

*****REVISED FINAL STUDY PLAN, Vers. 10/20/00***¹**

**ASSESS DEMOGRAPHIC AND PHYSIOLOGICAL STATUS
OF COLUMBIAN BLACK-TAILED DEER IN
OLYMPIC NATIONAL PARK**

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ABSTRACT

Reliable information on Columbian black-tailed deer (*Odocoileus hemionus columbianus*) populations is needed in Olympic National Park (NP) to assess prey available to support potential wolf reintroduction, interpret human/cougar interactions, and assess population consequences of disease/parasites. The need for information is accentuated by an apparent decline in the deer population, frequent observations of debilitated deer, and the highly politicized nature of wolf reintroduction. The proposed research will develop estimation methods for deer population size in coniferous forest habitats; estimate deer population size on park wintering areas; and describe factors that influence the health of park deer populations. This project will yield methods that can be applied in other areas needing to survey ungulates that are not visible from the air, and will provide information that is critical for a high-priority and highly visible management issue in Olympic NP.

PROBLEM STATEMENT

Deer and elk are dominant features, if not keystone species (Power et al. 1996), of coniferous forest systems of Olympic NP. They profoundly influence forest landscapes and vegetative structure in Olympic NP through herbivory (Happe, 1993, Schreiner et al. 1996, Woodward et al. 1994). The Columbian black-tailed deer is also primary prey of healthy cougar and bobcat populations in Olympic NP, and presumably was an important prey of the gray wolf before its extirpation in the 1920's.

¹This revision is based on final study plan that include responses to all peer-review comments plus additional comments by Lyman McDonald provided 05/08/00 and 5/16/00. This also includes some after the field season modifications and accurately reflects the actual procedures.

Researchers see fewer deer now than in the 1980's in some areas of the park, suggesting the population may have declined in local areas (K. Jenkins, personal observation). Debilitated deer are observed with symptoms of excessive hair-loss and extreme emaciation (K. Jenkins, unpublished data). Causes of the affliction are unknown. Necropsies suggest that a combination of external and internal parasites and nutritional condition may be involved, but causes of increased vulnerability to parasitism remain unknown. The public is aware of potential problems with black-tailed deer populations in the park and frequently requests information.

Relationships between cougar and deer populations are also of considerable interest in Olympic NP, although population trends are not known for either predator or prey. Visitors and staff reported seeing an average of 38 observations of cougars over each of the last 5 years in Olympic NP, of which 10 each year were observations made at close range and potentially dangerous. Changes in reporting effort in recent years prevent making comparisons to earlier time periods, but observations of cougars appear higher today than during previous decades (P. Happe, Olympic NP, Personal Communication). Better information is needed on deer population trends to understand long-term changes in predator and prey systems in Olympic NP.

Park managers require reliable information on the status of black-tailed deer not only for basic inventory needs, but also to assess feasibility of recurring proposals to reintroduce wolves to Olympic NP. The idea to restore wolves to Olympic NP has persisted since before the park was established (A. Murie, unpublished, 1935; D. Allen, unpublished, 1981). The most serious proposal in 1997 led to the completion of studies to assess feasibility of restoring the gray wolf to its historic range on the Olympic Peninsula (Ratti et al. 1999) and preliminary prey base research (Jenkins et al. 1999). The feasibility study was greatly hampered by absence of information on abundance and life history parameters of deer. Authors of the report concluded that "Deer populations within Olympic National Park are virtually unstudied and their populations could not be ascertained with any hope of accuracy. Any decision to re-introduce wolves should be preceded by an effort to gather the most basic data on the deer and elk of the Olympic Peninsula. At a minimum deer should be studied within the Park and generally throughout the peninsula." (Ratti et al. 1999:215).

This study will improve understanding of status and physiological health of black-tailed deer populations in the park, and will provide methods of monitoring deer population trends. Such information is needed to assess feasibility of wolf restoration, better understand deer/cougar/human interactions, and address public concerns regarding deer populations.

DESCRIPTION OF RECOMMENDED PROJECTS

The goals of the proposed project are to:

- Estimate abundance of black-tailed deer and Roosevelt elk populations using pellet group surveys.
- Evaluate persistence of deer and elk pellet groups.
- Identify factors influencing physical health of black-tailed deer in Olympic NP.

- Recommend program for monitoring abundance and health of black-tailed deer.

Estimate abundance of deer and elk pellet groups and population size

Background: USGS and Olympic NP recently completed a 1-year pilot study evaluating methods for estimating black-tailed deer populations in the park (Jenkins et al. 1999). Of 3 potential methods of estimation (i.e., mark-resighting sampling, line-transect distance sampling, and pellet-group sampling), only pellet group sampling appeared potentially suitable for widespread use at a park-wide scale (Jenkins et al. 1999). Mark-resighting sampling and line-transect distance sampling were hampered by high costs of deer capture and low encounter rates with deer, particularly in areas of moderate to low deer densities. Pellet group counts, when adjusted to include only certain decay classes of pellets, provided indirect estimates of deer density that agreed closely with direct estimates derived from mark-resighting and distance sampling (Jenkins et al. 1999).

Concerns over the utility of pellet group surveys focus primarily on variability in both the persistence of pellets and visibility of pellet groups. Variation in persistence of pellets and visibility affect both accuracy and interpretation of pellet group counts and must be given careful consideration in the design of pellet group surveys (Harestad 1987).

Indirect estimation of deer density from pellet counts requires estimation of both daily defecation rates of deer as well as duration of pellets in the sampling interval and plots under study. To improve reliability of population estimates from fecal sampling, plots should be cleared at the start of the sampling interval and care must be taken to ensure the sampling interval is not so long that pellets disappear within the interval (Harestad et al. 1987). Unfortunately, clearing plots is costly, time-consuming and not always feasible, particularly in large wilderness areas where extensive winter travel is not practical. Although clearing of plots improves reliability of interpretations, raw counts of pellet groups on uncleared sample plots have been used to indicate trends in relative abundance of deer over time (Kirchhoff 1990).

Visibility biases associated with pellet group counts (probabilities of missing pellet groups) may range as high as 10-48% in pacific coastal forests (Kirchhoff 1990), which could severely bias either indirect estimates of deer density or of pellet group density as a relative index of abundance. Therefore, detection biases should be incorporated into the design and analysis of pellet group surveys.

Study Approach and Design: We will estimate abundance of deer and elk pellet groups on available winter ranges below 2000 feet elevation in Olympic NP. Previous radio-telemetry studies indicate that the area below 2000 ft encompasses the primary winter range of deer and elk (Jenkins and Starkey 1984, Jenkins et al. 1999).

We will estimate abundance of black-tailed deer and Roosevelt elk pellet groups in associated studies of cleared and uncleared pellet-group plots. We will estimate abundance of deer and elk indirectly by clearing pellet-groups from a sample of plots and thereby establishing a known time interval for pellet deposition (Harestad et al. 1987). Because of logistical constraints, cleared

plots will be randomly selected from accessible parts of the winter range only (elaborated below).

We will, however, estimate abundance of pellet groups in uncleared plots randomly throughout all winter ranges to examine geographic patterns in relative abundance of deer and elk, and to establish a baseline for long-term monitoring of population trends at a parkwide scale. Further, we will determine statistical relationships between counts made in previously cleared and uncleared pellet-group plots to evaluate the reliability of using statistical models to estimate deer and elk abundance from uncleared pellet-group plots. Specifically, double sampling statistical procedures and the relationship between density of pellets on cleared and uncleared subplots will be used to extrapolate densities of pellets in the uncleared plots of the inaccessible strata to the entire inaccessible strata. These methods are elaborated below.

We will estimate density of deer and elk pellet groups separately within two geographic regions of the park's available deer and elk winter range: west-side drainages (Quinault, Queets, Hoh, Bogachiel, Calawah Rivers), northern/eastern drainages (Soleduck River, Lake Crescent, Elwha River, Little River, Morse Creek, Grey-wolf, Duckabush, Dosewallips, and Skokomish Rivers) (Figure 1). Those three regions partition gradients in precipitation and elk density that decrease from west to east, and presumed gradients in deer density that increase from west to east (Tabor and Raedeke 1980). West-side drainages differ from those in the north and east by having broad floodplain terraces, (up to 4 km across), distinctive old-growth temperate rainforest communities (Fonda 1974), high densities of elk that maintain high vegetation diversity (Schreiner et al. 1996), and ostensibly, low densities of deer. North and east-side drainages are narrower, have steeper gradients, and support fewer elk.

We will use a two-staged sampling procedure to estimate abundance of deer and elk pellet groups within each park region (Skalski 1994). We will sample pellet group abundance within 16-ha (400x400-m) primary sample plots distributed using stratified random sampling procedures among 6 sampling strata in each park region. Within plots we will subsample using variable sampling intensity that will depend primarily upon sampling time available. Optimally, at least 2 200-m line transects will be located within suitable areas (slopes $<35^\circ$) arranged in parallel 50-m apart. Transects may be shortened if darkness prevents completion within a single day. More than 2 transects and shorter transects may be substituted if unsuitable terrain precludes using the longer transect. The total length of transect within a randomly selected sample plot is the independent sample unit.

During the first year, we will sample approximately 20 primary plots in each park region (40 plots total). We will allocate sampling plots among three strata that partition the difficulty of human access to the deer/elk winter ranges, and two strata that partition the elevational gradient within each accessibility stratum. The strata are:

- High Accessibility/Low elevation
- High Accessibility/High Elevation
- Moderate Accessibility/Low elevation
- Moderate Accessibility/High Elevation
- Low Accessibility/Low Elevation
- Low Accessibility/High Elevation

We define high accessibility as sampling plots with centers within 1.5 km of a park road,

moderate accessibility as those with centers within 1.5 km of a park trail (up to 20 km from trailhead, and low accessibility as all other sampling plots. We define low- and high-elevation strata as <1000 and 1000-2000 feet elevation, respectively. During the first year, we plan to sample about 10 plots in the high and moderate accessibility strata in each geographic park region. Within accessibility strata, we will allocate high and low elevation plots in proportion to area within strata. During the second year, we will adjust sampling effort among strata based on optimal allocation formula (Cochran 1977:96). Areas of each sampling stratum (units of 400x400 potential sampling plots) have been determined using the Geographic Information System (GIS) at Olympic NP. Those areas are shown in appendix A.

During December 2000 and 2001, we will clear all deer and elk pellet groups from alternating 20-m segments of one transect in each sample plot in accessible strata. Optimally, we would clear pellets from a subsample of transects drawn from all pellet group plots throughout the park. Unfortunately, it is not feasible to visit backcountry plots during mid-winter, so we will limit cleared plots to accessible front-country areas.

During March 2001 and 2002, we will count pellet groups present in all sampling plots, including previously cleared and uncleared transect segments in both the accessible and moderately accessible strata. The resulting pellet sampling interval on cleared plots (approximately 90 days) reflects estimated persistence times of deer and elk pellets in Pacific coastal forests. Although persistence of black-tailed deer pellets has not been measured locally, 90% of Roosevelt elk pellets persist 130 days during winter in the wettest region of Olympic NP (Lehmkuhl et al. 1994). Pellets of black-tailed deer persist throughout winter in a region of somewhat lower precipitation on Vancouver Island (i.e., ~229 cm/year; Harestad et al. 1987).

Field Sampling Methods: As mentioned, we will establish sample plots in the accessible strata in November/December each year so that selected 20-m transect segments may be cleared of pellet groups at the beginning of a defined sampling interval. Center lines of transects will be flagged with ground-wire stakes every 10m so they can be relocated precisely at the end of the sampling interval. Two observers will search and mark pellet groups on each subplot to help insure that all pellet groups are detected and marked. The two observers will 'clear' plots in a manner that will allow us to obtain a preliminary assessment of visibility biases. The two observers will independently 'clear' pellet groups by each marking locations of all detected pellet groups on gridded plot maps. The independent maps will be compared and combined to determine the collective pool of existing pellet groups as well as pellet groups 'missed' by each individual observer. The preliminary assessment of visibility biases will be determined using logistic regression approaches described below and will be used to determine how much effort will be required during the March sampling to determine visibility biases reliably. Observers will record the same characteristics of pellet groups as described below.

The ability of observers to detect pellet groups of deer and elk is likely influenced by distance of pellets from the transect line (Jenkins et al. 1999), pellet group characteristics, vegetation, and observer (Kirchhoff 1990). During March sampling, we will collect data in a manner to permit analysis of such visibility biases. Field methods will be the same for previously 'cleared' and uncleared subplots, with the one exception that on previously 'cleared' plots it will be necessary

to determine if each pellet group detected was previously marked and therefore deposited before the sampling interval. Observers will make that distinction by comparing field maps of all detected pellet groups obtained from the two sample periods. Each transect will be marked incrementally by pulling a fiberglass 100-m tape and staking it down every 20 m. A primary observer will be assigned to each transect who will be responsible for searching the entire length of transect for pellet groups. Primary observers will search simultaneously but independently on adjacent parallel transects. Observers will be coached to focus their search directly on the line transect (0-20 cm either side), while recording perpendicular distances of all pellet groups observed up to 1.5-m from the transect line. Observers will map locations of all observed pellet groups on scaled maps of each transect segment, using the base transect and a hand-held meter stick to assist with mapping. Primary observers will also record the following ancillary variables for each pellet group observed:

- species (black-tailed deer or elk)
- distance of pellet-group center from transect
- number of pellets detected within 1 m of first detected pellet
- dispersion of pellets indexed as maximum diameter (cm) of area covered by pellet group. For areas greater than 1 m, record >100.
- decomposition class of pellet group, classified as:
 - Class 1: Pellet surface smooth, shiny, green/brown or brown. Pellet interior consistently same color as surface, firm consistency.
 - Class 2: Pellet surface smooth, brown. Pellet interior brown, spongy but not crumbly.
 - Class 3: Pellet surfaces rough or pitted, brown or blackened. Pellet interior brown, spongy or friable, but <10% of individual pellets partially decomposed.
 - Class 4: Pellet surface cracked, blackened. Pellets crumbly. 10-50% of pellets partially or completely decomposed.
 - Class 5: Like above, but >50% of pellets partially or completely decomposed.
- Vegetation obscuration: percent of 30-cm rule, lying horizontally centered on pellet group, that is obscured by vegetation <60 cm tall.
- Dominant ground cover (record as: moss, graminoid, forb, low-shrub, bare ground, fine litters (<1cm average diameter), coarse litter (>1 cm average diameter)).

After searching each transect, a segment will be selected at random and searched a second time by an independent secondary observer (i.e., primary observers will swap transects with each serving as a secondary observer). Such double counting provides the basis for evaluating detection biases. The length of double counted transect segments will depend upon the preliminary assessment of visibility biases obtained from the preliminary sample. Secondary observers will search the selected transect segments in the same manner as primary observers, focusing attention on the inner 40-cm band while also recording and mapping locations of all observed pellet groups up to 1.5 m from the transect line, but not recording any other ancillary variables. Following completion of the secondary searches, primary and secondary observers will interpret their recorded maps to determine which pellet groups detected by secondary observers primary observers missed. Primary observers will return to record ancillary variables of 'missed' pellet groups.

Data Analysis: Density of pellet groups will be estimated in the field, corrected for visibility bias, and expanded to estimates of deer abundance as appropriate based on the following considerations:

Step 1: Correct for visibility biases. --We will estimate biases in pellet-group density using maximum likelihood estimation for the double-count method with independent observers (Manly et al. 1996). We will model visibility biases as functions of independent ancillary variables of pellet groups (i.e., distance from line-transect, group size, dispersion index), vegetation obscuration and observer using the pooled sample of all double-sampled transect segments. The analysis estimates the probability that a given observer, e.g., the secondary observer, will detect (or not detect) a pellet group as a function of the ancillary independent variables. The dichotomous dependent variable (e., pellet groups seen by the primary observer and then seen or not seen by the secondary observer) is regressed on the ancillary variables using logistic regression models. The roles of the observers are then reversed to estimate the probability that the other ‘secondary’ observer will detect (or not detect) a pellet group as a function of the ancillary independent variables. Finally, the probability that at least one of the two observers will detect a pellet group is estimated to give the visibility correction factor.

We will estimate density of deer and elk pellet groups for individual sample plots based on computed sighting probabilities of individually detected pellet groups, using approaches described by Manly et al (1996:175-176). The visibility correction factor will adjust raw pellet-group counts, n , for the probability of pellet groups being seen by at least one observer. The corrected number of pellet groups (n_{tv}) is the sum of the reciprocal of the correction factor for each pellet group observed on the transect.

$$n_{tv} = \sum_{i=1}^n \frac{1}{(p_{ia} + p_{ib} - p_{ia}p_{ib})}$$

Where p_{ia} is the probability of observer A sighting the i th pellet group, p_{ib} is the probability of observer B sighting the i th pellet group, and $p_{ia}p_{ib}$ is the probability both observers sighted the i th pellet group.

We can also adjust for visibility on transects that did not have both observers using

$$n_{tv} = \sum_{i=1}^n \frac{1}{(p_{ia})}$$

if the observer was A.

Step 2: Estimate pellet-group densities. -- We will estimate mean corrected density and variance of pellet groups in all strata and geographic regions of the park (mean n_{tv}). This refers to the mean density of pellets measured in uncleared plots in March. Although these estimates cannot be used to estimate deer densities (because deposition interval is not considered), these indices of abundance may prove useful for comparing among strata or monitoring trends over time within

geographic park regions. We will estimate variance of pellet density estimates by bootstrap resampling of primary sample plots with each park region (Buckland et al. 1993, Manly et al. 1994).

Step 3: Adjust uncleared pellet group abundance to reflect abundance on 'cleared' plots.--We will explore using standard double sampling statistical analysis methods (Thompson 1992) to adjust abundance of pellet groups measured on uncleared plots to reflect abundance of pellet groups deposited during a known sampling interval. For each geographical region of the park, we will use ratios or regression models to explore relationships between Y (count of new pellet groups that were deposited in the plot during known sampling interval) and X (abundance of pellet groups counted on the same plot as if the plot were not 'cleared'). That ratio can be multiplied by number of pellets counted on uncleared plots to estimate number of pellet groups deposited since the plots were cleared (n_{tvc}).

The issue was raised in a preliminary review of this study plan that low densities of pellet groups may not permit the reliable estimation of correction ratios needed to estimate n_{tvc} . We expect this issue will be most prevalent in the west-side deer ranges. By contrast, higher deer densities and pellet abundance in northern and eastern winter range areas may favor the reliable estimation of n_{tvc} . If double sampling is judged appropriate, the ratio Y/X will be used to adjust the abundance of pellet-groups measured on a larger sample of uncleared sample plots in the inaccessible strata (the same expansion will be used in the accessible strata if time and money permit measurement of additional uncleared plots in the accessible strata during March). If double sampling is judged not appropriate for adjusting pellet densities measured on uncleared plots, the raw counts corrected for visibility biases will be used as an index of population abundance in inaccessible study strata (i.e., stop at Step 2).

Step 4: Compute deer abundance using two-staged sampling design.-- We will estimate abundance of deer in accessible strata of the park based on 'cleared' pellet group counts. We will extrapolate density of pellet groups in cleared plots of the accessible strata to the entire accessible strata using estimation procedures for the two-staged sampling design. The first stage is to convert from number of pellet groups on a subplot scale (2400m²) to plot scale (40,000 m²)

$$n_p = \frac{40000m^2 * n_{tvc}}{2400m^2}$$

Next, we will convert number of pellets per cleared plot per interval (n_p) to number of deer per plot (n_{deer})

$$n_{deer} = \frac{n_p}{d * s}$$

where d is the 'per-capita' daily deposition rate and s is the sampling interval (90 days per interval). We will assume a daily percapita deposition rate of 13 pellet-groups for both black-tailed deer and elk, which is consistent with measurements from black-tailed deer in coastal

Alaska (Kirchhoff 1990) and the general range of values in the literature (12-16/day, Neff 1968). Lastly we will inflate the estimated number of deer per plot to entire accessible strata in each park region based on land areas of each (weights).

We will also estimate numbers of deer in inaccessible strata using the same two-stage estimation methods in any park region where reliable estimation of n_{tvc} is possible using double sampling methods (i.e., as described in Step 3)

Evaluate persistence of deer and elk pellet groups

Background: Reliable estimation of elk and deer abundance from pellet group surveys on cleared plots requires that pellets persist throughout the established sampling interval. Pellets deposited and disappearing within the interval would bias estimates of both pellet-group and ungulate densities negatively.

Study Objectives: The objective of this phase of the study is to verify the persistence of black-tailed deer and elk pellets for at least a 90-day sample interval during winter.

Methods: *Pellet Disappearance.*--We will contrast decomposition of deer pellet groups among four sets of environmental conditions: (1) Low Precipitation Zone, Bottomland Hardwood Vegetation, (2) Low Precipitation Zone, Upland Conifer Vegetation, (3) High Precipitation Zone, Bottomland Hardwood, and (4) High Precipitation Zone, Upland Conifer. Because it will not be possible to describe pellet decomposition among all vegetation communities, our goal is to characterize disappearance rates under widely divergent vegetation conditions to gauge the overall adequacy of 90-day deposition period.

Low precipitation study sites will be located in the Elwha Valley where annual precipitation averages approximately 100 cm/year. High precipitation study sites will be located in the Hoh Valley where annual precipitation averages approximately 340 cm/year. Bottomland Hardwood vegetation will consist of the Red Alder vegetation community in both watersheds. Upland conifer vegetation will consist of the Douglas Fir/Swordfern forest association in the Elwha Valley and Sitka Spruce/Swordfern/Oregon woodsorrel in the Hoh Valley.

We will collect approximately 40 pellet groups from black-tailed deer and Roosevelt elk during November, 2000 and 2001. We will collect only pellet groups deemed <1 week old (i.e., Pellet Decay Class 1). We will store pellets in a refrigerator for up to 3 weeks before they are placed in the field.

We will deposit pellet-groups of deer and elk, each consisting of 50 individual pellets, at 40 sample sites on approximately December 1, 2000 and 2001. The 40 sample sites will consist of 10 sites randomly selected within each treatment group each year in accessible areas (<1 km from road). Deer and elk pellets will be deposited at each site approximately 1 m apart under similar micro-environmental conditions. Pellets will be placed carefully on the understory vegetation in such a manner that most pellets in the group remain visible when viewed from 70-cm above ground (i.e., pellets will not be dropped through coarse woody litter where they cannot be seen).

We will count the number of pellets visible from 70 cm above ground immediately after deposition and every month until pellets are no longer visible. Each visit, the average decay class of the pellet group will be categorized using decay classes described previously.

We will compare disappearance of elk and deer pellets among environmental treatments using confidence intervals on estimates and repeated measures ANOVA with percent of pellets remaining as dependent variable. We will estimate the probability of pellet groups changing from one decay class to the next by fitting proportional hazards models, i.e, by using survival analysis methods to estimate the probability of pellet groups not ‘surviving’ a class and changing to the next class for each of the time periods in the study.

Identify factors influencing physical health of black-tailed deer in Olympic NP

Background: During at least the last 3 years, debilitated deer have been observed in many low-lying areas of Olympic NP, as throughout much of the Puget Sound area (B. Hall, Washington Dept. Fish and Wildlife, Pers. Comm). Post-mortem examination of one 10-month-old male fawn from Olympic NP revealed heavy infestation of lice with bilateral hair-loss over the rib cage and rump, and severe infestation of internal parasites including *Sarcosystis* in the muscle tissues and lungworms (probably *Dictyocaulus viviparus*) in the bronchioles. The necropsy report concludes that the heavy infestation of both internal and external parasites ‘raises questions about the generalized herd health and carrying capacity of the range.’ The authors also note that this region is known to be selenium deficient and selenium deficiency in domestic animals is often associated with a degree of immunocompromise, which may be a complicating factor here as well (J. Quist, unpublished necropsy report, University of Georgia).

Subsequent studies of parasitic larvae in feces of black-tailed deer near Olympic NP reveal heavy seasonal infestation of the lungworm, *Parelaphostrongylus* spp. from late fall-June (B. Foreyt, Washington State University, Pers. Comm.). Although the adult worms have not been identified to species, the worm is suspected to be *P. odocoileus*, a lungworm common to mule deer throughout its range (W. Samuel, University of Alberta, Pers. Comm, and Pybus et al. 1984). The intermediate hosts of *P. odocoileus* are land gastropods, primarily of the genus *Derocerus*, *Zonitoides*, and *Discus* (Samuel et al. 1985). Experimental treatment of 4 captive black-tailed fawns with the anthelmintic drug, *Ivermectin*, during winter eliminated the parasite, stemmed the rate of weight loss, and doubled the mass of treated fawns at end of spring (B. Hall, Washington Dept. Fish and Wildlife, Pers. Comm.). That experiment corroborates indications that *Parelaphostrongylus* is an important factor influencing herd health in the wild.

Field observations suggest that black-tailed deer are more affected by parasites at lower than higher elevations (as manifested by hair loss associated with ectoparasites), young of the year are more affected than older deer, and females are more affected than males (B. Hall, Washington Dept. Fish and Wildlife, Pers. Comm.). We’ve postulated the following potential explanations for those general patterns, assuming that internal and external parasitic conditions are related through immunocompromise associated with internal parasites.

- Migratory life-history strategy influences parasitism. Larval output of *P.* spp. in the feces of

black-tailed deer is greatest from November through June, which suggests that infective larvae will be most plentiful in secondary gastropod hosts from late summer through fall on winter ranges. Fawns of migratory deer that are born in the park's high country may experience reduced exposure to parasitic larvae.

- Elevation and density influence parasitism. Density of deer and incidence of infected intermediate hosts may be greater in moist, productive low-lying habitats in the major river valleys and coastal areas than in comparatively dry uplands.
- Trace mineral deficiencies influence parasitism. This region is known to be selenium deficient, which may be associated with a degree of immunocompromise. Perhaps elevation gradients in trace minerals influence susceptibility to parasitic infestation.

Study Objective: The objectives of this segment of study are to determine relationships of parasitic infestation with life-history strategy, elevation, deer density, and forest community

Methods: We will examine relationships between parasitic infestation and life history strategy by collecting pellets of radio-collared adult female deer whose life-history strategy is known. We currently have 5 radio-collared migratory deer and 5 radio-collared resident deer in the Elwha Valley. We will radio-collar an additional 10 adult female deer during late-fall 2000 and 2001 to maintain a sample of 5-10 deer in each migratory category throughout the study. Although migratory status of each deer will not be known initially, we will focus collaring activities at low (<400m) and high elevations (400-800m) in an effort to target likely residents and migrants. For logistic purposes we will continue to focus studies of migratory versus resident deer patterns in the Elwha drainage. Although it will not be possible to strictly randomize the selection of radio-collared deer, we will attempt to sample deer from each of 10 geographic sampling blocks to ensure adequate spatial dispersion in the sample. The first 'dartable' deer will be selected from each geographic sampling block.

We will capture deer using a remote injection of ketamine hydrochloride (HCl) and xylazine HCl following an existing capture protocol approved by Olympic NP and Animal Use and Care Committee at Oregon State University. Each deer will be fitted with a 500-g radio-transmitter collar. We will assess body condition of each deer using a body condition score determined by palpating the relative amount of subcutaneous tissue in the shoulder, ribs, base of tail and pelvis (Franzman 1985, Gerhart et al. 1996). We will also measure heart girth, body weight, and hind foot length as independent indices of body condition (i.e., heart girth/hind foot length). We will index abundance of external parasites by counting them within 10 2.5x2.5-cm plots at standardized locations on the ventral surface of each deer. We will collect whole blood and hair samples to determine selenium concentrations. Elevation, dominant landform, and forest association (Henderson et al. 1989) will be recorded at each capture site.

We will collect fecal pellet-group samples from each collared deer to compare larval outputs between migratory classes of deer. We will collect pellet group samples monthly from January – April by following collared deer at close range until they defecate or by inspecting known bedding sites for fresh pellet groups. Concentrations of L1-stage larvae in fecal samples will be

determined under contract with the Department of Veterinary Microbiology and pathology at Washington State University using a modified Baermann technique (Platt and Samuel 1978). We will compare larval concentrations in feces of two classes of deer using individual deer as experimental units and monthly collections as temporal replicates in a repeated measures analysis-of-variance. We will compare selenium concentrations in the blood of migratory and resident deer in a two-factor ANOVA with year and migration status as factors.

We will evaluate potential relationships among elevation, pellet density, and larval concentrations from pellet collections made during spring pellet-group surveys. We will collect all pellet-groups judged as Pellet Decay Class-1 (defined above), and will record primary sample unit, elevation, and forest association (Henderson et al. 1989). Concentrations of larvae in fecal samples, as before, will be determined at Washington State University. We will examine relationships between the dependent variable, larvae concentration, and the independent variables elevation and fecal density using linear or non-linear regression models (SAS Inst. 1997). Estimated densities of fecal pellets measured on a primary sample unit will be used as the independent variable of fecal density. Differences in larval concentrations will also be compared among groups of forest associations reflecting gradients in soil moisture using confidence intervals and ANOVA-based models.

Recommend program for monitoring abundance and health of black-tailed deer

We will recommend a program of monitoring abundance and health of black-tailed deer in Olympic NP. Recommendations, based on results of this study, will provide guidance on the need for cleared plots, appropriate deposition interval, sampling requirements, and scale of study. Further, based on results of spatial variation in parasitic larvae concentrations, we will provide separate recommendations for fecal parasites as indicators of individual health of black-tailed deer.

EXPECTED PRODUCTS

An annual progress report of findings will be prepared in 2001. A final peer-reviewed report, including the monitoring recommendations mentioned above, will be submitted at the end of the project term, including copies of all ACCESS data bases and associated metadata. We anticipate publishing peer-reviewed papers summarizing results of pellet-group density estimation and patterns of *P. odocoileus* distribution in Olympic NP.

STAFFING

The project will be a cooperative project of USGS and Olympic National Park (ONP). USGS Wildlife Research Biologist (Jenkins) will supervise the project with cooperation from Olympic NP Wildlife Biologist (Happe). Graduate Research Assistant and/or term-appointed and temporary biological technicians of Olympic NP will conduct fieldwork. We will contract with biometricians to conduct analyses of visibility bias and abundance of deer and elk fecal pellet groups. Concentrations of *P. odocoileus* larvae in deer and elk feces will be measured under

supervision of Dr. William Foreyt at Washington State University.

WORK SCHEDULE

Dates	Tasks
April-May 2000	<ul style="list-style-type: none"> • Prepare study plan/Peer review
June-Sept 2000	<ul style="list-style-type: none"> • Order equipment • Select sample units • Select students/employees
October 2000	<ul style="list-style-type: none"> • Develop field forms/ACCESS database/Metadata
November 2000, 2001	<ul style="list-style-type: none"> • Radio-collar black-tailed deer • Collect deer and elk pellet groups for persistence studies
December 2000, 2001	<ul style="list-style-type: none"> • Deposit pellet groups for persistence studies • Establish and clear pellet group transects
January 2001, 2002	<ul style="list-style-type: none"> • Establish and clear pellet group transects
January-June 2001, 2002	<ul style="list-style-type: none"> • Monitor persistence of deer and elk pellet groups • Collect fresh fecal pellets from radio-collared elk
March-April 2001, 2002	<ul style="list-style-type: none"> • Conduct pellet group surveys
May-September 2001, 2002	<ul style="list-style-type: none"> • Enter Field data • Analyze data • Prepare annual/final reports

BUDGET

Because funds did not arrive in time to support fieldwork in FY2000, FY2000 funds will be carried over to FY2001 to be spent within 1-year of receipt at USGS-Forest and Rangeland Ecosystem Science Center. FY2000 funds will not be received until April or May 2000.

FY2000 Budget=46K

Budget Item	Amount (\$1000)
Seasonal Wildlife Biologist	5.0
20 radio-collars @ \$300 per	6.0
2 Global Positioning Systems	5.0
Field Sampling Equipment (tapes, compasses, altimeters, clipboards, etc)	2.0
Deer darting equipment/drugs	2.0

GIS Support to Olympic NP	2.0
Statistical Consulting	2.0
Subtotal	24.0
Funding Carryover	22.0
TOTAL	46.0

FY2001 Budget=82K+22K(Carryover)=104K

Budget Item	Amount (\$1000)
Term Biologist (GS-9 @ 1.7K/PP x 20PP or Graduate Student)	35.0
Crew Members (3 GS-5 @ 1.0K/PPx13PP)	40.0
Volunteers (2 @ 3K)	6.0
Field Perdiem (6 persons@60daysx\$10)	4.0
Vehicles (2 x 5 mo x \$500)	5.0
Statistical Consulting/Analysis	8.0
Fecal Analyses	2.0
Field Equipment	1.0
Park GIS Support	3.0
TOTAL	104.0

FY2002 Budget=82K

Budget Item	Amount (\$1000)
Term Biologist (GS-9 @ 1.8K/PP x 17PP or Graduate Student)	31.5
Crew Members (2 GS-5 @ 1.0K/PPx13PP)	26.0
SCA Volunteer (1 @ 3K)	3.0
Field Perdiem (4 persons@60daysx\$10)	2.5
Vehicles (2 x 5 mo x \$500)	5.0
Statistical Consulting/Analysis	8.0
Fecal Analyses	2.0
Field Equipment	1.0
Park GIS Support	3.0
TOTAL	82.0

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