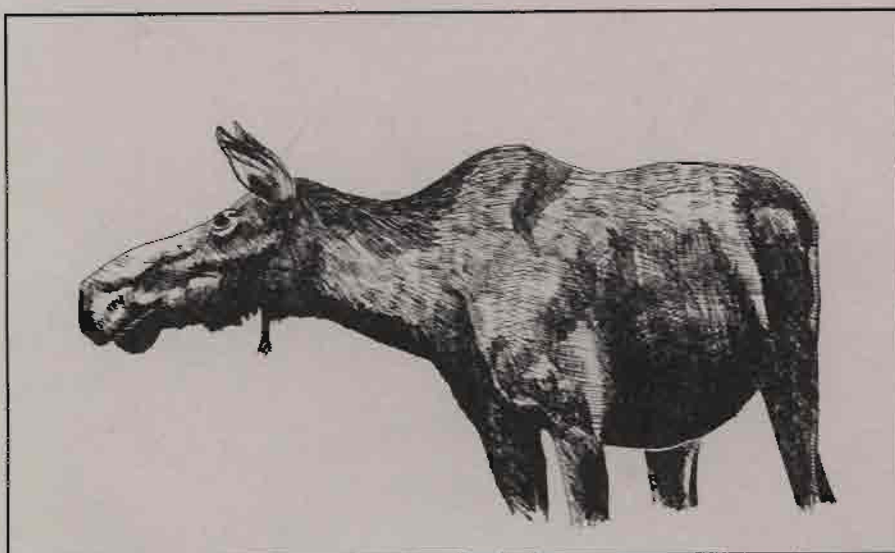
SUSITNA HYDROELECTRIC PROJECT
FINAL REPORT
BIG GAME STUDIES—VOL. V
MOOSE CARRYING CAPACITY ESTIMATE



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PREFACE

Between January 1980 and June 1986, the Alaska Power Authority (APA) contracted with the Game Division of the Alaska Department of Fish and Game (ADF&G) to provide field data and recommendations for assessing potential impacts and developing options for mitigating impacts of the proposed Susitna Hydroelectric Project on moose, caribou, brown bear, black bear, Dall sheep, wolf, wolverine, and belukha whales; ADF&G was only one of many participants in this program. Information on birds, small mammals, furbearers, and vegetation was collected by the University of Alaska and private consulting firms.

Formally, ADF&G's role was to collect data that could be used to describe the baseline, preproject conditions. This information was supplemented to include processes that might be sufficiently sensitive to either direct or indirect project-induced impacts to alter the dynamics of the wildlife populations. The responsibility of impact assessment and mitigation planning was assigned by APA to several private consulting firms. ADF&G staff worked closely with these firms, but only in an advisory capacity.

The project was cancelled before the impact assessment and mitigation planning processes were complete. In an effort to preserve the judgments and ideas of the authors at the termination of the project, the scope of this report has been expanded to include material relating to impact assessment and mitigation planning. Statements do not necessarily represent the views of the APA or its contractors. Conjectural statements sometimes are included in the hope that they may serve as hypotheses to guide future work, should the project be reactivated.

The following list of progress reports completely cover all of the Game Division's contributions to the project. It should not be necessary for the reader to consult them.

Moose

Modaferri, R. D. 1987. Susitna Hydroelectric Project, Big Game Studies, Final Report Vol. I - Moose - Downstream. Alaska Dept. of Fish and Game.

Ballard, W. R. and J. S. Whitman. 1987. Susitna Hydroelectric Project, Big Game Studies, Final Report, Vol. II - Moose - Upstream. Alaska Dept. of Fish and Game.

Becker, E. F. and W. D. Steigers. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report, Vol. III - Moose forage biomass in the middle Susitna River basin, Alaska. Alaska Dept. of Fish and Game.

Becker, E. F. 1987. Susitna Hydroelectric Project. Big Game Studies. Final Report. Vol. V - Moose Carrying Capacity Estimate. Alaska Dept. of Fish and Game.

<u>Caribou</u>

Pitcher, K. W. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. IV - Caribou. Alaska Dept. of Fish and Game. 59pp.

<u>Black Bear and Brown Bear</u>

Miller, S. D. 1987. Susitna Hydroelectric Project, Big Game Studies, Final Report. Vol. VI - Black Bear and Brown Bear. Alaska Dept. of Fish and Game.

<u>Wolf</u>

Ballard, W. B., J. S. Whitman, L. D. Aumiller, and P. Hessing. 1984. Susitna Hydroelectric Project, Big Game Studies. 1983 Annual Report. Vol. V - Wolf. Alaska Dept. of Fish and Game. 44pp.

Ballard, W. B., J. S. Whitman, and C. L. Gardner. 1987. Ecology of an exploited wolf population in southcentral Alaska. Wildlife Monographs No. __ (In press).

<u>Wolverine</u>

Whitman, J. S. and W. B. Ballard. 1984. Susitna Hydroelectric Project, Big Game Studies. 1983 Annual Report. Vol. VII - Wolverine. Alaska Dept. of Fish and Game. 25pp.

<u>Dall Sheep</u>

Tankersley, N. G. 1984. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. VIII - Dall Sheep. Alaska Dept. of Fish and Game. 91pp.

<u>Belukha Whale</u>

Calkins, D. 1984. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. IX - Belukha Whale. Alaska Dept. of Fish and Game. 16pp.

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INTRODUCTION

Construction of the proposed Susitna Hydroelectric project would result in the loss or alteration of extensive areas of moose (Alces alces) habitat through a variety of mechanisms (Ballard et al. 1987). As a result, both short- and long-term changes in moose carrying capacity would occur. While there would be at least short-term increases in carrying capacity in localized areas, a long-term net decrease in potential of the middle Susitna basin to support moose is expected. However, efforts to manipulate successional stages of certain plant communities have successfully increased moose carrying capacity in some areas of Alaska. Consequently, a key element in mitigation plans under consideration by the Alaska Power Authority is compensation for decreased moose carrying capacity through burning or mechanical manipulation of plant communities in the areas that will not be disturbed by the project.

These factors made it desirable to estimate moose carrying capacity in the area to be impacted by the hydroelectric project in terms that (1) could be integrated with the considerable body of available moose population data for prediction of actual population changes and (2) could also be used for establishing specific, measurable habitat management objectives for planning and evaluating mitigation actions. This requires an ability to quantitatively integrate the requirements of the animal with the ability of the habitat to supply these needs.

Past efforts to quantitatively apply the concept of carrying capacity to the habitat and the population management decision-making process have met with limited success because of insufficient understanding of the animals' requirements. Recent papers (Moen 1973, Robbins 1973, Wallmo et al. 1977) advocate that carrying capacity for wild ungulates be determined on a nutritional basis. Carrying-capacity models have recently been used to estimate elk (Cervus elaphus nelsoni) winter-range carrying capacity (Hobbs et al. 1982) and mule deer (Odocoileus hemionus) carrying capacity in burned and unburned mountain shrub habitat (Hobbs and Swift 1985). This basic approach, with some key modifications, has been adopted for moose through simulation models developed at the Kenai Moose Research Center (Hubbert 1987). These models provide a logical, quantitative basis for relating the nutritional needs of moose to the nutrients supplied by the range and seem particularly suited to the needs of the Susitna Hydroelectric Project. Application of this approach requires certain basic assumptions:

(1) Carrying capacity is defined as the number of healthy animals that can be maintained on a unit of land for a unit of time without habitat deterioration.

(2) The ultimate factor limiting the number of moose in an area is the supply of nutrients available during winter.

(3) When the population is at or above carrying capacity, the demand for nutrients exceeds the supply available in the specific area being evaluated (i.e., the moose population is capable of fully utilizing the nutrients measured).

It is important to keep these assumptions in mind, because throughout the range of a population of moose, there may be many areas that contain an abundance of nutrients that, for a variety of reasons (e.g., snow accumulation) cannot be used by the moose. Inclusion of such areas will yield carrying-capacity estimates that are too high, and attempts to increase forage in these areas will fail to increase carrying capacity of the population's range as a whole.

Available information indicate that these assumptions are reasonable for lower but, perhaps, not for higher elevations in the vicinity of the Susitna Hydroelectric Project (Becker and Steigers 1987). In the middle Susitna basin, moose browsing on willows increased with decreasing elevation until the 2,300-foot level was reached; from that point, browsing pressure no longer changed with decreasing elevation (Becker and Steigers 1987). These lower elevational areas, especially the ones below 2,600 feet, produce less moose forage than areas at higher elevations (Becker and Steigers 1987). Ballard et al. (1987) reported that moose move into the Watana Impoundment from early February to April; when coupled with the data on moose browsing by elevation, this suggests that forage at higher elevations may not be readily available to moose during the winter. In addition to the loss of moose forage because of winter range restrictions, the loss of leafy material further reduces the amount of forage available to moose during the winter. Reneker and Hudson (1986) reported that moose spend more time foraging (per unit of forage) in the winter; they attributed this to the decreased availability of forage and especially the unavailability of leafy forage. Studies by both Schwartz et al. (1984) and Reneker and Hudson (1985) found that moose forage intake is at its lowest during the winter period; April is the month of lowest intake (Schwartz et al. 1984). Reneker and Hudson (1986) and Steigers et al. (1986) found that digestibility of moose forage obtains its minimum value during the winter period. In spite of the reduced demand moose have for forage in the winter, it was during the winter period that moose carrying capacity was being limited because of a reduction in range, forage digestibility, and amount of forage available.

Moose Forage Intake Model

A ruminant model developed by Swift (1983) provided the conceptual framework for the development of a moose carrying-capacity model. Based on daily digestibility and nitrogen concentration, Swift's model predicts voluntary forage intake, rate of passage, and changes in lean body mass and body fat. Rumen volume and rate of passage is a key element of this model, since the animal is assumed to always eat to rumen fill.

Hubbert (1987) and Schwartz et al. (1984) modified the Swift model to predict voluntary forage intake based on body condition and seasonal energy demands. Studies of forage intake by moose (Schwartz et al. 1984) indicated that additional factors, other than rumen volume and rate of passage, affect voluntary forage intake in moose. Schwartz et al. (1984) measured physiological appetite changes in moose forage intake and found (1) complete fasting of bull moose during the rut and (2) for moose in general, forage intake reaching a peak during the summer months and a low point in late winter. Reneker and Hudson (1985) observed the same general pattern with regard to seasonal changes in forage intake for 2 free-ranging moose.

Hubbert and Schwartz modified Swift's model by establishing a maximum rumen capacity that allowed rumen fill to change seasonally in response to forage availability, forage quality, and energy demands. This modeling approach allows daily forage intake to be controlled by physical means (i.e., rumen volume and rate of passage, as altered by forage quality) and physiological needs (i.e., energy requirements and body condition). Other modifications included (1) changing how fat and protein stores were anabolized and catabolized and (2) changing parameter values to include recent moose data on rates of passage and rumen turnover time (Hjeljord et al. 1982), seasonal metabolic rates (Regelin et al. 1985), protein requirements (Schwartz et al. 1987), seasonal dynamics of food intake (Schwartz et al. 1984), body weight (Schwartz et al. 1986), and rumen volume (Gasaway and Coady 1974). Readers desiring more information about this model should consult Hubbert (1987).

Overview of Model Usage

The moose carrying-capacity model has a hierarchical structure, including a moose population submodel and an individual moose submodel. The moose population submodel is the process through which the time period and area of interest are specified and an estimate of the amount of forage available to moose during the specified time period is obtained. The main purpose of the individual moose submodel is to estimate the amount of forage intake needed by a moose to be maintained in a healthy condition for a specified period of time. The Hubbert-Schwartz intake model is used for this purpose; it calculates the amount of forage intake required by adult female moose. These 2 submodels are then joined together to obtain a carrying-capacity estimate.

Model Input Considerations

To use the moose population submodel, it is necessary to determine the area of interest, the amount of forage available to moose, the time period of interest, the duration and types of habitat loss, and the population's diet parameters. The area of interest should include all the areas that will be impacted by the project. Changing project designs often changes the exact boundaries of the area to be impacted, and it is questionable whether or not habitats adjacent to disturbed areas will be affected; therefore, the study area should be large enough to ensure that these areas are included.

The period of the year that the project will affect moose should be determined from seasonal moose distribution and habitat usage patterns. For instance, if the area being impacted by the project is moose winter range, then the time period in question would be the dates that moose would normally use their winter range, provided that lack of summer range is not a limiting factor.

Once the time period of interest has been established, the amount and type of moose forage in the study area must be determined. The sample design should allow inferences to be easily made to different subsets of the study area; some examples would include a systematic sample design or a stratified sample design, based on a vegetation map. If the area in question is winter range, then leafy material should be excluded from the forage estimates; however, if the area is summer range, then leafy material should be included. The amount of "swapping" that theoretically could occur between items in the diet needs to be determined to assess which items potentially could be limiting. Only diet items having the potential to be limiting need be measured. For instance, if mountain cranberry was ubiquitous but because of snow cover the moose diet could consist of no more than 15% mountain cranberry, this species could be considered nonlimiting and simply not measured. Because of its high palatability, the amount of willow forage present should almost always be measured. Given an estimate of the amount of browse that is present in the study area, the amount of browse available to moose must be determined if the area is winter range and snow depths make the forage close to the ground unavailable. Once the amount of browse available to moose has been determined, the maximum sustainable browsing rate needs to be determined for each species. This rate will be used to determine what proportion of the available browse is actually consumed by the moose.

To use the individual moose submodel, one simply runs the Hubbert-Schwartz forage-intake model with the parameters specified by the application. These parameters include the desired condition of the moose that we want to "support." At the current time, the model is set up to produce healthy moose; obviously, a piece of habitat could support more moose if the condition requirements were lowered. Animal condition can be altered by changing the desired percentage of body fat (Hubbert 1987). Animal age and weight will affect the amount of intake required for a given time period; in general, forage intake increases with increasing animal weight, while increasing animal age increases the "targeted" animal size and will cause the animal to adjust intake consumption to try and meet this targeted size. Other parameters include diet digestibility and nitrogen content. In general, intake increases with decreasing digestibility until rumen fill is reached; subsequently, intake is physically limited. Increasing protein levels do not cause forage intake to vary. Nitrogen and digestibility values should reflect diet composition at carrying capacity; i.e., generally, both digestibility and nitrogen content will decrease as less preferred items are substituted for the highly palatable diet items.

Application of the Model to the Susitna Hydroelectric Project

The original plan was to use the model as a tool for evaluating the effects of the Susitna Hydroelectric Project on moose carrying capacity under a variety of scenarios. This would have required numerous runs of the model using different inputs according to the assumptions of the scenarios. However, the project was suspended just as the information required for adapting the model to the project became available. The scenarios presented here are intended only to illustrate the application of the model and to provide one set of estimates of the decrease in carrying capacity due to impoundments, camps, access roads, and other facilities that will not be rehabilitated. The estimates presented should not be construed as an assessment of the impacts of the project as a whole. Different sets of assumptions would provide somewhat different estimates. Also, not all impacts are encompassed by the scenarios. Not included are impact mechanisms that might alter carrying capacity in areas adjacent to the impoundments (Ballard et al. 1987) or downstream (Modafferri 1987). The model could be used to evaluate these mechanisms with appropriate inputs.

METHODS

Area of Interest

For the purposes of this report, the area of interest is defined as the area lost to the impoundments, camps, access roads, and other facilities that will not be rehabilitated in the 3-stage Susitna Hydroelectric Project. The exact areas used in this design, broken down by the features listed above, are listed in Tables 13-15 of Becker and Steigers (1987). Areas adjacent to the impoundments are not included in this carrying-capacity estimate; however, given a hypothesis as to how these areas would be affected by the project, the model could be used to mitigate for loss of moose carrying capacity in these areas.

Duration of Use

Ballard et al. (1987) reported that moose normally migrate into the impoundment areas around the end of January. For the purposes of this report, 1 February was used as the starting date in the Hubbert-Schwartz intake model. Steigers et al. (1983) reported that green-up in the middle Susitna basin usually occurs around the end of April; thus 30 April was used as the ending date in the model run, because developing new willow and paper birch growth as well as reduced snow levels (i.e., making mountain cranberry more readily available) will cause forage to no longer be limiting on the winter range.

During this period of time, daily intake of current annual growth (CAG) by moose fluctuates greatly (Hubbert 1987). The moose forage intake model predicted that daily intake would increase from February through early March and decrease rapidly in early April (Figure 1) for moose inhabiting the middle Susitna Basin.

Diet

Steigers and Becker (1986) reported the monthly diet composition of moose in the middle Susitna basin. Their study also reported the crude protein and nitrogen content of the diet by month and dietary item. These figures were used as inputs into the Hubbert-Schwartz intake model.

Based on data collected by Steigers and Helm (1984), we decided that resin birch (Betula glandulosa) was not a limiting food item to moose in the middle Susitna basin but that willow (Salix), paper birch (Betula papyrifera), and mountain cranberry (Vaccinium vitis-idaea) had the potential to be limiting. Using this information, Becker and Steigers (1987) measured the amount of nonleafy CAG for willow, paper birch, and mountain cranberry in the Middle Susitna basin. Based on their estimates of the amount of mountain cranberry CAG and snow depths in the Susitna basin (Steigers et. al 1986), we determined that utilization of mountain cranberry by moose during the winter was probably limited by the ability of moose to paw through the snow. The amount of willow and paper birch CAG that is available to moose during the winter is unknown; however, there is strong evidence that this forage is less available outside of the impoundments and that these items become less available as elevation increases. A 2-year moose forage biomass study (Becker and Steigers 1987) was conducted in the middle Susitna River basin to estimate the amount of willow and paper birch CAG that is available (above 50 cm in height) to moose during the winter. These estimates were then used as inputs into the carrying-capacity model to generate the carrying-capacity estimates.

A review of diet substitution among mountain cranberry, willow, and paper birch can be found in Becker and Steigers (1987); for purposes of this report, mountain cranberry availability will be considered limited because of snow depth, and thus the diet composition for this component will not be allowed to change. Willow and paper birch will be allowed to be substituted for one another up to a diet consisting of 75% paper birch (Becker and Steigers 1987). Initial runs of the moose carrying-capacity model indicated that willow was the limiting diet item and that a surplus of paper birch existed. The amount of surplus paper birch was different for each of the impoundment stages and depended upon whether the point estimate or upper 80% confidence limit was used in determining the utilization rate. A review of sustainable moose forage utilization rates can be found in Becker and Steigers (1987). For the purposes of this report, moose utilization rates of 60% were sustainable during moderate winters; occasionally, a utilization rate of 100% was sustainable during a severe winter.

RESULTS

Carrying Capacity Estimates

Moderate Winter--Point Estimate:

In order to produce a moose carrying-capacity estimate during a moderate winter based on point estimates of the amount of browse available in the middle Susitna basin (Becker and Steigers 1987), the monthly moose diets given in Steigers and Becker (1986) were modified (Table 1). The modifications reflected different degrees of swapping of paper birch for willow in each of the 3 stages of the hydroelectric project (Table 2) and based on point estimates of available CAG for the months of February, April, and March. When we assume that the maximum sustainable CAG utilization rate is 60%, permanent habitat loss from the Susitna Hydroelectric Project would cause a reduction of 405 moose in the carrying capacity of moose in the middle Susitna basin (Table 3).

Moderate Winter--Upper 80% Confidence Limit:

To create a moose carrying-capacity estimate during a moderate winter based on the upper 80% confidence limit of the amount of browse available (i.e., willow and paper birch CAG above 50 cm) in the middle Susitna basin (Becker and Steigers 1987), the monthly moose diets given in Steigers and Becker (1986) were modified (Table 1). The modifications reflected different degrees of swapping of paper birch for willow in each of the 3 stages of the hydroelectric project (Table 4) for the months of February, April, and March. Based on upper 80% confidence estimates of available CAG and the assumption that the maximum sustainable utilization rate of CAG is 60%, permanent habitat loss from the Susitna Hydroelectric Project would cause a reduction of 603 moose in the middle Susitna basin (Table 5).

Severe Winter--Point Estimate:

To generate a carrying-capacity estimate for moose during a severe winter based on the point estimate of the amount of browse available (willow and paper birch CAG above 50 cm) in the middle Susitna basin (Becker and Steigers 1987), the monthly moose diets given in Steigers and Becker (1986) were modified (Table 1). The modifications reflected different degrees of swapping of paper birch for willow in each of the 3 stages of the hydroelectric project for the months of February, April, and March (Table 2). Based on point estimates of available CAG and the assumption that 100% of the CAG would be utilized, permanent habitat loss from the Susitna Hydroelectric Project would cause a reduction of 674 moose in the middle Susitna basin (Table 6). The 100% utilization rate could be sustained in severe winters as long as no more than 4 severe winters occurred within any 10-year period (Becker and Steigers 1987).

Severe Winter--Upper 80% Confidence Interval:

The monthly moose diets given in Steigers and Becker (1986) (Table 1) were modified to produce a severe winter moose carrying capacity estimate using the upper 80% confidence limit of the amount of browse available (willow and paper birch CAG above 50 cm) to moose in the middle Susitna basin (Becker and Steigers 1987). The modifications reflected different degrees of swapping of paper birch for willow in each of the 3 stages of the hydroelectric project (Table 4) during February, April, and March. Based on the assumption that 100% of the available CAG would be utilized, permanent habitat loss from the Susitna Hydroelectric Project would cause a reduction of 1,005 moose in the middle Susitna basin (Table 7). Using both point estimates and upper 80% confidence limits of the amount of available CAG, moose carrying-capacity estimates during a moderate and severe winter are expressed in Tables 8 and 9, respectively.

CONCLUSIONS

One of the purposes of this report was to give an overview of the moose carrying-capacity model. This model is hierarchical in structure and consists of two submodels: (1) a moose population submodel and (2) an individual moose submodel. The most sensitive parameter in the moose population submodel is the amount of browse that is available to moose as forage; while in the individual moose submodel, animal condition and diet digestibility are the most sensitive parameters. Overall, determining the amount of available moose forage is the most sensitive parameter in the generation of a moose carrying-capacity estimate.

Another purpose of this report was to highlight how the carrying-capacity modeling approach could be used to mitigate for habitat loss. This process is very flexible, and it allows one to generate moose carrying-capacity estimates under different biological assumptions. In addition, it is very easy to develop new carrying-capacity estimates when the project design has been changed.

For mitigation of loss of moose carrying capacity during both moderate and severe winters, the results based on the upper 80% confidence limits should be used. The point estimate on the amount of CAG in the middle Susitna basin will be off from the true value by some unknown amount, and the greater the demand is to be close to the true value, the less certain we will be of being that close (Stuart 1976). In terms of affecting the moose population, an underestimation of the amount of CAG available to moose in the middle Susitna basin will cause an underestimation of the number of moose (based on carrying-capacity estimates) and, in turn, result in insufficient compensation (i.e., mitigation) to offset the potential loss of moose. To minimize the probability of failing to fully compensate for loss, an upper confidence limit should be used in the carrying-capacity estimate. For this report, the upper 80% confidence limit on CAG of moose browse was used, because it balanced the desire to be fairly certain that loss of moose habitat was fully compensated for and limited the probability of major overcompensation. Given the consequences of these 2 types of errors, it may appear that a 90% or 95% upper confidence limit should have been used; however, if the distribution of CAG estimates is approximately normally distributed, then there is only a 10% chance that moose would be undercompensated for. In addition, the level of precision that most game management projects can ever hope to achieve is the 80% confidence level because of the inherent noise in biological systems.

The use of the upper 80% confidence limit in determining available CAG results in a trade-off between (1) spending money on impact assessment to get more precise estimates of the amount of CAG available to moose or (2) spending more money on mitigation work as a result of larger confidence limits. Using estimates of sampling and mitigation costs and the formula $(s/n^{1/2})$, one can determine the optimal allocation between the cost of getting precise estimates of the amount of CAG available to moose as well as the mitigation cost.

The moose carrying-capacity model is an extremely valuable and powerful tool for assessing the impact of a project on moose. However, the inferences obtained from the model are scenario specific, and as a result, it is very important to specify the model inputs correctly. On the moose population level, these inputs include specifying the area of interest, the types and amount of forage available to moose, the time period of interest, the duration and types of habitat loss, and the population diet parameters. On the level of the individual moose, it is important to specify the desired condition of the moose, the animal's age and weight, and the nitrogen content and digestibility of the diet.

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Table 1. Current moose diet composition during the months of February, March, and April.

Species	February % diet	March % diet	April % diet
Willow	71	71	67
P. Birch	4	4	3
R. Birch	15	15	15
M. Cranberry	10	10	15

Table 2. Moose diet composition during the months of February, March, and April, with swapping of excess paper birch for willow. The amount of excess birch was based on point estimates of the amount of moose forage available.

Impound. stage	Species	February % diet	March % diet	April % diet
	Willow	65	65	61
I	P. Birch	10	10	9
	R. Birch	15	15	15
	M. Cranberry	10	10	15
	Willow	65	65	61
II	P. Birch	10	10	9
	R. Birch	15	15	15
	M. Cranberry	10	10	15
	Willow	53	53	50
III	P. Birch	22	22	20
	R. Birch	15	15	15
	M. Cranberry	10	10	15

Table 3. Point estimate of moose carrying capacity in a moderate year (by Impoundment Stage) for the Susitna Hydroelectric Project. These calculations are based on the estimated amount of current annual growth above 50 cm in height in each stage and exclude the borrow pits that will be available as moose habitat after site rehabilitation.

Impound Stage[a]	Mi^2	Willow[b] biomass (kg)	Paper Birch[b] biomass (kg)	Moose[c] c.c.
I	10.09	31,313	4,694	190.5
III	10.15	26,464	4,327	162.9
I & III	20.24			353.4
II	4.00	7,056	2,932	50.9
I, II, III	24.24			404.3

[a] When finished, the Watana dam will consist of stage I and III; the Devils Canyon dam will consist of stage II.

[b] Biomass estimates are from Becker and Steigers (1987).

[c] These carrying-capacity estimates are based on a 60% utilization rate of browse current annual growth by moose (Becker and Steigers 1987).

Table 4. Moose diet composition during the months of February, March, and April, with swapping of excess paper birch for willow. The amount of excess birch was based on upper 80% confidence limits of the amount of moose forage available.

Impound. stage	Species	February % diet	March % diet	April % diet
	Willow	64	64	59
I	P. Birch	11	11	11
	R. Birch	15	15	15
	M. Cranberry	10	10	15
	Willow	63	63	59
II	P. Birch	12	12	11
	R. Birch	15	15	15
	M. Cranberry	10	10	15
	Willow	49	49	46
III	P. Birch	26	26	24
	R. Birch	15	15	15
	M. Cranberry	10	10	15

Table 5. Upper confidence estimates of moose carrying capacity in a moderate year (by Impoundment Stage) for the Susitna Hydroelectric Project. These calculations are based on the upper 80% confidence limit on the amount of current annual growth above 50 cm in height in each stage and exclude the borrow pits that will be available as moose habitat after site rehabilitation.

Impound Stage[a]	Mi^2	Willow[b] biomass (kg)	Paper Birch[b] biomass (kg)	Moose[c] c.c.
I	10.09	43,921	7,885	272.7
III	10.15	39,327	7,229	245.0
I & III	20.24			517.7
II	4.00	11,041	5,815	84.8
I, II, III	24.24			602.5

[a] When finished the Watana dam will consist of stages I and III; the Devils Canyon dam will consist of stage II.

[b] Biomass estimates are from Becker and Steigers (1987).

[c] These carrying capacity estimates are based on a 60% utilization rate of browse current annual growth by moose (Becker and Steigers 1987).

Table 6. Point estimate of moose carrying capacity in an severe winter year (by Impoundment Stage) for the Susitna Hydroelectric Project. These calculations are based on the estimated amount of current annual growth above 50 cm in height in each stage and exclude the borrow pits that will be available as moose habitat after site rehabilitation.

Impound. stage[a]	Mi²	Willow[b] biomass (Kg)	Paper Birch[b] biomass (Kg)	Moose[c] c.c.
I	10.09	31,313	4,694	317.5
III	10.15	26,464	4,327	271.5
I and III	20.24			589.0
II	4.00	7,056	2,932	84.9
I, II, III	24.24			673.9

[a] When finished the Watana dam will consist of stages I and III; the Devils Canyon dam will consist of stage II.

[b] Biomass estimates are from Becker and Steigers (1987).

[c] These carrying-capacity estimates are based on a 100% utilization rate of browse current annual growth by moose (Becker and Steigers 1987).

Table 7. Upper confidence estimate of moose carrying capacity in a severe winter (by Impoundment Stage) for the Susitna Hydroelectric Project. These calculations are based on the upper 80% confidence estimate of the amount of current annual growth above 50 cm in height in each stage and exclude the borrow pits that will be available as moose habitat after site rehabilitation.

Impound. stage[a]	Mi^2	Willow[b] biomass (Kg)	Paper Birch[b] biomass (Kg)	Moose[c] c.c.
I	10.09	43,921	7,885	454.5
III	10.15	39,327	7,229	408.4
I and III	20.24			862.9
II	4.00	11,041	5,815	141.3
I, II, III	24.24			1,004.2

[a] When finished the Watana dam will consist of stages I and III; the Devils Canyon dam will consist of stage II.

[b] Biomass estimates are from (Becker and Steigers, 1987).

[c] These carrying-capacity estimates are based on a 100% utilization rate of browse current annual growth by moose (Becker and Steigers, 1987).

Table 8. Carrying-capacity estimates as expressed in moose density (by Impoundment Stage) during a moderate winter. These estimates exclude short-term losses of moose habitat due to borrow pits.

Impound. stage[a]	Point estimate carrying capacity (moose/mi²)	Upper confidence estimate carrying capacity[b] (moose/mi²)
I	19.3	27.8
III	16.4	24.8
I and III	17.8	26.3
II	13.5	22.8
I, II, III	17.1	25.7

[a] When finished the Watana dam will consist of stages I and III; the Devils Canyon dam will consist of stage II.

[b] These carrying-capacity estimates are based on a 60% utilization rate of browse current annual growth by moose (Becker and Steigers 1987).

Table 9. Carrying-capacity estimates as expressed in moose density (by Impoundment Stage) during a severe winter. These estimates exclude losses of moose habitat due to borrow pits, because the habitat will have been rehabilitated.

Impound. stage[a]	Point estimate carrying capacity (moose/mi^2)	Upper confidence estimate carrying capacity[b] (moose/mi^2)
I	32.1	44.3
III	27.3	41.3
I and III	29.7	43.8
II	22.5	38.0
I, II, III	28.5	42.8

[a] When finished the Watana dam will consist of stages I and III; the Devils Canyon dam will consist of stage II.

[b] These carrying-capacity estimates are based on a 100% utilization rate of browse current annual growth by moose (Becker and Steigers 1987).

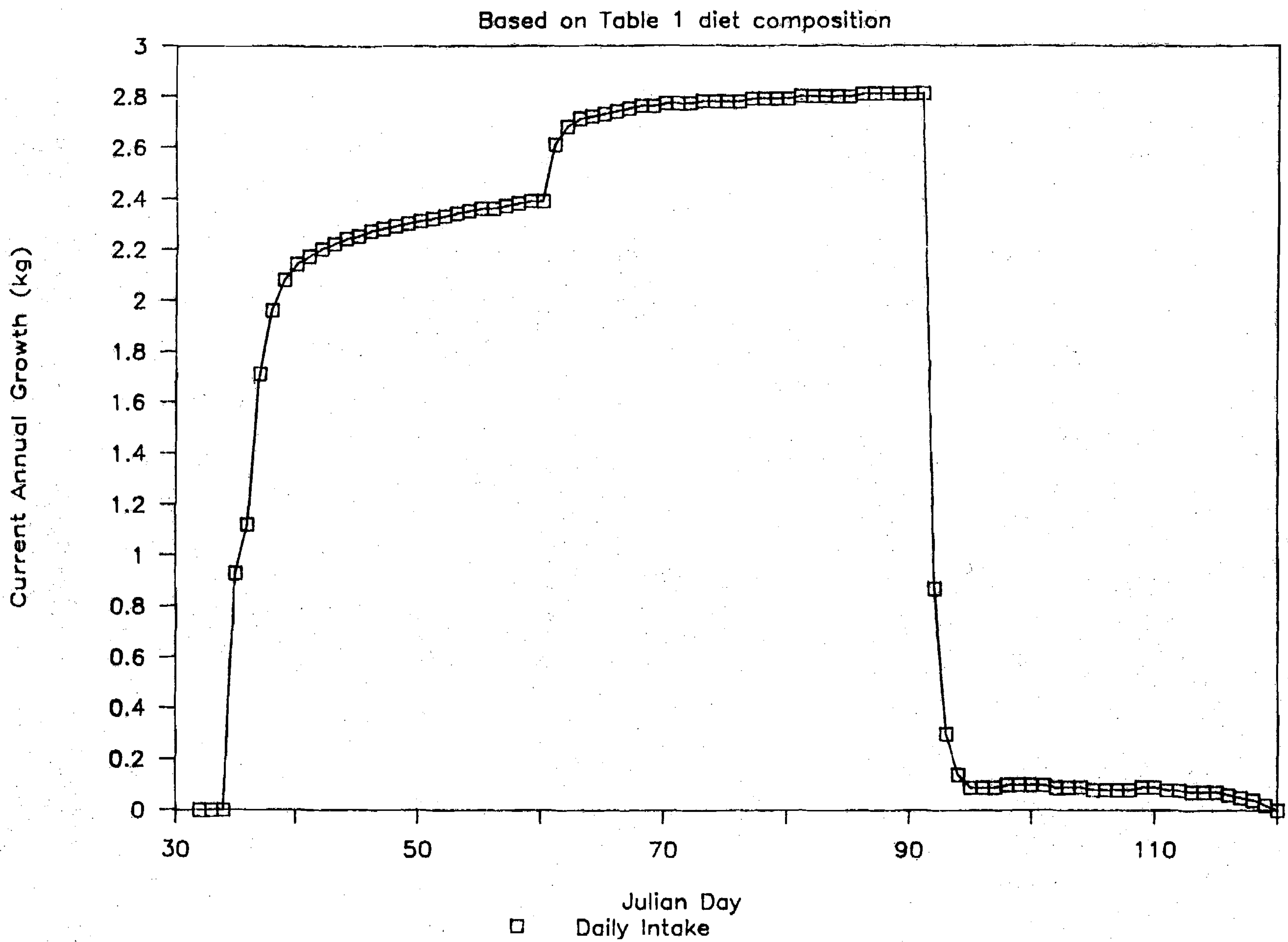

Figure 1. Daily intake of current annual growth (CAG) by moose.