Black-tailed Deer ecology in and around Pacific Rim National Park Reserve

Report prepared for
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Introduction

Only two native species of ungulates are found on Vancouver Island: the Roosevelt elk (*Cervus canadensis roosevelti*) and Columbian Black-tailed Deer (*Odocoileus hemionus columbianus*) and they are both found throughout the island (Cowan and Guiguet 1978; Cannings et al. 1999). This report discusses Black-tailed Deer only. In British Columbia, Columbian Black-tailed deer have been studied most intensively on Vancouver Island; the first reports were written in the mid 1900s, and Dr. I. McTaggart Cowan's (1945) study of the ecology of the species on Vancouver Island still provides valuable information today. Since then many aspects of Columbian Black-tailed Deer ecology have been examined including determining deer age by looking at eye lens growth (Child and Hagmeier 1974), fecal pellet deterioration rate (Harestad and Bunnell 1987), and the effect of deer harvest on morphological characteristics (Hovey 1984). Other aspects of deer ecology that have been examined on the island include deer use of seral stages (Gates 1968), impact of hunting pressure (Smith 1968), habitat use and selection (Cowan 1945; Willms 1971; Jones 1975; Harestad 1979; Bunnell et al. 1985; Bunnell et al. 1985), impact of wolf predation (Jones and Mason 1983; Jones and Mason 1983; Hatter 1988; Atkinson and Janz 1994; Atkinson and Janz 1994) and seasonal movements (McNay 1995), to mention a few.

This report reviews published literature as well as governmental reports that pertain to deer studies on Vancouver Island for use towards building a habitat model based on satellite imagery.

Objectives

1) Provide an overview of deer ecology
2) Determine Black-tailed Deer density in different forest seral stages on the west coast of Vancouver Island based on literature review

Background

Since 1998 Pacific Rim National Park Reserve has documented a marked increase in the number of human encounters with wolves and cougars. This emerging trend in the park's social ecological system has created concerns for park managers. Conflicts with humans have occurred within the park's social ecological systems with one or both of these carnivore species in each of the three components of the park (Long Beach Unit, Broken Group Islands, West Coast Trail). Part of the risk management response of Pacific Rim National Park is to facilitate research into the ecology of wolves, cougar and deer in the region. Furthermore, it is not possible to understand the increased human encounter with wolves and cougars in the park without understanding Black-tailed Deer ecology because they are the primary prey of the predators.

One specific component of this research initiative is to review the scientific literature, interview Black-tailed Deer experts and to use this information to describe the deer habitat suitability of land cover classes of various forest stand ages found in the region. An objective is to compile estimates of the potential deer densities that could be supported by various habitat types on the outer west coast of Vancouver Island. Similar work has been used to describe habitat suitability for the drier habitat types on the eastern side of Vancouver Island but not for the hypermarine outer west coast.

A recent NRCAN Environment and Health pilot project for Pacific Rim National Park used change detection analysis techniques and satellite imagery from various years to illustrate the degree and rate of landscape change in the greater Pacific Rim National Park ecosystem[1], and a Black-tailed Deer habitat and density model is planned using a similar approach .This report is intended to provide Parks Canada personnel with information that can be used towards building this model.

Deer ecology

Food, water and cover are basic requirements for Black-tailed Deer, and these requirements play a role in how deer move around and survive in any given landscape (Bunnell 1990). The deer's year consists of 5 seasons: natal (May and June), spring (June), summer (July and August), hunting and rut (September through November) and winter (December through February) (McNay 1995). In each of these seasons deer seek out the most nutritional foods available. Their four stomachs allow deer to partly digest cellulose and other carbohydrates that many other mammals cannot eat. The digestive system benefits from a diverse diet because the microbes in the rumen have different abilities. Winter diet consists of species such as western redcedar (*Thuja plicata*), deer fern (*Blechnum spicant*), bunchberry (*Cornus canadaensis*) and arboreal beard lichen (*Alectoria* and *Bryoria*). Salal is another important winter food but is not easily digested when eaten alone. In spring fireweed (*Epilobium angustifolium*), bunchberry, roses (Rubus spp.)) and *Vaccinium spp.*, are important forage plants but other species are consumed as well. Water is partially derived from the plants eaten, but deer need to drink as well (Bunnell 1990).

Black-tailed Deer use cover for a variety of purposes such as security (Dasmann and Taber 1956), thermo protection, and snow interception. Security cover is used for concealment from hunters and predators. Security cover can be provided by vegetation and topography, hence deer can be found hiding in clear-cuts with vegetation no higher than 1-2 m. Deer use areas within the first 100 m of the forest border, whereas centers of openings more than 400 m receive very little use (Kremsater and Bunnell 1992; Chang et al. 1995), so clear cuts larger than 50 ha are unlikely to be used for shelter or forage in the center (Chang et al. 1995). Willms (1966; 1971) found a negative correlation between deer use and cut block size on Vancouver Island. Also, Black-tailed Deer tend to use clear-cut interspersed by mature forest more than when the clear-cuts were isolated (Weger 1977).

In the winter, the deer's thick coat provides a thermo-neutral zone in still air with temperatures between -6 to 18°C and in the summer, with a thinner coat, the range is from about 12 to 27°C. Forest canopy protects deer from cold, the night sky, wind and solar radiation, and hence varies with the season. The forest canopy also intercepts snow which allows deer to forage during periods of heavy snowfall. A snowfall event that creates a 50 cm snow depth in a clear-cut would create only a 5 cm depth in an adjacent

[1] In the process of classifying landsat images it is important that "biologists who make use of classified land-cover data evaluate their analyses for potential sensitivity to error, examine confusing matrices provided with accompanying metadata, and conduct error simulations when feasible" (Fleming et al. 2004).

forest stand with a 70% crown closure. Sinking depths for adult deer greater than 25 cm significantly increases energy expenditure. In a snow depth of 30 cm, a fawn uses 8-10 times the energy compared to a 10 cm snow depth (Bunnell 1990). Not surprisingly, winter survival is correlated to weather severity (Picton 1979 in Hatter 1988) and the availability of protected forest canopy areas.

In the 1930's, Hosley and Ziebart (1935) recognized the importance of winter range to the survival of deer populations, and winter range has been studied extensively on Vancouver Island (Harestad 1979; Nyberg, Bunnell, Janz, and Ellis 1986; Bunnell 1990; McNay 1995) as well as in Alaska (Klein 1965; Bloom 1978). Migration of deer is seasonally controlled by elevation, crown closure, understory density (Barichello 1975) and arboreal lichen density (Rochelle 1980). They require winter, spring and summer ranges and Black-tailed deer habitat includes forest stands of varying successional stages. Although old growth forest stands are important for winter survival, young forests likely provide better winter habitat in most years in BC (McNay 1995). Stevenson (1978) found that deer winter ranges had moderate to high amounts of lichen. Calcium content in the soil of winter rages were significantly higher than in summer ranges, and nitrogen levels were highest on summer ranges (Barrett 1977).

McNay (1995) found that migration between summer and winter ranges takes three forms. Black-tailed Deer are obligate migrants, facultative migrants or residents, depending on local climate (especially snowfall), terrain and forest cover. Three movement patterns were identified: resident deer did not migrate, facultative migrants migrated inconsistently from year to year, whereas obligate migrants migrated every year. Facultative migrants mostly migrated along valley bottoms in December, generally after snowfall (no snow meant they stayed in their summer range), and returned in February. Obligate migrants crossed 1 or 2 valleys to winter ranges in October and returned in May. Generally deer preferred young forests over old and were least likely to choose open forests (clear-cut), except in the Nimpkish Valley that had few open forests (at the time of the study). Migratory deer preferred old-growth forest in winter (alternate) ranges in all three study areas. Optimal deer winter range habitat was characterized by being situated in old-growth stands located at mid-elevations with a southern aspect. Response by deer to logging of old-growth forest stands in their winter range was that deer retained their traditional areas or did marginal adjustments towards adjacent un-logged stands. Preference for aspect did not vary with any of the three movement patterns, but home ranges tended to be located on slopes with southerly aspects and not in areas with westerly aspects. Deer were in general found to use all elevation categories during the summer, but migratory deer generally preferred elevations > 600 m in the summer.

Because it can alter its environment, Black-tailed Deer can be considered a keystone species (Rooney 2001) and an ecosystem engineer (Jones et al. 1997). This has been documented in the special case on Haida Gwaii where there are no predators (Martin and Daufresne 1999; Engelstoft 2001; Martin and Joron 2002). Nevertheless, it is not clear whether the deer density is controlled from the bottom up (food supply) or top down (predation) (Schmitz and Sinclair 1997). Deer density is not a simple relationship between plant abundance and deer abundance, but hinges on the functional relationship between tree species abundance and the consumption rate of trees (Schmitz and Sinclair 1997). Deer habitat should also be defined in terms of survival and production characteristics, as well as the density, of a species occupying that habitat (Horne 1983). The Exploitation Ecosystem Hypothesis suggests that predators will regulate herbivores at relatively constant density whenever primary production exceeds 700g/m^2/yr and under this threshold forage production determines herbivore density (Crete 1999). Hatter (1994) found that wolf predation appeared to control juvenile recruitment on Vancouver Island. McNay (1995) found that cougar and wolf predation was the largest cause of death, and which of the two was the main predator varied among study areas. There is evidence in the literature that predators can only regulate deer in populations with low density levels (Rooney 2001).

Population density did not influence dispersal rate or dispersal distance, nor did forest cover influence dispersal rate, but dispersal distances of juvenile male deer were greater in habitats with less forest cover (Long et al. 2005). Health and survival of deer, however, depends on density, available nutrition and habitat. It is generally accepted that the prevalence of parasites and diseases is density dependent, so it can be expected that deer in dense populations are less healthy than animals living in low density populations (Davidson and Dolster 1997). Diseases such as hair-loss syndrome have been thought to cause a decline in population in Washington and Oregon (Bender and Hall 2004). In southeast Alaska malnutrition of deer was higher when they foraged in pole-stage and second-growth forest, juvenile deer had an increased risk of death when they used pre-commercially thinned second-growth, and flat terrain increased the risk of predation (Framer et al. 2006). Framer (2006) also found that deer using open habitats, such as muskegs and young clear-cuts increased the probability of death, and when these areas were accessible by roads there was an increased risk of death from hunting.

From 1982 to 1991 the BC Ministry of Environment, Lands and Parks, the BC Ministry of Forests, and the University of British Columbia conducted a collaborative study of Black-tailed Deer in the Caycuse, Chemainus, Nanaimo and Nimpkish watersheds on Vancouver Island. This study investigated the impact of logging on deer winter ranges, how deer move and use the landscape, mortality causes, and management implications (McNay 1995). McNay (1995) found that "fidelity, rather than habitat choice, dominates initial response (i.e., 1-2 year post disturbance) by deer to large striking changes in habitat condition (i.e. 45-60 ha clear-cut logging of old growth forests)", and that winter home range sizes did not vary with disturbance. Site fidelity by deer is likely closely related to survival from previous experience, because deer appear to remember good forage areas (Gillingham and Bunnell 1989). McNay's (1995) study characterized deer habitat in three ways. Forests were categorized as open forest (0-5 year old), young forest (6 – 45 year old) and old-growth forest (>250 year old), non- commercial forest (sub-alpine or alpine) and non-forest (water or rock). Area elevation above sea level was divided into the following categories: < 400 m, 401-600m, 601- 800m, and >800m. The third deer habitat characteristic was by aspect where northerly aspect was from 316 to 45°, easterly aspect was between 46-135°, southerly aspect was between 136-270° and westerly aspect was between 271-315° (McNay 1985). They found that deer preferred a wide range of habitats, with preferences varying strongly among the three study areas and only to some extent with migration pattern.

The life-history characteristics of many large herbivores and carnivores are scale sensitive and depend on varying temporal and spatial scales. Some animals make some decisions concerning their spatial distribution at scales well beyond the size of the home range, and other decisions involving sexual segregation of sexes or where to give birth may be made at scales below the level of the habitat patch (Bowyer and Kie 2006). There might be other criteria when deer make decisions. Young deer on Vancouver Island, for example, appeared to establish winter home ranges based on their mother's historical choice rather than by assessing habitat quality (McNay 1995). This suggests that there is a lack of habitat preference and more a tendency to use available habitat.

The retention of old-growth forest is considered important for rebuilding deer populations and ensuring a resilient population because forest harvesting and road building isolate winter habitats, intensify predation on resident deer and impede recruitment from migratory deer (McNay 1995).

Deer density in habitat types

Early estimates based on deer counts suggested that there is 0.4 deer km^2 (1 deer/square mile) in coastal forest between Jordan River and Port Renfrew (Cowan 1945), and Dr. Cowan also estimated the density in logged areas on the east coast of Vancouver Island to be approximately 8 deer/km^2 (approximate 20 deer/square mile). In one incident on Bald Mountain in October, Dr. Cowan suggested a density of 24 – 36 deer/km^2. Bunnell (1990) suggests that "favourable habitat can reach densities of 20 deer/km^2 year-round and many times that when deep snow concentrates the animals on key winter ranges". Ministry of Enviroment's assessment of the deer density in areas adjacent to the Pacific Rim National Park varies between 0.4 and 1.8 deer/km^2 with the average being closer to the lower end of the range (Table 1). These estimates are based on formulas developed by Hatter and Janz (1994) utilizing hunter reports and pellet group surveys conducted some time ago.

The succession of forests from clear cut to old-growth provide varied opportunities for deer to forage and varied carrying capacity and Gates (1968) suggested that the elevated production of high quality food in the early seral stages will inevitably regress as the forest grows back.

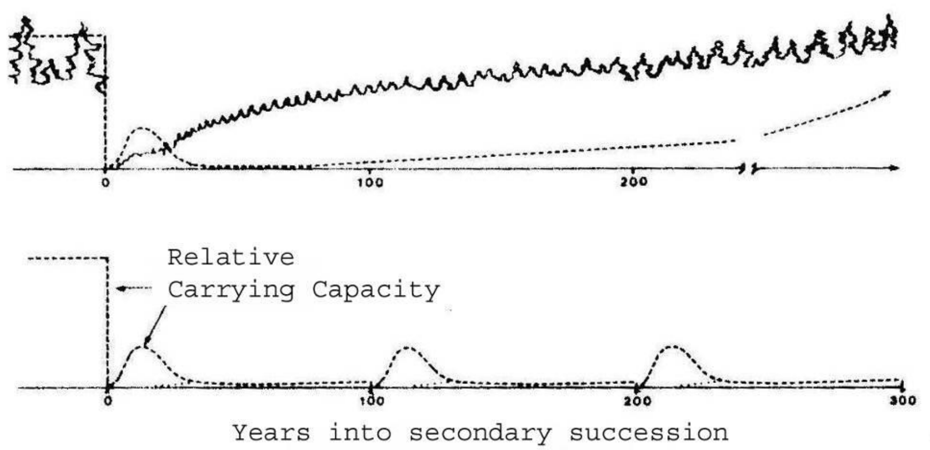
Table 1: Overall deer populations estimated by the Ministry of Environment in selected management units (MU) and sub-units (SU) adjacent to Pacific Rim National Park

MU	SU	SU Name	Area (km2)	Estimated #	deer/km^2
3	10	Upper Gordon	177	312	1.8
3	11	Owen	92	32	0.4
3	12	Walbran	129	46	0.4
3	14	Carmanah	86	30	0.4
3	16	Tsusiat-Hobiton	124	38	0.3
3	17	Klanawa	288	102	0.4
3	18	Pachena	142	44	0.3
3	19	Sarita	226	80	0.4
3	20	Tzartus	28	10	0.4
8	1	Effingham	438	97	0.2
8	2	Long Beach	401	106	0.3
8	3	Kennedy	280	99	0.4
8	4	Clayoquot	336	104	0.3
8	5	Bulson	136	42	0.3
8	6	Meares	87	31	0.4
		Total	2970	1172	0.4

Carrying capacity is the idea that an area of land can support a given number of deer assuming that the area does not change (Smith 1968), but vegetation does change making it difficult to determine the carrying capacity of any particular area over the long term. In South East Alaska the first 1 or 2 years after clear cutting has taken place little forage is available for the deer partly due to reduced forage but also to impeded access by logging debris (Wallmo and Schoen 1980) Following that period, clear-cuts produce deer forage for 20-30 years and none for the following 150 (Chang et al. 1995).

As the area is "greening-up" 5-10 years after cutting and Wallmo and Schoen (1980) found that about 61% of such areas were accessible to deer. They also suggested a carrying capacity model for the Western hemlock – Sitka spruce forest in Southeast Alaska that showed a relatively short-lived increase in carrying capacity after clear-cutting has taken place followed by a period of very low carrying capacity, which slowly begins to increase again after approximately 100 years (Figure 1). The figure also suggests what happens when areas are repeatedly clear- cut. The deer carrying capacity most likely follow a similar model here on the west coast on Vancouver Island, and Willms (1971) found that the maximum use was 8 years after a cut block had been burned..

Figure 1: Hypothesized change in carrying capacity during the successional development of Western hemlock - Sitka spruce forest in Alaska. Upper graph shows succession to climax: lower graph succession with clear-cut every 100 years. In the early stages (dotted line), winter carrying capacity may be eliminated by snow (Wallmo and Schoen 1980).



Source: Wallmo and Schoen (1980) p 460.

Predictive Models

Modeling to predict carrying capacity after logging was developed in Southeast Alaska (Schoen et al. 1985), and several models have been developed to determine forestry and deer population interactions on Vancouver island (McNay and Davies 1985). The ESSA model (McNamee et al. 1981) was created in 1981 during a workshop and the objectives were to 1) develop a framework for co-operation and communication between wildlife and forestry interests, 2) develop a conceptual computer simulation model to guide research planning for IWIFR, 3) develop a set of hypotheses about important processes in the system under study, 4) develop a framework for testing hypotheses and evaluating the relative importance of processes in the system under study and 5) resolve the question of the level of detail for research in the IWIFR program

The STUFF deer model was developed at UBC (Shank and Bunnell 1982) and it focused on the impact of snow, trees, ungulates and forage (hence the name) on deer and explicitly ignored the influence of predators. It was developed to 1) guide research directions concerning deer and intensive forestry interactions and provide a dynamic synthesis of research results, 2) identify relevant processes in the system under consideration, 3) create an understanding of sectors of strength and weaknesses in the system leading to a sharper conceptual image of the perceived interactions and 4) develop a sense of which processes and parameters might be most important.

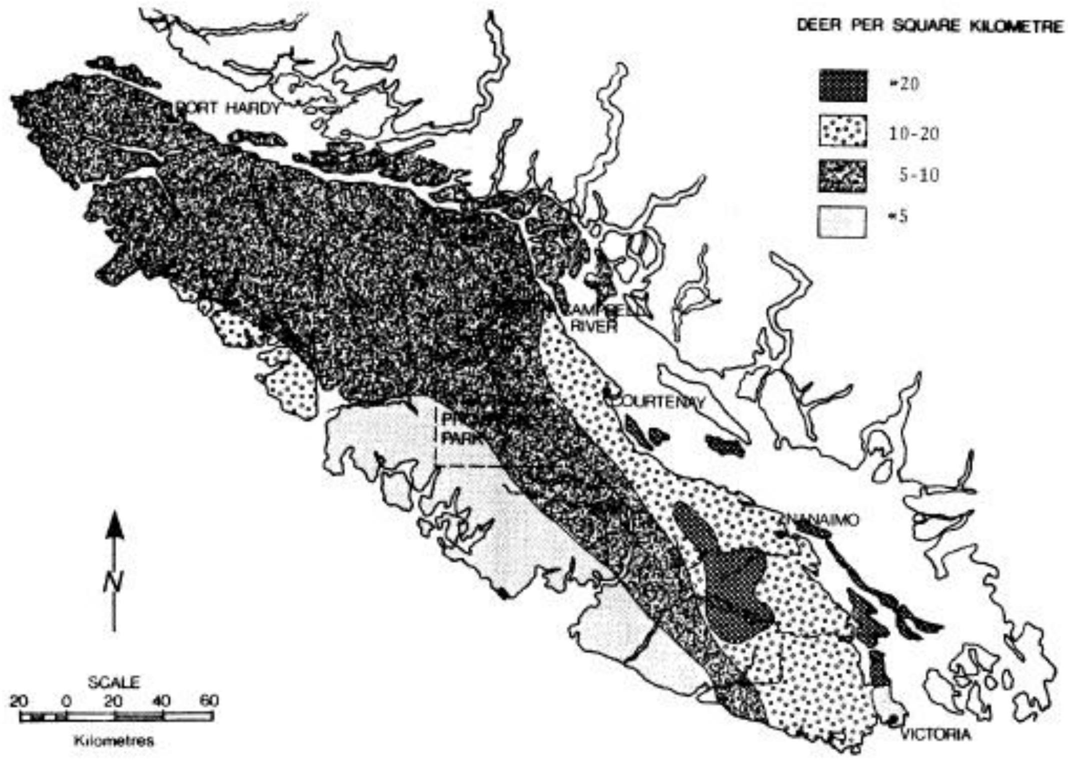
A preliminary deer winter range model was developed for the central coast of BC due to the scope of the model it did not incorporate many of the "majority of life history requirements of coastal deer" (Darimont et al. 2003). The output only defines areas that provide winter range and those that do not.

Deer density in different forest seral stages

The highest density on Vancouver Island in the 1980s were estimated to be in the central areas of the south-end of the island (Figure 2), while the southern west coast was estimated to have the lowest deer density (McNay and Davies 1985). This 1980 estimate was similar to estimates in the 1968 to 1974 time interval, suggesting that the average deer density on the west coast is relatively low. Other estimates from Vancouver island ranged form 16-80 deer/km^2 (Robinson 1958; Gates 1968; Willms 1971) (Jones 1972; Davies 1974; Kale 1976). Densities of similar magnitude were found in Washington (Brown) and Oregon (Einarsen 1946; Hines 1975), and California (Bonn 1967; Anderson et al. 1974)but in Alaska density of deer was on average 5 -10 deer/km^2 (Schoen and Wallmo 1978; Schoen and Wallmo 1979).

Literature about deer density categorized in seral stages is not ready available. It has been possible to find only two references that break deer density down in different forest classes. Mcnay's (1995) categories were used as a template because other authors (Cowan 1945; Dasmann and Hines 1959; Gates 1968) did not survey all age classes (Table 2). It was necessary to convert the Dasmann and Hines' (1959) surveys to deer-year/km^2, and in order to do so I first converted 1 mil-acre plots to metric by assuming that 1 mil-acre equaled 2470 ha (Abbott and Loneragan 1984). Next I used the formula McNay and Davies (1985) provided to convert the pellet group count to deer-years. I included Mcnay's (1995) relational estimates because they might help guide the development of the intended deer population model. Gates's (1968) estimates seem relatively high, probably because his work took place during a period of sizeable deer population (Smith 1968). Due to the varying seral stage classification, data is also provided as a bar graph.

Figure 2: Estimated distribution and abundance of Black-tailed Deer in 1980 on Vancouver Island (McNay and Davies 1985)



It is advisable that the densities provided in Table 2 be used to develop an index indicating the general trend, similar to the model for Alaska (Wallmo and Schoen 1980), rather than attempting to determine actual deer densities. It is also worth noting that Dasmann and Hines' (1959) work took place in California in an enclosure, so it might not be directly transferable to a free roaming population. Smith (1968) developed a model to estimate the predicted number of deer in Northwest Bay on the east coast of Vancouver Island in the time period between 1948 and 1966 (Figure 4). Ministry of Environment has Broad Ecosystem Inventory maps that allow you to map deer capabilities on Vancouver Island at a 1:50,000 scale (K. Brunt, MOE, pers. comm. 2007).

Table 2: Deer density in different seral stages

Forest stand age	Deer density	Source	Notes
0-5 yr	Least	(McNay 1995)	
	28 d/km^2	(Gates 1968)	Avg. calculated from Table 13
	8 d/km^2	(Dasmann and Hines 1959)	
6-25 yr	Highest	(McNay 1995)	
	22 d/km^2	(Gates 1968)	Avg. calculated from Table 13
	27 d/km^2	(Dasmann and Hines 1959)	Avg. calculated 6-20 yrs
26-250 yr	17 d/km^2	(Gates 1968)	Older > 17 years, Table 13
	2 d/km^2	(Dasmann and Hines 1959)	21-50 years
older	Highest (Winter)	(McNay 1995)	
	0.4 winter d/km^2	(Cowan 1945)	Coast south of Port Renfrew
	1 d/km^2	(Dasmann and Hines 1959)	Virgin timber

Figure 3: Deer densities in different seral stages

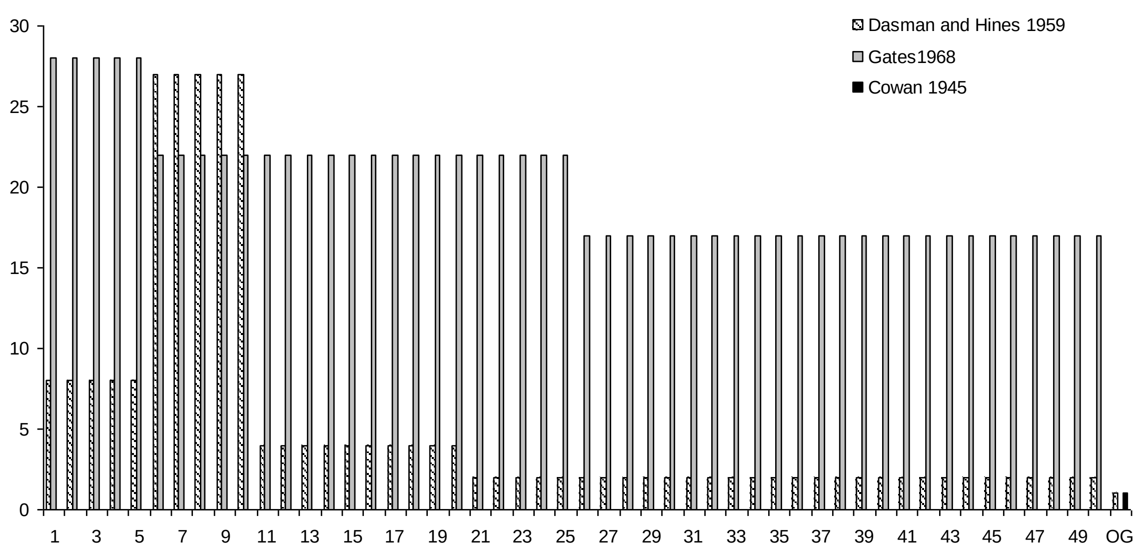
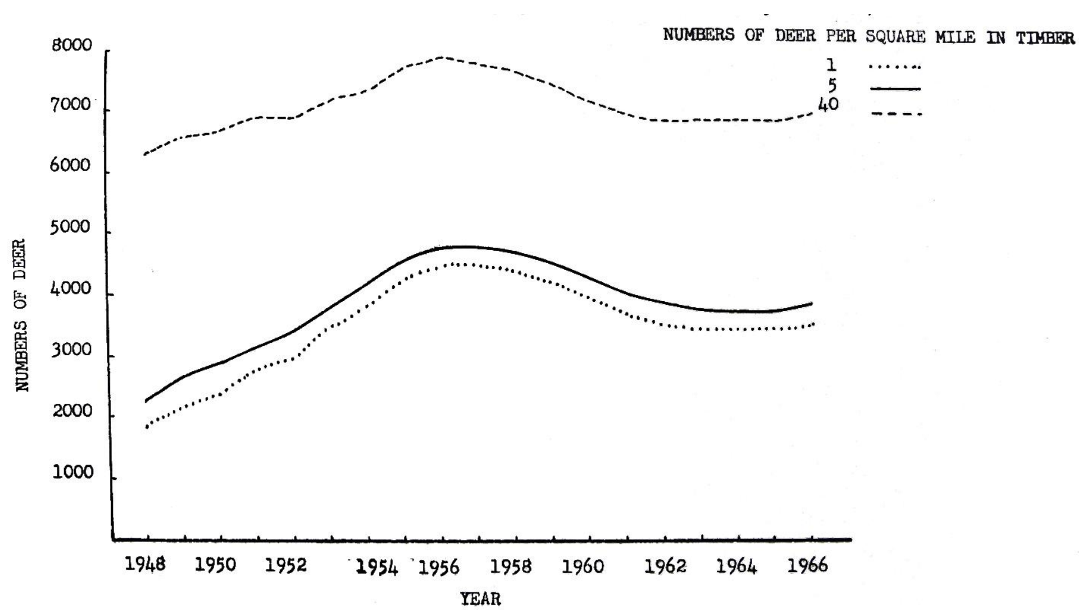


Figure 4: Changes in estimated number of deer that could theoretically be supported in Northwest Bay, on the east coast of Vancouver Island (from Smith 1968, Fig 13)



Habitat description and characteristics

The best Black-tailed Deer habitat found on the west coast of Vancouver Island is found in the Coastal Western Hemlock wetter sub-zones (Nyberg 1985) in which the Pacific Rim National Park is situated. Despite this, the population is relatively small (Robinson 1958) The variant is the Southern Very Wet Hypermaritime Variant (CWHvh1) that is restricted to a narrow coastal fringe on the outer coast of Vancouver Island from approximately Port Renfrew to Quatsino Sound in the northwestern part of the island. It stretches from sea level to an elevation of about 200 m. The climate is cool with little snow, but fog, clouds and drizzle are common weather conditions throughout the year. Precipitation varies in this bioclimatic zone with the lowest amounts occurring in the rain shadows in northeastern parts of the island and the highest where air masses are blown up steep mountains (Green and Klinka 1994).

Deer seem to prefer browse species that are the most nutritious they encounter during their search for food (Table 3). This does not, however, mean that they do not eat other species, quite the contrary (Blower 1982). When the density and abundance of preferred forage species is decreased, deer will eat plants such as Polystricum munitum which have low palatability and nutrient value (Klein 1965). Blower (1982) rated 61 coastal deer forage plants in BC and found that 9 were of high importance and 20 of moderate importance. Arboreal lichens (Alectoria, Bryoria, and Usnea spp.) are important winter food and, when Alectoria is consumed with salal, digestibility of salal increases (Rochelle 1980). In the spring, deer prefer to eat young bracken fern, fireweed and pearly everlasting (Bunnell 1990)

Nutrients such as N, P and K are important in determining the nutritional values of plant species and, in southeast Alaska, leaves of shrubs and forbs from forested areas had higher concentrations of these nutrients than leaves from open clear-cut areas, and the nutrient levels were higher in May than in July and October (Van Horne et al. 1988).

During site series classification in the Long Beach Unit and West Coast Trail Unit, crews used grid #9 (sites series 01 - 07 and 11 -13) to classify upland plants and on floodplains they used grid #28 (site series 08 – 10) from A Field Guide for Site Identification and Interpretation for the Vancouver Forest Region (Green and Klinka 1994) (B. Hansen, Pers. Comm, 2007). From a deer's point of view the most important site series during the spring and summer in or near the Pacific Rim National Park is the Salal-huckleberry site series (03 CwYc-Salal). This site series has the highest potential for producing forage for deer in the summer, whereas the sword fern site series (07- CwSs-Devil's Club) provide food in the winter. The skunk cabbage site series (13 CwSs-Skunk Cabbage) is important during the spring (Bunnell 1990).

Table 3: Vegetation table of plants used to characterize the CWHvh1 biogeoclimatic zone that are also used by Black-Tailed Deer

Scientific name	Common name
Abies ambilis	amabalis fir
Alectoria spp	arboreal lichen
Blechnum spicant	deer fern
Carex spp.	sedge
Cornus canadensis	bunchberry
Gaultheria shalon	salal
Linnea borealis	Twinflower
Menziesia ferruginea	false azalea
Poa spp	grass
Taxus brevifolia	western yew
Thuja placate	western redcedar
Tsuga heterophobia	western hemlock
Vaccinium alaskaense	Alaskan blueberry
Vaccinium ovalifolium	oval-leaved blueberry
Vaccinium parvifolium	red huckleberry

Source: (Cowan 1945; Klein 1965; Nyberg, Bunnell, Janz, and Ellis 1986; Bunnell 1990; Green and Klinka 1994)

Survey methods

There are two basic forms of surveys. One can either count the deer directly or use indirect measures to assess deer populations.

Standard methods have been developed for both ground based techniques and aerial surveys in BC (Resource Inventory Committee 1998; Resource Inventory Committee 2002). It is possible to estimate deer populations using sightings of deer along transects; counts can be used to estimate population densities by measuring distance and angle form transect line to observed deer (Batcheler 1975). Night counts have been used on Vancouver Island to monitor deer populations, but this method is biased towards open flat areas and becomes less appropriate as vegetation in clear-cuts grows up (Resource Inventory Committee 1998). In open areas, however, this is a cheap way to gather information population trends (Winchcombe and Ostfeld 2001). During aerial surveys animals are spotted from planes while flying on predetermined transects and is recommended for the CWH biogeoclimatic zone when conducting encounter transects (Resource Inventory Committee 2002). Incorporation of infrared technology into aerial counts of deer have been successful in some instances in some areas, but in areas with limited optimal counting weather the infrared method is less appropriate (Daniels 2006) and dense forest canopy also decreases the usability of the method (Potvin and Breton 2005).

Indirect counts:
Pellet group counts have been used since the 1940s (Bennet et al. 1940) and provide a relatively simple and cost efficient method to obtain general population trend information (Neff 1968). A dense understory can impede the counting process, making it difficult to accurately count the groups, and consequently provide less accurate results. It is also worth noting that pellet group counts do not accurately predict habitat use (Gillingham et al. 2001). Developing a browsing index is another indirect method of monitoring the populations trends of deer (Patton and Hall 1966; Rutherford 1979; Morellet et al. 2001). The basis for this method is the direct relationship between the number of browse point and deer density, similar to the pellet group counts. It is also possible to count tracks as and index for deer population trends (McCaffery 1976).

DNA finger printing is the latest in animal population estimates and ecology. Microsatellite DNA markers (appendix) has been developed for White-tailed deer (Anderson et al. 2002), and these can most likely also be used for Black-tailed Deer (Jason Herreman, pers com, 2007). The method is a non-intrusive approach because the DNA can be obtained from hair samples or possibly fecal pellets, and can provide information about parameters such as relationships between individual animals, sex-ratio, and population size.

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Correspondence

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Dr. Rick Page, Victoria, sent email 5 February 2007 received answer to my request.
Kim Brunt provided literature list, but was contacted by Bob Hanson prior to my involvement, and further information by email and phone calls
Brian Nyberg, Brentwood, sent email 5 February 2007, no response
Ian Hatter left a message 6 February, 2007, no reply
Jason Herreman, Wyoming State University, Laramie, email correspondence

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Appendices

Appendix 1: List of available DNA primers for deer

Mr. Jason Herreman, Wyoming Stat University, provided the following list of deer primers. He also suggested that the cheapest is to get laboratories that work with the primers to do lab work if it ever came to that.

BM4208	F	CACGACGTTGTAAAACGACTCAGTACACTGGCCACCATG
	R	CACTGCATGCTTTTCCAAAC
BM888	F	CACGACGTTGTAAAACGACAGGCCATATAGGAGGCAAGCTT
	R	CTCGGTCAGCTCAAAACGAG
BM4107	F	GGATAACAATTTCACACAGGTAGCCCCTGCTATTGTGTGAG
	R	ATAGGCTTTGCATTGTTCAGG
BM1225	F	CACGACGTTGTAAAACGACTTTCTCAACAGAGGTGTCCAC
	R	ACCCCTATCACCATGCTCTG
CERV 1	F	CACGACGTTGTAAAACGACAAAATGACAACCCGCTCCAGTATC
	R	TCCGTGCATCTCAACATGAGTTAG
T7	F	GGATAACAATTTCACACAGGTTTCACTGTTTTCTCCTTCAG
	R	TGCCCAATCAGATGTTGTAG
RT #1	F	CACGACGTTGTAAAACGACTGCCTTCTTTCATCCAACAA
	R	CATCTTCCCATCCTCTTTAC
RT#5	F	CACGACGTTGTAAAACGACCAGCATAATTCTGACAAGTG
	R	AATTCCATGAACAGAGGAG
RT#13	F	CACGACGTTGTAAAACGACGCCCAGTGTTAGGAAAGAAG
	R	CATCCCAGAACAGGAGTGAG
RT #24	F	GGATAACAATTTCACACAGGTTGTATCCATCTGGAAGATTTCAG
	R	CAGTTTAACCAGTCCTCTGTG
RT #30	F	GGATAACAATTTCACACAGGTCACTTGGCTTTTGGGACTTA
	R	CTGGTGTATGTATGCACACT

Primer sequences use at the Wyoming Game and Fish Laboratory (including M13 tail) for mule deer

800 GGATAACAATTTCACACAGGT
700 CACGACGTTGTAAAACGAC

References:

Coulson, T.N., Pemberton, J.M., Albon, S.D., Beaumont, M., Marshall, T.C., Slate, J., Guinness, F.E., and Clutton-Brock, T.H. 1998 Microsatellites reveal heterosis in red deer. The Royal Society. 265: 489-495

Wilson, G.A., Strobeck, L. WU, and Coffin, J.W. 1997. Characterization of microsatellite loci in caribou Rangifer tarandus, and their use in other artiodactyls. Molecular Ecology. 6:697-699.

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Appendix 2: Partially annotated list of deer literature

Addison RB. **1970.** *Response of axial growth gradients within the skeleton of the black-tailed deer to variations in the level and pattern of energy availability*. Vancouver, B.C: University of British Columbia.

Alaska Dept. of Fish and Game. Alaska Dept. of Fish and Game. Sitka black-tailed deer proceedings of a conference in Juneau, Alaska. 1979. Juneau, U.S. Dept. of Agriculture. Forest Service. Region 10. United States.

Alldredge AW, Lipscomb JF, Whicker FW. **1974.** Forage intake rates of Mule Deer estimated with fallout Cesium-137. *Journal-of-Wildlife-Management.* **38:** 508-516.
Abstract: The Rocky Mountain mule deer (Colorado) has an overall mean forage intake of 21.9 g dry weight/ kg carcass/day mean Haida Gwaii deer 63 lbs= 28.602 kg hence eat 0.6 kg/day. Adult in Winter eat 17.3 g/kg/day (HG: 0.49 kg/day). Subadult winter 32.5 g/kg/day (HG: 0.9 kg/day). Summer and winter intake were statistically different ($p<0.1$) whereas male and female were not different. Subadult eat more than adult ($p<0.05$)

Andersen R, Duncan P, Linnell JDCE. **1998.** *The European roe deer: the biology of success*. Oslo, Norway: Scandinavian University Press.

Anderson AE, Medin DE, Bowden DC. **1974.** Morphometry and organ weights of Mule Deer. *Wildlife Monographs* **39:** 73-122.

Anderson JD, Honeycutt RL, Gonzales RA, Gee KL, Skow LC, Gallagher RLHDA, DeYoung RW. **2002.** Development of microsatellite DNA markers for the automated genetic characterization of white-tailed deer populations. *Journal of Wildlife Management* **66:** 67-74.
Abstract: Nuclear microsatellite DNA loci have proven useful for the establishment of parentage, determination of relationships among individuals in a population, estimation of gene flow patterns among populations, and examination of geographic variation throughout the range of a species. These loci have considerable potential for managers interested in the behavior, breeding biology, and basic ecology of wildlife species. We present the characterization of 4 multiplexed primer sets, representing 21 microsatellite DNA loci, which can be used to evaluate the population structure and genetic relationships among white-tailed deer (*Odocoileus virginianus*). These markers are useful to establish parentage and study gene flow and genetic divergence within and between populations. Indices of genetic diversity for these loci were estimated using genotypes of 72 free-ranging deer from southeastern Oklahoma. The mean expected heterozygosity of the overall panel was 0.723, and mean number of alleles per locus was 8.38. The total exclusion power of the panel was calculated for 2 scenarios. First parent exclusion, with neither parent known, was 0.999977. Second parent exclusion, with the genotype of 1 parent known, was 1.000000, This panel of microsatellite DNA loci should prove very effective for use in genetic studies of both captive and free-ranging populations of white-tailed deer

Armleder HM, Thomson RN. Habitat relationship of mule deer in the interior Douglas-fir zone of central British Columbia: Working plan. 1984. Victoria, Ministry of Forest, Province of British Columbia.

Atkinson KT, Janz D. Effect of wolf control on black-tailed deer in the Nimpkish Valley on Vancouver Island. 1994. Nanaimo, B.C., Fish and Wildlife Branch, Ministry of Environment, Lands and Parks. Wildlife bulletin: Wildlife bulletin (Victoria, B.C.).

Aycrigg JL, Porter WF. **1997.** Sociospatial dynamics of white-tailed deer in the central Adirondack Mountains, New York. *Journal of Mammalogy.* **78:** 468-482.
Abstract: We compared the sociospatial behavior among and within kin groups of white-tailed deer (*Odocoileus virginianus*) inhabiting a contiguous forest environment of the central Adirondack Mountains, New York. This population had not been hunted since 1932 and contained females gt 10 years old. We estimate that 60-75% of all females were individually marked. Although actual genetic relatedness among females was uncertain, previous research on this population included genetic analyses of kin groups and our data showed long-term fidelity of individuals to kin groups. We hypothesize that although sociospatial behavior at the group level is relatively rigid, the sociospatial patterns of individuals within groups are more flexible. Specifically, we predict that sociospatial patterns within groups vary with age and reproductive status. Data from radiotelemetry and visual observations were used to delineate kin groups. Kin groups were classified using two techniques; distance between !

Balgooyen C, Waller D. **1995.** The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in Northern Wisconsin, USA. *Natural Areas Journal* **15:** 308-318.
Abstract: We examined how woody and herbaceous plant frequency, cover, and overall species diversity have responded to regional variation, both historic and recent, in white-tailed deer densities in the Apostle Islands and nearby Wisconsin mainland. We observed lower frequencies of several woody species, including mountain maple (*Acer spicatum*), yellow birch (*Betula alleghaniensis*), and mountain-ash (*Sorbus decora*), in areas of high deer densities. Higher historic (1950s and 1960s) and recent (1980s and 1990s) estimated deer densities tended to depress the frequency of Canada yew (*Taxus canadensis*). The proportion of unbrowsed sugar maple (*A. saccharum*) twigs at a site also decreased predictably with deer density, as did the frequency of bluebead lily (Clintonia borealis). Frequencies of wild sarsaparilla (*Aralia nudicaulis*), Canada mayflower (*Maianthemum canadense*), and *Clintonia borealis* decreased in areas of historically high deer density. We also observed that herbaceous species richness and frequency and percent cover of *C. borealis* decreased with recent increases in deer density. Path analyses of C. borealis frequency and species richness suggest that deer have both immediate and persistent effects on herbaceous community structure. Population size and scape height in *C. borealis* may provide reliable and efficient indicators for the impact of deer on both common and rare herbaceous species.

Ballenberghe VV, Hanley TA. Predation on deer in relation to old-growth forest management in southeastern Alaska. W. R. Meehan, Merril, T. R., and Hanley, T. A. Fish and Wildlife Relationships in Old-growth Forests.   291-296. 1982. Morehead City NC, American Institute of Fishery Research Biologists.

Baltzinger C, Martin J-L. The effect of browsing by deer on the regeneration of Western Red Cedar in Haida Gwaii (Queen Charlotte Islands). Annual Scientific Report, 1997. Gaston, Tony. Laskeek Bay Research, No. 7. 1998. Queen Charlotte City, Laskeek Bay Conservation Society.
Abstract: Studied the impact of BTD on Western Redcedar in areas affected by logging. Results: 1) cedar germination is abundant and is independent of pre-logging forest. 2)

regeneration occurs when deer are present, but at a much lower frequency than in absence of deer. 3) the effect of deer browsing may be dependent on the density of deer, regeneration being higher in areas more accessible to hunters. Some redcedar regenerate in secondary forest but not in primary forest. Conclusion, future occurrence of redcedar, given present populations of deer may depend on i) deer density ii) the type of disturbance regime created by forestry

Bandy PJ. **1965.** *Study of comparative growth in four races of black-tailed deer*. Vancouver, B.C.: University of British Columbia.

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Batcheler CL. **1975.** Development of a distance method for deer census from pellet groups. *Journal of Wildlife Management* **39:** 641-652.

Bender LC, Anderson DP. **2004.** Annual and seasonal habitat use of Columbian black-tailed deer in urban Vancouver, Washington . *Urban Ecosystems* **7:** 1573-1642.
Abstract: We investigated habitat use of Columbian black-tailed deer in urban Vancouver, Clark County, Washington, at 3 spatial scales: (1) placement of the annual home range within the landscape mosaic, (2) annual and seasonal locations of deer within the annual home range, and (3) short-term use of critical habitats (fawning areas) within seasonal ranges. Annual home range sizes of deer were 162 ha (SD = 133; 95% minimum convex polygon; MCP) and 266 ha (SD = 228; 95% adaptive kernel; AK) for does, and 756 ha (SD = 290; MCP) and 1,235 ha (SD = 382; AK) for bucks. Home range composition of does did not differ from the study area; home ranges of bucks contained more Natural ecological land-use cover types (ELUs) than did the study area. Within home ranges, both does and bucks used Natural ELUs more often than expected by their occurrence in the home range, both annually and seasonally. During the fawning season, does were also found in Natural ELUs more often than expected. Clark County-designated habitat corridors differed from both the study area and deer home ranges in habitat composition, primarily by containing more Natural and other undeveloped ELUs. Deer were located in habitat corridors more than expected. Deer in urban areas appear to use undeveloped habitat types for security. Management that maintains Natural ELUs, such as establishment of wildlife corridors, can provide important habitat components for black-tailed deer in urban habitats.

Bender LC, Hall PB. **2004.** Winter fawn survival in Black-tailed Deer populations affected by hair loss syndrome. *Journal of Wildlife Diseases* **40:** 444-451.
Abstract: Overwinter fawn mortality associated with hair loss syndrome (HLS) is anecdotally thought to be important in declines of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) populations in Washington and Oregon (USA). We determined prevalence of HLS in black-tailed deer, September and April fawn:doe ratios, and minimum overwinter survival rates of fawns for selected game management units (GMUs) in western Washington from 1999 to 2001. Prevalence of HLS ranged from 6% to 74% in fawns and 4% to 33% in does. Minimum fawn survival ranged from 0.56 to 0.83 and was unrelated to prevalence of HLS in either does (*r*50.005, *P*50.991) or fawns (*r*520.215, *P*50.608). The prevalence of HLS in either does or fawns was also unrelated

to either fall fawn:doe ratios (HLS does: *r*520.132, *P*50.779; HLS fawns: *r*50.130, *P*50.760) or spring fawn:doe ratios (HLS does: *r*520.173, *P*5 0.711; HLS fawns: *r*520.020, *P*50.963). However, the prevalence of HLS in does and fawns was strongly related (*r*50.942, *P*50.002), and GMUs with high prevalence of HLS had lower deer population densities (fawns: *r*520.752, *P*50.031; does: *r*520.813, *P*50.026). Increased overwinter mortality of fawns because of HLS was not supported by our data. Decreased production of fawns, increased summer mortality of fawns, or both were seen in six of eight study GMU–year combinations. Observed rates of productivity and minimum fawn survival were inadequate to maintain population size in five of eight study GMU–year combinations, assuming an annual doe survival rate of 0.75. The influence of deer condition and population health on adult survival, fawn production, preweaning fawn survival, parasitism, and prevalence of HLS in both fawns and adults need to be clarified to identify what factors are limiting black-tailed deer productivity.

Bennet LJ, English PF, McCain R. **1940.** A study of deer populations by use of pellet-group counts. *Journal of Wildlife Management* **53:** 398-403.

Bennett J. The effect of deer browsing on shrub and herbaceous plant growth and Cedar regeneration in Sewell Inlet, Queen Charlotte Islands. 1996. Western Forest Products Ltd.
Abstract: Qci/ vegetation production/ Sewell Inlet/ Western Forest Product

Bergquist J, Orlander G. **1998.** Browsing damage by roe deer on Norway spruce seedlings planted on clearcuts of different ages - 1. Effect of slash removal, vegetation development, and roe deer density. *Forest Ecology and Management* **105:** 283-293.
Abstract: A two-year long field experiment was established in May 1993, on clearcuts ranging in age from fresh to 4 years old at four sites in southern Sweden. The aim of the experiment was to study the effect of clearcut age and removal of slash (i.e., twigs, branches, and tops of harvested trees) on browsing damage by roe deer (*Capreolus capreolus* L.) on planted Norway spruce (*Picea abies* (L.) Karat) seedlings. The cover and height of the vegetation, as well as the number of plant species increased rapidly during the first two years after cutting, whereafter these variables continued to increase, although more slowly. Hairy grass (*Deshampsia flexuosa* L.) made up about 90% of the vegetation cover. The nitrogen concentration of hairy grass was highest in two-and three-year old clearcuts. The height of the slash was lower on older clearcuts. Roe deer density increased with clearcut age. Browsing occurred during winter and the frequency of browsed seedlings was 31.2% in the 1993-1994 period and 24.8% in the 1994-1995 period. During both years the browsing damage tended to be highest on the one-year old clearcuts, but the effect was not statistically significant (p = 0.058). The level of damage was about equal on the clearcuts of other ages. The level of browsing damage was not correlated with the quantity or quality of associated vegetation, slash quantity, or roe deer density on the clearcuts.

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Abstract: We evaluated the efficacy of translocation to control an urban white-tailed deer (*Odocoileus virginianus*) population in Town and Country (TC), Missouri. Captured deer (n=80) were fitted with radiotransmitters and translocated approximately 160 km to Huzzah Conservation Area (HC) in south-central Missouri. Released deer were monitored on a 20-hour sampling regime for 1 year. Annual survival was 0.30 (SE=0.05)

for translocated deer and 0.69 (SE=0.05) for radiomarked resident TC deer that were not translocated. Mortality causes for the 55 translocated deer that died during the study were hunting (33%), capture myopathy (29%), poaching (13%), unknown causes (11%), roadkill (9%), and wounding from hunting (5%). Mortality causes for the 25 resident deer that died during the study were roadkill (68%), hunting (12%), unknown causes (8%), fences (8%), and wounding from hunting (4%). Post-translocation home range size increased (0.86 km2 vs. 2.5 km2), and fawn recruitment by translocated adult females was higher (Z=2.88, P<0.01) than for TC resident deer. Cost per translocated deer was dollar sign387. The use of translocation for controlling urban deer populations was costly relative to other methods and may result in significant mortality from capture myopathy and human activities at release sites.

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Abstract: Rehabilitating and releasing abandoned or "picked up" white-tailed deer (*Odocoileus virginianus*) fawns back to the wild is a popular alternative to euthanasia, but the fates of these fawns are often unknown. We measured survival rates and sources of mortality for radiomarked white-tailed deer fawns that were orphaned or picked up by the public, raised by wildlife rehabilitators, and released into the wild. A total of 14 of 23 and 8 of 19 fawns during 2000 and 2001, respectively, died within 30 days of release. The Kaplan- Meier 100-day survival rate was 0.232 for all deer. We found no difference in survival distributions based on rehabilitation site. Sources of mortality for released fawns were canids (50%), unknown cause (20%), accidents (10%), bobcats (*Lynx rufus*) (10%), poaching (6%), and legal harvest (3%). Most rehabilitated and released fawns died, but those that survived did so around human dwellings and may have become a nuisance or presented public safety concerns.

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Abstract: We assessed seasonal movement patterns and survivorship of black-tailed deer, *Odocoileus hemionus columbianus*, crossing Trinity Reservoir (Clair Engle Lake) in northern California by monitoring 2 fall and 2 spring migrations, beginning in fail 1993. Black-tailed deer traversed the reservoir using 43 routes located predominately in the narrowest sections of the reservoir. A group of 2-3 black-tailed deer typically swam together. Adult males and females were segregated by sex, but not by date. We estimated that as many as 389 black-tailed deer swam across the reservoir during daylight in a

single migration. Two hundred and ninety-two of 302 black-tailed deer observed swimming crossed successfully. The fate of the remaining 10 was not determined. Trinity Reservoir does not appear to be a major mortality source for migrating black-tailed deer when it is ice free.

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Abstract: We studied habitat selection by neonatal (2 -10 days old) black tailed deer (*Odocoileus hemionus columbianus*) on Big Flat, Trinity Co., California, during June August, 1992-1993. Even deer 2-3 days old frequently followed their mothers and occurred in social groups with other adult deer. Neonates used south facing slopes with gentle terrain and high variability in overstory and concealment cover more often than expected from availability of those habitat variables. Young deer also selected sites with more herbaceous vegetation but avoided areas with more browse. Forage was more digestible at sites with neonates than at random sites, but no difference occurred in nitrogen content of forage between those sites. Variables identified as important components of habitat for young deer more were likely related to the thermal environment of the neonate and nutritional demands of lactating females than to risk of predation. Alternatively, variation in concealment cover may have been related to predation risk, resulting in a positive relationship between forage availability and risk predation. Minimizing the predation: forage ratio was not a viable model for explaining habitat selection in neonates.

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Abstract: Research has demonstrated that even-aged regeneration harvests, especially clearcutting, can have a major and long-lasting detrimental effect on forest amphibians, but the effects of less intensive silvicultural treatments have not been well documented. Additionally, the chronic overabundance of white-tailed deer (*Odocoileus virginianus*) has become a problem in many parts of North America, with associated effects on vegetation composition and structure and on other wildlife. I assessed the effects of crown thinning and deer overabundance on the relative abundance of forest-floor salamanders in a southern New England mixed oak-hardwood forest. I surveyed salamanders by using cover boards in 16 forest stands with thinned or unthinned treatments and with histories of low (3-6 deer/km2) or high (10-17 deer/km2) deer densities. Surveys were conducted 5 times a year for 3 years. Northern redback salamanders (*Plethodon cinereus*) were the dominate species in all surveys and in al!

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Abstract: Increases in the distribution and abundance of white-tailed deer (*Odocoileus virginianus*) throughout much of their range, coupled with hunter accessibility limitations, have prompted many state wildlife agencies to consider the future effectiveness of hunting as a population control mechanism under current regulatory systems. Wildlife managers in many areas experiencing abundant deer are questioning the conditions under which public hunting serves to control deer populations. In this article, we evaluate the performance of hunting as a deer population control mechanism and propose criteria to assess the effectiveness of public hunting for that purpose across the landscape, including rural and developed areas. We conclude that to control deer populations across broad landscapes, many wildlife agencies will have to adopt hunting regulations that are robust to 3 conditions: decrease in hunter numbers, increase in refugia that limit hunter access to deer, and increase in importance of urban and suburban areas as elements of deer range. To stabilize or reduce the high-density deer populations currently existing across much of white-tailed deer range, regulations need to give hunters incentives to shoot antlerless deer voluntarily or simply require them to do so. It is likely that comprehensive population control programs of the future will combine general recreational hunting regimes that promote great per-hunter harvests of antlerless deer across broad scales with complementary, site-specific, highly regulated hunts and programs to diminish the effects of refugia created by hunting-access limitations. Recreational hunting is unlikely to be sufficient as the sole management tool for most urban and suburban areas; other control methods will be part of integrated strategies for developed sites. We use New York data to illustrate ideas presented in this paper to assess utility of an existing hunting program to control deer populations across broad landscapes.

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Abstract: Managers have three potential ways of manipulating deer numbers: 1) altering hunter harvest 2) controlling natural predators and diseases 3) modifying habitat. Habitat long lasting effect. Hunter short p32 Description: Female 35-45 kg in summer (up to 50-60 kg). Males 50-100 kg p34. Range quality affects antler development and body size. As yearlings 90% of males grow spikes and 10% of these might have a additional point on each side. By 2.5 years most males have antlers and 4.5 and more have = 3 points Social behaviour: Black-tailed Deer not herding sometimes smaller groups of 3-4 occur p35 Columbian Black-tailed Deer can loose 20-25% of peak fall weight. Antlers shed by Jan and reground during summer. Van.Isl. Black-tailed Deer breed during Nov and early Dec and most does conceive during second ovulation mid Nov to mid Dec. A buck is not likely to service more than 4 females during a 28 day period. Birth occur 200 days after conception in beginning of June. Fawn rarely conceive in the wild but 45-80% of

yearlings do all depending on nutritional conditions. The average is 1.5 fawn per older doe. The high potential for population growth is reduced by mortality, which can be significant during severe winters and when predator density is high.. Few deer live to be 10 years old. Mortality is highest among fawns (45-75% per yr) and lowest among adult females (15-25% per yr) During favorable conditions populations growth can be 25% per year and decline can be 40% per year during unfavorable conditions p 36-7Deer have three basic requirements: food, water and cover Food: In southwestern British Columbia digestible energy (runs the system) and nitrogen (protein building) are scares enough during some seasons that it can influence health and deer abundance. (Bunnell et al 78, Rochelle 80). Phosphorus may also be limiting (Ellis 84) in some area, but there is no evidence that vegetation is deficient in other nutrients. New growth such as stem and leaf tissue (cell sap) with simple chemical composition easiest digestible. Digestibility therefore changes with season. p 38 fig 25 Most vascular plants are far less valuable in winter than in spring because of increased complexity of compounds . The chances are eg starch to cellulose, and proportionally more lignin (indigestible) Some plants hold more digestible compounds than others. Forbs (fireweed) contain less fiber. The quality depends on the interaction in the rumen fermentation process. This interaction is important for habitat management. Discussion of digestive physiology p 38 Deer can starve with their stomachs full, eg if nitrogen content is very low so microbes can do their job p39 Deer narrow mouth allow them to be selective forager compared to elk The menu in winter, spring and summer is given in Table 4 and table 5 gives forage value per season trend are also shown in fig 27 p 41 and 28 p 42 in winter Salal not good alone but with lichen value increase (Rochelle 1980)On Northern Vancouver Island female deer lose 20-25 % of body weight over the winter and males like more p42 Water: highest need through late spring throughout the summer Management implications: Migratory deer have 12.6 times greater home range (1770 ha) than resident deer (140 ha). Migratory deer do not exploit all of it home range but select micro-habitats that meet specific seasonal requirements. Forest management activities in large home range might influence the migratory deer but not the resident population p53 When a behavior is adopted by a deer (migratory vs resident) they will not change abruptly, but behavior might shift if recourses gradually change p54 deer in deep snow zone have larger home range (48 ha) switching to smaller in spring (25 ha) The climatic condition in shallow and moderate snow-pack zones have the overall potential for higher production of Stand types that can meet deer's food need are: Clearcuts = 15 yr, forest with < 70% canopy cover and old-growth forests. Stand types that can meet deer's cover need are: patches of dense young forests > 2m tall, stands with aller trees with dense trunks, lower branches or understory, or dense deciduous vegetation (riparian zone)Stand types that can meet deer's thermal needs are: most forest with =70% closed canopies. Clearcut, rock outcrops and openings allow deer to warm themselves in direct sunlight on clear days The key factors are 1) heterogeneous forest that provide a mixture of open and closed canopies within stands, and 2) areas with interspersed clearcuts and forested patches that provide different stand ages, forage and cover < 200 apart p55 Critical winter range: The habitats that can sustain a large no. of deer in severe winters (deep snow). A) Stand age is important because of lichen is important food source. B) Topographical features are: southerly aspect, moderate to steep slope (40-100%), low elevations (<1000m) C) critical features of stand structure Well developed crows, small openings in a variable canopy that average 65-70 % closed, multiple canopy layers. Characteristics are best provided by old-growth stands eg Herbert (79) found that densities could exceed 100 deer /km-sq. P56 Very deep snow zone might be used when snow depth is shallow, but deer move out as it gets deeper. (p58) Spring range: Come spring, pregnant females enter the last term of gestation and the nutritional demands of the embryo increases dramatically. Survival of the developing fawn is closely related to the birth weight, which depends on the does nutritional status (Bunnell 1987). The most important feature of spring range is that it produces large quantities of tender, young plant material and early initiation of growth. Hence open areas such as clearcuts and rock outcrops and deciduous and widely spaced coniferous stands provide the most rapid snow melt and early growth on south slopes with small openings surrounded by forests as security and thermal cover. p 59 Summer range: males develop antlers and fat reserves that the draw on during rut and winter. Females also add fat and need large quantities for milk production. Sub alpine provide earlier phonological growing stages later in season. Animals migrating to alpine generally weigh more. Fireweed, *Vaccinium* and *Rubus* are key summer food items. When berries are out *Vaccinium* and *Rubus* are eaten by deer. Clearcut are heavily used in summer, but deer remain within 200 m from cover. (There are less need for cover at the alpine fewer predators). Deer also use topographic features such as dips and swales, bluffs and ridges for security cover p61 Spatial Patterns of habitat: A major impact of timber management has been to increase the size of openings and reduce the degree of habitat interspersion. P62 See summary of "important habitat features" p 63

Bunnell FL, Harestad A. S. **1983.** Dispersal and Dispersion of Black-Tailed Deer: Models and Observations. *Journal of Mammalogy* **64:** 201-209.
Abstract: The term dispersal is used to include individual movements out of an area larger than a home range that exhibit no predictable return; many models examining dispersal incorporate time explicitly. Dispersion is defined as the distribution of animals in space, ignoring time since birth. Direction, distance, and age at dispersal were examined for *Odocoileus hemionus columbianus* on Vancouver Island, B.C., and in western Washington. Empirically, movements >5 km were dispersive. Dispersive movements showed significant directionality as a function of topography; non-dispersive movements showed none. Dispersive movements averaged 15.2 a 5.1 and 12.2 +- 1.7 km for males and females, respectively; comparable values for non-dispersive movements were 1.8 +- 0,3 and 1,7 +- 0.4 km. Movements greater than 12 km were rare (5 to 10%) and generally were made by males. Dispersal was greatest at 1-2 years of age. The Sex and age distribution of dispersing individuals suggested that increased access to mates could explain observed patterns. When models were compared statistically with observations, the latter showed neither attributes of a random walk or diffusion process nor normal distribution about birth sites. Observed patterns suggest two phenotypes-"non-dispersers" and "dispersers."

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Abstract: Sinking depths in snow of a captive black-tailed deer (Odocoileus hemionus columbianus) were recorded in old-growth, second-growth, and recently clear-cut forests. Data were collected over a wide range of snow conditions. Snow hardness was extremely variable, even within 30 cm, and only weakly correlated with deer sinking depths (r = 0.52 for upper crust hardness). Snow density in the upper 48 cm of the snowpack was a better predictor of deer sinking depths (r-2 = -.65), but the best prediction was from density and hardness combined (r-2 = 0.86). Snow depth alone was a poor predictor, because the deer rarely sank to the bottom of the snowpack (9 of 630 cases). Two indices of sinking depth were evaluated: human sinking depth and Hepburn's index. Human sinking depth was both a simpler and better predictor, especially when snow hardness values gt 256 g cm-2 (deer static foot loading) were eliminated (r-2= 0.65).

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Abstract: We used a vector-based geographic information system (GIS) to examine habitat selection by radiocollared Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in logged forests of southeast Alaska. Our main objective was to explain deer habitat selection relative to old-growth/clear-cut edges and edge habitats at two different spatial scales. Deer home ranges contained higher percentages of recent clear-cuts (50-69%) than the study area (37%; P lt 0.01) and had higher old-growth/clear-cut edge densities than expected by chance (P lt 0.01). Deer relocation points were closer to old-growth/clear-cut edges (average = 135 m) than random points located within each deer's relocation area (average = 168 m; P = 0.05). Likewise, deer relocations were closer to old-growth/clear-cut edges than points randomly located within old-growth stands or recent clear-cuts (P lt 0.01). As the size of clear-cuts increased, both deer relocation density and the proportion of a clear-cut occupied by deer home ranges decreased. Because old growth is important deer habitat and clear-cuts can produce deer forage for only 20-30 years after logging in southeast Alaska, deer management plans such as preserving entire watersheds and maintaining mixes of old growth and recent clear-cut have been proposed. Our data suggest that deer need a diversity of habitats near each other within their home ranges.

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-defecation rate varied with habitat sub unite
-low defecation rate while grazing and high while resting
-Peek found that pellet groups was higher on trail between foraging areas
-Fuglham found that defecation rate doubled when deer changed from a winter forage of shrubs to herbaceous forage

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Abstract: In non-territorial species, individuals can move freely and should be distributed in an ideal free manner between habitats and areas with respect to resources that influence lifetime reproductive success (LRS). Consequently, no relationship between diet quality and LRS should be expected. However, there have been no attempts to test this prediction. The present paper investigates the relationship between forage habitat use and LRS in red deer (*Cervus elaphus*) hinds within three neighbouring areas on the Isle of Rum which differed in their amounts of high-quality-forage habitat. Within areas, hinds move widely and have access to the same resources. We found no correlation between LRS of individual hinds and their use of high-quality-forage habitat (i.e. short

Agrostis/Festuca grassland). Our analysis suggests that high hind densities on short Agrostis/Festuca grassland offset any advantages of increased access to preferred forage. These results support the hypothesis that !

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Abstract: 1. Different counting methods are currently used to estimate red deer populations in the open range in Scotland, but there are few data available to compare variation in estimates, or relative cost-effectiveness. 2. While it is impossible to determine the accuracy of counts (as real numbers are unknown), variation within and between different methods can be measured by repeat counts of the same area within as short a period as possible. 3. This study aimed to quantify the variation observed from repeat counts using each of four methods (ground, helicopter, infrared helicopter and dung-counting methods) at one of three study sites in late winters 2003, 2004 and 2005. Additional data from digital camera images of groups from counts in other areas of Scotland were also used to assess the accuracy of visual counts. 4. Coefficients of variation (CVs) within any method of between 5% and 16% were recorded, consistent with previous comparisons for red deer open range counts in Scotland. CVs were lowest for ground and helicopter counts. The infrequency of optimal conditions was likely to limit the applicability of infrared counts in Scotland. 5. In terms of cost-effectiveness, helicopter counting was the least labour-intensive, with costs of other techniques depending on the availability of existing manpower as an overhead cost. 6. It is concluded that helicopter counts are most likely to minimize errors while maximizing cost-efficiency. Accuracy can be improved by the use of digital photography for counting larger deer groups. Estimates are likely to be improved further by increasing the frequency of counts and using the same methods, counters and routes for repeat counts.

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Abstract: Studies of those elements of the behavior of the Columbian black-tailed deer important to population ecology were carried out in Lake County, California, during 1948 to 1955. Particular attention was given to mobility, group structure, aggression and territorial behavior, and to other density-related behavioral aspects. The deer were non-migratory and tended to occupy restricted home ranges throughout the year. Movements beyond home range boundaries were in- frequent, and consisted of netting season travels, wandering and dispersal. Deer could not be driven from their home ranges, nor did they leave them to seek qualitatively superior forage. The stable social aggregations of deer were the family group and buck groups. Particularly in winter and spring larger feeding bands would form temporarily. However the deer were not herd animals. Adult does were found to be mutually intolerant during the period when the fawns were young. Centers of activity of adult does were spaced well apart, much as if they were defended territories. Aggression between does was a factor causing one adult to avoid the activity center of another. Among bucks no such spacing was found. Aggression, alarm behavior and play were all related to population density. When density was higher there was more strife and alarm flight and less play. Territorialism and density-dependent behavior may prevent populations from increasing to the maximum that the food supply might otherwise sustain.

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Abstract: Studied understory on five islands on HG.
Found
* a decrease in understory vegetation
* a reduction in plant and community diversity
* a replacement of original understory species by saplings of dominant canopy trees
* 33 deer/km^2
* deer forage mainly on foliage of tree saplings

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Abstract: As public pressure increases to manage wildlife populations using nontraditional methods, development of safe and effective reproductive inhibitors becomes a growing priority. Therefore, we tested a prostaglandin F-2alpha (PCF-2alpha) implant for its effectiveness at reducing pregnancy rates in white-tailed deer (*Odocoileus virginianus*). We treated 18 does in Connecticut using a biobullet delivery system and 8 does in Indiana using a combination of remote delivery and drug administration after capture under a rocket net. PGF-2alpha reduced (P lt 0.01) the reproductive rate at both

sites. None of the deer in Connecticut and 38% of the deer in Indiana were pregnant or produced offspring after PGF-2alpha treatment. PGF-2alpha shows promise as an alternative population control technique; it is as effective in reducing fertility as contraceptive agents that have been tested. Moreover, PGF-2alpha is safe for both treated does and potential consumers, and it can be effectively delivered using a remote delivery system.

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Abstract: We documented a 27.4 km migration by a five-day-old white-tailed deer (*Odocoileus virginianus dacotensis*) fawn in the central Black Hills of South Dakota. The migration of the fawn and its radiocollared mother began 11 June 1996 on winter range and ended one day later on summer range. Based on the available migration information for this species, we suggest this is the longest documented migration by a fawn of this age.

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Abstract: Identifying and managing Sitka black-tailed deer (Odocoileus hemionus sitkensis) habitat has been an important wildlife issue for many years on the Tongass National Forest of southeastern Alaska, USA. We evaluated habitat selection of Sitka black-tailed deer in the central portion of the region during a winter with snowfall 43% above average using telemetry relocations from 30 individuals that survived the winter. Ivlev indices for habitat selection within home ranges indicated that deer used less than expected, based on availability, north, east, and west aspects, areas > 244-m elevation, noncommercial forests, and the low-timber volume stratum while selecting south aspects, areas < 153-m elevation, and areas within 305 m of saltwater. Deer used less than expected moderately coarse-canopied forests in the medium- and high-timber volume strata typically found on north slopes while selecting moderately fine-canopied forest in the high-timber volume stratum on south slopes. The lower than expected use of higher volume gap-phase old growth was likely because these were on north aspects where snow accumulated and persisted due to protection from maritime storms. Point relocations suggested less use than expected in clearcuts < 41 years of age, while data from 7.2-ha error polygons showed deer were neutral to clearcuts. This suggests that if deer do avoid clearcuts they remain close to the forest-clearcut edge. Of 4 habitat-mapping methods evaluated, the method that incorporated timber volume strata and a wind disturbance-related aspect had greatest utility in identifying areas selected for or used disproportionately little by deer during the deep snow winter. We found that deer exhibited marked changes in habitat use during deep snow conditions compared to a low snow winter, and we agree with previous researchers that providing habitats selected by deer during deep snowfall is an important consideration in Sitka black-tailed deer habitat

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Abstract: Biologists are increasingly using classified satellite data in habitat analyses, especially due to the recent availability of the National Land Cover Dataset (NLCD) and Gap Analysis Project (GAP) classified maps. However, this type of land-cover data may contain substantial class error incorporated during the classification process. Accuracy assessments provide a measure of class-specific error, but they do not provide information on the spatial distribution of error. Error simulation procedures allow users to gauge the sensitivity of their analyses output errors in the input land-cover data, although these procedures tend to be computationally intensive. We used pixel- and patch-based error simulation to evaluate the effect of class error in the NLCD on the calculation of habitat-suitability index (HSI) values for white-tailed deer (*Odocoileus virginianus*) in a high-suitability (agricultural) landscape and a low suitability (forested) landscape. We incorporated error into landscapes at rates reported in the NLCD accuracy assessment for New York and New Jersey using 2 techniques: pixel based simulations, in which individual pixels were changed from one cover type to another, and patch-based simulations, in which entire patches were changed. Resulting HSI values were higher in all simulated landscapes than in the original landscapes. The largest increase in HSI, 0.57, occurred using a pixel-based simulation in the low-suitability landscape, due partially to increased interspersion and creation of new one-pixel patches. Patch-based simulations provided a more conservative estimate of the effect of error, an increase in HSI of 0.07–0.28. The difference in HSI between pixel- and patch-based error simulations suggests that the spatial distribution of error in land-cover data may strongly affect the calculation of HSI, especially if the model contains habitat variables related to landscape configuration. We suggest that biologists who make use of classified land-cover data evaluate their analyses for potential sensitivity to error, examine confusion matrices provided with accompanying metadata, and conduct error simulations when feasible.

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Framer CJ, Person DK, Bowyer RT. **2006.** Risk factors and mortality of Black-tailed Deer in managed forest landscape. *Journal of Wildlife Management* **70:** 1403-1415. Abstract: We investigated the influence of habitat use on the risk of death of Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) on Heceta Island in Southeast Alaska, USA. A mosaic of even and uneven-aged forests covered much of the island and provided a model setting in which to assess relationships between habitat use and mortality of deer. We radiocollared and monitored 51 adult females, 11 adult males, and 19 young of the year. We compared risk of death with habitat composition, habitat distribution, topography, distances to features such as roads, and functional habitat characteristics such as seasonal forage biomass within 50-, 500-, and 1,000-m circular buffers around relocations of deer. Those buffers encompassed habitats used at scales of radiolocations, home ranges, and landscapes. We addressed hypotheses that related habitat composition and distribution to risk of death from malnutrition, predation, and hunting. Predation by wolves (*Canis lupus*) and malnutrition were the principal causes of death of adult females and young, whereas hunters killed most adult males. Habitat factors at scales of 500 and 1,000 m had the greatest effect on mortality of adult females and young, whereas habitat characteristics in the immediate vicinity of radio relocations had the greatest effect on mortality of adult males. Malnutrition was positively associated with use of forage-poor habitats such as pole-stage, second-growth forest. Use of pre-commercially thinned second growth increased risk of death for young deer. Use of level terrain was the most influential factor with respect to predation and increased risk of death at all scales. Use of open habitats, such as muskegs and young clearcuts, also increased risk of death. Use of shrub-sapling-stage clearcuts in landscapes accessible by roads increased risk of death from hunting. We showed that use of specific habitats and the landscape context of those habitats were important factors influencing mortality of deer. We also demonstrated the importance of comparing habitat use with measures of fitness rather than simply with availability when evaluating habitat suitability for deer. Our results should be useful to wildlife researchers investigating contributions of habitat to fitness and population dynamics of ungulates, and to wildlife managers attempting to manipulate habitats to benefit deer populations.

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Abstract: 1. The reliability of deer population management could be improved with good density estimates, but current methods are either labour-intensive or suffer from uncertainties regarding accuracy. 2. Visibility varies substantially in forests depending on stand type, age and understory vegetation. In such conditions distance sampling would be an efficient estimation method, but observer disturbance often results in bias when the method is applied to deer. 3. The performance of thermal imaging for estimating deer density by distance sampling was assessed in seven forest deer populations. Thermal imaging equipment can detect the long-wave energy radiated by natural objects, clearly revealing warm-bodied animals even if partly obscured by vegetation. 4. Many more deer were detected at night using a thermal imager than along the same transect routes in daytime. Detection distances were correlated with visibility but were substantially longer than the average distances at which most animals were disturbed. Most deer were detected without causing prior disturbance. 5. Densities were estimated with a coefficient of variation ranging from 10-2-28.4%. Precision depended on sampling effort and sample sizes obtained. 6. A Monte Carlo simulation revealed a quadratic relationship between accuracy and visibility, with accuracy increasing with average visibility and a tendency for deer to select more open habitats within a forest. Under conditions that are likely to be typical of temperate forests (< 40% thicket and neutral selection, or < 70% thicket if thicket is avoided), accuracy was generally good and changed relatively little in relation to visibility and habitat selection. 7. Likely sources of bias as well as alternatives to thermal imaging are discussed. It is concluded that the method would be suitable for estimating ungulate densities in forests with an adequate network of tracks.

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with increased experience in a particular food distribution. This was accomplished by repeating search paths that had been effective during previous trials. Consequently, performance was poor when the food distribution was changed. Under controlled conditions, memory of previous foraging events can play a role in food selection by deer. Description of a foraging bout as a static process ignoring its internal dynamics may be convenient but misleading.

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Abstract: Based on observations of tractable free ranging deer, the rhizomes of Shield Fern (*Dryopteris dilatata*) are an important winter food for Black tailed Deer (*Odocoileus hemionus sitkensis*) in coastal southeastern Alaska. To examine the effects of this herbivory on subsequent vegetative growth, in late winter we marked 71 *Dryopteris* rhizomes for which we knew the proportion of the rhizome that had been consumed by foraging deer/ we selected 51 control plants from a nearby site for comparison. Removal of any portion of the rhizome greatly reduced vegetative growth during the following summer. Plants with more than 25% of their rhizomes removed produced essentially no growth during the next growing season/ removal of 1 25% of the rhizome greatly retarded growth of the ferns and sometimes resulted in highly succulent forage being produced in September. The presence or absence of Shield Fern is used to distinguish plant communities in the Western Hemlock (*Tsuga heterophylla*) forest type, but abundance of this species can potentially be reduced by intensive deer browsing on rhizomes during mild winters.

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(*Capreolus capreolus*) in winter. *Gibier Faune Sauvage* **12:** 253-269.
Abstract: In two forest environments of Sweden, we compared winter habitat use by roe deer, *Capreolus capreolus*, with habitat availability, using seven ways of comparison resulting from two kinds of data collecting: telemetry and pellet-group counts. Telemetry was conducted on 22 female roe deer between January and March 1994, while pellet groups deposited between October and April were counted on plots in April 1994. Preference indexes as quotients between the occurrence of frequented habitat types and the occurrence of available habitat types, were calculated. No correlation was found between preference indexes resulting from the two techniques, but both identified strongly avoided habitat types such as fields, and ranking of habitat types highly represented in the study area such as forest and mature forest was similar. Radio-tracking was unable to determine preference of habitat types which were smaller than the error polygon, and pellet-group counts to quantify the time spent by roe deer in a given habitat. Differences between the two techniques in study period and population sample may have influenced the results, some habitat types being used during a limited part of the winter only, and habitat selectivity probably being different for female roe deer and for the whole population. Improvements to the methods are discussed.

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Abstract: For mammals, home range size expands with increases in energy requirements, and contracts with increase in habitat productivity (Harestad and Bunnell 79) p3 Nutritive difference in the forage available on seasonal ranges are due largely to differences in the phonological condition of the forage (Cook 72, Klein 65) Earlier Black-tailed Deer was thought to migrate in area with high snowfall and be residents in regions with low snow fall. Migration was proposed to be a progressive movement p4 home range are an integrated expression of an animal's locations and movements over a specific time interval Important food plants are *Alectoria sarmentosa*, *Gaultheria shallon* (Very important p14), *Vaccinium* sp. (Very important p14), *Rubus* sp., *Cornus canadensis*, *Linnaea borealis*, *Epilobium angustifolium*, *Blechnum spicant*, *Pseudotsuga menziesii*, *Thuja plicata*, and *Tsuga heterophylla*, p 13 Lichen, *Alectoria sarmentosa*, used seasonally p14 The proportion of standing crop of lichen that falls to the the ground is

12% (Stevenson) p 14 Conifers provided most of the available food in the newly logged seral stages p22 In old seral stages shrubs comprised most of available food p22 Snow can bury food source and restrict deer movements Rochelle measured 96 and 392 kg/ha of available forage in low and mid elevation forested habitat respectively p29 The movement of deer between two seasonal home range may occur more than once during a particular migratory period p49 both in summer and winter periods exploration trips p77 The occupancy of the winter home range reflected the occurrence an severity of the first snowfalls. Deer at high elevations moved earlier than deer in lover areas. P51 Deer migrated altitudinal and horizontally p52 All seven deer considered use of forested habitat was greater during the day, use of cutovers were more frequent at night p 64 (Use open forest during night) Summer home range was largest (165 ha) home range have an upper size limit (Covich 76 and Harestad & Bunnell 79) Black-tailed Deer wintered on side hills in forest areas using nearby cutovers when available. During spring moved to the valley bottom and used the cutovers near winter range more intensely. In summer some changed use of cutovers other migrated up-hill. P70 It is generally accepted that proximate factors that induce seasonal fluctuation is food availability (Orr 70 , p 24) p71 Herbs were sufficiently covered by 8 cm of snow to eliminate it as food p 71 Dept of snow that would be sufficient to impede movements is about 37 cm p71 Forested areas provide more food in winter, food in cutovers is more likely to be covered or impede movements p72 Winter ranges had generally snowfall and shorter snow cover than other seasonal home range p72 Winter ranges therefore more than food at a lower energetic cost p73 Snowfall of 12 cm coincided with altitudinal migration p73 Predator density influenced migration p 77 It appeared that Black-tailed Deer responded to the density of digestible dry matter p 78 In costal areas forage sense later than in other types of habitat p 78 On Vancouver Island deer's principal forage, shrubs and herbs, maintained their nutrient value long than grass p 78 If winter range habitat is to be provided for Black-tailed Deer then it must include both mild and sever winter ranges p 86

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Sn = 0.94, Mh = 0.03, R = 0.23. The recruitment (Rs) required to balance adult mortality (lambda = 1.00) was similar to 16%. Sensitivity analyses using plausible extremes in demographic rates suggested that changes in juvenile survival had the greatest impact on recruitment. Rate of population change appeared to be most sensitive to juvenile survival and adult nonhunting survival.

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Abstract: I developed a model of energy balance in mule deer (*Odocoileus hemionus*) that predicts changes in body size and fatness of the average doe and fawn and predicts rates of mortality due to starvation in populations of does and fawns. Model predictions respond to input on the amount, quality, and structure of forage, the density of deer, and daily weather conditions (max. and min. temp. and snow depth). Application of the model is restricted to shrub-steppe and shrub-woodland ranges. Energy expenditure is simulated as the sum of hourly costs of activity (posture, locomotion, eating), resting (lying, ruminating), and thermoregulation. Daily snow depth and characteristics of forage influence energy intake. Differences between energy intake and expenditure are related to a normal distribution of energy reserves that is used to predict mortality rate. Model predictions of over winter mortality in does and fawns closely resembled trends in field measurements of mortality during 14 different years in 2 different habitats. Model predictions of fat reserves did not differ from measured values during early and midwinter, but diverged from measurements at winter's end. Weather during a severe winter increased simulated energy expenditure by 4% (10,019 vs. 9,621 kcal/kg-0.75/winter) in does and 2% (10,879 vs. 10,632 kcal/kg-0.75/winter) in fawns relative to their expenditures during a mild winter, and reduced intake of metabolizable energy by 17% in both does (133,183 vs. 161,292 kcal/winter) and fawns (94,663 vs. 11,4643 kcal/winter). Predictions of mortality were more responsive to changes in snow depth

than to changes in temperature. Simulated mortality declined sharply in response to increases in parameter values for digestibility of winter forage, forage intake rate, supplemental feed offered, and fatness of animals during autumn. Reducing deer density and increasing forage amount influenced mortality only when pre-winter forage was scarce (lt 150 kg/ha) or when there was a high variance in the quality or availability of food. Enhancing thermal cover had negligible effects on simulated mortality. By organizing results of nutritional research in a form that is accessible and interactive, the model can facilitate decisions on managing mule deer populations and their habitats.

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Abstract: Translocation to manage overabundant deer (Odocoileus spp.) is viewed by some people as an acceptable alternative to harvest. Yet, posttranslocation mortality is generally high, and impacts of translocated animals on deer already present at the release site are unknown. We tested the hypotheses that: (1) female white-tailed deer translocated with other members of their social group have lower postrelease dispersal and higher survival than unrelated deer, and (2) movements of resident deer at the release site are not affected by translocation. A social group of 12 females and a group of 5 randomly selected, unrelated females from a well-studied population in northern New York were translocated and released together at a site 60 km west, in May and June 1994. Mean dispersal distance of all translocated deer was 23.5 km and did not differ between social-

group and unrelated group animals (P=0.87). Postparturient females released without their fawns dispersed farther than females released while pregnant or barren (P ltoreq 0.04). Survival did not differ between translocated groups (P=0.47), but translocated deer had lower survival than resident deer at the release site (P=0.06). Home-range size of 5 translocated deer after 1 year postrelease did not differ from 8 resident deer (P=0.88). Movements of resident deer indicated no measurable response to the presence of translocated deer.

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6 months. The density increased again during the third growing season after the burn, however, this increase was not as great as the previous growing season. No significant change in fawn survival resulted from the burn, and the increase in density during the growing season was attributable to female groups moving into chaparral from oak woodlands. The use of chaparral was accounted for by a complex interaction between habitat structure, species composition, and the distance from oak woodlands and grasslands. The results demonstrate that the application of fire to chaparral may not translate into increased deer numbers.

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deer (*Odocoileus hemionus columbianus*) were examined to gauge how well fecal N could predict diet quality. Correlation coefficients were generally weak and inconsistent between study area years. Diet composition variables were significant predictors of fecal N but the coefficients of determination were small (0.16 in summer, 0.31 in winter). Fecal N appears to be useful only for confirming broad (i.e., winter to summer) seasonal trends in diet quality for free-ranging cervids

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Abstract: I studied habitat use of Columbian black-tailed deer (Odocoileus hemionus columbianus) in the Klickitat Basin of Washington. The habitat mosaic for Klickitat deer consisted of large tracts managed independently by the Yakama Indian Nation, the Stare of Washington, and two corporate forest-owners. Selection of habitats at the landscape and patch scale was investigated using radiocollared deer. During winter, deer preferred habitats with an overstory dominated or co-dominated by Oregon white oak (*Quercus garryanna*) at both scales of selection. Also during winter, deer selected home ranges with less mixed conifer cover type than available in the background mosaic, but showed some preference for mixed conifer patches within home ranges. Deer occupying mid-elevation home ranges on the Yakama Reservation preferred mature/old-growth and younger, closed-canopy conifer stands at both selection scales during summer. Mid-elevation deer on corporate forestland summer range preferred mature/old-growth stands and open-canopy conifer stands at the landscape scale and the same two habitat classes in reverse order at the patch scale. During summer, deer with high elevation home ranges used habitats in relative proportion to their availability at both selection scales. Habitat conservation for Klickitat deer is complicated by a mixed-ownership mosaic and diverse management approaches. Private land habitat values are important during summer and winter, and conservation may require extensive coordination between public and private resource managers and incentives for private landowners. Conservation of oak-dominated habitat on winter range and mature and old-growth habitat on summer range should be a priority for Klickitat deer managers.

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Abstract: I studied movements, survival, and mortality sources for migratory Columbian black-tailed deer (*Odocoilcus hemionus columbianus*) in the Klickitat River Basin (KRB) of Washington during 1988-95. During 1988-93, 490 deer were captured and marked: an additional 69 adult deer were radiocollared and relocated 3,152 times. Fifty-seven of 66 radiocollared deer (86%) seasonally migrated, anti distances between seasonal activity centers averaged 27.8 km (range = 5.0-85.6 km). Among migrants, 34 (60%) summered on the Yakama Indian Reservation; the remainder summered on state and corporate forest

lands adjacent to the reservation. All but 2 deer wintered on state and private land south of the reservation. Annual survival for radiocollared adult females averaged 0.82 but was 0.71 during a severe winter. The survival of radiocollared adult males averaged 0.50. Most deaths of radiocollared deer were caused by hunting, whereas malnutrition during winter was the major mortality source for neck-banded females. Illegal kills exceeded legal kills for radiocollared females and represented 20% of all hunting deaths for radiocollared males. Most hunting mortality occurred on state and private lands and was associated with recreational hunting, even among deer that had summer home ranges on tribal lands. The timing of autumn migrations subjected many-deer to the cumulative effects of tribal and non-tribal harvest and highlighted the importance of coordinated management. These data suggested tribal deer harvests had little effect on recreational hunting opportunities in the KRB.

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in the previous October, with doe kill accounting for 77% and October rainfall for 23% of identified variance (R-2 = 0.79). Doe kill apparently decreased density and increased fawn recruitment that subsequently yielded a higher buck kill. Burning and domestic livestock grazing were not related to deer productivity. It could not be determined whether or not a downward trend in pellet group population estimates reflected an actual decrease in population size. This analysis was used to make predictions about population response to doe kill that are being tested in a management experiment. A management strategy of adjusting kill of does incrementally upwards from 28% of buck kill to 80% of the buck kill is being pursued to test the prediction that increased buck kill will occur.

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and mean temperature in April (0.3-8.1 degree C) explained most of the variation in mean departure dates from two winter ranges (Ely, R-2, 0.87, P lt 0.0005, n = 19 springs; Isabella, R-2, 0.85, P = 0.0001, n = 12 springs). Mean differences between observed mean departure dates and mean departure dates predicted from equations ranged from 3 days (predictions within the study area) to 8 days (predictions for winter ranges 100-440 km distant).

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calibrated using data on deer abundance acquired from aerial population surveys and nutritional condition of females removed by a concurrent culling program. Effort was influenced by 4 factors: deer population density, approachability of individual deer, access to private and public land, and efficacy of the contraceptive treatment. Effort and deer density were inversely related. Cumulative effort for treatment increased exponentially because some deer were more difficult to approach than others. Potential of using immunocontraception at low deer population densities (<25% ecological carrying capacity) is limited by the interaction of the proportion of breeding-age females in the population and treatment efficacy, as well as encounter rates. Immunocontraception has the best potential for holding suburban deer populations between 30 and 70% of ecological carrying capacity, but is likely to be useful only in localized populations when the number of females to be treated is small (e.g., ltoreq200 deer).

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options. We used the GAPPS II modeling system to simulate temporal effects of contraception on deer population control and the interaction between contraception and uncertain immigration rates. Contraception rates less than 50% of female deer curbed population growth with a long (30 year) planning horizon, but did not reduce the size of the population. A minimal contraception rate of 50% was necessary to reduce population size, but even with contraception rates gt 50% a 5-10 year planning horizon was necessary to see significant population declines in a closed population. Variability among simulations with the same contraception rate was high and suggests difficulty in detecting population changes in the field. This difficulty could pose management problems because contraception is most economically applicable for smaller populations. For an open population, population size was a non-linear function of contraception and immigration rates. Contraception does not seem a viable option for an open population unless a landscape-level conservation strategy is implemented to control metapopulation growth.

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for 8 yr in the Adirondack Mountains of New York. Deer were box-trapped on their winter or summer ranges, and 105 radio-collared animals and 266 marked with ear streamer-collar combinations were released. Movements from summer to winter range were associated with snow depths of about 38 cm. Seasonal home-range size among sexes did not differ (P gt 0.05), and females had a larger (P lt 0.05) summer than winter range. With few exceptions, females and adult males used the same home range from year to year, and there was no range separation between sexes. Range fidelity to a specific area was less pronounced in winter than in summer. The sizes of summer and autumn home ranges of females and adult males did not differ (P gt 0.05). Most 1.5-2.5-yr-old males made dispersal movements. Adult bucks showed a shift in their center of activity in autumn. Nine social groups of deer identified from 366 marked ! animals had different movement patterns and exhibited range fidelity and exclusiveness (between groups). Seasonal movements and home ranges of deer were influenced by timber harvesting on both summer and winter range. Individual summer home-range selection was influenced primarily by social factors and not habitat type. Management of winter habitat not being used by deer may be cost-ineffective unless fidelity to a specific range can be altered. Intensive herd management may require cooperation of several landowners, and management practices should be directed at a specific deer population to be most effective.

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Abstract: We tested a new contraceptive method that offers a potential alternative to white-tailed deer (*Odocoileus virginianus*) population control where hunting is unfeasible. We report the first successful, remotely delivered immunocontraception in captive, unrestrained white-tailed deer using porcine zona pellucida (PZP) antigen. None of 7 PZP-vaccinated dose produced fawns, whereas 6 of 7 control does did. No adverse effects of treatment were observed. These results encourage further investigation of immunocontraception in wild white-tailed deer populations.

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Areas" (sensu Alverson et al. 1994) should focus on landscape-level patterns of habitat used by discrete deer populations.

Van Deelen TR, Campa HI, Hamady M, Haufler JB. **1998.** Migration and seasonal range dynamics of deer using adjacent deeryards in northern Michigan. *Journal of Wildlife Management* **62:** 205-213.
Abstract: In Michigan's Upper Peninsula, forest management that seeks to integrate wildlife, recreation, and silviculture goals is complicated by the seasonal movements of white-tailed deer (*Odocoileus virginianus*) between summer and winter ranges. From January 1992 to January 1995, we conducted a radiotelemetry study of seasonal range use by deer that winter in 2 important deeryards in the central Upper Peninsula. Distance, direction, and timing of seasonal movements between summer and winter ranges were largely independent of age class or sex ($P > 0.05$, $n = 95$). Yearly overlap of seasonal ranges for individual deer suggested that spatial use was traditional. Overlap of composite ranges of deer that occupied study area deeryards suggested that herds specific to deeryards were isolated spatially during winter but not other seasons. These findings suggest a secondary level of social structure reflecting the location of suitable winter range in the surrounding landscape. We suggest!

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Abstract: Deer yards are wintering areas used by white-tailed deer in the northern part of their range. In northern Michigan, deer yards typically consist of extensive stands of cedar-dominated (*Thuja occidentalis*) or mixed conifer swamps where thick evergreen overstories provide shelter from winter conditions. Forest and wildlife management in and around cedar-dominated swamps of the upper Great Lakes have created a nearly optimal interspersion of early-seral summer range and mature conifer winter range. For a variety of reasons which include favorable habitat changes, deer populations are today larger than those of presettlement conditions. We used General Land Office survey records from the 1840s to compare presettlement forest composition with present-day forest composition in two important deer yarding areas in Michigan's Upper Peninsula. Except for tamarack (*Larix laricina*), woody plant species that are unpalatable to deer or tolerant of browsing have increased. Species that are palatable and intolerant of browsing have decreased. Ages of extant mature cedars indicate establishment during a period of low deer populations in Michigan. Change in forest composition has many causes, but deer populations encouraged by forest and wildlife management may contribute to a changing ecology in northern Michigan's conifer swamp communities, and may change the structure of plant communities in areas where deer use is concentrated.

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concentrations of phenolics, terpenes, total nonstructural carbohydrates, and cyanide. In the shrub and forbs, concentrations of N, P, and K tended to be higher in leaves from forested than from open clear-cut areas, and higher in May than in July and October. These nutrients tended to covary in an opposite manner to Ca, Mg, and Na and in a similar manner to the trace elements Cu, Zn, Mn, and Fe, although these patterns were inconsistent. In these species there was also a general pattern of higher levels of total nonstructural carbohydrates, astringency, and phenolics in the three young open stands than in the shaded forest understories of the two oldest stands. Dry matter digestibility did not differ across stands but did vary seasonally. The among-stand differences in foliage chemical composition may have resulted from differences in the availability of light. While seral stage affected both the inorganic and organic quality of understory forage species, the combined results suggest that the impact on N economy of deer is greater than that on their energy economy.

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Abstract: Uneven-aged, silviculturally overmature stands of western hemlock-Sitka spruce (*Tsuga heterophylla-Picea sitchensis*) forest in southeast Alaska were used more heavily by Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) than adjacent or nearby comparison areas that had been clearcut, regardless of their postlogging age. Mean ratios of use, overmature forest: young growth, were 5.3:1 in summer and 7.0:1 in winter. Overmature stands had a more diverse and abundant understory than did second-growth stands ranging in age from 30 to 147 years. Similar results from Vancouver Island, B.C., are reviewed. Elsewhere, little attention has been given to the quality of climax coniferous forest as deer habitat relative to that of seral forest. It is concluded that even-age management of coniferous forest in the areas studied, and perhaps more generally, will result in a significant decrease in carrying capacity for deer.

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Abstract: To understand deer-habitat interactions important to making management decisions, it is necessary to ask questions in an evolutionary framework. Then, patterns that are detected can be evaluated in terms of how they potentially influence fitness, and to make more accurate predictions about changes in habitat use with changes in the environment. Intersexual resource partitioning in *Odocoileus* spp. is considered to be affected by sexual dimorphism in body size. Body size influences metabolic requirements which in turn presumably influence feeding behavior. Thus, I tested 5 predictions with

black-tailed deer (O. hemionus columbianus) on Hopland Field Station, Mendocino County, California (USA), 1989-91, to determine if body size and its presumed impact on feeding behavior cause intersexual resource partitioning. Predictions, tested using radio telemetry and by measuring feeding behaviors of free ranging animals, ranged from general expectations about spatial distribution of specific predictions about feeding behavior. Males had larger (P lt 0.001) home range sizes than females, except in summer. Based on body size considerations female home ranges should be 0.75 the size of males. Mean ratios mostly varied from 0.30 to 0.40. However, because of large variation, confidence intervals overlapped 0.75 during most seasons. Females exhibited a higher (P lt 0.05) degree of site fidelity among seasons than males. The sexes differed (P lt 0.001) in use of habitats among months, however, the pattern was not consistent. Generally, deer used more open habitats (grassland, chaparral grassland, and oak grassland habitats) in the wetter winter months, and more closed habitats (oak woodland, chaparral) in the drier summer months. There was considerable monthly variations in percent of time active (P = 0.004) but no differences (P = 0.59) between the sexes. Type of forage and percent of time a deer's head was in the feeding position were the only variables correlated (P lt 0.001) with number of bites taken in 7- to 10-minute feeding sessions. Type of forage accounted for 92% of the variation associated with number of bites. No differences were detected between the sexes in number of bites taken (P = 0.34) or percent of time head was in the feeding position (P = 0.39) on any forage type. There was no (P gt 0.42) relationship between incisor breadth and body mass for each sex. Deer on Hopland Field Station exhibit sexual segregation, but the reason they segregate cannot be explained by differences in body size that may impact feeding behavior. The sexes do not partition resources to reduce intersexual competition. Harvest programs that assume no resource partitioning, however, ignore the possibility of intrasexual density dependent effects being manifested because of individuals avoiding the opposite sex or grouping with their own sex.

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Abstract: Selectivity of forages by ungulates may be in response to the abundance of forages (forage- abundance hypothesis) or the nutrient quality of palatable forages (selective-quality hypothesis). I examined predictions of both hypotheses by measuring feeding behaviors of free-ranging black-tailed deer (*Odocoileus hemiolas columbianus*) at Hopland Field Station, Mendocino Co., California. 1 observed 98 foraging sessions (foraging bout of 7- 10 min) of adult males and females in all seasons and measured the number of bites, time the head was in the feeding position, type of forage, and biomass of plants along foraging paths. Selection (seconds per bite) was strongly correlated with biomass of forages only when deer foraged on dried grass or fords. Seconds per bite varied considerably among types of forages: green grass-forbs (X = 1.3 s), leafy browse (3.8 s), dry grasses and fords (6.1 s), acorns (19.6 s). The head was in the feeding position significantly less when foraging on dry grasses and fords, and acorns than when deer foraged on green grass-forbs and leafy browse. Selectivity (seconds per bite) of leafy browse and acorns by deer was correlated with Julian date, an index to nutrient content. Number of bites was positively related to time the head was in the feeding position only when deer foraged on green grass- forbs. Selectivity of deer ostensibly varied in response to nutrient content, and searching was probably the dominant process influencing selectivity on most types of forages.

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Abstract: Understanding how overwinter survival of fawns changes as a function of density of deer is a critical relation for managing mule deer (*Odocoileus hemionus*) populations. We examined change in overwinter survival of fawns in response to intentional density reduction by radiotracking fawns on control and treatment areas. Deer density on the treatment area was lowered about 75%, mostly from antlerless harvests in December. There were 7 years of pretreatment data, 4 years of harvest, and 3 more years of posttreatment monitoring. Fawn survival rate on the treatment area during the 3 winters after density was lowered averaged 0.16 higher ($P = 0.001$) than the control area. After density was lowered, body mass of fawns on the treatment area in November-December averaged 0.8 kg more than the control ($P < 0.001$). A parallel decline in deer density began on the control area 2 years after initiation of the intentional density reduction on the treatment area. This decline was unexpected and the cause unknown, which left unanswered what the differences in fawn survival and body size between the 2 areas might have been if the control population remained high.

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Abstract: Knowledge of trends in deer abundance is required to manage deer populations effectively. We analyzed 18 years of spotlighting data to determine the minimal effort required to index a white-tailed deer (*Odocoileus virginianus)* population with a high degree of confidence on a 778-ha property in southeastern New York. Spotlight counts obtained from 2 and 4 nights of spotlighting were highly correlated ($r > 0.94$) with those obtained from 6–11 nights, suggesting that a modest spotlighting effort can suffice as a useful index to changes in local deer numbers. Spotlighting counts revealed an average 2% annual increase in deer numbers from 1981 to 1998. Environmental parameters such as mean temperature, relative humidity, and wind speed did not correlate well with spotlight counts. The number of deer harvested in the prior year did not predict numbers counted in the present year. We suggest that a modest annual spotlighting effort can

produce accurate indices of deer abundance while saving time and resources for agencies and organizations that index deer numbers.

Xie J, Hill HR, Winterstein SR, Campa HI, Doepker RV, Van DTR, Liu J. **1999.** White-tailed deer management options model (DeerMOM): Design, quantification, and application. *Ecological Modelling* **124:** 121-130.
Abstract: The deer management options model (DeerMOM) is a computer simulation model designed to assess the effects of management options on population size, sex and age structure of white-tailed deer (*Odocoileus virginianus*). In this model, we grouped deer into three age classes: fawn, yearling, and adult. Reproductive rates and fetal sex ratios were age-specific, while natural and harvest mortality rates were both age- and sex-specific. Deer MOM was parameterized to represent the deer population in the Upper Peninsula of Michigan, USA. Effects of winter severity were incorporated into the model. Population estimates derived from annual pellet group surveys were used to validate the model. Different management options were evaluated using two criteria: a quantity goal (number of deer) and a quality goal (percentage of antlered bucks in the deer population). Simulation results indicated that current management practices (with a high rate of buck harvest) resulted in high deer numbers with a low percentage of antlered bucks. Under the condition of high buck harvest rate, increasing doe harvest did not achieve both the quantity and the quality goals simultaneously. Moderate harvest of both sexes would control population growth and increase the percentage of antlered bucks. The simulations also showed that winter weather conditions and doe harvest shaped deer population trends but buck harvest determined the percentage of antlered bucks. Our findings indicated that quality deer management objectives can be reached only by lowering buck harvest rates while simultaneously increasing the doe harvest. The best option for achieving both the quantity and the quality goals was moderate harvest of bucks and does without sex bias.

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