HYPOTHESES OF IMPACTS ON MOOSE DUE TO HYDROELECTRIC PROJECTS

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ABSTRACT: Hypothetical impacts on moose (*Alces alces*) populations from hydroelectric projects in northerly latitudes were classified: significant, moderate, and minor. Eleven potentially significant impacts were identified and discussed. These included permanent and temporary habitat loss, displacement, disruption of movements, and increased mortality from accidents, human-causes, and predation. Of the nine identified moderate impacts, possible changes in climate within an unknown radius of the impoundments could be the most significant. Several likely minor impacts were listed for consideration. Actual losses to a moose population due to hydroelectric development cannot be predicted accurately at this time. Well designed pre- and post-impoundment studies are needed to provide a scientific basis for impact assessment.

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Adoption in the United States of the 1969 National Environmental Policy Act required that projects involving federal funds or lands be evaluated for environmental impacts as part of the decision-making process. Prediction of impacts on fish and wildlife populations was to be an important part of this process. However, biologists have a limited basis for assessing potential impacts, particularly for hydroelectric development projects in northerly latitudes. Inundation of riparian habitats due to hydroelectric developments may be considered a major impact on ungulates like moose, which depend heavily on such habitat during winter. A number of other impacts may occur, but available literature is inadequate for assessing their significance. Numerous studies have documented the pre- or post-impoundment status of wildlife populations, but rarely have impacts been identified and accurately quantified on the same project.

Baxter and Glaude (1980) provided a review of impacts on fish and wildlife populations due to hydroelectric developments in Canada. However, the majority of their review is devoted to impacts on aquatic environments. During the past decade, several investigations were conducted in southcentral Alaska with the objective of predicting the impacts to wildlife, particularly moose, due to proposed hydroelectric development. The purpose of this report is to describe the general types of impacts predicted to occur on moose as a result of hydroelectric development and to explain the logic or evidence (literature) used. This report is based on evaluation of the proposed Susitna Hydroelectric Project in southcentral Alaska but is intended to aid assessments of hydroelectric developments elsewhere in northern latitudes where impacts to moose populations are a major concern. We hope biologists will build upon these hypotheses or provide analyses to refute them.

IMPACT ASSESSMENT MODEL

Three approaches were used for assessing the potential impacts of hydroelectric development on moose. The first identified specific impacts based on available literature or other evidence, and their effects on various moose population parameters were estimated. The second approach included estimating winter habitat carrying capacity of the land to be inundated or destroyed by project facilities (see Becker and Steigers 1987). The last approach involved modeling the moose population under pre-project conditions, then projecting moose population response to different scenarios of impact (Ballard *et al.* 1986). This report is limited to discussion of the first approach as it relates primarily to moose populations. Baseline pre-project biological data for moose populations are presented elsewhere (Taylor and Ballard 1979; Ballard and Taylor 1980; Ballard et al. 1982, 1983, 1985, and 1987a,b; and Ballard and Whitman 1988).

To provide readers with a reference for assessing the significance of various types of impacts to their area, we provide the following brief description of the proposed Susitna Hydroelectric Project which served as the basis for the impacts model. Moose populations associated with potential development of a 2-dam hydroelectric power project along the middle Susitna River of southcentral Alaska (between latitudes 60° 30' to 63° 15' north and longitudes 140° 30' to 149 west) were studied from 1976 through early 1986. The proposed 2-dam system would annually provide approximately 6.1 billion kws of electrical power to the rail-belt area (Anchorage to Fairbanks) of south-central and interior Alaska. Proposed facilities include: the Devil Canyon concrete dam (193m high), the rock-fill Watana dam (247m high), and living quarters, warehouses, and administrative facilities erected at the dam sites. A road system, railroad spur-line, airstrip, and several extensive gravel borrow pits would accompany the project. The dam system with facilities would eliminate approximately 20,700 hectares of vegetated land. Water levels at the lower reservoir are expected to remain constant at approximately 444m elevation, but fluctuations up to 55m could occur. Water levels in the upper reservoir would fluctuate seasonally up to 78m. Downstream flows will be modified to eliminate flooding, and the river will no longer freeze during winter for unknown distances below each dam site. Detailed descriptions of the proposed project are included in a license application to the U. S. Federal Energy Regulatory Commission, Washington D. C.

IMPACT MECHANISMS AND PREDICTION OF IMPACTS DUE TO HYDROELECTRIC DEVELOPMENT

Impact Mechanisms

Hydroelectric development projects may impact moose populations directly or indirectly, positively or negatively, and/or involve only certain subpopulations of moose. Changes in a moose herd may be difficult to measure and occur subtly over time. An impact which would have been unimportant under normal healthy pre-project situations may become important, particularly if it occurs with other impacts.

Available literature is inadequate to guide assessment of the magnitude of beneficial and detrimental impacts on moose which are likely to occur. Consequently, until comparative pre- and post-impoundment studies document the nature and extent of impacts, prediction of impacts remains speculative. Impacts on moose have been classified into three broad categories: (1) habitat alteration, (2) impacts on population dynamics processes, and (3) sociological-political-economic consequences (Ballard *et al.* 1987b). This report does not discuss sociological-political-economic consequences except as related to reduced moose hunting and viewing opportunities.

We formulated hypotheses for assessing how hydroelectric development might impact moose populations, which are summarized in a matrix-type table (Ballard *et al.* 1987b). Hydroelectric development was divided into components of the biotic and abiotic environment which directly and indirectly influence factors regulating moose population dynamics. Construction and operation aspects were categorized into project actions, then effects of these actions were categorized into impact mechanisms. Detrimental and beneficial influences on moose populations due to these impact mechanisms were then predicted for the moose population.

Classification And Identification Of Impacts

Levels of anticipated impacts due to hydroelectric development were categorized by potential significance and our ability to detect significant changes in specific moose population parameters:

Significant Impacts (SI) - Project-induced impacts which have a high probability of causing measurable change in moose population size and/or productivity. Such change may affect moose natality, mortality, or indirectly alter a process which affects a key moose population parameter. Such impacts usually result in major changes in population size and/or distribution.

Moderate Impacts (MoI) - Project induced impacts which could alter moose population size or productivity, but insufficient evidence exists to confirm the significance or potential to limit the population. Moderate impacts may be difficult to quantify because the effects of impact mechanisms may be masked or current abilities to detect changes may be insufficient.

Minor Impacts (MiI) - Impacts which data and logic indicate have a low probability of altering moose population size or distribution. These impacts may affect survival or behavior of individual animals but will not constitute a significant limiting factor.

Specific impacts are described (not in order of anticipated magnitude):

Significant Impacts

1. Permanent habitat loss due to impoundments and other permanent facilities will permanently impact area moose populations. Loss of ungulate habitat is not detrimental if the habitat does not contribute to potential carrying capacity. Impoundments and other facilities may significantly reduce carrying capacity through elimination of habitat used during winter and spring. If adjacent habitat is either at capacity or not available, e.g., deep snow, several population parameters could be altered. Moose usage of wintering areas is highly traditional, so moose may suffer high mortality even if alternate habitat is available. Therefore this habitat loss will result in long-term lower moose numbers.

Timing of usage is important when determining value of habitat. Moose subpopulations may utilize the same winter habitat annually while others only use it for short periods during severe conditions. Intensive habitat use during severe winters may limit mortality but cause long term range capacity to be reduced. Slight reductions in mortality rates during severe winters can allow more rapid recovery during subsequent years of mild winters.

Both seasonal and year-round resident moose can be displaced from a development project area leading to increased starvation mortality for several years. Winter-weakened moose might suffer higher rates of mortality from predation. Survival rates of displaced adults are expected to be relatively lower. Surviving adults will be in poorer physical condition resulting in lower rates of calf production and/or calf moose mortality may be especially high, and annual recruitment may be less than mortality. Calves may be smaller and less viable, hence more vulnerable to predation, accident-caused mortality, and other nonpredation losses. Reductions in calf survival may preclude dispersal to other areas.

Increases in mortality may cause a moose population to decline and may affect other populations. Adjacent subpopulations of moose will absorb displaced animals, suffering increased winter kill and predation but at lesser rates than displaced moose.

A significant decrease in the numbers of moose available for harvest in the vicinity of the project can be expected. Dispersals will be reduced, so numbers of moose available for harvest and viewing in surrounding areas may also be reduced.

2. Displacement of moose and disruption of seasonal movement patterns during and following reservoir filling may create abnor-

mal concentrations of moose adjacent to impoundments. This displacement will attract and concentrate predators, resulting in higher predation rates. Predation by brown bears, black bears, and wolves are currently the largest sources of mortality affecting dynamics of many area moose populations, particularly in Alaska (Ballard et al. 1981, 1985; Ballard and Larsen 1987; Franzmann et al. 1980). The sex and age of moose killed by predators is determined by vulnerability. Usually predation focuses on young and old of a population (Mech 1970). Deep snow may cause animals to be unusually vulnerable to surplus killing (Eide and Ballard 1982), or animals may be weakened by severe weather conditions. When moose and predators are concentrated at abnormal densities, moose may suffer increased mortality. Displaced moose will be particularly vulnerable because of stress, weakened condition, and lack of familiarity with escape routes. Resident moose will be less vulnerable than displaced moose but more vulnerable than before the project due to increased competition for forage and living area and increased numbers of predators. Resident calves will be more vulnerable than adults because this age class is usually subjected to higher mortality rates.

In conjunction with other mortality factors, increased predation could significantly decrease the moose population and hold it at a lower density. Because there are no fast acting feedback mechanisms between large ungulates and their principal predators (wolves and bears), such population declines and the resulting lower threshold levels could span decades (Gasaway *et al.* 1983; Ballard and Larsen 1987).

Wolf and bear predation are generally considered to be additive sources of mortality (Ballard and Larsen 1987) hence compete directly with human harvests. If predation contributes to a moose population decline or maintains the population at low densities, human harvests of moose will be greatly curtailed or eliminated unless a harvestable surplus is regained.

3. Open water downstream of impoundments, in addition to ice shelving, may block access to traditional winter and calving areas. Open water during winter, when ambient air temperatures are relatively low, is expected to impede and possibly halt river crossings. Moose may not cross major rivers when ice is of varying thickness and thawing conditions occur.

Opposing views exist as to the potential significance of this impact factor. Bonar (1985) reported that moose crossed open water near Revelstoke Dam at air temperatures of -20° C. Harper (1985) at Fort St. John, British Columbia (several hundred kms north of Revelstoke), believed that open water downstream of the Bennett Dam was a major barrier to moose movements during winter. He stated that moose were not willing to cross open water when air temperatures were about -30 to -40°C. During winter 1979-80, moose refused to leave an island which was inundated by 1 m of slush ice and surrounded by open water. The net result was that at least 23 moose died from exposure. High moose mortality in the vicinity of reservoirs during and after ice formation has been reported in the Soviet Union (Danilov 1987), suggesting that blockage of movements may severely impact moose directly by mortality or indirectly by preventing access to important habitat.

Seasonal habitat usage by moose is traditional (LeResche and Davis 1974, Van Ballenberghe 1978, Ballard and Taylor 1980, and Gasaway *et al.* 1983). Usage patterns suggest that individual moose have developed successful strategies for using seasonal environments. Although remaining habitat surrounding a hydroelectric project may be capable of supporting more moose, displaced moose may not modify formerly successful survival strategies quickly enough to avoid mortality. A similar scenario exists for white-tailed deer populations which yard up during winter and may starve in an overbrowsed area even though suitable habitat exists in adjacent areas (Taylor 1965).

In summary, mortality due to starvation is expected to increase. Relatively large moose die-offs may occur during severe winter conditions because of blockage to winter range. Eventually moose may adapt to this phenomenon, but populations may be held at low levels by artificially high densities of predators which may not quickly respond to lower densities of prey (Gasaway *et al.* 1983, Ballard and Larsen 1987). A lower proportion of moose may become pregnant due to disruption of social behavior and poorer physical condition as a result of malnutrition. Calves are expected to experience greater rates of natural mortality due to accidents, pneumonia, and other nonpredator forms of mortality. Bear and wolf predation may be higher due to weakened condition and crowding.

Short-term mortality from human harvests may increase due to moose concentrating in relatively accessible areas if hunting regulations are not modified to reduce moose vulnerability. In the long-term, numbers of moose available for harvest will decrease.

4. Ice shelving, open water, thin ice and floating debris may cause direct mortality to moose attempting to cross impoundments. Most moose populations experience direct mortality from natural factors such as falling through ice or injuries resulting from slipping on ice (W. Ballard, A. Franzmann, R. Modaferri, and others, unpubl. data). Such accidents normally occur when moose encounter frozen water bodies. This type of mortality is usually insignificant to population dynamics and considered density independent. These types of accidents will continue to occur regardless of whether the project is built but, because more area will be covered by water and ice, conditions will be less stable and an increase in mortality rate may occur.

Ice thickness and stability in rivers are different below dam sites than what occurs during natural conditions. Moose generally cross water bodies during ice-free periods or when ice is sufficiently thick to support them. Moose may not adapt to abnormal thawing and icing conditions; e.g., moose may attempt unsuccessfully to cross ice covered areas during normally safe time periods resulting in increased mortality due to ice-related accidents and drowning.

Depending on steepness and surface characteristics of ice shelving along impoundment edges, moose may be unable to escape from open water and/or broken ice. Fatal injuries due to slips on ice shelves occur naturally, but the frequency of these occurrences may increase as a result of the project. Floating debris, e.g., logs, may increase moose mortality from drowning.

Several references exist which document occurrences of direct mortality from thin ice. R. Lindsey (unpubl. data) documented that about 60 elk (*Cervus elaphus*) fell through ice while attempting to cross Blue Mesa Reservoir in Colorado. Bonar (1985) indicates at least 10-20 moose fall through ice each year at Revelstoke Dam in southern British Columbia (BC); he considered such losses insignificant to the population, although river crossings had probably been reduced as a result of the hydroelectric project. In the Soviet Union, mortality caused by falling into impoundments during and after ice formation is variable by area and year, but may reach 10-45% of the moose population (Danilov 1987). F. Harper (pers commun.) reports several instances of newborn moose becoming entangled in shoreline debris and unable to escape from Williston Reservoir, BC.

Under normal circumstances, mortalities from these types of impacts may not be significant, but as additive sources of mortality on a stressed population, they could be viewed as a significant adverse impact.

5. Train and highway vehicle collisions due to new transportation access routes and traffic increases on existing routes may result

in increased moose mortality. Moose are attracted during winter to snow free roads and railroad corridors due to easier travel than in unplowed areas (Rausch 1959, Child 1983). Plowing roads and rail-lines results in steep banks and deep snow on either side. Moose then become reluctant to reenter deeper snow areas when vehicles approach. Moose typically exhibit anti-predator behavior to oncoming trains, charge or hold their ground, and are killed (Child 1983).

Access for hydroelectric projects may be achieved through a combination of railroad and road construction, connecting existing access to construction camps and dam sites. These features may be built at elevations used by moose during winter, causing high mortality from collisions.

Moose migrate from high elevation areas in response to autumn's first heavy snowfall. Depending on snow depth, large numbers of moose could congregate on snow free roads and rail-lines. Mortality could remove the annual surplus of moose and, in conjunction with other factors, could cause a population decline. Experience with railroad/moose collisions in southcentral Alaska support this scenario; e.g., during the severe winter of 1984-85, over 300 moose were killed (J. Didrikson, pers commun.). Once moose densities are lowered, other mortality factors such as predation may prevent the population from increasing. Mortality from this impact is additive, so importance depends on magnitude and on predator and moose population densities.

6. Snow drifts from impoundments and other major developments may impede moose movements and/or subject moose to higher risk of collision mortality and may reduce the value of some areas as winter range. Impoundments and other facilities or developments may create substantial snow drifts, particularly along shorelines. Areas prone to drifting prior to the project will likely accumulate more snow. If moose movements are impeded or moose avoid deep snow areas, creation of new drifts will result in loss of habitat.

Prediction of exact locations and extent of snow drifting is impossible because numerous factors influence its occurrence. Predictions that drifting will occur only in "localized areas" in relation to total project area may be appropriate; however, "localized" impacts, depending upon how defined, may become extremely important to specific subpopulations of moose if migration corridors, e.g., drainages, are blocked. Snow drifts may also occur along newly created transmission line corridors, but prediction of the importance of this impact is even more difficult than that resulting from impoundments and related developments.

Areas covered by snow drifts retain snow longer than nondrift areas, possibly delaying green-up of vegetation in comparison to other areas. Importance of this impact depends on quantity and type of early spring habitat lost because moose are typically in relatively poor nutritional condition.

Mortality from starvation may increase due to disruption of movements and loss of habitat. Some moose may become more vulnerable to predation because their escape may be delayed by snow drifts.

7. Increases in mortality of moose may occur due to increases in legal hunting and poaching. Creation of impoundments and improved access may result in increased hunting pressure. Total harvests may be expected to increase because moose will be more vulnerable due to stress and a combination of project impacts. Whether increased legal harvest is detrimental or even occurs depends on type of season and regulations in effect.

Additional access could facilitate harvest of specific sex or age groups which would necessitate revised regulations to limit or redistribute harvest. Increased hunting pressure may increase crippling losses.

Increased access may create a situation more conducive to illegal harvests. Whether increases in moose mortality due to poaching would be of sufficient magnitude to affect a moose population is not known. Because the moose population will be stressed from a number of impacts, increases in hunting and poaching mortality will be additive sources of mortality which could contribute to a population decline. Unregulated access may initially result in high hunter success but also may create unpleasant hunting conditions because of hunter density. Ultimately, the number of moose available for legal harvest and other uses will decline.

8. Both temporary and permanent loss of winter habitat may occur as a result of borrow site development. Creation and excavation of borrow pits will remove all vegetation and destroy summer and winter habitat. Actual loss of vegetation may only last from 2-20 years (LGL 1985) depending on a number of factors including whether all sites are eventually recovered with topsoil and become revegetated with useful moose forage species. Regardless, loss of these sites will contribute to a moose population decline through the same processes described under SI - 1 with some differences.

Although actual loss of vegetation may be short term, long term impacts could result if areas are revegetated by browse species less palatable to moose or drifting snow renders areas unavailable. After the moose population declines due to habitat loss and other factors described in the preceding and following sections, the moose population may then be regulated by factors other than forage (Gasaway *et al.* 1983; Ballard and Larsen 1987).

9. Permanent loss and alteration of moose habitat may occur as a result of access corridor construction, maintenance, and use. Construction, maintenance, and use of roads and rail facilities will require additional gravel pits and berm construction beyond that needed for actual construction of the impoundments. Use of the areas and maintenance may create disturbance causing moose to actually avoid some areas. The problems encountered for this impact are integral parts of those discussed for other impacts.

10. Due to improved access created by the project, surrounding areas may be subjected to increased commercial development which will result in loss of moose habitat and increased moose mortality. Depending on remoteness, the area surrounding a project may or may not be commercially developed. Land owners in the vicinity of the project and adjacent areas may take advantage of new access routes. Creation of access and resulting secondary private developments are considered to negatively impact wildlife. In some cases, secondary developments could have a greater impact on moose than the actual project itself. Depending on the nature and location of developments (e.g., mining activities, lodge facilities), significant losses of habitat, increases in direct moose mortality due to auto collisions, poaching, and hunting, and increases in indirect mortality, e.g. stress, could occur. The effects on various moose population parameters will be identical to those described under many of the impacts previously described.

11. Habitat quantity and quality for moose will improve along the transmission corridor because vegetation will be maintained in early successional stages. Clearing transmission corridors and maintaining early successional stages of spruce and mixed spruce-deciduous vegetation are expected to result in an improved browse biomass. This is expected to increase the carrying capacity for moose wintering along the transmission corridor. Winter mortality may be reduced for some subpopulations and increases in productivity may occur. Access into previously inaccessible areas will be greatly improved.

Due to improved nutrition, some increase in productivity might occur. Mortality due to winter starvation may be reduced. Mortality during severe winters would not be reduced because much of the improved habitat would be inaccessible during a severe winter. Increased numbers of moose should be available for harvest and viewing. Transmission lines would also provide additional access for all-terrain vehicles facilitating additional legal harvests and poaching with associated possible negative impacts.

Moderate Impacts

1. Local climatic changes resulting from the impoundments will include increased summer rainfall, increased winds, cooler summer temperatures, increased early winter snowfall, hoar frost deposition on vegetation in winter, delayed spring plant phenology, and changes in plant growth and species composition. These changes will reduce habitat carrying capacity for moose and increase vulnerability to a number of mortality factors. It is well documented that creation of large artificial bodies of water alters the climate of the surrounding area. This warm-bowl and cold-bowl effect can significantly alter climate to such an extent that large differences in precipitation and temperature can occur. In earlier studies for the proposed Rampart Dam and Reservoir, Henry (1965) modeled available climatic data and predicted that a 10 percent change in precipitation would occur up to several hundred kms away from the impoundment. A number of other climatic changes were also predicted. Based on studies such as Henry's and others (Taber and Raedeke 1976 - Ross Lake in Washington), it appears reasonable to assume that impoundments result in measurable changes in some climatic parameters. To determine the magnitude of change, systematic pre- and post-impoundment studies would be necessary to quantify potential impact.

The following is a detailed discussion of climatic changes which could potentially be most important to moose:

a. Cooler summer temperatures - this change could make conditions less favorable for survival of newborn moose calves due to exposure to cooler temperatures in conjunction with delayed snow melt and delayed plant phenology (see c and d).

b. Increased snowfall - increases in snow depths adjacent to the impoundments due to increased evaporation could reduce desirability of important wintering areas. Assuming the area adjacent to impoundments receives higher use than areas of more abundant but less available browse due to greater snow depths, increasing snow depths within a 1-5 mile zone from the reservoir could significantly decrease the value of remaining important winter range. For example, a 10 percent increase in snow depth over several km^2 zone in critical winter range could reduce the area's capacity to support moose.

c. Hoar frost deposition on vegetation - hoar frost and ryme ice naturally occur on vegetation along rivers during some time periods. Where open water will occur year-round due to impoundments (e.g., downstream), the frequency of frost and ryme ice deposition on moose browse will increase. Although difficult to measure, the addition of substantial amounts of frost and ryme ice on vegetation requires additional energy for moose to melt. If frosting or icing repeatedly occurs over the winter, this energy expenditure could increase stress on the moose population, given that their physiological condition is downward even during moderate winters. In northern British Columbia, Harper (1985) suggested that the occurrence of ice fog from the creation of Bennett dam and reservoir on the Peace River may have been an additional factor causing reduced moose populations on the north side of the river. The Peace River Valley is now "fogged-in" most of the winter due to warmer water coming from the dam, effectively eliminating the insulation benefits of south-facing winter ranges (Harper 1985).

d. Delayed spring melt - cooler temperatures in conjunction with increased snow depths could delay onset of spring thaw and increase length of time necessary for snow melt. This would also delay availability of some food plants. Moose would avoid areas which retain snow, resulting in a change in moose distribution and habitat selection, hence increased pressure on adjacent habitats and populations.

e. Delayed spring plant phenology - plant phenology is influenced by a wide variety of factors (LGL 1985). With lower air temperatures and increased snow depths, plant development would be slower than in areas with high temperatures and less snow. Moose are usually in poorest physiological state just before onset of greenup, hence delay of greenup could significantly affect survival. The length of this delay depends on how long increased snow drifting and deeper snows take to melt.

f. Precipitation and temperature are among several factors which influence composition, distribution, and growth of vegetation. Growth of existing vegetation may be altered due to cooler temperatures, increased snow depths, delayed spring melt, etc., all of which lead to a shorter growing season. This may alter the growth rates of willows and reduce the range carrying capacity. Changes in plant species composition will likely be very subtle and take several decades to detect.

In summary, this impact in northern latitudes ultimately reduces habitat carrying capacity and increases mortality. Loss of critical late winter-early spring habitat and delayed greenup of vegetation may reduce calf survival. Poorer physiological condition of cows results in production of less viable calves. Increased mortality may result from exposure to a less suitable climate. Moose may be more vulnerable to predation because of the poorer physical condition and displacement from desirable habitat. Winter mortality from starvation may increase due to loss of habitat and increases in energy expenditures to find and process forage.

2. Warmer water in downstream areas may result in open water, consequently altering plant phenology and affecting spring forage and cover for moose. LGL (1985) speculated that warm water conditions would retard river ice development in late winter and melt existing river ice faster. However, existing hydroelectric developments provide scenarios for projecting impacts on moose. For example, on the Peace River below Bennett Dam in northern BC during 1979-80, flow ice piled up in downstream areas creating ice dams. These dams then caused flooding and inundation of riparian areas (Harper 1985). The inundated habitat was unusable by moose the remainder of the winter. We suspect that these areas freeze and thaw more slowly, thus eliminating winter habitat and retarding spring plant growth. Moose which become trapped on inundated areas suffer increased mortality due to exposure because they do not move from the islands (Harper 1985). Therefore, overall carrying capacity for moose would be reduced and rates of mortality would increase (see discussion for SI - 3 and 4).

3. Clearing of vegetation in the impoundments and facilities area may reduce carrying capacity. Clearing vegetation prior to filling the impoundment may modify and destroy browse which traditionally has served as important moose winter range. Loss of winter range may occur as a result of clearing large areas for locating facilities and for reservoir filling, therefore, many impacts identified under SI - 1 can be anticipated with few differences in initial reaction.

4. Habitat quality may temporarily decrease near the reservoir as a result of locally high densities of moose dispersing from inun-

dated areas. Moose which become displaced due to inundation will concentrate on adjacent habitat and utilize vegetation which currently supports other moose. The amount of forage present in and immediately adjacent to the impoundments is less than that outside the impoundments. However, it receives much greater utilization (Becker and Steigers 1987), apparently because it is more available due to shallow snow depths. Because this vegetation is heavily used, additional usage by displaced moose would probably exceed annual growth and reduce carrying capacity. Starvation mortality would increase due to increased competition and reduced carrying capacity. Remaining moose would experience decreased productivity along with increased mortality of calves.

5. Continued loss of moose habitat due to erosion of impoundment shores. Erosion of shorelines will destroy an unknown quantity of moose habitat, depending upon size, steepness, water fluctuations, etc. Some areas may become revegetated with species more useful as moose forage. LGL (1985) considered this impact to be a slight adverse impact which could be offset by colonization of new vegetation, assuming that the steepness of newly colonized areas will not preclude moose use. This is an additive impact which, in conjunction with other impacts, may result in additional loss of habitat and accidental deaths.

6. Drifting snow in the transmission line corridor may preclude use of winter browse. Areas vegetated by plant species of low growth form appear more prone to snow drifting. This may negate some of the positive benefits derived from increases in browse production as a result of clearing corridors. New browse may be unavailable due to snow drifting. As a result, increases in moose productivity due to predicted increased browse supplies may not occur to the degree anticipated because increased browse may not be available due to snow drifting. Consequently, starvation mortality during mild winters may not be reduced to the level anticipated.

7. Accidental fires resulting from human activities may rejuvenate decadent moose habitat. Increases in human activities during construction and operation will likely result in accidental fires. Because many portions of southcentral Alaska have historically been subjected to wildfire, much of the moose habitat is fire dependent. If accidental fires occurred, moose habitat quality and quantity would improve resulting in increases in range carrying capacity. Whether the moose population could respond to the improved habitat may dictate whether it becomes used. Improvements in habitat could be expected to last about 25 years before additional habitat improvement would be needed. Assuming vegetation and moose respond similarly to wildfires in Interior Alaska, no short-term detrimental impacts are anticipated (Gasaway and Dubois 1985). However, with increased private and commercial developments, fire suppression programs usually intensify, reducing the potential for habitat improvement from wildfire and controlled burning will probably never materialize.

Depending on size of area burned, improvements in quality and quantity of forage could benefit moose. Cow moose could be in better physiological condition resulting in production of vigorous healthy calves. Moose of all age classes could be in better physical condition and less prone to predation. Numbers of starvation mortalities could decline. If not limited by other factors, numbers of moose available for harvest and viewing could increase. If annual surpluses are not removed by hunting and predation, surplus animals may disperse to less populated areas serving to restock areas depleted by other factors.

8. Increase in ground-based activity (road traffic, village activities, dam construction)

may preclude use of some areas by moose, particularly sensitive areas such as calving sites and winter habitat. Increased human presence, particularly at villages and areas where major habitat alterations are occurring, will result in disturbance to moose. Disturbance can manifest itself in many forms; e.g., ungulate heart rates and other body functions increase when confronted with unnatural stimuli. Additional stress does not necessarily result in an outward change in behavior or in direct harm, but is an additive stress factor to be considered in energy dynamics of moose. The most outward result of disturbance will be avoidance of areas where noise and visual stimuli cause harassment. Moose are expected to avoid habitat areas near impoundments during active construction and other areas between impoundments, villages, gravel borrow pits, and other facilities. Continued high intensity use of villages, rail facilities, airports, and dam sites may result in permanent avoidance. Avoidance of specific sites which historically served as winter habitat is equated with at least a temporary loss of habitat. This loss will affect several moose population parameters, particularly those mentioned under SI - 1.

9. Increase in disturbance over the entire area may occur due to increased human recreational activities. LGL (1985) combined this impact with increases in commercial developments such as mining, lodging facilities, etc., resulting from access provided by construction and operation of the project. Our discussion separates those kinds of activities from recreational activities. Creation of new access in former undeveloped areas will increase recreational uses. Depending on the type and distribution of recreational activities and the numbers of people participating, increased recreational activities could impact several subpopulations of moose. Impacts would likely occur as a result of disturbance and/or displacement.

Minor Impacts

1. Alteration of moose distribution may occur due to corridor traffic and disturbance. Initially, activities associated with construction and operation of transportation corridors will cause moose to avoid these areas. This may result in short-term habitat loss if the avoidance occurs during winter. However, moose should become acclimatized to this disturbance, so no long-term impacts are anticipated. The greatest amount of disturbance may occur during hunting season by use of access corridors. Disruption of movements in autumn could alter rutting behavior and force moose into less desirable areas. Potentially, this could affect reproduction and result in a short-term loss of productivity. Moose may suffer increased rates of starvation mortality until they become accustomed to traffic and noise. Rutting behavior may be temporarily disturbed.

2. Prior to filling, clearcut areas in the impoundment may inhibit movements due to slash piles and human disturbances. Although seemingly not important in itself, this impact is another additive source of negative stimuli for moose. No long-term impacts are anticipated to moose or their uses.

3. Impeded drainage caused by road and railroad berms may alter moose habitat as a result of flooding. Water drainage will be altered by construction of berms. In many cases this alteration will be minimized by proper installation of culverts and bridges. However, some alterations will occur such as temporary inundation of small localized areas which kill vegetation. There may be equal probability of creating higher quality habitat as a result of berm construction through colonization by desirable plant species. However, this attractant may render moose more susceptible to death from vehicle collisions.

Impacts on moose forage from berm construction will be localized and probably not result in measurable impact on the moose population. However, like many other impacts associated with this project, it may not be individually important, but in summation with other impacts, may be significant.

4. Increase in aircraft overflights may stress animals or preclude use of some areas. Experience with moose populations occurring in close proximity to airports (files ADFG, Anchorage) suggests that this impact should not have permanent, long-term effect. However, there may be differences between air traffic at airports and that which might occur with the project. Although moose become accustomed to aircraft overflights at airports, these areas are usually fenced so little additional human disturbance occurs. The airports may, in conjunction with construction and impoundment operations, be adjacent to village sites, transportation corridors, gravel extraction, etc., possibly resulting in some avoidance due to other disturbances in addition to aircraft.

SUMMARY

All methods of evaluation of potential impacts from hydroelectric development usually suggest that losses to a moose population can be great. This finding is consistent with the hypotheses of biologists in other areas of North America where riparian habitats important to moose have been inundated or altered (E. Warren pers. comm.; K. Child pers. comm.; F. Harper pers. comm.). The impacts of hydroelectric development on wildlife, and particularly moose, have never been quantified because either post-impoundment studies were not comparable to data prior to inundation or no pre-development studies were conducted. Consequently, estimates of losses are speculative. To properly assess actual losses, it will be necessary to conduct indepth pre- and post-impoundment studies for comparison.

A large number of potential mechanisms of impact have been identified as a result of this study. Unfortunately many of the specifics will remain speculative, but the net results of several impacts should be measurable. For example, any effects on the moose population from drifting snow will be difficult to separate from other types of habitat loss or alteration. However, the cumulative effects of those impacts could be quantified by comparing estimates of numbers of moose in the study area before and after the project with those in control populations. Therefore, for efficiency of study, several similar impact mechanisms could be grouped and evaluated by similar study methods. In conclusion, we hope that these analyses will serve as a guide for assessment and provide a basis for generating additional hypotheses concerning impacts of hydroelectric development on moose populations.

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