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Project Title: Survivorship of Sitka black-tailed deer fawns in Southeast Alaska

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Cooperators: University of Alaska Fairbanks: U.S. Forest Service, Tongass National Forest

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Work Location: Ketchikan, Alaska**.**

I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) is the most important ungulate for sport and subsistence hunting in Southeast Alaska. In additional, deer are the most abundant ungulate in the region and serves as prey for Alexander Archipelago wolves (*Canis lupus ligoni*), black bears (*Ursus americanus*), and brown bears (*U. arctos*) (Klein 1965, Olson 1979, Wallmo 1981, Hanley 1984, Hanley 1993, Person et al. 1996, Kohira and Rexstad 1997, Person 2001). In additional, Sitka black-tailed deer was selected for a management indicator species by U.S. Forest Service (USFS) for the Tongass Land Management Plan due to their strong association with productive old-growth forest habitat (USFS 1997, 2008). To better understand deer population dynamics, we need information on sources and rates of fawn mortality. Also, we need to know whether fawn morality is strongly linked to habitat quality or composition and the proximity of the deer population to carrying capacity (*K*) (McCullough 1979, Bartmann et al. 1992, Person et al. 2001, Bowyer et al. 2005).

Adult deer can store fat during summer and fall that may enable them to survive winters on relatively poor winter range (Parker et al. 1993). Fawns do not accumulate fat reserves as readily and are, therefore, likely to be more sensitive indicators of habitat quality and composition than adults. Shrub/sapling and second-growth forest habitats result from clearcut logging (they may also originate from rare large windstorm events) (Alaback 1982, Kramer et al. 2001) and provide poor habitat for deer because forage is scarce (Wallmo and Schoen 1980, Schoen et al. 1988, Hanley et al. 1989 throughout the year, especially in winters with snow. These conditions significantly increased the risk of malnutrition for fawns (Farmer et al. 2006). These conditions persist for the remainder of the timber rotation. Shrub/sapling and younger seral forest stands that were pre-commercially thinned at 10–20 years post logging may have levels of forage biomass comparable to young clearcuts and unmanaged old-growth forest (Farmer and Kirchhoff 2007*)*. Those stands may provide abundant summer forage for deer under some conditions and enhance recruitment temporarily.

In addition to increasing risks of malnutrition, even-aged forest management may indirectly increase risk from predation. Preliminary data from a study of deer on Prince of Wales Island (POW) indicated that predation by black bears was the major source of mortality of neonates and deer <1 year old (ADF&G unpublished data) that were monitored in managed forest landscapes. Schwartz and Franzmann (1991) observed that young seral coniferous stands on the Kenai Peninsula of Alaska had significantly higher densities of black bears than older coniferous stands. Litter sizes of black bears were larger and age at first reproduction was younger for sows in the younger seral forest. They also noted that predation by bears on moose calves was 4 times greater in younger forest habitat than in older forest. Young regenerating coniferous stands in Southeast Alaska may promote high densities of black bears and increase risks of predation for fawns. Unfortunately, there are no data comparing densities and ecology of black bears in managed and unmanaged forests in Southeast Alaska.

Some predation of fawns may be compensatory rather than additive mortality. Neonate fawns that are nutritionally stressed and likely to die of disease or starvation may be more vulnerable to predation (Kunkel and Mech 1994). Additionally, some fawns killed by predators likely would not survive their first winter regardless of predation, and thus would not be recruited into the deer population. Mortality from all sources may be largely compensatory as an ungulate population approaches carrying capacity (K) (McCullough 1979, McCullough 1987, Kie et al. 2003, Bowyer et al. 2005). Nonetheless, compensatory mortality may be significant even in ungulate populations well below carrying capacity (K). Compensatory mortality (as compared to additive mortality) is important to differentiate before interpreting the effects of predation of fawns on deer population dynamics. Thus, compensatory mortality is an important measure of population resilience needed to evaluate the effects of habitat change, predation, and hunting on deer.

II. REVIEW OF PRIOR RESEARCH AND STUDIES IN PROGRESS ON THE PROBLEM OR NEED

Although much is known about the ecology and energetics of deer in Southeast Alaska (Klein and Olson 1960, Klein 1965, Olson 1979, Wallmo 1981, Hanley 1984, Parker et al. 1999), little is known about reproduction and recruitment. Previous telemetry studies have focused on home range, habitat use, and survivorship of adult and yearling deer (Schoen and Kirchhoff 1985, Yeo and Peek 1992, Farmer et al. 2006, Doerr et al. 2005). Few data are available concerning fawn survivorship and recruitment.

Estimates of fecundity derived from fetal counts have been made (Johnson 1987); however, net recruitment may be more a function of fawn survival than birth rate or fecundity (Bartmann et al. 1992). In a study of deer survivorship on Heceta Island in Southeast Alaska, shrub/sapling and seral stage second-growth habitat significantly increased the risk of malnutrition for fawns (Farmer et al. 2006). For example, Farmer et al. (2006) reported that annual mortality rate from disease or malnutrition was 0.31 (SD = 0.11, *n* = 19) for fawns on Heceta Island. Heceta Island has few black bears, but does have wolves. Wolf predation accounted for 10.0% (SD = 7%). In contrast on POW, 55% (SD = 10%, *n* = 27) of fawns were killed by black bears and wolves annually, whereas no fawns died from disease or malnutrition (ADFG unpublished data). Total annual mortality of fawns on Heceta (49%, SD = 12%) was not different than total mortality on POW (65%, SD = 9%) (Z = 1.09, *P* = 0.274), however, the power to detect differences between studies was low.

III. APPROACHES USED AND FINDINGS RELATED TO THE OBJECTIVES AND OR NEEDObjective 1: Evaluate fawn mortality as a result of malnutrition.

Approach: Southeast Alaska comprises a narrow strip of mainland and a chain of islands, the Alexander Archipelago, which is oriented roughly parallel to the mainland. The archipelago consists of thousands of islands ranging in size from <0.01 to 6,335 km^2, with distances between islands and the mainland ranging from several meters to 15 km. Weather conditions are highly variable, with annual precipitation ranging between 130 and 400 cm (National Weather Service 2006). Accumulation of snow is greatest on the mainland and northernmost islands and becomes intermittent in the southern portion of the archipelago. We selected POW, the largest island in the Alexander Archipelago, as our study area.

Neonatal survival is a key ecological metric, driving the reproductive success of individuals and subsequent population change. To measure neonatal survival, we captured 54 adult female deer in April and May during 2010–2012. Each deer was fitted with a global positioning system (GPS) radio collar with mortality sensor, measured to determine body size and condition and fitted with a vaginal implant transmitter (VIT) if pregnant. Pregnancy was assessed using a portable ultrasound machine (Sonosite Titan, Sonosite, Bothel, WA, USA). VITs had temperature switches triggered by expulsion at birth, producing a birth signal at temperatures below 35 °C. VITs were monitored twice daily, and ground searches for birth sites were initiated immediately upon detection of a VIT birth signal. In addition to fawn captures using VITs, we opportunistically captured neonatal fawns encountered along roads or otherwise encountered in the environment. Fawns were approached on foot and gently restrained in a mesh sack with eyes covered. We estimated fawn mortality rate (*M*) and the causes of mortality.

Findings: Of the adult female deer captured, 51 were determined to be pregnant at the time of capture and 49 were successfully fitted with VITs. Of the 49 deployed VITs, 81% resulted in confirmed birth sites and 62% in captured fawns at the birth site, representing very high retention and fawn detection rates in comparison with other VIT-based studies. In addition, 8% of females fitted with VITs expelled the devices before parturition, identified by VITs found at sites lacking the characteristics of birth sites.

Using VITs to locate birth sites to capture fawns, rather than opportunistic captures of fawns spotted along roads, trails or in open areas, proved important for accurately estimating early survival. Many fawns died within 1–2 days of birth, or were even consumed at birth by black bears. In contrast, these very early deaths were missing from the opportunistically captured sample, biasing the estimates of survival upwards. For example, comparing the survival rates of fawns captured during the final 2 years of the study, over-summer survival was estimated to be 0.44 (SE = 0.08) using only opportunistically-captured fawns, but 0.33 (SE = 0.13) using only VIT-captured fawns. Vital rates, including fawn survival in summer and winter, were estimated using all three years of data, and correlated with environmental variables. Pregnancy rates averaged 0.91 (SE = 0.17) across years, while fertility, measured as fawns per female, averaged 1.45 (SE = 0.27). Adult female survival was high and constant, with an average annual rate of 0.90 (SE = 0.07), while survival for fawns was lower in summer (mean = 0.41, SE = 0.24) compared with winter (mean = 0.73, SE = 0.41). Causes of mortality (*M*) varied across life-history phases. The largest source of mortality (*n* = 3, *M* = 0.05, SE = 0.03) was from hunting, followed by malnutrition (*n* = 2, *M* = 0.03, SE = 0.02) and black bear predation (*n* = 1, *M* = 0.02, SE = 0.02). No adult deer monitored during this study were killed by wolves, but wolf predation was a major source of mortality for deer monitored in the same study area 10 years previously (Person 2009). Wolves are currently at low numbers and restricted distributions due to high trapping pressure (Alaska Department of Fish and Game 2014).

In summer, fawn mortality rates were 0.46 (*n* = 21, SE= 0.08) due to black bear predation, and 0.11 (*n* = 6, SE = 0.05) due to other causes. Other causes of mortality included unknown predation (*n* = 1), eagle predation (*n* = 1), drowning (*n* = 1), and premature birth (*n* = 3). In winter, fawns mortality rates were 0.21 (*n* = 16, SE = 0.05) from malnutrition, 0.03 (*n* = 2, SE = 0.02) from wolf predation, 0.02 (*n* = 1, SE = 0.02) from bear predation (in late September), and 0.03 (*n* = 2, SE = 0.02) due to other causes (*n* = 1 car collision, *n* = 1 illegal hunting). Based on fawn survival models, fawn mass at birth was strongly predictive of summer survival, indicating that nutrition of females and/or fawns affected survival, including risk of predation by bears (i.e., some portion of bear predation was compensatory). In winter, both total snow depth and birth date affected survival. Fawns born later in the spring had lower survival rates and fawn mortality was higher during winters with deeper snow, indicating that snow limited access to forage and movement. Late-born, and therefore smaller fawns, were more impacted by harsh winter conditions. Despite high rates of female survival during relatively deep snow, population models indicated that snow deeper than 2 meters reduced fawn survival to near zero, and resulted in a negative annual rate of population growth.

Objective 2: Evaluate habitat selection of adult females

Approach: Adult female deer were fitted with GPS collars at capture, which recorded relocations of deer every 2 hours. Resulting adult female GPS data were used to construct habitat selection models using resource selection functions (RSFs) in summer, and step selection functions (SSFs) in winter. SSFs are similar to RSFs, but narrowly define available habitat (for comparison with used habitat) based on animal movement patterns found in the data (Thurfjell et al. 2014). We used SSFs in winter because snow depth is thought to be an important driver of winter habitat selection through its effect on forage availability and cost of movement, and thus incorporating animal movement patterns into the selection function should increase accuracy.

In summer, we used a black bear RSF (which we developed with additional data from ADF&G), a wolf RSF (from a previous, unpublished ADF&G analysis), and a forage biomass layer developed in coordination with the USFS (Hanley et al. 2012, 2014) as predictive variables in the female deer selection models, and build separate models for reproductive phases (gestation, lactation, and recovery after all fawns had died). We also included time as an interactive term with the predator RSF and forage variables, such that time counted down as “weeks until birth,” upwards as “weeks since birth,” and upwards as “weeks since fawns’ death” in the gestation, lactation, and recovery models, respectively.

In winter, we developed a detailed model of daily snow depth from data collected at weather stations we deployed across the study area. We interpolated snow measurements from each weather station across the landscape, then corrected for elevation, slope, aspect, and percent canopy cover (Hanley et al. 2012). In addition, we included other predictive covariates, including composition of a 100-m buffer around each used and available point in terms of vegetation classes, proportion of buffer that was south facing, and density of roads and edges. Vegetation classes included old-growth forest classes (low-, medium-, and high-volume old growth), second-growth forest classes (young and old second growth).

Findings:

Summer selection by reproductive adult females:

At the population level, adult females did not trade-off selection of forage with avoidance of risk, and predation risk and forage were negatively correlated among home ranges, indicating variation in home-range quality. Females increasingly avoided bear risk, relaxed avoidance of wolf risk, and increased selection for forage as parturition neared. After parturition, deer continued to avoid bear risk, increasingly avoided wolf risk, and increasingly selected for forage through time. If fawns died, females relaxed avoidance of bears, increased avoidance of wolves, and intensified selection for forage. Among individuals, females with more forage availability relaxed selection towards forage, whereas females with more predation risk intensified avoidance of predation risk. However, quality of home range did not predict spring body condition, which was instead correlated with selection of forage. A likely explanation is that deer density increases with habitat quality, leading to more generalized selection by deer in better home ranges, but that some deer make better choices than others regardless of home-range quality (i.e., individual heterogeneity).

Winter selection by adult females:

Snow depth had the strongest effect on selection, based on relative effect size. At low snow depths, young second-growth forest was positively selected for and old second-growth forest was avoided, while high-volume old growth was avoided. As snow depths increased, young second growth was avoided and old second growth and high-volume old growth selected. Deer selected strongly for south-facing slopes and selection increased with snow depth. Deer selected for forb biomass and other measures of biomass, decreasing selection as snow depth decreased. Deer selection was influenced by availability of vegetation classes and biomass, with positive functional responses for old second-growth forest, productive old-growth forest, and understory biomass. Deer selection of old second growth decreased with increased availability of productive old growth. Whereas deer displayed plastic patterns of selection with snow depth and availability of productive old growth, behavioral plasticity alone does not ensure animals fulfill energetic requirements if adequate forage and snow interception are not available during deep snow events. Therefore, conservation of habitats preferred during deep snow may be critical to ensuring resilient deer populations across variable winters.

Objective 3: Evaluate whether black bear predation on fawns is positively related to levels of bear activity or is spatially correlated with habitat composition and distribution.

Approach: See Objective 1.

Findings: These analyses have not yet been completed. We are currently in the early stages of an analysis relating habitat selection of adult females and fawns (including the black bear RSF as a habitat variable) to survival. In addition, we still have all the data from summer fawn mortality sites and paired random sites to analyze, which included counts of black bear scats around each site.

Objective 4: Evaluate whether bear predation is partly compensatory and additive.

Approach: See Objective 1.

Findings: See Objective 1. Bear predation appears to be partly compensatory, as summer fawns survival was primarily determined by bear predation, and summer fawn survival was also strongly predicted by mass at birth (a measure of nutritional condition). This objective will further explored in the near future.

Objective 5: Report and manuscript writing

Approach: We analyzed the data to prepare a final report and publications.

Findings: We completed the data analysis and the final report. Sophie Gilbert completed her Ph. D. dissertation at University of Alaska Fairbanks (Appendix A) using data from this project. We have published one paper, one paper is in press, and we anticipate at least 2 additional publications from the project (see below)

IV. MANAGEMENT IMPLICATIONS

As hypothesized, fawn deer are highly vulnerable to predation, primarily by black bears during summer. However, black bear predation appears to be at least partially compensatory, and malnutrition played a major role in fawn mortality during the single deep-snow winter of the study, to the extent that population growth was negative despite high survival rates of adult females. In addition, there was very low recorded wolf mortality for fawns, and no wolf mortality for adult females, even during the deep-snow winter of 2011–2012, suggesting that the deer population on POW is currently limited by restricted nutrition during periodic severe winters rather than by predation. Combining this strong effect of winter severity on the deer population with deer avoidance of deep snow areas and increasing preference for areas with a higher composition of productive old growth forest as snow depths increased, managing deer habitat for severe winters, rather than average winters, is recommended. We found deer behavior in winter to be quite plastic, with higher selection for young and old second-growth forest when these modified habitats were widely available. However as snow depth increases, availability of forage in young second-growth decreases and the cost of locomotion increases. As snow depth increases in older second-growth forest, the cost of locomotion may remain low, but this habitat has little forage. While older second-growth forest may provide a useful matrix of habitat for deer during deep snow conditions, managers should examine landscape configuration to ensure adequate connectivity among productive old-growth patches to maintain necessary resilience of the deer population to deep-snow winters.

V. SUMMARY OF WORK COMPLETED ON JOBS

FROM PROJECT STATEMENT:

Objectives:

Objective 1: Evaluate fawn mortality as a result of malnutrition.

Job/activity 1a: Capturing and radiocollaring adult does and neonate fawns and training and purchasing equipment.

Accomplishments: This project concluded field data collection in 2012-2013, and met or exceeded all data collection goals. The analysis and conclusions have been described in Gilbert (2015). The key findings have been included in Section III.

Objective 2: Evaluate habitat selection

Job/activity 2a: Monitor and tracking does and fawns.

Accomplishments: This project concluded field data collection in 2012-2013, and met or exceeded all data collection goals. The analysis and conclusions have been described in Gilbert (2015). The key findings have been included in Section III.

Objective 3: Evaluate if black bear predation on fawns is positively related to levels of bear activity or is spatially correlated with habitat composition and distribution.

Job/activity 3a: Vegetation sampling and estimating deer and bear activity.

Accomplishments: This job was completed. The analysis and conclusions have been described in Gilbert (2015). The key findings are in Section III.

Objective 4: Evaluate whether bear predation is partly compensatory and additive.

Job/activity 4a: Data analyses.

Accomplishments: This job was completed. The analysis and conclusions have been described in Gilbert (2015). The key findings are in Section III.

Objective 5: Report and manuscript preparation

Job/activity 5: Report and manuscript writing

Accomplishments: We completed the data analysis and the final report. Sophie Gilbert completed her Ph. D. dissertation at University of Alaska Fairbanks (Appendix A) and one paper has been published (Gilbert et al. 2014) using data from this project.

VI. PUBLICATIONS

Gilbert S. L, M. S. Lindberg, K. J. Hundertmark, D. K. Person. 2014. Dead before detection: addressing the effects of left truncation on survival estimation and ecological inference for neonates. Methods in Ecology and Evolution. DOI: 10.5061/dryad.p1r40.

Gilbert, S. L. 2015. Environmental drivers of deer population dynamics and spatial selection in Southeast Alaska. Doctoral dissertation, University of Alaska Fairbanks, Fairbanks, AK.

Gilbert, S. In press. Bald eagle predation on Sitka black-tailed deer fawns. Northwestern Naturalist.

Gilbert, S., M. Boyce, K. Hundertmark, D. K. Person, P. Barboza, M. Lindberg. In revision. Behavioral plasticity in a variable environment: snow depth and habitat interactions drive deer movement in winter. *Journal of Mammalogy*.

Gilbert, S., M. Boyce, K. Hundertmark, D. K. Person, P. Barboza, M. Lindberg. In preparation. Fear, forage, or fawns: nutrition and predation risk drive behavior for female deer. In preparation for *Journal of Animal Ecology*.

VII. ADDITIONAL FEDERAL AID-FUNDED WORK NOT DESCRIBED ABOVE THAT WAS ACCOMPLISHED ON THIS PROJECT

None.

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PREPARED BY: Rodney W. Flynn, Research Coordinator (*for Person and Gilbert*)

SUBMITED BY: Rodney W. Flynn, Research Coordinator

DATE: 15 September 2015

Appendix A.

Gilbert, S. L. 2015. Environmental drivers of deer population dynamics and spatial selection in Southeast Alaska. Doctoral dissertation, University of Alaska Fairbanks, Fairbanks, AK.

Abstract

The coastal temperate rainforest is one of the rarest ecosystems in the world, and a major portion of the global total is found in Southeast Alaska. In this ecosystem, Sitka black-tailed deer are the dominant large herbivore, influencing large carnivores that prey on deer such as wolves and bears, as well as plant species and communities through browsing. In addition, deer play an important economic and cultural role for humans in Southeast Alaska, making up the large majority of terrestrial subsistence protein harvested each year as well as providing the backbone of a thriving tourism industry built around sport hunting. Given the importance of deer in this system, there remain a surprisingly large number of key gaps in our knowledge of deer ecology in Southeast Alaska. These knowledge gaps are potentially troubling in light of ongoing industrial timber-harvest across the region, which greatly alters habitat characteristics and value to wildlife. This dissertation research project was undertaken with the aim of filling several connected needs for further understanding deer ecology, specifically 1) patterns of reproduction and fawn survival, 2) population dynamics in response to environmental variability, and the underlying drivers of spatial selection during 3) reproduction and 4) winter. Much is unknown regarding reproduction in this species, including what ecological drivers influence pregnancy, fetal rates, and fawn survival through the seasons. As a result, population dynamics of deer are also poorly known, as fawn production and survival are key demographic parameters, particularly in species such as ungulates where adult female survival is typically high and constant. In addition, whereas several past studies have focused on spatial selection by adult females in various areas across the Alexander Archipelago, few studies have examined the underlying ecological drivers of spatial selection. Consequently, there is poor agreement as to what habitats are most important for deer across Southeast Alaska, resulting in conflicting management paradigms for deer across natural resource agencies. In chapter 2 of this dissertation, I developed robust statistical tools for estimating rates of fawn survival, and fitting models of fawn survival with environmental covariates. I found that fawns must be captured at birth, rather than within several days of birth, in order to produce unbiased estimates because highly vulnerable individuals died quickly and were thus absent from the latter sample. However, fawns captured several days later could be combined with the at-birth sample after 30 days of age, when daily survival estimates converged. I then use this robust approach to estimate vital rates, including fawn survival in winter and summer, and in chapter 3 develop a model of population dynamics for deer. I found that winter weather had the strongest influence on population dynamics, via reduced over-winter fawn survival, with mass at birth and gender ratio of fawns important secondary drivers. In chapter 4, I examined how reproductive female deer balance wolf and bear predation risk against access to forage over time. I found that females reduce overlap with bears (which are fawn predators) throughout gestation, continue to avoid bears while fawns are

alive, then relax avoidance of bears if all fawns died. Similarly, females increased selection of forage throughout gestation and into lactation when nutritional demands are highest, and further increased selection for forage if fawns died, presumably in order to recover body reserves for winter. Finally, females were increasingly tolerant of risk from wolves (an adult female predator) during gestation, increasingly avoided wolves once fawns were born, then relaxed avoidance of wolves after fawns died. Overall, predation risks and forage were strong drivers of deer spatial selection during summer, but reproductive period and time within reproductive period determined deer reaction to these drivers. To ensure adequate reproductive habitat for deer, areas with low predation risk and high forage should be conserved. In chapter 5, I evaluated deer spatial selection during winter as a response to snow depth, vegetation classes, forage, and landscape features. I allowed daily snow depth measures to interact with selection of other covariates, and found strong support for deer avoidance of deep snow, as well as changes in deer selection of other covariates with increasing snow depth. Importantly, deer avoided productive old-growth forest at low snow depths, but increasingly selected it at greater snow depths. Conversely, deer selected young second-growth forest at low snow depths, but increasingly avoided it at greater snow depths. Old second-growth forest, which will become increasingly common in the future given forest successional patterns and projected timber-harvest declines, was avoided at low snow-depth, increasingly selected at high snow-depth, increasingly selected as it was more available to deer, and increasingly selected as productive old-growth alternatives were less available. However, this forest type has very little forage for deer, and so although deer may use it in order to avoid moving through deep snow, it cannot sustain deer throughout winter. Hence, productive old growth must be maintained as winter habitat for deep-snow winters. Collectively, this dissertation greatly improves our understanding of deer ecology in Alaska, and suggests habitat management actions that will help ensure resilient deer populations in the future.