Factors Affecting the Survival of Black-tailed Deer Fawns on the Northwestern Olympic Peninsula, Washington

****Final Report****

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INTRODUCTION

Black-tailed deer have historically been harvested at a higher rate than either white-tailed deer or mule deer in Washington (WA). Despite their significance to hunters, black-tailed deer populations are believed to have declined over the last 2 decades (Washington Department of Fish and Wildlife 2003, Gilbert and Raedeke 2004) and managers are unsure of the extent and possible reasons behind a decline as little information exists about the population dynamics of black-tailed deer in WA (Kantar 2003, Washington Department of Fish and Wildlife 2003).

Currently, population management for black-tailed deer in WA utilizes a Sex-Age-Kill (SAK) population reconstruction model to estimate population sizes annually in established Population Management Units (PMU), which in turn provides an index of population performance over time. The SAK model relies upon inputs such as total deer harvest, age and sex composition of harvested deer, and measures of recruitment (number of fawns per 100 does) as collected in composition surveys. The SAK model is cost effective as it relies on data that are routinely collected by wildlife management agencies, however, it was recently criticized in Wisconsin and a formal evaluation revealed a number of deficiencies (Millspaugh et al. 2006). These deficiencies may limit the ability of the current model used in Washington to detect declines in black-tailed deer populations.

Deterministic models are used by many state agencies to estimate deer population size over time. These models rely heavily on adult survival, which has been identified as the stage-specific vital rate that has the greatest influence on population growth (Nelson and Peek 1982). However, adult survival has been found to be relatively stable over broad geographic scales (Gaillard et al. 1998, Unsworth et all 1999) and has been indicated to play a much smaller role in population dynamics than juvenile survival which is highly variable (Unsworth et al. 1999, Raithel et al. 2007) and can count for $\geq 70\%$ of annual variation in population rates of increase (Gaillard et al. 2000).

Characteristics of wildlife populations are ultimately governed by natality and mortality. For a population to persist, annual recruitment must on average, at least equal annual adult mortality (Whittaker and Lindzey 1999). Fawn survival has been studied throughout North America to better understand recruitment and identify factors associated with fawn mortality such as predation, malnutrition, parasites, disease, harvest, abandonment, and accidents (Cook et al. 1971, Carroll and Brown 1977, Steigers and Flinders 1980, Trainer et al. 1981, Temple 1982, Hamlin et al. 1984, Hatter 1988, Benzon 1996, Mackie et al. 1998, Unsworth et al. 1999, Whitaker and Lindzey 1999, Vreeland 2002, Burroughs et al. 2006, Lomas and Bender 2007, Rohm et al. 2007). The aforementioned studies primarily focused on white-tailed deer and mule deer. With the exception of Hatter (1998) on Vancouver Island, a focused study of black-tailed deer fawn survival and mortality sources has not occurred. Current state population status and trend data (Washington Department of Fish and Wildlife 2009) indicate that potential declines in the black-tailed deer population may be related to low recruitment rates or low survival rates of reproductive does.

One of the primary factors believed to be affecting black-tailed deer fawn recruitment is hair loss syndrome (HLS), which was first documented in 1996 in western Washington subsequently spreading into western Oregon by 1998 (Bender and Hall 2004) and has been confirmed in northern California as far south as Mendocino County (D. Lancaster, CA Dept.of Fish and Game, personal communication). Recently, it was discovered that HLS is caused by an exotic species of chewing louse, *Damalinia* (*Cervicola*) that is not native to the Pacific Northwest and is a new parasite for the black-tailed deer (Bildfell et al. 2004). Incidence of HLS is noticed in deer typically in the winter and spring months. Clinical signs include darkening of the hair coat on both sides in November-December. From January to April deer show signs of hair loss and yellow to white discoloration of hair over the ribcage, flanks, rump, and neck. Hair loss results from excessive licking and scratching of infected areas. Deer can then become emaciated, lethargic, and have diarrhea, which can subsequently lead to death. Fawns and does appear to be most affected, with young between 6 and 12 months particularly prone to the condition (Bildfell et al. 2004).

Very little field research has been conducted to determine the population level effects of HLS, which may increase mortality and/or decrease fecundity in black-tailed deer populations (Bildfell et al. 2004). Bender and Hall (2004) investigated winter fawn survival and the effects of HLS and concluded that it did not have a large impact on survival or population declines. This study estimated fawn survival based on changes in fawn to doe ratios between fall and spring rather than directly measuring fawn survival or differences in survival rates between affected and non-affected animals. Adult/young ratios can be biased due to low sampling effort, timing of surveys, differential visibility of adults and young, presence of a large number of yearling females with lower fecundity, and antlerless harvest prior to winter surveys (White et al. 2001, Millspaugh 2006). Bender and Hall (2004) did report probable declining populations in 6 of 8 study GMU-year combinations due to decreased production of fawns and/or increased summer mortality of fawns and indicated the need to clarify the factors limiting black-tailed deer productivity. Thus, regardless of the influence of HLS on productivity, additional work is required to estimate annual recruitment rates and to identify factors affecting survival of black-tailed deer fawns.

The objectives of this study were to determine age specific survival rates, sources of mortality, and assess the influence of HLS on black-tailed deer fawn survival on the northwestern Olympic Peninsula in Washington. This information will provide managers with a better understanding of the influence of fawn survival on the population rate of change in western Washington and potentially identify factors that may be limiting fawns survival. Additionally, known survival/recruitment of fawns would benefit population-modeling efforts by providing a validation of traditional sampling methods (ratio data) or use as a direct estimate of survival. This information is invaluable as recruitment can play a key role in the precision of population estimates generated by SAK models (Millspaugh 2006).

STUDY AREA

The study took place on the Makah Reservation and adjacent Hoko Game Management Unit (GMU) in Clallam County, Washington (Figure 1). The dominant use of land on the Makah Reservation and Hoko GMU is commercial timber harvest. The majority of lands within the Hoko GMU are privately owned industrial timberlands. The Washington Department of Natural Resources also manages public timberland, of which the largest block is located in the Carpenter Creek area. A minor amount of land within the Hoko GMU is developed either as small residential areas, isolated homes, or small ranching operations (primarily fenced pastureland for livestock grazing). These developments are primarily located along Highway 112 between the mouth of the Hoko River and the Makah Reservation and along the Hoko-Ozette Road.

Elevations range from sea level to nearly 610 m at the higher peaks. The climate is markedly influenced by the orographic interaction of maritime air masses and the mountainous topography is characterized by warm, dry summers and cool, wet winters. Temperatures are typically mild and on the average range from 3 to 12° C in January and 10 to 19° C in August. However, occasionally the prevailing westerly wind flow is disrupted and replaced by easterly winds with wider extremes of continental air. During the winter arctic air can spread south and during the summer hot, dry air can inundate the region from Idaho and Montana. The average annual precipitation averages 254 cm. About three-quarters of the yearly precipitation occur from October to March, with about 8 % occurring from June-August. Winter storms are commonly accompanied by severe winds that routinely exceed 64 kilometers per hour at the coast and commonly accelerate to 80 to 96 kilometers per hour in mountain valleys. Warm westerly winds restrict snowfall to the higher elevations usually above 914 m except when the westerly winds are disrupted between December and February. Even when snow falls in the lowlands it rarely exceeds 8 cm and lasts only a few days. During the summer months fog frequently moves inland at night and inundates hollows and valleys. Where fog is thick it condenses on evergreen needles and drips to the ground, thereby boosting annual precipitation. By mid-day, air temperatures rise and the fog typically dissipates (Dion et al. 1980, Schultz 1990).

The northern Olympic Peninsula is dominated by temperate coniferous forests and is characterized by the *Picea sitchensis* (Sitka spruce) zone. Constituent tree species are the Sitka spruce, western hemlock (*Tsuga heterophylla*), western red-cedar (*Thuja plicata*), Douglas fir (*Psuedotsuga menziesii*), and Pacific silver fir (*Abies amabilis*). Red alder (*Alnus rubra*) is one of the most abundant trees on disturbed sites. Understory vegetation typically consists of red huckleberry (*Vaccinium parvifolium*), salmonberry (*Rubus spectabilis*), thimbleberry (*Rubus parviflorus*), devil's club (*Oplopanax horridus*), salal (*Gaultheria shallon*), red elderberry (*Sambucus recemosa*), sword fern (*Polystichum munitum*), lady fern (*Athyrium felix-femina*), deer fern (*Belchnum spicant*), Oregon oxalis (*Oxalis oregana*), trillium (*Trillium ovatum*), and Oregon grape (*Berberis nervosa*) (Franklin and Dyrness 1973, Makah Forestry 1999).
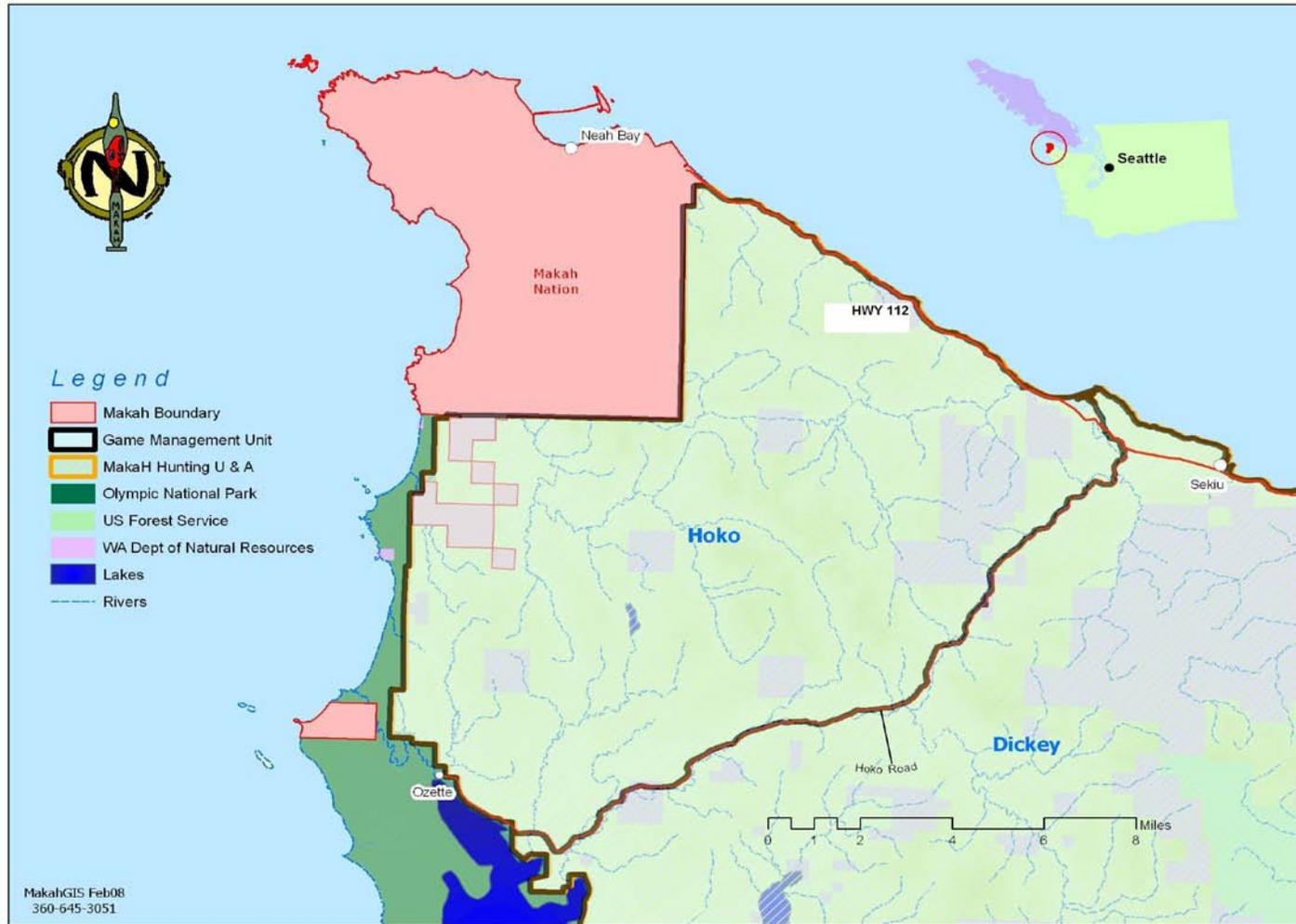
Figure 1. Study area including the Makah Reservation and adjacent industrial timberlands in the Hoko Game Management Unit (area north of Hoko Ozette Road) on the northwestern Olympic Peninsula, Washington, USA.

Specialized communities commonly found with the *Picea sitchensis* zone are the cedar and alder swamps. The constant habitat characteristic is a high water table, or even standing surface water, for all or a portion of the year. The primary tree species on these sites are western red cedar, red alder, or both. The understory is often dominated by skunk cabbage (*Lysichitum americanum*) and/or slough sedge (*Carex obnupta*), however a great variety of shrubby or herbaceous species may be present. Some of the more characteristic are salal, false azalea (*Menziesia ferruginea*), Alaskan blueberry (*Vaccinium alaskaense*), evergreen huckleberry (*V. ovatum*), red huckleberry, and salmonberry. Typical herbs include deer fern, false lily-of-the-valley (*Maianthemum dilatatum*), and bunchberry (*Cornus Canadensis*) (Franklin and Dyrness 1973).

Intensive timber harvest has converted what was historically extensive old growth to primarily second growth forests with stand conditions ranging from grass-forb following clearcutting to closed-sapling-pole sawtimber (Hall et al. 1985). Timber harvest occurs in second growth stands at 45-70 years, thus, these stands never attain old growth characteristics. A mosaic of stand conditions exist within the study area, however, are largely dominated by younger stands as the area has been subject to significant timber harvest over the past 10 years.

Intensive timber harvest has resulted in high road densities. Prior to 1987, the majority of roads on industrial timber lands in the Hoko GMU were open to public access, resulting in probable reduced deer use of available habitat near heavily traveled roads, increased disturbance of wintering and fawning deer, and increased vulnerability of deer to hunting. Since 1987, roads on industrial timberlands in the Hoko GMU have been closed to the public. Hunting is allowed, however access is limited to non-motorized transportation from locked gates along Hwy 112 and the Hoko-Ozette Road. This has resulted in a probable corresponding increase in the deer use of available habitat near many roads, a decrease in disturbance during the wintering and fawning season, and a decrease in vulnerability associated with hunting. On the Makah Reservation access is limited by gates in some areas, however, is largely unrestricted over most of the Reservation. Hunting is limited to tribal members only.

METHODS

Capture and Handling
Fawns of both sexes were captured by hand annually between 13 May and 28 June in all years from 2006 to 2009. Captures occurred by monitoring daily movements and behavior of radiocollared parturient females and vehicle searches within the study area. Vehicle searches involved 2-4 person teams in multiple vehicles driving slowly along roads, stopping at strategic viewing locations to search clearcuts with binoculars for fawns and observe doe behavior. Searching, nursing, aggression toward other adult deer, and careful visual monitoring of specific sites are characteristic behaviors of does with fawns (Downing and McGinness 1969, White et al. 1972, Ozoga et al. 1982, Heister 1985). All search teams had a fawn bleat call (Diem 1954, Arthur et al. 1978) to elicit behavioral responses from does that may have a fawn nearby. When fawns were observed or does elicited requisite behavior, localized foot searches were conducted.

Fawns were captured by hand and with the aid of nets (0.9 m. hoop diameter, 1.2 m. handles; Lund 1975). The net was carefully laid on top of a bedded fawn to prevent the fawn from bolting as handlers approach. Limiting handling time and the number of persons handling each fawn minimized transferal of human scent to fawns. Additionally, fawns were processed > 10 m from the site of capture to limit scent transferal to the fawn's bed. Fawns were returned to the site of capture after processing. Handlers wore latex gloves that were discarded after each fawn was handled. A 7.5 kg scale and a polypropylene sack were used to weigh fawns. Fawns were weighed to the nearest 0.1 kg, sex was determined and 8 ml of blood was drawn. A chi-square test (Zar 1984) was used to determine if sex ratios were different from a 1:1 ratio in any year. Total length of fawns, girth circumference, left hind foot length, and femur length was measured to the nearest 0.1 cm. Curvilinear length was measured to nearest 0.1 cm from nose to rump using a standardized body position. The length of new growth of the hind hoof was measured to the nearest 0.1 mm (Haugen and Speake 1958) and was used to estimate date of birth following equations developed by Robinette et al (1973). Weight-at-birth (WAB) was estimated by taking the daily growth rate, calculated from a linear regression equation, and multiplying it by the estimated age of fawns at capture, then subtracting that value from the weight of the fawn at-capture. Weight at capture and weight at birth were tested for differences between sex and years using Analysis of Variance in program R (version 2.10.1, Free Software Foundation, Inc., Boston, Massachusetts).

Each fawn was fitted with a very high frequency (VHF) expandable radio collar (Advanced Telemetry Systems, Inc., Isanti, Minnesota) with a mortality delay. Each transmitter-collar combination weighed approximately 68 g., which represent less than 3% of total body mass at birth (Cowan and Wood 1955). This is consistent with recommendations for terrestrial neonate mammals (Animal Care and Use Committee 2001).

Survival Monitoring and Mortality Assessment
Ground-based telemetry was used to monitor fawns (White and Garrot 1990). Captured fawns were monitored daily thru August, then minimally 2 times weekly for the remainder of the year until recruitment as yearlings (May). Additionally, from December to April, captured fawns were visually observed twice monthly at a minimum to classify all fawns afflicted with HLS. When mortality signals were detected the radiocollar was located and the cause of mortality was immediately investigated. The mortality source was identified by site and carcass evidence and classified into 6 categories: natural (abandonment, malnutrition, disease), predation, accident/trauma, human caused, unknown, and slipped. During the period of the year when HLS affects fawns (December to April) the carcass was assessed for the presence of lice. Nutritional stress was determined from examination of bone marrow, where red, gelatinous marrow indicates malnutrition (Riney 1955, Takatsuki 2001). HLS influenced mortalities were identified by condition of fawn at death as well as high prevalence of lice on multiple locations of the carcass (>35 lice per cm^2, Bildfell et al. 2004). The source of predation was determined using a modified key from Vreeland (2002) for bobcat (*Lynx rufus*), coyote (*Canis latrans*), and black bear (*Ursus americanus*) and following Hayes (2000) and

McKinney (2001) for mountain lion (*Puma concolor*). When evidence could not conclusively identify a predator, but predation was the cause of death, the mortality source was documented as unknown predation. In 2007, 2 fawns were sent to the Washington State University Animal Diagnostic Laboratory; in 2008 and 2009, 5 and 12 fawns, respectively, were sent to the USGS National Wildlife Health Center to determine the source of mortality, as no obvious cause of death was evident.

Survival Analysis

The known fates model in Program MARK version 5.1 (White 2008) with staggered entry of fawns was used to estimate survival from date of birth to recruitment and investigate covariates influencing survival through the first 9 weeks of life. Model set 1 was developed for the 2006 to 2009 cohorts to determine the best possible estimate of survival to recruitment (Table 1). A priori models for model set 1 reflected age and seasonal differences in survival. Model set 2 was developed to specifically look at survival to 9 weeks for the 2006 to 2009 cohorts. Studies have indicated that fawn mortality is highest during the first 60 days of life (Steigers and Flinders 1980, Temple 1982, Hamlin 1984, Hatter 1988, Mackie et al. 1998, Whitaker and Lindzey 1999, Vreeland 2002, Rohm et al. 2007) and has been speculated as an important period for black-tailed deer fawns as well (Brown 1961, Bender and Hall 2004, Gilbert and Raedeke 2004). Model set 2 incorporated capture year (cohort) as a grouping variable and individual covariates such as Julian date of birth and estimated weight at birth (Table 2). We used Akaike's information criteria (AIC), corrected for small sample size (AIC$_c$), to select the model(s) that best described fawn survival. If more than one plausible model existed, survival rates and 95% confidence intervals were estimated using model averaging.

Table 1. A priori models in model set 1 used to determine the influence of age and seasonal effects on black-tailed deer fawn survival to recruitment as yearlings from 2006-2009 on the northwestern Olympic Peninsula, WA, USA.

Model	K[a]	Description
S_{age}	51	Survival varies by the age (weeks) of the fawn
S_{year}	5	Survival is constant within years and different between years
$S_{constant}$	2	Survival is constant
$S_{age \times year}$	201	Survival varies by age and between years
$S_{age-2interval}$	3	Survival varies by age in 2 stages: between 0-9 and 10-50 weeks
$S_{age-2 intervals \times year}$	9	Survival varies by age in 2 stages (see above) and between years
$S_{age-3 intervals winter}$	4	Survival varies by age in 3 stages: between 0-9, 10-29 & 43-50[b], and 30-42 weeks
$S_{age-3 intervals winter \times year}$	13	Survival varies by age in 3 stages (see above) and between years

[a]No. of potential parameters, includes 1 parameter to hold survival constant before entry into marked population.
[b]Survival held constant between 10-29 and 43-50 weeks, weeks 30-42 primary winter months.

Table 2. A prior models in model set 2 used to determine the influence of individual covariates on black-tailed deer fawn survival to 9 weeks of age from 2006-2009 on the northwestern Olympic Peninsula, WA, USA.

Model	K^a	Description
S_{age}	9	Survival varies by the age (weeks) of the fawn
$S_{constant}$	1	Survival is constant
S_{year}	4	Survival varies between years
$S_{age \times year}$	36	Survival varies by age and between years
$S_{age-2\ interval}$	2	Survival varies by age in 2 stages: 0-4 and 5-9 weeks
S_{JDB}	2	Survival varies by Julian date of birth (JDB)
Sage x JDB	20	Survival varies by age and Julian date of birth (JDB)
S_{WAB}	2	Survival varies by estimated fawn weight at birth (WAB)
Sage x WAB	20	Survival varies by age and weight at birth (WAB)

[a] No. of potential parameters

Survival rates and 95% confidence intervals were estimated for 4 weeks, 9 weeks, 16 weeks, 26 weeks (approximately 6 months), and to recruitment as a yearling (50 weeks). Sixteen weeks of age represented survival to the general archery season for deer in northwestern Washington. Some studies have used survival to hunting season as an estimate of recruitment for white-tailed deer (Vreeland 2002, Burroughs et al. 2006, Rohm et al. 2007); however, this date fluctuates between studies. Twenty-six week survival (~ 6 months) is a common benchmark in many studies, thus, was included for comparative purposes. Fawns were considered at risk from the week they were born, based on an estimated date of birth, using a staggered entry format. This resulted in fawns of different ages throughout the analysis time period based on the week they were born (i.e. fawns born in week 1 survived 50 weeks to recruitment, while fawns born in week 4 survived 46 weeks to recruitment).

Survival was also estimated for the period of the year (winter) when fawns were susceptible to HLS using known fates. Clinical signs of HLS are typically apparent between December and April. All fawns alive during this timeframe were classified as having or not having HLS through observation of live fawns or classification at mortality sites if clinical signs were not apparent through visual observation (typical of fawns dying early in the HLS analysis period). The total number of fawns surviving and dying from 2006-2009 in each class (HLS affected, not HLS affected) was tabulated. A chi-square test of heterogeneity ($\alpha = 0.05$; Zar 1984) was used to determine if survival was similar among years. Data were then compared using a 1-tailed Fisher's exact test ($\alpha = 0.05$; Zar 1984) to determine if survival of fawns not afflicted with HLS was similar to (H_o), and not higher than (H_a), survival of fawns that were afflicted with HLS.

Finally, the survival data reflecting recruitment to the yearling age class was used to estimate the trend of the population being studied by calculating the finite rate of population increase or λ. For the population studied, $\lambda = S_{yearling}/2 + S_{doe}$, where $S_{yearling}/2$ is the survival rate of fawns (adjusted for female fawns and assuming sex ratio of fawns is 1:1) to recruitment and S_{doe} is the annual survival rate of adult does. Annual adult doe survival rates have been variable over time in the Hoko GMU throughout the past 5 years (ranging from 0.74 to 0.95), based on concurrent research of adult deer within the study area by the Makah Tribe (R. McCoy, unpublished data). To account for variability, λ was estimated using the extreme ends of the range of doe survival along with the 6-year average adult doe survival of 0.83. Confidence intervals for lambda were calculated using 1000 iterations of fawn recruitment and doe survival following bootstrap methods (Efron and Tibshirani 1993, Bender et al. 2004).

RESULTS

A total of 228 fawns were captured, between 29 May to 9 June in 2006 (n=50), 22 May to 8 June in 2007 (n=50), 20 May to 11 June in 2008 (n=66) and 13 May to 28 June in 2009 (n=62). Mean capture date and date of birth was similar for males and females but was earlier in 2008 compared to 2006, 2007 and 2009 (Appendix A). Average age of fawns at capture was 3.5 days (range 0-11 days). The male-to-female sex ratio of captured fawns varied by year (Appendix A), but averaged 0.98:1 over all 4 years and was not significantly different from a 1:1 ratio for any year ($\chi^2 = 3.2$, $P=0.36$). The average number of fawns per doe over the four years was 1.5 and the twinning rate of fawns was 0.62. However, in 2009 the number of fawns per doe and the twinning rate were lower than those in the previous 3 years (Appendix A).

The average capture weight for males and females combined was 4.2 kg (95% CI = 3.9 - 4.5), 4.1 kg (95% CI = 3.8 - 4.4), 3.9 kg (95% CI = 3.7 - 4.1) and 3.7 kg (95% CI =3.5 - 3.9) in 2006, 2007, 2008 and 2009, respectively. The difference in capture weight over the years was significant ($F_{1,215}=7.25$, $P=0.008$), and was generally greater for males than females ($F_{1,215}=4.32$, $P=0.04$). The average weight at birth for males and females combined was 3.2 kg (95% CI = 2.9-3.4), 3.2 kg (95% CI = 3.0-3.4), 2.8 kg (95% CI = 2.6-3.0) and 2.8 kg (95% CI =2.7 - 3.0) in 2006, 2007, 2008 and 2009, respectively. Weight at birth was greater for males than females but only significantly so in 2006 and both males and females had the lightest birth weights in 2008 ($F_{1,216}=4.54$, $P=0.03$; Appendix B).

Cause-Specific Mortality
One hundred twenty-nine of the 228 fawns radio collared between 2006-2009 died from various mortality sources (Table 3) and 41 fawns (18%) slipped their collars. Fawns that slipped their collars provided information on survival to the date of collar loss but were censored for subsequent analysis. We censored 4 newborn fawns that died within 24 hours of capture from survival analysis, since their death may have been related to capture activities. Predation was the leading cause of mortality (74.4%) followed by natural non-predation (19.4%), unknown (3.9%), and human caused (2.3%). Specific details regarding cause of mortality and necropsy results are outlined in Appendix C.

Table 3. Cause specific mortality of black-tailed deer fawns through 50 weeks on the northwestern Olympic Peninsula, WA, USA, 2006-2009.

Mortality cause	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Total
Mountain lion	12	13	11	11	47
Bobcat	7	2	1	10	20
Black bear	2	1	0	0	3
Coyote	1	0	0	1	2
Unknown predation	3	4	14	3	24
Unknown	0	1	2	2	5
Natural, non-predation	2	5	4	14	25
Human caused	3	0	0	0	3
Total	30	26	32	41	129

Survival Analysis

The best known-fates model for model set 1 was $S_{\text{age-3 intervals winter x year}}$ (Table 4). This model performed much better than any other model in the set and was 165 times greater than the second best model. All other models that were tested did not support our data. The model $S_{\text{age-3 intervals winter x year}}$ provided evidence that survival differed between years and was age dependent with fawns being vulnerable during the first 9 weeks then again later in the year during the winter timeframe, between weeks 30-42. However, timing of winter mortalities differed between years. The best known-fate model for model set 2 was $S_{\text{age x WAB}}$ (Table 5). This model was 31 times greater than the second best model and over 200 times greater than the third and fourth models. All other models that were tested did not support our data. Model $S_{\text{age x WAB}}$ provided support for age dependent survival over the first 9 weeks and included the individual covariate weight at birth. Examination of data showed that fawns with a lighter birth weight died earlier than fawns with a heavier birth weight, although the relationship was weak ($R^2 = 0.21$; Figure 2).

Table 4. Performance of top 3 models (model set 1) describing black-tailed deer fawn survival to 50 weeks for 2006-2009 cohorts on the northwestern Olympic Peninsula, WA, USA.

Model	K^{a}	ΔAIC_c^{b}	AIC_cweight[c]
$S_{\text{age-3 intervals winter x year}}$	13	0.00	0.994
$S_{\text{age-3 intervals winter}}$	4	10.27	0.006

[a]No. of parameters in model.
[b]Akaike's Information Criteria, corrected for small sample size.
[c]Relative weight attributed to model.

Table 5. Performance of top 4 models (model set 2) describing black-tailed deer fawn survival to 9 weeks for 2006-2009 cohorts from the northwestern Olympic Peninsula, WA, USA.

Model	K^a	$\Delta AIC_c{}^b$	AIC_cweight^c
$S_{age \; x \; WAB}$	20	0.00	0.962
$S_{age \; x \; JDB}$	20	6.89	0.031
S_{age}	9	10.73	0.004
S_{WAB}	2	11.62	0.003

[a]No. of parameters in model.
[b]Akaike's Information Criteria, corrected for small sample size.
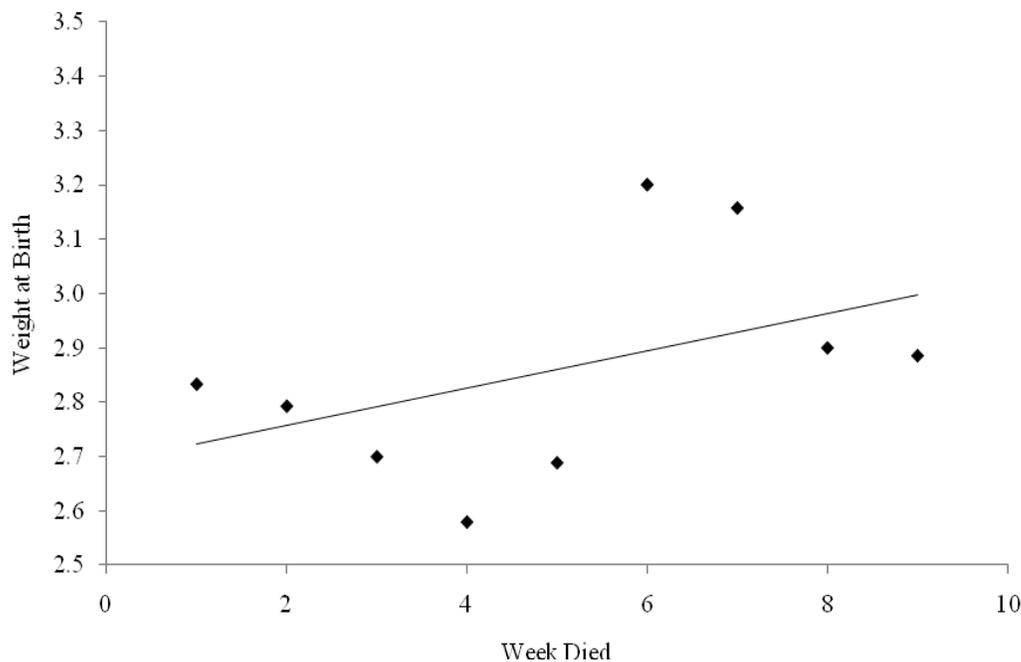[c]Relative weight attributed to model.

Figure 2. Relationship between the mean Weight at birth and week for all fawns that died during the first 9 weeks of life on the northwestern Olympic Peninsula, WA, USA.

Thirty-one percent (n = 40) of all mortality occurred during the first 4 weeks of life and 26 % (n = 33) occurred during the next 5 weeks. The remainder of the mortalities occurred after this date between 10 and 46 weeks (n = 56; 43%). Of those, 19% (n=24) occurred between weeks 30 to 42, the winter/hair loss timeframe.

The average survival rate through recruitment, or 50 weeks, for the 4-year period was 0.33 (95% CI = 0.24 – 0.43), estimated using the best model from model set 1. The survival rate through the first 4 weeks was 0.82 (95% CI = 0.79-0.85) and was 0.65 (95% CI = 0.60 – 0.68) at 9 weeks, 0.58 (95% CI =0.47-0.68) at 16 weeks, and 0.51 (95% CI =0.41-0.61) at 26 weeks. Trends in survival are best indicated by examination of weekly cumulative survival rates to recruitment (Figure 3). Survival declined rapidly over the

first 9 weeks, then again during the winter timeframe for the first 3 years. However, during 2009, early survival declined rapidly through week 11, but did not decline sharply over the winter.
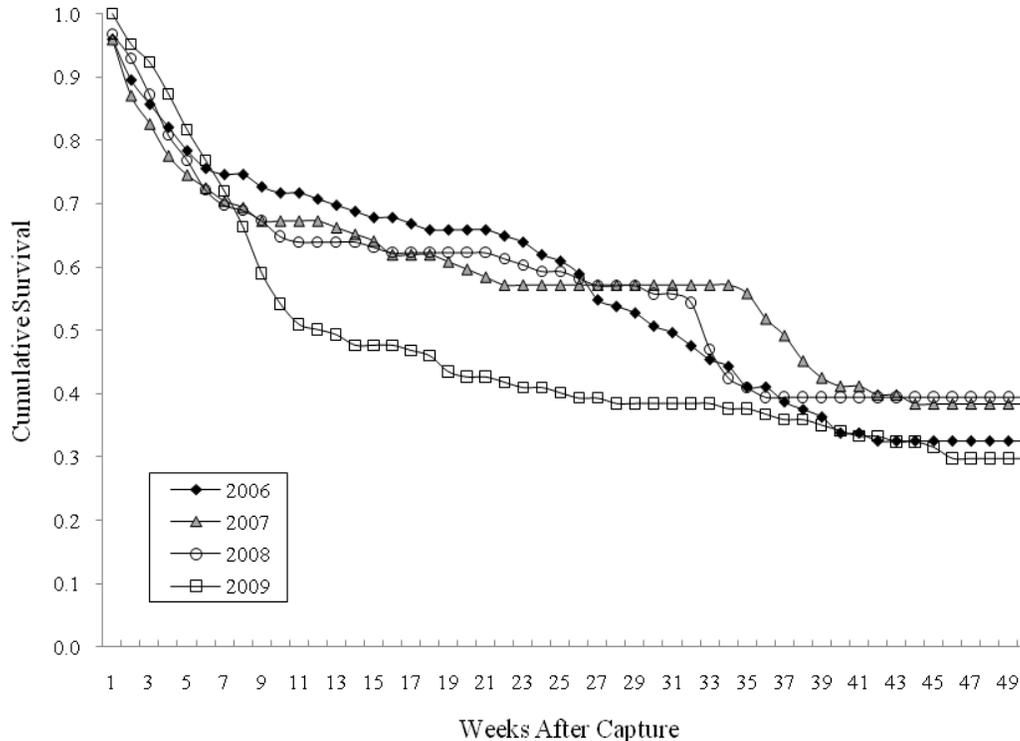

Figure 3. Cumulative survival of black-tailed deer fawns to recruitment (50 weeks) on the northwestern Olympic Peninsula, WA, USA.

During the HLS analysis timeframe a total of 83 fawns were at risk. Thirty-seven fawns (45%) were classified as afflicted with HLS (Appendix D). Thirteen of the 37 fawns afflicted with HLS died from predation, and 3 died from severe emaciation with a heavy infestation of lice. Nine of 46 fawns not affected with HLS died from predation (Appendix E). A chi-square test for heterogeneity indicated no difference in survival between years ($\chi^2_1 = 4.96$, $P > 0.17$), therefore data were pooled for all cohorts. The survival rate for fawns afflicted with HLS was 0.57 (95% CI = 0.41-0.72) and was 0.80 (95% CI = 0.65-0.89) for fawns not afflicted with HLS. The Fisher's exact test indicated that fawns with HLS suffered greater rates of mortality than fawns without HLS ($P = 0.018$).

A mean annual fawn survival of 0.33 and mean annual doe survival of 0.83, results in a slightly declining population growth rate (λ) of 0.995 (95% CI = 0.80-1.17), a declining population with doe survival at 0.74 ($\lambda=0.905$), and an increasing population with doe survival at 0.95 ($\lambda=1.115$). The trend of the population based on these estimates likely indicates a slightly declining to static rate of increase overall.

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DISCUSSION

Low fawn survival has been suspected to play a role in limiting black-tailed deer populations in Washington (Bender and Hall 2004, Gilbert and Raedeke 2004). Early summer mortality has been suspected as an important factor (Brown 1961, Gilbert and Raedeke 2004). Gilbert and Raedeke (2004) reported that low temperatures in May and frequent precipitation might have reduced fawn survival. Parker (1988) similarly identified that rainfall posed energetic constraints for deer in summer pelage. Poor nutrition has also been cited as a contributing factor. Poor doe body condition may result in decreased numbers of fetuses, lower rates of twinning, increased pre-natal fawn mortality, low birth mass, later birth dates, decreased post natal care, increased fawn abandonment, and lowered rates of mass gain all of which may lower pre-weaning fawn survival (as cited in Bender and Hall 2004). Habitat conditions were shown to limit mule deer populations in New Mexico due to poor condition of females and consequently low survival of fawns (Lomas and Bender 2007).

Results from this study indicated that non-predation related natural mortality was the second leading cause of mortality overall, accounting for almost 20%. The majority of these occurred during the first 9 weeks of life, and largely occurred in 2009 compared to the first 3 years (Table 3). In 2009, spring and summer were uncharacteristically hot and dry, contradicting models that predicted greater fawn mortality during cold, wet spring and summer weather (Gilbert and Raedeke 2004). Additionally, winter 2009-10 was dryer and warmer than normal, without snowfall accumulation, and fawn survival did not decline sharply as in the previous 3 years (Figure 2). Our data also indicated that fawn production in 2009 may have been affected by weather by influencing doe condition. The 2009 cohort had the lowest mean capture weight of all years and twinning rates were lowest. The winter of 2008-2009 preceding the 2009 fawning season, was colder than normal and characterized by significant and persistent snow from late December into January. Future models should incorporate spring temperature and rainfall as well as winter severity to determine if these factors are influencing early fawn mortality. Direct mortality from natural causes was only recorded 3 times throughout the fall and winter timeframe and all of these fawns had HLS.

Capture records and subsequent monitoring of radiocollared fawns indicates a fairly high proportion of twinning occurs (62%). However, may have been influenced by winter severity preceding the 2009 cohort as addressed previously. A concurrent study involving radiocollared adult does also indicate consistent yearly reproduction and high occurrence of twinning (R. McCoy, unpublished data). Thus, doe condition does not appear to be limiting initial production of fawns within the study area in most years. Modeling indicated that Julian date of birth did not account for variability in early fawn survival, but weight-at-birth did. Data show that early mortality was negatively correlated to lighter mean birth weights. In addition, we tested a posteriori model incorporating weight at birth and Julian date of birth to see if there was an interaction between these covariates and age at mortality. This model performed better than our original a priori model set indicating that smaller fawns born later suffered higher rates of mortality than heavier fawns or those born earlier. This suggests a potential advantage to

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heavier fawns and to fawns born earlier, both of which are consistent with a healthy deer population.

Interestingly, both Bender and Hall (2004) and Gilbert and Raedeke (2004) did not indicate predation might play a significant role in fawn recruitment, which the results of this study do seem to support. Hatter (1988) found that predation was affecting black-tailed deer fawn survival and recruitment on Vancouver Island, British Columbia, which has similar habitat and environmental conditions to the Olympic Peninsula in Washington. Numerous studies have indicated that predation is a major factor influencing fawn survival (Nelson and Woolf 1987, Hatter 1988, Whitaker and Lindzey 1999, Vreeland 2002, Rohm et al. 2007). Important predators identified have been the gray wolf (*Canis lupus*; Hatter 1988), mountain lion (this study, Temple 1982), coyote (Cook et al. 1971, Whitaker and Lindzey 1999, Vreeland 2002, Rohm et al. 2007), bobcat (this study, Trainer et al. 1981, Temple 1982, Vreeland 2002, Roberts 2007), and black bear (Temple 1982, Kunkel and Mech 1994, Vreeland 2002). Typically, most studies have implicated coyotes as the major predator responsible in the absence of wolves. This study is the first to implicate mountain lions as a major predator for fawns (Ballard et al. 2001); however, this should not be surprising, as mountain lions are known to predate all age classes of deer (McKiney 2001). Recently, Knopff et al. (2010) documented that cougar predation patterns varied by seasons and cougars killed 1.5 times more frequently in summer when juvenile ungulates dominated the diet. Bobcats were the second leading mortality source. This is consistent with other studies; however, most have reported bobcat predation as important within the first few months of life, while we documented bobcat predation during the winter and early spring timeframe. This may be explained by the fact that few studies track fawn survival over a year, rather recruitment is estimated to hunting season. Roberts (2007) found bobcat predation to be the primary limiting factor in fawn recruitment, leading to static population growth of a deer herd on Kiawah Island. Witmer and DeCalesta (1986) reported black-tailed deer were found in 22.2% of the bobcat scat during the winter in Oregon. While scavenging could account for presence in scat, bobcats have been reported to kill deer and other ungulates throughout the year (Anderson 1987, Blankenship 2001). Black bear and coyote were both minor sources of predation in this study. Habitat use may have played a role in limiting black bear predation. A study occurring on the Makah Reservation with radiocollared black bears has indicated very little use of young seral stages following clearcut harvesting. Bears seem to prefer older regenerating clearcuts and forested stands (R. McCoy, unpublished data) similar to results reported by Heyden and Meslow (1999). Black bear are also subject to intensive management through damage control hunts every spring within the study area. Black bears cause significant damage to regenerating tree crops and are regularly removed. Over time this has likely reduced black bear numbers in the study area and decreased their influence on juvenile deer survival. In contrast, black-tailed deer prefer younger seral stages and fawning regularly occurred in these habitats. Coyote predation was expected to be higher, particularly during the first 9 weeks. Coyotes are observed within the study area; however, the size of the population is unknown. Coyotes are visual predators (Wells and Lehner 1978) and with a fairly high proportion of young seral stands where fawns were commonly born it would seem to favor coyote predation. Potential explanations are the amounts of logging slash left after timber harvest and/or

the rapid regeneration of ferns, shrubs, grasses, and herbs which limit visual field of view or alternative prey availability (Hamlin et al. 1984). Additionally, some of the unknown predation events could have been coyote, where positive identification was not possible or carcasses were not recovered.

Several research studies have indicated that fawns are most vulnerable during the first 60 days. In this study, predation accounted for 68% of the mortality events during the first 4 weeks of life and survival over this time frame was 82%. Rohm et al. (2007) reported similar results in Illinois, where predation by coyotes was listed as the primary source of mortality for white-tailed deer fawns and survival to 4 weeks was approximately 78%. Whitaker and Lindzey (1999) indicated survival of mule deer and white-tailed deer fawns was 66% and 34%, respectively, through the first 4 weeks in Colorado. Coyotes were responsible for 79% of all fawns dying. Vreeland (2002) studied white-tailed deer fawn survival in 2 landscapes in Pennsylvania: agricultural and forested. Fawn survival within agricultural landscapes was higher, however, in both instances fawn survival was lowest during the first 4 weeks averaging about 75%. Important predators were black bear, coyote, and bobcat. Hatter (1988) studied black-tailed deer fawns on northern Vancouver Island. The majority of mortalities occurred during the first 4 weeks of life with survival estimated at approximately 62%. Predation accounted for 63% of all mortalities by the end of August. Wolves were the primary species preying on fawns. While early loss of life is common, the timing of loss is not always equivalent between studies. In this study, fawn mortality rates declined after 5 weeks in year 1 but remained high through week 8 in year 2 and 3 and through week 11 in year 4, similar to those seen in other studies (Hatter 1988, Nelson and Woolf 1987). In addition, the highest mortality rate throughout the first 9 weeks occurred at different times each year including week 4 in years 1 and 3, week 2 in year 2 (similar to results seen by Rohm et al. 2007), and weeks 8-9 in year 4. Early loss of young from predation has also been reported in other species of ungulates. Jornemo and Liberg (2005) reported red fox were affecting roe deer (*Capreolus capreolus*) survival accounting for 88% of total mortality. Swenson et al. (2007) found that 92% of brown bear (*Ursus arctos*) predation on moose calves (*Alces alces*) took place in the first month of life in Sweden.

Few studies follow fawns to recruitment as yearlings for comparative purposes, most studies estimate survival to approximately 26 weeks or even shorter timeframes. Comparisons among species of deer for survival to 4-9 weeks appear to provide fairly consistent results. However, differences exist for survival beyond this timeframe with studies occurring in agricultural landscapes providing different estimates than those in forested landscapes (Table 8). Forested landscapes may have lower habitat quality and predator densities may be higher (Vreeland 2002). Fawns may also be less vulnerable in agricultural landscapes due to habitat conditions that favor fawns survival due to dense ground cover, better foraging conditions resulting in increased body condition, or lower populations of predators (Vreeland 2002, Burroughs et al. 2006).

Table 8. Estimates of white-tailed and black-tailed deer survival rates at specific intervals from British Columbia, Canada and the USA (including this study).

Landscape	Species	13 weeks	26 weeks	Annual
Forested				
This Study–(2006-2009)	Black-tailed	57.8	51.4	33.0
Vreeland (2002)	White-tailed	54.0[a]	45.6	27.7
Ballard et al. (1999)	White-tailed	59.0[a]	40.0	23.4
Hatter (1988)	Black-tailed	42.0[a]	40.0[a]	
Agricultural				
Vreeland (2002)	White-tailed	70.0[a]	58.6	52.9
Burroughs et al. (2006)	White-tailed	93.5[a]	90.5	75.5
Rohm et al. (2007)	White-tailed	64.0[a]	59.0[b]	

[a]Estimated values from figures within cited source.
[b]Reflects survival to 19 weeks not 26 weeks.

Results from this study indicate that survival was somewhere between forested and agricultural landscapes through 26 weeks. The habitat conditions within the study area may partially explain some similarity with agricultural conditions. Young seral age classes of regenerating timber are heavily represented. Typically, these regenerating stands have significant slash left after logging and ferns, shrubs, grass, and herbs quickly re-colonize. This may provide fawns with security cover and increase their ability to escape predation after the first 4 weeks of life, despite the diverse predator community present within the study area. By recruitment age, however, fawn survival in this study is similar to other studies in forested landscapes indicating a significant change in over winter fawn survival. Model $S_{age-3\ intervals\ winter\ x\ year}$ best captured the variability in fawn survival reflecting a decline at a more rapid rate during the winter (Dec 1 through Feb 28) and corresponding HLS timeframe. The survival rate during this period of time was similar to the survival rate from birth through the first 9 weeks of life, resulting in a bimodal distribution of peak mortality rates (Appendix F).

Winter has been indicated as a potentially limiting time frame for fawns when they are in poor condition (Ballard et al. 2001). Body condition of black-tailed deer has been shown to decline during the winter. Brown (1961) reported average winter weight loss of 9-10% for fawns, between 7-12% for yearling and adult does, and 9-14% for yearling and adult bucks. Roosevelt elk (*Cervus canadensis roosevelti*) diets have been investigated within the study area (Hutchins 2006) and overlap exists with the diet for black-tailed deer reported by Brown (1961). The amount of digestible energy available in common species of forage drop considerably between November and February (Hutchins 2006) and probably plays a key role in weight loss. Brown (1961) documented substantial winterkill of both black-tailed deer adults and fawns during severe winters, particularly the winter of 1949-50. Mortality following this winter was estimated at 26-30% within the area investigated. The 2008 cohort did experience a significant snow event with accumulations persisting for several weeks from late December into January of 2009. The major decline in fawn survival during the winter of 2008-2009 occurred during this timeframe (Figure 2).

The majority of winters in western Washington are not as severe and snowfall does not typically limit access to forage for deer. However, mortalities investigated after December showed signs of malnutrition upon examination of the bone marrow, including 100% of the HLS afflicted fawns and 78% of the fawns not afflicted. Even though predation played a large role in influencing survival of black-tailed deer fawns during the winter, it may be the proximate cause of mortality, particularly during the HLS timeframe. Interestingly, only 9 fawns (20%) not afflicted with HLS died out of 46 at risk from December 1 to April 1, while 16 fawns (43%) out of 37 afflicted with HLS died. The statistically significant difference in survival among HLS and non-HLS fawns is also biologically significant, given that HLS animals died at a higher rate and all were visibly in much poorer physical condition than fawns that were not afflicted. HLS puts tremendous physiological stress on afflicted deer (Bildfell et al. 2004) and the constant licking and scratching has been linked to a reduction in the amount of time spent feeding (Murphie 2010). Thus, the poor body condition of fawns, particularly those affected by HLS, probably contributes to an increased risk of predation and considering a 45% incidence rate among study fawns, may explain low rates of recruitment. The low number of fawn deaths due to natural (non-predation) causes during the winter (n=3) was surprising. The majority of fawns with HLS that survived to April were known to be alive in June and clinical signs of hair loss were gone with the growth of summer pelage. This suggests that in the absence of predation many fawns may be able to survive the extreme physiological stresses of HLS during relatively mild or average winters. The data also suggests that HLS in concert with unusual and persistent accumulations of snow may be particularly devastating to winter fawn survival.

The overall trend of the population appears to be slightly declining to stable based on the data collected to date. Managers in Washington have noted the apparent downward trend in black-tailed deer populations and speculated that HLS may play a key role by limiting recruitment (Washington Department of Fish and Wildlife 2009). This study indicates that early fawn mortality followed by a significant secondary pulse of winter fawn mortality combine to limit black-tailed deer population growth rates. The evidence suggests that in the absence of HLS more fawns would survive the winter timeframe and provide for improved population growth rates. Additionally, intensive management of predator populations which improve both early and winter fawn survival rates may provide for improved population performance.

Ballard et al (2001) conducted an extensive review of literature pertaining to deer predator relationships that suggested predation does not cause population declines, particularly in altered ecosystems such as those present within the study area. However, they cited a number of sources indicating predation can be an important mortality factor when populations have declined due to other variables by retarding or preventing population recovery. Hamlin and Mackie (1989) and Mackie et al. (1998) suggested there was the potential for predation to influence deer population trends and that multiple predator species could exert greater and more consistent pressure than that exerted by single predator systems. Hamlin and Mackie (1989) indicated predation combined with even low to moderate levels of other mortality could be sufficient to further reduce low

density deer populations, or at least keep them from increasing. Another factor could be alternative prey availability, particularly for mountain lions. Weilgus (2007) monitored sympatric mule and white-tailed deer populations to explain decreasing mule deer populations in eastern Washington. Results suggested that invasion by white-tailed deer lead to increased mountain lion numbers and predation on mule deer. Our study area supports a healthy and growing population of Roosevelt elk, which may sustain greater mountain lion densities regardless of a declining population of black-tailed deer.

This study seems to provide preliminary evidence that the local deer population may benefit from predator control, particularly of mountain lions and bobcats. Targeted removal may improve recruitment of black-tailed fawns and subsequently increase total deer populations on the northern Olympic Peninsula, Washington. Deer numbers, within the study area, do not appear to be at or near carrying capacity based on fawning rates, survival to the winter timeframe, and habitat conditions (amount of early seral stage stands). However, this evidence is largely based on anecdotal evidence and additional study into the influence of habitat conditions and winter severity on fawn production may be warranted, particularly considering the influence of weight at and timing of birth on early fawn survival. Regardless, predator control is costly, difficult to maintain, unpopular with some of the public, and may not be the answer. When control of mountain lions was implemented in eastern Washington to reduce both mule deer declines and human/mountain lion interactions it was largely unsuccessful (Weilgus 2007). The female mountain lion population growth rate declined as a result of heavy hunting but the total number of mountain lions was not reduced. The age structure simply shifted towards numerous immigrant and sub-adult males. In 1996, Voter Initiative 655 banned the use of dogs for recreational hunting (Washington Department of Fish and Wildlife 2003). Even with the elimination of hound hunting, mountain lion harvest has been similar due to increases in season lengths, only the sex and age classes harvested has changed (Washington Department of Fish and Wildlife 2003). Knopf and Boyce (2007) indicated that specialization by some mountain lions could have substantial impacts on alternate prey in multi-prey systems. They suggested that general mountain lion reductions will have minimal impact on predation; however, targeted hunting of specialists using trained hounds is probably a much more effective method. Identifying specialists could be labor intensive but may be possible through DNA from scats found at mortality sites. Continued monitoring of fawn survival and cause-specific mortalities will be important to determine the impacts of implementing a predator control program as well as identifying any substitution of alternative predators such as coyotes or bears.

Managers should continue to be conservative in terms of antlerless harvest to minimize human impacts where black-tailed deer populations appear to be struggling. Sex-age-kill modeling in Washington currently uses pre-hunting season fawn:doe ratios to estimate recruitment. This study indicates that pre-hunting season survival is not indicative of recruitment to the yearling age class. Recruitment can play a key role in the precision of population estimates (Millspaugh 2006) particularly since it can be highly variable and can account for significant variation in population rates of increase (Unsworth et al. 1999, Gaillard et al. 2000, Raithel et al. 2007). Managers should consider adjusting the SAK model to account for the variability in fawn survival over the winter timeframe.

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Appendix A. Table showing a summary of fawn capture statistics from 2006-2009 on the northwest Olympic Peninsula, WA.

	2006	2007	2008	2009
Number captured	50	50	66	62
Mean capture date	3 June	2 June	29 May	2 June
Mean date of birth	30 May	30 May	25 May	30 May
Mean age at capture (days)	3.7	3.3	4.0	3.1
Mean weight at capture (kg)	4.17	4.14	3.94	3.71
Mean weight at birth (kg)	3.13	3.12	2.76	2.84
Sex ratio (M:F)	1-1	0.92-1	1.4-1	0.72-1
Twinning rate	0.76	0.68	0.72	0.31
Number of Fawns/Doe	1.7	1.6	1.6	1.3

Appendix B. Table showing the capture and birth weights of all male and female fawns by year from 2006-2009 on the northwest Olympic Peninsula, WA.

	2006	2007	2008	2009
Mean capture weight - Males	4.49	4.26	3.91	3.77
Mean capture weight - Females	3.85	3.96	3.94	3.65
Mean birth weight - Males	3.48	3.18	2.81	2.90
Mean birth weight - Females	2.77	3.08	2.68	2.78

Appendix C. Detailed information regarding specific causes of death in black-tailed deer fawns from 2006-2009 on the northwest Olympic Peninsula, WA.

In 2006, human caused mortalities were the illegal harvest of two fawns and one capture myopathy. The myopathy was related to a recapture during the winter to place a yearling collar on a fawn that was in danger of losing its fawn collar. The fawn was in poor condition and was found dead 24 hours later.

In 2007, two of five fawns classified as natural non-predation mortalities were sent to the Washington Animal Diseases Diagnostic Laboratory (Washington State University, Pullman, Washington). The findings for one fawn were a severe deficiency in adipose tissue stores, leading to the conclusion that the animal's death was the consequence of a negative energy balance. In the second fawn, the most important histological abnormality was hyperbilirubinemia and erythrophagoscytosis in the liver. Liver sections were stained and the antigen detected with immunohistochemistry was *Leptospira* sp. indicating *Leptospira* sp. was the cause of death.   The one fawn classified as unknown had signs of major trauma (substantial bruising) and was completely intact with no signs of predation.

In 2008, we submitted five fawns to the USGS National Wildlife Health Center (Madison, Wisconsin). Two of these fawns were siblings, found opportunistically as they had died immediately after being born and exhibited characteristics consistent with piebald anomaly including severe skeletal and internal organ malformations. These two fawns were not included in the sample of 228 fawns. Two other fawns had pneumonia, one of which may have been caused by a bacterial infection. The cause of death was not determined for one fawn, which appeared to be emaciated, but had not been abandoned due to milk found in the stomach.

In 2009, we submitted 12 fawns to the USGS National Wildlife Health Center (Madison, Wisconsin), 10 less than 9 weeks old and 2 over 6 months old. The majority of the younger fawns were in poor nutritional condition and had multiple nutritional deficiencies, including mineral abnormalities such as reduced levels of cadmium, cobalt, molybdenum, selenium, phosphorus and vitamin E, and increased levels of calcium and iron. Five of these fawns had suppurative bronchointerstitial pneumonia caused by bacteria *Staphylococcus aureus* and *Streptococcus sp.*, one fawn had pneumonia and meningitis caused by *Pasteurella multocida*, one fawn had hepatitis, and one fawn had an abscess with cultured *Clostridium* bacteria. The cause of death for one fawn was unknown, it was found to be in good condition and had not been abandoned, but suffered the same mineral deficiencies as those listed above. We have not received results from the 2 older fawns, but both were considered to be emaciated with a heavy infestation of lice.

Appendix D. History of fawns from 2006-2009 afflicted with HLS including survival, mortality information, and indication of malnutrition on the northwest Olympic Peninsula, WA.

Fawn	Year Cohort	Survived	Date of Mortality	Mortality source	Malnutrition
69743	2006	Y			
69034	2006	N	8-Jan-07	Bobcat	Y
69063	2006	N	3-Mar-07	Bobcat	Y
69831	2006	Y			
69134	2006	Y			
69104	2006	N	19-Jan-07	Bobcat	Y
69143	2006	Y			
69153	2006	N	7-Jan-07	Mountain lion	Y
69993	2006	N	22-Feb-07	Unknown	U
69173	2006	Y			
78563	2007	N	1-Apr-08	Unknown	U
79547	2007	Y			
79503	2007	Y			
78493	2007	N	04-Feb-08	Bobcat	Y
79572	2007	N	19-Feb-08	Unknown Feline	Y
78605	2007	N	27-Jan-08	Mountain lion	Y
78414	2007	Y			
78212	2007	Y			
78586	2007	Y			
79224	2007	Y			
79423	2007	N	01-Feb-08	Mountain lion	Y
88652	2008	Y			
89033	2008	N	05-Jan-09	Unknown Predation	Y
89105	2008	Y			
89163	2008	N	05-Jan-09	Natural-Poor Condition	Y
89184	2008	Y			
90060	2009	Y			
98013	2009	N	28-Mar-10	Natural-Poor Condition	Y
98025	2009	N	28-Mar-10	Mountain Lion	Y
98072	2009	Y			
98084	2009	Y			
98092	2009	N	13-Feb-10	Bobcat	Y
98234	2009	N	14-Jan-10	Natural-Poor Condition	Y
98344	2009	Y			
98393	2009	Y			
98542	2009	Y			
99413	2009	Y			

Appendix E. History of fawns from 2006-2009 not afflicted with HLS including
survival, mortality information, and indication of malnutrition on the northwest
Olympic Peninsula, WA.

Fawn	Year Cohort	Survived	Date of Mortality	Mortality source	Malnutrition
69723	2006	Y			
69044	2006	N	8-Dec-06	Unknown predation	N
69752	2006	Y			
69953	2006	Y			
69913	2006	N	5-Mar-07	Mountain lion	Y
69624	2006	Y			
69645	2006	N	3-Jan-07	Bobcat	Y
69962	2006	Y			
69164	2006	Y			
69814	2006	Y			
69203	2006	N	14-Dec-06	Unknown predation	N
78014	2007	Y			
79303	2007	Y			
78513	2007	Y			
79403	2007	Y			
78313	2007	N	14-Mar-08	Unknown Feline	Y
78502	2007	Y			
78344	2007	Y			
79364	2007	Y			
79324	2007	N	10-Feb-08	Mountain lion	Y
78254	2007	Y			
78544	2007	Y			
81701	2008	Y			
81941	2008	N	03-Jan-09	Unknown Predation	Y
88013	2008	Y			
88043	2008	Y			
88173	2008	Y			
88194	2008	Y			
88263	2008	N	02-Jan-09	Unknown Predation	Y
88563	2008	Y			
88575	2008	Y			
89044	2008	Y			
89204	2008	Y			
89302	2008	Y			
90003	2009	Y			
90043	2009	Y			
90070	2009	Y			
98134	2009	Y			
98172	2009	Y			
98273	2009	Y			
98424	2009	Y			
98434	2009	Y			
98494	2009	N	19-Feb-10	Bobcat	Y
98513	2009	Y			
98554	2009	Y			
99741	2009	Y			

Appendix F. Graph of the probability of mortality by week for fawns on the northwest Olympic Peninsula, WA, showing the bimodal distribution of peak mortality in the first 9 weeks and weeks 30-42.