategies for cougars by recommending ways to reduce the risk of human-cougar conflict. Within this goal, I established two specific objectives:

- 1) To evaluate the efficacy of noninvasive survey methods to obtain baseline information about cougars. More specifically, I wanted to field test four survey methods, namely, a detector dog, sign surveys, scented rub pads, and remotely triggered cameras, to determine field time requirements and equipment costs, and overall capacity to detect and monitor cougars in coastal temperate rainforests.

- 2) To examine the spatial and temporal patterns of human-cougar interaction reports to determine whether factors relative to landscape characteristics and human activity influence the potential for encounters between people and cougars to occur.

Chapter 2: Study Area

Ecological Setting

The general study area is located in Pacific Rim National Park Reserve and Clayoquot Sound UNESCO Biosphere Reserve on the west coast of Vancouver Island (Figure 2.1). The area is situated within the Vancouver Island Ranges of the Insular (outer) Mountains physiographic region (Holland 1976), and is comprised of a diversity of ecosystems including saltwater, freshwater rivers and lakes, bogs, and forests.

Ecologically, the study area lies within the very wet hypermaritime (vh1) subzone of the Coastal Western Hemlock (CWH) biogeoclimatic zone, except for a very small area (Log Jam Creek to Port Renfrew) that is located in the very wet maritime subzone (vm1) (Pojar et al. 1991). Yearlong mild temperatures and heavy rainfall, combined with infrequent catastrophic disturbances (e.g., fire), influence the native flora, producing large trees and dense understory. Mean annual temperatures of the CWH zone are characteristically temperate, ranging between 7 C and 18 C. The average yearly precipitation, of which only 15% occurs as snow, is 3295 mm concentrated between the months of October and March (Pojar et al. 1991).

Zonal stands of the maritime subzone are found at elevations ranging between sea level and 600 m. They are dominated by western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), Douglas-fir (*Pseudotsuga menziesii*), and amabilis fir (*Abies amabilis*). This subzone typically features a well-developed shrub layer of salal (*Gaultheria shallon*), oval-leaved blueberry (*Vaccinium ovalifolium*), red huckleberry (*Vaccinium parvifolium*); a sparse herb layer dominated by

deer fern (*Blechnum spicant*); and a moss layer dominated by step moss (*Hylocomium splendens*), lanky moss (*Rhytidiadelphus loreus*), and Oregon beaked moss (*Kindbergia oregana*) (Green and Klinka 1994).

The hypermaritime subzone occurs at elevations ranging between sea level and 200 m. Zonal hypermaritime forests are characterized by mixed stands of western hemlock, western redcedar, and Sitka spruce. Yellow cedar (*Chamaecyparis nootkatensis*), shore pine (*Pinus contorta*), and amabilis fir are locally abundant, occurring under various conditions. The understory of this subzone consists of a well-developed shrub layer dominated by salal, salmon berry (*Rubus spectabilis*), red huckleberry, Alaskan blueberry (*Vaccinium alaskanese*), and deer fern; a sparse herb layer dominated by bunch berry (*Cornus canadensis*); and a moss layer dominated by lanky moss, Oregon beaked moss and step moss. Bogs are prevalent in low lying areas of the hypermaritime subzones (Green and Klinka 1994).

Three species of large terrestrial carnivores inhabit the region; cougar, grey wolf, and black bear. The principal prey species of these carnivores are Columbian black-tailed deer (*Odocoileus hemionus columbianus*), river otter (*Lontra canadensis*), raccoon (*Procyon lotor*), mink (*Mustela vison*), and grouse (*Dendragapus obscurus* and *Bonansa umbellus*). Another potential prey species is Roosevelt elk (*Cervus canadensis roosevelti*), but they are localized to a few watersheds in the study area and are otherwise considered rare.

Hunting is permitted in some parts of the study area, which is situated within Management Units (MU) 1-3 and 1-8 of Region 1 (BC Ministry of Environment 2008). Designated hunting areas are located outside the National Park boundaries and within specified zones of the Biosphere Reserve. The hunting season for cougar typically occurs between November and mid-June. The hunt is unlimited entry, with a bag limit of two cougars per hunter per season; hunting kittens or any cougar(s) in the presence of kittens is prohibited (BC Ministry of Environment 2008). The number of cougar on Vancouver Island is currently estimated to be between 400 – 600 animals, with approximately 10 – 20 cougars inhabiting the general study area (J. MacDermott, BC Ministry of Environment, pers. comm. 2010).

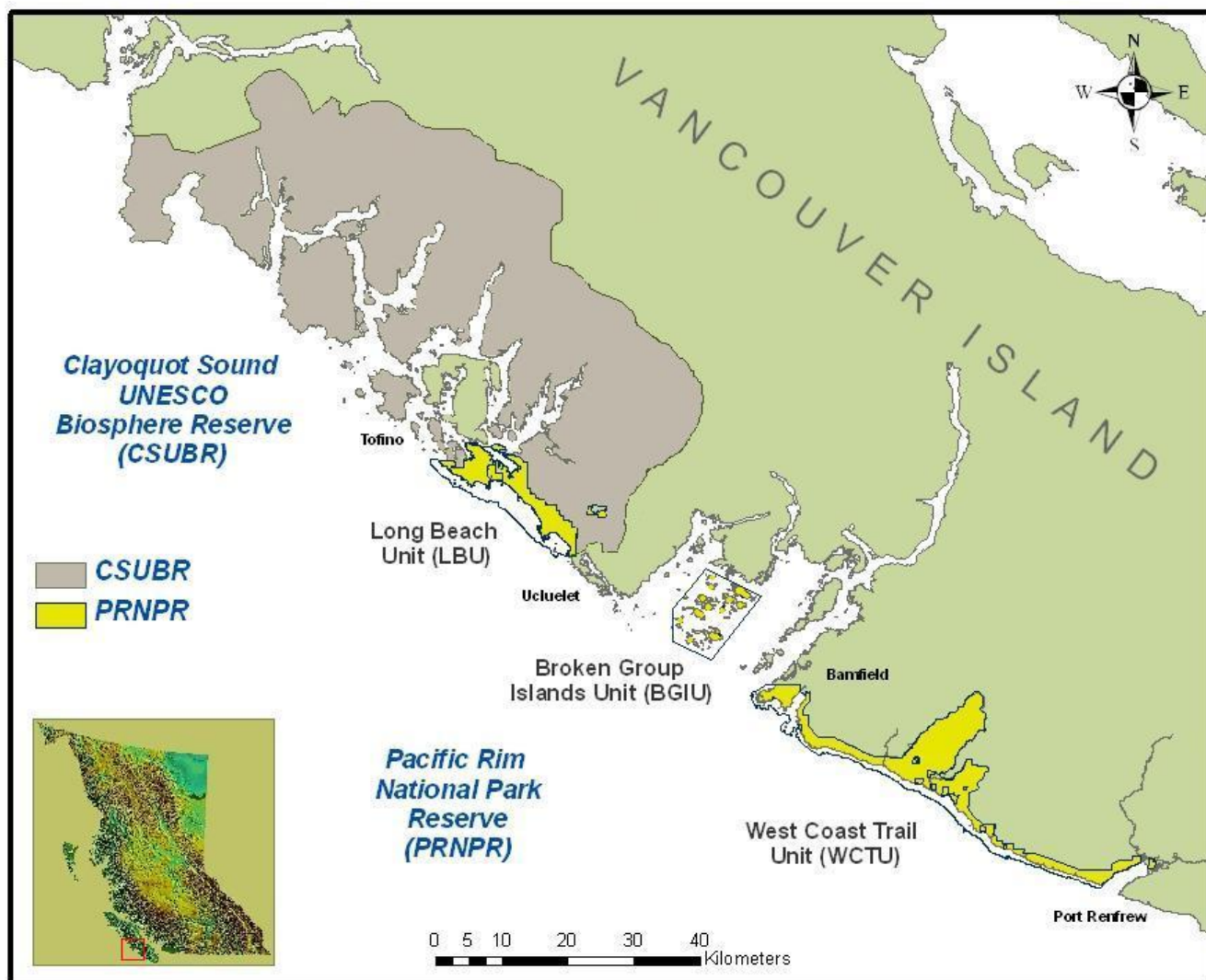


Figure 2.1 Location of the Clayoquot Sound UNESCO Biosphere Reserve and the Long Beach Unit, Broken Group Islands Unit and West Coast Trail Unit of Pacific Rim National Park Reserve on the west coast of Vancouver Island, British Columbia (Map developed in a GIS using Parks Canada and BC Government data layers).

Pacific Rim National Park Reserve

Created in 1970, Pacific Rim National Park Reserve covers an area of approximately 500- km² that stretches the 125 km between the towns of Tofino in the north and Port Renfrew in the south. The National Park Reserve represents the coastal lowland forests of the Pacific Coast Mountain region, and the near-shore waters of the Vancouver Island's Shelf Marine region. This area is within the Nuu-chah-nulth traditional territory that is currently under treaty negotiation. In acknowledgement of pending land claim settlements, the area is designated as a “National Park Reserve” but is managed in accordance with the statutory laws of the Canada National Parks Act (Parks Canada 2007). The development and extraction of natural resources, for example, are strictly prohibited within the confines of National Park boundaries.

Despite the fact that that much of the region was logged prior to park inception, several tracts of old-growth temperate rainforests still exist within the National Park Reserve. However, with extensive logging continuing along the park boundary, the area protects just a narrow band (the average width is approximately 2 km) of coastal landscape (Figure 2.2). Pacific Rim National Park Reserve is geographically divided and managed as three separate units: the Long Beach Unit (LBU), the Broken Group Islands Unit (BGIU), and the West Coast Trail Unit (WCTU).



Photo Credit: Dani Thompson 2007

Figure 2.2 Aerial photograph showing the proximity of logging activity along the boundary of Pacific Rim National Park Reserve (West Coast Trail Unit) that protects a narrow band of coastal old-growth forest.

Long Beach Unit

The Long Beach Unit is situated between the towns of Tofino and Ucluelet, encompassing the traditional territories of the Tla-o-qui-aht and Ucluelet First Nations. Proximity to an airport, highway and local marinas provide easy access to the LBU and surrounding areas, which have become popular for residential, recreational and tourist activities. Not surprisingly, the LBU sustains the highest levels of human use within the region. Edwards (2005) documented an escalating trend in number of visitors, with annual numbers exceeding 1 million by the late 1990's.

Broken Group Islands Unit

The Broken Group Islands Unit is located approximately 15 km south of Ucluelet in Barkley Sound. This unit of the National Park Reserve encompasses the traditional

territory of the Tseshaht First Nation. Access to the BGIU is restricted to marine vessels only. As a result, human use levels are relatively low, averaging 11,000 visitors on a seasonal basis (Edwards 2005). Visitors to the area are predominantly kayakers who come to explore the tidal ecosystems of over 100 islets and rocky outcrops within this unit.

West Coast Trail Unit

The West Coast Trail Unit is the southernmost management unit of the National Park: it is situated between the coastal communities of Bamfield (Pachena Bay) and Port Renfrew, and includes the traditional territories of the Huu-ay-aht, Ditidaht, and Pacheedaht First Nations. The area includes the historic West Coast Trail that was originally built as a telegraph line to enable communication between Victoria and Cape Beale. Later, in response to the tragic wreck of the Valencia in 1906, the telegraph line was upgraded to a rescue trail to improve life-saving and evacuation efforts (Parks Canada 2007).

Today, the West Coast Trail is a world-renowned wilderness hike acclaimed for its stunning views and challenging terrain. Access to the trail is restricted to the respective trailheads in the north and south, and to Nitinat Narrows at the south end of Nitinat Lake, approximately mid-way between the trailheads. It takes 5-6 days, on average, to complete the entire trail depending on hiker experience and weather conditions. Despite these challenges, an average of approximately 6,000 hikers use the trail each year (PRNPR Visitor Database 2006).

The West Coast Trail is open seasonally, between May 1st and September 30th, to avoid the dangers associated with high seas and inclement weather that often make river crossings, beach routes and trail infrastructure unsafe for use during winter months. During the open season, visitors must purchase a permit for day use and overnight camping privileges, which thereby enables monitoring of human use.

Clayoquot Sound UNESCO Biosphere Reserve

The Clayoquot Sound region has witnessed considerable conflict over local land-use practices (e.g., Magnusson and Shaw 1997). In 2000, the area was designated as a United Nations Educational, Scientific, and Cultural Organization (UNESCO) Biosphere Reserve as way to address the concerns of local First Nations and surrounding communities about sustainable resource development and conservation. The Clayoquot Sound UNESCO Biosphere Reserve encompasses an area approximately 3,500- km², combining large tracts of remnant temperate rainforest and marine ecosystems. Although some parts of the Reserve have been extensively logged, many of the valleys remain intact and isolated from human use.

Under the UNESCO World Biosphere Reserve model, resource extraction activities are excluded from a legally protected core area that is set aside to ensure the preservation of natural ecosystems. However, varying degrees of resource development can occur within specified buffer and transition zones so long as these activities are sustainable and do not adversely impact the protected core areas (Clayoquot Sound Biosphere Nomination Working Group 1999). Approximately one third (1,100 km²) of the Reserve is constituted as marine and terrestrial protected core areas. The Long Beach Unit of Pacific Rim

National Park Reserve is one of many parks and ecological reserves designated as protected core areas of the Biosphere Reserve (Clayoquot Sound Biosphere Nomination Working Group 1999).

There are five Nuu-chah-nulth Central Region Tribes inhabiting the region; Ahousaht, Hesquiaht, Tla-o-qui-aht, Toquaht and Ucluelet First Nations. The region includes the communities of Hesquiaht, Hot Springs Cove, Ahousaht, Tofino, Opisaht, and Esowista, and the communities of Ucluelet, Ittattoo and Macoah located just outside the Biosphere Reserve boundary. The resident population of the Clayoquot Sound Biosphere Reserve is estimated to be approximately 5,000 people, over half of whom reside in Tofino and Ucluelet. During summer months, however, visitors to the region can exceed over 1 million (LEAD International 2004).

Study Areas

The study areas selected for this project were located in human use areas where the frequency and intensity of cougar-human interactions have increased over time, and where a paucity of information about cougars has precluded efforts for proactive management. Records ($n = 617$) from the Pacific Rim National Park Reserve wildlife observation database between 1985-2006 indicate the majority of cougar-human interactions occurred in and around the Long Beach Unit and surrounding Clayoquot Sound UNESCO Biosphere Reserve ($n = 298$) and in the West Coast Trail Unit ($n = 313$). Accordingly, data for this study were collected within these two areas:

- 1) The Long Beach Unit of PRNPR and adjacent CSUBR lands (hereafter referred to as the Long Beach study area) located between the communities of Tofino ($49^{\circ} 9.2' \text{ N}$, $125^{\circ} 54.1' \text{ W}$) and Ucluelet ($48^{\circ} 55.5' \text{ N}$, $125^{\circ} 32' \text{ W}$) (Figure 2.3).

- 2) The West Coast Trail Unit of PRNPR (hereafter referred to as the West Coast Trail study area) between the Pachena Bay ($48^{\circ} 47.6' \text{ N}$, $125^{\circ} 6.9' \text{ W}$) and Port Renfrew ($48^{\circ} 34.7' \text{ N}$, $124^{\circ} 25.1' \text{ W}$) (Figure 2.4).

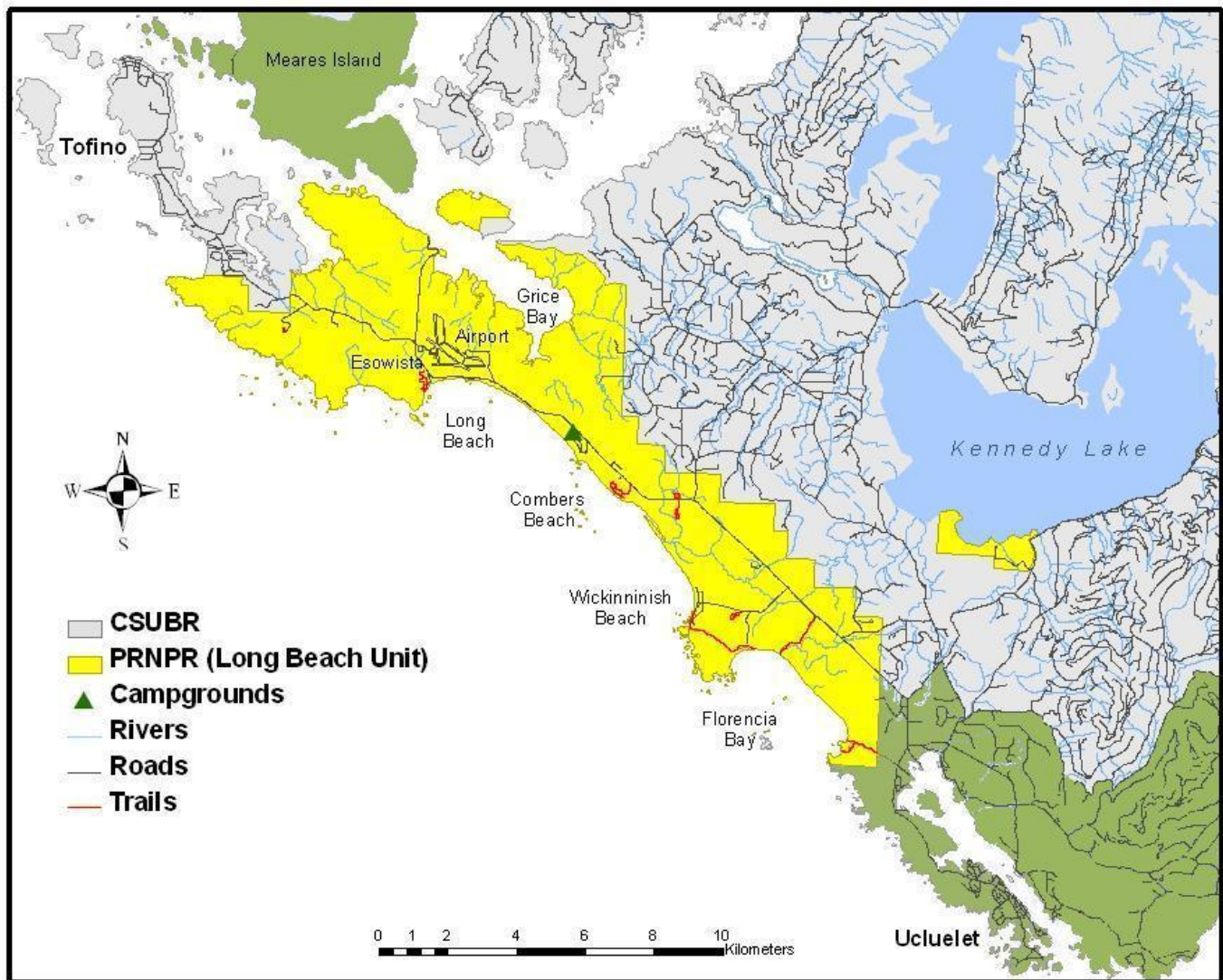


Figure 2.3 Map of the Long Beach study area situated in the Long Beach Unit of Pacific Rim National Park Reserve, Clayoquot Sound UNESCO Biosphere Reserve and adjacent non-park lands on the west coast of Vancouver Island, including towns, campgrounds, trails, roads and freshwater drainages (Map developed in a GIS using Parks Canada and BC Government data layers).

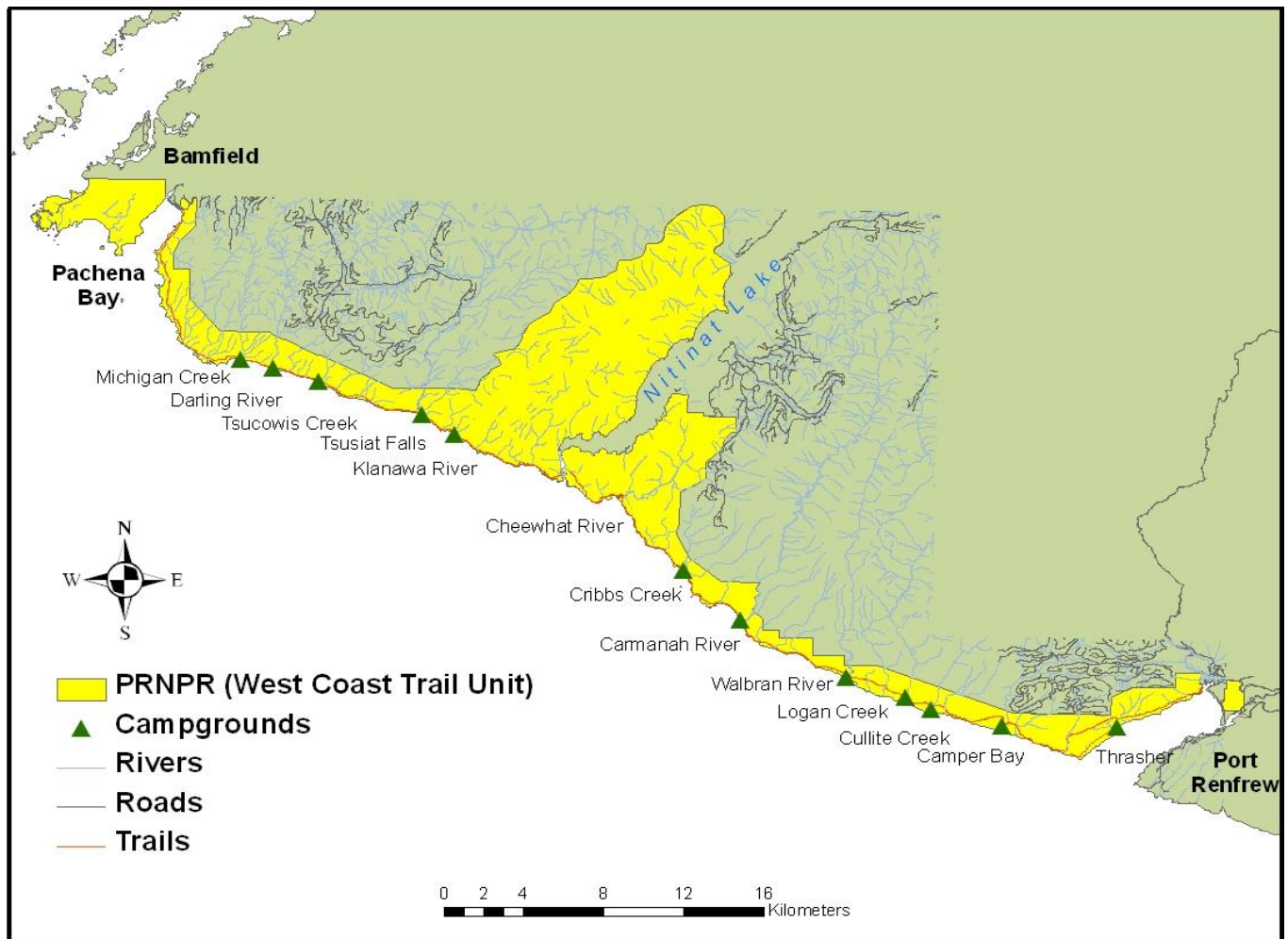


Figure 2.4 Map of the West Coast Trail study area situated in the West Coast Trail Unit of Pacific Rim National Park Reserve on the west coast of Vancouver Island, including towns, campgrounds, trails, roads and freshwater drainages (Map developed in a GIS using Parks Canada and BC Government data layers).

Chapter 3: Efficacy of Noninvasive Survey Methods to Detect Cougars in Coastal Temperate Rainforests

Introduction

Globally, large carnivores are of increasing concern to conservation biologists because the numbers of most species are declining. Factors causing this decline are varied, but in all cases, effective conservation of large carnivores requires monitoring spatial and temporal use of habitats, documenting the status and temporal trends of populations, and understanding the factors that influence those trends. Reliable estimates of species distribution and abundance are necessary for reintroduction and recovery programs (Merrill et al. 1999), and for developing policies to reduce human-carnivore conflicts in protected areas (Treves and Karanth 2003; Nyhus and Tilson 2004; Wilson et al. 2005).

Large carnivores often occupy large territories at low natural densities, and exhibit elusive behaviours – characteristics that render them difficult to study (Noss et al. 1996; Crooks 2002; Smith et al. 2003; Ruell and Crooks 2006). In many ways, cougars epitomize the difficulties associated with large carnivore research and monitoring.

Average cougar home range sizes vary between 230 km² - 485 km² for males, and 67 km² - 113 km² for females (Logan et al. 1986; Beier and Barrett 1993; Laundre and Hernandez 2003), and population density estimates typically range between 0.37- 4.7 cougars/100 km² (Ross and Jalkotzy 1992; Lindzey et al. 1994; Spreadbury et al. 1996). Cougars are also solitary predators that employ ‘stalk and ambush’ strategies to hunt their prey, the success of which depends on stealthy movements and behaviours. Not surprisingly, cougar habitat is characterized by dense vegetation and rugged terrain (i.e., frequent

changes in slope and aspect) that effectively reduce the sight lines of prey and allow greater ambush speed (Laing and Lindzey 1993; Jalkotzy et al. 1999; Riley and Malecki 2001; Dickson and Beier 2002; Dickson et al. 2005). In much the same way, cougars use of the ‘cover of darkness’ to minimize their detection by exhibiting crepuscular activity patterns (Beier et al. 1995; Sweanor et al. 2004). Collectively, these traits explain some of the logistical challenges of studying cougars, and why capture-based methods are often criticized as too costly (Smallwood and Fitzhugh 1995).

In comparison, noninvasive methods are well suited to study animals across large areas and are cost-effective. The term ‘noninvasive’ is used to describe techniques that allow surveyors to obtain information about target species without direct observation or handling (MacKay 2008). Conspicuous and distinctive marking of main travel routes are territorial behaviours commonly exhibited by large carnivores (Beier 1995; Murphy 1998; Whittington 2002). These behaviours enable surveyors to indirectly ‘capture’ elusive species through the detection of sign (e.g., tracks, photos, hair). Recent advancements of noninvasive survey methods (e.g., Silveira et al. 2003; Gompper et al. 2006; Harrison 2006; Long et al. 2006b) have extended applications beyond verifying species presence to yield information about relative abundance and distribution over large geographic areas and, with repeated sampling over time, trends in numbers (Long and Zielinski 2008).

For example, DNA-based capture-recapture methods utilizing hair and scats have enabled biologists to identify species accurately and to document trends in population size, occurrence and distribution (Mills et al. 2000; Haynes et al. 2005; MacKay et al. 2008),

information that heretofore was impossible to obtain without expensive capture and radio telemetry. DNA analyses of hair samples collected from barbed wire snares were used to determine grizzly bear densities (Mowat and Strobeck 2000; Boulanger et al. 2004), and scented rub pads have been used to determine the conservation status of ocelots (*Leopardus pardalis*; Weaver et al. 2005). Similarly, analyses of faecal DNA have revealed information about the foraging behaviours of wolves in north and central British Columbia (Darimont et al. 2004) and grizzly bears in Banff National Park, Alberta (Raine and Kansas 1990), and of population trends of wolverine (*Gulo gulo*) in Norway (Flagstad et al. 2004).

More recently, detection dogs have been used to locate carnivore scat detection over large areas. Domestic dogs (*Canis familiaris*) possess a remarkably keen sense of smell and the ability to hone in on odours originating as far as 400m away (Wasser et al. 2004). Field trials conducted by Smith et al. (2001) demonstrated that dogs were much more proficient at locating carnivore scat than human surveyors and therefore could reduce bias when scats are obscured from view. Dogs detect airborne scent molecules that are dispersed from the source in a cone-like pattern, with higher concentrations occurring closer to the source. However, landscape features, such as dense vegetation and sloped terrain, often inhibit airflow and cause scent molecules to pool. As such, method success depends largely on the dog handler's ability to assist the dog to locate the source by paying close attention to behaviours that indicate scent detection by the dog – quick turns and exaggerated air-sniffing – and by recognizing site conditions that may be confusing the dog. Once the target scat has been found, the handler rewards the dog with a play object, such as a tennis ball. The allure of the play object maintains the dog's motivation for

searching and, ultimately, distinguishes a proficient detector dog from a less proficient one (Smith et al. 2001; Wasser et al. 2004). Detector dogs have been used with marked success for wide-ranging and rare carnivores, including grizzly bear (Wasser et al. 2004), black bear and fisher (*Martes pennantni*; Long et al. 2006a), kit fox (*Vulpes macrotis*; Smith et al. 2003), bobcat (*Lynx rufus*; Harrison 2006; Long et al. 2006a), and tiger (Kerley and Salkina 2007).

Technological advancements in photographic equipment have also increased the use of cameras as a noninvasive method to survey large carnivores. Digital cameras are designed to trigger when an animal passes through an infrared beam, thus allowing target species to be ‘captured’ remotely. Used alone or in combination with other methods, such as bait stations (González-Esteban et al. 2004) and scent lures (Crooks and Soulé 1999; Weaver et al. 2005), remotely triggered cameras have been used extensively to verify species presence and distribution. Also, by using unique traits to identify individuals, mark and recapture methods can be used to estimate abundance (Karanth and Nichols 1998; Silveira et al. 2003; Kawanishi and Sunquist 2004; Kelly et al. 2008).

The overall breadth of noninvasive methods available for study of large carnivores illustrates the diversity that exists among species and ecosystems – method effectiveness varies inconsistently with different behavioural and habitat characteristics. Species colour, size, and density, for example, may greatly influence sampling effort (Gompper 2006; Harrison 2006). Equally, the logistical constraints of sampling within heavily forested and/or complex terrain may affect the probability of detecting species and, ultimately, method feasibility (Gese 2001; Silveira et al 2003; Long et al. 2008).

Noninvasive survey methods have previously been used to study cougars. For example, sign surveys were used to determine the relative abundance of cougars across California (Smallwood and Fitzhugh 1995), and to determine changes in the population status of cougars in south-eastern Arizona (Beier and Cunningham 1996). Similarly, remote camera surveys were used to detect cougar presence in central Brazil (Silveira et al. 2003), to estimate cougar densities within Bolivia, Argentina, and Belize (Kelly et al. 2008), and in conjunction with scent lures, to inventory cougars and other forest-dwelling mammals in south eastern Brazil (Trolle 2003). However, the effectiveness of noninvasive survey methods has not yet been assessed for cougars inhabiting coastal temperate rainforests.

My primary objective was to evaluate the utility of noninvasive survey methods for cougar research and monitoring in the human use areas of Pacific Rim National Park Reserve and Clayoquot Sound UNESCO Biosphere Reserve. I field tested four commonly used methods: a detector dog, sign surveys, scented rub pads, and remotely triggered cameras. I examined their effectiveness in detecting cougars and assessed their cost-effectiveness with respect to their field-time requirements and equipment costs.

Methods

Noninvasive survey methods were applied to determine their effectiveness in detecting cougars. Sign of wolf, black bear and deer was also recorded to examine the possibility that the detection of one species may affect the detection of another species. Wherever possible, sites were chosen to maximize survey area coverage and so increase the

probability of detecting cougar, and to reduce the potential loss of data from public interference with detection devices and animal sign.

To evaluate method effectiveness, I recorded the number of days required to set up and conduct surveys and compared the rate of detected sign (i.e., # of detections/day) for each species. For the purposes of this study, a field day was defined as a 5-hour period, not including associated travel times to and from survey sites. In addition, I recorded the equipment costs required to apply each survey method. Again, I did not include associated project costs such as technician wages, travel expenses, and accommodation because these costs were collectively shared among methods and survey areas.

I used Fisher's exact tests to determine if the number of sign detections and survey hours differed between years (i.e., Long Beach 2005 and 2006) and study areas (i.e., Long Beach and West Coast Trail).

Detector Dog

Field trials with a detector dog were conducted over a 4-week period during July and August, 2005 in the Long Beach survey area (Figure 2.3). Following methods described by Wasser et al. (2004), the area was divided into seventeen systematically distributed 5 km x 5 km (25 km²) grid cells. Taking into account the regional population density estimate of 5 cougars/100 km² (Hahn 2001), the grid cell size was chosen to increase the likelihood of detecting cougars while ensuring maximum coverage throughout the survey area. Logistical and cost constraints precluded multiple visits to all sites. Thus, all grid cells were searched once by a detector dog-and-handler team, and three grid cells were searched twice.

Beginning at dawn within a specified grid cell, the dog team searched a transect of 5-12 km for cougar scats, following unpaved roads, trails, beaches, ridgelines and watercourses. Transect routes were recorded using handheld Global Positioning Systems (GPS) units (Garmin International Inc., Olathe, KS). The dog searched off-leash several meters in front of the handler who guided and intently watched from behind (Figure 3.1). Inaccessible areas (e.g., cliffs, water bodies, dense vegetation) were avoided to facilitate travel. Depending on terrain and prevailing weather conditions, the resultant transects varied in duration between 4 – 6 hrs. Mock searches for cougar scat, using previously collected samples, were conducted on a daily basis to confirm the detection ability of the dog and to reinforce his continued motivation for a play reward.



Photo Credit: Dani Thompson 2005

Figure 3.1 Detector dog and handler team searching for cougar scats in the Long Beach study area in 2005.

Sign Surveys

Sign surveys were conducted in the Long Beach study area (Figure 2.3) during two summers (May – August) in 2005 and 2006, and in the West Coast Trail survey area (Figure 2.4) during the summer (June – August) of 2006. Surveys in the Long Beach study area were conducted along transects (2005, $n = 11$; 2006, $n = 18$) varying between 1-8 km in length. Transects were well distributed throughout the survey area and monitored bi-weekly as separate sampling units. Survey routes were recorded as UTM coordinates using handheld GPS units. Surveys in the West Coast Trail study area were conducted along the main hiking trail. The trail was surveyed five times at 13-day intervals, and data were recorded for each 1-km segment.

On each transect, observers scanned an area of approximately 2 m width, looking for sign (i.e., tracks and scats) of cougar, wolf, black bear and deer. Deer and black bear sign is readily identifiable but cougar and wolf scat can often be difficult to distinguish from each other due to overlapping size and morphological characteristics. For this reason, scat identity in the field was based on the co-occurrence of additional sign or other species-specific characteristics (e.g., scat placement, presence of bones/hair, colour, and smell). Once identified, scat and tracks were marked (e.g., with a drawn circle or a boot print) to reduce the potential for repeat counting during subsequent surveys (Figure 3.2). The locations of all scats and tracks were recorded using the GPS units.



Photo Credit: Dani Thompson 2005

Figure 3.2 Example of a detected cougar track marked with a drawn circle in the sand to prevent the possibility of re-counting during subsequent sign surveys.

Scented Rub Pads

Scented rub pads were set up in the Long Beach and West Coast Trail study areas during June – August, 2006. In the Long Beach study area, 40 rub pads were set up in 10 previously established 25-km² grid cells used for the detector dog surveys. Rub pads were installed 1 – 2 km apart and were checked on five separate occasions at 13-day intervals. In the West Coast Trail study area, 34 rub pads were installed. Sites were located approximately 1 – 2 km apart and at least 20 m off the main trail to avoid possible interference by hikers. Rub pads were checked on four separate occasions at 13-day intervals.

Each rub pad consisted of one 10 x 10-cm piece of carpet pad punctured with approximately 8-10 roofing nails (1.6 cm long) arranged in a circular pattern to facilitate

the snagging of hair (McDaniel et al. 2000; Weaver et al. 2005) (Figure 3.3).

Approximately 5ml of Weaver's CatCall™ scent lure was smeared into the carpet fibres within the circle of nails, which was then sprinkled with fresh catnip (*Nepeta cataria*).

This scent lure was specifically designed to evoke the natural cheek-rubbing behaviours used by many felids as a method to mark territories or to exchange olfactory information (Mellen 1993; J. Weaver, pers. comm. 2005). The scented rub pads were nailed to selected target trees 0.6 to 1 m above ground. To increase the likelihood of visitation by cougars, an aluminium pie plate was attached to a swivel and suspended by fishing line in a nearby tree as a visual attractant (Figure 3.4).

When each site was checked, the rub pads were examined for hair samples using gloved hands. When samples were present, the rub pad was removed and replaced with a new one; rub pads without hair were revamped with a new application of scent lure. Removed rub pads containing hair were placed in a dry envelope and stored until further laboratory analysis.



Photo Credits: Dani Thompson 2006

Figure 3.3 From top left: Carpet pad showing the circular pattern of nails; cheek rubbing response of a domestic cat on a scented rub pad; aluminium pie plate (located at picture centre) attached to a swivel and suspended with fishing line used for a visual attractant near scented rub pads.

Remotely Triggered Cameras

Remotely-triggered infrared digital cameras (Stealth Cam, LLC, Grande Prairie, TX)

were deployed in the Long Beach and West Coast Trail study areas during summer, 2006

(Figure 3.4). This make of camera was selected because its hard plastic housing could potentially withstand leakage from heavy precipitation and damage by curious bears. Infrared cameras are heat-sensitive and, therefore, are less likely than optical sensors to trigger during high wind and precipitation events. Compared to film-loaded cameras, digital cameras require relatively less maintenance and have a larger storage capacity for images. Digital images also display the date and time at which the camera was triggered and, thus, can provide accurate information about animal presence.

In the Long Beach survey area, 10 cameras were installed at a subset of rub pad sites. Cameras were located >2 km apart and checked, with hair-snare stations, on five sampling occasions at 13-day intervals. Similarly, 11 cameras were installed at selected rub pad sites along the West Coast Trail. Cameras were located > 4 km apart and checked four times at 13-day intervals.

All remotely triggered cameras were programmed to record three consecutive images at 1-second intervals when the emitted infrared beam was disrupted (broken), and the flash was set to operate when light levels were low.



Photo Credit: Billy Wilton 2006

Figure 3.4 Stealth Cam remotely-triggered digital camera set up to photograph animal visitations at a scented rub pad station.

Results

Detector Dog

In 2005, the detector dog-and-handler team located 1 cougar scat during 23 days of searching 171 km of transect distributed across the Long Beach study area at a rate of 0.04 detections/day (Table 3.1). This scat was located next to a very old cache site containing the skeletal remains of a deer. The scat was aged (>1 month old) and partially buried – it was found at the bottom of a small forest gully separating two waterfront properties in Ucluelet. This was the second search of the grid cell where cougars had been reportedly sighted three times during the two weeks prior to detector dog surveys – the scat was missed by the dog during the first search of the grid cell.

During surveys, black bear scats were frequently ($n = 72$) observed along transect routes. Wolf and deer scats were observed less frequently ($n = 19$ and 2 , respectively). Non-target scats were not included in the survey results.

The costs of hiring the detector dog-and-handler team, not including the cost of accommodations and travel expenses to and from survey sites, was approximately \$2000 for the study period, or \$87/day (Table 3.1). Although not done in this study, DNA confirmation of detected scat samples would require an additional cost of approximately \$25/scat (e.g., Harrison 2006).

Sign surveys

During 2005 in the Long Beach study area, a total of 230 km were surveyed over 31 field days, resulting in 120 tracks and 111 scat detections. Of those, 1 track and 1 scat were identified as cougar, comprising 1% ($2/231$) of sign detected at a rate of 0.06 detections/day. Black bear comprised the majority (56%; $130/231$) of sign detected at a rate of 4.19 detections/day. Deer comprised 33% ($75/231$) of sign detected at a rate of 2.42 detections/day, and wolf comprised the remaining 10% ($24/231$) of sign at a rate of 0.77 detections/day (Figure 3.5; Table 3.1).

During 2006 in the Long Beach study area, a total of 296 km were surveyed over 35 field days, resulting in 64 tracks and 75 scat detections. Of those, 4 scats were identified as cougar, comprising 3% ($4/139$) of detected sign at a rate of 0.11 detections/day. Black bear comprised the majority (45%; $63/139$) of sign detected at a rate of 1.80 detections/day. Deer sign comprised 43% ($59/139$) of detections at a rate of 1.69

detections/day, and wolf sign comprised the remaining 9% (13/139) of detections as a rate of 0.37 detections/day (Figure 3.6; Table 3.1).

In 2006 in the West Coast Trail study area, a total of 375 km were surveyed over 40 field days, resulting in 106 tracks and 44 scat detections. Of those, 1 track and 1 scat were identified as cougar, comprising 1.3% (2/150) of sign detected at a rate of 0.05 detections/day. Wolf and deer comprised the majority (35%; 53/150, and 35%; 52/150, respectively) of sign detected at rates of 1.35 and 1.30 detections/day, respectively. Black bear sign comprised the remaining 29% (43/150) of sign detected at a rate of 1.07 detections/day (Figure 3.7; Table 3.1).

The number of detected sign and survey hours for cougar, wolf, and deer did not differ between years in the Long Beach survey area (Fisher's exact tests, $P = 0.68$, $P = 0.10$, and $P = 0.29$, respectively). However, numbers of black bear detections in 2005 were significantly higher than that in 2006 (Fisher's exact test, $P < 0.01$) in the Long Beach study area.

Similarly, the number of cougar detections did not differ between the West Coast Trail and Long Beach study areas for both years (Fisher's exact tests, 2005; $P = 1.00$, and 2006; $P = 0.42$, respectively). Conversely, numbers of wolf detections in the West Coast Trail area were significantly higher than the Long Beach study area for both years (Fisher's exact tests, 2005; $P < 0.001$, 2006; $P < 0.001$). Detections of black bear and deer sign were significantly higher in the Long Beach study area in 2005 than the West Coast Trail study area (Fisher's exact tests, $P < 0.001$, $P < 0.05$, respectively); however,

they did not differ between study areas in 2006 (Fisher's exact tests, $P = 0.098$, $P = 0.455$, respectively).

There were no costs associated with sign surveys, excluding the cost of technician wages, accommodations and travel expenses to and from survey sites.

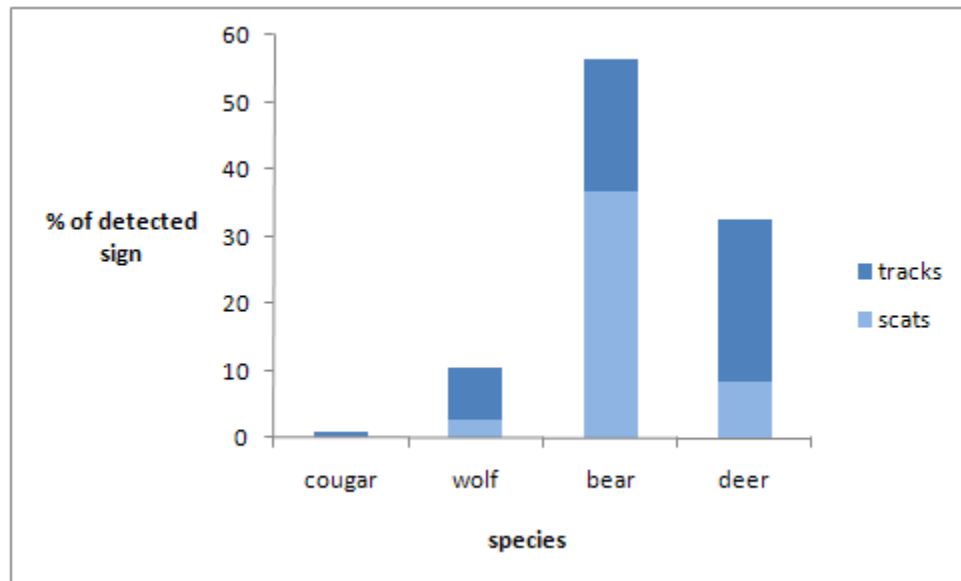


Figure 3.5 Results of sign surveys conducted in the Long Beach study area in 2005 as a percentage of total track and scat detections ($n = 231$) for cougar, wolf, black bear and deer.

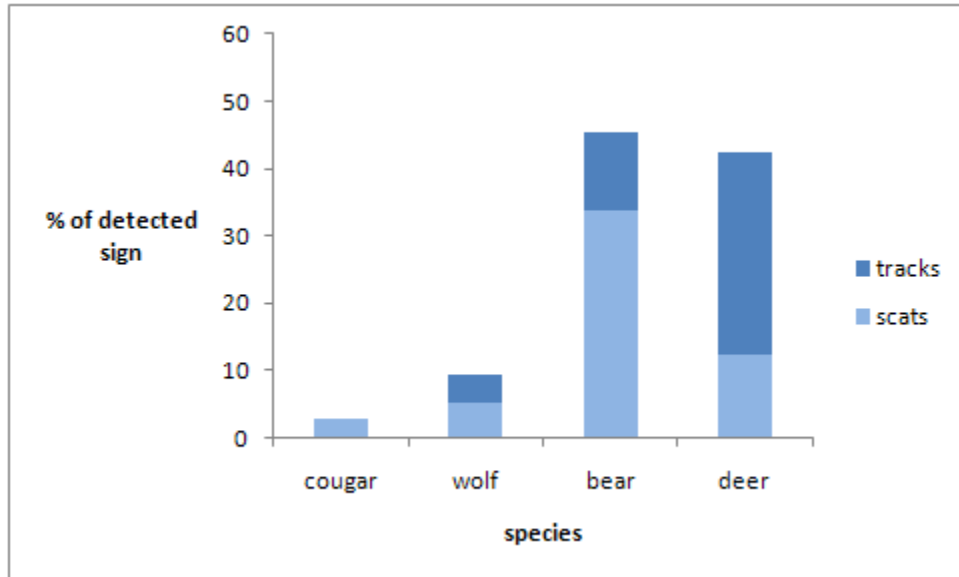


Figure 3.6 Results of sign surveys conducted in the Long Beach study area in 2006 as a percentage of total track and scat detections ($n = 139$) for cougar, wolf, black bear and deer.

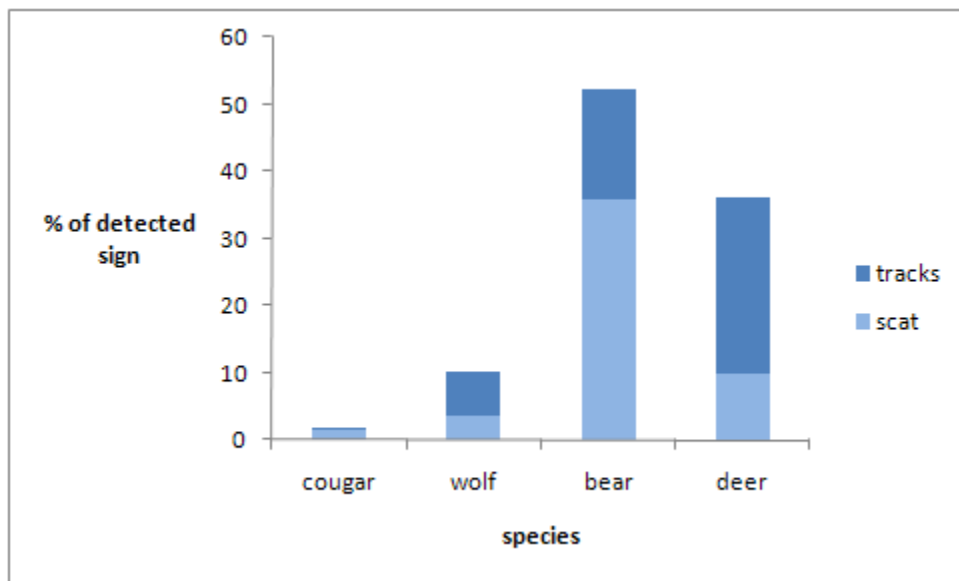


Figure 3.7 Results of sign surveys conducted in the West Coast Trail survey area in 2006 as a percentage of total track and scat detections ($n = 150$) for cougar, wolf, black bear and deer.

Scented Rub Pads

In 2006 in the Long Beach study area, a total of 41 hair samples were collected during the 35 days that were required to set up and monitor rub pads ($n = 40$) over five sampling intervals. Black bear comprised the majority of collected hair samples (95%; 39/41) at a rate of 1.17 detections/day (Figure 3.8; Table 3.1). The remaining 5% (2/41) of hair samples were of unknown identity; however, they were suspected to be domestic dog because free-roaming dogs were frequently observed near the sites at which the samples were collected. Rub pads were removed from trees on 26 separate occasions by bears, as revealed by bite and claw marks, hair, and tracks present at the site.

During 2006 in the West Coast Trail study area, a total of 8 hair samples were collected during the 40 days required to set up and monitor rub pads ($n = 34$) over four sampling intervals. Black bear comprised the majority (63%; 5/8) of collected hair samples at a rate of 0.12 detections/day (Figure 3.9; Table 3.1). Wolf hair comprised 12% (1/8) of collected hair samples at a rate of 0.03 detections/day. The remaining 25% (2/8) of hair samples could not be identified. Although not confirmed, the unidentified samples were not attributed to cougar because of dissimilar colour and morphology, and little in the way of other evidence indicating cougar presence.

Scented rub pads failed to detect cougar and deer in either study area, and wolf in the Long Beach survey area. However, black bear were frequently detected in both survey areas, albeit significantly more often in the Long Beach survey area than in West Coast Trail survey area (Fisher's exact test, $P < 0.001$).

The costs to establish scented rub pads in both study areas, not including the cost of accommodations and travel expenses to and from survey sites, was \$280 for the scent lure and \$70 for carpet, nails and aluminium pie plates. Thus, it cost approximately \$189, or \$5.40/day, to establish rub pads in the Long Beach study area, and approximately \$169, or \$4.23/day, to establish rub pads in the West Coast Trail study area. Although not done in this study, DNA confirmation of collected hair samples would require an additional cost of approximately \$28/sample (Harrison 2006).

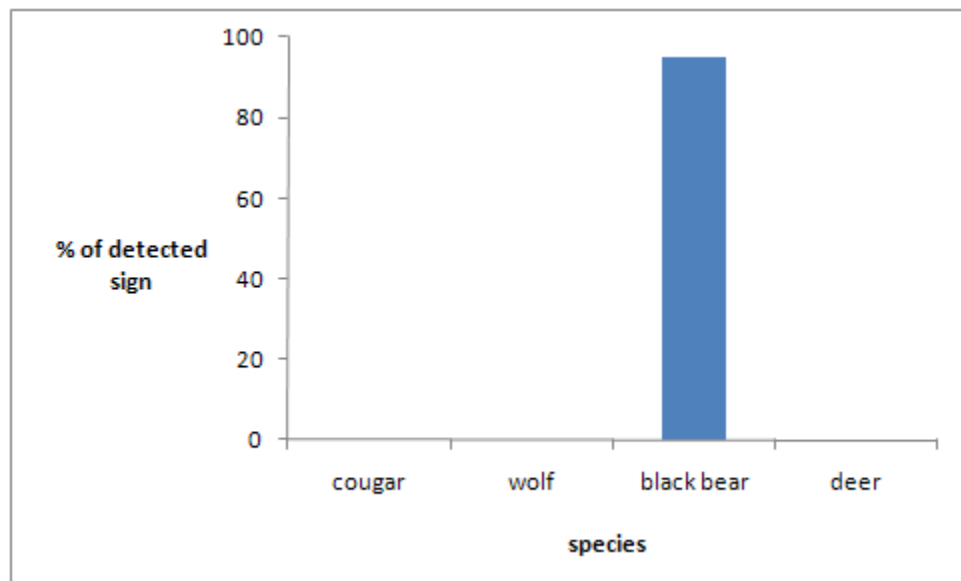


Figure 3.8 Results of scented rub pad surveys conducted in the Long Beach study area in 2006 as a percentage of total hair detections ($n = 41$) for cougar, wolf, black bear and deer.

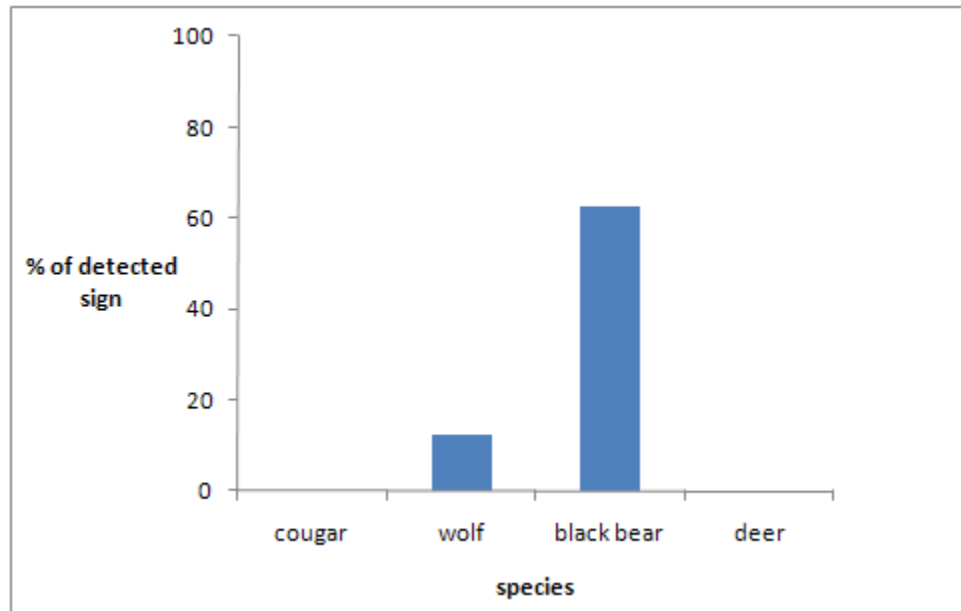


Figure 3.9 Results of scented rub pad surveys conducted in the West Coast Trail study area in 2006 as a percentage of total hair detections ($n = 8$) for cougar, wolf, black bear, and deer.

Remotely Triggered Cameras

During 2006 in the Long Beach study area, 8 photos were collected from 10 cameras during the 35 field days required to set up and monitor the cameras over five sampling intervals. Black bears comprised 75% (6/8) of photos at a rate of 0.17 detections/day, while deer comprised the remaining 25% (2/8) of photos at a rate of 0.06 detections/day (Figure 3.10; Table 3.1).

During 2006 in the West Coast Trail study area, a total of 20 photos were collected from 11 cameras during the 40 days required to set up and monitor cameras over four sampling intervals. Black bears comprised 30% (6/20) of photos at a rate of 0.15 detections/day (Figure 3.11; Table 3.1). Deer comprised 25% (5/20) of photos at a rate of 0.12

detections/day, and wolf comprised 15% (3/20) at a rate of 0.08 detections/day. The remaining detections were of elk (20%; 4/20) and raccoon (10%; 2/20).

Black bears damaged one half (5/10) of the deployed cameras in the Long Beach study area. Bears knocked down cameras on separate occasions at two different sites and, on one occasion, chewed a camera beyond repair. All cameras damaged by bears were located at rub pad sites that had also been spoiled by bears. In some cases, bears were detected before the camera became inoperable; in other cases, bears were not detected by cameras despite the presence of bear hair at corresponding rub pad sites. In the West Coast Trail study area, device failure occurred in 18% (2/11) of deployed cameras because of bear-caused damage and sensor malfunction. Non-functioning cameras were not included in results.

Remotely triggered camera surveys failed to detect cougars in both study areas, and wolves in the Long Beach study area. Interestingly, detections of black bear and deer did not differ between study areas (Fisher's exact test, $P = 1.00$, and $P = 0.45$, respectively).

In total, the cameras cost \$5250, plus an additional \$150 for batteries. Thus, it cost approximately \$2571.42, or \$75.63/day to deploy cameras ($n = 10$) in the Long Beach study area, and approximately \$2828.57, or \$70.71/day, to deploy cameras ($n = 11$) in the West Coast Trail study area.

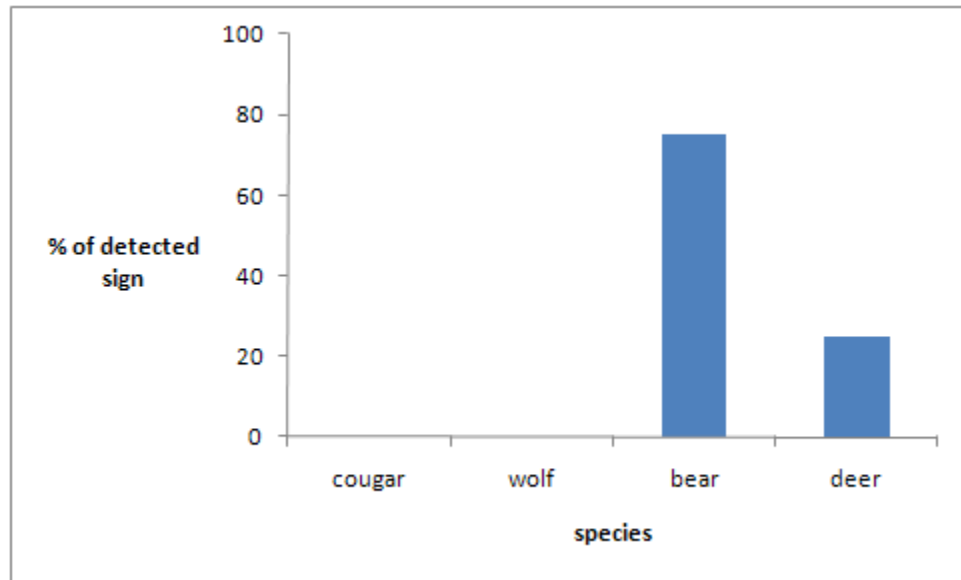


Figure 3.10 Results of remotely triggered camera surveys conducted in the Long Beach study area in 2006 as a percentage of total photos detections ($n = 8$) for cougar, wolf, black bear, and deer.

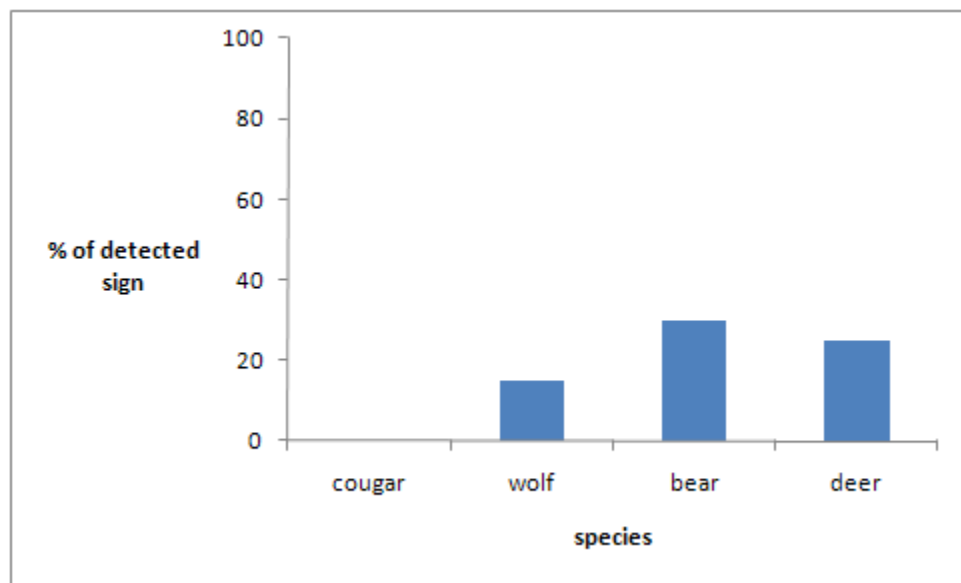


Figure 3.11 Results of remotely triggered camera surveys conducted in the West Coast Trail study area in 2006 as a percentage of total photo detections ($n = 20$) for cougar, wolf, black bear, and deer.

Table 3.1 Comparison of detection rate, field time requirements and equipment costs for species detected by a scat detection dog, sign surveys, scented rub pads, and remotely triggered cameras in the Long Beach and West Coast Trail study areas in 2005 and 2006.

Survey Method (area, year) ^a	No. of Detections (Rate) ^b				Field Time Requirements (days) ^c	Equipment Costs (\$) ^d
	cougar	wolf	bear	deer		
Detector Dog (LB, 05)	1 (0.04)	--	--	--	23	2,000
Sign Surveys (LB, 05)	2 (0.06)	24 (0.77)	130 (4.19)	75 (2.42)	31	0
(LB, 06)	4 (0.11)	13 (0.37)	65 (1.80)	59 (1.69)	35	0
(WCT, 06)	2 (0.05)	53 (1.33)	43 (1.08)	52 (1.30)	40	0
Scented Rub Pads (LB, 06)	0	0	39 (1.11)	0	35	189
(WCT, 06)	0	1 (0.03)	5 (0.12)	0	40	161
Cameras (LB, 06)	0	0	6 (0.17)	2 (0.06)	35	2,571
(WCT, 06)	0	3 (0.08)	6 (0.15)	5 (0.12)	40	2,829

^a Areas; LB = Long Beach study area, WCT = West Coast Trail study area.

^b Rate is the # of species sign (i.e., tracks, scats, hair or photos) detected/day during the time required to conduct surveys in the field using each noninvasive method.

^c Field time requirements is defined as the number of 5-hour days to complete surveys, not including travel time to and from survey sites.

^d Equipment costs are the total costs of equipment required to conduct surveys using each detection method. Costs do not include associated project costs, such as field technician wages, travel expenses, and accommodation.

Discussion

Sign surveys were the most effective method for detecting cougar, wolf, black bear, and deer compared to the detector dog, scented rub pads, and remotely triggered camera surveys in both study areas. In addition to achieving relatively high detection rates for all species, sign surveys cost less with respect to equipment and field time. This point is particularly important because long-term funding and staffing resources for wildlife research in the Pacific Rim National Park and the Clayoquot Sound UNESCO Biosphere Reserves are often limited and uncertain. Overall, sign surveys seem the most appropriate noninvasive method for use in the study areas; however, there are several inherent challenges that may limit the use of sign surveys for long-term monitoring applications.

The foremost consideration is the necessity for stringent training and survey protocols to increase the rigour and robustness of sign surveys (Smallwood and Fitzhugh 1995). In 2005, sign surveys in the Long Beach study area were conducted by experienced research technicians with proficient track and scat identification skills. In 2006, sign surveys were conducted by volunteers. In spite of training and constant supervision, the capacity of volunteers to consistently detect and identify species sign greatly varied, as did the propensity of surveyors to record data and follow survey protocol. Inconsistent survey effort may possibly explain why the detection rate of black bear sign in 2005 was twice that of 2006. Thus, surveyor proficiency is paramount to ensure consistency between sign surveys. Similarly, it is important to consider site variability and conditions that can strongly bias species detection rates (Haynes et al. 2005; Heinemeyer et al. 2008). Track detection and identification greatly depend on favourable substrate that may or may not be present during surveys. Sand, mud and road dust, for example, tend to register tracks

well unless subjected to high winds, rain or drought. Scats, on the other hand, are generally more resistant to weather conditions and can persist long after they have been deposited. Nonetheless, the detection of scats is influenced by landscape and substrate characteristics and the degree to which they are obscured from view (Van Dyke and Brocke 1987a). In the Long Beach and West Coast Trail study areas, site conditions varied and, at times, were unsuitable because of poor tracking substrate, weather and dense ground cover. Consequently, the rates of species detection by sign surveys are likely higher in areas where tracks and scats were more readily observed.

Unlike human surveyors, trained detector dogs are less reliant upon visual detection to locate scat and therefore can minimize bias associated with species detection and identification. In spite of this, and good success reported in other studies (Beckman 2006, as cited in Long et al. 2008; Long et al. 2006a), use of a detection dog to locate cougar scat in the Long Beach study area was ineffective. Several reasons might explain the failure of this technique. First, the dog's ability to hone in on cougar scats may have been inhibited by factors within the study area. According to Wasser et al. (2004), car fumes and other human-related activities can obscure scat odours, while strong ocean breezes and dense vegetation can influence the dispersal of scent molecules from the source of origin. Such conditions predominate throughout the study area and may have made cougar scats more difficult to locate by the detector dog. Second, the detector dog may have had difficulty remaining focused to locate cougar scats during surveys. The dog had been explicitly trained to detect cougar scat; however, it had had been formerly trained to detect grizzly and black bear scats. Compared with black bear scats that are conspicuous and abundant throughout the Long Beach study area, cougar scats are often

buried and naturally sparse if numbers of cougars are low. Switching to a new target scat, especially to one that did not yield a frequent play reward, may have confused the dog and his ability to stay focused during long search days. Last, the relative rarity of cougars in the study area may have also contributed to the failure of this technique. These possible constraints are supported by the age (> 1 month old) of the detected scat sample, and the low rate of cougar detection by other noninvasive survey methods. Although anecdotal reports indicated the occurrence of at least one cougar during the study period, the spatial and temporal scale of cougar activity was likely too large for the detector dog surveys to be effective. Preferably, several detector dog-and-handler teams should be employed to conduct transect searches to reduce bias and increase the likelihood of cougar scat detection over large area. However, increasing the number of detector dog teams would have substantially increased project costs.

Scented rub pads and cameras (located at a subset of rub pad stations) failed to detect cougars in the Long Beach and West Coast Trail study areas. Although some studies have reported good success with rub pads for detection of felids (McDaniel et al. 2000; Weaver et al. 2005), others have not (Downey et al. 2006; Harrison 2006; Long et al. 2006b). One possible explanation is interference by black bear and wolf with felid marking behaviour. Although Weaver's CatCall™ scent lure was specifically designed to attract felids, it may have inadvertently attracted wolves and bears that depend largely on olfactory cues. A paper published during the course of this study reported similar findings – territorial rubbing and marking behaviour by coyote, wolf, dog, black and grizzly bears on rub pads scented with Weaver's CatCall™ (Apps 2005). Presumably, scent-marking by bears and wolves dissuades cougars from cheek-rubbing, particularly because

interactions between sympatric carnivores are often negative. Interspecific competition for shared resources (e.g., prey) can potentially give rise to exploitation and interference interactions, including resource limitation, kleptoparasitism (i.e., food stealing) and deadly conflict (Durant 1998; Palomares et al. 1998; Fedriani 2000; Linnell and Strand 2000). In Banff National Park, Alberta, for example, wolves “appeared to be dominant with respect to interference interactions, including the direct predation of cougars and usurpation of prey killed by cougars” (Kortello 2005:3). Similarly, Downey et al. (2005) reported poor rubbing response of margay (*Leopardus wiedii*) on scented rub pads because of interference by gray fox (*Urocyon cinereoargenteus*) in the El Cielo study area in Mexico. In this study, the occurrence of bears and wolves at scented rub pads in the Long Beach and West Coast Trail study areas may explain the lack of cougar sign. In particular, the high degree of interference (and camera damage) by black bears in the Long Beach study area effectively limits the use of this method for long-term monitoring applications.

Another explanation for low detection rates might be the lack of scented rub pad encounters by cougars. Station-based methods require the target species to visit and respond to the scent lure at a particular site, resulting in detection rates that are inherently lower than methods constituted by physical searches over large areas (e.g., Silveira et al. 2003; Gompper et al. 2006). Successful detection of target species therefore depends, not only upon site placements that correspond to typical movement and behaviour patterns, and the visibility of the visual attractant (Apps 2005), but also upon the density of detection devices and the frequency of site revisits (Long et al. 2006b). During my study, protocols for scented rub pad and remotely triggered camera surveys were comparatively

minimal as most studies employing these methods revisit rub pad stations every 2-7 days, and deploy cameras at higher densities (e.g., Gompper 2006; Harrison 2006). Frequent station revisits may have increased cougar detection in these study areas because rub pads would have been re-baited more often, and camera malfunctions would have been discovered earlier in the surveys. Again, increasing the number of station revisits and the density of cameras would significantly increase project costs.

The lack of cougar detection by rub pads and cameras, despite detection by sign and detector dog surveys, draws attention to the fact that non-detections may not necessarily indicate true absences but rather false absences as a result of small populations, elusive behaviours and landscape features that may impair detection of animals that are actually present (MacKenzie et al. 2005; Long and Zielinski 2008). Low detection rates and false-absences are common for species that occur in low-densities over large territories, or in circumstances with inadequate sampling effort (Gu and Swihart 2003).

When the objective of surveys is to detect the presence or relative abundance of a rare species, it is often more effective to survey a larger proportion of areas less intensively (MacKenzie and Royle 2005) using multiple survey methods. While absences can never be absolutely verified, the occurrence of an animal in a well-defined area should become evident after several weeks of surveys. Other study objectives, however, such as estimates of species abundance, density, or trend in population are based on capture-mark-recapture techniques. As such, they require more intensive sampling so that actual individuals can be identified (Long and Zielinski 2008).

For this reason, cameras are often favoured for long-term monitoring applications. Unlike sign, detector dog and rub pad surveys, cameras provide a permanent record of detected sign (photographs) as well as unambiguous identification of species and, in many cases, individuals (e.g., Karanth and Nichols 1998; Silveira et al. 2003; Kawanishi and Sunquist 2004; Kelly et al. 2008). Notwithstanding initial investment costs, cameras are relatively cost effective because they require relatively minimal labour (depending on the size of the study area and the density of the target species) and have few additional costs (i.e., DNA analysis of scats and hair detections) to identify species and individuals (Kays and Slauson 2008). During this study, cameras proved particularly advantageous because they detected species that did not respond to scent lures. Deer, elk, and raccoon were detected at rub pads stations despite a lack of other evidence that indicated their presence.

Chapter 4: Spatial and Temporal Patterns of Human-Cougar Interactions on the West Coast Trail

Introduction

Conflicts between people and cougars are increasing throughout western North America, as evidenced by numbers of reported human-cougar interactions and dangerous encounters. In Canada and the United States, for example, 53 cougar attacks resulted in 10 deaths between 1890 and 1990 (Beier 1991). However, during the last two decades, 90 cougar attacks resulted in 12 deaths (Torres et al. 1996; Fitzhugh et al. 2003; Lewis 2009). These statistics indicate almost a nine-fold increase in attacks and a seven-fold increase in deaths per year. Human-cougar conflicts are particularly concentrated on Vancouver Island, where the frequency of cougar attacks on people far exceeds that of anywhere else (Beier 1991).

Still, cougar attacks are relatively rare – they occur far less frequently than human deaths due to a spate of hazards associated with outdoor activities, including lightning strikes, rattlesnake bites, and bee-stings (Beier 1991). Nonetheless, many people harbour an inequitable fear of being killed by cougars (Kellert et al. 1996; Quigley and Herrero 2005), likely fuelled by the inordinate amount of media attention that large carnivore attacks typically attract. Media hype also tends to focus public concern for the responsibility of wildlife agencies to inform or shield the public from the dangers cougars pose to human safety. Consequently, as people increasingly live, recreate and develop in wildlife habitats, human-cougar interactions will require greater attention from wildlife managers (Cougar Management Guidelines Working Group 2005).

Reasons for increased human-cougar interactions are poorly understood and largely speculative. Many assume that changes to cougar management policies and the legal status of cougars (bountied predator to game species) have caused considerable growth and expansion of populations so there are more cougars for people to encounter (e.g., Beier 1992; Riley and Maleki 2001). Lambert et al. (2006), however, showed that populations of cougars in the Pacific Northwest were declining in spite of growing reports of human-cougar conflict within the region. Others believe that cougars are habituating to increasing levels of human activity in cougar habitat (Ruth 1991; Dickson and Beier 2002; Cougar Management Guidelines Working Group 2005). Animals are considered to be habituated when their natural avoidance responses wane after repeated exposure to neutral stimuli (Whittaker and Knight 1998; Smith et al. 2005). For example, successful acquisition of prey near human activity without any aversive penalties may positively reinforce cougar occurrence despite their natural wariness (Ruth 1991). Indeed, the potential for human-cougar conflict will increase if cougars do not avoid people, and worse, if cougars begin to consider people and their domesticated animals as prey. Another factor contributing to increased interactions may be that more people are spending time in cougar habitat, so the likelihood of encounters increases.

Notwithstanding such speculations, the underlying causes of interactions between people and cougars are likely a culmination of many different factors that vary regionally (Torres et al. 1996; Cougar Management Guidelines Working Group 2005).

Despite a growing need to monitor and reduce human-cougar conflict, very little published research has addressed methods by which these activities can be accomplished. The lack of knowledge concerning interactions between people and cougars, including

the factors that influence cougar occurrence in human-use areas, constrain effective conflict management. As such, wildlife managers are often forced to make decisions with little or no empirical data – consequences of insufficient funds, monitoring efforts and detection capabilities (Merrill et al. 1999; Reece et al. 2004). Moreover, in circumstances when swift action is required to thwart escalating threats of human injury or attack by cougars, managers often respond using reactionary methods (e.g., lethal control and translocation) that draw public criticism. Such actions also undermine the utility of protected areas for large carnivore conservation (Treves and Karanth 2003; Woodroffe et al. 2005; Treves 2008).

A more proactive approach would be to anticipate the locations of human-cougar conflict and focus outreach and management interventions accordingly. This requires identifying the intersection of people and cougars, and particular landscape characteristics associated with human-cougar interactions (Treves et al. 2004). Despite several limitations, data on reported human-wildlife interactions contain valuable information necessary for efficient allocation of resources and the development of strategies aimed to reduce future conflicts. Previous studies have shown that spatiotemporal analyses of such data can infer species distribution and habitat relationships (Stoms et al. 1993; Palma et al. 1999), and predict locations where human-wildlife conflicts will likely occur (Riley and Malecki 2001; Treves et al. 2004; Wilson et al. 2005; Baruch-Mordo 2007).

I sought to develop an integrative approach by combining a geographic information system (GIS) and the existing human-cougar interaction database to obtain baseline information about cougars in Pacific Rim National Park Reserve and Clayoquot Sound

UNESCO Biosphere Reserve. My specific objectives were to determine if human-cougar interactions were associated with landscape characteristics and human activity and, if so, recommend ways to reduce the potential risk of future conflict. I examined the spatial and temporal patterns of human-cougar interactions in the West Coast Trail study area relative to the distribution of ecotype, slope, and linear distance to the nearest campsite, freshwater drainage, viewpoint and road. In addition, I examined the monthly and yearly trends of human-cougar interactions relative to hiker activity on the West Coast Trail.

Methods

Human-cougar interaction data

All reports involving wildlife within Pacific Rim National Park Reserve, Clayoquot Sound UNESCO Biosphere Reserve, and surrounding communities are compiled into a central database maintained by staff at Pacific Rim National Park Reserve. The database is used by parks staff and regional conservation officers to monitor long-term trends of species distribution and risk of human-wildlife conflict. Entries in the wildlife database include: date, location with corresponding Universal Transverse Mercator (UTM) coordinates, habitat, species, estimated number of animals, and duration and type of interaction. When UTM coordinates are not obtained in the field, coordinates are automatically assigned with user-selected locations. On the West Coast Trail, these locations correspond to prominent landscape features (e.g., Tsusiat waterfall, Logan suspension bridge) and 1-km distance markers – hikers who report wildlife observations typically provide their locations in relation to their observed surroundings. The spatial resolution of these data is therefore within each 1-km section of the West Coast Trail.

All documented reports of human-cougar interactions (i.e., cougar sightings, encounters and observations of sign) that occurred within the West Coast Trail study area were obtained from the wildlife database. As noted by Wilson et al. (2005), it is important to include all reports of cougar occurrence because cougars near human activity are at risk of becoming habituated and pose a significant threat to human safety. These data were carefully reviewed to ensure consistency. For example, records with inaccurate or missing location coordinates were corrected or removed from the analyses. Doubtful reports of cougar presence (e.g., heard but not seen, hiker observations of scats) were also removed to increase the level of confidence of the anecdotal observations.

Human-cougar interaction locations (x, y coordinates) were incorporated into a GIS and projected (UTM Zone 10N, NAD 1983) as vector point data onto coverages made from 1:20,000 scale, Terrain Resources Information Management (TRIM) data (Province of British Columbia 1996). These data were converted to shape files and displayed to show the spatial distribution of human-cougar interactions along the West Coast Trail. Data clusters were examined using the ArcGIS9.2 (ESRI 2006) selection tool to remove duplicate records (i.e., observations by multiple people). According to Beier et al. (1995), 5 km is the maximum daily distance travelled by cougars. Thus, if more than one interaction occurred within a 5-km distance on the same day, only the first interaction report (and corresponding point location) was included in the analyses.

Spatial patterns of human-cougar interactions

I used kernel density estimation (KDE) as a spatial analysis tool to generate surfaces of human-cougar interaction intensity in the West Coast Trail study area. KDE is a

nonparametric probability density function useful for analysing small samples of point data with no constraints placed on the underlying distribution of the data (Silverman 1986; Worton 1989). KDE was first applied in ecology to describe the utilization distribution, a two-dimensional frequency of animal locations over time (Van Winkle 1975), by creating contours that represent the probability of occurrence (e.g., the estimated number of animals one may expect to observe) at any location in space (Worton 1989; Collyer 2008). KDE is considered to be one of the most suitable spatial analysis techniques for visualizing clusters in point data, and its applications have expanded to include hotspot identification for observational data such as insect infestation (Nelson and Boots 2005), wildlife-vehicle collisions (Ramp et al. 2005) and crime reports (Chainey et al. 2008).

As described by Seaman and Powell (1996), observations are aggregated into kernels that are analogous to summed 'hills' rising from the two-dimensional plane of a map, where kernel height is greatest over the centre of the observation point and declines smoothly and symmetrically to zero over a user specified distance. This distance, also known as the search radius or bandwidth, greatly affects the density estimate by influencing the amount of data smoothing (Silverman 1986). Thus, the volume of the kernel density surface at any location represents an estimate of the number of observational data that have been reported at that location (Collyer 2008).

Several kernel functions can be used to generate the kernel estimate. ArcMap uses a kernel with a quartic distribution function for which the intensity of observations at any location on the map plane is calculated by:

$$\hat{f}(x, y) = N \frac{3S}{\pi h^2} \left(1 - \frac{r^2}{h^2}\right)^2 \text{ for } r \leq h \text{ and } \hat{f}(x, y) = 0 \text{ for } r > h$$

where $\hat{f}(x, y)$ is the height of the density surface at an evaluation point having the geographic coordinates (x, y) , h is the search radius, r is the distance from the observation point to the evaluation point, N is the number of animals associated with the observation point (the population value) and S is a scaling factor often used to avoid rounding errors (Breyer 2006).

There is flexibility when selecting the search radius and grid cell size. If the search radius is too small, only nearby observations will influence the density estimation causing estimations to break into individual kernels, and the loss of data variability. Too large of a search radius allows more distant observations to influence the estimate, creating a single kernel, and an inability to observe trends in the distribution of data (Seaman and Powell 1996). Grid cell size has less effect on the density estimation – a larger cell size would simply include more aggregated points that get averaged over a larger area to estimate density (Silverman 1986). Despite many useful recommendations (e.g., Silverman 1986; Worton 1989; Seaman and Powell 1996), there is no universal doctrine on how to set these parameters and under what conditions. Expert opinion and careful review of the results are considered the most important criteria to optimize tradeoffs between detail and distributional trend in observations.

A 1-km search radius was used in this study because this distance represented the spatial resolution of the human-cougar interaction data, and because it revealed patterns in these data without over-smoothing. The default grid cell size of 100 m² was used to create the map surface. As noted by Potvin et al. (2005), this cell size is efficient for spatial analysis

and does not lead to loss of accuracy. The resulting output rasters were reclassified to exclude zero values using the quantiles classification method. Using Hawth's Tools (Beyer 2006), areas that contained the top 10, 25, and 50% of the volume of the kernel density surfaces were identified. This process involves adding grid cells with the highest surface values to cells with the next highest values until the desired proportion of the observations is reached (Potvin et al. 2005). Preliminary tests indicated that the 25 and 50% volume contours covered large proportions of the study area and therefore were not very useful to identify human-cougar interaction hotspots. Thus, for the purposes of this study, human-cougar interaction hotspots are defined as areas containing the top 10% volume of the density surface created from the input observations.

Associations with landscape characteristics

To determine whether the locations of human-cougar interactions were associated with particular landscape characteristics, I adopted a "use/availability" approach (e.g., Neu et al. 1974; Byers et al. 1984). I estimated the availability of ecotype, slope, and linear distance to the nearest freshwater drainage, campsite, viewpoint, and road in each of the 75 1-km sections of the West Coast Trail (this 1-km section represents the maximum level of spatial resolution in the cougar sighting reports). I then compared the 'expected' numbers of human-cougar interactions (based on the estimated proportions of each landscape category) with the 'observed' numbers of human-cougar interactions that occurred in each landscape category.

Ecotype

During field surveys, vegetation cover along the West Coast Trail was delineated into five broad habitat types; old-growth forest, second growth forest, bog, ocean spray and beach (Figure 4.1). Ecotypes were described using the Biogeoclimatic Ecosystem Classification (BEC) system field guide for the Vancouver Forest District (Green and Klinka 1994) in which predominant forest structure and stage of succession, with corresponding plant assemblages, are identified (Table 4.1). No attempt was made to discriminate sample units by vegetation height and density because these variables likely changed over the period for which the human-cougar interaction data were gathered (Agee et al. 1989; Stoms et al. 1993).

Locations where the West Coast Trail vegetation changed from one ecotype into another, and where alternative routes along the forest or beach were accessible, were recorded as UTM coordinates using a hand-held GPS unit. These data were incorporated into a GIS and overlaid onto a digitized layer of the West Coast Trail. Using the editor tool in ArcMap, ecotypes were delineated by re-digitizing the West Coast Trail layer between appropriate data points using a 150 m buffer (to account for indistinct boundaries of ecotypes). The proportions of ecotype(s) in each 1-km section of the West Coast Trail were estimated using the distance-measure tool.



Photo Credits: Dani Thompson 2006 and Jerry Etzkorn 2010 (center)

Figure 4.1 Photographs of the five ecotypes within the West Coast Trail study area. From top left; Old-growth forest, Second growth forest, Ocean Spray, Bog and Beach.

Table 4.1 Descriptions of ecotypes identified within the West Coast Trail study area (Taken from Green and Klinka 1994).

Ecotype	Description
Old-growth Forest	Forested types comprised of complex stands of uneven-aged and uneven-sized mixtures of western hemlock, Sitka spruce, western redcedar and Amabilis fir with a well-developed understory. Shrub layers are comprised of salal, salmon berry, oval-leaved blueberry and deer fern. Herb layers are dominated by sword and lady fern, and moss layers were dominated by step and lanky moss.
Second growth Forest	Forested types comprised of mixtures of even-aged mature western hemlock, Sitka spruce and western redcedar. Understory growth is sparse; shrub and herb layers are dominated by a red huckleberry, salal and deer fern, and moss layers are dominated by lanky and Oregon beaked mosses. Large diameter stumps provide further evidence of past logging activity.
Bog	Forested types comprised of stunted stands of western hemlock, western redcedar, Sitka spruce and shorepine growing under wet soil conditions. Bog laurel (<i>Kalmia microphylla</i>), crowberry (<i>Empetrum nigrum</i>), shiney liverwort (<i>Pellia neesiana</i>) and sphagnum moss dominate the sparse understory shrub, herb and moss layers, respectively.
Ocean Spray	Forested types comprised of wind-swept stands of stunted Sitka spruce with a thick salal understory located adjacent to the shoreline.
Beach	Non-forested types, with little or no vegetative cover, located adjacent to the ocean. Includes sand, cobble rock, and shelf beaches.

Slope

During field surveys, estimates of ‘on-trail’ and ‘off-trail’ slope were determined for each 1-km section of the West Coast Trail using the declination scale on a Suunto MC-1 mirror compass as a clinometer. For the purposes of this study, ‘on-trail’ refers to measurements of slope along the contours of hiking trail and ‘off-trail’ refers to measurements of slope of the surrounding terrain in which the hiking trail is situated. Estimates of slope for each kilometre are averages of three field measurements obtained every 250 m (i.e., at 250 m, 500 m and 750 m). Average measurements for on and off trail slope for each 1-km section of the West Coast Trail were grouped into four categories; <5, 5 - <10, 10 - <15, and >15 degrees.

Freshwater drainages

The location coordinates (UTM) of freshwater drainages along the West Coast Trail were obtained from TRIM data (Province of British Columbia 1996) and confirmed during field surveys. From the National Park Reserve’s perspective, differences between drainages on the West Coast Trail primarily relate to size and the types of transport used by hikers to make crossings (e.g., boat, suspension bridge, trolley etc.). In recognition of these differences, drainage widths were measured at crossing locations using a rangefinder, and tabulated according to one of three categories; <10 m, 10-20 m, and >20 m.

These data were incorporated into a GIS and displayed as point data. Average linear distances from each 1-km section of the trail to the nearest freshwater drainage were determined for each width category. Distance values were obtained from three

measurements obtained every 250 m (i.e., at 250 m, 500 m and 750 m) in each 1-km section, using the distance measure tool. Average linear distances to the nearest freshwater drainages for each width category were grouped into 1-km distance categories (i.e., 0.0 – 0.9 km, 1.0 – 1.9 km, 2.0 – 2.9 km, etc.).

Campsites

Campsites are not formally designated along the West Coast Trail; rather, they are areas popular for camping due to their logistical and aesthetic location, proximity to water, and availability of food and storage lockers and outhouse facilities. For the purposes of this study, campsites are defined as the 12 most popular camping areas having food storage lockers and outhouses (PRNPR Monitoring Report, Theberge 2005).

The location coordinates (UTM) of campsites were obtained from Parks Canada hiking maps and confirmed during field surveys. These data were incorporated into a GIS and displayed as point data. Average linear distances from each 1-km section of the trail to the nearest campsite were determined. Distance values were obtained from three measurements obtained every 250 m (i.e., at 250 m, 500 m and 750 m) in each 1-km section using the distance measure tool. Average linear distances to the nearest campsite were grouped into 1-km distance categories (i.e., 0.0 – 0.9 km, 1.0 – 1.9 km, 2.0 – 2.9 km, etc.).

Viewpoints

Viewpoints are defined as popular lookouts and rest areas (e.g., lighthouses, beach accesses, historic sites, etc.) along the West Coast Trail. The location coordinates (UTM) for viewpoints were obtained from Parks Canada hiking maps and confirmed during field

surveys. These data were incorporated into a GIS and displayed as point data. Average linear distances from each 1-km section of the trail to the nearest viewpoint were determined. Distance values were obtained from three measurements obtained every 250 m (i.e., at 250 m, 500 m and 750 m) in each 1-km section using the distance measure tool. Average linear distances to the nearest viewpoint were grouped into 1-km distance categories (i.e., 0.0 – 0.9 km, 1.0 – 1.9 km, 2.0 – 2.9 km, etc.).

Roads

Average linear distances for each 1-km section of the West Coast Trail to the nearest road were determined in a GIS using TRIM (Province of British Columbia 1996) data. Road data were primarily related to logging activity occurring at various locations on the boundary of the West Coast Trail Unit. Distance values were obtained from three measurements obtained every 250 m (i.e., at 250 m, 500 m and 750 m) in each 1-km section using the distance measure tool. Average linear distances to the nearest road were grouped into 1-km distance categories (i.e., 0.0 – 0.9 km, 1.0 – 1.9 km, 2.0 – 2.9 km, etc.).

Temporal patterns of human-cougar interactions

I examined the trends of hiker activity within each year as well as trends across all years along the West Coast Trail to determine if different levels of human activity along the West Coast Trail influenced the frequency of human-cougar interactions. Hiker activity is closely monitored and regulated through a permit system. These data are compiled in a database and used by Parks Canada staff for resource allocation and monitoring purposes.

Statistical tests

To evaluate the spatial relationships of human-cougar interactions, I used chi-squared goodness-of-fit tests to determine whether there was a significant difference between the “expected” numbers of human-cougar interactions (based on the estimated proportions of each landscape category) and the “observed” numbers of human-cougar interactions that occurred in each landscape category. When chi-squared tests were significant (i.e., $\alpha = 0.05$), simultaneous confidence intervals were computed using the Bonferroni inequality procedure to determine statistical significance within categories (e.g., Neu et al. 1974; Byers et al. 1984). For example, if the expected proportion of observations did not lie within the computed interval, then there was a significant difference between expected and observed numbers of human-cougar interactions (Byers et al. 1984). Thus, one can be $100(1 - \alpha) \%$ certain that the interval contains the true proportion of use, p_i . Confidence intervals were constructed for each ‘family’ of observations using the formula:

$$\bar{p}_i - Z_{\alpha/2k} \sqrt{(\bar{p}_i(1 - \bar{p}_i/n))} \leq p_i \leq \bar{p}_i + Z_{\alpha/2k} \sqrt{(\bar{p}_i(1 - \bar{p}_i/n))}$$

where \bar{p}_i is the proportion of observations in the i th habitat category and n is the sample size, $Z_{\alpha/2k}$ is the upper standard normal table value corresponding to a probability tail of $\alpha/2k$; $\alpha = 0.05$ and k is the number of categories (Byers et al. 1984). For example, simultaneous intervals for each of five ecotypes would be constructed with $\alpha = 0.05$ and k equal to 5 categories, $Z_{\alpha/2k} = Z_{0.005} = 2.576$. Seventy two human-cougar interactions occurred in beach ecotype. Thus, $\bar{p}_i = 0.459$ (72/157) and the Bonferroni confidence interval for p_i would be:

$$0.459 - 2.576\sqrt{(0.459(1 - 0.459/157))} \leq p_i$$

$$\leq 0.459 + 2.576\sqrt{(0.459(1 - 0.459/157))}$$

or $0.357 \leq p_i \leq 0.561$

To evaluate the temporal patterns of human-cougar interactions, I tabulated counts of interactions as a function of time (i.e., year and month) and examined the relationships between interaction frequency and seasonal levels of hiker activity using chi-square tests for association.

Results

Human-cougar interactions

A total of 157 records of human-cougar interactions from 1993-2006 were used for this study. These data represented 50% of the total number of interactions ($n = 313$) obtained from the wildlife observation database for the West Coast Trail study area between 1985 and 2006 (Table 4.2). However, prior to 1993, hiker activity records were largely incomplete and some years were missing. For this reason, only human-cougar interactions that occurred between 1993 and 2006 were included in the analyses.

Approximately 24% of human-cougar interaction records were omitted due to location errors and missing data, observational uncertainty (e.g., cougar was heard but not seen, misidentified sign), and duplicate records. Out-of-area (e.g., Cape Beale lighthouse, Bamfield and Port Renfrew) records accounted for approximately 9% of record omissions, and out-of-season (i.e., between October 1st and April 30th) accounted for

approximately 8% of omissions. An additional 7% of records were omitted as duplicates because they occurred on the same day within a 5-km distance.

Table 4.2 Numbers of human-cougar interaction reports in the West Coast Trail study area from 1993 – 2006 removed from analyses by omission type.

Omission type	No. of reports omitted	Percent of total records ($n = 313$)
Uncertainty and error	75	24
Outside of study area	29	9
Outside of study period*	31	10
Duplicates	21	7
Total	156	50

* Outside of the study period refers to omitted reports of human-cougar interaction that occurred before 1993 ($n = 7$; or 2% of records), and reports that occurred between November 1st and April 30th when the West Coast Trail is not operational ($n = 24$, or 8% of records).

Spatial trends of human-cougar interactions

Human-cougar interaction hotspots on the West Coast Trail were delineated by first creating a kernel density surface of input observations (Figure 4.2), and then identifying the areas that comprised the top 10% of the volume of the density surface (Figure 4.3). Using this approach, four human-cougar interaction hotspots were identified: the areas of Michigan Creek/campsite between km 11.5 – 12.5, Tsocowis Creek/campsite between km 16.2 – 16.7, Cheewhat River between km 34.8 – 36.7, and Camper Bay River/campsite between km 61.3 – 63.1. Combined, these four hotspots accounted for 20% of cougar-human interactions ($n = 157$) that occurred during 1993-2006.

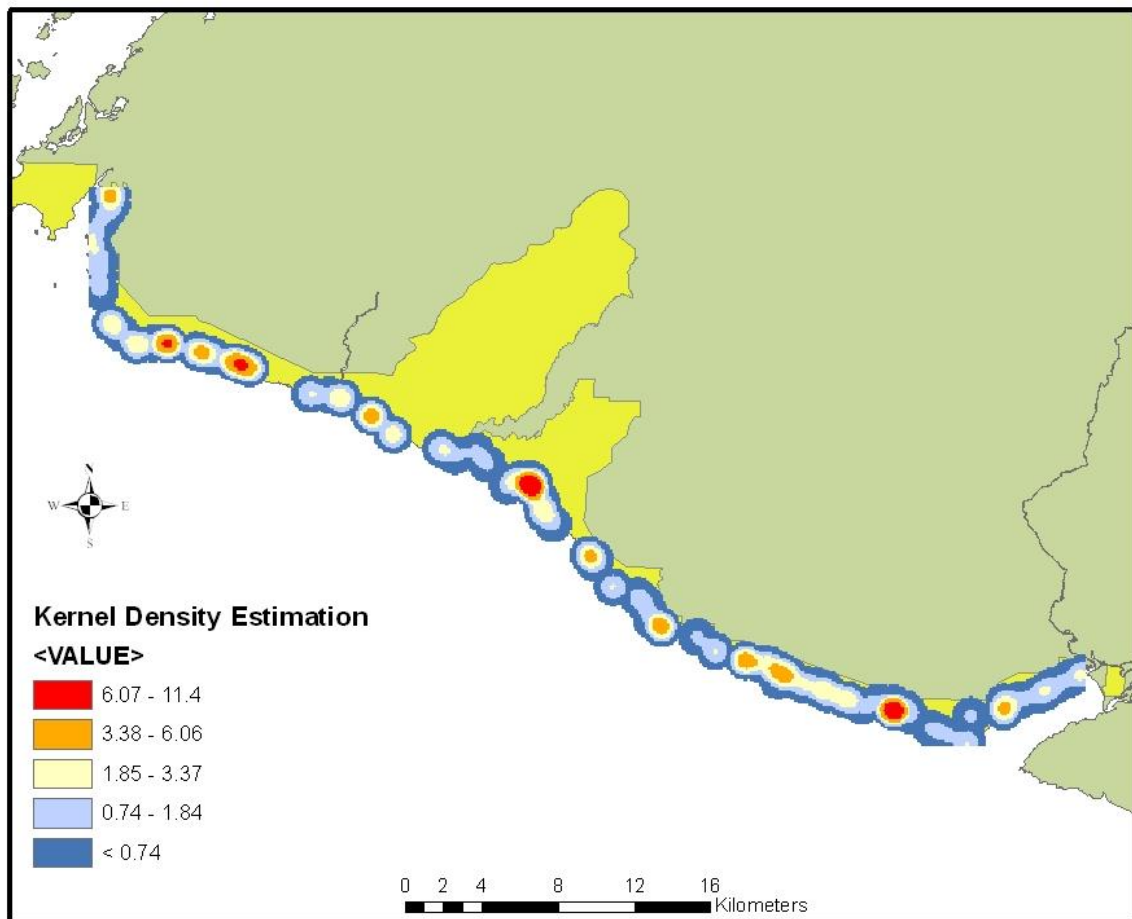


Figure 4.2 Estimated density of human-cougar interactions ($n = 157$) that occurred during 1993-2006 on the West Coast Trail. The kernel density surface was created using a 1-km search radius and 100 m cell size (Map developed in a GIS from Parks Canada and BC Government data layers).

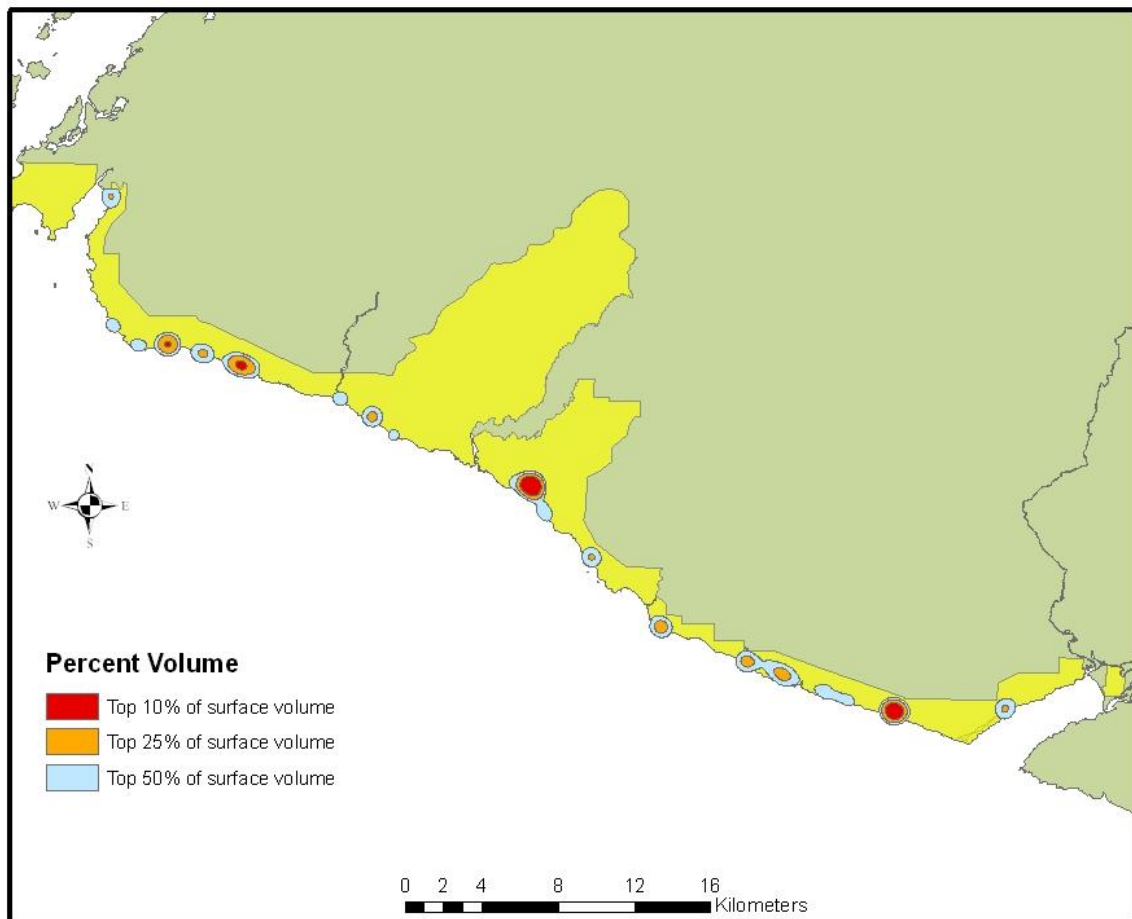


Figure 4.3 A map of human-cougar interaction hotspots based on kernel density surfaces converted to percentage volume polygons. Hotspots are defined as areas covered by the top 10% of the volume of the density surface (shown as red polygons) generated from human-cougar interactions ($n = 157$) that occurred during 1993-2006 on the West Coast Trail. Hotspots are located (from top left to bottom right) at Michigan Creek, Tsocowis Creek, Cheewhat River and Camper Bay River campsite areas (Map developed in a GIS from Parks Canada and BC Government data layers).

Associations with landscape characteristics

Ecotype

The majority (32%) of 1-km sections of the West Coast Trail ($n = 75$) were comprised of beach ecotype, followed by old-growth forest (27%), ocean spray (22%), bog (13%), and second growth forest (6%) (Table 4.3). The distribution of human-cougar interaction locations among ecotypes differed from that expected based on the estimated proportions of each ecotype ($\chi^2 = 13.5$, 4 df, $P = 0.008$). Human-cougar interactions occurred with greater frequency in 1-km sections of the West Coast Trail categorized as beach ecotype (Bonferroni confidence interval at $\alpha = 0.05$).

Table 4.3 Relationships between ecotypes and human-cougar interactions ($n = 157$) that occurred during 1993 – 2006 in the West Coast Trail study area. (**Bold** denotes significant difference $\alpha = 0.05$).

Landscape characteristic category	Proportion ^a of total area (p_{i0})	No. of Obs	No. ^b of Exp	Proportion of Obs in each area (\bar{p}_i)	Confidence ^c interval on proportion of occurrence (p_i) ^d	P -value (level) ^e
Ecotype						0.008
Old-growth	0.265	32	41.6	0.204	$0.121 \leq p_1 \leq 0.348$	(0)
2 nd growth	0.063	9	9.9	0.057	$0.009 \leq p_2 \leq 0.105$	(0)
Bog	0.128	17	20.1	0.108	$0.044 \leq p_3 \leq 0.172$	(0)
Ocean spray	0.222	27	34.8	0.172	$0.094 \leq p_4 \leq 0.250$	(0)
Beach	0.322	72	50.6	0.459	$0.357 \leq p_5 \leq 0.561$	(+)
Total	1.000	157	157	1.000		

Obs = observed; Exp = expected.

^a Proportions of total area represent the expected proportions of human-cougar interactions if interactions occurred in each category in exact proportion to availability.

^b Calculated by multiplying $p_{i0} \times n$; i.e., $0.265 \times 157 = 41.6$.

^c 95% family of confidence intervals for $k = 5$ categories (Neu et al. 1974).

^d p_i represents theoretical proportion of observations and is compared to p_{i0} determine if hypothesis of proportional occurrence is accepted or rejected.

^e Level: + means numbers of human-cougar interactions in the category were more than expected given the availability of the category; – means interactions in the category were less than expected given the availability of the category, and 0 means interactions were not statistically different from random (Stoms et al. 1993).

Slope

Most (79%) of the West Coast Trail ($n = 75$ km) had average ‘on trail’ slope measurements of less than 5 degrees (Table 4.4). The distribution of human-cougar interaction locations among slope categories differed from that based on the estimated proportions of each category ($\chi^2_{on\ trail} = 11.4$, 3 df, $P = 0.010$). Numbers of interactions were less than expected in 1-km sections that had ‘on-trail’ slope measurements of less than 5 degrees (Bonferroni confidence interval at $\alpha = 0.05$).

To compare, 53% of 1-km sections ($n = 75$) had average ‘off trail slope measurements of less than 5 degrees. There was no significant difference between the proportions of interactions that occurred in each category of ‘off trail’ slope than expected given the estimated availability of each category ($\chi^2_{off\ trail} = 3.76$, 3 df, $P = 0.288$).

Table 4.4 Relationships between ‘on trail’ and ‘off trail’ slope (degrees) and human-cougar interactions ($n = 157$) that occurred during 1993 – 2006 in the West Coast Trail study area. (**Bold** denotes significant difference $\alpha = 0.05$).

Landscape characteristic category	Proportion ^a of total area (p_{i0})	No. of Obs	No. ^b of Exp	Proportion of Obs in each area (\bar{p}_i)	Confidence ^c interval on proportion of occurrence (p_i) ^d	P -value (level) ^e
On slope (deg)						0.010
<5	0.787	108	123.6	0.688	0.607 ≤ p₁ ≤ 0.770	(-)
5 - <10	0.100	25	15.7	0.159	0.086 ≤ p ₂ ≤ 0.232	(0)
10 - <15	0.088	18	13.8	0.115	0.051 ≤ p ₃ ≤ 0.178	(0)
≥15	0.025	6	3.9	0.038	0.000 ≤ p ₄ ≤ 0.076	(0)
Total	1.000	157	157	1.000		
Off slope (deg)						0.288
<5	0.525	85	82.4	0.541	--	--
5 - <10	0.125	12	19.6	0.076	--	--
10 - <15	0.125	23	19.6	0.147	--	--
≥15	0.225	37	35.4	0.236	--	--
Total	1.000	157	157	1.000		

Symbols and definitions as in Table 4.3.

Freshwater drainages

Most (37%) 1-km sections of the West Coast Trail ($n = 75$) were situated within 0.0 – 0.9 km of a freshwater drainage <10 m wide ($n = 19$; mean = 2.3 km, median = 1.5 km). 21% of 1-km sections were situated ≥ 9.0 km of a freshwater drainage 10 – 20 m wide ($n = 9$; mean = 5.0 km, median = 3.3 km), and 24% of 1-km sections were situated ≥ 9.0 km of a freshwater drainage > 20 m wide ($n = 5$; mean = 6.1 km, median = 4.2 km) (Table 4.5).

The distribution of human-cougar interaction locations among distance categories of all freshwater drainages differed from expected given the availability of each category in the study area ($\chi^2_{<10m} = 13.59$, 6 df, $P = 0.036$; $\chi^2_{10-20m} = 44.78$, 9 df, $P = 0.0001$; $\chi^2_{>20m} = 34.81$, 9 df, $P = 0.0001$).

Within distance categories, numbers of human-cougar interactions occurred less frequently than expected 6.0 – 6.9 km away from small-sized drainages, 1.0 – 1.9 and 7.0 – 7.9 km away from medium-sized drainages, and 3.0 – 3.9 and 7.0 – 7.9 km away from large drainages. In contrast, human-cougar interactions occurred more frequently than expected 0.0 – 0.9 km away from large drainages (Bonferroni confidence interval at $\alpha = 0.05$).

Table 4.5 Relationships between average linear distance (km) to the nearest freshwater drainage <10, 10-20, and >20 m in width and human-cougar interactions ($n = 157$) that occurred during 1993 – 2006 in the West Coast Trail study area. (**Bold** denotes significant difference $\alpha = 0.05$).

Landscape characteristic category	Proportion ^a of total area (p_{i0})	No. of Obs	No. ^b of Exp	Proportion of Obs in each area (\bar{p}_i)	Confidence ^c interval on proportion of occurrence (p_i) ^d	P-value (level) ^e
FWD <10 m						0.036
0.0 – 0.9	0.373	66	58.6	0.420	$0.315 \leq p_1 \leq 0.526$	(0)
1.0 – 1.9	0.213	23	33.4	0.146	$0.071 \leq p_2 \leq 0.222$	(0)
2.0 – 2.9	0.146	29	23.1	0.185	$0.102 \leq p_3 \leq 0.268$	(0)
3.0 – 3.9	0.107	18	16.8	0.115	$0.046 \leq p_4 \leq 0.183$	(0)
4.0 – 4.9	0.027	6	4.2	0.038	$0.000 \leq p_5 \leq 0.070$	(0)
5.0 – 5.9	0.027	7	4.2	0.045	$0.000 \leq p_6 \leq 0.089$	(0)
≥ 6.0	0.107	8	16.7	0.051	$0.003 \leq p_7 \leq 0.098$	(–)
Total	1.000	157	157	1.000		
FWD 10-20 m						<0.001
0.0 – 0.9	0.187	42	29.4	0.268	$0.168 \leq p_1 \leq 0.367$	(0)
1.0 – 1.9	0.160	9	25.1	0.057	$0.005 \leq p_2 \leq 0.109$	(–)
2.0 – 2.9	0.107	20	16.8	0.127	$0.053 \leq p_3 \leq 0.203$	(0)
3.0 – 3.9	0.080	7	12.6	0.045	$0.000 \leq p_4 \leq 0.091$	(0)
4.0 – 4.9	0.053	20	8.3	0.127	$0.053 \leq p_5 \leq 0.202$	(0)
5.0 – 5.9	0.053	14	8.3	0.089	$0.025 \leq p_6 \leq 0.153$	(0)
6.0 – 6.9	0.053	10	8.3	0.064	$0.008 \leq p_7 \leq 0.119$	(0)
7.0 – 7.9	0.053	3	8.3	0.019	$0.000 \leq p_8 \leq 0.050$	(–)
8.0 – 8.9	0.041	7	6.4	0.045	$0.001 \leq p_9 \leq 0.091$	(0)
≥ 9.0	0.213	25	33.5	0.159	$0.078 \leq p_{10} \leq 0.241$	(0)
Total	1.000	157	157	1.00		
FWD >20 m						<0.001
0.0 – 0.9	0.133	37	20.9	0.236	$0.141 \leq p_1 \leq 0.331$	(+)
1.0 – 1.9	0.120	18	18.8	0.115	$0.043 \leq p_2 \leq 0.186$	(0)
2.0 – 2.9	0.107	15	16.8	0.096	$0.030 \leq p_3 \leq 0.161$	(0)
3.0 – 3.9	0.107	6	16.8	0.038	$0.000 \leq p_4 \leq 0.081$	(–)
4.0 – 4.9	0.093	9	14.7	0.057	$0.057 \leq p_5 \leq 0.681$	(0)
5.0 – 5.9	0.053	14	8.3	0.089	$0.025 \leq p_6 \leq 0.153$	(0)
6.0 – 6.9	0.053	10	8.3	0.064	$0.008 \leq p_7 \leq 0.119$	(0)
7.0 – 7.9	0.053	1	8.3	0.006	$0.000 \leq p_8 \leq 0.024$	(–)
8.0 – 8.9	0.041	10	6.4	0.064	$0.008 \leq p_9 \leq 0.119$	(0)
≥ 9.0	0.240	37	37.7	0.235	$0.141 \leq p_{10} \leq 0.331$	(0)
Total	1.000	157	157	1.000		

Symbols and definitions as in Table 4.3.

Campsites

Most (27%) 1-km sections of the West Coast Trail ($n = 75$) were situated between 0.0 – 0.9 km of a campsite ($n = 12$; mean = 2.8, median = 2.0 km) (Table 4.6). The distribution of interaction locations in each distance category differed from expected given the availability of each category in the study area ($\chi^2 = 33.73$, 8 df, $P = 0.0001$). Numbers of interactions were greater than expected within 0 – 0.9 km of a campsite, and less than expected 2.0 – 2.9 km of a campsite (Bonferroni confidence interval at $\alpha = 0.05$).

Table 4.6 Relationships between average linear distance (km) to the nearest campsite and human-cougar interactions ($n = 157$) that occurred during 1993 – 2006 in the West Coast Trail study area. (**Bold** denotes significant difference $\alpha = 0.05$).

Landscape characteristic category	Proportion ^a of total area (p_{i0})	No. of Obs	No. ^b of Exp	Proportion of Obs in each area (\bar{p}_i)	Confidence ^c interval on proportion of occurrence (p_i) ^d	P -value (level) ^e
Campsite						<0.001
0.0 – 0.9	0.267	68	42.0	0.433	0.325 ≤ p_1 ≤ 0.543	(+)
1.0 – 1.9	0.227	35	35.6	0.223	0.131 ≤ p_2 ≤ 0.315	(0)
2.0 – 2.9	0.147	6	23.1	0.038	0.000 ≤ p_3 ≤ 0.081	(–)
3.0 – 3.9	0.120	12	18.8	0.076	0.018 ≤ p_4 ≤ 0.135	(0)
4.0 – 4.9	0.053	11	8.3	0.070	0.014 ≤ p_5 ≤ 0.126	(0)
5.0 – 5.9	0.053	9	8.3	0.057	0.006 ≤ p_6 ≤ 0.109	(0)
6.0 – 6.9	0.040	4	6.3	0.026	0.000 ≤ p_7 ≤ 0.060	(0)
7.0 – 7.9	0.040	4	6.3	0.026	0.000 ≤ p_8 ≤ 0.060	(0)
≥8.0	0.053	8	8.3	0.051	0.002 ≤ p_9 ≤ 0.100	(0)
Total	1.000	157	157	1.000		

Symbols and definitions as in Table 4.3.

Viewpoints

The majority (29%) of 1-km sections of the West Coast Trail ($n = 75$) were situated between 0.0 – 0.9 km of a viewpoint ($n = 16$; mean = 2.6, median = 2.0 km) (Table 4.7).

The distribution of human-cougar interaction locations in each distance category differed from expected given the availability of each category in the study area ($\chi^2 = 28.34$, 6 df, $P = 0.0001$). Numbers of interactions were less than expected in 1-km sections 0.0 – 0.9 km from a viewpoint, and greater than expected in 1-km sections located 2.0 – 2.9 km from a view point (Bonferroni confidence interval at $\alpha = 0.05$).

Table 4.7 Relationships between average linear distance (km) to the nearest viewpoint and human-cougar interactions ($n = 157$) that occurred during 1993 – 2006 in the West Coast Trail study area. (**Bold** denotes significant difference $\alpha = 0.05$).

Landscape characteristic category	Proportion ^a of total area (p_{i0})	No. of Obs	No. ^b of Exp	Proportion of Obs in each area (\bar{p}_i)	Confidence ^c interval on proportion of occurrence (p_i) ^d	P -value (level) ^e
Viewpoint						<0.001
0.0 – 0.9	0.293	28	46.0	0.178	0.096 ≤ p_1 ≤ 0.260	(–)
1.0 – 1.9	0.200	40	31.4	0.255	$0.161 ≤ p_2 ≤ 0.348$	(0)
2.0 – 2.9	0.160	43	25.1	0.274	0.178 ≤ p_3 ≤ 0.370	(+)
3.0 – 3.9	0.133	14	20.9	0.089	$0.029 ≤ p_4 ≤ 0.150$	(0)
4.0 – 4.9	0.080	7	12.6	0.045	$0.000 ≤ p_5 ≤ 0.089$	(0)
5.0 – 5.9	0.027	3	4.2	0.019	$0.000 ≤ p_6 ≤ 0.048$	(0)
≥6.0	0.107	22	16.8	0.140	$0.066 ≤ p_7 ≤ 0.214$	(0)
Total	1.000	157	157	1.000		

Symbols and definitions as in Table 4.3.

Roads

The majority (19%) of 1-km sections of the West Coast Trail ($n = 75$) were situated between 3.0 – 3.9 km of a logging road (mean = 3.6 km, median = 3.3 km) (Table 4.8).

The distribution of human-cougar interactions ($n = 157$) in each distance category did not differ from expected given the availability of each category in the study area ($\chi^2 = 7.30$, 8 df, $P = 0.504$).

Table 4.8 Relationships between average linear distance (km) to the nearest road and human-cougar interactions ($n = 157$) that occurred during 1993 – 2006 in the West Coast Trail study area. (**Bold** denotes significant difference $\alpha = 0.05$).

Landscape characteristic category	Proportion ^a of total area (p_{i0})	No. of Obs	No. ^b of Exp	Proportion of Obs in each area (\bar{p}_i)	Confidence ^c interval on proportion of occurrence (p_i) ^d	<i>P</i> -value (level) ^e
Road						0.504
0.0 – 0.9	0.080	17	12.6	0.108	--	--
1.0 – 1.9	0.173	31	27.2	0.197	--	--
2.0 – 2.9	0.173	27	27.2	0.173	--	--
3.0 – 3.9	0.187	35	29.3	0.223	--	--
4.0 – 4.9	0.120	12	18.8	0.076	--	--
5.0 – 5.9	0.080	10	12.6	0.064	--	--
6.0 – 6.9	0.093	14	14.6	0.089	--	--
7.0 – 7.9	0.067	7	10.5	0.045	--	--
≥8.0	0.027	4	4.2	0.025	--	--
Total	1.000	157	157	1.000		

Symbols and definitions as in Table 4.3.

Temporal patterns of human-cougar interactions

Yearly trends

Between 1993 and 2006 in the West Coast Trail study area, the number of hikers per year decreased while the number of human-cougar interactions moderately increased over the same period. General trends over time showed that reports of human-cougar interactions ($n = 157$) varied annually within the same bounds, except during 1999, 2002 and 2003 when the number of interactions were high.

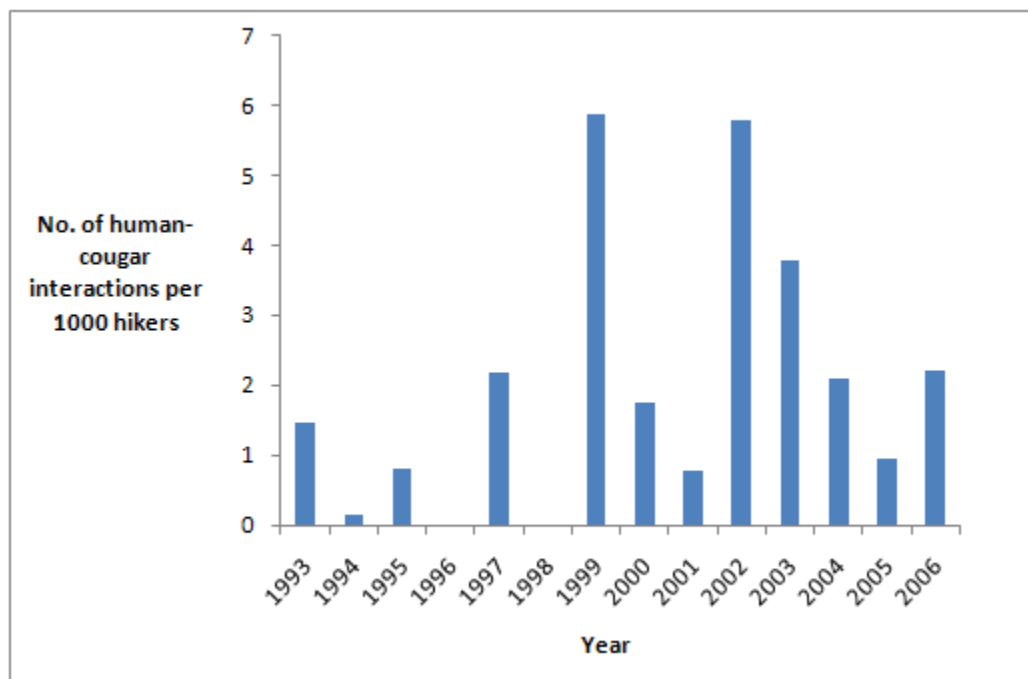


Figure 4.4 Yearly trends of human-cougar interactions ($n = 157$) per 1000 hikers in the West Coast Trail study area during 1993 – 2006 (PRNPR Visitor and Wildlife databases).

Seasonal trends

Most (56%) of human-cougar interactions ($n = 157$) occurred in August (29%) and July (27%), followed by June (16%), September (15%) and May (14%) (Table 4.9). The

proportions of human-cougar interactions per month differed from expected given the proportions of hikers per month ($\chi^2 = 13.5$, 4 df, $P = 0.009$). The frequency of human-cougar interactions were less than expected in the month of July (Bonferroni confidence interval at $\alpha = 0.05$).

Table 4.9 Relationships between the average numbers of hikers per month and human-cougar interactions ($n = 157$) that occurred during 1993 – 2006 in the West Coast Trail study area. (**Bold** denotes significant difference $\alpha = 0.05$).

Seasonal level of human activity	Proportion ^a of total hikers (p_{i0})	No. of Obs	No. of Exp ^b	Proportion of Obs (\bar{p}_i)	Confidence ^c interval on proportion of occurrence (p_i) ^d	P -value (level) ^e
Month						0.009
May	0.138	20	21.7	0.127	$0.059 \leq p_1 \leq 0.2196$	(0)
June	0.161	35	25.3	0.223	$0.137 \leq p_2 \leq 0.309$	(0)
July	0.269	28	42.2	0.178	$0.100 \leq p_3 \leq 0.257$	(-)
August	0.285	41	44.7	0.261	$0.171 \leq p_4 \leq 0.351$	(0)
September	0.147	33	23.1	0.210	$0.126 \leq p_5 \leq 0.294$	(0)
Total	1.000	157	157	1.000		

Obs = observed; Exp = expected.

^a Proportions of total hikers represent the expected proportions of human-cougar interactions if interactions occurred in exact proportion to numbers of hikers per month.

^b Calculated by multiplying $p_{i0} \times n$; i.e., $0.138 \times 157 = 21.7$.

^c 95% family of confidence intervals for $k = 4$ categories (Neu et al. 1974).

^d p_i represents theoretical proportion of observations and is compared to p_{i0} determine if hypothesis of proportional occurrence is accepted or rejected.

^e Level: + means numbers of human-cougar interactions in the category were more than expected given the availability of the category; – means interactions in the category were less than expected given the availability of the category, and 0 means interactions were not statistically different from random (Stoms et al. 1993).

Discussion

The results of this study confirmed the general increasing trend of human-cougar interactions that is being observed throughout western North America (Beier 1991; Torres et al. 1996; Fitzhugh et al. 2003; Lewis 2009). Despite a steady decline in hiker numbers in the West Coast Trail study area from 1993 – 2006, reports of human-cougar interactions moderately increased. In addition, spatial clusters of interaction locations (hotspots) were identified for combined data across these years.

Locations of interaction hotspots corresponded well with predicted distribution of cougar observations based on associations with landscape characteristics. As expected, human-cougar interactions occurred more frequently near areas with human activity: near campsites and landscape characteristics that were associated with campsites (i.e., beaches and freshwater drainages >20 m in width). These findings are consistent with anecdotal observations of rare species – sightings tend to be located in places most accessible to observers – and represent one of the main problems of using human-wildlife interaction data to infer underlying associations of habitat (Agee et al. 1989; Stoms et al. 1993). Thus, although cougar sightings are generally rare and random events, the locations of cougar sightings are in part a consequence of observer availability and in part, the landscape characteristics present at each site. Assuming that cougars use areas of more suitable habitat more intensively than they use less suitable habitat, sighting locations should reflect the broader landscape characteristics of the surrounding habitat (Palma et al. 1999). Because of my methodology and the limitations of the Park database, I cannot separate the contribution of intensity of use by humans and intensity of use by cougars to human-cougar encounters.

Observer availability only partially explains the occurrence of hotspots. For example, the hotspot at Michigan Creek is one of the most popular campsites on the West Coast Trail (Theberge 2005). However, the hotspots at Tsocowis Creek, Cheewhat River, and Camper Bay River seem less influenced by higher levels of human activity because, relative to other areas (e.g., Tsusiat Falls, Cribbs Creek, Thrasher Cove and Walbran River), these areas are less popular for camping (Theberge 2005). There are no food storage lockers or outhouse facilities at Cheewhat River, and hikers are often advised not to camp in the area because interactions between people and cougars, wolves and black bear frequently occur. In fact, cougar-human interactions occurred with greater frequency near Tsocowis, Cheewhat and Camper Bay areas, as signified by hotspots that are larger than that at Michigan Creek.

Cougars may avoid areas where people are consistently more active. This supposition is corroborated by the spatial patterns of human-cougar interactions with respect to viewpoints: interactions between people and cougars occurred less frequently than expected between 0.0 – 0.9 km and more frequently than expected between 2.0 – 2.9 km away from viewpoints. Similar patterns were observed in Cuyamaca Rancho State Park, California, where radio-collared cougars avoided areas with human activity during the day and crepuscular periods when people were most active (i.e., people at campsites are typically more active earlier in the morning and later into the evening than people hiking on the trail), and occurred closer to areas at night when people were least active (Sweanor et al. 2007). Seasonal patterns of human-cougar interactions in the West Coast Trail study area may provide further evidence of cougar avoidance of human-use areas when people

are most active. For example, numbers of human-cougar interactions were less than expected during July, which marks the beginning the 'peak' hiking season (i.e., July and August) and a 10% spike in hiker numbers compared to those in May, June and September. However, the majority (26%) of human-cougar interactions occurred in August when the majority of people hike the trail, suggesting that additional factors may affect the distribution of cougars.

Timing of reproduction may influence the distribution and movement patterns of cougars. Although cougars can breed and produce young at any time of year (Cougar Management Guidelines Working Group 2005), cougars inhabiting northern latitudes tend to produce litters most often during summer months (e.g., Ross and Jalkotzy 1992; Logan and Sweanor 2001; Ruth 2004). Female cougars with kittens are also known to travel less (i.e., 1.5 km/day) compared to solitary animals (Hemker et al. 1984). Thus, it may be that lower numbers of human-cougar interactions in July coincide with the birth and rearing of kittens in the study area, with higher numbers of interactions occurring again in August when the kittens are weaned and the female begins to travel greater distances in search of food.

Other factors such as prey availability, competition with syntopic carnivores and activities outside the protected area reserves, such as hunting and logging, may further affect the distribution of cougars inside the reserves. Past research in North America has consistently shown that deer is the main prey species of cougar, based on the frequency of occurrence (Iriarte 1990; Katnik 2002; Robinson et al. 2002; Anderson and Lindzey 2003). On Vancouver Island, Gladders (2000) determined that 92% of the diet of cougars

consisted of Columbian black-tailed deer. However, estimates of black-tailed deer populations on Vancouver Island have been steadily declining since the late 1970's (BC Ministry of Forests 1996). McNay and Voller (1995) attributed increasing rates of deer mortality to increased predation by cougars, wolves, and people as a direct consequence of logging that effectively isolates important deer winter habitat (i.e., patches of low-elevation old-growth forest), and provides improved access to these areas. Their study also showed that deer that did not leave winter habitats were particularly vulnerable to cougar and wolf predation in areas that were 'isolated' in space (i.e., surrounded by less suitable habitat). Similarly, for coastal islands in British Columbia, Darimont et al. (2004) demonstrated that the occurrence of deer in wolf faeces was best predicted by the degree of isolation of islands from the mainland because it affected dispersal and allowed sustained predation by wolves until deer populations were reduced.

Little is known about the abundance of black-tailed deer populations on the west coast of Vancouver Island, and it is unclear if deer remain active in the study area throughout the hiking season (i.e., May – October). Detections of sign (e.g., sightings, scats, tracks) during noninvasive surveys (Chapter 3) confirmed the presence of deer during July and August, which suggests that these deer are resident or non-migratory. Alternatively, deer may seek refuge from predation in human use areas when people are most active (e.g., Isabelle and Young 1993; Kloppers et al. 2005). In any case, concurrent detections of cougar and wolf in the study area may indicate competition for deer as prey. Growing evidence has shown that exploitative (i.e., differential use or depletion of a shared resource) and interference (i.e., direct exclusion from a shared resource) interactions commonly occur between cougars and wolves (Kunkel et al. 1999; Kortello 2005; Ruth

and Buotte 2007). Cougars (35 – 85 kg) and wolves (32 – 64 kg) are similar in size and are heavily reliant on ungulate prey >25 kg (Ruth and Murphy 2009). However, unlike wolves, cougars are solitary predators and therefore require longer periods to consume their prey (i.e., three to six days) than a pack of wolves that can quickly consume its prey. As such, cougars typically bury the carcass remnants to prevent rapid decay and possible detection from scavengers and predators (Hornocker and Ruth 1997) and bed within 50-400m of the cache until the carcass is consumed (Beier et al. 1995). Despite such efforts, cougar-killed prey are often scavenged and usurped by wolves. What is more, cougars can be injured or killed defending their kills and, thus, tend to exhibit spatial avoidance and prey switching behaviours in attempts to reduce negative interactions with more dominant competitors (Kunkel et al. 1999; Kortello 2005; Ruth and Buotte 2007).

Interestingly, dietary analysis of cougar scats ($n = 29$) located in Pacific Rim National Park Reserve during 2005 and 2007 revealed that raccoon comprised the majority (28%) of prey consumed by cougars, followed by black-tailed deer (24%) and harbour seal (*Phoca vitulina*) (24%), river otter (10%), California sea lion (*Zalophus californianus*) (7%), mink (*Mustela vison*) (4%), and unknown (3%) (Wilton 2007). In comparison, the primary prey item found in wolf scats ($n = 113$) was black-tailed deer (34%), followed by raccoon (23%), river otter (21%), harbour seal (16%), sea lion (4%), and other (2%) (Wilton 2007). Consumption of secondary prey items by cougars may indicate increasing competition for decreasing numbers of deer, with wolves being the more dominant of the two predators. Also, cougars may have avoided the West Coast Trail study area when wolves were present as evidenced by disproportionate numbers of detected wolf sign compared to that of cougar (Chapter 3).

Hunting pressure may indirectly influence the diet of cougars, as well as the potential for human-cougar interactions to occur. Past research has shown that hunted cougar populations exhibit younger age structures than non-harvested populations (Logan et al. 1986; Ross and Jalkotzy 1992; Stoner et al. 2006). Because most cougar attacks on people involve juvenile and newly dispersed animals (Beier 1991), growing rates of human-cougar conflict may be caused by the removal of older cougars and the subsequent disruption of natural replacement patterns (e.g., Laing and Lindzey 1993, Lambert et al. 2006). Younger cougars are generally less adept at hunting large ungulates than adults, and are therefore more reliant on smaller prey items for survival (Beier 1991). Thus, the abundance of small mammals may be a predictor of cougar presence in areas used by people, particularly for hunted populations.

Considering that most of the West Coast Trail study area is situated in low-elevation old-growth forest, it is also reasonable to suggest an affiliation between increasing trends of human-cougar interactions and the logging that steadily continues along the National Park boundary. Undoubtedly, the close proximity of logging roads provides cougars with increased access to deer populations within the study area. Cougars tend to exploit travel routes that are less rugged than their surroundings to minimize the energetic costs of hunting and movement (Dickson et al. 2005), especially in areas of dense vegetation (Beier 1995). Besides dirt roads and ridgelines, freshwater drainages are important travel corridors because they provide increased concealment and hunting opportunities (Van Dyke et al. 1986; Dickson and Beier 2002, Dickson et al. 2005).

Spatial patterns of human-cougar interactions along the West Coast Trail suggest that freshwater drainages >20 m wide may be an important landscape feature for cougar as interactions between people and cougars occurred with greater frequency than expected between 0.0 – 0.9 km from large-sized drainages. Hence, because campsites are concomitant with freshwater drainages (the reverse is not true), it is possible that the co-occurrence of roads, freshwater drainages and campsites in an area increases the potential for human-cougar interactions to occur. Indeed, identified human-cougar hotspots in the study area are located in areas where campsites are situated adjacent to freshwater drainages that extend past the National Park boundary and into previously logged areas.

Several factors may have biased the reported frequency and distribution of human-cougar interactions and the identification of hotspots. First, hikers often have difficulty determining their exact location on the West Coast Trail and usually estimate their location using distance markers along the trail. For these reasons, human-cougar interactions are referenced with low precision, i.e., to a 1-km resolution. Despite efforts to ensure locational accuracy and consistency between records as described in the methods, associations with landscape characteristics may therefore be underestimated.

Second, reported observations of cougar (i.e., sightings, tracks and scats) are often unverified, which inherently makes it difficult to evaluate the reliability of human-cougar interactions. Given the behaviour and ecology of cougars, most people have never seen one in the wild and therefore are not adept at identifying cougars or their sign. This assumption is supported by Van Dyke and Brocke (1987b), who showed that a low proportion of survey respondents (i.e., hunters and campers) in several western states in

the U.S. were not able to correctly identify cougar when presented with a track questionnaire. In the West Coast Trail study area, hikers commonly misidentify river otter tracks for those of cougar, presumably because of similar track morphology when registered in sand. Hikers also confuse mink and pine marten (*Martes americana*) with cougar kittens despite obvious differences in body characteristics.

Third, false absences due to unreported interactions likely occurred. Despite the fact that hikers are strongly encouraged to report all wildlife sightings to Parks Canada staff located at the trailheads, there are no systems in place to determine the numbers of unreported wildlife observations. Undoubtedly, many people do not report wildlife, especially in circumstances when wildlife are viewed in their natural habitat and do not appear threatening in any way. False absences may also occur if cougars are present, but hikers do not see them. Past research demonstrated that radio-collared cougars were frequently undetected by hikers although they were bedded down close to heavily used trails, picnic areas and roads (Beier 1995, Jalkotzy et al. 1999). Indeed, some hikers are vigilant with respect to noticing wildlife and their sign, while others focus their attentions towards other aspects of personal safety (e.g., physical exertions and landscape hazards). As noted by Long et al. (2008), the resultant 'presence-only' data are difficult to statistically analyse because of inherent biases (e.g., varying aptitudes) and unequal sampling effort (e.g., little can be said about locations where cougars were not observed).

Other potential sources of error may have also biased the results of this study. The development of maps in a GIS, for example, requires multiple inputs of data that are typically obtained from a variety of different sources (Ottaviani et al. 2004). As such,

data error and uncertainty commonly exist, especially in datasets in which multiple individuals perform data collection and input over long periods without well-defined study designs or overall intended use (Reece et al. 2004). Moreover, because data layers are often expensive to develop, they can be difficult to obtain and/or keep up to date. The road layer used in this study, for example, was derived from TRIM data (Province of British Columbia 1996) that was compiled in 1990. Most probably, the density and spatial distribution of logging roads would have changed since then because harvesting activity has continued since that time. Thus, the association between human-cougar interactions and the distances to roads will likely be underestimated.

Chapter 5: Summary and Conclusions

I examined the use of noninvasive approaches to address increasing concerns of human-cougar interactions in Pacific Rim National Park Reserve and Clayoquot Sound UNESCO Biosphere reserve on the west coast of Vancouver Island. I evaluated the efficacy of a detector dog, sign surveys, scented rub pads, and remotely triggered cameras by comparing the field time requirements and equipment costs, and the overall capacity to detect and monitor cougars in coastal temperate rainforests. Additionally, I demonstrated the utility of pre-existing data by analysing the spatial and temporal trends of human-cougar interactions to identify areas where people and cougars repeatedly overlap (hotspots), and the factors consistent with human-cougar interactions relative to human activity and landscape characteristics that may influence the potential risk of future conflict.

Efficacy of noninvasive survey methods for use in coastal temperate rainforests

Cougars were poorly or never detected by any method (presumably because of their relative rarity within the Long Beach and West Coast Trail study areas). Nonetheless, the results of this study demonstrate the strengths and weaknesses of four survey methods for use in coastal environments.

Sign surveys were the most effective method for detecting cougar, wolf, black bear and deer, and the least expensive method to conduct with respect to equipment costs. The success of sign surveys in the study areas can be attributed to the availability of favourable tracking substrate (i.e., sandy beaches, dirt roads and trails). However, this method largely depends on site conditions and the proficiency of surveyors to detect and

identify tracks and scats (Van Dyke and Brocke 1987a; Haynes et al. 2005; Heinemeyer et al. 2008). Rain, wind and dense vegetation can obliterate and obscure sign from view, thereby reducing the rate of species detection, particularly if skill levels vary between surveyors. Consequently, stringent training and survey protocols must be established to ensure data consistency and accuracy necessary for long-term cougar monitoring programs (Smallwood and Fitzhugh 1995; Heinemeyer et al. 2008).

Detector dogs and camera surveys are less dependent on human surveyors and therefore, can reduce bias associated with varying landscapes and field personnel (Wasser et al. 2004). Thus, given different circumstances (i.e., increased funding), detector dogs and cameras may be useful for long-term cougar monitoring initiatives. For example, increasing the numbers of dogs to detect cougar scats may yield higher sources of DNA necessary for estimating trends in populations (Long et al. 2008). Similarly, deploying higher numbers of cameras would be useful to determine the relative abundance of cougars in an area if individuals can be uniquely identified (e.g., by colour, markings, and scars). However, achieving these objectives by either detector dogs or camera surveys would require substantial financial investment. Hence, in circumstances where long-term funding resources are uncertain, remotely triggered cameras may be more practical because, after initial investment costs, relatively little funding is required. Moreover, camera surveys can be executed by less skilled personnel and have the added advantage of providing a permanent photographic record for other researchers to verify (Gese 2001; Kays and Slauson 2008). In contrast, detector dogs require specific training for each target species, and are subject to environmental conditions such as strong wind, heavy precipitation and dense vegetation that inhibit their ability to hone in on scats (Wasser et

al. 2004). Thus, the overall utility of remotely triggered cameras may surpass that of detector dogs for long-term research and monitoring applications in coastal environments.

Lastly, scented rub pad surveys were the least effective method applied in the two study areas. Despite relatively low equipment costs, this technique has relatively few advantages for cougar research and monitoring. The failure of this technique was, for the most part, attributed to interference by black bears and wolves. Black bears, for example, frequently destroyed, licked and rubbed the carpet pads, thereby reducing the numbers of devices available for cougar detection. This apparent attraction of black bears to the scent lure resulted in several cameras being damaged because of their proximity to the rub pads. Wolves also visited the rub pads, although less frequently than bears. Nonetheless, the presence of wolves may have caused cougars to avoid areas marked by wolves in attempts to reduce negative interactions with more dominant predators. For these reasons, therefore, scented rub pad surveys are not recommended for use on the west coast of Vancouver Island.

Spatiotemporal patterns of human-cougar interactions

I used kernel density estimation (Van Winkle 1975) and 10% volume contours (e.g., Potvin et al. 2005) to delineate spatial clusters of interaction locations on the West Coast Trail, and was able to identify Michigan Creek, Darling Creek, Cheewhat River and Camper Bay River as areas where there is a greater potential for the activities of people and cougars to overlap.

Locations of human-cougar interactions along the West Coast Trail during 1993-2006 were primarily associated with campsites, beaches, flat terrain and large-sized drainages (i.e., >20 m wide). At first glance, these results suggest that the locations of human-cougar interactions may be a consequence of observer availability rather than the particular landscape characteristics present at each site, especially because all campsites (e.g. areas with outhouse facilities and food storage lockers) are situated on beaches next to freshwater drainages. Upon closer inspection, however, observer availability does not appear to be the sole predictor of human-cougar interaction locations. For example, yearly trends of human-cougar interactions increased during 1993-2006 despite decreasing trends of hiker numbers on the West Coast Trail. Similarly, seasonal numbers of human-cougar interactions were less than expected near popular viewpoints and during July, which marks the beginning of the peak hiking season. Further still, although each of the four identified hotspots occurred at campsites, Tsocowis Creek, Cheewhat River and Camper Bay River are considerably less popular for camping compared to other areas along the trail (Theberge 2005). In fact, human-cougar hotspots were identified at campsites situated close to freshwater drainages that extend beyond the National Park boundary and into previously logged areas (based on 1990 TRIM data). These results suggest that cougars may be accessing the study area by logging roads and using freshwater drainages as natural movement corridors. Thus, it is likely that the co-occurrence of these landscape characteristics (i.e., high levels of human activity, the distribution of travel corridors, and proximity to logging roads that provide cougars with increased access to the study area) increase the likelihood of human-cougar interactions and, in doing so, underlie the formation of human-cougar hotspots.

Management Implications

The results of this study provide managers with noninvasive approaches for obtaining baseline information about cougars to address the growing concerns of human-cougar interactions in Pacific Rim National Park Reserve and Clayoquot Sound UNESCO Biosphere Reserve.

My research demonstrated that sign surveys and remotely triggered camera surveys are effective methods for use in coastal temperate rainforests. These methods will provide protected area managers with the necessary tools to develop long-term cougar monitoring programs for proactive mitigation of human-cougar conflict. Monitoring efforts should be focused primarily in areas where there is a greater risk of spatiotemporal overlap between people and cougars (i.e., at identified human-cougar interaction hotspots). However, additional monitoring outside human-use areas may provide useful information about cougar-habitat relationships and, over time, the status and trends of populations. In any case, before initiating a large-scale monitoring program it is important to determine any constraints of time, costs, logistics and available personnel. Similarly, the success of noninvasive survey methods for long-term monitoring initiatives will ultimately depend on careful consideration of the study objectives and the development of an appropriate study design.

Although the identification of human-cougar interaction hotspots will allow protected area managers to allocate limited resources and focus mitigation efforts more effectively, it is not my intent to suggest that interactions between people and cougars will inevitably occur in hotspots areas. Rather, my goal is to contribute to a better understanding of the

circumstances that contribute to the formation of hotspots. My research showed that interaction locations were primarily associated with high human activity; however, these results suggest that the likelihood of human-cougar interactions may be greater in human-use areas that are situated close to travel corridors used by cougars. Consequently, a proactive approach by protected area managers involving the identification of important cougar travel routes and visitor education may help to ensure long-term conservation of cougars while minimizing risks to visitor safety. Cheewat River, for example, is an area frequently used by cougars. Hence, I recommend that managers continue to discourage hikers from camping at Cheewat by effecting an 'area closure', and by withholding outhouse facilities and food storage lockers. I further recommend that visitors be provided with educational materials on the elevated risks of cougar encounters near freshwater drainages like Cheewat, particularly at dawn and dusk when cougars are more active (Beier et al. 1995; Sweanor et al. 2004). Similarly, visitors should be provided with information about appropriate human responses during a cougar encounter that may reduce the potential for human injury or attack, and the destruction or removal of the offending animal. In general, efforts to mitigate future human-cougar conflict should be based on solutions that prevent the activities of people and cougars from intersecting in space (Treves and Karanth 2003).

Lastly, despite several identified biases associated with wildlife sighting data, the results of my study showed that reports of human-cougar interactions can provide valuable information about the spatial and temporal distribution of cougars in areas used by people. Nonetheless, I encountered many issues concerning the quality and accuracy of these data. For example, approximately 24% of the human-cougar interactions reports I

obtained for the West Coast Trail survey area could not be used because they contained locational errors, missing data, and observational uncertainty (e.g., misidentifications and unverified reports). Hence, to increase the level of inference for future human-cougar conflict studies, I recommend the following improvements for data collection and entry protocols: 1) provide UTM co-ordinates on all distributed protected area maps so that visitors can determine their location more accurately when documenting observations of wildlife; 2) post species identification sheets with photos and track descriptions at public facilities and hiking trails to improve the confidence level of reported wildlife observations; 3) ramp up efforts to encourage visitors to report observed (and encountered) wildlife by providing wildlife observation forms and drop boxes in convenient locations (e.g., at trailheads, information centres, and parking lots), and 4) ensure that all reported human-cougar interactions are verified (e.g., in the field, personal interview, hiker-submitted photo or drawing) before being entered into the wildlife observation database. These recommendations may be more easily achieved if people are provided with the rationale explaining the importance of visitor participation to ensure the continuance of public safety and wildlife conservation in protected areas.

Recommendations for Future Research

To extend my research on the factors that influence human-cougar conflict on the west coast of Vancouver Island, I suggest the following investigations;

- 1) Study the distribution and abundance of deer and small prey populations to determine whether prey are key predictors of cougar occurrence in human use areas.

- 2) Examine the spatiotemporal patterns of human-cougar interactions relative to logging activity to determine how road access influences the potential risk of interactions on the West Coast Trail.

- 3) Continue to monitor cougars using sign surveys and remotely triggered camera surveys to determine the status of populations, and the long-term impacts of increasing human activity in protected areas.

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