BALANCING THE CONSERVATION OF WILDLIFE HABITAT WITH ROAD ACCESS FOR SUBSISTENCE HUNTING IN YAKUTAT, ALASKA

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A

THESIS

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Abstract

This thesis was an interdisciplinary investigation with the goal of balancing the conservation of wildlife habitat with road access for subsistence hunting in Yakutat, Alaska. The problem posed by land managers and subsistence moose hunters revolved around the use of off-highway vehicles (OHVs; e.g. "four-wheelers") for subsistence moose hunting and the potential disturbance OHVs have on moose. This complex social-ecological problem is becoming an increasingly common management dilemma faced by rural mixed cash-subsistence communities across the Circumpolar North. I addressed this problem in two chapters with a combination of methods from wildlife ecology, landscape modeling, subsistence land-use, and scenario planning. The data used for analysis in Chapter 1 was derived from a three-year moose GPS-collar dataset, remote sensing imagery, and mapped routes. I modeled moose distribution with multi-scale, seasonal and sex-specific resource selection functions in a GIS. The best-fit models suggested female moose were displaced by OHV routes. Male moose were displaced by routes or areas where routes were in close proximity to primary forage. A combined pattern of route avoidance was quantified beyond approximately 1 km of total vehicle travel/km^2/day. Chapter 2 describes the application of distribution models from Chapter 1 to a social-ecological assessment of route closures. Meetings with land managers and moose hunters were conducted to identify their respective values and management goals. Then I evaluated the effect of four road closure scenarios on moose habitat and hunting access. A measure of hunting access was evaluated with interviews about hunter land-use patterns, as well as the mapping of harvest areas in a GIS. The results of the scenario evaluation showed the spatial arrangement of routes influenced the total amount of high probability moose habitat and access to preferred harvest areas. A balance in the conservation of wildlife habitat and the maintenance of hunting access may be found in the closure of routes through valuable moose habitat and the spatial arrangement of future routes around valuable moose habitat, within reach of important harvest areas. The results of the analysis and interdisciplinary approach may prove useful to land managers who must evaluate the trade-offs between wildlife habitat conservation and the increasing use of motorized access for contemporary subsistence hunting practices.

Table of Contents

List of Appendices

Page

List of Figures

List of Tables

Page

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Thesis Introduction

This interdisciplinary thesis is the result of a two-year study, 2006-2008, in cooperation with the U.S. Forest Service Yakutat Ranger District of the Tongass National Forest in Southeast, Alaska. Since 2005, regional land managers have been developing an access management plan mandated by the 1997 Tongass Land Management Plan. The planning process included an evaluation of the environmental impact of existing roads and off-highway vehicle (OHVs; e.g. "four-wheelers") routes to designate areas as open or closed to motorized vehicle access (USDA Forest Service 2007). To support the evaluation process, my project addresses land managers' particular concern that roads and "user-created" OHV route activity have been disturbing moose (e.g. OHV noise), and effectively reducing the amount of habitat available to moose. The evaluation process was also identified as a contentious management issue because there was a large constituency of subsistence hunters that used the current network of roads and OHV routes for harvesting moose.

In a prior preliminary analysis, a three-year dataset of moose locations derived for the purposes of a different study (Oehlers et al. in review), were compared to random locations to test a relationship between locations used by moose and the distance to roads and OHV routes. The results of that analysis showed that there was a marginal relationship between routes and moose occurrence, and some evidence of displacement from key habitats (Pyare et al. 2006). This analysis, however, had two shortcomings. The first information gap was that vegetation data available for the analysis was outdated and not accurate due to successional vegetation change. Thus, it was difficult to ascertain how vegetation influenced moose distribution. The second information gap was the need for a more accurate measurement of how often routes were used. For example, it was suspected some routes were rarely used and would have less of a disturbance affect on moose than routes that received more frequent OHV use.

I met with land managers and subsistence moose hunters in spring 2006 to understand better the management issue and focus my analysis. Land managers were primarily interested in a scientifically defensible understanding of the influence of roads and OHV routes on moose distribution in relation to limited habitat, and how they might balance the need for subsistence hunting access. Subsistence moose hunters were primarily interested in maintaining enough access to support their cultural, economic, and nutritional use of moose. Meetings and open-ended conversations with land managers and subsistence moose hunters served as the basis for the formation of my two thesis chapters.

In Chapter 1, I conducted a multi-scale, seasonal and sex-specific analysis of resource selection with a three-year moose GPS-collar dataset, new remote sensing imagery, and weighted route information collected from community interviews. In Chapter 2, I tested four road closure scenarios for effects on moose habitat and access for subsistence hunting. The subsistence hunting access was evaluated by interviewing resident moose hunters about their patterns of land-use and by mapping their preferred harvest areas in a Geographic Information System (GIS).

Chapter 1, "Evaluating the road-effect zone on wildlife in rural landscapes", was written as a conservation planning study prepared for submission to *Biological Conservation*. The chapter was based on the concept of the "road-effect zone" introduced by Forman et al. (1997). Building from the original concept of the road-effect zone and other related studies, I believed the impact of rural roads and more specifically OHV routes on wildlife distribution needed to be better understood for future conservation planning efforts in rural landscapes. Forman and Deblinger (2000) described a suite of nine ecological effects that roads had on an urban landscape (Massachusetts, USA), with an impact "zone" extending >600 m from the physical road (e.g. road salt, invasive species, and wildlife abundance). Forman and Deblinger (2000) also postulated that rural roads have an even greater potential impact across North America as a whole—due to the sheer quantity of rural roads (e.g. logging roads) and the use of OHVs on rural roads as a point of access for hunting and recreation. I took this postulation as an opportunity to test the concept of the road-effect zone in rural landscapes with the latest analytical techniques from wildlife modeling.

From my review of wildlife disturbance literature (e.g. Ciarniello et al. 2007; Farmer et al. 2006; Sawyer et al. 2006; Stankowich 2008), I came to the conclusion that a resource selection function (RSF) analytical framework would allow me to test for a road-effect zone and conduct a spatially-explicit analysis of wildlife distribution in relation to road and OHV routes. The theory behind a RSF is that if animals select habitats and food resources disproportionately to their availability, then those habitats or food resources improve their fitness, reproduction and survival (Thomas & Taylor 2006). For example, used locations (e.g. recorded by GPS-collars) can be compared to random locations (within an animal's home range) using logistic regression (Manly et al. 2002). Then the variable coefficients with the logistic regression equation can be entered into a GIS to model the probability of occurrence from 0 to 1 across the study area. I used an information-theoretic approach with Akaike Information Criterion (AIC) to select the best-fitting, most parsimonious models that explained the most variation. An AIC approach has become preferred in many ecological studies because it allows the development of multiple working hypotheses (Anderson 2008; Burnham & Anderson 2002). I believed the AIC approach was the best for my study because it allowed me to develop multiple models (10 *a priori*), with and without a route variable, to determine if routes helped explain the observed distribution of moose from the existing GPS-collar data. If the ΔAIC scores improved with the inclusion of the route variable, then routes were influencing moose distribution. The positive or negative logistic regression coefficients would determine if moose have a positive or negative relationship with routes.

Current wildlife habitat selection studies also suggested season, sex, and scale as an important analytical consideration (e.g. Bowyer & Kie 2006; Boyce et al. 2003; Johnson et al. 2004; Kie et al. 2002). Therefore, I conducted the same analysis at multiple spatial scales (250 m, 500 m, and 1000 m buffer on used and random locations) for each sex over two seasons (summer and fall). All the models were validated with an area-corrected k-fold cross validation procedure. This validation method was developed by Boyce et al. (2002) because many datasets used to develop RSFs use all the location data available to develop the distribution models, without withholding location data for validation of the distribution models. The validation method uses a 5-fold partitioning of the complete dataset to test the final models against 20% of the data in five iterations. The method has been subsequently used in many other studies (e.g. Boyce et al. 2003; Ciarniello et al. 2007; Johnson et al. 2004).

The final step in Chapter 1 was an exploratory analysis to identify an ecological disturbance threshold for moose by road and OHV route activity. This additional analysis was done because I was interested in the application of resilience theory (e.g. system thresholds; Walker et al. 2004), and I believed identifying a disturbance threshold would provide a useful metric for land managers to evaluate the trade-offs between the conservation of wildlife habitat (e.g. Goss-Custard et al. 2006) and the increasing demand for OHV access.

Chapter 2, "Balancing the conservation of wildlife habitat with subsistence hunting access: a geospatial scenario approach", is an interdisciplinary social-ecological assessment prepared for submission to *Ecology and Society*. The chapter is based in the concept of scenario planning and ties together methods and results from the landscape modeling in Chapter 1, subsistence land-use studies, and resilience theory. Scenario planning became a popular interdisciplinary study tool with the Millennium Ecosystem Assessment (2005), where scenarios were developed to investigate plausible futures for complex social-ecological issues. The idea behind scenario planning is that scenarios can be used as an exercise to explore possible futures and create "stories" that provoke discussion and identify uncertainties in the dynamics of the system of interest (Peterson et al. 2003b). Scenario planning exercises can be used to help communities and organizations plan and shape a shared vision with the integration of different types of datasets and descriptive information (e.g. Hulse et al. 2004; Kruse et al. 2004; Peterson et al. 2003a). For example, Peterson et al. (2003a) used scenario planning in the Northern Highland Lake District of Wisconsin to help communities visualize alternative futures with respect to housing development. These scenario exercises helped identify potential pitfalls and opportunities for retaining important ecosystem services, such as valued fishing opportunities.

Scenario planning methods were applicable to Chapter 2 because the Yakutat Ranger District was already in the process of developing four road closure alternatives and their cumulative impacts (e.g. salmon habitat, nesting bird habitat, etc.). By working within the bounds of the Forest Service's existing alternatives, I was able to provide another "layer" of information with respect to moose habitat and subsistence hunting access. To evaluate the impact of road closures on moose habitat, I used the habitat models from Chapter 1 and applied them to the four road closure scenarios. This modeling process allowed me to quantify the relative impact that the different road closure scenarios would have on the total amount of high probability moose habitat. I assumed that habitat with a high probability of moose occurrence positively correlated with individual fitness, forage availability, and ultimately population productivity.

To evaluate the impact of the road closure scenarios on subsistence hunting access, I adapted ideas from the most current land-use mapping studies (e.g. Berkes et al. 1995; Berman & Kofinas 2004; Pedersen & Coffing 1984; Stephen R. Braund & Associates 2007; Tobias 2000) and incorporated "resilience thinking" (*sensu* Walker & Salt 2006) into my analysis approach. Stephen R. Braund & Associates (2007) used interviews to map preferred harvest areas that were later digitized in a GIS to create spatially-explicit "hotspot" maps of harvest areas in the communities of Beluga and Tyonic, Alaska. The hotspots were later used to illustrate potential land-use conflicts with a proposed mine construction. I applied the resilience concept of system thresholds to evaluate each road closure scenario in terms of access with an adapted hotspot mapping technique. In scoping meetings, I asked hunters a series of questions to understand better the importance of road access to subsistence moose hunting. I wanted to determine if there was a threshold with OHV access at which hunters would no longer be able to harvest a moose. Answers to these questions suggested that there was indeed a threshold distance at which moose hunters could feasibly transport a harvested moose from a kill site to a road or OHV route. Therefore, I selected a random sample of one-third of federally registered subsistence moose hunters (n=25) and investigated how far hunters were willing to transport a harvested moose. It was understood, however, this distance could be dynamic and this study would be a "snapshot" in time that represents the current social and ecological conditions. The harvest areas were digitized in a GIS and an index of access was calculated with a threshold retrieval zone represented by a buffer on roads and OHV routes comprising each road closure scenario.

The Chapter 2 discussion covers the relative impact of the road closures on moose habitat and subsistence hunting access. While the indices created for the scenario evaluation are only approximations, I believe they provide a quantitative and qualitative comparison of each road closure scenario with respect to moose habitat and subsistence access. The maps of moose habitat and important harvest areas will also allow land managers to explore the potential impacts and trade-offs associated with access alternatives in the future.

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Chapter 1- Evaluating the road-effect zone on wildlife in rural landscapes*

Abstract: The road-effect zone is the area in which ecological effects extend outward from a road. The concept of the road-effect zone can be useful to land managers evaluating the impact of road development on wildlife. To evaluate the road-effect zone of off-highway vehicle (OHV) activity that is common to rural landscapes of Alaska, I conducted an analysis of moose (*Alces alces gigas*) occurrence in relation to rural roads and OHV routes. Data for the analysis was derived from a three-year dataset of GPS-collared moose, mapped OHV routes from satellite imagery, and interviews of community members to quantify route use. I used logistic regression and AIC model selection criterion to develop resource selection functions (RSFs) for male and female moose at three spatial scales (250 m, 500 m, and 1000 m) in two seasons (summer and fall). I validated the models with an area-corrected *k*-fold cross validation procedure. A variable for route activity improved the fit of RSF models for both sexes at all spatial scales and in both seasons. A negative relationship was found between moose occurrence and routes or areas in which routes were in close proximity to moose primary forage (i.e. willow), with the exception of male moose at the 1000 m scale in the fall. The road-effect zone for male moose was therefore determined to be between 500 m and 1000 m and the road-effect zone for female moose was >1000 m. The mapped RSFs show a reduced probability of moose occurrence in areas of increasing traffic with a pattern of avoidance beyond approximately 1 km of total travel/km^2/day. The results of my study suggest the dispersed ecological effect of rural roads and OHV routes should be considered in transportation and land-management planning efforts.

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Introduction

The growing network of roads in rural landscapes across North America is creating new challenges and opportunities for transportation planning and the conservation of wildlife habitat. Forman et al. (1997) introduced the unifying concept of the "road-effect zone", which illustrates the ecological effect of roads and the flow of traffic beyond the physical extent of the road. A subsequent field study (Forman & Deblinger 2000) demonstrated that this "zone" was >600 m from roads in an urban landscape. Effects were measured among nine ecological communities or species: wetlands, streams, road salt, exotic plants, moose, deer, amphibians, forest birds, and grassland birds. When this impact zone was extrapolated to roads across the 6.2 million-km road system of the United States, ecological effects were projected to occur on 19% of the country's area, underscoring the large extent of road-effected lands across the U.S. (Forman 2000). An additional insight from this study also showed the disproportionate impact that roads in rural areas could have (16.5%) as compared to roads in urban areas (2.5%). This impact was also recognized as a conservative estimate, due to the inability to account for the dispersed effect of off-highway vehicles (OHVs; e.g. four-wheelers and snowmachines) used on rural roads as a point of access for hunting and recreation. Noise and visual disturbance has been shown to have a greater effect on wildlife rural landscapes, where habituation is less likely to occur (Stankowich 2008). The potential ecological impact of dispersed OHV use suggests a need to extend the concept of the road-effect zone for wildlife conservation and transportation planning to rural landscapes.

In the last 35 years, the use of OHVs on public lands across the U.S. has increased seven-fold (USDA Forest Service 2004). Many early human-wildlife disturbance studies were limited to visual data that underestimated the "area of influence" (Taylor & Knight 2003). However, the rise of Global Positioning System (GPS) technology and spatially-explicit methods of analysis using Geographic Information Systems (GIS) has improved understanding of species habitat selection in relation to patterns of disturbance (Farmer et al. 2006; Gaines et al. 2005; Johnson et al. 2004). This is especially true for large mammals that can be remotely monitored with GPS-collars (Ciarniello et al. 2007). For example, at a fine scale, Preisler et al. (2006) showed the short-term flight response by GPS-collared elk (*Cervus elaphus*) was >1000 m from OHVs in a controlled landscape experiment. Over broader time scales, Sawyer et al. (2006) used three years of collar location data to quantify the effective area of mule deer (*Odocoileus hemionus*) habitat lost by natural gas development (a single well pad disturbed 3-4 acres of habitat). The application of these new data-collection and evaluation methods in rural areas where new roads are being built and old roads are being decommissioned offers significant analytical improvements for wildlife conservation planning (Strittholt & Dellasala 2001; Trombulak & Frissell 2000).

It is becoming increasingly evident that conservation strategies aimed at mitigating the environmental impacts of OHVs must also account for the social drivers of the issue (Buckley 2004). As the number of OHV users grows, advocacy groups are forming to petition for more access and public agencies are challenged to designate environmentally sound routes. As a result, illegal OHV use on public lands has been a growing problem across the U.S. (Karasin 2003). OHVs are also used for non-recreational purposes that add another layer of complexity to access management plans in many rural areas. For example, OHVs are used as the primary means of transportation for the harvest of subsistence resources in many rural communities across the Circumpolar North (Berkes & Jolly 2001; Brinkman et al. 2007; Ford et al. 2006; Gordon et al. 2007). OHV users are utilizing existing infrastructure, such as old logging roads, and making dispersed "user-created" routes in search of game (Schmidt et al. 2005; Stedman et al. 2004). Therefore, it is challenging for land managers to evaluate to what extent OHVs are impacting the landscape and how to balance the conservation of wildlife habitat (Ahlstrand et al. 1998; Happe et al. 1998; Sowl & Poetter 2004).

My study area of Yakutat, Alaska, is a rural community that relies on roads and OHVs for the harvest of subsistence resources (Mills & Firman 1986). Yakutat land managers have started to develop a travel-access management plan that includes the use of OHVs on National Forest lands. The evaluation process is part of an Environmental Assessment (EA) to comply with 1997 Tongass Land and Resource Management Plan (TLMP), which mandated the inventory of roads and OHV routes and their environmental impacts for management of motorized access. Initial public meetings held by the Yakutat Ranger District that introduced the EA revealed that indigenous and non-indigenous groups in Yakutat were heavily reliant on OHVs to access subsistence resources, making the EA a contentious management issue. Agency land managers and subsistence hunters identified Alaskan moose (*Alces alces gigas*) as a species of mutual concern. Managers were concerned that OHV routes displaced moose from limited high-quality habitat, while OHV users were concerned that restrictions on access routes would effectively prevent them from reaching important hunting areas (USDA Forest Service 2007).

To support the evaluation process, I designed a study to evaluate the effect of rural roads and OHV routes on moose distribution. I met the objective of this study with the following steps: (1) developing a method to interview land managers and community members to derive an index of OHV use on routes in the region, (2) employ the route-use index to weight routes in an analysis of moose distribution as a function of habitat, landscape, and route variables and (3) map the road-effect zone with resource selection functions to identify an ecological disturbance threshold for moose, by the amount of traffic on rural roads and OHV routes.

Methods

Study area

Yakutat, Alaska is a community of approximately 800 residents with a rural mixed cash-subsistence economy (Mills & Firman 1986). It is located along the coast of Southeast Alaska in the northernmost portion of the Tongass National Forest (Figure 1). For modeling purposes, the geographic bounds of the study area were defined by the availability of high resolution multi-spectral remote sensing imagery from the U.S. Forest Service (Figure 1; SPOT5 – August 2005). The imagery covered the town area and approximately 1000km^2 of adjacent terrain. Approximately 60% of the residents are Alaska Native and the majority of the residents are employed seasonally in the commercial fisheries industry (U.S. Census 2000). The most recent estimates of wild food harvest (e.g. salmon, moose, and berries) in the region showed that 40% (181 kg) of the annual diet is derived from wild foods (ADF&G 1987).

The Tongass is a coastal temperate rainforest, with the Yakutat area having a mean annual temperature of 4.1°C and mean annual rainfall of 381 cm. The topography of Yakutat is a relatively flat strip of coastline abutting the Fairweather Range with a mosaic of wetlands, shrub lands, and forests. The area is bisected by several large glacial and rain-fed rivers that support five species of salmon (Shephard 1995). The forested areas are dominated by Sitka spruce (*Picea sitchensis*) interspersed with western hemlock (*Tsuga heterophylla*) and black cottonwood (*Populus trichocarpa*). The wetlands and shrub lands are composed of graminoids, forbs, and shrubs with several species of willows (*Salix spp.*) and Sitka alder (*Alnus sinuate*). In addition to moose, the terrestrial megafauna include grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), grey wolf (*Canis lupus*), and mountain goat (*Oreamnos americanus*) in the nearby alpine and fjords (Mills & Firman 1986).

The first OHVs started to make an impact on Yakutat during World War II. Tracked vehicles were used to move military supplies along the coast and created many of the OHV routes still in use today. After the war, some of these tracked vehicles were sold to local people and were primarily used for hauling fishing equipment (Mills & Firman 1986). Modern OHVs with rubberized wheels arrived in the 1970s but did not become popular until engine size increased to 185-250ccs during the 1980s. The larger engine allowed residents to haul supplies and harvest game across the beach and inland meadows (USDA Forest Service 2007).

Animal location data

I used a three-year dataset derived from 20 GPS-collared moose. The dataset had approximately 40,000 locations from November 2002 – March 2005. The dataset was previously used to examine the implications of sex and spatial scale on moose habitat selection in the region (Oehlers et al. in review). The collars were formatted to record a GPS location every six hours. This interval was sufficiently long to maintain relative independence between locations and minimize spatial autocorrelation (Nielson et al. 2002). To investigate a road-effect, the dataset was further screened in the following steps:

(1) To eliminate spurious and inconsistent animal locations, locations were removed after an animal had died, a collar had been dropped, or a formatting inconsistency occurred resulting in locations closer than six hours.
(2) For a season-specific comparison, locations were separated into discrete five-week analysis periods corresponding to summer or fall (Table 1).
(3) To account for the possibility of behavioral differences, male and female moose were separated (Bowyer et al. 2001; Miquelle et al. 1992; Spaeth et al. 2004).
(4) To minimize the influence of individual variation on pooled locations for modeling, an equal number of the remaining locations were selected from each individual (Thomas & Taylor 2006).

I conducted an analysis on a resulting dataset of 2,374 points representing 5 female and 5 male moose. A maximum number of 106 equal locations per individual were available in the summer analysis period. A maximum number of 146 equal locations were available in the fall analysis period, with one male vacating the study area during the fall. A matched use-availability design was used to compare used locations to random locations within seasonal home ranges (Design II; Manly et al. 2002). I explicitly assumed that randomly selected locations within a home range were available, but not necessarily unused. In contrast, a used-unused design required a dataset with explicit knowledge about areas that remain unused by animals. Seasonal home ranges were created for individual animals. Kernel home ranges

(99.9%) were created for each individual with the Home Range Extension (Rodgers et al. 2007) in ArcGIS 9.2 (ESRI Inc. 2008). The smallest whole kernel was found by lowering the h*ref* (smoothing parameter) in 0.1 increments until the home range polygon split or a hole formed. The individual home ranges were then combined among sex and seasons to represent third-order, sex-specific and season specific resource selection (Johnson 1980). After lakes, rivers, and coastline were removed from these four home ranges, the available locations were randomly selected for analysis.

Route mapping and classification

The mapping of vehicle routes and classification of their level of use required a series of steps that included updating existing datasets with the most current routes, meeting with local land managers to identify which routes were actively used, and interviewing residents to quantify how often the routes were used. The majority of existing route information was digitized from IKONOS remote sensing imagery in 2004 by the U.S. Forest Service Yakutat Ranger District. This information was supplemented and verified with ground-based GPS delineation of routes used by OHVs and by aerial survey from a helicopter. I then held a series of meetings with the land managers in 2006 to build on existing route information. To update and refine the route information, land managers did the following:

(1) Visually verified new routes observed on the most recently classified 2005 SPOT5 remote sensing imagery;
(2) Identified which routes were actively used over the study period;
(3) Categorized routes in three categories (Low OHV, High OHV, and All-Vehicles) according to perceived level of use as well as the visible wear and soil types (Table 2);
(4) Selected three representative routes in each category to sample for subsequent interviews with OHV users.

A total of 523 km of routes were mapped across the study area. The routes were composed of 184 km of Low-Use OHV, 118 km High-Use OHV, and 221 km of All-vehicle routes. A random sample of approximately one-third (n=25) of federally registered subsistence moose hunters were interviewed in December 2007 to quantify their route-use. Hunters were interviewed in person and presented a 1.5 m x 1 m high-resolution aerial photograph of the region with mapped OHV routes. Without disclosing the hypothesized route-use categories to hunters, the hunters were asked to provide their best estimate of the number of one-way trips made on the nine representative routes in each seasonal analysis period.

The results of the route-use estimates were pooled for each route category, resulting in 75 route-use estimates for each category in each of the two seasonal analysis periods. Analysis of variance (ANOVA) between route categories was used to determine if the average use across categories was different. Differences in the frequency of use among route-use categories were statistically significant, so the average frequency of use in each route category was treated independently and used as a weight in subsequent road-effect modeling (Table 3).

Road-effect modeling

I used an information-theoretic approach with multiple working hypotheses (Anderson 2008; Burnham & Anderson 2002) to investigate a road-effect on moose. My rationale for the 10 *a priori* habitat models that I developed was as follows. First, I eliminated commonly used habitat variables (e.g. elevation, slope, and aspect) due to the relatively flat terrain over the study area. Second, I was interested in evaluating the effect of route activity on moose distribution. And third, I hypothesized the primary predictors of moose occurrence in my study area during the snow-free summer and fall would be the proximity to high-quality forage, cover from predators, and riparian areas (Dussault et al. 2005; Kunkel & Pletscher 2000; Van Ballenberghe & Ballard 1998).

With the GIS and remote sensing data available from the U.S. Forest Service, I produced three corresponding data layers at a 20 m x 20 m raster cell resolution: (1) percent willow, (2) edge density (McGarigal & Marks 1995), and (3) stream density (Table 4). Selected combinations of these variables were tested with and without a route variable and an interaction term for routes with willow to determine if inclusion of routes improved model fit (Table 4). Each variable was calculated at three spatial scales for each sex over the two seasonal analysis periods in ArcGIS 9.2 (ESRI Inc. 2008). Circular buffers were created around each used and random point with fixed radii of 250 m, 500 m, and 1000 m (Figure 2). These spatial scales were used in multi-scale habitat selection studies by Kie et al. (2002) for mule deer and in Oehlers et al. (in review) for moose, to represent an *a priori* gradient in habitat selection. Before variables were used in modeling, a Pearson's pair-wise correlation analysis was conducted at each scale to identify multi-collinearities that should be excluded from modeling (Hosmer & Lemeshow 1989). The variables were not collinear ($|r| > 0.60$), and therefore used in the modeling.

I then used logistic regression in SAS 9.1 (SAS Institute Inc. 2002) on the 10 *a priori* models for each sex at each scale in both seasons. Akaike's Information Criterion (AIC) was used for model selection and the lowest ΔAIC scores and highest Akaike weights were used to select the most parsimonious best-fit models for mapping (Anderson 2008). I evaluated the predictive performance of selected models with an area-corrected *k*-fold cross validation procedure (Boyce et al. 2002). This technique used a random draw of presence-only data divided into five equal datasets and running each sex, scale, and season-specific model on the remaining four datasets. The range of logistic regression probability scores resulting from each dataset was divided into 10 equal-interval probability "bins" determined by the mapped area available across the landscape. The bins were area-corrected by dividing the probability scores by the amount of mapped area for each probability range available across the landscape. The average score across the 10 area-corrected probability bins was ranked, and Spearman rank analysis (r_s) was used to analyze the correlation between the ordinal rank and observed rank of probability bins.

The scale of the most explanatory models (i.e. 500 m buffer) was used in an exploratory analysis to identify an ecological disturbance threshold on moose distribution by route activity. The most explanatory scale was justified as having the same coefficient on the route variable for both sexes in both seasons. One thousand point locations were randomly generated to estimate the predicted probability of use against a metric of vehicle traffic calculated with the following formula at the 500 m scale:

$$\left[\frac{(\text{Total } km \text{ of vehicle travel in } 500m \text{ buffer}) \times \left(\dfrac{1.27km^2}{500m \text{ buffer}}\right) \times (3 \text{ user samples in population})}{35 \text{ day sampling period}}\right] = \text{Total } km \text{ of vehicle travel} / km^2 / \text{day}$$

Travel was defined as the total number of one-way trips combined across the three route categories for the 1/3 of the user population interviewed.

Results

All models with the route variable yielded the lowest ΔAIC score and highest Akaike weights. This trend suggests that rural roads and OHVs influence moose distribution (Table 5). The most common best-fit model for both sexes in both seasons included all four main variables: Willow + Edge + Streams + Routes. In two cases, comparable models resulted with a ΔAIC ≤ 2, which means those models had approximately equivalent explanatory power. The model with the least number of variables was selected as the most parsimonious best-fit model (Anderson 2008).

For female moose, route coefficients in the best-fit models were consistently negative in the summer and fall at all three spatial scales. This pattern suggests that female moose avoid rural roads and OHV routes at multiple spatial scales (Table 6). Route coefficients were also statistically significant in all models, except in the summer at the 250 m scale. The non-significant route variable at the 250 m scale in the summer may suggest a larger spatial scale of analysis is more appropriate to evaluate a road-effect on female moose in the summer. The main four variables were included in the best-fit models for females in each season across scales, with the exception of the 250 m scale in the summer and fall. At the 250 m scale in summer, all five variables (i.e. Willow, Edge, Streams, Routes and Willow*Routes) had the best-fit, although the interaction term was not statistically significant. The non-significant interaction term also supports the need for a larger spatial scale of analysis as more appropriate to evaluate a road-effect on female moose in the summer. Large scale models had more statistically significant route variables. At the 250 m scale in the fall, Willow + Streams + Routes had the best-fit, suggesting edge density may be of less importance to females at the 250 m scale in the fall or, again, a larger spatial scale of analysis is more appropriate to evaluate a road-effect on female moose in the summer.

For male moose, route coefficients and the interaction term Willow*Routes were negative in best-fit models, with the exception of the 1000 m scale in the fall (Table 6). These results suggest male moose also avoid rural roads and OHV routes or areas where routes are in close proximity to willow. The positive relationship between males and routes at the 1000 m scale also suggests male moose may be less sensitive to routes than female moose at larger spatial scales. All the route coefficients were statistically significant, with the exception of the 250 m scale in the summer. This was also observed at the 250 m scale in females, suggesting that the 250 m scale is too fine a scale to evaluate a road-effect for both male and female moose in the summer. The exception to the main four variables as the best fit model was in the summer at the 1000 m scale and in the fall at the 250 m and 500 m scale. In the summer at the 1000 m scale, the best-fit model included the interaction term for the Willow*Routes with a negative coefficient. The observed pattern at this larger spatial scale suggests males are less likely to use areas where routes are in close proximity to willow. In the fall at the 250 m and 500 m scale, the best-fit models were Willow + Edge + Routes + Willow*Routes. The lack of selection for stream density may mean riparian areas are of less importance at smaller spatial scales for male moose in the fall.

Model validation showed predictive power with high Spearman rank correlations (r_s) and statistically significant p-values between used datasets and withheld datasets (Table 7). The highest Spearman rank correlation model for females in the summer was the same at the 250 m and 1000 m scales with a $r_s = 0.988$ ($p < .0001$). In the fall, the female model with the highest Spearman rank correlation was at the 250 m scale with an $r_s = 0.952$ ($p < .0001$). For male moose in the summer, the model with the highest correlation was in the summer at the

250 m scale with $r_s = 0.952$ ($p < .0001$). In the fall, males had the highest correlation at the 250 m scale with an $r_s = 0.988$ ($p < .0001$).

Among all models, the 500 m scale was selected to evaluate an ecological disturbance threshold by route activity on moose distribution. The 500 m scale model was chosen because it had the clearest effect for both sexes in both seasons, with statistically significant negative coefficients for the route variable. The mapped resource selection functions (Figure 3) show a reduced probability of use in areas of increasing route-use and density for both sexes in both seasons. This pattern is also accentuated in the fall season when route-use in Low-OHV and High-OHV categories increased. The plotted data show a similar pattern with a nonlinear response of decreasing probability of moose occurrence with increasing OHV use (Figure 4).

Discussion

The results of my analysis suggest rural roads and OHV traffic are creating a road-effect zone that displaces moose. The size of the road-effect zone was shown to be different for male and female moose. My results suggest rural roads and OHV routes have a greater impact on wildlife in rural landscapes than Forman & Deblinger (2000), who suggested a road-effect zone extending >600 m from urban roads; among the spatial scales of my analyses (250 m, 500 m, and 1000 m), male moose were found to be negatively impacted at least 500 m from rural roads and OHV routes, whereas for female moose, the road-effect zone may extend >1000 m. In addition, approximately 1 km of total vehicle travel/km^2/day is a space and time-explicit metric that land managers could use to most effectively reduce the probability of moose disturbance by roads and OHV traffic in areas where demand for OHV access is high.

In this study, the impact of roads and OHV routes on moose habitat selection was clearly evident from the consistently lowest ΔAIC scores and predominantly negative coefficients for the route variable or the interaction term for Willow*Routes. The only exception to a negative association with routes or the interaction term for Willow*Routes was for males at the 1000 m scale in the fall. This positive association with routes could be explained by the fact that many OHV routes are specifically created by hunters to access concentrations of male moose for the fall hunting season (USDA Forest Service 2007). This pattern could also explain the positive association seen in male moose at the fall 500 m scale for Willow*Routes and routes at the summer 1000 m and fall 250 m scale. Or, perhaps, male moose are less sensitive to disturbance than female moose at larger spatial scales. In general, female moose appeared more sensitive to disturbance, with no statistically significant positive associations with routes or Willow*Routes. This could be explained by a female's higher levels of vigilance necessary for protecting calves (Bowyer et al. 1998; Stankowich 2008).

High Spearman rank correlations that resulted from the model-validation process suggested a high level of model accuracy. This led me to believe that rural roads and OHV traffic had an effect on moose habitat selection at multiple scales. This also supports the importance of a multi-scale approach in wildlife studies (Bowyer & Kie 2006; Johnson 1980). The multi-scale approach allowed me to select the best scale of analysis (500 m) to specifically evaluate routes. All models at the 500 m scale had a statistically significant negative coefficient for the route variable. The negative coefficient for routes allowed me to examine an ecological disturbance threshold that could be applied to the management of both male and female moose.

The scatter plots showing the relationship between the predicted probabilities of use and route activity at the 500 m scale demonstrate avoidance beyond approximately 1 km of total vehicle travel/km^2/day. The only exception to this trend was male moose in the fall, due to their positive association with Willow*Routes at the 500 m scale. While this may be a coarse estimate, identification of an ecological disturbance threshold is a promising direction in resilience-based wildlife studies and disturbance research (e.g. Goss-Custard et al. 2006; Walker 2002). In this case, I provided land managers with an index they can use to evaluate the trade-offs between the effect of rural roads and OHVs on wildlife and the increasing demand for more OHV access. I also believe the strong nonlinear response supports the need for designating roadless areas with restricted OHV access, because maintaining low-levels of access necessary to reduce the potential for disturbance effects may prove to be an enforcement challenge (Berry 1980; Buckley 2004; Webb & Wilshire 1983).

Previous studies on the indirect effect of roads on moose distribution may not be comparable to this study due to differences in the resolution of data and the scale of analysis. I believe these previous findings could have been confounded by the spatial arrangement of habitats on moose distribution. While there have been many studies on the direct effect of roads on moose (i.e. vehicle collisions) from Europe and North America (Ball & Dahlgren 2002; Bangs et al. 1989; Groot Bruinderink & Hazebroek 1996; Krisp et al. 2004; Seiler 2005), there have been relatively few studies on the indirect effect of roads or OHV routes. Coarser scale analyses have shown a positive association between moose and roads while finer scale analyses have shown a negative association between moose and roads. Coarser scale analysis of moose in relation to roads has been accomplished previously with moose density estimates. Schneider and Wasel (2000) suggested that while access is generally assumed to have a negative effect on moose locally, the regional density of moose was positively associated with roads in northern Alberta, Canada. Likewise, Remm and Luud (2003) found that the density of moose was positively associated with roads at a regional scale in Estonia. In contrast, the number of moose observed within 100 m of roads in Denali National Park, Alaska declined by >50% when visitor use increased eight-fold (Burson et al. 2000). Yost and Wright (2001) also found that moose sightings were less than expected up to 1,200 m from a road in Denali. However, the analysis didn't include the spatial configuration of habitats that they believed better explained their finding. It has been shown that the availability of preferred moose habitat was near roads in Sweden, suggesting an analysis that does take into account the spatial pattern of habitats could produce misleading results (Ball & Dahlgren 2002).

The conflicting results of these studies led me to believe the spatial configuration of habitats must be taken into consideration to more accurately detect the effect of roads. Roads may interact with habitat to influence the observed distribution of wildlife (Maier et al. 2005). The need for this additional habitat information has been shown in more recent GIS-based habitat selection studies that detected a road-effect on grizzly bears, mule deer, and elk (Roever et al. 2008; Sawyer et al. 2006; Sawyer et al. 2007). As the analysis methods and data resolution improve, these studies show that animals are avoiding preferred habitats with increasing levels of traffic, with potential repercussions on forage availability, individual fitness, and ultimately population productivity.

I hypothesize the road-effect detected in moose is due to noise produced by road and OHV traffic and a perceived risk from hunting shown to disturb many ungulates. Ungulates in rural landscapes that experience low-levels of disturbance are less likely to habituate and therefore have a stronger tendency to show disturbance effects (Stankowich 2008). Noise could also inhibit predator detection for moose in rural landscapes, particularly with respect to their primary predators (i.e. grizzly bears and wolves) not found in most urban landscapes. A hunted population of moose, such as those in my study area, could also be avoiding roaded areas were hunting is more likely to occur (Schmidt et al. 2005) and have a negative association with the sight and sound of OHVs that are commonly used for hunting.

While the resolution of my GPS-collar dataset and remote sensing imagery improves confidence in my results, the findings should be treated with caution due to the assumptions I had to make in my analysis. The use of social interviews to quantify route use and the limited number of individual GPS-collared moose available could have introduced bias into my analysis. Additional individual GPS-collared moose (>20) would have reduced the chance an individual moose would exhibit "abnormal" disturbance behavior. Hence, an equal number of locations were used from each individual to reduce this possibility. The use of infrared or magnetic trail-counters (e.g. Shephard & Whittington 2006) would also have provided a less biased measurement of route use than interviews. However, I believed quantifying route use through interviews was better than treating route types equally when the size and soil wear of routes indicated different levels of use.

Conclusion

The results of my study on moose in a rural landscape suggest rural roads and OHV activity need to be considered in transportation planning and wildlife conservation efforts. A road-effect >1000 m could have substantial impact on the effective amount of habitat moose and other road-affected species are likely to utilize. The demonstrated avoidance of preferred habitats could have potential repercussions on forage availability, individual fitness, and ultimately population productivity. For regions such as the Tongass National Forest and my study area of Yakutat, Alaska, where road and OHV access are important to livelihoods, a scenario planning approach (e.g. alternative road closures) is a promising direction in conservation planning. Scenario planning would allow land managers and OHV users to create alternative futures where the trade-offs between wildlife conservation and OHV access can be evaluated for potential pit-falls and opportunities to develop a shared conservation strategy.

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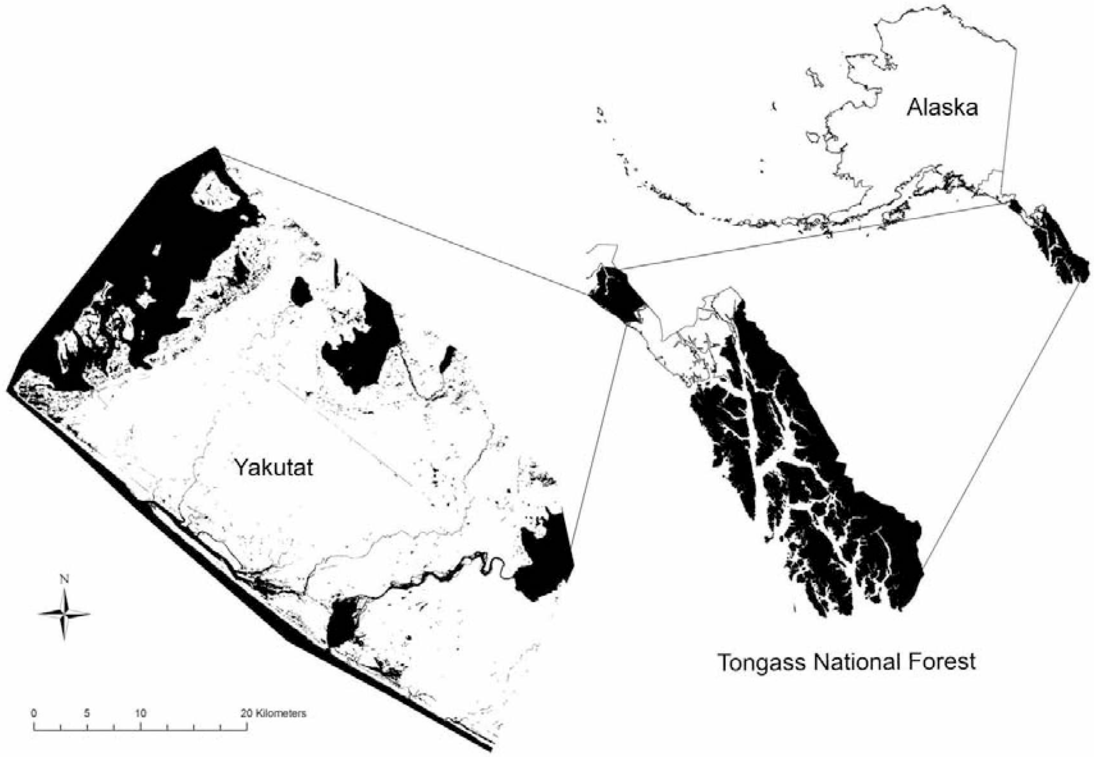


Figure 1. The extent of remote sensing imagery covering the study area of Yakutat, Alaska, located in the Tongass National Forest, USA.

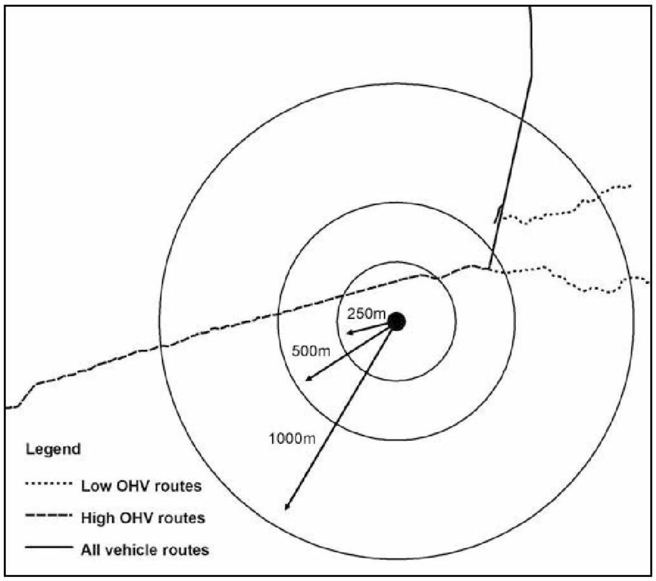


Figure 2. Illustration of circular radii used for analyzing the landscape surrounding each used and random location for a multi-scale assessment.

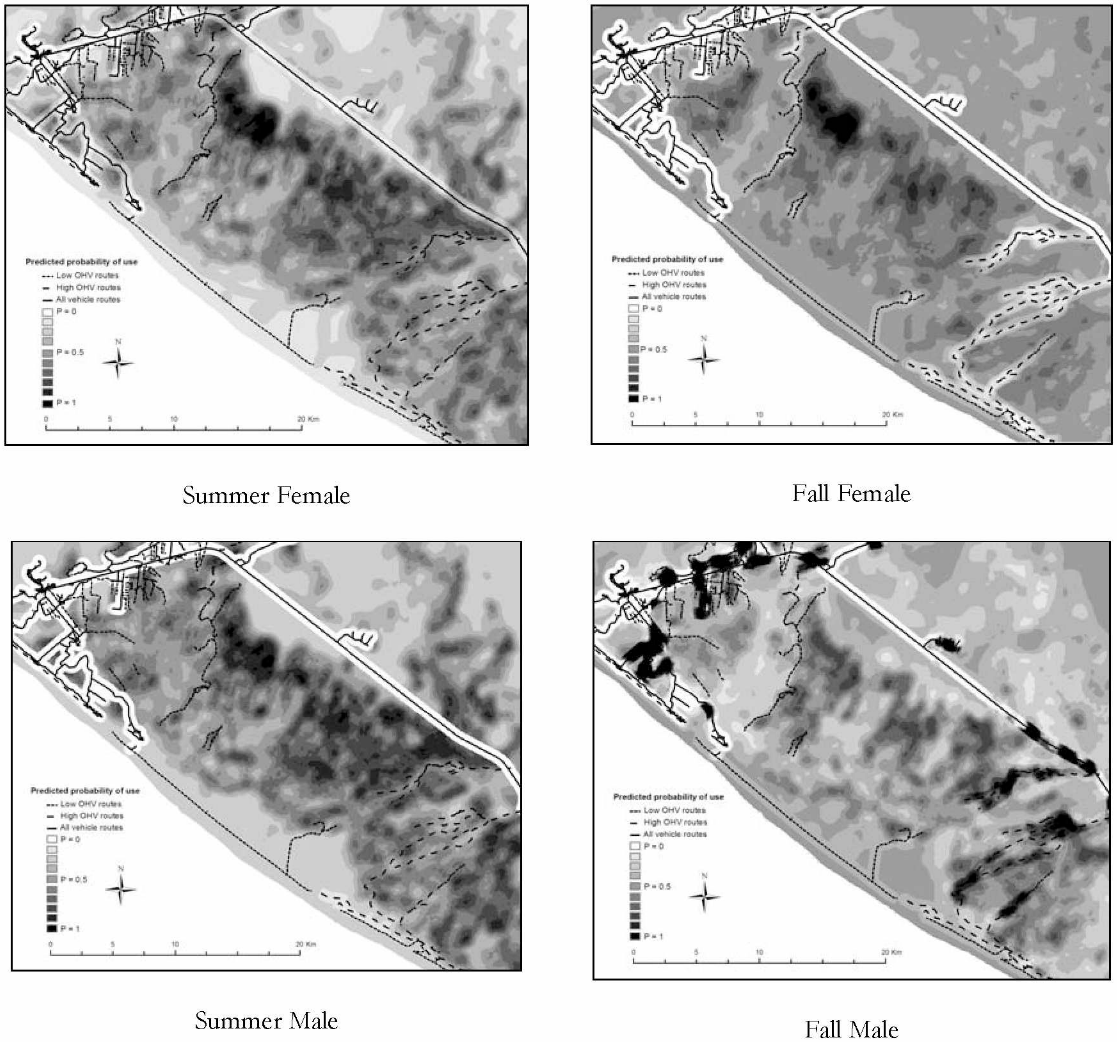
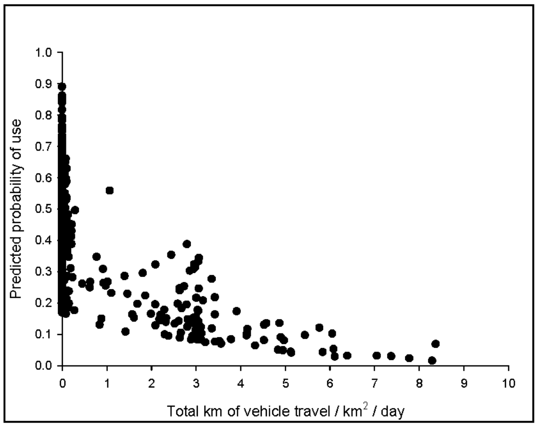
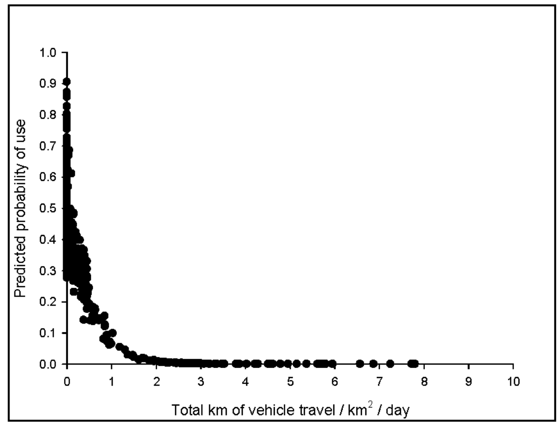


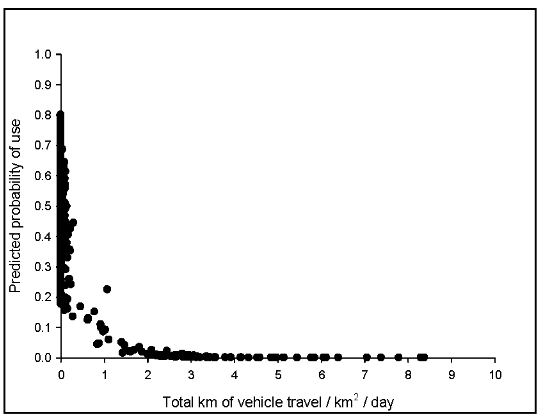
Figure 3. Resource selection functions for male and female moose at the 500 m scale in the summer and fall; illustrating the road-effect zone created by rural roads and OHV routes in Yakutat, Alaska.



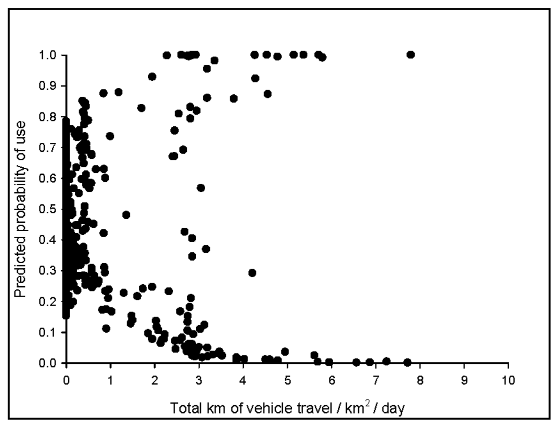
Summer Female



Fall Female



Summer Male



Fall Male

Figure 4. Scatter plots showing the probability of moose occurrence from resource selection function at the 500 m scale, relative to the total km of vehicle travel/km^2/day in Yakutat, Alaska.

Table 1. Biological and anthropogenic factors used to justify the classification of GPS-collar data into seasonal analysis periods to evaluate a road-effect on moose in Yakutat, Alaska.

Season	Biological factors	Anthropogenic factors	Approx. time frame	Five-week analysis period
Summer	Summer forage Post-calving	Low terrestrial subsistence / low OHV traffic	June 1 - Sept. 15	July 1 - Aug. 7
Late Fall	Fall forage Post-rut	High terrestrial subsistence / high OHV traffic	Oct. 8 - Nov. 30	Oct. 8 - Nov. 15

Table 2. The classification of routes based on vegetation displacement and soil types in Yakutat, Alaska.

Route type	Criteria
Low OHV	(a) Silt and clay soils: lack of incised ruts, wheel track is generally vegetated, one wheel track predominates, few parallel wheel tracks for short distances only
	(b) Beach or sand/gravel proximal outwash soils: not connected to the road system directly and not connected to high use trails through other soil types
High OHV	(a) Silt and clay soils: incised ruts, displaced soil, track denuded of vegetation, many parallel tracks, often in marginally passable areas
	(b) Beach or sand/gravel proximal outwash soils: connected to the road system directly or connected to high use trails through other soil types
All-vehicles	Any route known to be driven by motor vehicles at any point in time that may also have OHV traffic

Table 3. The total length of digitized routes as well as the results of a one-way ANOVA (α=.05) used to test for differences in the frequency of use among route use categories.

		Average frequency of use	
Route type	Total length (km)	Summer ± SE	Fall ± SE
Low OHV	184	0.03 ± 0.04	0.75 ± 0.31
High OHV	118	0.50 ± 0.26	2.04 ± 0.66
All-vehicles	221	14.1 ± 2.83	13.1 ± 2.42
		P- values	
Low OHV & High OHV		0.0116	0.0126
High OHV & All-vehicles		<.0001	<.0001
All routes		<.0001	<.0001

Table 4. Independent variables calculated for each used and random location at three spatial scales.

Variable	Description
Willow	Percent willow was created by adding the total amount of cells the remote sensing imagery identified as willow, divided by the area of each scale buffer.
Edge	Edge density was created with the spatial statistics software FRAGSTATS (McGarigal and Marks 1995). All the cells the remote sensing imagery idenfied as trees were combined to create a tree canopy for the software to determine the average canopy edge density at each scale buffer.
Streams	Stream density was created by adding the total length of streams in each scale buffer by the number of hectares in each scale buffer.
Routes	A measure of route use at each scale was created from the average number of one-way trips in each route category. The total length of routes in each category were added within each scale buffer, and then multipled by the average number of one-way trips for each category. These results for each scale buffer were combined across categories to represent the total number of one-way trips per kilometer in each scale buffer.

Table 5. Differences in AIC scores (ΔAIC), weights (*w*), and number of model parameters (*k*) used to evaluate rural roads and OHV routes effect on moose habitat selection with resource selection functions. Male and female moose were evaluated separately during the summer and fall at three spatial scales.

		Female											
		Summer						Fall					
		250m		500m		1000m		250m		500m		1000m	
Model	*k*	AIC	AIC*w*	AIC	AIC*w*	AIC	AIC*w*	AIC	AIC*w*	AIC	AIC*w*	AIC	AIC*w*
Willow	1	43.1	0.000	35.2	0.000	36.8	0.000	51.7	0.000	63.9	0.000	111.5	0.000
Willow + Edge	2	44.0	0.000	36.1	0.000	37.2	0.000	48.5	0.000	53.1	0.000	101.4	0.000
Willow + Edge + Routes	3	26.1	0.000	23.3	0.000	23.2	0.000	32.0	0.000	19.9	0.000	11.8	0.002
Willow + Edge + Routes + Willow*Routes	4	22.1	0.000	24.9	0.000	25.0	0.000	33.9	0.000	20.8	0.000	8.6	0.008
Willow + Streams	2	19.3	0.000	12.2	0.001	14.6	0.000	5.2	0.032	21.7	0.000	59.1	0.000
Willow + Streams + Routes	3	9.0	0.009	8.1	0.011	12.4	0.001	0.0	0.425	3.5	0.098	10.6	0.003
Willow + Streams + Routes + Willow*Routes	4	4.3	0.095	9.2	0.006	14.4	0.000	2.0	0.157	3.9	0.080	10.9	0.003
Willow + Edge + Streams	3	17.5	0.000	7.2	0.018	6.1	0.031	12.1	0.001	20.1	0.000	57.4	0.000
Willow + Edge + Streams + Routes	4	4.4	0.088	0.0	0.642	0.0	0.649	0.8	0.281	0.0	0.561	1.0	0.372
Willow + Edge + Streams + Routes + Willow*Routes	5	0.0	0.808	1.4	0.321	1.4	0.318	2.8	0.104	1.5	0.261	0.0	0.613

		Male											
		Summer						Fall					
		250m		500m		1000m		250m		500m		1000m	
Model	*k*	AIC	AIC*w*	AIC	AIC*w*	AIC	AIC*w*	AIC	AIC*w*	AIC	AIC*w*	AIC	AIC*w*
Willow	1	62.4	0.000	68.3	0.000	68.8	0.000	24.2	0.000	33.0	0.000	54.7	0.000
Willow + Edge	2	50.4	0.000	62.1	0.000	66.3	0.000	7.3	0.017	17.5	0.000	25.3	0.000
Willow + Edge + Routes	3	16.5	0.000	9.1	0.007	18.1	0.000	5.2	0.050	6.0	0.026	2.5	0.159
Willow + Edge + Routes + Willow*Routes	4	17.9	0.000	10.4	0.004	6.9	0.031	0.0	0.663	0.7	0.372	4.0	0.075
Willow + Streams	2	40.2	0.000	50.1	0.000	51.3	0.000	26.0	0.000	32.4	0.000	51.9	0.000
Willow + Streams + Routes	3	19.2	0.000	16.0	0.000	22.6	0.000	24.9	0.000	27.5	0.000	38.7	0.000
Willow + Streams + Routes + Willow*Routes	4	21.0	0.000	17.6	0.000	12.3	0.002	20.5	0.000	23.6	0.000	38.2	0.000
Willow + Edge + Streams	3	26.3	0.000	39.8	0.000	43.7	0.000	9.2	0.007	11.8	0.001	15.2	0.000
Willow + Edge + Streams + Routes	4	0.0	0.693	0.0	0.703	8.7	0.012	7.2	0.018	3.9	0.075	0.0	0.555
Willow + Edge + Streams + Routes + Willow*Routes	5	1.6	0.307	1.8	0.286	0.0	0.954	2.0	0.245	0.0	0.526	1.9	0.210

Table 6. Coefficients (β) and 95% confidence intervals of the most parsimonious RSF models used to evaluate rural roads and OHV routes effect on moose habitat selection. Male and female moose were evaluated separately during the summer and fall at three spatial scales.

	Female											
	Summer						Fall					
	250m		500m		1000m		250m		500m		1000m	
Variable	ß	95% CI	ß	95% CI	ß	95% CI	ß	95% CI	ß	95% CI	ß	95% CI
Willow	0.0186*	0.01102, 0.02618	0.0222*	0.0127, 0.0317	0.019*	0.00744, 0.03056	0.016*	0.00956, 0.02244	0.00767	-0.00117, 0.01651	-0.00608	-0.01742, 0.00526
Edge	0.00436*	0.00086, 0.00786	0.00764*	0.0028, 0.01248	0.0126*	0.00588, 0.01932			-0.00448*	-0.00832, -0.00064	-0.00908*	-0.01444, -0.00372
Streams	0.01*	0.00586, 0.01414	0.0129*	0.00772, 0.01808	0.0162*	0.00968, 0.02272	0.0108*	0.00708, 0.01452	0.011*	0.00612, 0.01588	0.0101*	0.00438, 0.01582
Routes	-0.00119	-0.002702, 0.000322	-0.00004*	-0.000068, -0.000012	-0.000009*	-0.000016, -0.000002	-0.00051*	-0.000834, -0.000186	-0.00023*	-0.000342, -0.000118	-0.00015*	-0.000194, -0.000106
Willow*Routes	0.00004	-0.000012, 0.000092										

	Male											
	Summer						Fall					
	250m		500m		1000m		250m		500m		1000m	
Variable	ß	95% CI	ß	95% CI	ß	95% CI	ß	95% CI	ß	95% CI	ß	95% CI
Willow	0.0208*	0.0135, 0.0281	0.0257*	0.01616, 0.03524	0.0392*	0.0265, 0.0519	0.0195*	0.01238, 0.02662	0.0257*	0.01632, 0.03508	0.0421*	0.02904, 0.05516
Edge	0.00726*	0.00408, 0.01044	0.00915*	0.00479, 0.01351	0.0119*	0.00556, 0.01824	-0.00729*	-0.01051, -0.00407	-0.0109*	-0.01548, -0.00632	-0.0216*	-0.02856, -0.01464
Streams	0.00852*	0.00452, 0.01252	0.00814*	0.00324, 0.01304	0.00882*	0.00288, 0.01476					-0.00672*	-0.01304, -0.0004
Routes	-0.00084	-0.002206, 0.000526	-0.0002*	-0.000346, -0.000054	0.000031	-0.000009, 0.000071	0.000751*	0.000263, 0.001239	-0.00006*	-0.00019, -0.00007	0.000044*	0.000022, 0.000066
Willow*Routes					-0.000005*	-0.000009, -0.000001	-0.00002*	-0.000035, -0.000005	0.000008*	0.000014, 0.000002		

* Coefficients significant at 5%

Table 7. Spearman rank correlations (*r*) of cross validated and area-corrected RSF-bin ranks for male and female moose during the summer and fall at three spatial scales.

	Female			
	Summer		Fall	
Scale	r	*P*	r	*P*
250 m	0.988	<.0001	0.952	<.0001
500 m	0.976	<.0001	0.794	0.0061
1000 m	0.988	<.0001	0.879	0.0008

	Male			
	Summer		Fall	
Scale	r	*P*	r	*P*
250 m	0.988	<.0001	0.988	<.0001
500 m	0.912	0.0002	0.733	0.0158
1000 m	0.891	0.0005	0.903	0.0003

Chapter 2- Balancing the conservation of wildlife habitat with subsistence hunting access: a geospatial scenario approach*

Abstract: Increased motorized access used for subsistence hunting has created a challenge for land managers trying to balance the conservation of wildlife habitat with the greater environmental impact of motorized access. I used an interdisciplinary approach to evaluate this challenge in a case study of subsistence moose hunters who used off-highway vehicles (OHVs) to access remote harvest areas in Yakutat, Alaska, USA and the conservation needs to sustain moose. I applied a resilience-based framework that combined methods from wildlife ecology, land-use mapping, and scenario planning. The study started at the community level by working with local hunters to evaluate their values and goals for subsistence moose hunting, and to identify thresholds of undesired change. This process served as the basis for evaluating how four road closure scenarios would effect the distribution of moose and hunters' access to moose harvest areas. The effect of roads and OHV routes on moose distribution was quantified in Chapter 1 using a long-term dataset on moose locations with a GIS-based resource selection function model. An index of access was quantified as the distance hunters were willing to transport a harvested moose on a digitized map of the harvest areas. The results of the scenario analyses suggest that a balance in the conservation of wildlife habitat with subsistence access could be found in the spatial arrangement of routes that are outside of important moose habitat, but within reach of preferred harvest areas. This approach may prove useful in northern communities experiencing an increased use of motorized access for contemporary subsistence hunting practices.

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* Shanley, C. S., G. P. Kofinas, and S. Pyare. "Balancing the conservation of wildlife habitat with subsistence hunting access: a geospatial scenario approach." Prepared for submission to *Ecology and Society*.

Introduction

Background

Subsistence hunting communities across the Circumpolar North are experiencing increased social and ecological changes that require rapid adaptation (Berkes & Jolly 2001; Brinkman et al. 2007; Condon et al. 1995; Ford et al. 2006; Gordon et al. 2007). One such adaptation is the increased use of motorized access for more efficient hunting (e.g. "snowmachines"). The increased use of motorized access for hunting has created new challenges for land management and planning efforts to balance the conservation of wildlife habitat with the need for subsistence access (Ahlstrand et al. 1998; Happe et al. 1998; Sowl & Poetter 2004).

The conservation of wildlife habitat and subsistence hunting with motorized vehicles are typically considered mutually exclusive. A challenge in interdisciplinary research is to develop new and creative methods to meet both these social and ecological goals (Chapin et al. 2006). For example, a resilience-based approach that incorporates scenario planning for travel access (e.g. road closures) could be used as an effective framework to balance these social and ecological goals. A resilience-based approach has been shown to reveal the most valued social and ecological attributes of a system to all the stakeholders involved (Walker et al. 2002). In my study, for instance, the valued attributes were identified as wildlife habitat conservation and access to subsistence resources. In a resilience-based approach, one searches for ways to maintain valued attributes by avoiding thresholds in which valued attributes are lost. In my study, the ecological threshold is the point at which wildlife habitat is effectively lost from high levels of motorized disturbance. The social threshold is the point at which subsistence hunters do not have sufficient access to harvest subsistence resources.

Scenario planning can be used at different scales to address resource management questions in an interdisciplinary manner and, through the process, build resilience into the sustainability of valued ecosystem services (Peterson et al. 2003b). Peterson et al. (2003a) used a scenario planning approach on a regional scale in the Northern Highlands Lake

District, Wisconsin, to explore the future consequences of urbanization and ecological vulnerability to undesired change, such as the loss of valued fishing opportunities. Focusing on the sustainability of arctic subsistence communities, Kruse et al. (2004) used scenario analysis to explore the multiple effects of climate change, oil development, and tourism on caribou hunting. In each of these cases, researchers took a different approach to scenario planning based on the central question, scope of the project, and the available data. To balance the conservation of moose habitat with off-highway vehicles (OHVs; e.g. "four-wheelers"), I developed spatially-explicit scenarios to evaluate effects on both moose disturbance and subsistence hunting access. I used this approach for three reasons: (1) spatially-explicit scenarios with GIS improves the evaluation and analysis of potential sources of disturbance on wildlife (Manly et al. 2002), (2) many subsistence hunters have a strong spatial and visual orientation (Tobias 2000), and (3) a GIS allowed me to integrate and synthesize a variety of data types (i.e. wildlife distribution and land-use).

The use of GIS technology for evaluating social and ecological data has become increasingly important in comprehensive land-use planning. For example, an ecological study by Sawyer et al. (2006) used collar location data from mule deer (*Odocoileus hemionus*) and a GIS to evaluate the loss of deer habitat by natural gas development in Wyoming, U.S. Similarly, Stephen R. Braund & Associates (2007), used community interviews and participatory mapping with residents to create a geo-database of traditional land-use near Tyonek and Beluga, Alaska. This baseline information was used in an Environmental Impact Assessment to illustrate potential land-use conflicts between the proposed development and residents. While these studies represent different types of assessments, in this study I illustrate how a resilience-based framework could provide a more holistic analysis for land-use planning and management by integrating both the goals of habitat conservation and resource access.

Case study

My case study occurred on the Yakutat Ranger District of the Tongass National Forest in Southeast Alaska, USA (Figure 5). The location and timing of subsistence hunting has traditionally been unregulated (Mills & Firman 1986). With the advent of OHVs, subsistence hunters incorporated them into subsistence hunting strategies because OHVs allowed more ground to be covered in search of game and greater efficiency in transporting large game species from remote harvest areas (Mills & Firman 1986). The continual use of OHVs has visibly impacted the landscape with ruts in wetland areas that remain for years, even after a single event. The prevalence of ruts became a concern for regional land managers when anadromous (salmon) streams were impacted and the disturbance (e.g. noise) of wildlife species seemed likely (USDA Forest Service 2007).

Regulated access was mandated by the 1997 Tongass Land and Resources Management Plan (TLMP). Initial public meetings that introduced an Environmental Assessment (EA) revealed that residents were concerned that restricted motorized access would impede subsistence hunting practices. The subsistence activity of most concern with regards to restricted access was the harvest of Alaskan moose (*Alces alces gigas*) because moose were harvested in remote areas and these large animals (>500 kg) are difficult to transport before the meat spoils, and ultimately, the large amount of meat a single moose provides a family. Moose were also a species that land managers were concerned would be impacted by unregulated access given visual OHV damage had increased in areas thought to contain the region's best moose habitat (USDA Forest Service 2007).

To help address this social-ecological problem, I developed a geospatial scenario planning approach with the goal of balancing the conservation of wildlife habitat with subsistence hunting access. The objectives of Chapter 2 were to evaluate the effect of four road closure scenarios on both social and ecological goals. Habitat models from Chapter 1 that accounted for OHV impact on moose distribution were used to evaluate the scenario's effect on moose habitat. Likewise, interviews of subsistence moose hunters were used to evaluate the scenario's effect on subsistence hunting access.

Methods

Social-ecological system

Yakutat, Alaska, has approximately 800 residents with a mixed cash-subsistence economy. Approximately 60% of the residents are Alaska Native. The predominant indigenous group is the Tlingit. Tlingit subsistence activities were traditionally focused around marine resources with salmon as the main source of protein (Mills & Firman 1986). During the early 1930s, moose migrated into the Yakutat area from interior Canada and were opportunistically harvested from river shores with fishing vessels to supplement marine protein sources. There was no evidence of moose in the area prior to that time. By the late 1980s, moose was the primary source of red meat with 70% of households consuming moose, either through direct harvest or sharing networks (Mills & Firman 1986).

In the 1960s, the Yakutat area was heavily vegetated with high-quality moose forage (i.e. willow) and the moose population grew steadily (Mills & Firman 1986). During this period, the moose population size was believed to be >2,000 (Smith & Franzmann 1979) and the human population of Yakutat was approximately 300 residents with over 80% Alaska Native (U.S. Census 1960). The road system was limited and hunting of moose was conducted primarily from fishing vessels along river outwash areas where a harvested moose could easily be transported. In the late 1960s, the road network expanded with logging activities, allowing increased hunting opportunities, new job opportunities and a concomitant increase in the human population (Mills & Firman 1986). Competition between hunters also increased among residents of Yakutat and members of other communities (e.g. residents from Juneau, AK), with hunters increasingly using OHVs to access remote harvest areas.

The peak harvest of 324 moose occurred in 1969 (ADF&G 1970). Moose had become a highly valued source of protein to indigenous and non-indigenous groups, and liberal harvest limits continued despite the belief of biologists that the moose population was declining (Mills & Firman 1986). In the early 1970s, a series of severe winters with snowfalls >7 m

(NOAA 1983) resulted in high moose mortality levels. By the mid-1970s, the moose population declined to the point that hunting was closed between 1974 and 1977. Since then, the moose population has never returned to pre-1960s levels. Captured female moose in the late-1970s showed normal pregnancy rates, although they were shown to be nutritionally stressed (Smith & Franzmann 1979). Long-term residents suggested the nutritional stress arose from the rapid change in the region's vegetation composition, from higher quality moose forage communities with willow (*Salix spp.*) and alder (*Alnus sinuate*) to cottonwood (*Populus trichocarpa*) and spruce (*Picea sitchensis*) communities that contain lower quality moose forage (Larsen et al. 2005; Mills & Firman 1986; Shephard 1995). A similar pattern of successional change with an increase and decline in moose population was studied in an adjacent coastal area of the Copper River Delta, Alaska (Stephenson et al. 2006) The moose population of Yakutat has remained relatively stable in recent history, utilizing early successional habitats created from natural disturbance events such as spring river flooding and avalanches, with approximately 800 to 1000 in the population estimated by aerial surveys during 2003 and 2004 (Oehlers et al. in review).

Identifying values, goals, and thresholds

In the spring of 2007, I held a series of meeting separately with land managers and resident moose hunters, with follow-up discussions for clarification. The purpose was to define each group's respective values, management goals, and perceived thresholds to undesired changes with respect to moose conservation and harvesting access (e.g. Berkes et al. 2001). Land managers identified their goal as the management of habitat on the Yakutat landscape to support a healthy moose population. Due to the reduced population counts of moose on the portion of the region heavily used by OHVs, they suspected OHVs were effectively reducing the region's carrying capacity for moose (USDA Forest Service 2007). Managers were therefore primarily interested in whether or not there was a reduced probability of moose occurrence relative to OHV routes.

Resident moose hunters emphasized the importance of using OHVs to retrieve large game species from remote harvest areas, since these species were critical to meeting their economic, nutritional, and cultural needs. Hunters suggested there was a maximum distance from which they could feasibly transport a moose from the harvest site to an OHV route or road. It was understood, however, this distance could be dynamic and this study would be a "snapshot" in time that represents the current social and ecological conditions. For example, with new sources of adaptation (e.g. wheeled carts) this distance would likely change. Nevertheless, in the near-term, moose hunters were primarily interested in maintaining sufficient OHV access to important harvest areas.

Road closure scenarios

The four road closure scenarios under consideration by the Yakutat Ranger District were used for analyses. For comparison, Scenario 1 maintained the status quo with unlimited OHV access (Table 8). All main roads (221 km) and the extensive network of hunter created OHV routes (302 km) across inland meadows and beaches would remain available to search for moose and transport a harvested moose back to the community. Scenario 2 retained most of the main roads (182 km) and restricted many of the hunter created OHV routes to a select few (85 km) routes that could be maintained to National Forest engineering standards and monitored (Table 8). A seasonal closure would also be put on OHV routes near tern (*Onychoprion aleuticus* and *Sterna paradisaea)* nesting habitat (May to mid-August). Hunters would be allowed to retrieve a harvested moose from open roads and OHV routes, if they could do so without causing resource damage. Resource damage was defined as "soil displacement or cutting of living vegetation to create a path" from the road or OHV route to a harvested moose. Hunters would also have to attain a permit from the Alaska Department of Natural Resources to cross streams used by anadromous salmon. Scenario 3 was similar to Scenario 1 in terms of the total amount of main roads (185 km), and met the minimum TLMP regulations (Table 8). However, Scenario 3 retained fewer OHV routes than any of the other scenarios (39 km). Perhaps most importantly, hunters would also not be able to use OHVs to retrieve moose from open roads or OHV routes. Finally, Scenario 4 incorporated public comments on Scenario 2 from a meeting with the Yakutat Ranger District in 2005. Public comments suggested maintaining less main roads (182 km) that lacked utility (e.g. old logging roads) and a greater number of designated OHV routes (55 km) (Table 8). Hunters in Scenario 4 were also allowed to use OHVs to retrieve moose from open roads and OHV routes, if they could do so without causing resource damage. Seasonal closure in areas of nesting terns and a permitting process for crossing of salmon streams would also apply to Scenario 4.

Evaluating moose habitat

A female moose distribution model from Chapter 1 was used to evaluate the effect of the four road closure scenarios on moose habitat in ArcGIS 9.2 (ESRI Inc. 2008). This model was derived from a three-year dataset of GPS-collared moose, remote sensing habitat classifications, and mapped roads and OHV routes. Logistic regression was used to develop the model at the 500 m scale in the fall. The model was mapped with a spatially-explicit resource selection function (RSF Design II; Manly et al. 2002). The model was validated with an area-corrected k-fold cross validation procedure (Boyce et al. 2002); and suggested strong predictive power (Chapter 1; Table 7). A variable accounting for activity on each route improved model-fit, suggesting that OHV activity influenced female moose habitat selection. There was a negative relationship between the route variable and female moose. This negative relationship for female moose suggested female moose avoided areas with routes.

A habitat score was developed to rank the impact of the four road closure scenarios on the amount of high probability female moose habitat. A new route layer was created in a GIS from the proposed configuration of roads and OHV routes in Scenarios 1-4. Three categories of routes (Low OHV, High OHV, and All-Vehicles) that were used to develop the original habitat model were also used to weight the impact of the configuration of roads and OHV routes in each scenario. The weight of each route category was proportional to the average number of one-way trips sampled in each route category for the season. The resulting RSF for each scenario was a mapped surface of 20 m x 20 m grid cell representing the probability of moose occurrence across the study area. Cells were classified into 5 probability categories between 0.5 and 1 at increments of 0.1 (e.g. .5 to .6, .6 to .7, etc.). Cells with values <0.5 were not included because of their low probability of use. Assuming a linear relationship between the probability of moose occurrence and the relative importance of habitat, the total area of habitat in each probability interval was multiplied by the average probability of the interval. The final habitat score was calculated from the sum of the probability-corrected habitat intervals for each road closure scenario.

Evaluating subsistence access

A random sample of one-third (n= 25) of the federally registered subsistence moose hunters were interviewed to document their land-use patterns in 2007. During these interviews, hunters were asked to map their preferred harvest areas and estimate how far they were willing to transport a harvested moose to an OHV route or road. Interviews lasted approximately 45 minutes. 21 hunters agreed to map their preferred harvest areas and all 25 hunters agreed to estimate how far they were willing to transport a harvested moose to an OHV route or road. A preferred harvest area was defined as an area valued for hunting moose. To delineate these, each hunter was presented a 1.5 m x 1 m high-resolution aerial photograph of the region. The hunters delineated preferred harvest areas with dry erase markers on a transparency. Harvest areas for each hunter were manually ("heads-up") digitized into polygon layers in a GIS. Then each hunter's harvest areas were converted into a surface of 50 m x 50 m grid cells in a GIS. A value of 1 was assigned to each grid cell that was used for hunting and a value of 0 assigned to each grid cell that was not used for hunting. A final layer of combined use for all the hunters was created by summing all the hunter's harvest areas. For example, if the harvest areas of three hunters overlapped, cells in the composite harvest surface acquired a value of three, indicating that 14% (3 hunters/21 total hunters) used the cell area for hunting.

The distance hunters were willing transport a moose from an OHV route or road was defined by the distance hunters verbally indicated they were willing to transport a harvested moose without motorized assistance. The distance hunters were willing to transport a harvested moose was averaged across all 25 hunters and the upper 95% CI (2412 m) was used to buffer the proposed roads and OHV routes for each scenario. The buffered area for each scenario represented areas that were accessible for hunting in each road closure scenario.

An access score was developed to rank each scenario. The access score was calculated from the grid values within the access buffer around each road closure scenario. The access score was analogous to the calculation of the habitat score above. I assumed a linear relationship between the relative importance of cells and the percent of hunters using the hunting area. To calculate each scenario's final access score, the total cell area of each harvest area category (e.g. 2 hunters= 10%, 3 hunters= 14%, etc.) was summed across all categories and multiplied by the percentage of hunters that used the area those cells represented.

Results

Scenario 1: Status quo

Maintaining the status quo in Scenario 1 provided the best score for subsistence hunting access (Figure 6) and the lowest score for female moose habitat (Figure 7). Scenario 1 provided the greatest amount of access because it had the most roads and OHV routes. Scenario 1 provided the least amount of habitat for female moose because female moose avoided the many roads and OHV routes. Additional OHV routes could also be created in Scenario 1 because there was no associated legislation preventing the creation of new OHV routes, and therefore a potential for improved access and further reductions in female moose habitat.

Scenario 2: Forest Service preferred alternative

The Forest Service preferred alternative provided the second lowest score for subsistence hunting access and a habitat score for female moose similar to Scenario 4. The closing of many roads and OHV routes would lead to a reduction in access by just over half of the amount of access provided by Scenario 1. Scenario 2 yielded fewer routes and more habitat for female moose than Scenario 1. The proposed legislation for Scenario 2, banning the creation of new routes but allowing retrieval of a harvested moose from designated routes, would reduce future impacts on female moose habitat and allow for a more efficient method of transporting a harvested moose.

Scenario 3: Minimum policy requirements

Meeting the minimum policy requirements in Scenario 3 resulted in the lowest score for subsistence hunting access and the greatest habitat score for female moose. The low access score and the high habitat score was the result of low total number of roads and OHV routes. The proposed legislation for Scenario 3, which bans the creation of new routes and does not allow retrieval of a harvested moose, would likely limit the impact on female moose habitat in the future, but also limit hunting access.

Scenario 4: Inclusion of public comments

Scenario 4 was based on public comments from Scenario 2. Scenario 4 provided the second highest score for subsistence hunting access and a habitat score for female moose similar to Scenario 2 (Figures 6 and 7). Scenario 4 had fewer roads but more OHV routes, which could explain why it provided for greater hunter access. The proposed legislation bans the creation of new routes but allows retrieval of a harvested moose from designated routes, therefore limiting future impact on female moose habitat and allowing for more efficient transportation of a harvested moose.

Discussion

The results of the road closure scenarios illustrate a complex social-ecological dynamic created by the spatial configuration of routes on moose habitat and subsistence hunting access. No clear "winner" emerged as the best scenario for the conservation of moose habitat and the maintenance of subsistence hunting access. However, the total amount of roads and OHV routes may not be the best determinant of moose habitat conservation or subsistence hunting access. Rather, a balance in the conservation of wildlife habitat and subsistence hunting access may be achieved via the precise spatial configuration of transportation networks. More specifically, a balance could be achieved by the strategic closure of roads and OHV routes in specific areas with high probability moose habitat and the maintenance of routes that are particularly within reach of important harvest areas. Comparison of the results of Scenario 1 with Scenario 4 illustrates how public comments incorporated in Scenario 4 improved hunting access with minimal impact on moose habitat (Figures 6 and 7). The existing network of routes in Scenario 1 yielded a large degree of access, but there is a noticeable disturbance effect on female moose. Scenario 4 has fewer total routes, but more harvest areas are within reach of roads and OHV routes than in any of the other scenarios. The modeling of moose habitat and the mapping of harvest areas will also allow land managers to query future scenarios as new conditions arise or should additional land-use conflicts persist.

A review of other land-use studies suggests my geospatial scenario approach may be useful in many other regions where motorized subsistence access is increasing and the conservation of wildlife habitat is of concern. Some of the first subsistence land-use studies occurred in the Canadian Arctic, documenting Native land claims in the face of industrial development (Freeman 1976). The results of these studies demonstrated how subsistence mapping can elicit detailed use of the landscape and show how far hunters travel to reach harvest areas. Subsequent studies have also produced species specific harvest maps, demonstrating high value harvest areas that have stayed in the same locations for generations and others where the social and ecological conditions have changed and required adaptation, such as motorized vehicle use to hunt more efficiently (Berkes et al. 1995; Natcher 2004; Pedersen & Coffing 1984). The variety of subsistence land-use patterns depends on the region and species of interest, and underscores the importance of time and place specific analyses. For example, Berman and Kofinas (2004) showed that the subsistence hunters of Old Crow, Yukon preferred to harvest caribou on time-tested accessible migration routes in order to save resources (i.e. time and money), when possible. When the migrations changed, additional resources had to be used on extended trips with motorboats and snowmachines to secure a sufficient harvest. A similar pattern of preferred harvest areas mixed with long distance motorized travel was shown by Natcher (2004) in the Yukon Flat communities of interior Alaska. Moose hunters of Birch Creek preferred to hunt local wetland areas, but changing interior fire regimes (natural and prescribed) caused a time lag in forage availability between burns and thus the presence of moose. The changing distribution of moose required an additional investment of time and money searching for moose with motorboats or snowmachines, which did not always result in a successful hunt. In addition to the variety of land-use patterns that different subsistence studies have described, it is clear that accessing and securing subsistence resources is changing, and motorized access is shaping how hunters perceive and use the landscape (Brinkman et al. 2007).

Conclusion

The use of motorized access for the harvest of subsistence resources across the Circumpolar North is likely to increase with forecasted social and ecological conditions (Berkes et al. 1995; Condon et al. 1995; Ford et al. 2006; Gordon et al. 2007). Increased integration of subsistence practices with the cash economy is likely to mean contemporary subsistence hunters will have less time to spend on the land than past generations, requiring more efficient means of accessing hunting areas. In addition, the expense of modern equipment such as snowmachines, OHVs, rifles, ammunition, and fuel, will require higher involvement in the cash economy (Berman & Kofinas 2004; Fast & Berkes 1998). In the long-term, changing ecosystem processes (i.e. climate change) will likely require more investment to locate and secure the shifting distribution of resources (Chapin et al. 2004).

In some regions or with some species, the influence of motorized access on wildlife habitat may be negligible (i.e. highly dispersed wildlife) or ecological changes will improve hunting opportunities. However, as my study suggests, there will also be regions where the increased use of motorized access is a concern for both land managers and subsistence hunters. The geospatial scenario planning approach I developed to balance the conservation of wildlife habitat with subsistence access could be used in areas facing the same issue. The use of a resilience-based approach in future studies might also provide a useful framework to define the values, management goals, and thresholds to undesired change for land managers and community members (Chapin et al. 2006). A growing body of studies suggest that northern subsistence communities are experiencing rapid change. New and creative analytical approaches are needed to inform decision making as agencies and communities seek to meet new social and ecological goals.

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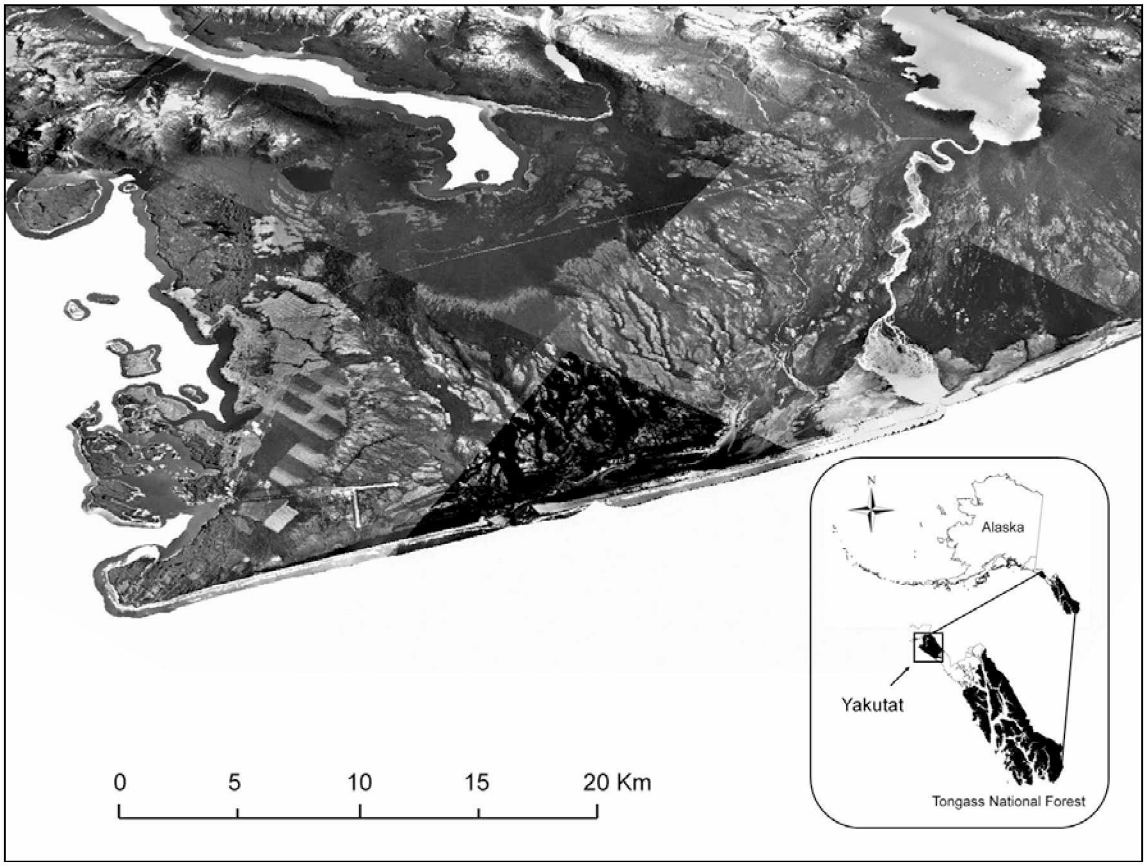

Figure 5. Aerial photograph of Yakutat, Alaska, study area. Yakutat is located along the Gulf of Alaska in the northernmost corner of the Tongass National Forest, USA.

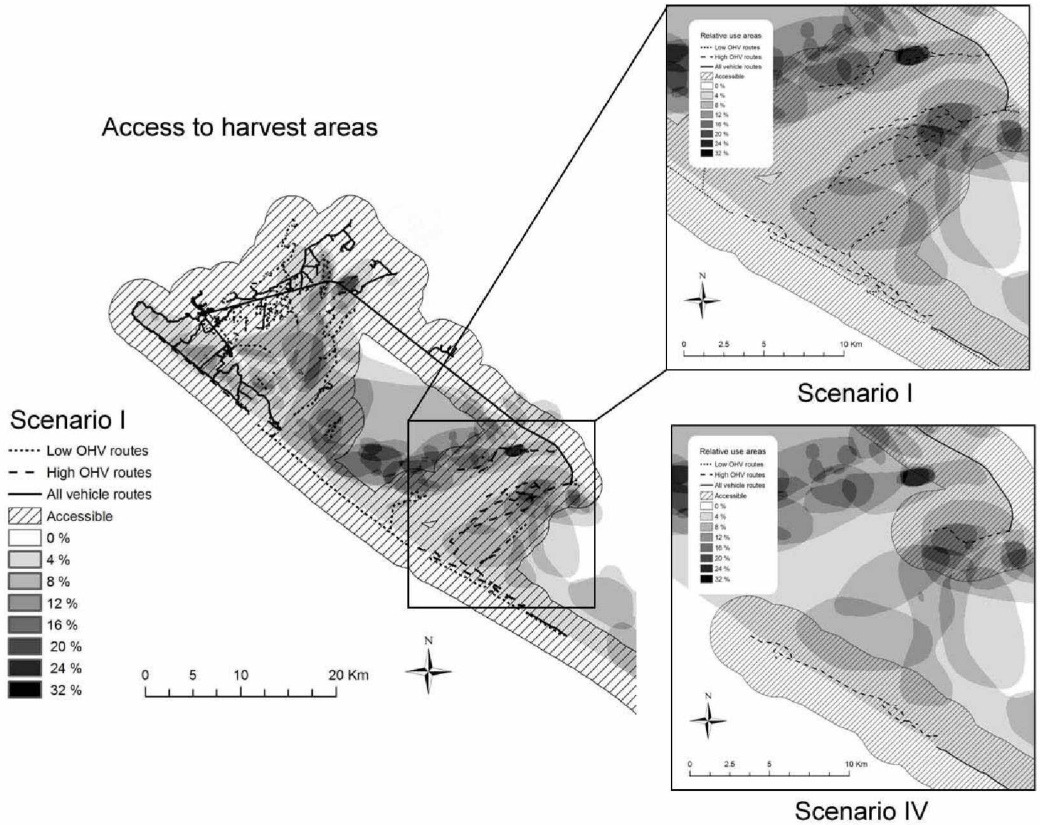

Figure 6. Map of subsistence moose hunters land-use in Scenario 1 (with an inset from Scenario 1 and 4); illustrating concentrations of harvest areas and the zone in which hunters can feasibly transport a harvested moose in Yakutat, Alaska.

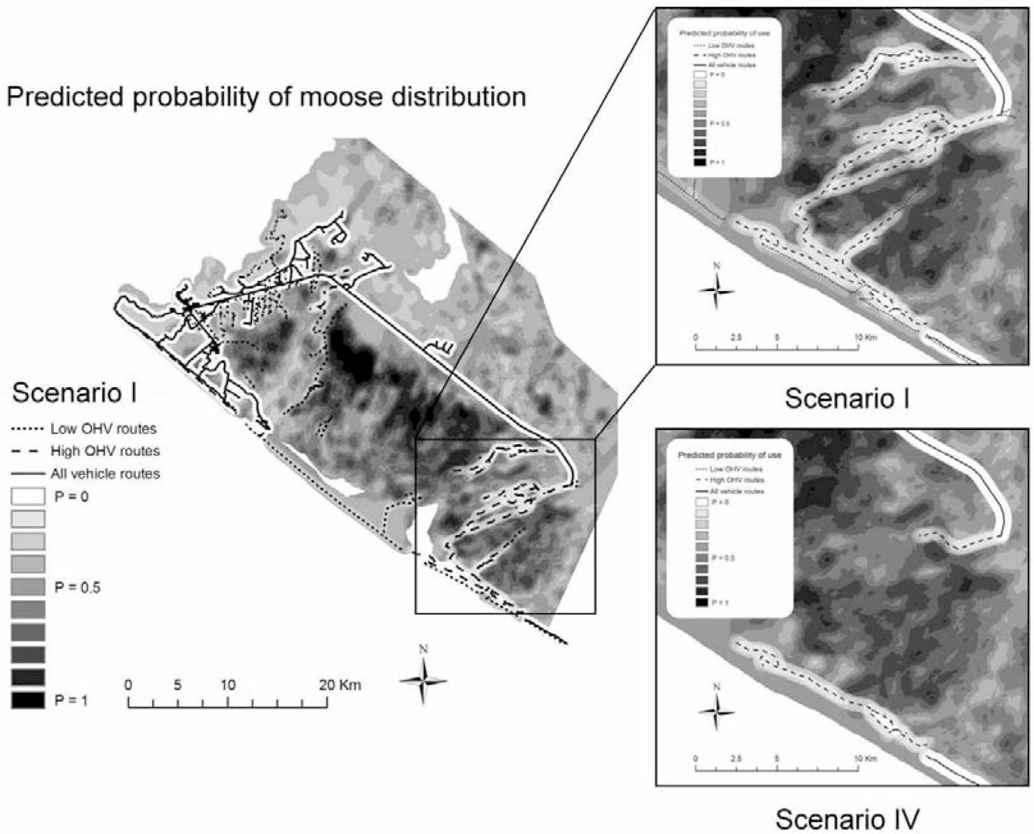

Figure 7. Resource selection function model of female moose distribution in Scenario 1 (with an inset from Scenario 1 and 4); illustrating the impact of roads and OHV routes on female moose habitat selection in Yakutat, Alaska.

Table 8. Categorized route lengths (km) and sum for each of the four road closure scenarios in Yakutat, Alaska.

	Scenarios			
Routes (km)	I	II	III	IV
Low OHV	184	54	18	21
High OHV	118	31	21	34
All-vehicles	221	182	185	182
Total OHV	302	85	39	55
All routes	523	267	224	237

Table 9. Overlapping harvest area (km^2) categories and access score in the four road closure scenarios for Yakutat, Alaska.

Hunter harvest area % use categories	Scenarios I	II	III	IV
5%	1192.7	906.4	876.3	906.4
10%	495.1	346.7	319.8	383.2
14%	379.6	226.8	197.5	243.1
19%	196.0	66.0	50.5	80.4
24%	96.8	29.2	12.8	31.9
29%	22.2	10.0	6.4	10.0
33%	4.2	1.4	0.8	1.4
38%	0.3	0.0	0.0	0.0
Access Score	230.7	134.6	118.2	144.0

Table 10. Moose habitat (km^2) by probability interval and habitat score (corrected for average probability of use) in the four road closure scenarios for Yakutat, Alaska.

	Scenarios			
Moose habitat probability intervals	I	II	III	IV
0.5 - 0.6	196.0	218.6	222.4	218.6
0.6 - 0.7	72.9	75.4	75.7	75.4
0.7 - 0.8	23.3	23.4	23.4	23.4
0.8 - 0.9	7.9	7.9	7.9	7.9
0.9 - 1.0	0.2	0.2	0.2	0.2
Habitat Score	179.5	193.7	195.9	193.7

Thesis Conclusion

Integrating new data with existing data can help inform decision making and address complex social-ecological problems such as balancing the conservation of wildlife habitat with subsistence hunting access. In this study, the collaboration with land managers and subsistence moose hunters provided invaluable insight on the management problem. I used a two-step process with a detailed ecological analysis of moose distribution (Chapter 1) followed by a social-ecological assessment (Chapter 2).

The results of Chapter 1 showed that the existing network of rural roads and OHV routes on the Yakutat Ranger District was displacing moose from limited high-quality habitat. A road-effect was detected >1000 m from existing roads and OHV routes. This road-effect has implications for the conservation of moose habitat and raises the question of whether many other species of wildlife are impacted. The analysis also showed that there was an ecological disturbance threshold of approximately 1 km of total vehicle travel/km^2/day. Land managers could use this space and time explicit metric to guide the allowance of low-levels of motorized access with a limited impact on moose for important land-use activities such as subsistence hunting.

The results of Chapter 2 showed that the spatial arrangement of roads and OHV routes will affect the amount of habitat moose are likely to use. Chapter 2 also showed that subsistence moose hunters have distinct harvest areas, and that motorized access within reach of these harvest areas is an important management consideration to sustain the cultural and economic characteristics of the community. The scenario development process illustrated that the total amount of roads and OHV routes may not be the best determinant of moose habitat conservation or the best determinant of access necessary to reach preferred harvest areas. The scenario analysis revealed that a balance in the conservation of moose habitat and subsistence access may be achieved through the specific spatial arrangement of routes that are outside of important moose habitat, but within reach of important harvest areas. Hunters described having a threshold retrieval distance in which they could feasibly transport a harvested moose to a road or OHV route. Land managers in other similar regions could use the results of my study and approach to delineate important harvest areas and evaluate the trade-offs between the conservation of wildlife habitat and the use of motorized vehicles for contemporary subsistence hunting practices.

This study also serves as the basis for several management recommendations for the Yakutat Ranger District. The first recommendation is to use my moose habitat models to identify areas of potentially high-quality moose habitat that are currently being under utilized by moose due to road and OHV disturbance. Then I would determine if any of the roads that are in potentially high-quality moose habitat are no longer of importance (e.g. old logging roads) and suggest the decommission of those roads. The second recommendation is to use my harvest area maps to determine if any of the historically utilized OHV routes that are being considered for closure are used to access important harvest areas. Then I would consider making a closer inspection of those routes' environmental impacts, as well as consider whether alternative routes could be constructed to reach important harvest areas. Many of the harvest areas are also accessible by historically utilized river corridors that would likely result in less impact to moose habitat than road and OHV access.

The completion of this study raises several questions worthy of future research on the Yakutat Ranger District. With respect to moose habitat and potentially many other species (e.g. bears and wolves), there is a need to study the rates of successional habitat change, as a result of glacial recession and isostatic glacial rebound. This would allow a better understanding of how the availability of wildlife habitat might change in the future and inform current management strategies. With respect to subsistence access, I suggest studying hunters' preferences for the structure and timing of hunts, and the social conditions that affect them. Short hunting seasons and increased competition from outside communities appears to increase the use of motorized access for hunting. I suspect that if a longer, more flexible hunting season was agreed upon, there would be reduced environmental impacts associated with contemporary subsistence hunting practices.

Aside from my thesis insights into balancing wildlife habitat conservation with subsistence hunting access, one essential message has emerged for future research that attempts to address and inform complex social-ecological problems. The social and ecological conditions that land managers and community members are facing today are rapidly changing. The drivers of these changes are linked. Treating these drivers and changes as linked is essential to effective management strategies. I began this project from a primarily disciplinary background, and by engaging with land managers and community members I came to the understanding that an interdisciplinary approach that considers both the social and ecological dimensions was necessary to adequately address the problems land managers and communities are facing. New and creative approaches for integrating social and ecological information promise an exciting frontier in the advancement of sustainability science.

Appendices

Appendix A- Informed Consent Statement

THE YAKUTAT MOOSE HUNTER STUDY

Description of the Study

You are being asked to participate in a University of Alaska Fairbanks study about moose and moose hunting. The goal of this study is to learn about moose hunting patterns and moose habitat use with local knowledge and science. The information collected will be a part of a graduate project by Colin Shanley. We ask that you participate in this study because of your experience as a moose hunter in Yakutat. Please read this form and ask any questions you may have before you agree to be in this study.

If you decide to take part, you will be asked to complete an interview with a questionnaire. The interview has questions in three areas: (1) moose observations, (2) hunting patterns, and (3) moose hunting access. The interviews will be recorded by hand and with a sound recorder. The interview will take about one hour.

The information will be used by researchers at the University of Alaska Fairbanks for reports and articles. A report for the public will be printed and made available. At the time of the interview, you will have the opportunity to review your answers on the questionnaire and provide further clarification of the interview.

Risks and Benefits of Being in the Study

The risk to you if you take part in this study is public access to the manuscripts and reports prepared using the information you and other hunters share with the research. However, your name will not be associated with any materials produced from this questionnaire or interview.

We do not guarantee that you will benefit from this study. However, your participation in this study potentially gives you the opportunity to improve the understanding of moose habitat use and hunter access preferences. In addition, this study gives you the opportunity to voice your concerns and perspectives on the management and research of moose in Yakutat, Alaska.

Compensation

Participation in this study is on a volunteer basis. We appreciate your time and information but there is no monetary compensation.

Anonymity

Your name and contact information will not be connected with your answers to the interview questions. A number will be used on the interview form so no one can trace the information collected on the questionnaire and during the interview to your name. The information gained from this study will be used in reports, presentations, and publications but you will not be identified.

Contact and Questions

If you have any questions now, feel free to ask. If you have any questions later, please contact Colin Shanley (P.O. Box 210676 Auke Bay, AK 99821; Phone 518-669-5505; Fax 907-796-6406; Email colin.shanley@uaf.edu); Dr. Sanjay Pyare (University of Alaska Southeast, 11120 Glacier Highway, Juneau, AK 99801; Phone 907-796-6007; Fax 907-796-6406; Email sanjay.pyare@uas.alaska.edu); Dr. Gary Kofinas (University of Alaska Fairbanks, P.O. Box 757000, Fairbanks, AK 99775; Phone 907-474-7078; Fax 907-474-6967; Email ffgpk@uaf.edu).

If you have questions or concerns about your rights as a research subject, please contact the Research Coordinator in the Office of Research Integrity at 474-7800 (Fairbanks area) or 1-866-876-7800 (outside the Fairbanks area) or fyirb@uaf.edu.

Statement of Consent

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been provided a copy of this form.

We are not asking for your signature to protect your confidentiality.

Appendix B- Moose Hunter Questionnaire

THE YAKUTAT MOOSE HUNTER STUDY
2007-2008 QUESTIONNAIRE
UNIVERSITY OF ALASKA

Interview ID number__________
Date of Interview_____________
Start time____________________
Stop time____________________

☐ Presented informed assent/dissent form
☐ Started audio recorder

►General background information

1. What year were you born?

   Year__________ Sex: ☐ Male ☐ Female

2. Where did you spend your childhood and adult life?

   Childhood residence ___________________ Adult residence____________________

3. Are you Alaska Native?

   ☐ Yes ☐ No

4. How often do you work?

   ☐ Part-time ☐ Seasonally ☐ Full-time ☐ Unemployed

5. At what age did you start hunting moose in Yakutat?

   Age_________

6. How many moose have you killed in Yakutat in your lifetime?

   Number of moose_________

7. What percentage of your household's red meat intake is moose?

   Percentage________

8. What percentage of your moose meat, that you harvested, do you share with other households?

   Percentage________

9. What percentage of your moose meat do you receive from other hunters?

   Percentage_________

10. If you didn't have moose meat, what meat would you substitute?

    Substitute________________________________

11. How often do you moose hunt? As an individual or with others?

    - ☐ Every year ☐ Some years ☐ Almost never
    - ☐ As an individual ☐ As a group

12. Please describe the steps of a typical hunt for you.

13. Has the time you put into hunting moose changed since the early 1980's? If so, why?
    ☐ No ☐ Yes →

14. Has the importance of moose to you changed since the early 1980's? If so, how and why?
   ☐ No ☐ Yes →

► Moose observations and hunting patterns

15. Please draw your preferred harvest areas (on provided map overlay). Why are they important harvest areas?

16. Are there more, less, or the same amount of good hunting areas now than there have been since the early 1980's? What makes a good hunting area?

   ☐ More ☐ Less ☐ Same

17. How many times did you go up and down these routes (labeled on provided map) this past year?

Route	Summer (July 1 – Aug. 7)	Fall (Oct. 8 – Nov. 15)
(a) 10 mile bog trail		
(b) 9 mile meadow		
(c) Colorado trail		
(d) Dangerous cabin trail		
(e) East of Situk trails beyond cabins		
(f) Forest highway 10 beyond mile 17		
(g) Miller creek trail		
(h) Road system east of Cannon beach		
(i) West fork road		

18. Do you access your preferred hunting areas by foot, boat, plane, vehicle, OHV or a combination of them? How do you use them?

☐ Foot ☐ Boat ☐ Plane ☐ Vehicle ☐ OHV

19. What year did you start using OHVs?

Year_______

20. Does OHV access, by you and/or other hunters affect your chance of a successful hunt? If so, how?
☐ No ☐ Yes →

21. Do you think moose are affected by roads and/or OHV trails? If so, how?
☐ No ☐ Yes →

22. How many other hunting parties in your preferred harvest areas do you typically see? How many would you feel like is too many?

    Typically see________ Too many_________

23. Do you feel other hunting parties in your preferred harvest area will diminish your chance of success? If so, why?
    ☐ No ☐ Yes →

24. Do you feel other hunting parties in your preferred harvest area compromise your safety? Can you give an example?
    ☐ No ☐ Yes →

25. Have you ever butchered a moose in the field in order to pack it out by foot? If yes, conservatively how far did you walk?
    ☐ No
    ☐ Yes → Distance______

26. What percentage of the moose that you kill do you pack out by foot?

    Percentage_____

27. If not, would you butcher a moose in the field in order to pack it out to an OHV/vehicle/boat/plane? How far are you willing to pack it?
    ☐ No
    ☐ Yes → Distance______

28. On average, how many days do you hunt before you kill a moose? What is the maximum number of days you would hunt for moose?

    Day's hunting_______ Max number of days________

►Moose hunting access

29. Are you familiar with the upcoming Forest Service Access Travel Management plan (no searching for moose using OHVs off designated trails, off-trail only to retrieve moose with tag and without causing resource damage)?
    □ Very □ Some □ Not at all

30. Would restricted OHV access in the FS access plan create a problem for your moose hunting? If so, how?
    □ No □ Yes →

31. Do you think moose populations in the OHV restricted areas will go up, down, or stay the same in the next 10 years?

    □ Up □ Down □ Stay the same

32. Will restricted OHV access prevent you from getting to your preferred harvest areas or do you move around from year to year? If so, why?
    □ No □ Yes →

    a. What percentage of your hunting areas?

    Percentage________

    b. Is it possible to still get to these areas by foot or would that be too much effort? If so, why?
    □ No □ Yes →

►Future ideas

33. How do you think moose hunting will change in the future?

34. If you were making the rules, how would you manage hunters' OHV use in the region?

35. What other kinds of moose research might be needed?

►Additional comments: