Alaska Department of Fish and Game
Division of Game
Federal Aid in Wildlife Restoration
Research Final Report

PREDATOR—INDUCED LIMITATIONS ON DEER POPULATION GROWTH IN SOUTHEAST ALASKA

by
Christian A. Smith
E. L. Young
Charles R. Land
Kent P. Bovee

Project W-22-4, W-22-5, and W-22-6
Job 14.14R
May 1987

STATE OF ALASKA
Steve Cowper, Governor

DEPARTMENT OF FISH AND GAME
Don W. Collinsworth, Commissioner

DIVISION OF GAME
W. Lewis Pamplin, Jr., Director
Robert A. Hinman, Deputy Director

Additional copies of this report, or reports on other species covered in this series may be obtained from:

Publications Technician
ADF&G, Game Division
P.O. Box 3-2000
Juneau, AK 99802
(907) 465-4190

Cover art by Todd Sherman, Fairbanks, Alaska.

FINAL REPORT (RESEARCH)

State: Alaska

Project No.: W-22-4, W-22-5, W-22-6 Project Title: Big Game Investigations

Job No.: 14.14R Job Title: Predator-Induced Limitations on Deer Population Growth in Southeast Alaska

Period Covered: 1 July 1984-30 June 1987

SUMMARY

Current deer (*Odocoileus hemionus sitkensis*) population densities in Game Management Unit (GMU) 3 are among the lowest in the range of this species. Although results of nightcounts conducted on southern Mitkof Island suggest deer numbers in that area may be increasing slowly, numbers remain well below levels required to meet management objectives.

Wolf (*Canis lupus*) numbers appear to be relatively low and stable; lack of snow has prevented a more accurate population estimation. Few wolves are harvested in GMU 3 due to difficult trapping conditions and poor financial return for effort expended.

Attempts to monitor fawn mortality were frustrated by our inability to locate sufficient neonates for telemetry. Indirect estimation of productivity and/or survival was not possible because samples were too small to permit estimation of the population's age structure.

Theoretical and empirical studies of the interactions between deer and wolves from several regions of North America (including coastal forest systems) suggest that predation is a major regulator of deer numbers. The prolonged lack of recovery of deer populations in much of GMU 3 following winter die-offs in the late 1960's and early 1970's may be due to wolf predation. Habitat alteration through logging may also have contributed to reduction of deer numbers to levels where wolf predation has become suppressive.

Key words: *Canis*, deer, *Odocoileus*, population dynamics, predation, wolf.

CONTENTS

BACKGROUND

This study was initiated in an effort to evaluate the role of predation in recovery of deer (*Odocoileus hemionus sitkensis*) populations in Game Management Unit (GMU) 3 following major population declines in the late 1960's and early 1970's. A thorough review of predator-prey literature and local background information related to this project was documented in Smith et al. (1986). Since that time, Atkinson and Janz (1986) have provided further support for the hypothesis that deer populations in GMU 3 are limited by wolf (*Canis lupus*) predation.

STUDY OBJECTIVE

To determine the effects of predation on population dynamics of Sitka black-tailed deer in Southeast Alaska.

JOB OBJECTIVES

1. To determine relative or absolute population density of deer within the study area.

2. To determine relative or absolute population density of wolves within the study area.

3. To determine causes of fawn mortality.

4. To determine sex and age composition of the deer population within the study area.

5. To assess historic trends in deer and wolf populations in GMU 3.

STUDY AREA

The study area consisted of Mitkof, Kupreanof, and Kuiu Islands in GMU 3. Biophysical attributes of the area are detailed in Smith et al. (1986).

METHODS

Deer Population Density

Relative density of deer on southern Mitkof Island was determined using the nightcount technique as described by Harestad and Jones (1981). Locations of survey routes were presented in Smith et al. (1986).

To determine trend in deer numbers, nightcount data were log-transformed and regressed against time (Caughley 1977). Reliability of trend lines and significance of rate of increase were determined by generation of 68% confidence intervals ($\pm$1 SE) around the observed rate of change in mean number of deer seen on each transect each year (Harris 1986).

Wolf Population Density

Wolf numbers were estimated from aerial surveys following fresh snowfall and from reported sightings by local residents.

Fawn Mortality

Fawn mortality was assessed using radiotelemetry as described by Hatter (1984). Methods of capture and monitoring were presented by Smith et al. (1986).

Sex and Age Ratios

Sex ratio of adult deer was determined by classifying those individuals encountered within 50 m of the road during spotlight counts. Beyond this distance it was not possible to positively identify sex. In addition, in 1986 a helicopter survey of clearcut units within the study area was used to classify deer.

Historic Trends

Sources of information and discussion of historic trends were detailed in Smith et al. (1986). No further work was conducted on this objective during this report period.

RESULTS AND DISCUSSION

Deer Population Density

Nightcounts were conducted on 18 March and on 2, 3, and 5 June 1986. When compared with results of previous years' counts (Fig. 1), these data imply that the deer population is increasing. However, limitations in these data (i.e., only 3 years' monitoring) demand substantial caution in reaching this conclusion (Harris 1986). For example, although all of the confidence intervals for the estimated rates of increase (r_o) exclude "0," we are only 68% confident that the true rate of increase falls within these intervals. Furthermore, Harris (1986) indicated that violation of any of the assumptions inherent in this analysis (a very real possibility for these nightcounts) causes underestimation of SE (r_o), so these intervals may be too narrow.

With the exception of Transect 3, the positive slopes of the regression lines are generated entirely by the changes in numbers between 1984 and 1985. In all other cases, there were no changes between 1985 and 1986 values (Fig. 1). In fact, if mean numbers of deer counted on transects are taken as point estimates, rather than log-transformed, none of the values on any transect are significantly different ($P > 0.1$) for the 3 years.

Due to variability of nightcounts conducted in areas of relatively low deer numbers (Harestad and Jones 1981, Smith et al. 1986) and the lack of any other tests of their reliability in southeast Alaska, the conclusion that deer on southern Mitkof Island are increasing is tentative at best. At least 1 additional year's data will be necessary to clarify trend.

For comparison with other areas, the number of deer seen on nightcounts was converted to an index of relative density by dividing the total count by length of each transect (Harestad and Jones 1981). Mean number of deer observed per km of transect driven in the study area during 1984-86 ranged from 0.1 to 3.2 (Table 1).

Prior to recovery of the Vancouver Island wolf population in the mid-1970's, nightcounts there averaged 10-20 deer/km on central island watersheds (Jones and Mason 1983). By the early 1980's, counts had declined to less than 5 deer/km in most areas. From 1983 through 1986, counts increased slightly, but most transects still have fewer than 8 deer/km (Atkinson and Jones 1986).

At current deer densities on Vancouver Island, wolves have been found to have a significant impact on recruitment (Hatter 1984), and wolf predation is believed to be the primary agent preventing deer population increases in many areas (Jones and Mason 1983, Atkinson and Janz 1986, Janz and Hatter 1986). Inasmuch as deer density on southern Mitkof Island is lower than on Vancouver Island, the potential for wolf predation's being a major limiting factor is even greater (Van Ballenberghe and Hanley 1982).

Wolf Population Density

Weather during the winter of 1985-86 did not permit aerial wolf-track surveys, but reports by local residents indicated that a pack of wolves was using the Woodpecker Cove area where Smith et al. (1986) estimated 2-4 wolves occurred in 1984-85. Although 3 wolves were taken by trappers from Mitkof Island during the 1985-86 season, it is probable that at least 3 pups were produced during 1986. Thus, the current population on Mitkof is estimated to be at least as large as the 1985 estimate of 4-8 wolves. In view of the fact that recruitment might have been greater and that wolves may have been missed by Smith et al. (1986) it is possible that the population is actually at least 8-12 wolves.

A population of 8-12 wolves on Mitkof Island would result in a density of 1 wolf per 50-75 km^2. This density is intermediate to values reported by Atkinson and Janz (1986) for their wolf-removal area on Vancouver Island (1 wolf per 100 km^2) and an adjacent nonremoval zone (1 wolf per 37 km^2). The maximum density reported for the coastal region was 1 wolf per 12-17 km^2 (Hebert et al. 1982).

Fawn Mortality

During June 1986 we captured and radio-collared 3 fawns (Table 2). Two of these are believed to be siblings, although they were captured 2 days apart. The 2nd fawn was found incidental to radio-locating the first. This indicates that future fawn-capture efforts may be improved by intensively searching the area surrounding each collared fawn during times when fawns have been hidden by the doe. The 3rd fawn was captured incidental to conducting a helicopter survey of the study area. As of 1 September 1986, all 3 fawns were still alive.

The limited number of fawns monitored in this study (n = 6) and the early termination of the project preclude drawing any firm conclusions regarding rates or causes of fawn mortality in the study area. However, data on fawn mortality from a comparable predator-prey system on Vancouver Island revealed that wolf predation was the only significant factor in reducing survival of deer less than 1 year old under normal weather conditions (Hatter 1984). Neither bear nor cougar predation, starvation, disease, or hunter kill, singly or in combination, accounted for mortality equal to wolf predation. Subsequently, Atkinson and Janz (1986) reported a significant increase in fawn survival to 6 months of age in the same area following reduction of wolves when compared with survival in adjacent areas without wolf reductions.

Sex and Age Ratios

The observed sex ratio among captured fawns (5 males: 1 female), though based on a very small sample, suggests that males predominate among neonates. Taber (1953) reported that this is typical of the genus *Odocoileus*.

Results from nightcounts and a June 1986 helicopter survey (Table 3) indicate that the adult sex ratio does not differ significantly from 50:50 ($P > 0.50$). Taber and Dasmann (1954) reviewed earlier studies and reported that populations of both species of *Odocoileus* have adult sex ratios approximating 50:50 under favorable range conditions, but that females dominate in food-stressed herds. The equal sex ratio found in this study implies that deer on Mitkof Island are not nutritionally limited.

Age ratios could not be determined for the population. Deer density was so low that it was impossible to locate sufficient numbers of deer in fall or winter to classify a useful sample of fawns and adults.

CONCLUSION

The historical information on deer and wolf populations reported in Smith et al. (1986) indicates that prior to 1960, periodic wolf control efforts may have "released" deer from the limiting effects of predation. This resulted in major increases in deer numbers until the next series of harsh winters caused major die-offs (Merriam 1970, Olson 1979). Analysis of long-term weather patterns reveals that such winters occurred at approximately 10-12 year intervals (Juday 1982, Smith 1986).

Following the last major reduction in deer in the winters of 1968-69, 1970-71, and 1971-72, wolves were not reduced through government control activities, and deer numbers did not "rebound." However, in addition to the lack of wolf control, the most recent "cycle" also has the additional variable of habitat alteration. Between 1960 and 1968, a substantial portion of the critical winter range for deer on Mitkof Island was eliminated by clearcut logging. This may have resulted in excessive deer losses in the late 1960's and early 1970's and greatly increased the potential for wolves to suppress deer numbers (Van Ballenberghe and Hanley 1982).

The prolonged (i.e., >10 years) lack of increase in deer in GMU 3, while deer have increased by several orders of magnitude in adjacent GMU 4 (where wolves are absent), further implicates wolf predation as the major limiting factor. Empirical data from Vancouver Island (Jones and Mason 1983, Atkinson and Janz 1986) and Minnesota (Hoskinson and Mech 1976, Mech and Karns 1977, Nelson and Mech 1981), as well as theoretical models (Van Ballenberghe and Hanley 1982, Appendix A), support the hypothesis that wolf predation is currently suppressing deer populations in GMU 3.

Although results of nightcounts reported here suggest deer may be increasing slowly on southern Mitkof, it would take at least one more year's data to confirm population trend. Furthermore, even if deer are increasing, the population is well below the level necessary to fulfill management objectives for this area (ADF&G Draft Wildl. Manage. Plans 1977). As discussed by Janz and Hatter (1986) for Vancouver Island, failure to meet objectives for deer can erode support for protection of deer habitat, with adverse consequences for other old-growth-dependent species.

A conservative management approach at this time would be to continue to conduct nightcounts along existing transects to clarify population trend; to continue to prohibit the taking of deer in most of GMU 3; and to intensify efforts to estimate wolf numbers for modeling purposes. Given the sex ratio of adults, a limited harvest of males would likely have no adverse effect on reproduction, but could intensify predation on does and/or juveniles.

In view of mounting evidence that wolf predation is capable of limiting, or even depressing, a variety of ungulate populations (Bergerud 1974, Keith 1974, Mech and Karns 1977, Bergerud et al. 1983, Carbyn 1983, Gasaway et al. 1983, Jones and Mason 1983, Hatter 1984, Atkinson and Janz 1986) future wildlife management efforts in the coastal region must address deer and wolves as an integrated system (Janz and Hatter 1986). Sustaining desired population levels of both species will become increasingly difficult as logging continues to eliminate old-growth forests (Van Ballenberghe and Hanley 1982). If wolves are in fact limiting deer populations in GMU 3, greatly reduced opportunities for harvesting deer will probably continue in the absence of a wolf reduction program designed to eventually increase both deer and wolves.

LITERATURE CITED

Atkinson, K., and D. W. Janz. 1986. Effect of wolf control on black-tailed deer in the Nimpkish Valley on Vancouver Island. Prog. Rep. WR - 19. Min. Environ. Fish and Wildl. Branch. Nanaimo, B.C. 31pp.

Bergerud, A. T. 1974. Decline of caribou in North America following settlement. J. Wildl. Manage. 38(4)757-770.

__________, W. Wyett, and B. Snider. 1983. The role of wolf predation in limiting a moose population. J. Wildl. Manage. 47(4):997-988.

Carbyn, L. 1983. Wolf predation on elk in Riding Mountain National Park, Manitoba. J. Wildl. Manage. 47(4):963-976.

Caughley, G. 1977. Analysis of vertebrate populations. J. Wiley and Sons. New York, N.Y. 234pp.

Gasaway, W. C., R. O. Stephenson, J. L. Davis, P. E. K. Shepherd, and O. E. Burris. 1983. Interrelationships of wolves, prey and man in interior Alaska. Wildl. Mono. 84. ,50pp.

Harestad, A. S., and G. W. Jones. 1981. Use of night counts for censusing black-tailed deer on Vancouver Island. Pages 83-96 in F. L. Miller and A. Gunn, eds. Proc. Symp. on Census and Inventory Methods for Populations and Habitats. NW Sec., The Wildl. Soc.

Harris, R. B. 1986. Reliability of trend lines obtained from variable counts. J. Wildl. Manage. 50:165-171.

Hatter, I. W. 1984. Effects of wolf predation on recruitment of Vancouver Island black-tailed deer. M.S. Thesis, Univ. of Ida. 156pp.

Hebert, D. M., J. Youds, R. Davies, H. Langin, D. Janz, and G. W. Smith. 1982. Preliminary investigations of the Vancouver Island wolf-prey relationships. Pages 54-70 in F. H. Harrington and P. C. Paquet, eds. Wolves of the World. Noyes Publ. Park Ridge, N.J.

Hoskinson, R. L., and L. D. Mech. 1976. White-tailed deer migration and its role in wolf predation. J. Wildl. Manage. 40(3):429-441.

Janz, D., and I. W. Hatter. 1986. A rationale for wolf control in the management of the Vancouver Island predator-ungulate system. B.C. Min. of Environ. Wildl. Bull. No. B-45. 35pp.

Jones, G. W., and B. Mason. 1983. Relationships among wolves, hunting and population trends of black-tailed deer in the Nimpkish Valley on Vancouver Island. Fish and Wildl. Rep. No. R-7. Min. Environ. Victoria, B.C. 25pp.

Juday, G. P. 1982. Temperature trends in the Alaska climate record: Problems, update and prospects. Paper presented at a Conf. on the Potential Effects of Carbon Dioxide-Induced Climatic Change in Alaska, April 7-8, 1982. Univ. of Alaska. 68pp.

Keith, L. B. 1974. Some features of population dynamics in mammals. Trans. Int. Congr. Game Biol. 11:17-58.

Mech, L. D., and P. D. Karns. 1977. Role of the wolf in a deer decline in the Superior National Forest. U.S. Dep. Agric. For. Serv. Res. Pap. NC-51. North Cent. For. Exp. Stn., St. Paul, Minn. 62pp.

Merriam, H. R. 1970. Deer fluctuations in Alaska. Paper presented to Ann. Mtg. Northwest Sec., The Wildl. Soc., Spokane, Wa. 5pp.

Nelson, M. E., and L. D. Mech. 1981. Deer social organization and wolf predation in northeastern Minnesota. Wildl. Mono. 77. 53pp.

Olson, S. T. 1979. The life and times of the black-tailed deer in southeast Alaska. Pages 160-168 in O. C. Wallmo and J. W. Schoen, eds. Sitka black-tailed deer. USDA For. Serv., Alaska Region. Ser. No. RIO-48.

Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. J. Wildl. Manage. 46:(2)281-301.

__________, __________, and C. S. Bienz. 1982. Parturition behavior and territoriality in white-tailed deer: Impact on neonatal mortality. J. Wildl. Manage. 46(1):1-11.

Taber, R. D. 1953. The secondary sex ratio in Odocoileus. J. Wildl. Manage. 17:(1)95-97.

__________, and R. F. Dasmann. 1954. A sex difference in mortality in young columbian black-tailed deer. Jour. Wildl. Manage. 18:(3)309-315.

__________, E. L. Young, C. R. Land, and K. P. Bovee. 1986. Effects of predation on black-tailed deer population growth. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-22-4. Job 14.13. Juneau. 35pp.

Van Ballenberghe, V., and T. A. Hanley. 1982. Predation on deer in relation to old-growth forest management in southeastern Alaska. Pages 291-296 in W. R. Meehan, T. R. Merrell, Jr., and T. A. Hanley, tech. eds. Proc. Symp. Fish and Wildl. Rel. in Old-growth Forests. Am. Inst. Fish. Res. Biol., Wash. D.C.

PREPARED BY:

Christian A. Smith
Game Biologist IV

SUBMITTED BY:

David A. Anderson
Regional Supervisor

APPROVED BY:

W. Lewis Pamplin Jr. /bt
W. Lewis Pamplin, Jr.
Director, Division of Game

Steven R Peterson
Steven R. Peterson
Chief of Research, Division of Game

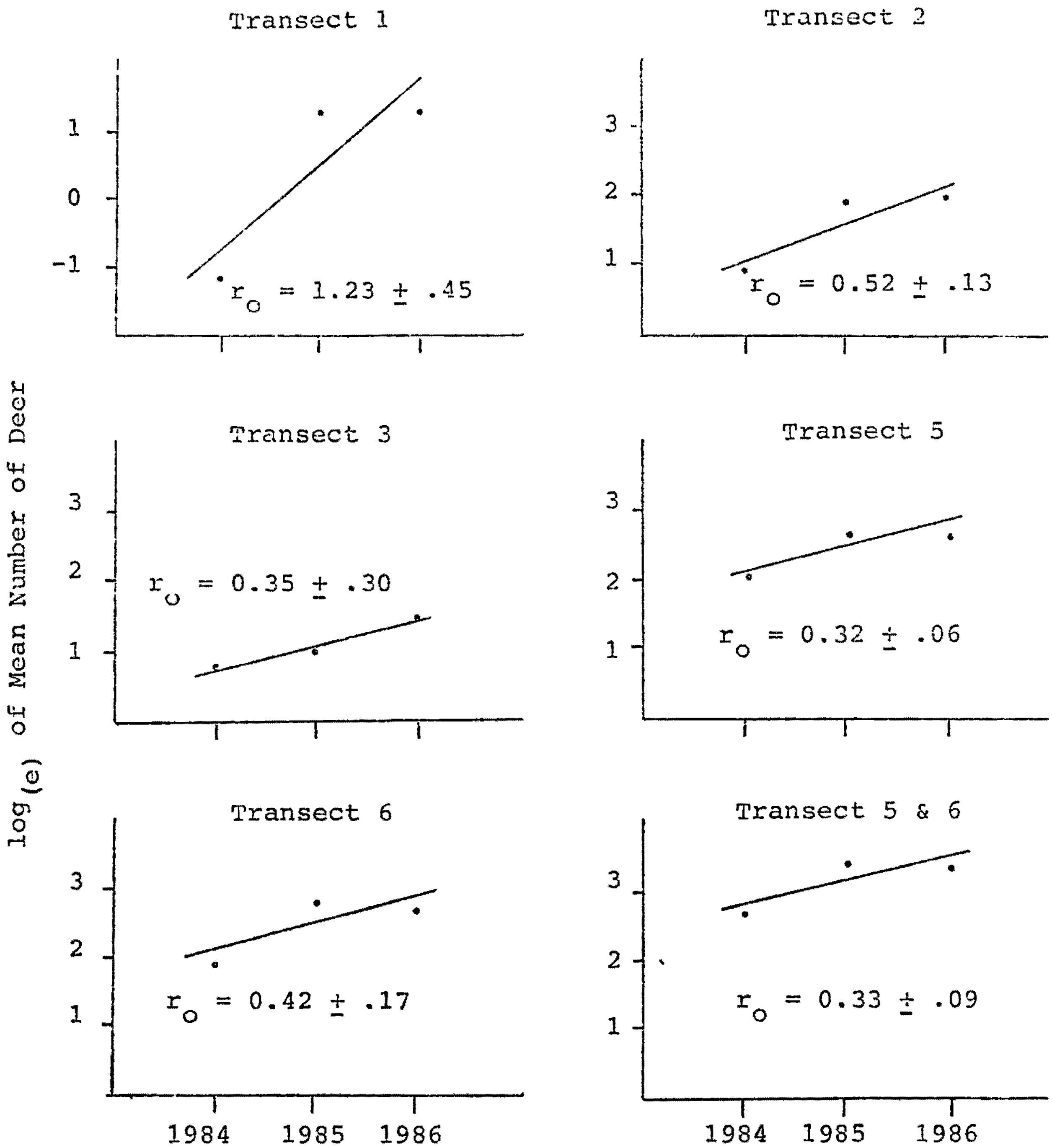

Fig. 1. Trend lines for nightcount transects on southern Mitkof Island, Alaska, 1984-86 along with observed rate of increase (r_o) ± S. E.

Table 1. Deer density index (deer/km) from nightcount transects on southern Mitkof Island, Alaska, 1984-86.

Transect	Year	Mean	Range	(n)
1	1984	0.1	0.0 - 0.3	4
	1985	1.1	0.6 - 1.6	2
	1986	1.1	0.6 - 2.2	4
2	1984	0.6	0.2 - 1.2	5
	1985	1.5	1.2 - 1.6	4
	1986	1.6	1.2 - 1.9	4
3	1984	0.5	0.0 - 1.2	3
	1985	0.8	0.4 - 1.5	4
	1986	1.5	0.4 - 3.0	4
4	1984	--	--	-
	1985	0.7	0.0 - 1.4	3
	1986	0.7	0.0 - 1.4	2
5	1984	1.7	1.0 - 3.1	5
	1985	3.2	1.4 - 4.5	4
	1986	3.2	2.4 - 3.5	4
6	1984	1.0	0.4 - 1.4	7
	1985	2.5	1.7 - 3.3	4
	1986	2.3	0.5 - 4.4	4
5&6	1984	1.4	1.0 - 2.1	5
	1985	2.8	2.0 - 3.4	4
	1986	2.6	1.7 - 3.6	4

Table 2. Results of fawn capture and mortality monitoring on Mitkof Island, Alaska, 1984-86.

Fawn No.	Capture date	Sex	Age (days)	Fate
1	6/6/84	M	5	Shed collar; seen alive 7/85
2	6/4/85	M	4	Shed collar in 10/85
3	6/5/85	M	4	Killed 6/18/86 by black bear
4	6/3/86	M	10	Alive as of 6/30/86
5	6/5/86	M	12	Alive as of 6/30/86
6	6/13/86	F	14	Alive as of 6/30/86

Table 3. Results of classification of adult deer on nightcounts in 1984 and 1986, and an aerial survey in 1986, Mitkof Island, Alaska.

Date	Method	Males:100 females	(*n*)
June 1984	Nightcount	113:100	32
June 1986	Nightcount	67:100	10
June 1986	Aerial survey	100:100	26

Appendix A

A DEER - WOLF STABILITY MODEL FOR SOUTHEASTERN ALASKA

By

Christian A. Smith
Alaska Department of Fish and Game
Ketchikan, Alaska[1]

Introduction:

This computer model can be used to estimate the population density of deer whose numbers would be maintained at equilibrium in the presence of known numbers of wolves and of any given hunting pressure for any area in southeastern Alaska. It can be applied at the level of a VCU, an individual wolf pack's territory, or an entire island. Users are cautioned that reliability probably decreases as the area modeled increases, but to date no tests of precision have been made.

The model is intended to be used as a management tool which will allow biologists to generate a range of theoretical deer density estimates which can be compared with winter range densities as measured by standard pellet group transects or any other method. The model is extremely simple, to permit multiple runs with various input parameters in a short "gaming" session. This was considered a necessity in view of the lack of good data on wolf and deer numbers or the relative magnitude of hunter kill in most areas. The results are presented as a range of values which will require certain local knowledge for interpretation. This was considered acceptable since the objective of the model is not to tell us something we do not already know, but simply to help quantify and evaluate "gut feelings" and test the potential outcomes of various management options.

The model is based on Keith's (1983) stability equation:

$$N = K/[(r-1)(1-H)]$$

in which N = ratio of deer to wolves in spring prior to births, K = the number of deer killed per wolf per year, r = the potential rate of increase in deer if predation and hunting suddenly stopped and H = the proportion of the annual

[1] Current address: Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701.

increment to the deer herd that is removed by hunting. This equation was selected because, in spite of its simplicity, it incorporates all the factors relevant to the influence of wolves and hunting on deer population growth and produces a numerical result that can be used to calculate other meaningful values.

Input/Output Parameter Values:

Wolves have been found to be highly efficient predators of deer and are expected to display a broad functional response to deer density. Thus K can be expected to vary over a relatively wide range. Published values for K in other wolf:deer systems range from 18 (Mech and Frenzel 1971) in Minnesota to 25 (Hebert et al. 1982) on Vancouver Island. Due to the smaller size of Sitka black-tailed deer, K may be even higher in Alaska in areas where deer:wolf ratios are high. Conversely, in areas of extremely low deer:wolf ratios, wolves may be able to sustain themselves where K falls below 15 due to the availability of alternative foods such as beaver, salmon, waterfowl, or marine mammals.

In this model, K has been given values ranging from 5 to 30. Although it is anticipated that each wolf will generally take at least 15 deer per year, some users may wish to examine results for extremely low K values. As illustrated below, using minimal K values can provide insight into the impact of chronic low-level wolf predation on some deer populations.

The potential rate of increase for deer used in this model is 1.35. This implies that if predation and hunting were eliminated, the population would increase at about 35% per year. While there are no published estimates of rate of increase for deer in Alaska, Connolly (1981) reported that the highest estimates of potential rate of increase for established populations of mule and Columbian black-tailed deer herds was 1.4. This model's use of an r value near this maximum assumes:

1) deer are currently well below the carrying capacity of the range and,

2) that predation and hunting are the major sources of loss to the population.

The 1st assumption is supported by the abundance of available forage in many areas of potential deer winter range. The latter is supported by the lack of known pathological parasites and diseases in deer in Game Management Units 1 - 3, and the mild nature of recent winters in this area.

If assumptions 1 and 2 are rejected, a lower r could be used, but this would result in higher deer:wolf ratios being required for stability. The use of $r = 1.35$ appears to be biologically sound and produces conservative results with respect to wolves' ability to control deer.

To use the program the following parameters must be used:

1) The name and size of the area you wish to consider. You must specify whether you are working in metric (km^2) or English (mi^2) units.

2) The number of wolves occupying the area in late winter, before birth of new pups.

3) The proportion of the annual increment to the deer population removed by hunting.

In the absence of good data for inputs 2 and 3, estimates may be used, and the program can be run several times for a given area using different values to provide a range of outputs. One must, of course, be aware of the influence of liberal or conservative estimates on the nature and quality of the results.

Given the proportion of the annual increment of deer taken by hunters (H), the program calculates the deer:wolf ratio (N) required for stability with the different wolf killing rates. These ratio values are multiplied by the given number of wolves to determine the number of deer at equilibrium. To convert deer numbers to a value more easily compared with available data the number of deer is divided by 10, 20, 30 and 40% of the total area to provide density estimates for deer on winter range for conditions ranging from severe to mild.

Program output is provided as a matrix of values for stability threshold deer densities under varying winter conditions and wolf kill rates. These values can be compared with actual density estimates based on pellet group counts to provide some indication of the likelihood that wolves are limiting deer in the area. If estimated deer densities are less than the predicted threshold values, a decline in deer numbers can be expected. If estimated density is approximately equal to the predicted threshold level, it is probable that wolves are controlling deer. If measured densities significantly exceed the threshold, wolf predation should not be limiting deer numbers.

Applications:

To illustrate the use of the model, the program was run for Zarembo Island which has an area of about 475 km^2 (182 mi^2).

Initially, it was estimated that 9 wolves live on the island and that hunters take 10% of the annual increment of deer (E. L. Young, pers. commun.). The model predicted that if deer were able to utilize 40% of the island as winter range and that each wolf on the island killed as few as 5 deer per year, deer numbers would remain stable as long as winter range density was 1 deer/km^2 (Table 1). On the other hand, if deer could only use 10% of the island in winter, and wolves killed 30 deer each per year, there would have to be 18 deer/km^2 on winter range for the system to remain at equilibrium.

Although winter-range deer density has not been quantified on Zarembo Island, it is believed to be comparable to that of Security Bay on northern Kuiu Island, or approximately 0.5 - 1.0 deer/km^2 (E. L. Young, pers. commun.). Inasmuch as this value is less than or equal to the predicted threshold density for all values of K, a population of 9 wolves could suppress deer numbers on Zarembo even if deer constituted a very minor part of their diet.

The program was run several more times for Zarembo Island, with constant hunting pressure and decreasing numbers of wolves, to determine what degree of wolf removal would be necessary to permit the deer population to increase. When wolf numbers reached 3, a density of 1 deer/km^2 wintering on 30% of the island would increase if K = 5, but would still be held at equilibrium if the killing rate equaled or exceeded 10 (Table 2). If wolves were reduced to 2, 1 deer/km^2 wintering on 30% of the island could increase if K = 10, but not if K were higher (Table 3). This indicates that even a few wolves could continue to suppress the limited deer population on Zarembo if deer constituted a significant part of their diet.

The model was also run for Heceta Island, an area of about 190 km^2 (72 mi^2), using a wolf population of 5 and hunter kill of H = 0.3. Although much of the eastern half of the island is covered in nonproductive second-growth forest, in view of the relatively mild nature of winter weather on this western island, deer may be able to winter over as much as 20-30% of the land area. Accordingly, the stability threshold densities predicted by the model range from 2-16 deer/km^2, depending on the value of K (Table 4).

Pellet group transects surveyed on Heceta Island in 1984 and 1985 indicated that winter range deer densities are probably in the range of 25-35 deer/km^2. This exceeds the stability threshold for deer even at K = 30, so it is not likely that 5 wolves would limit population growth on this island. However, if wolf numbers increased to 10 and hunting pressure increased to H = 0.5, deer would fall below the stability threshold if K exceeded 20-25 (Table 5). Under these conditions, the deer population would decline. Until data are available on actual values of K, a conservative management approach would seek to maintain wolf numbers at 5-7 and limit hunter kill to less than half the annual increment on Heceta Island until future pellet-group surveys indicate that deer density has increased.

These examples illustrate how the model can be used to test the effect of wolf control or to set management guidelines. Because the output is presented as a range of values, users will have to apply local knowledge to decide what percentage of the area is usable winter range and what value of K can be considered realistic. The model is only intended to help the user establish boundaries on probable outcomes and is based on certain assumptions that may not hold in all cases.

Literature Cited

Connolly, G. 1981. Limiting factors and population regulation. Pages 245-285 *in* O. C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. of Neb. Press. Lincoln, Nebr.

Hebert, D. M., J. Youds, R. Davies, H. Langin, D. Janz, and G. W. Smith. 1982. Preliminary investigations of Vancouver Island wolf (*Canis lupus crassodon*) prey relationships. Pages 54-70 *in* F. H. Harrington and P. C. Paquet, eds. Wolves of the World. Noyes Publ. Park Ridge, N.J.

Keith, L. B. 1983. Population dynamics of wolves. Pages 66-77 *in* L. Carbyn, ed. Wolves in Canada and Alaska: Their status, biology and management. Canadian Wildl. Serv. Rep. Ser. No. 45.

Mech, L. D. and L. D. Frenzel. 1971. Ecological studies of the timber wolf in northeastern Minnesota. USDA Forest Service, Res. Pap. NC - 51. Nor. Cent. For. Exp. Sta., St. Paul, Minn.

Table 1

STABILITY THRESHOLD DEER DENSITIES (DEER/KM^2)
FOR VARIOUS KILL RATES (DEER/WOLF/YEAR) AND WINTER RANGE AREAS

AREA: ZAREMBO ISLAND (475 KM^2) ESTIMATED WOLF NUMBERS: 9

PROPORTION OF DEER RECRUITMENT TAKEN BY HUNTERS: 10%

Wolf kill rate	Percentage of area used by deer in winter			
	10	20	30	40
5	3	2	1	1
10	6	3	2	2
15	9	5	3	2
20	12	6	4	3
25	15	8	5	4
30	18	9	6	5

Table 2

STABILITY THRESHOLD DEER DENSITIES (DEER/KM^2)
FOR VARIOUS KILL RATES (DEER/WOLF/YEAR) AND WINTER RANGE AREAS

AREA: ZAREMBO ISLAND (475 KM^2) ESTIMATED WOLF NUMBERS: 3

PROPORTION OF DEER RECRUITMENT TAKEN BY HUNTERS: 10%

Wolf kill rate	Percentage of area used by deer in winter			
	10	20	30	40
5	1	1	0	0
10	2	1	1	1
15	3	2	1	1
20	4	2	1	1
25	5	3	2	1
30	6	3	2	2

Table 3

STABILITY THRESHOLD DEER DENSITIES (DEER/KM^2)
FOR VARIOUS KILL RATES (DEER/WOLF/YEAR) AND WINTER RANGE AREAS

AREA: ZAREMBO ISLAND (475 KM^2) ESTIMATED WOLF NUMBERS: 2

PROPORTION OF DEER RECRUITMENT TAKEN BY HUNTERS: 10%

Wolf kill rate	Percentage of area used by deer in winter			
	10	20	30	40
5	1	0	0	0
10	1	1	0	0
15	2	1	1	1
20	3	1	1	1
25	3	2	1	1
30	4	2	1	1

Table 4

STABILITY THRESHOLD DEER DENSITIES (DEER/KM^2)
FOR VARIOUS KILL RATES (DEER/WOLF/YEAR) AND WINTER RANGE AREAS

AREA: HECETA ISLAND (190 KM^2) ESTIMATED WOLF NUMBERS: 5

PROPORTION OF DEER RECRUITMENT TAKEN BY HUNTERS: 30%

Wolf kill rate	Percentage of area used by deer in winter			
	10	20	30	40
5	5	3	2	1
10	11	5	4	3
15	16	8	5	4
20	21	11	7	5
25	27	13	9	7
30	32	16	11	8

Table 5

STABILITY THRESHOLD DEER DENSITIES (DEER/KM^2)
FOR VARIOUS KILL RATES (DEER/WOLF/YEAR) AND WINTER RANGE AREAS

AREA: HECETA ISLAND (190 KM^2) ESTIMATED WOLF NUMBERS: 10

PROPORTION OF DEER RECRUITMENT TAKEN BY HUNTERS: 50%

Wolf kill rate	Percentage of area used by deer in winter			
	10	20	30	40
5	15	8	5	4
10	30	15	10	8
15	45	23	15	11
20	60	30	20	15
25	75	38	25	19
30	90	45	30	23