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# Moose Habitat Enhancement in Alaska's Boreal Forest

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# Moose Habitat Enhancement in Alaska's Boreal Forest

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Abstract

The technical information herein is intended for reference use by biologists, planners, and habitat managers, but portions on early-seral wildlife habitat and species may be of interest to others.

Objectives for moose abundance and harvest clarify public expectations and guide feasibility assessments. Vegetation treatments are designed to enhance biomass and dispersion of shrubs and young deciduous trees that are preferred winter forages in areas where moose nutrition may be limiting productivity. However, enhancing forage at the landscape scale to increase moose productivity for elevated yield has technical and cost challenges. Learning from treatment implementation through designed monitoring of vegetation, moose, and harvest responses will inform judgment of efficacy and aid evaluation of habitat management policy.

Mechanical treatments to enhance moose habitat include timber harvest, post-logging scarification to promote seed germination, and cutting or crushing of shrubs and trees to simulate sprouting of desired species. Mechanical treatments can be precisely designed in space (stand scale) and time. However, treatment scale is limited by cost per unit area. Hazardous fuel breaks that reduce conifers can lessen the risk of fire spread near communities and often enhance less flammable browse species. With present climatic trends increasing potential for insect mortality in trees or years with extreme fire behavior, leveraging habitat funding with fuels treatment funding may be the most productive strategy to maintain productive moose habitat near communities. Where large wildland fires occur near communities, periodic crushing of willows and young trees prior to reaching a free-to-grow condition in 20–30 years will maintain accessible forage and concealment cover for early-seral game (moose, grouse, hares) and minimize height of regenerating conifers as a crown fuel. This also helps maintain a dispersion of smaller treatments that attract local moose and spreads hunting opportunities to limit hunter crowding. Riparian willow crushing near communities may also be prudent to maintain moose in good nutritional condition for elevated yield when scouring floods are infrequent.

Prescribed fire is implemented under planned conditions. Spreading the fixed costs of planning and mobilization to the landscape scale can reduce cost per unit area to much less than mechanical treatments. However, implementation challenges include public acceptance of risk, relatively high fixed costs regardless of project scale, competition with suppression needs for equipment and skilled labor, and other factors. Shaping wildland fires ("fire use") within predetermined boundaries of acceptance can fragment continuous fuels, potentially increasing public tolerance for a more natural fire regime and habitat diversity at the landscape scale. Partnering with agencies that manage lands and fires to reduce fire risk near urban or rural communities has strong potential to secondarily enhance early-seral wildlife habitat and hunting opportunities in areas accessible to hunters.

***Key words:*** *Forestry, guidelines, mechanical treatments, monitoring, planning, prescribed fire, wildland fire.*

# Introduction

We (the authors) compiled technical information to guide planning and implementation decisions and monitoring strategies for moose (*Alces alces*) habitat enhancement in the boreal forest of Interior and Southcentral Alaska. This bulletin describes Alaska Department of Fish and Game (ADF&G) involvement with projects to enhance habitat features for moose while considering hunter access as a tool for maintaining or elevating sustainable harvest of moose. The department is responsible for managing wildlife habitat on state and municipal lands in a sustainable manner within a legal and policy framework (Appendix A).

Weeden (1973:9–10) succinctly described 2 broad management objectives for moose (elevated harvest yield and trophy quality/hunt experience) and their different requirements with respect to degree of active management for habitat and hunter access. Habitat enhancement for elevated moose yield means to implement vegetative disturbance (prescribed fire or mechanical treatments) or facilitate use of wildland fires to maintain or increase young forage biomass and concealment cover of deciduous woody forages preferred by moose: Alaska birch (*Betula neoalaskana*), balsam poplar (*Populus balsamifera*), quaking aspen (*P. tremuloides*), black cottonwood (*P. trichocarpa*), and several species of willow (*Salix* spp.). Specifying management direction for habitat enhancement projects aligns agency staff, funding sources, public or private partners, and interest groups as to why, where, and how the Division of Wildlife Conservation (DWC) pursues habitat enhancement projects.

Guidance in this bulletin is based on scientific literature and agency experience in Alaska. We provide technical and policy considerations for 1) planning, 2) implementing, and 3) evaluating projects to encourage comprehensive thought before project commitments are made and actions are taken. The time and degree of formality to conduct these 3 steps should reflect a) the extent, complexity, and duration of the project, b) the magnitude of staff time and operational resources proposed to be allocated over project duration; and c) the potential for unintended consequences such as escape risk with prescribed fire or controversy over creation of new access. Consultation with public interest groups is critical for shared understanding of how habitat management contributes to objectives for moose abundance and harvest as these relationships are often complicated by other simultaneous changes, such as motorized access or hunting regulations. Biologists monitor effectiveness in achieving objectives for tangible outputs of moose habitat, moose abundance, and moose harvest. DWC staff should also engage the public in the planning phase to identify additional criteria of desired outcomes often based on intangible measures of satisfaction or “success” to aid subsequent policy evaluation. On high-profile projects, this might involve public surveys in cooperation with social scientists before and after treatments.

Planning factors should be described in a feasibility assessment for habitat enhancement (Appendix B). Proposed projects require objectives (quantifiable performance standards) and an evaluation strategy to track progress and achievement, including biological responses, management outcomes, and costs over a specified period. These implementation and monitoring factors for larger or more complex projects should be described in an operational plan (Appendix C). Recurring treatments require comparatively less effort to estimate costs, reaffirm interest with the public, or gauge new direction. An example of this is crushing or roller chopping every

2–3 decades to maintain young deciduous forest and shrubs within browsing reach of moose. Recurring stand-scale prescribed burns will require updating of fire planning documents.

# Basis for Habitat Management

## Habitat, Predation, and Moose Abundance

Moose habitat is broadly distributed across Alaska and is fully occupied by moose, with continued expansion into coastal tundra where boreal vegetation is expanding (Tape et al. 2016, Barten 2018, Perry 2023). Shrub communities in tundra and subalpine areas are stable climax habitats because of infrequent stand-scale disturbance, with willow being the dominant forage species. In contrast, seral communities regenerate after forest disturbance and, depending on seed source and site conditions (soil type, soil moisture, and aspect), the primary winter forage species may be paper birch, balsam poplar, quaking aspen, or willow. Fluvial action may produce primary succession from a silt deposit or secondary succession when ice scouring simulates asexual sprouting by poplars or willows. Riparian disturbance is a chance event in a relatively predictable location within a floodplain (Telfer 1984), and more broadly on a landscape (LeResche et al. 1974). Boreal forest uplands are subject to stochastic large fires of complex configuration that influence vegetation dynamics (Johnson et al. 2001) and subsequently wildlife population dynamics during decades of postfire succession (Appendix D; Fisher and Wilkinson 2005). Fires stimulate regeneration of young deciduous trees and shrubs, either from seed or by sprouting, that may dominate cover within foraging reach of moose (<10 ft) for 1–3 decades (Telfer 1984). Geist (1974) postulated that the moose reproductive strategy of twin births reflects an adaptation for greater fitness when large fires increase forage and cover.

The concept of using habitat enhancement to increase moose abundance for the intent of increased harvest yield is predicated on forage resources limiting reproduction and survival. European explorers arriving in the late nineteenth century observed that Alaskan Natives were using fires set intentionally to modify vegetation for benefits including game habitat enhancement (Roessler and Packee 2000, Natcher et al. 2007). Moose increased dramatically from moderately low density in the 15 years following a 497 mi$^2$ burn in 1947 on the northern part of the Kenai Peninsula (Spencer and Hakala 1964). This increase occurred before wolves reestablished a breeding population on the peninsula following their extirpation around 1915 (Peterson and Woolington 1982). The robust moose response to the 1947 burn was attributed to patchiness of the fire that spread over a long-burning period that summer, creating enhanced forage adjacent to unburned security cover for a high degree of "edge" habitat (Schwartz and Franzmann 1989). As moose density within the 1947 burn perimeter declined, another numeric response was evident in the nearby 1969 Swanson River burn (133 mi$^2$) where moose abundance went from 0.2 moose/mi$^2$ in 1970–1971 to 1.4 moose/mi$^2$ in 1986–1987. This response coincided with a higher reproductive rate (Franzmann and Schwartz 1985) despite black bear predation on calves (Schwartz and Franzmann 1989).

Predation has been shown to limit moose abundance and harvest yield for many populations in the boreal forest in Alaska and Yukon Territory (Van Ballenberghe and Ballard 1994, Ballard and Van Ballenberghe 1997:269) to a low-density dynamic equilibrium of 0.1–1.1 moose/mi$^2$ (Gasaway et al. 1992) despite abundant forage in large recent burns or active floodplains. Within predation-limited systems, Boertje et al. (1995) noted that a localized, moderate density of moose (about 1 moose/mi$^2$) can be maintained in large burns that have developed optimal habitat. Examples include the Teslin burn in Yukon Territory (Gasaway et al. 1992: Table 11) and the Tok burn in Alaska (Gardner 2000:109). Other limiting factors on moose abundance include weather, hunting, disease, and parasites (Gasaway et al. 1983, Lankester and Samuel 1997, Van Ballenberghe and Ballard 1997:239–240).

Ballard and Van Ballenberghe (1997:270) found no case studies in areas with multiple large predators (black bears, brown bears, wolves) at their food-based carrying capacity in Alaska or western Canada where habitat enhancement had increased moose reproduction or survival sufficiently to offset predation once the moose population had declined to low density. Testa (2004) modeled population dynamics in a declining moose population in Southcentral Alaska and found limited capacity for increase through reproductive enhancement when compared with the effects of predation. Moose at lower densities in boreal systems are expected to be in better nutritional condition (lower intraspecific competition for forage) than moose at higher densities (Boertje et al. 2007). Thus, we do not expect forage enhancement at lower densities (<1 moose/mi$^2$ maintained by predation) to strongly increase reproductive potential or moose abundance. Increasing moose abundance from low density may require predator reductions to increase calf survival coincident with creating early seral forest that enhances moose productivity (Schwartz and Franzmann 1989).

Where predation is not limiting moose abundance, habitat enhancement may be suitable to maintain moderate to high density of moose in good nutritional condition and, in turn, their predators. Forage enhancement alone may not increase moose abundance if habitat features important for other life requirements (e.g., calving areas, mineral licks, aquatic plant sources) are limited or degraded, or if human land use displaces moose and limits access (LeResche 1974:410), such as with expanding urbanization. Areas of persistently deep snow may not be accessible to moose most winters or receive relatively little foraging use (Ballard et al. 1991, Collins and Helm 1997, Modaferri 1999, Poole and Stuart-Smith 2006) and thus should generally be of lower priority for habitat enhancement.

Moose response to habitat enhancement may have a time lag because of the demographic process of female calf recruitment to breeding age (Boertje et al. 2019: Fig. 4). At moderate densities (about 1.1–2.0 moose/mi$^2$), increasing moose abundance through greater reproduction assumes breeding-age females not born under nutritional limitation can promptly respond with a higher twinning rate. A case study of twinning-rate lag following dramatic reduction from high density in Unit 20A suggests it may take several years to produce a higher reproductive rate through recruitment of females subsequently born under reduced intraspecific competition, even when aided by habitat improvement (Boertje et al. 2019). In contrast, reducing calf mortality at lower moose densities (better nutrition) can produce a more immediate response on population growth (Keech et al. 2011). Other considerations for increasing moose abundance through habitat enhancement include scale of desired moose response (Appendix E) and type of plant regeneration technique (Appendix F).

## HABITAT STRATEGIES TO INCREASE MOOSE ABUNDANCE AND HARVEST

Understanding potential capabilities and limitations of habitat is important in planning strategies for elevated ungulate yield (National Research Council 1997:185–186). If forage is a limiting factor, improving forage quantity and quality can influence ungulate abundance and the potential for elevated harvest following predator control. If predator control is planned, habitat enhancement should occur either before or concurrently for the greatest potential population growth and subsequent increased harvest (Schwartz and Franzmann 1989). Prey harvest increase is contingent on hunter access, regulatory opportunity, and degree of user conflict.

Large wildland fires have occurred simultaneously in areas with predator reductions to benefit moose. After an initial growth of moose abundance associated with predator reductions soon after a wildland fire (Keech et al. 2011), continued population growth of moose in Unit 19D has occurred primarily in the burned portion of the predator reduction area and to a lesser degree outside the treatment area (D. Caudill, Regional Research Coordinator, ADF&G, unpublished data). In the mid-2000s in southern Unit 20E, moose increased most in the portion of the predator reduction area that was most affected by burns (Wells 2018:2)

An increase in prey abundance is the generally assumed outcome of intensive management (IM; see principles and guidelines below). This output would increase the harvestable surplus (sustainable yield) of moose. However, increased harvest without population growth is plausible in 3 scenarios: 1) prey mortality can be reallocated from predation to harvest following predator control; 2) where neonatal calf mortality by black bears or brown bears is low, greater productivity could be translated into a modest yield increase prior to wolf predation in winter if calf harvest in fall is socially acceptable; and 3) if the existing harvestable surplus is not fully utilized because of limited hunter access, then habitat enhancement can attract local moose to hunter accessible areas for a modest harvest increase, particularly where mechanical treatments required creating equipment trails or forest roads.

Boertje et al. (1995) reviewed factors of how habitat changes following wildland fires can decrease the negative effect of predation on abundance, such as when moose increase time spent in burns to utilize enhanced forage that improves their nutritional status and thus fitness (Gasaway et al. 1989, Schwartz and Franzmann 1989). Recent burns may also result in suboptimal, short-term foraging resources for bears, resulting in lower bear abundance (Gardner et al. 2014) that reduces risk of calf predation. Burns may also create woody debris (deadfall) that hinders predator movements. This phenomenon was observed to reduce black bear predation on moose in an area of willow crushing (Schwartz and Franzmann 1983).

In situations where managing moose abundance near communities is a challenge among competing interests (e.g., hunting and viewing opportunity versus crop damage and risk of vehicle collision). Periodic habitat enhancement may be feasible to simply maintain the desired density and nutritional condition for elevated yield (potentially including females and young at time), or to proactively prevent a decline below a defined objective (Appendix G). Projects near communities may include an attempt to attract moose away from areas of conflict, such as highway or railroad corridors, or to maintain attractive habitat in large river floodplains that may compose the highest concentration of hunting (Johnson et al. 2016). However, moose behavioral patterns, such as migration between seasonal ranges, or human disturbance of moose near settlements may still result in road or rail crossings by moose that pose collision risk. Habitat management to mitigate vehicle collisions should be considered experimental and evaluated with a rigorous study design (see Section 3. Evaluation).

## Principles and Guidelines for Intensive Management

Habitat enhancement and predation control are listed as primary tools under IM to achieve or sustain elevated levels of consumptive use of moose, barren ground caribou (*Rangifer tarandus*), and Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) using methods as prescribed in Alaska Statute 16.05.255(e–g) and (k). The IM Protocol (Alaska Department of Fish and Game 2011) contains principles and guidelines for planning and implementation. Those listed below directly apply to enhancement of habitat and public access to help achieve or maintain an elevated ungulate harvest:

PRINCIPLE 1: Intensive management programs should be ecologically sustainable.

> Guideline 1.1. Managers should ensure ungulate and predator populations and their habitats will be managed for their long-term sustainability.
>
> a) Elevated ungulate populations should not degrade forage, nutritional condition, or population productivity to unsustainable levels.
>
> b) Habitat management practices intended to maintain or enhance forage (plant) health and availability should be implemented where and when they are feasible, acceptable, and cost-effective.

PRINCIPLE 2. Intensive management programs should be based on scientific information.

> Guideline 2.1. Managers should design and conduct IM programs in a systematic and scientific manner to ensure learning from treatments and responses.
>
> a) The size and location of treatment areas should adequately influence the intended species while using natural boundaries easily recognized by hunters; managers should clarify rationale if smaller than area defined in regulation.
>
> b) Populations of ungulates and their predators, ungulate habitat, and wildlife harvest should be monitored using scientific methods.

PRINCIPLE 3. Intensive management programs should be socially sustainable.

> Guideline 3.1. Managers should work with public stakeholders to identify desired outcomes and mitigate potential or actual conflicts that may ensue as a result of elevated ungulate harvests; these steps should occur in the planning phase.
>
> b) Public access problems that may impede harvest of ungulates or predators, create unacceptable crowding conditions, or lead to conflict among users; these issues should be identified and mitigated, where feasible.

While an increase in a moose population to near maximum sustainable yield is desired, as in most IM programs (5 AAC 92.106(2)), local stakeholders should understand that if extension of hunting season or new hunt opportunity is authorized by the Alaska Board of Game, then an increase in harvestable surplus may attract nonlocal users. Increasing moose density in an area where vehicle collisions are historically common incurs risk of further collision, particularly during the period of late fall through late winter (McDonald et al. 2019). The primary factors associated with moose collisions (e.g., traffic speed and volume; DelFrate and Spraker 1991, Seiler 2005, Danks and Porter 2010) are difficult to mitigate through land management. If higher moose density is desired in areas with high incidence of vehicle collisions, targeted hunts of all age and sex classes near highways prior to the period of increased movements during the rut might reduce density of local nonmigratory moose, provided sufficient public lands exist adjacent to relevant road sections. Maintaining moose density well below food limitation at a carrying capacity (*K*, sometimes abbreviated as *Kcc*) in this type of situation would enhance harvest yield (the intent of IM) and benefit public highway safety. Where habitat enhancement is part of an IM program including predator control, an IM feasibility assessment (Appendix H) should be completed to address moose population and harvest objectives.

# 1. Planning

## Process Overview

Planning of habitat projects should begin with agreed-upon definitions by stakeholders (user groups, landowners, land managers, etc.) of intended outputs (elevated game harvest, increased wildlife viewing opportunity, etc.) and their duration (years to decades) that are expected from the management action or experimental treatment. Project scope should include the area to be treated and the vegetation management technique to be applied. Quantifiable project objectives should be jointly defined through discussions among DWC staff, landowners and managers, and external partners like nongovernment organizations to identify the implementation and evaluation parameters and potential funding sources including in-kind contributions. In cases where larger holdings of Alaska Native corporation lands are involved and only shareholders may have access, we assume nonshareholders will benefit from harvest when moose occupy nearby public lands during the hunting season.

DWC staff who specialize in habitat, fire, or forestry may have lead roles in habitat projects, but it is essential that the area management biologist participate in public scoping and local outreach. Where DWC is the lead partner, we assume primary responsibility to perform, contract, or coordinate treatments with other entities. For projects that are large (e.g., >10 mi$^2$) or complex (e.g., multiple phases over several years, multiple landowners, involvement of multiple aircraft, or adjacent to high-value infrastructure), conditions of collaboration should be in an agreement signed by all partners. Prescribed fire plans require careful delineation of the burn prescription parameters, modeling of smoke emissions, and an explicit technical review prior to signatures by the fire suppression agencies and land managers, regardless of project size or complexity. As such, prescribed fire planning (Appendix I) should be coordinated by DWC fire specialists in concert with outside expertise in fire management and prescribed fire.

We strongly advise a feasibility assessment with decision factors for DWC engagement for large or complex projects. This will ensure consideration of state funds expenditure and staff time as directed in the agency Science Policy (Alaska Department of Fish and Game 2012). Staff should document planning considerations identified throughout this bulletin to complete a feasibility assessment (Appendix B). For comparison, a feasibility assessment is also done prior to implementing predator control (Alaska Department of Fish and Game 2011). The degree of planning necessary for smaller projects, or those where ADF&G is a lesser partner, is at the discretion of the DWC regional supervisor. One-time projects, such as a proof-of-concept demonstration for an enhancement technique, may be planned as part of a research project (e.g., Lowell and Crain 1999, Paragi and Haggstrom 2007).

A public workshop to present information on the planned project may be useful if it is close to a community. Timmermann and McNicol (1988) produced an illustrated overview of moose-habitat interactions and nutritional ecology that is a useful starting resource for outreach.

## Considerations for Habitat Projects

Habitat enhancement projects have land management and public access implications. Projects may incur substantial liability risk from unintended consequences (e.g., prescribed fire spreading outside of the designated area) and substantial costs in planning, implementation, and evaluation due to spatial extent of intended effects, complexity of land ownership and associated policies, and permitting requirements (Appendix A). When proposing habitat enhancement projects, DWC has a responsibility to 1) clarify vegetation and wildlife objectives through discussions between staff and members of the public (Decker et al. 2015), and 2) evaluate the efficacy of implemented projects to achieve ecological and policy objectives, including marginal cost per unit of net return (viewing opportunity or harvest). Rausch (1967) emphasized the need for clarifying access policy among competing hunting outcomes (e.g., meat yield versus trophy hunting experience not always contingent on harvest) before embarking on programs with land managers to increase hunter access. The early wildlife management plans in Alaska (Alaska Department of Fish and Game 1976:6) discussed optimizing moose harvest for various outcomes (meat, trophy, regulating density to avoid human conflicts) and the balance of public access to allow harvest and nonconsumptive uses at levels “without detrimental effects to wildlife.”

The following considerations are not in priority order because priorities will differ among projects. Supervisory and field staff should discuss these factors and put them in priority order for each project to clarify management direction. This will allow for transparent scoring when decisions and priorities about what will be funded are made at the regional or statewide level.

- There is evidence of nutritional stress in moose (e.g., low twinning rates) or high levels of forage offtake that include widespread severe plant damage from browsing;
- The appropriate scale of vegetation types and site conditions (soil type, landform, etc.) exist. Mechanical or fire treatments are feasible with respect to whether attraction of existing moose (individuals at forest stand scale) or increased abundance (population at landscape scale) is the desired outcome;
- Private landowners or public land managers are amenable to treatments on their property, and the public can achieve wildlife benefits directly through access or indirectly through animal movements onto public lands;
- Public requests to increase access or opportunity for hunting or viewing is occurring in the currently accessible portion of moose habitat;
- Shrub and deciduous forest regeneration in appropriate locations can serve as a fuel break to reduce risk of wildland fire spreading toward homes, with added benefit of enhancing local food supply (game and berry harvest), and other cultural desires like wildlife viewing[1];
- Desired vegetation outcome (stimulate existing species or create seral conversion from conifer to deciduous) is feasible with respect to ecological attributes of the site and commensurate with the preferred treatment method; and
- Communication on objectives and feasibility with hunters, wildlife interest groups, and other local stakeholders confirms support for the project.

Identifying resources required for implementation, scoping the geographic scale, communicating with potential agency partners, and considering costs in advance allows planning of "shovel ready" projects for funding matches and partnerships, particularly on fiscal-calendar deadlines. However, it is critical to avoid the pitfall of planning treatments before clarifying explicit goals and objectives (Dörner 1996:186).

## Assessing Feasibility and Expectations

A feasibility assessment aids decision-makers by using the scientific information and professional judgement of staff to rank the potential (high, moderate, low) for achieving stated objectives in a specified area for a defined period. The feasibility rank is used by agency officials and the public to inform decisions on whether to fund and how to implement a project. A project with low feasibility may still be pursued if there are overriding social or economic factors, with the assessment document providing a written record of factors considered. Agency officials should consider implications for existing programs (opportunity cost), potential partners (e.g., public and private landowners), and third-party funding entities. During project scoping, public discussions about proposed habitat enhancement, predator control, or other associated

[1] Creating defensible space near communities (Lojewski 2016, Miller 2016) may be of higher priority than habitat enhancement in the wildland-urban interface. ADF&G staff can work with foresters and land managers to optimize establishment of woody deciduous vegetation that competitively hinders grass (ground fuels when dry) or conifers (crown fuels), thus prolonging the need for recurring costs of fuel break maintenance, and simultaneously provides benefit to habitat through increased concealment cover and winter forage production.

management actions should include expectations on the cost, acceptability, and reliability to result in enhanced game harvest or wildlife viewing opportunity.

Mechanical treatments, prescribed fires, and predator control can be applied with spatial precision to enhance ungulate yield. A feasibility assessment should acknowledge management constraints (biological, economic, social) for a transparent discussion of expectations. Unlike game ranching of confined ungulates as a form of livestock agriculture, free-ranging wildlife may not exhibit a spatially precise response of habitat use or population growth in areas accessible to hunters. Thus, game management cannot ensure harvest for individual hunters, even if the average rate of harvest success is elevated and remains relatively consistent over time for the hunter population.

Habitat enhancement projects should have objectives based on a clear definition of stakeholder desires for outcomes, especially the expected magnitude of increased harvest or viewing opportunity. A specific definition of the problem for the proposed project (not simply "increase moose" or "increase harvest") is a prerequisite to effective planning. Each situation has a unique biological and societal context, so clear definition of what the various stakeholders expect is critical to define the project goals, objectives, and spatial extent of implementation, along with evaluation of outputs and outcomes (Brunner 1997, Clark 2002; see Section 3. Evaluation, and Appendix B). Stakeholders may be local and nonlocal users, landowners, or land managers (potentially a mix of public and private), DWC staff who manage programs, and other interested parties seeking to provide input to project planning. DWC has the lead responsibility to bring biological and harvest information to the planning phase. However, societal issues or concerns should be included in scoping, so all stakeholders have an informed expectation of outcomes. In addition, stakeholders should be informed as to how specific criteria for program outcomes will be evaluated for public satisfaction. It is crucial that expectations are documented in writing as an agreed-upon basis for subsequent implementation and evaluation steps, which can serve a valuable role in subsequent policy analysis (Brewer 1981). Where public lands are involved, wildlife managers should recognize that biological guidelines for habitat enhancement without a supporting policy statement of the land manager can result in habitat guidelines being ignored or rejected at the field level (McNicol and Gilbert 1987). This highlights the importance of written agreements specifying objectives, methods, and mutual responsibilities in partnerships for habitat enhancement projects, regardless of implementation strategy.

## Clarifying Objectives, Scale, and Evaluation Metrics

Chambers (1983) characterized 3 goals of wildlife habitat management pertinent to scale:

1) Creating or maintaining all required features for a species so as to increase its abundance on the managed area;

2) Creating or maintaining only a portion of required features with an expectation it will complement features in the surrounding area to increase species abundance on the managed area;

3) Managing features of an area to attract a species without necessarily increasing its abundance.

Moose utilize relatively large home ranges, and many populations are migratory (LeResche 1974, Modafferi 1999), so goal 1 is infeasible for moose. Goal 2 requires considerations at the landscape scale such as a Game Management Unit or management unit of the Tanana Valley State Forest (ADNR 2001; Paragi and Rodman 2020). Goal 3 describes a common outcome when enhancing some features in a small area that creates a perception of increased abundance or may increase local harvest success.

Agency staff and stakeholders should discuss project objectives, desired outputs, and expected outcomes before the project is undertaken. *Outputs* are typically renewable resources metrics quantifiable by natural sciences (proximate means to an end: kg/ha of forage, animal density, total harvest or kill-per-unit effort, cost per unit of harvest return on funding expenditure, etc.), whereas *outcomes* are measures of public satisfaction described by social sciences (the ultimate end: proportion of stakeholders that characterize a hunting experience as enjoyable regardless of harvest success, policy evaluation of whether cost-per-unit return was acceptable, etc.). Scientific evaluation of outputs is essential to an eventual policy evaluation of desired outcomes (Birkland 2005). A similar characterization was proposed by Riley et al. (2003) that contrasted enabling objectives (outputs) and fundamental objectives (outcomes). DWC biologists are primarily involved in measuring outputs of habitat and game, whereas social scientists evaluate outcomes of public satisfaction or frame conflicts among competing public values that influence management decisions.

Presently, the monitoring of moose nutritional condition (Boertje et al. 2007, Cook et al. 2010) and forage offtake (Seaton et al. 2011, Paragi et al. 2015) are used to gauge the strength of density-dependent responses in moose. Increased negative feedback may trigger management actions to reduce intraspecific food competition by reducing moose density (Young and Boertje 2011), enhancing forage quantity, or both. Attempting to design a habitat project to provide forage for a desired number of moose (as specified in IM population objectives set at “near maximum sustained yield” per 5 AAC 92.106(2)) at a defined nutritional status or productivity involves some approximation of habitat capability as a proxy for an estimate of *K* (McCullough 1979, Macnab 1985, Hundertmark and Schwarz 1996).

*K* can be approximated by estimating moose density in an “undisturbed area” after there is sufficient coexistence of herbivores and forage (Crete 1989); however, it more commonly quantifies forage (biomass and nutritional value) for a defined landscape and includes assumptions of moose energetic demand relative to environmental variation in space and time (e.g., Hobbs et al. 1985). Carrying capacity has its basis in livestock agriculture (Stoddart et al. 1975) and was used to conceptualize range capacity as a limiting factor in game management (Leopold 1933, Edwards and Fowle 1955). However, it is challenging to apply carrying capacity to production objectives on free-ranging wildlife when the goal is harvesting near maximum sustained yield (MSY; McCullough 1979, MacNab 1985, Hundertmark and Schwarz 1996). Biologists should carefully consider outreach messages on the concept to avoid confusion (Dhondt 1988).

The parabolic relationship between abundance and productivity for ungulates is bounded on the upper end by *K*, where net production and sustained yield is zero at maximum abundance; the inflection point of population growth at maximum sustained yield (*I*) is peak net productivity at about 50% of *K*. This was show experimentally for white-tailed deer (McCullough (1979:150–

155) and depicted conceptually for considering optimum sustained yield of moose, with and without predators (Gasaway et al. (1992:48) Managing for high moose density closer to *K* allows the public to see more animals but comes at the cost of reduced productivity from a density-dependent effect that lowers per capita nutrition and increases risk of increased mortality during a severe winter, particularly for calves (see Keech 2012:18 for an example at even relatively low density). Maintaining a lower nutritional condition at high density can delay onset of both parturition and twinning, resulting in lower lifetime reproductive output (Boertje et al. 2019). Carrying capacity models inform discussions with the public and Board of Game by illustrating a "productivity penalty" of managing for higher density >*I* and its implication on the desired IM yield "near MSY."

Presently, models of moose carrying capacity are insufficiently refined for the scale of a game management subunit. Research on captive and free-ranging moose in Alaska has evaluated forage, range, environmental, and nutritional components necessary for a dietary energetic approach to estimating carrying capacity (e.g., Regelin et al. 1987, Schwartz et al. 1987, Schwartz et al. 1988). Estimates of moose *K* to date have not included associated estimates of variance, thus limiting confidence in their accuracy and hindering judgment of differences among study areas or within one area over time. Nonetheless, techniques for nutritional analysis (McArt et al. 2006, Spalinger et al. 2010, Carnahan et al. 2013) and remote sensing of forage quantity and quality (e.g., Walton et al. 2013) continue to improve. Parameter estimates are integrated into a modeling framework called FRESH moose (D. Spalinger, Associate Professor of Biology, University of Alaska, Anchorage, personal communication, August 2021); the model is written in R but not yet published. This model is based on the FRESH deer model that was developed in coordination with the U.S. Forest Service (Hanley et al. 2012). Research on carrying capacity can inform IM population objectives in the context of historic moose abundance that resulted from large wildland fires near populated areas (e.g., 1947 and 1969 fires on Kenai Peninsula) that would likely now be suppressed during initial attack. Forage sampling began in 2020 by DWC staff to analyze nutritional content in the 2019 Swan Lake Fire on the Kenai Peninsula (D. Thompson, wildlife biologist, ADF&G Moose Research Center, personal communication, September 2021). DWC staff with the Kenai Moose Research Center[2] and the Foraging Ecology and Wildlife Nutritional Analysis Lab in Palmer[3] are key resources for advice on monitoring changes in habitat quality, moose nutrition, and reproductive performance for informed judgment of habitat capability to support moose.

Thompson and Stewart (1997:383–385) described considerations of scale in time (short term of 10–20 years versus long term of 80–100 years) and space (local versus landscape) for recommendations in managing moose habitat. As human influence on the landscape in which moose are adapted becomes more pervasive than natural disturbances, conserving moose access to calving areas, aquatic foraging sites, mineral licks, and other habitat features will become important to maximize fitness and harvestable surplus of game. This situation will become more common as logging and agriculture increase and the wildland-community interface (often called "wildland-urban interface" in technical literature) expands with human population growth and residential settlement. Public and private land managers will seek to exclude fire except under planned circumstances. Society will have to adapt to climatic changes influencing disturbance

[2] https://www.adfg.alaska.gov/index.cfm?adfg=wildliferesearch.mrc
[3] https://www.adfg.alaska.gov/index.cfm?adfg=wildliferesearch.fawna

processes, but human influences are ultimately managed through planning and, when necessary, regulation enforcement.

Managers cannot influence location or frequency of fluvial disturbance in remote areas of Alaska, but they can use mechanical treatments such as dozer crushing to maintain dense young willows or hardwood saplings. Collins and Helm (1997) recommended focusing mechanical treatments or prescribed fire enhancement on upland sites where natural disturbance is more stochastic than in active river floodplains. However, in remote roadless areas with minimal logging activity, dozer crushing in winter along accreting river bars is more feasible for machinery access. This also maintains habitat in boat-accessible areas typically used by rural hunters. Habitat improvement in the riparian corridor may additionally help stabilize moose population size following predator control because animals attracted to the riparian area in fall and winter are exposed to higher harvest and predation than moose overwintering on upland sites (Paragi and Kellie, *In Prep*, Winter habitat evaluation for moose management in Interior Alaska).

Broad and substantial consultation should precede a project with multiple phases or a long-term plan (e.g., 20 years) such as where treatments are done over time to maintain a "shifting mosaic" of early seral conditions in a defined landscape (Gullion 1984). The periodic crushing or shearing of shrubs and young hardwoods that regenerate after a large burn near the road system is an example of this and was done in 1987 and 1994 burns near Delta and a 1990 burn near Tok. Prior to recurring treatments, targeted outreach to local stakeholders on achievements to date can identify any changes in public desires for the defined area that might require modification of original plans.

Identifying performance metrics and specifying a decision framework to implement or suspend habitat treatments in the operational plan for IM (Alaska Department of Fish and Game 2011) will greatly aid an objective evaluation of the project. If during the implementation or evaluation phase of a multi-year or complex project, the variables used to define feasibility are overcome by failure, excessive cost, or significant departure from the intended outcome, the project lead should consider modifying the treatment or terminating the project. Decision thresholds to modify or terminate a habitat project should ideally be defined in the operational plan. If habitat enhancement is proposed as a secondary benefit of another purpose, such as in the creation or maintenance of a hazardous fuel break, secondary status should be clarified to distinguish relative expectations in a return-on-investment analysis.

Elevated moose harvest is the ultimate output from IM, so harvest evaluation should be an explicit component of habitat enhancement for IM programs. Other satisfaction metrics such as success rate are important to define through public outreach as measures of satisfaction. Kill per unit of hunting effort defines efficiency (minimum time to harvest) that may be tangible where wild meat acquisition competes with other food gathering and seasonal activities necessary for individual and community wellness, especially in rural areas. Hunting longer to get a moose reduces time and fuel available to get fish, firewood, and other necessities, or to participate in community life. However, the ambiguous definition of a reported "day" of hunting, the small number of hunters involved at the relatively small scale of habitat treatments, annual availability of other resources (e.g., Alaska Department of Fish and Game 2024), and the potential for confounding factors (changes in access or regulations) complicate use of this metric. Male-female ratio in the moose population is a common management objective of hunter satisfaction because moose harvest is approximately 90% male statewide (ADF&G unpublished data). This ratio is related to hunting pressure more so than moose density, but it might be a useful metric of habitat modification outcome if treatments attract males more than females during hunting season.

## Interaction of Habitat Enhancement and Public Access

Public use desires and acceptable methods for access creation and resource management are important components of wildlife management (Crowe 1983, Riley et al. 2003). Increasing access would likely increase harvest opportunity, which is a positive outcome until harvest exceeds the sustainable yield, hunter crowding reduces user satisfaction, or there is conflict among users based on competing means of access. Creation or improvement of public access for hunting or wildlife-related recreation often occurs in association with habitat enhancement, such as trails created by heavy equipment, or in response to natural disturbances, such as salvage of burned timber. Access creation to enhance hunting opportunity can also be done independent of habitat enhancement through creation of motorized or nonmotorized trails, landing strips for fixed-wing aircraft, or boat launches to facilitate water access to remote natural disturbances and anthropogenic disturbances (e.g., power line or pipeline clearings). Creation or enhancement of access by itself is more directly an allocation of harvest opportunity among user groups, such as motorized and nonmotorized means. Allocation of game harvest methods and means normally reserved for decisions by the Alaska Board of Game and other appointed or elected bodies that govern wildlife uses through policy or rule-making authority (Smith 2011, Harrison 2021:131–134). Beyond hunting opportunity within Board of Game purview, managing access also requires concurrence from the land manager.

Schmidt and Dial (2017) did a preliminary analysis of moose harvest and increase in motorized access during 1990–2015 for Unit 20B. They found that increased harvest was associated with new access up to a point, with the largest harvest levels along secondary (unpaved) roads. However, increased road and trail access over time increased the number of hunters using an area faster than harvest increased, thus lowering harvest success (amount of harvest/number of hunters). They also found that access and habitat enhancement are important at slightly different scales. Habitat enhancement improved harvest in the immediate area (small drainages represented at the minor specific scale of a uniform coding unit (UCU[4]) and in surrounding areas, whereas harvest near increased road access was largely in the immediate area.

Managers have long recognized that areas not readily accessible by boat or vehicle act as wildlife refugia from hunting pressure, where greater harvest is often available with increasing distance from communities (Johnson et al. 2016). These remote areas commonly allow popular general-harvest-ticket hunts for more freedom of choice in where to hunt with few restrictions. In contrast, accessible areas tend to have depressed bull-to-cow ratios (Bishop and Rausch 1974, Schwartz et al. 1992), which can reduce bull harvest success and hunter satisfaction derived from evaluating several bulls for size of antlers. More accessible areas may have various antler size

[4] History and description of Uniform Coding Units is found at ADF&G Home (www.adfg.alaska.gov) | Hunting | Maps | GIS & Data Downloads | Game Management Unit & Subunit Boundaries: https://adfg.maps.arcgis.com/home/item.html?id=f1019b8731aa4ec4921501d035c7ba5e&_ga=2.170052576.1309681226.1681869076-1470568579.1677524760.

restrictions or be available only by lottery (drawing) unless the objective is to manage moose for lower density to avoid human conflicts. Prior to creating new access, land management agencies may require scoping or consultation through the public process. New access often requires consideration of trailhead parking, public toilets, wildlife-proof trash bins, and associated trail maintenance costs. Habitat enhancement projects may also require trespass mitigation across private lands (e.g., right-of-way corridors) or other stipulations based on landowner objectives. Examples may include gate installation or other barriers that restrict the sizes of motorized vehicles allowed to pass. The time needed to complete planning should be considered, particularly if predator control is being done simultaneously.

Creating or enhancing motorized ground access is likely to be permanent (a net increase) given human density on the road system and technological advances in mechanized transport and electronic communication. Habitat enhancement that will substantively increase motorized trail access should receive appropriate public consultation with local residents and applicable user groups. Type of access (trail, road, boat launch, etc.) often favors a particular user group, so public consultation is critical in the planning process to avoid an appearance of DWC allocating methods or means of access specifically related to hunting (an authority of the Alaska Board of Game). Hunters expend substantial effort to access areas without trails for motorized vehicles through use of aircraft, watercraft, and nonmotorized travel for solitude, which is an important motivation for some hunters. Consultation with established trail advisory committees in state and municipal or borough government is advisable to fully understand the issues, especially those of local residents most likely to be affected by increased public use, such as potential trail damage from increased or new uses that could hinder existing uses. Scoping can identify compromises or mitigate conflict through joint problem solving among user groups. This consultation should be done in concert with reviews by local ADF&G Fish and Game Advisory Committees and issues should be identified in the feasibility assessment.

## Avoiding Unintended Vegetation or Wildlife Responses

In describing the decision to implement predator reductions to increase moose abundance and harvest, Ballard et al. (1991:38) recommended that "any management action should preferably satisfy two important criteria: 1) a high likelihood of attaining the immediate objective (e.g., attracting moose or causing the moose population to increase), and 2) side effects that are predictable, easily measurable, moderate in magnitude, of short duration, and easily reversible." Those same considerations apply to habitat enhancement, although the duration is contingent on time lags of years to decades in shrub or forest succession. Agency staff should review scientific literature and consult specialists to avoid unanticipated and potentially undesirable vegetative or wildlife responses to habitat management.

Vegetation response to logging has the potential to emulate stand-replacement fire, which is common in boreal, spruce forests. However, logged sites may have less vegetation diversity than burned sites (Rees and Juday 2002). A direct comparison of timber harvest and fire effects on moose abundance has not been made in northern boreal forest (Magoun and Dean 2000). A recent review of moose response to logging and roads in the circumboreal region (Johnson and Rea 2024) mentioned of fire in the context of its increasing frequency and scale in a warming climate and how moose utilize older forest for shade as temperatures increase.

The concepts and recommendations for creating winter forage and cover to benefit moose may also enhance brood-rearing habitat for gallinaceous birds like ruffed grouse (*Bonasa umbellus*; Gullion 1984) or spruce grouse (*Canachites canadensis*) and many passerine birds inhabiting boreal forest (Kessel 1998). In some situations, retention of late-seral legacies as habitat features may be equally important for meeting public desires stipulated in a planning process. This could affect game species (e.g., furbearer maternal dens in large tree cavities or mustelid access to subnivean hunting of small game beneath woody debris tangles) or nongame species (e.g., bird nesting in tree cavities or hunting perches in snags). Guidelines are provided by ADF&G on how to retain late-seral habitat features for furbearers or forest birds when logging contractors enhance early seral moose habitat in boreal timber sales (Paragi and Rodman 2020).

Habitat management should "do no harm" through unintended consequences, such as stimulating dense conifer regeneration in a fuel break, attracting moose to high-volume traffic routes that increases collision risk, or introducing invasive plant species by not following best practices during vegetation treatments (see below for precautionary steps on invasive plants). Treatments for habitat objectives should acknowledge risks and mitigation steps, such as *Ips* beetle infestation emanating from logging slash to adjacent conifer forest (Holsten et al. 2013). Small scale experimentation is prudent to evaluate questionable situations before broader implementation.

Manipulating vegetation for habitat enhancement near communities should involve consultation with experienced fire or land managers. This is important in understanding the risk of enhancing spruce recruitment from competitive release of advanced regeneration, site preparation for stored seed in the soil, or influx of new seed (e.g., anticipated high production based on local knowledge of periodicity from climate signals; Juday et al. 2003, Krebs et al. 2012). Unless hazardous fuel treatments convert sites to nonvegetated surfaces, a key aspect of their cost effectiveness is the duration of reduced flammability in the regenerating vegetation that allows a suppression advantage by reducing fire behavior (flame length or rate of spread; Finney 2001) or providing an option for back firing on the side closer to the wildland fire for further fuel reduction (Lojewski 2016). Hardwood enhancement at stand initiation can initially suppress conifer growth, but premature disturbance of the hardwood canopy on midseral sites can potentially stimulate growth of established conifer seedlings, the antithesis of crown fuels reduction and habitat enhancement for moose (Appendix F). Similarly, maintaining high density of moose can lead to excessive browsing of preferred species and competitive release of conifers (Butler et al. 2007). Hazardous fuel treatments should be evaluated in consultation with fire managers after about 10 years to verify that conifer trees have not regenerated at sufficient density to increase fire behavior beyond the intended limits of the fuel break for manual (firefighter), or mechanized (dozer) fire suppression tactics. Fuel treatments require monitoring to know when retreatment is prudent (Melvin et al. 2018).

Taking precautionary steps to minimize the introduction and spread of invasive plant species during habitat enhancement is most readily done through best management practices for equipment cleaning between job sites (Graziano et al. 2014). These practices are endorsed by the Society of American Foresters (2022) and increasingly required for contractors working on public lands for fire suppression or prescribed fire[5], forest-road construction and maintenance (Ferguson et al. 2003), and forestry practices[6]. Public access in the snow-free season, including across or along river systems, also can spread invasive plants (Rooney 2006, Bella 2011). Signage at habitat enhancement sites and public outreach can increase awareness of risks and mitigation. Simple cleaning procedures (footgear cleaning brushes, vehicle inspection and washing as needed) before moving between sites can help reduce potential for spread [7,8,9]. Interestingly, moose have been shown as a possible vector in spreading white sweet clover (*Melilotus albus*; Seefeldt et al. 2010), which could occur if this invasive plant establishes coincidental to intended moose forages on treatment sites.

Attraction of moose to treatment sites is generally a positive outcome except where it might increase risk of vehicle collision. Prior to initiating habitat enhancement projects near traffic corridors of high volume and speed, biologists should evaluate collision locations and historical data on seasonal range use and movement corridors to identify major crossings. Collision risk is often highest with return of darkness in fall immediately preceding the rut (Noordeloos 2016, McDonald et al. 2019) and in periods of deep snow (Didrickson and Kramer 1986, Del Frate and Spraker 1991). The concept of creating abundant forage to attract moose away from areas of high collision risk has not been validated as successfully reducing collisions, but there are strategies to mitigate collisions through timing of roadside vegetation cutting (Rea 2003). Moose movement patterns are often established as migration routes, particularly in areas of high snowfall (Modafferi 1999, Poole and Stuart-Smith 2006). Habitat enhancement may delay crossing of roads or rails but are unlikely to alter the endpoints of migration (cf. Gasaway et al. 1989). Attempts to mitigate collisions using habitat enhancement should be clearly described to the public as "experimental."

Fall and winter hunts to reduce moose density have been offered in targeted areas such as road corridors near suburban areas on the Alaska road system to mitigate collision risk during winter (e.g., Units 14A and14B). Such strategies require access consent of private landowners and may be challenging in proximity to residential areas with limited public land for hunting.

Persistent, high levels of browsing offtake at high moose density can hasten transition to nonpreferred plant species (Butler et al. 2007) and reduce the vigor of or even kill preferred browse plants (reviewed in Paragi et al. 2015). Reducing high moose density through elevated

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[5] Invasive species pocket guide for Alaska firefighters (USDA Forest Service, 2018; https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd586115.pdf).

[6] Forestry operations fact sheet (Invasive Species Council of British Columbia, 2019; https://bcinvasives.ca/wp-content/uploads/2021/01/Forestry_OperationsFINAL_04_24_2019.pdf. Similar recommendations were given by 2016 implementation group on reforestation practices in Alaska (p. 33 under "New topics: (https://forestry.alaska.gov/Assets/pdfs/forestpractices/IG%20Chart%20of%20%20recommendations%20-%20May%2026%202016%20am.pdf).

[7] Invasive plants and agricultural pest management (Alaska Department of Natural Resources, Division of Agriculture, 2023) https://plants.alaska.gov/invasives/index.htm#:~:text=When%20we%20travel%20to%20our%20favorite%20spots%2C%20our,area%20that%20was%20previously%20free%20of%20invasive%20plants.

[8] Hikers, hunters, and ATV enthusiasts: knock it off. Invasive species of Idaho, 2023 (https://invasivespecies.idaho.gov/hikers-hunters).

[9] Inspection and Cleaning Manual for Equipment and Vehicles to Prevent the Spread of Invasive Species (< https://www.usbr.gov/lc/region/g2000/envdocs/EquipmentInspectionandCleaningManual2021.pdf)

harvest is advisable prior to investments in habitat enhancement so browse species can become established and build root nutritional reserves in the absence of high disturbance (Bartos 2001). This strategy is expected to increase the long-term carrying capacity of the area (more forage and better nutritional condition of adult female moose) while providing more short-term harvest opportunity.

Use of fire to enhance moose habitat in boreal forest can affect caribou habitat in different ways. Lichens are the major forage for caribou in winter and typically take 80 years after fire disturbance to achieve biomass suitable for caribou winter range (Klein 1982). Forage lichen biomass in the Fortymile region was greatest in 80- to 220-year-old stands but virtually absent from stands less than 60-years old (Collins et al. 2011). Fire can also reduce availability of winter forage to caribou if deadfall inhibits travel and snow interception by conifers no longer occurs; the deeper snow inhibits forage detection by smell and increases energy spent on digging to the forage (Schaefer and Pruitt 1991). Shrubs are important early summer forages for caribou prior to insect harassment (reviewed in Ehlers et al. 2021), so knowledge of seasonal range use will inform ungulate species tradeoffs in specific areas.

A need to consider habitat needs of caribou and other species favored by late-seral habitat features has long been recognized in managing for moose habitat (Rausch et al. 1974). Where conservation of limited winter range for smaller caribou herds or protection of local winter range used for hunting of larger migratory herds is desired, managers could plan for an acceptable rate of range replacement by fire to avoid strong detriment to caribou. For example, allowing no more than 5% of the range to burn per decade gives complete range replacement (turnover by fire) in 200 years. Assuming a start with good-quality winter range (≥60 years old) for caribou over the entire area, allowing ≤5% of the range to burn per decade without spatial overlap (reburn of young range) would maintain ≥70% of the range in the 60- to 200-year age class over the long run. If >5% burns in an extreme fire year, greater suppression vigilance in the next decade within the defined area can get the replacement rate back on schedule.

## Consider Evaluation Design in the Planning Phase

Design of a project should begin with the evaluation in mind (see Section 3. Evaluation). This requires consideration of appropriate temporal and spatial scales for evaluating performance standards that are defined in measurable objectives. For example, moose harvest is reported by drainage (UCU), so when practical, planning spatial alignment among large treatment areas, moose survey areas, and UCU boundaries optimizes the strength of scientific inference on treatment effect. This clarifies public and agency expectations for a project and informs an optimal treatment schedule (see Section 2. Implementation).

Evaluation of managed boreal ecosystems should recognize the slower dynamics of forest succession within which the faster dynamics of predation and harvest occur (Carpenter and Turner 2001, Brown et al. 2015). The IM Protocol (Alaska Department of Fish and Game 2011) includes habitat enhancement as a minor component, instead focusing on the relatively fast (3–6 year) cycles of predator-prey dynamics and harvest regulation changes. The time lag needed to create browse biomass 1.5–10.0 feet tall with associated security cover in older forest (concealment against detection by predators) and shading in summer attractive to moose can vary substantially. Aspen or willow sprouting on productive sites can be beneficial to moose in

1–4 years. In contrast, willow or hardwood regeneration from seed on severely burned sites of low productivity, or on logged sites with dense grass competition, can take 1–3 decades. When browse enhancement occurs, the duration of peak available browse can vary from a few years (before deciduous trees grow beyond reach of moose) to several decades (shrub willows where browse remains <10 feet). Moose density can reflect the pulse of browse abundance with peaks at 10–30 years post-disturbance (Appendix D; Maier et al. 2005), although predation or winter severity can temporarily offset the numeric response from improved moose productivity.

Lags in response time are important to recognize for planning the type of evaluation you anticipate accomplishing during the funding cycle of a habitat project. These might be lags in vegetation response to disturbances or lags in moose productivity to vegetation changes (particularly where population increase is the goal). Although moose can rapidly utilize young vegetation in a home range or along migration routes (Gasaway and DuBois 1985, Gasaway et al. 1989), a population increase driven by increased moose productivity would require several years of improved calf production and female cohort survival under improved nutritional condition to increase production in the breeding population of adult females (Boertje et al. 2019). Harvest response to increased moose abundance may take additional time as hunters figure out access in the fire-changed landscape.

The planning process should consider the potential for time lags in vegetation response, such as scheduling the sampling window to document the most rapid changes in vegetation soon after treatment (e.g., stem density ≥1.5 ft as available for browsing above snow). The silvicultural prescription requires knowledge of site conditions that can affect vegetation response, such as mechanical or fire treatments that can optimize mineral soil exposure (Appendix F). Most habitat treatments are unlikely to align with boundaries of sampling units for moose abundance (Geospatial Population Estimator surveys) or harvest reporting (drainages defined by UCU). However, evaluating moose movements and seasonal distribution is beneficial for substantiating effectiveness of the habitat treatment to increase moose harvest. Finally, evaluating harvest success for a habitat enhancement project can be confounded by merely creating access for hunter vehicles. Thus, the planning process should identify ways to separate the effects of vegetation treatment with carefully designed moose harvest monitoring (Appendix F).

For proposed habitat enhancement projects, a feasibility assessment (Appendix B) includes factors to consider in judging whether stated goals and objectives within a specified period have been met. Goals provide internal direction and guidance to the agency while serving as the basis for consultation with other government entities, public interests, and private enterprise (Crowe 1983:2). An IM feasibility assessment (Appendix H) clarifies variables associated with the potential to achieve ungulate population and harvest objectives. For projects with an active IM program, habitat planning may have already been addressed in an IM feasibility assessment or IM operational plan.

## Partnerships in Planning and Funding

Enhancing moose habitat at the stand scale can be as simple as leveraging habitat funds with entities that conduct postlogging site treatments or create hazardous fuel breaks. Assisting with the cost of scarification, crushing, roller chopping, or shearing can aid woody regeneration for different needs. Scarification helps landowners meet reforestation requirements (Appendix A), especially on moist sites with grass potential, and provides tree planting sites where natural generation may be insufficient but otherwise not affordable based on stumpage revenue.

Enhancing habitat at the landscape scale of moose populations identified for IM in Game Management Units (GMU) may be thousands of square miles. This often requires collaboration among multiple agencies, landowners, and organizations. Partnerships may combine funding and in-kind services. Investing state funds for habitat enhancement on private lands requires mutual understanding of expected benefits to the wildlife population (e.g., seasonal habitat use) and a mutual understanding that wildlife is a public-trust resource. Officers or supervisors in collaborating entities should sign a Memorandum of Understanding to guide field personnel that describes common, complementary, and unique objectives, partner roles, deliverables, time frames, and fiscal responsibilities.

Partnerships enable more habitat enhancement on a landscape scale beneficial to moose populations than any one agency or entity alone by leveraging funding sources and staff capacity. Nonfederal funds or in-kind services (donation of labor or equipment use) matched 1:3 with Federal Aid program grants through the Office of Conservation Investments[10] are the primary source of funding. Projects may be contracted directly by DWC, although work on lands managed by the Alaska Division of Forestry and Fire Protection (DOF&FP) may be done by having funds transferred through a Reimbursable Services Agreement (RSA). Fish and Game Fund monies composed of hunting license fees are a primary source of match. Nongovernment organizations (e.g., wildlife interest groups) may contribute match, although minimum amounts may be required to cover administration. Use of Federal Aid matching funds acknowledges that while not all lands are open to public access, wildlife species are a mobile, public trust resource, and habitat improvements on a site will be realized by wildlife that move through the area. It is appropriate to review this concept in each new project funded through Federal Aid to ensure that any potential new staff can reconcile the intent of the project. Private lands are eligible to receive other matching funds for wildlife habitat management through the Environmental Quality Incentives Program[11] administered by the U.S. Department of Agriculture (USDA), National Resource Conservation Service (NRCS). Alaska Native lands may occur within tribal conservation districts[12] that could serve as the partner for incentive programs. Regardless of funding sources, DWC administrative staff should review potential funding mixes and contracting options to ensure proper matching, recovery of overhead, and spending authority before planning advances to a detailed stage. Third party matches require an agreement with ADF&G to ensure that reporting requirements set by Federal Aid are complied with by the organization.

Land management activities require verifying legal ownership of affected lands during the planning process. Additionally, prescribed burns require compliance with protecting agency[13] policy and contingency planning for the respective fire management options and designations on

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[10] From an excise tax on sporting arms and ammunition through the Pittman-Roberston Act, administered by the U.S. Fish and Wildlife Service; prior to March 2024, it was known as the Federal Aid in Wildlife and Sport Fish Restoration (WSFR) program.
[11] https://www.nrcs.usda.gov/wps/portal/nrcs/ak/programs/financial/eqip/ (accessed 29 June 2021).
[12] Consult the nearest USDA Natural Resources Conservation Service (NRCS) office for information.
[13] Map of wildland fire protection areas:
https://fire.ak.blm.gov/content/maps/aicc/Large%20Maps/Alaska_Fire_Management_Zones.pdf

surrounding lands in the event of a prescribed fire spreading beyond the intended boundary (project area). Prescribed fire plans must be signed by all public landowners or managers and the participating agencies, including the protecting agency with jurisdiction for fire suppression. The challenge of increasing partnership complexity is finding mutual agreement on objectives and acceptable techniques or outcomes (e.g., smoke tolerance, even in distant urban areas). As legal scrutiny increases due to liability concerns, fixed costs of salary in planning small burns near communities or larger burns (encompassing complex ownership) are likely to increase, raising the fixed costs of implementing a burn.

To the extent possible, identifying the degree of risk for potential of an unintended outcome and its consequence for wildlife (minimal to substantial) is important for mutual understanding of expectations among partners and the interested public. This is particularly important if novel approaches are being applied and outcomes are uncertain. Beyond the cost efficiency of the financial commitment, there should be recognition of tradeoffs among other desired outcomes. DWC may engage in projects that are less than optimal for wildlife habitat to build constructive partnerships, gain financial leverage, and achieve complementary goals, such as hazardous fuels reduction near communities. Modest-sized proof of concept or research projects done in concert with scientists and managers knowledgeable of the situation may be advisable for identifying degree of risk before larger projects using novel approaches are considered. This type of cautious but deliberate experimentation is prudent in considering management options for achieving community resilience in a changing environment (Chapin III et al. 2009, Schuurman et al. 2022).

Where partnerships are anticipated, regardless of who initiates it, the DWC role in scoping is to define project parameters sufficiently to clarify partner roles and responsibilities (i.e., land, labor, or in-kind services; financial contribution; acceptance of risk) in a draft Memorandum of Understanding. Once a conceptual agreement with partners has been assured, DWC could invest staff time in pursuing Federal Aid matching grants or other sources of funding, then proceeding with planning steps for the project (Appendix B).

# 2. Implementation

Successful and efficient implementation requires understanding of silvicultural techniques (Appendix F) and prescribed fire operations (Appendix I). Treatment details should be succinctly stated in an operational plan. Public acceptance of methods and strategy should be addressed in the planning phase to avoid conflicts that hinder or preclude implementation. In the case of prescribed fire, much of the contents of the operational plan will be components of the burn plan (see Appendix I).

## Mechanical Treatments

Mechanical treatments can be directly contracted by DWC staff;[14] through an RSA with DOF&FP; a cooperative agreement with federal agencies; or a private or nonprofit entity. In this document, “mechanical” refers to treatments other than timber harvest, including but not limited to felling without salvage, crushing, shear blading, roller chopping, mastication, or hydro (rotary)

[14] Contract templates are located on ADF&G’s internal SharePoint site under Wildlife Conservation | DWC Libraries | Moose Habitat Enhancement.

axing. Mastication has not been common for habitat treatments in Alaska because there is a greater cost per area treated, and a perceived risk of nitrogen binding by decomposing organisms which occurs when high volumes of small woody material are left on top of the soil or mixed into the soil. Elevation of the C-to-N ratio (Stewart 2012, Overby and Gottfried 2017) could inhibit growth of hardwoods and other early seral plants that are preferred as moose forage in boreal forest. However, a review of mastication in drier, temperate forest did not find this to be a problem (Busse et al. 2014:86–87). Treatment objectives and specifications are important in this process, and examples in Alaska exist where masticated fuel breaks have returned productive moose forage with delayed regeneration of hardwood trees and willow after scarification was added to the treatment. The Sterling Fuel Break initiated in 2016 is an example where low-snow conditions in November and December allowed the small-scale masticating equipment to scarify the woody debris from the soil surface during the operation. Barren spots were created where plants could establish seedlings or regenerate from residual root material. Willow and other shrubs regenerated on this site providing plentiful moose forage. The timing of treatment relative to snow depth directly affects the density of bluejoint reedgrass (*Calamagrostis* spp.) in the following seasons. When densely established, this grass strongly competes with shrub and tree regeneration on moist sites after disturbance (Collins 1996, Collins and Schwartz 1998) and was not able to be reduced once reestablished on disturbed moist sites, even after experimental overgrazing by domestic livestock (Collins 2001, Collins et al. 2001).

At a minimum, performance evaluation of enhancement activities at project completion ensures contract specifications have been achieved satisfactorily to authorize payment for services. It is advisable to meet on the job site with contractors prior to implementation to reiterate objectives and intended outcomes stipulated in the contract. Periodic visits to verify performance throughout treatments will ensure timely corrective actions for compliance. Training new contractors at the start of a project is crucial; visits to past satisfactory treatments may be helpful if practical and may be stipulated in the contract. Images of equipment in action, sheared stumps, or other desired outcomes can be useful information in future bid packages (Requests For Quotation) and for training new contractors. Where available, provide guidance on treatment rates (e.g., cost per acre) based on past experience for equipment type and working conditions (tree size, snow depth, temperature, etc.) in the Request for Quotations so inexperienced operators have an informed expectation of performance efficiency. Ensure that the bidding contractors have visited the site to understand access and topography.

Performance standards in commercial timber sales implemented on state, municipal, and private lands are specified and administered by DOF&FP (Appendix A). Silvicultural prescriptions include the size and species of tree to be harvested, spacing and size of remaining trees not harvested, disposition of slash, and the reforestation practices desired to achieve a specified stocking density by natural means (seed fall, sprouting) or artificial methods (seeding, planting, site preparation). Input regarding wildlife habitat in timber sales occurs indirectly through a variety of directives (Appendix A). Guidelines have been provided to operators in the Interior by DOF&FP for training operators of logging equipment (Paragi and Rodman 2020). These specify how to enhance hardwood regeneration and retain desired late-seral features for habitat of other species.

## PRESCRIBED FIRE

Prescribed fire requires comprehensive planning between ADF&G and an agency partner with authority to implement a burn (Appendix I). The National Wildfire Coordinating Group (NWCG) is a consortium of land and fire managers that set goals and standards for wildland fire management. The "burn plan," or "prescribed fire plan" describes the purpose, location, resource goals, fire objectives, operational procedures, safety, and other elements that must be addressed before, during, and after the operation. The template is based on the NWCG Standards for Prescribed Fire Planning and Implementation (National Wildfire Coordinating Group 2023; search for PMS 484). This federal standard is also adopted by state agencies, including Alaska. Within the burn plan, the Prescribed Fire Complexity Worksheet and accompanying Fire Complexity Rating System Guide (National Wildfire Coordinating Group 2023; search for PMS 424-1 and 424, respectively) provides "a focused, subjective assessment by qualified prescribed fire burn bosses that is evaluated and approved by Agency Administrators to provide insight and improve understanding of the significant risks associated with prescribed fire." The Complexity Worksheet defines each element of the burn plan and associates the risk to values with technical difficulty, which then allows for a rating of high, moderate, or low that corresponds to the resources required to implement the project. Other elements of the burn plan include smoke management, a contingency plan for fire escape beyond the intended boundary, safety procedures, and when to declare a wildfire. With respect to operational planning, this comprehensive burn plan fulfills many of the same requirements in a separate and distinct format. However, a DWC operational plan is critical for describing the resource objectives and justification for a habitat enhancement project.

A fire behavior analyst conducts the necessary research and analysis to determine the appropriate Fire Weather Indices along with a range of weather conditions in which the fire is expected to burn while achieving the objectives of the burn plan. The basis for these analyses lies in the Canadian Forest Fire Danger Rating System as applied to Alaska[15] (that is supported by Natural Resources Canada[16] and endorsed for use in the United States by the NWCG (National Wildfire Coordinating Group 2023; search for PMS 437). Application of this system to Alaska is an accepted practice across suppression agencies in the state considering the decades of research and field reconciliation of the system (Wolken 2014, Ziel 2014).

A technical review and subsequent authorization of the plan allows for the local authority to implement the burn with consideration for the statewide and sometimes national fire situation assessment (e.g., whether resources may need to be deployed elsewhere on short notice based on active fires and forecasted fire weather). The authorization is an agreement by the land managers that the plan meets the respective agency requirements for implementation.

Preparation and execution of a burn plan is a joint effort with DWC and typically DOF&FP and may also include the U.S. Bureau of Land Management (BLM) Alaska Fire Service, U.S. Forest Service, or others. To adequately define roles and responsibilities for each agency partner and specific personnel in preparing the burn plan and its many components, along with outreach and communications to stakeholders and the public, the team must be committed to the objective and

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[15] https://www.frames.gov/afsc/projects/cffdrs-in-alaska (accessed 29 April 2024).
[16] https://cwfis.cfs.nrcan.gc.ca/background/summary/fdr (accessed 29 April 2024)

have a timeline. ADF&G is expected to facilitate this process and gain assurance from partnering agency staff that they have time and capacity to fulfill the project needs during this phase. A Memorandum of Understanding or cooperative agreement may be needed in some cases.

Two general scenarios, each with nuances, exist for application of fire to benefit habitat. A low-severity fire, when fine fuels (leaves and twigs) first become dry after snow melt, is suitable to 1) stimulate fresh grass growth of native species for bison forage in selected field environments (such as the Delta Junction Bison Range), and 2) rejuvenate willows and hardwoods by scorching the bole, and saving the root crown or root network, respectively. A high severity fire can achieve stand conversion from coniferous to deciduous cover type in mature forests. This typically requires fuel drying by early-to-mid summer so duff layer consumption can occur. These conditions occur during seasonal weather conducive to lightning ignitions. Partnerships among agencies are critical for prescribed fire during drier conditions when competition for fire suppression resources will likely take priority over prescribed burns.

Broad guidance on use of prescribed fire comes from the ADF&G Fire Management Policy (Lloyd 2009:3):

1. Use prescribed burning to either augment or replace wildland fire where property protection and safety needs preclude wildland fire.
2. Support continued development of dedicated, funded state and federal prescribed burn programs comprised of well-trained and equipped fire professionals largely independent of the wildland fire program.

ADF&G supports the National Cohesive Wildland Fire Management Strategy in its strategic approach toward resilient landscapes, fire-adapted communities, and safe and effective wildfire response (U.S. Department of Interior and U.S. Department of Agriculture 2014). In the interest of protecting Alaskans while maintaining fire's ecological role on the landscape, this approach complements the objectives of protecting communities and infrastructure while allowing for wildlife habitat benefits that may increase game harvest.

A future vision for habitat enhancement projects using prescribed fire includes a dedicated prescribed fire module for burning forested fuels in Alaska. An interim solution may be to contract trained wildland fire modules from the western U.S. to ensure that the skills and resources are available. This applies to both ground-based operations for localized projects and landscape-scale burns using aerial ignition. The contracting cost could be substantially greater than using Alaska resources, with the funding decision based on urgency in completing the project. The process used in recent years includes involvement from DOF&FP and BLM to identify local burn bosses, coordinate across agencies to complete the burn plan, and select a lead agency to implement the project. The challenge with using in-state resources is their commitment to wildland fire response which may conflict with the prescribed fire implementation.

There are many tasks associated with preparing and implementing a prescribed burn, starting with the burn plan[17]. Appendix I describes this process and its associated timelines for planning purposes.

## 3. Evaluation

IM is predicated on assumed cause-effect relationships where habitat enhancement and predator control produce an increase in ungulate abundance, which is an increased harvestable surplus at an assumed yield rate (e.g., IM harvest objective/IM population objective). Relationships of ungulate abundance and sustainable harvest are established in part by case studies of management "experiments" (e.g., Gasaway et al. 1983, 1992; NRC 1997). A robust evaluation of habitat enhancement intended for remediation of low moose abundance requires the design of monitoring to 1) specify the desired outputs and thus magnitude of expected change; 2) be properly scaled to the treatment area and time frame; and 3) such that confounding factors and responses to treatment can be confirmed as causation rather than correlation. To best evaluate treatment outcomes, "policy-thinking is and must be causality-thinking" (Tufte 1997:6).

Evaluation begins with clear definition of the current conditions and the project's objectives: desired outputs, area affected, and time frame. Stakeholder agreement on evaluation criteria is particularly important where projects may be controversial, or interest groups might be inclined to criticize methodology or otherwise discredit findings unfavorable to their values. Achievement of IM objectives depends not only on ecosystem dynamics but on hunting system dynamics under the purview of the Board of Game which are subject to change after treatments are implemented: seasons, bag limits, methods and means, and allocation of access and harvest. Location of hunts, mode of transportation, hunting regulations, use of commercial services, year, road density, hunter-to-moose ratio, moose density, and residency of hunters are all important predictors of moose harvest success in Alaska (Schmidt et al. 2005). Details of evaluation will be unique to individual project objectives based on biological and management factors (Appendix E) and experimental design considerations (Appendix J).

### POLICY BASIS FOR ESTIMATING "BENEFITS"

Public trust resources such as wildlife are managed by trustees with decision authority to allocate public uses and expenditures of public funds for conservation based on scientific information and other factors (Smith 2011). Documenting outputs and outcomes of management actions is a key scientific role for agency staff (Crowe 1983). Agency staff are the trust managers that commonly evaluate biological responses of wildlife populations to management actions (Smith 2011) or the achievement of program outputs (e.g., game harvest, success in viewing) to characterize efficacy in uses of funding and professional services. DWC can contract with neutral third parties such as universities to evaluate outcomes (e.g., degree of public satisfaction; Birkland 2005) or a "return on investment" (Van Lanen 2017). Working with stakeholders to define desired outcomes can guide fiscal allocation by the legislature and ADF&G, and inform regulatory deliberations on game harvest allocation or IM objectives by the Alaska Board of Game. These actions and

[17] Burn plan templates are found on ADF&G's internal SharePoint site under Wildlife Conservation | DWC Libraries | Moose Habitat Enhancement.

processes are how wildlife management policies are implemented in the public interest (Harrison 2021:131–134).

The goal of IM is to enhance or maintain ungulate harvest, although increased viewing from highways and range expansion into the Yukon Territory were also stated goals of reducing predation for the Fortymile caribou herd (Fortymile Caribou Herd Planning Team 1995). Thus, evaluation of IM should focus on fundamental objectives (harvest success or viewing opportunity) rather than intermediate or enabling objectives of earlier steps in the management system, such as forage enhancement or increased prey abundance (Bailey 1982, Crowe 1983, MacNab 1983, Riley et al. 2003). Habitat enhancement may increase forage biomass, but if predation is limiting abundance, there may not be a numeric response by moose, or a net increase in forage offtake (a possible response metric). However, a functional response of local moose being attracted to increased forage could allow harvest to increase within the sustainable limit. Quantifying the ultimate response (harvest or viewing) in the context of cost to produce them will allow the public and trustees of the wildlife resources (elected and appointed officials; Smith 2011) to evaluate project outcomes in the context of policy intent, particularly if relevant facts are used in surveys of public opinion on degree of satisfaction. Clarifying satisfaction metrics through public surveys before implementing a project creates a strong evaluation design for public policy outcomes.

Cost-benefit analysis is a tool of policy implementation and analysis (Birkland 2005) where the definition of "benefit" often extends from tangible outputs to intangible outcomes. Cost evaluation for habitat enhancement requires defining the duration of expected habitat benefits (e.g., 30 years for moose browse enhancement) for amortizing 1) planning and implementation costs, and 2) total output over the evaluation period. Using the framework of Riley et al. (2003), output could be forage produced or moose abundance (enabling objectives), but an evaluation based on harvest (a fundamental objective) would more directly address the intent of IM for elevated yield. Beyond achievement of the IM objective, harvest could be represented in standardized measures, such as success rate (reported harvest/number of license holders who reported hunting), which incorporates environmental, economic, and social factors that can affect participation and effort. Another metric of system efficiency in producing outputs might be harvest divided by harvestable surplus (that which could be taken on a sustained yield basis).

Van Lanen (2017) documents an example of calculating the return on energy investment for game harvest. The marginal cost is how much additional money is required to produce a tangible unit of output (e.g., harvested moose) above what is already being produced. There are system inefficiencies, monitoring challenges, and social constraints to estimating marginal cost in game harvest from free ranging species across public and private lands. Where IM is intended or perceived as a food production system, we encourage managers to engage economists and social scientists to estimate return on investment for policy analysis.

## Degree of Evaluation Emphasis among Vegetation, Moose, and Harvest

Vegetation management on the landscape is relatively precise and predictable, especially with mechanical treatments, when compared with population dynamics of free-ranging wildlife or factors affecting hunter access and harvest success. Management-induced changes in forage biomass and cover can benefit prey over many years. In contrast, wildlife vital rates and sustainable harvest opportunity vary in the short term due to predation and environmental variation (e.g., severe winters; Gasaway et al. 1983). In the long term, reducing predation sufficiently to improve prey vital rates may require periodic follow-up treatments. In Alaska predator control programs, wolves and bears have increased in abundance to pretreatment levels within a few years of treatment (NRC 1997:52–53, Keech et al. 2014). Harvest success can also vary in the short term based on annual weather (animal movements, hunter travel conditions on water or ice) and changes to hunter access in land management policies. As a moose population begins to increase, harvest can be elevated sufficiently to prevent population growth to where per capita nutritional condition (thus productivity) is reduced (Boertje et al. 2009, Young and Boertje 2011) because of greater intraspecific competition for browse (Paragi et al. 2015). The management strategy of increasing moose harvest in lieu of population growth is an important component of maintaining an elevated yield from a relatively stable habitat base (McCullough 1979). Improvements in productivity from habitat enhancement can be translated into further harvest increases without an increase in prey density (or a decline in productivity) if harvest of females and young are acceptable, as in the high-yield systems of Fennoscandia (Lavsund et al. 2003).

With limited agency resources, the degree of evaluation effort (staff salary and operational cost) should be optimally allocated among vegetation, moose abundance and distribution, and moose harvest. If the ultimate output (harvest or viewing) is not enhanced to the degree desired, it will be important to understand at which step(s) the process failed. For example, biological response of vegetation and wildlife may not lead to increased harvest if hunter access to wildlife is hindered by physical obstruction (e.g., deadfall in burns) or seasonal constraints on modes of travel (Brinkman et al. 2013). Presently, the degree of hunter access in Alaska is strongly tied to motorized access, with use of all-terrain vehicles (ATVs) having increased relative to other methods of transportation in moose hunting since the 1980s. Where ATV use for hunting is common in forested areas, moose may have begun selecting for cover that reduces visual detection by hunters (Brown et al. 2018).

In general, greater emphasis should be considered for moose abundance response and harvest (the ultimate ends that justify the habitat enhancement) than vegetation responses to habitat treatments. Applied research on efficacy of mechanical treatments and fire to enhance browse species as cover and forage has occurred in Southcentral Alaska (Oldemeyer and Regelin 1987, Collins 1996, Collins and Schwartz 1998, Stephenson et al. 1998) and Interior Alaska (Nellemann 1990, Paragi and Haggstrom 2005, 2007). Given these research findings, vegetative response on management projects should be evaluated as inexpensively as possible simply to verify treatment efficacy in meeting objectives for forage or cover, with research reserved for testing novel approaches (Appendix J). Inexpensive metrics aid resampling at later periods of vegetative succession to distinguish transient effects soon after disturbance from long-term effects and localized versus large-scale effects (Walters and Holling 1990).

Staff involvement depends on the scope of evaluation. Vegetative responses are typically done by regional research or statewide program staff, whereas wildlife responses and harvest evaluations are more commonly done by area managers through survey and inventory activities. Monitoring of vegetation, moose, and moose harvest among multiple areas for adaptive management (Lee 1999, Allen and Gunderson 2011) might best be coordinated by a researcher or regional biologist. Establishing cause-effect relationships through strength of experimental evidence in hypothesis testing (Romesburg 1981) is typically the realm of research because it involves study design and substantially more biometric support than survey & inventory (S&I)[18] projects. Design of a monitoring framework is beyond the scope of this document, but a review of considerations in sampling and study design (Appendix J) is strongly advised before committing time and funding to field work when evaluating habitat projects.

Where wildlife viewing is a formal goal, the analysis is more complicated than with harvest because multiple people can achieve viewing success (sighting of the desired species) without hindering one another. However, there is also a limit to viewing whereby too many people might displace the desired species and reduce opportunity for further sightings. Like for harvest, public access to participate in a wildlife viewing can affect success.

[18] Periodic reports and plans: https://www.adfg.alaska.gov/index.cfm?adfg=librarypublications.wildlifepublications&sort=all&species=Moose&publicationtype=Species+Management+Report+%28and+Plan%29&submit=Search

**Appendix A. Legal authority, requirements, and policy guidance for management and enhancement of wildlife habitat on state, municipal, and private lands in Alaska.**

DWC is the manager of public trust resources involving wildlife (Alaska Statute 16.05, Smith 2011). The Alaska Constitution (Article VIII, Section 4) provides the highest level of policy guidance on habitat management: "Fish, forests, wildlife, grasslands, and all other replenishable resources belonging to the State shall be utilized, developed, and maintained on the sustained yield principle, subject to preferences among beneficial uses." Soon after statehood ADF&G chose, in many circumstances, to influence administration of lands for wildlife habitat through participation in joint management with local, state, and federal agencies instead of assuming the cost of land purchase and recurring costs of administration, except for select refuges and critical habitat areas (Weeden 1973:11–12). Following the statement of an Alaska game management policy (Alaska Department of Fish and Game 1973), step-down management plans were drafted for the regions of the state, each with verbatim sections explaining natural features of wildlife habitat and the role of habitat manipulation or protection (e.g., Alaska Department of Fish and Game 1976:16–17).

Passage of the intensive management (IM) law in 1994 created an imperative for DWC to consider quantity and quality of habitat (implicitly forage) for caribou, deer, and moose. "'Intensive management' means management of an identified big game prey population consistent with sustained yield through active management measures to enhance, extend, and develop the population to maintain high levels or provide for higher levels of human harvest, including control of predation and prescribed or planned use of fire and other habitat improvement techniques" (AS 16.05.255(k)(4)). Habitat is among the factors considered (5 AAC 92.106(2C)) when making recommendations for IM population and harvest objectives (5 AAC 92.108) and assessing feasibility of proposed IM programs (AS 16.05.255(e)(3); Alaska Department of Fish and Game 2011).

The only habitat guidelines specific to moose on state lands are in the Matanuska Valley Moose Range Management Plan (Alaska Department of Natural Resources, and Alaska Department of Fish and Game 1986:148) for the "maximum amount of suitable acres of land into browse-producing habitat and to apply the knowledge learned in the southwest corner of the subunit to other areas in the Range." On state forest lands, AS 41.17.400(e) describes the intent of IM without clarifying which wildlife species: "The wildlife management objective of the Tanana Valley State Forest is the production of wildlife for a high level of sustained yield for human use through habitat improvement techniques to the extent consistent with the primary purpose of a state forest." However, goals for fish and wildlife habitat in the management plan for the Tanana Valley State Forest (Alaska Department of Natural Resources [ADNR] 2001:14) are less specific: "provide for the diverse needs of fish and wildlife resources" and to maintain "the natural range of species and habitat diversity."

Implementation of projects must conform to laws and regulations and consider policies of the landowners or managers. Land ownership and agency affiliation with each project will also determine the extent to which various regulations apply. Where federal lands are included in a project plan, an Environmental Assessment or Environmental Impact Statement may be required per the National Environmental Protection Agency pending the current applicable management plan and categorical exclusions available per the treatment designated. Prescribed fire plans must be compliant with NWCG and state requirements including the Alaska Interagency Wildland Fire Management Plan (Alaska Wildlife Fire Coordinating Group 2022; Appendix I); approvals must include land managers. Other permits may be required such as an Alaska Department of Environmental Conservation (ADEC) open-burn permit, ADNR land-use permit, eagle- and eagle-nest-take permit (if eagles are present), and land-use permits where private land is included. Additionally, cultural resources must be addressed through the State Office of History and Archaeology (ADNR State Historic Preservation Office). Consideration for the Migratory Bird Treaty Act applies to treatments occurring during nesting season[19]. When projects are funded by Federal Aid match, other permits and consultations may also apply; reviewing the project with the Federal Aid office will help staff navigate this process.

Mechanical treatments intended to regenerate woody vegetation are generally allowed as silvicultural practices. Guidance on ensuring treatments do not adversely affect other resources can be found in the Alaska Forest Resources and Practices Act (FRPA; AS 41.17.010–41.17.955). FRPA governs how timber harvesting, reforestation, and timber access occur on state, private, and municipal lands. This applies to commercial timber sales >40 acres in Interior and Southcentral Alaska, and land ownerships >160 acres in Interior Alaska (11 AAC 95.190). Article 4 of the Alaska Lands Act (AS 38.05.110 to.123) provides considerable direction on the harvest of state timber. FRPA primarily focuses on fish habitat and water quality; its relationship to wildlife habitat is discussed in Paragi et al. (2020).

FRPA considers 3 categories of lands, each with its own level of standards:

- State lands managed by ADNR (most restrictive standards);
- other public lands (state land managed by state agencies other than ADNR, land owned by a municipality, and land owned by the University of Alaska (midrange standards); and
- private lands, including Alaska Native corporations, Native allotments, and Alaska Mental Health Trust (least restrictive standards).

Federal land is not directly addressed in FRPA, although “the degree of resource protection may not be less than that established by this chapter for state land except that AS 41.17.119 [the standard for other public land] establishes the minimum riparian standard…” (AS 41.17.900(b)(1)). Habitat enhancement for moose can occur on sites classified as wetlands by the U.S. Army Corps of Engineers under a silvicultural exemption to Section 404 of the Clean Water Act (33 U.S. Code 1344), which requires the intent to regenerate forest vegetation.

In addition to fish habitat and water quality, “allowance shall be made for important fish and wildlife habitat” on state and municipal lands (AS 41.17.060(7)). Before harvesting timber, a forest land use plan is developed for ADNR-managed lands, while a detailed plan of operations must be submitted to DOF&FP for commercial timber or firewood sales on all other nonfederal land ownerships. ADNR and ADF&G must work cooperatively with private landowners to identify and protect important wildlife habitat to the extent consistent with landowner goals

[19] Timing recommendations for land disturbance and vegetation clearing: Planning ahead to protect nesting birds [chart]. May 2017. U.S. Fish and Wildlife Service, Region 7. https://dot.alaska.gov/stwddes/desenviron/assets/pdf/resources/vegetation_clearing_2017.pdf Accessed 16 August 2022).

(AS 41.17.910). This distinction between private and public lands in FRPA refers to the due deference extended to ADF&G by ADNR, limited to fish habitat on private lands while including both fish habitat and wildlife habitat on public lands (AS 41.17.098(d)). Specifically, AS 41.17.910(a) directs DOF&FP and DWC to work cooperatively with private landowners to "protect, maintain, and enhance wildlife habitat to the maximum extent practicable, consistent with the interests of the owners in the use of their timber resources." Section 910(b) further requires DWC to "provide educational and technical assistance and extension services…to assist in identifying important wildlife habitat and to assist in designing voluntary management techniques that minimize adverse effects on wildlife habitat." on private lands. For commercial timber harvest on state game refuges and other lands comanaged by ADNR and ADF&G, the ADF&G Division of Habitat must be consulted for procedural guidelines.

Guidance on IM practices related to habitat is contained in Alaska Board of Game policies[20] on conservation and management of bears and wolves, the agency policy on wildland fire management and prescribed fire (Lloyd 2009), and in the Intensive Management Protocol (Alaska Department of Fish and Game 2011). There is no formal policy on mechanical treatments of vegetation, but enhancement projects have been based on researched principles. Haggstrom and Kelleyhouse (1996) reviewed forestry-wildlife relationships in boreal Alaska and described the basis for a policy of habitat management. Their strategy favored early seral forests typical of fire-driven ecosystems that benefit moose where logging can be implemented without detrimental effects on boreal wildlife species that utilize predominately late-seral features (e.g., caribou on lichen-dominated winter range; and birds and mammals that use snags, trees with large cavities, and woody debris). Paragi et al. (2020) reviewed forestry practices and recommended a similar balance of early- and late-seral habitat features at different spatial scales. Recent habitat enhancements in Alaska were partnerships between ADF&G, fire managers, and land managers to create or maintain hazardous fuel breaks in the wildland-community interface.[21] These treatments favor early seral habitat in strategic locations to provide fire suppression agencies with tactical options for protecting resources at risk (homes, timber, etc.). Productive moose habitat on hunter-accessible lands close to communities is a positive externality of fuel breaks that can elevate harvest by attracting local moose, even without an increase in moose density.

[20] http://www.adfg.alaska.gov/index.cfm?adfg=gameboard.findings (Accessed 19 April 2023)
[21] An example partnership is the *2018 Kenai Peninsula All Lands All Hands Action Plan*: https://www.kpb.us/images/KPB/OEM/AHMP/Annexes/Annex_H_All_Lands_All_Hands_Action_Plan.pdf.

**Appendix B. Feasibility assessment template for enhancing moose habitat.**

The questions below assess variables associated with the proposed project to identify costs, timelines, and logistics involved with preparing and implementing a project. Some questions only apply to prescribed fire. This summary can be provided to division leadership for approval, to request funds, and develop a project budget authorization and accompanying Federal Aid match funding[22]. The following template allows a clear outline of funding sources and amounts by fiscal year[23].

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Project Summary** | | | | < Project Name > | | | | |
| Potential to increase moose harvest* | LOW | MODERATE | HIGH | Objective: | | | | |
| Associated game research: | | | | | | | | |
| Timeline summary: | < begin > | < end > | | | | | | |
| Cost per Acre: | | | | | | | | |
| **Action** | **Month-Year** | **Fiscal Year** | **Cost** | **Fund Source** | **Amount** | **Match Source** | **Amount** | **Cooperators** |
| Feasibility Study | | | | | | | | |
| Literature Review | | | | | | | | |
| Field Reconnaissance | | | | | | | | |
| Evaluation & Review | | | | | | | | |
| Stakeholder Outreach | | | | | | | | |
| Public Scoping | | | | | | | | |
| Planning | | | | | | | | |
| Prescribed fire plan | | | | | | | | |
| Mechanical treatment plan | | | | | | | | |
| Pre-treatment monitoring | | | | | | | | |
| Post-treatment monitoring | | | | | | | | |
| NEPA, if applicable | | | | | | | | |
| Cultural Resource Review | | | | | | | | |
| USFWS Eagle/Nest Take Permit | | | | | | | | |
| DNR Permit | | | | | | | | |
| DEC Open Burn Permit | | | | | | | | |
| Outreach & Communication | | | | | | | | |
| Implementation | | | | | | | | |
| Mobilization | | | | | | | | |
| Treatment | | | | | | | | |
| Demobilization | | | | | | | | |
| Air Quality Monitoring | | | | | | | | |
| Post Treatment Follow-Up | | | | | | | | |
| Outreach | | | | | | | | |
| Reporting | | | | | | | | |
| Division of Wildlife Conservation Recommendation | | | | | | | | |
| Decision to Implement | Yes | No | | Decision date | | MM/DD/YYYY | | |
| Approving Authority | < Name, Position > | | | | | | | |
| Conditions | < details in attachment > | | | | | | | |

*Overall response refers to habitat enhancement treatment: If habitat enhancement occurs simultaneously with predator control, the evaluation design should try to separate the effects.

[22] Formerly called Wildlife and Sportfish Restoration; as of March 2024, the Office of Conservation Investment.
[23] Cost source templates are found on ADF&G's internal SharePoint site under Wildlife Conservation | DWC Libraries | Habitat Management Guidelines.

The following questions allow staff to gauge the potential to achieve objectives and clarify expectations on project scope, potential treatments, stakeholders or partners, and evaluation.

Project Description

1. Define project scope and need.
    a. Describe the objective for context of why an increase in moose observed or harvested is desired by the department. Specify the size of treatment (acres), plant communities or species conversion, and duration of enhanced status after treatment.
    b. Describe a project boundary and area of treated sites. For example, mechanical treatments might be 6 polygons of 30 to 70 acres within a 1,000-acre project. Alternatively, a prescribed burn may be designated in 4 burn units of 10,000 acres each within a project area of 100,000 acres.
    c. Specify land ownership boundaries within and adjacent to the project area. Include agency and private landowner names with acreages. Provide a map to show the relationship of the project area, treatment units, and ownership boundaries.
    d. State whether the proposed project is part of an IM program authorizing predator control.[24] If not, clarify the goal as attracting local or migratory moose to the treatment site sufficiently increase harvest without requiring predator control for a numeric response, or of treating a large enough area for a moose numeric response.
    e. Describe status of moose nutrition or evidence of forage-limitation in the proposed area (e.g., low calf weight, low twinning rate, high forage offtake).
    f. Identify other goals or desired outcomes of habitat enhancement, particularly as defined by stakeholders. Besides improved harvest, this might include improved moose viewing or an experiment to reduce vehicle collision risk.
    g. Attach scaled map(s) of topography and vegetation cover types or recent satellite imagery with these attributes overlaid:
        - Ecological and disturbance context of surrounding area (fire history, logging sites, agriculture, beetle kill of spruce, etc.)
        - Development context of surrounding area (roads, trails, and rivers for access; communities; dominant ownership, etc.)
2. Describe proposed treatment and management constraints.
    a. Proposed method for vegetation treatment (mechanical or prescribed fire); consider vegetation type, topography, and desired treatment outcome.
    b. Define the intention of the vegetation treatment. It might be primarily for habitat enhancement where existing vegetation is manipulated to stimulate regeneration or convert to a distinct plant community for the benefit of moose forage. It might

[24] A feasibility assessment for intensive management will be useful to review (Alaska Department of Fish and Game 2011).

secondarily be habitat enhancement in a hazardous fuel break that increases comfort of local residents to allow wildland fire beyond the wildland-community interface.

   c. Identify biological constraints, implementation factors, or potential for unintended vegetation or moose responses (e.g., condition or age of aspen may not yield vigorous regeneration after cutting, topography and slope may limit application of mechanical equipment, spread of nonnative species, heavy browsing of small treatment patches, concentrated moose use that may result in human conflicts).
   d. Identify potential financial or social constraints to implementation (e.g., smoke sensitivity by local residents, fear of fire spread, lack of fiber market, ownership pattern).
   e. Specify criteria and thresholds for advancing or stopping this project (e.g., financial, regulatory, feasibility, other).

3. Define stakeholder concerns and partnerships.
   a. If the project is not concurrent with predation control, do stakeholders recognize the limited potential to increase moose harvest given the scale of the project and other constraints?
   b. Is the proposed treatment site within a Community Wildfire Protection Plan (CWPP)? Can the treatment objectives be paired with the CWPP through the lead agency for that plan? If there is not a CWPP and the proposed treatment is prescribed fire, identify resources to be protected from wildland fire (homes, timber, caribou lichen range, etc.). Does resource protection require additional treatments (fuel breaks, etc.)? What are the estimated costs?
   c. What is the potential for the treatment to cause an increase in the risk of vehicle collision with moose attracted to the site? Will crowding of hunters increase substantially with increased hunting opportunity (more moose) or access?
   d. Is there an opportunity to enhance ground or water access to this site as part of this project through coordination with the Hunter Access Development Program?[25]
   e. If the project is coordinated with private landowners, describe how the public will still achieve wildlife benefits directly (through access) or indirectly (through animal movements onto public lands). Are seasonal movements of moose well known?
   f. Describe project partners and define roles, responsibilities, and contributions to implementation, evaluation, and time frame. Propose partners to implement project and evaluate results (specify roles for implementation and evaluation, general terms of cooperative agreement, cost share, and time frame[26]).
   g. Identify hunting, harvesting, or viewing concerns (e.g., inadequate public access, crowding during hunting season, or viewing opportunities constrained by conflicting activities).

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[25] https://www.adfg.alaska.gov/index.cfm?adfg=access.fh_access

[26] These factors are the basis for a signed Memorandum of Understanding among partners.

h. Develop an outreach plan for stakeholders and local communities regarding how the treatment may cause an increase in moose and hunters in the area and what options exist for mitigating high densities of moose or hunter crowding. To gauge potential number of additional hunters, divide the IM harvest objective by the proportion of successful hunters in the proposed treatment area in recent years, and then subtract the current average number.

4. Describe strategies for evaluating moose abundance response and harvest.

   a. Monitor habitat selection (relative abundance) for treatment area if numeric response is not anticipated.

   b. Assess moose population change. Is the project area is large enough to monitor with Geospatial Population Estimator (GSPE) cells or a census approach?

   c. Develop a harvest assessment strategy to better correlate the treatment with harvest. Consider alignment of UCU boundaries for reporting, hunter contact along access routes for sampling, etc.

   d. Briefly explain the study design (data collection before and after treatments, use of data from nontreated areas, etc.) to account for factors that would confound inference on vegetation treatment causing observed result (e.g., mild winters improving survival, adjacent disturbance displacing moose to treatment area, reduced harvest opportunity or hunter concentrations elsewhere, etc.).

   e. If habitat enhancement is done simultaneously with predator control, describe if and how you will attempt to separate response effects of the two treatments (e.g., moose habitat selection, prey survival, etc.).

**Appendix C. Operational plan template for enhancing moose habitat.**

The feasibility assessment (Appendix B) provides the foundation in developing an operational plan for habitat enhancement. For projects that are advanced to a funding decision, the operational plan clarifies implementation details.

Guidelines for DWC Research Operational Planning[27] may help develop project evaluation protocols. Completing the template below can help ensure that the habitat enhancement approach is ecologically consistent with the resources to be manipulated and the wildlife it supports.

For implementing prescribed fire, the feasibility assessment (Appendix B) will support the economic and ecological requirements to advance the planning process. The prescribed fire plan (Appendix I) will serve as one chapter of the operational plan in combination with supporting text to describe monitoring, outreach, and other details.

Specific elements to address when formulating a habitat enhancement operational plan include:

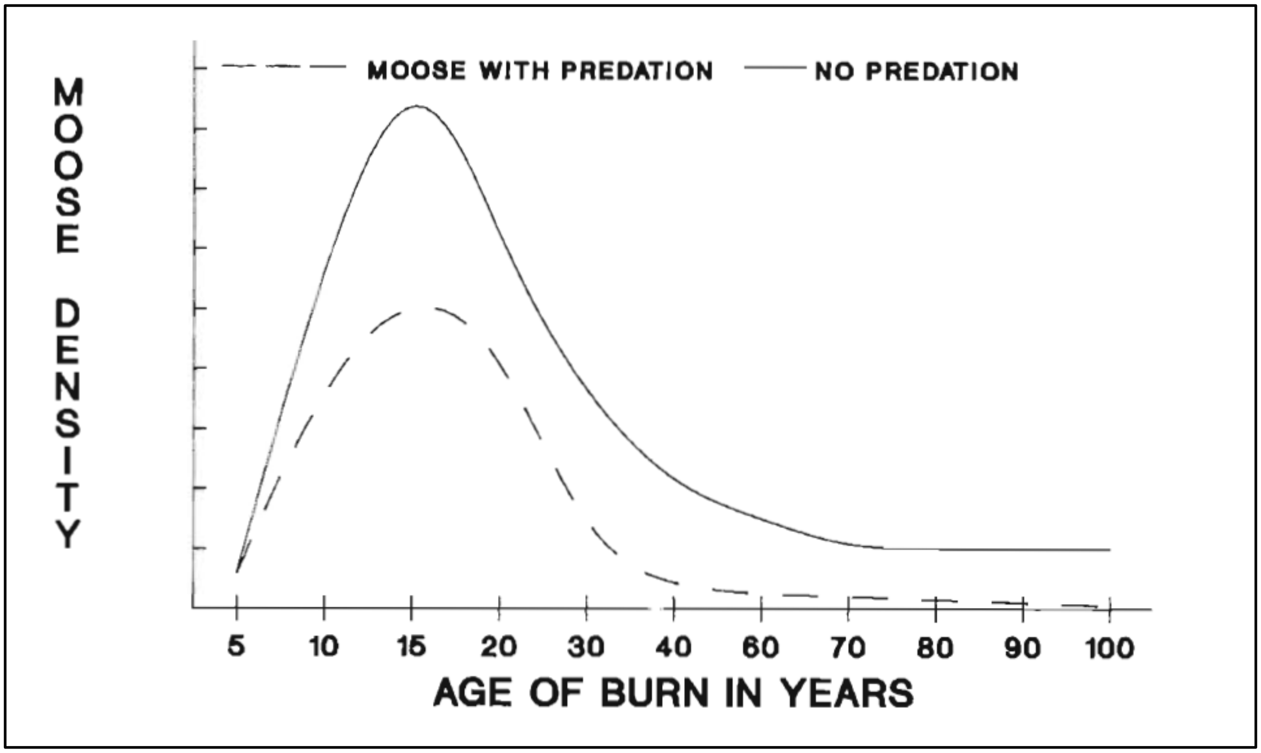
1. The background and objectives should describe the ecological relationships between the vegetation type, treatment, and response expected to benefit moose. Identify specific objectives that are measurable and directly relate to the intended outcomes so that a commensurate evaluation can be done after the project. Ensure that these metrics can be achieved within the timeframe of the project. Describe the project in a way that stakeholders understand the logic and justification for spending funds and agency staff time.
2. Treatment to be implemented should include the most effective method for achieving the stated objectives; cost, scale, and potential outcomes must be balanced with the estimated response of the resource to the treatment. Estimate the timeline and associated activities for each element of the process to include planning, monitoring, partner agency cooperation and agreements, implementation, and post-treatment evaluation. In most cases, treatment will involve some type of partnership for either landowner permission, contracting support, or implementation of silvicultural or prescribed fire treatments. These partnerships must be established prior to requesting funds. In some cases, partnering agencies or entities may be interested in providing financial support or otherwise seeking additional financial support from another program such as NRCS.
3. Identify evaluation criteria and a commensurate study design for monitoring vegetation response, browse utilization, moose abundance, or population attributes (e.g., age-sex ratio, movement patterns), and other variables that may be influenced by habitat quality (e.g., forage quality, moose body condition), and external variables affecting the area (fire history, forest health, and anthropogenic development). Each project will have its own set of metrics that will correlate the treatment to the response of both vegetation and moose.

[27] Research planning information is found on ADF&G's internal SharePoint site under Wildlife Conservation | RCT | RCT Documents | RCT Guiding Documents | Guidelines for DWC Research Operational Planning 18 December 2015 (template elements on pages 6–7).

4. Ensure public involvement for project success by developing an outreach plan and scope of public interest on the proposed strategy. This step takes considerable time and can be done in stages to allow for project modification with respect to public concerns. Regional outreach staff and area biologists will ensure contact with the appropriate stakeholders.
5. Provide for safety and health through public notification and signage of the operation. While many projects are done out of the public's common view, it is still important to provide information on the project, its intent, impacts to the resources, and potential benefits over time. This is even more important when the project is on a roadside or involves prescribed fire that draws considerable attention and carries risk. Use of heavy equipment or fire applications is likely to impact public use of an area, transportation corridors in the vicinity, or health of the residents (e.g., smoke). Road signs and community-based messaging will alert the public to the operation.
6. Design the project evaluation to improve future operational standards. Conducting an 'After Action Review' with colleagues and agency associates may reveal issues, actions, and processes that could result in improved policies and treatment methods. Regardless of the project's success, staff involved in the process will always learn something new about themselves, the organization, or the science that substantiates the work.

**Appendix D. Generalized relationship of moose density and forest succession following a wildland fire in the presence and absence of predators.**

Figure 2 in Schwartz and Franzmann 1989; reprinted with permission from Alces.



## Appendix E. Biological and management considerations for moose habitat enhancement.

This appendix reviews the rationale to focus on forage enhancement, how seasonal habitat use by moose and hunter access should guide selection of enhancement sites, the scale of treatments needed for moose population increase, pros and cons of fire and logging as treatments, and adapting to a changing environment and society.

### Forage Plant Enhancement

A typical objective of moose habitat treatments is to increase biomass of young twigs and leaves on deciduous trees (aspen, birch, poplar) and shrubs (particularly willows) within reach of moose, or its proxy of young stem density. These woody species are amenable to rejuvenation of young nutritious growth by silvicultural techniques (Appendix F) that may include fire management, logging with wood salvage, and mechanical treatments without wood salvage. In winter, moose utilize dormant twigs from the prior growing season (current annual growth) that is typically <10 feet above the ground unless higher browse becomes available when snow bends limbs, moose break stems, or snow drifts are compacted enough to support a moose. Snow can limit browse available to moose through burial or when depth exceeds 28 inches, causing moose to select habitats where energy expenditure is lower (Coady 1974) but potentially suboptimal to fitness.

Winter forage is a static resource of defined quality (e.g., nitrogen content) once new growth is finished in late summer. Winter range is often assumed to be critical to ungulate fitness in highly seasonal environments because it controls the rate of body condition decline until the next forage growing season (Mautz 1978), but the relative importance of summer and winter forages is complex (Stephenson 2003:2). Intake of herbs, graminoids, aquatic plants, and willow leaves during the growing season drives weight gain for moose in summer and fall (Peek et al. 1976, Schwartz et al. 1988). Managing summer and transitional fall and spring ranges to provide abundant forages with high digestible energy could play an important role in moose fitness. However, estimating abundance and nutritional quality (and associated variance) of the wide range of summer forages, which are dynamic in biomass and quality over the growing season, would be a substantial undertaking. The degree to which various summer forages could be enhanced is unknown. By comparison, the quantity and quality of a relatively small number of woody forages preferred by moose in winter is evident by late fall and readily measured in late winter (Seaton 2002). For smaller projects, even simple metrics such as percentage of plants that have a broomed architecture caused by moose browsing over several years can indicate degree of foraging pressure or changes in time (habitat succession) or moose density (Paragi et al. 2015). Unlike surveys to estimate offtake biomass, architecture surveys can be done in any season and can supplement vegetation sampling for other purposes. Managing summer range has consisted of monitoring human activities or natural influences that reduce area of wetland vegetation (e.g., factors leading to wetland draining or drying) and minimizing human-caused reduction of habitat features through permitting of resource development projects.

### Seasonal Habitat Use by Moose and Hunter Access

Moose movement and seasonal habitat use data is useful in defining optimal spatial scale and location for habitat enhancement and informing feasibility of harvest expectations. The attraction of existing moose to areas of enhanced browse within their home range or migration corridor that are also accessible to hunters during hunting seasons (typically in September for bulls) may increase harvest. Manipulating vegetation to create young forage in proximity to older forest that provides security cover at the stand scale ("edge effect") has long been recognized to enhance habitat for herbivore prey (Leopold 1933:135). Relative attractiveness of browse enhancement on a site is partly a function of the surrounding landscape condition, such that creating browse within a matrix of mature forest will likely attract moose more strongly than creating more browse in an already early seral landscape. This "apparent" or perceived increase in moose abundance (e.g., Johnson et al. 2016) is not a numeric response but a behavioral response of habitat selection. Attracting existing moose to sites accessible to hunters may be more successful and cost-effective for moderate increases in harvest than attempting to achieve an increase in abundance over a larger area if large portions of the area are poorly accessible during hunting season (e.g., Brinkman et al. 2013). Caution is warranted with this strategy for populations at low-to-moderate density because improved hunter access alone could increase harvest yield beyond a sustainable level unless other actions are taken to increase abundance of the prey population, such as predation control.

Moose have relatively strong philopatry to seasonal ranges and migration routes, and slower moving, low intensity fires do not appear to displace moose from within an active burn perimeter (e.g., Gasaway and DuBois 1985). Dispersal into new habitats occurs primarily by subadults, even in growing populations, and it may be more prevalent at higher moose densities (Hundertmark 1997). Moose should respond to habitat enhancement more rapidly in areas where they are already abundant (thus per capita food resources relatively limiting) or along migration corridors where density is low, but the number of migratory moose is high. Where moose are at low density (and not food limited), the potential for habitat enhancement to attract moose is low because they do not randomly search for better habitat (Gasaway et al. 1989). However, use of recently burned areas by moose varies widely and is likely related to fire severity and its enhancement effect on browse biomass (Lord and Kielland 2015, Brown et al. 2017), fire intensity, adjacent habitat, and prefire moose density and movement patterns (Gasaway et al. 1989).

Scale of Moose Response to Meet Population and Harvest Objectives

Smaller treatments (single or grouped sites to <1,000 acres [1.6 mi$^2$]) may attract local moose to areas accessible to hunters, which can be a perceived increase that provides more harvest opportunity up to the harvestable surplus at an existing abundance of moose. This phenomenon of individual-level behavioral response includes moose that may spend more time in recent burns (Gasaway et al.1989) or in logging areas where deciduous trees and willows have increased along established migration routes, such as observed in aspen regeneration patches on Nenana Ridge southwest of Fairbanks (Paragi and Haggstrom 2007). Land managers wishing to enhance harvest opportunity for limited numbers of hunters (including those with proprietary access to private lands) or to avoid user conflicts if many hunters were attracted to an area may prefer small-scale attraction of a few moose. This situation should be clear in planning documents so a measurable increase in moose abundance is not anticipated. In these situations, mechanical treatments such as conifer logging with scarification, hardwood logging, willow crushing, and smaller scale prescribed fire can be focused onto optimal sites.

The scale of habitat enhancement required to increase moose abundance to an extent detectable with existing survey methods (Kellie and DeLong 2006) is comparable to the scale of larger wildland fires. Oldemeyer and Regelin (1987:177) proposed that burns or other habitat improvements be at least 5,000 acres (7.8 $mi^2$) with 40% of the area in undisturbed cover to avoid over-browsing of new forages, which is roughly half the scale (13.7 $mi^2$) at which Maier et al. (2005) found moose density related to environmental factors. Collins and Schwartz (1998:360, 362) and Collins (DWC wildlife physiologist, Palmer, personal communication, 2013) considered energetic requirements of moose and nutritional quality of common browse species that can be translated into gross "habitat qualities" that would need to be enhanced to support an additional 100 adult moose in a hypothetical situation:

- 5,000 acres of "excellent" quality browse,
- 25,000 acres (39 $mi^2$) of "good" quality browse,
- 150,000 acres (234 $mi^2$) of "moderate" quality browse.

Given this variability in vegetation type (potential to carry fire) and its patchiness, and other factors beyond control in manipulating wild systems using fire (e.g., resulting fire severity), the department has used 10,000 acres (15.6 $mi^2$) as the expected scale of habitat enhancement necessary to produce a measurable population-level response in moose fitness. This size has been a minimum planning target for landscape-scale prescribed burns. Achieving these scales of treatment with prescribed fire is a challenge, particularly close to communities where high moose density may cause conflicts. This challenge highlights the prudence of considering short-term, elevated harvest to reduce moose density (Young and Boertje 2011) in concert with attempts at landscape-scale habitat enhancement for populations showing strong nutritional constraints. Density reduction is a more definitive treatment and has demonstrated effects in reducing forage offtake (Paragi et al. 2015), which would reduce browsing pressure on young plants that may result from habitat treatments.

In boreal vegetation communities, prescribed burns with scale potential to increase moose abundance (>10 $mi^2$) are likely to include suboptimal community types dominated by spruce. Thus, expectations of post-fire browse "quality" at the landscape scale should be tempered by the tradeoffs of where large burns are acceptable to stakeholders, adequate fuels to carry the fire under the intended prescription, and initial distribution of browse species likely to increase after fire. In spruce forests, a prescription for relatively high fire severity is needed to consume duff and organic soil, thus exposing the mineral soil that is conducive to seed germination and establishment of young deciduous trees and shrubs favored as moose forage (Lord and Kielland 2015). Large, prescribed fires could result in an improvement to "good" quality habitat, but results of "moderate" quality are more likely as a larger fire that spreads into different vegetative communities and burns at varying severity, including patchiness of unburned areas.

The temporal scale of habitat outcomes is decades, substantially longer than the dynamics of predator-prey or hunting-regulation cycles and approaching the career length of a biologist. This highlights the importance of conducting a feasibility assessment, documenting treatment details, and archiving pretreatment and early-response information to permit project evaluation on a temporal scale more typical of forest management (decades) than wildlife management (years).

Wildland Fire Management

Wildland fires predominantly of lightning origin annually burned 150–10,417 $mi^2$ in Alaska during 2001–2016 (median within perimeter = 1,043 $mi^2$, $n = 1747$) [28], representing by far a much greater upland disturbance that other natural factors or human influences combined. Fire management options (limited, modified, full, and critical) are specified for geographic areas to provide guidance on initial attack suppression activities based on human habitation, resources at risk, cost, and other factors (Alaska Wildland Fire Coordinating Group [AWFCG] 2022:21). The goal of fire management options is not to minimize the area burned but rather:

> "are employed statewide by federal and state agencies, and Alaska Native groups in order to:
>
> • Prioritize areas for protection actions and the allocation of available firefighting resources to achieve protection objectives.
>
> • Optimize the ability to achieve land use and resource management objectives and integrate fire management, mission objectives, land use, and natural resource goals.
>
> • Reinforce the premise that the cost of suppression efforts should be commensurate with the values identified for protection."

Most often, this equates to minimizing damage or loss of identified resources at risk, typically in proximity to communities. Limited suppression most closely reflects a natural disturbance regime with respect to lightning ignitions and is the primary means to maintain early-seral boreal forest at the landscape scale (Alaska Wildland Fire Coordinating Group 2022). Wildland fire ignitions are unpredictable, and spatial control of fire extent is limited to tactical decisions in suppression, but this "natural treatment" has no operational cost to habitat managers. Fire management options are reviewed annually and may be changed through a nomination process with concurrence of the landowners or managers. Area biologists can contact DWC regional fire specialists to develop proposals for changing management options in specific areas. Short of changing management options, "nonstandard responses" may be specified for geographic areas to allow fires to achieve resource objectives, such as fuel reduction or habitat enhancement, under specified circumstances for broader areas where suppression still protects resources at risk (Alaska Wildland Fire Coordinating Group 2022). This prior planning step allows "fire use" by suppression agencies to "shape" natural ignitions for beneficial outcomes.

Creating hazardous fuel breaks (Agee et al. 2000, Finney 2001) may allow wildland fire to be tolerated closer to communities if potential for tactical suppression is increased, thus facilitating changes in management options or retention of existing options despite increasing development. Fuel breaks can enhance habitat, but their main value in the long term is reducing risk of damage to identified resources (such as property) or values that could permit acceptance of wildland fire on a larger portion of the landscape to achieve wildlife habitat objectives.

Conducting prescribed fires and the management of wildland fires and hazardous fuels involves public input on objectives and other concerns whether on public or private lands, such as risk of

[28] Calculated from Large Fire Database maintained by the Alaska Fire Service (Accessed October 2016).

prescribed fire escape, smoke emissions, and visual aesthetics. Public acceptance of these tools for habitat management is affected by public perception of past actions, degree of local knowledge incorporated, and factors of trust in agencies (Rasch and McCaffrey 2019).

Timber Harvest

Expansive logging of boreal forest in Fennoscandia (Finland, Norway, and Sweden), during the 1960s–1980s when large predators were rare, produced dramatic increases in the abundance and harvest of moose, and unfortunately, also in vehicle collisions (Lavsund et al. 2003). Timber harvest in Alaska's boreal forest has the potential to emulate fire disturbance and enhance moose habitat through hardwood regeneration (Collins and Schwartz 1998). However, the forest products industry in boreal Alaska has generally operated on thin economic margins because of the high cost for shipping raw products to world markets, so the amount of logging along the continental road system is relatively small (Wurtz et al. 2006). Most timber harvest in boreal Alaska is for white spruce, but hardwood and willow regeneration are common after these operations (Allaby et al. 2017). Harvest occurs to a lesser degree for paper birch and rarely for quaking aspen or balsam poplar, so market-driven regeneration on these sites is rare; habitat focused treatments are the most feasible mechanism to support regeneration in these forest types. Commercial firewood sales for birch allow for hardwood regeneration through required site scarification in state or municipal forestry contracts. Without a fiber market like a pulp mill, mature aspen debris remains after mechanical treatments and hinders sprouting from some mechanical treatments like shearing or felling mature trees (Paragi and Haggstrom 2007).

For context of disturbance scale, an area including the Tanana Valley State Forest plus a 20 mile buffer to include large fires that burned into the state forest (combined area = 21,756 $mi^2$) was analyzed for area of fire and logging disturbance. During 1963–2013, the mean size of wildland fires (26,045 acres, total area burned 13,281 $mi^2$, $N = 326$) was 3 orders of magnitude larger than mean size of logging sites (24 acres, total area of timber sales 55 $mi^2$, $N = 1488$), despite the state forest being primarily under full suppression (Paragi et al. 2020:40–42). Timber harvest after fire optimally occurs within a few years before decay agents reduce the value for salvage of dimensional lumber. Salvage from large burns near the road system make up a substantial portion of the total harvested area. For example, salvage was 43–95% of harvested area in the Fairbanks Area for the 6 years following the 1983 Rosie Creek Fire, and it has a range of 29–90% and 39–100% for similar periods in the Delta Area (Paragi et al. 2020:46). Post-fire salvage can create a net increase in public access through a combination of all-season and winter-only roads and thus an increase in moose harvest opportunity in regenerating burns.

Adapting to a Changing Environment and Societal Needs

DWC conducted and monitored a few mechanical enhancement projects prior to the IM law (Oldemeyer and Regelin 1987, Nellemann 1990) during a period when wildland fire was annually less frequent or extensive than in recent years (Appendix K), and suppression was effective near urban areas (DeWilde and Chapin 2006). The habitat program expanded in the 1990s with more research (Collins 1996) and perspective on wildland fire in Interior Alaska being relatively less frequent and extensive than during the mid-20th century (Haggstrom and Kelleyhouse 1996). The desire was to enhance moose habitat, using 1) mechanical treatments in targeted areas near settlements and 2) prescribed fire in larger areas outside the wildland-community interface where fire suppression protected human lives, infrastructure, and specific values at risk. In the early 2000s, larger fires became more common with a warming climate (Appendix K). Land and fire management agencies began assessing fire risks based on fuel types and implementing hazardous fuel reductions in strategic locations. During this era, ADF&G implemented 4 large, prescribed burns as part of IM (Haggstrom 1999, Tobey and Kelleyhouse 2006:151). However, these burns were increasingly a challenge due to public concerns with smoke and competition with suppression resources during optimal periods for burn prescriptions. Some did not occur because of policy decisions by land and fire managers and elected officials during the fire season. Presently the U.S. Bureau of Land Management in Alaska is increasing fuels management capacity that includes staff modules with capability to plan and execute prescribed fire.

With an increase in wildland fire since 2001, DWC has shifted to use crushing, shearing, or roller chopping to create and maintain structural (tree height and diameter) and age-class diversity within large burns that occurred near the road system and are accessible for hunting and wildlife viewing. Roller chopping has a long history in management for wildlife habitat in North America, including preparation of woody vegetation for broadcast burning to favor forbs and graminoids (Stoddard 1937). Pieces of debris from younger trees are smaller and more easily crushed to the ground for more rapid decay, making sites more publicly accessible than jack-strawed large debris typical of felled mature trees. Felling remains an option for aspen regeneration on steep sites where prescribed fire may not be acceptable in proximity to homes higher on the slope.

Fuel breaks that reduce the risk of wildland fire spread are another opportunity for mechanical treatments. These treatments can also create habitat benefits in the wildland-community interface. For treatments close to homes, some stakeholders may favor thinned rather than sheared forest for aesthetics[29] (Little et al. 2018). If shearing is done, optimal design for aesthetics may include leaving reserve islands (especially hardwoods) and visual buffers of uncut vegetation along margins that reduces visibility of the sheared area from roads and avoid creation of unsafe “shooting lanes” directly visible from existing roads or trails. Retention of late seral habitat features may also be desirable (Paragi 2010). Initial studies from Alaska suggest that potential for grass establishment (fine fuel when cured in spring and fall) may be higher in sheared treatments on some sites compared to thinned (Butler et al. 2013). Potential for enhancing shrubs and deciduous trees was higher on sheared sites than on thinned sites (Melvin et al. 2018).

ADF&G advocates for wildland fire use as an indirect enhancement action that can cover vast areas by allowing wildland fire ignited by lightning to maintain a natural disturbance regime (Lloyd 2009). The limited fire management option defers suppression of fires that do not threaten specified resources or where cost or safety risk of suppression exceeds monetary or cultural value of identified resources (Alaska Wildland Fire Coordinating Group 2022). Monitoring fires under the limited option has comparatively negligible cost (surveillance) compared with suppression. However, wildland fire is a chance event in time and space. A

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[29] A brochure was created in 2023 by a committee of the Alaska Wildland Fire Coordinating Group to aid comparison between sheared and thinned sites: https://www.frames.gov/sites/default/files/AFSC/presentations/AWFCG_Fuels_Treatment_Tri-Fold_FRDAC_2023-04-05.pdf

remote burn that enhances moose abundance requires a corresponding degree of increased hunter participation (access) to produce an increase in harvest.

DWC can facilitate acceptance of wildland or prescribed fire near communities by supporting the development of hazardous fuel breaks that provide options for tactical suppression response or "decision space" (Lloyd 2009). Fuel breaks and their periodic maintenance reduce risk to identified resources (homes, timber, etc.) and may stimulate early seral vegetation beneficial to wildlife, depending on the site prescription and existing cover type. Mechanical treatment sites on public lands are generally accessible for hunting and wildlife viewing, so fuel breaks generally serve societal benefits (e.g., wildlife and berry harvest) that may mitigate social concerns about aesthetics.

Climate forecast scenarios suggest that years of substantial wildland fire will likely continue in Alaska (Veraverbeke et al. 2017, Young et al. 2017), at least until landscapes dominated by black spruce (*Picea mariana*) might transition to less-flammable fuels such as deciduous trees (Johnstone et al. 2010, Weiss et al. 2023). For the coming decades, the prevalence of wildland fire will remain the primary tool for habitat enhancement at a scale sufficient to produce increases in moose abundance in areas, with extent of increase contingent on predator density (Gasaway et al. 1992). Fuels management to reduce landscape spread of wildland fires and carbon emissions may influence maintenance of young forage for moose habitat in some areas.

Allowing natural fires or using prescribed fires to fragment the continuity of spruce forests near communities will reduce risk to human infrastructure during dry years with extreme fire behavior and provide moose harvest closest to where most people live. Reducing fire risk near identified resources for protection may increase tolerance of natural fires, but air pollution from smoke may remain a greater concern than habitat benefits for many citizens, thus requiring stakeholder compromise to avoid political override of suppression policies or prescribed burns during fire season. Another challenge to wildland fire use is from continued expansion of the wildland-community interface as housing subdivisions, individual homesteads, and remote land disposals for recreational cabins spread out from communities along roads, trails, and rivers with additional sites spreading from aircraft landing strips or float plane accessible waters. Owners of this infrastructure have various expectations for protection from fire and may protest attempts to use fire to manage fuels or enhance habitat. These challenges should be addressed during the planning phase where fire is involved as a tool for habitat enhancement.

**Appendix F. Silvicultural and cost considerations for enhancing moose forage production.**

Vegetation response after various methods of moose habitat enhancement has been evaluated in Alaska (Oldemeyer and Regelin 1980, 1987; Nellemann 1990; Collins 1996; Collins and Schwartz 1998; Paragi and Haggstrom 2007). Logging methods designed to periodically harvest most trees in a stand to establish a new cohort are "even-aged" methods of forest regeneration that vary by decreasing degree of stem removal from clear cut to seed-tree cut to shelter-wood cut (Yahner et al. 2005). Seed-tree and shelter-wood cuts provide seed sources and degrees of shade for stand regeneration (Nyland 2002). Mechanical treatments without wood salvage and prescribed fire both leave debris, although some may remain standing for a while in burns depending on fire severity (high-severity burns weaken the root system of residual standing trees). The summary below highlights observations specific to Alaska applications. The 2 primary regeneration techniques for deciduous, woody vegetation are coppice sprouting from existing roots and seedbed preparation (fire or mechanical) that permits seral conversion from conifer forest to shrubs and hardwoods for a few decades.

<u>Coppice Sprouting of Deciduous Woody Plants</u>

Hardwood tree and willow sprouting can be stimulated by top killing the plant during winter dormancy when plant reserves are in the roots. Aspen stands are clones that are genetically identical groups of trees connected by roots. To get maximum sprouting you would cut all the stems in a clone because adult trees send auxins to the roots to suppress sprouting and even 1 tree can reduce sprouting (Peterson and Peterson 1995, Collins 1996). However, a clear cut may be infeasible for aesthetics near mixed property ownership in the wildland-community interface or undesirable for other reasons (see treatment configuration below).

Top kill may be achieved by felling, tipping, or fire contact on the bottom 3–4 feet of the trunk given adequate heat to scorch the bark. Prescribed fire is mostly done in spring just prior to leaf emergence (late April to mid-May depending on the location and year). In spring the ground is frozen or saturated, but fine fuels are sufficiently dry to carry surface fire (low relative humidity). This ensures adequate intensity (heat release per length of flaming front) but results in low severity (depth of burn into organic mat and rooting zone) and low potential for fire holdover (Gordon 1976). Adequate flame length is achieved through the fire prescription that utilizes slope, fuel type, and wind to produce the desired fire behavior. It is difficult for fire to burn effectively for this prescription on flat sites or with >15% relative humidity. Unlike crown fires later in the season when larger fuels have dried, early season burning of surface fuels that leave a largely intact organic layer and trees do not release substantial amounts of volatilized nitrogen to the atmosphere (Miesel et al. 2018).

Logging to supply timber or fiber markets removes merchantable-sized wood. Where markets do not exist, felling trees without salvage leaves debris that shades the ground during early succession and hinders access by humans, and to a degree, by wildlife (Nichols 2005) until decomposition allows its settlement to the ground. Where grouse habitat is desired as a cobenefit, debris may also enhance small mammal abundance, thus attracting nest predators like weasels (*Mustela* spp.) and martens (*Martes americana*).

Felling individual trees by use of chain saws or cut-to-length harvesters provides some opportunity to directionally lay the boles to reduce debris stacking or jackstraw. Felling does not require frozen ground and can occur any time after leaves drop. Dormant twigs of current annual growth in the crown of freshly cut tops, along with bark of larger limbs, can be utilized by snowshoe hares (*Lepus americanus*) and moose. Twigs in the crown are otherwise beyond the reach of terrestrial herbivores and tend to have fewer secondary chemicals that inhibit herbivory compared with lower twigs of juvenile plants (Palo 1984, Erwin et al. 2001).

In contrast, shear blading, even with a directional blade, often results in jack-strawed debris. Operators should use portable grinders to sharpen the shear blade, so stumps are not ripped out. Dozer crushing or roller chopping shrubs and young hardwood trees (>4–6 in diameter at breast height) is optimal when the ground is frozen, temperatures −20ºF to 20ºF, and snow <12 inches. Attempting these treatments under warmer conditions has risk of vegetation springing upright instead of snapping. Beware of enhancing advance spruce regeneration if a competitive overstory of hardwoods is heavily reduced for a few years by browsing from moose at high density. If spruce regeneration is dramatic, maintenance to manually fell or brush hog spruce regeneration may be required.

Windrowing of debris can improve sprouting density of aspen on cleared portions (Paragi and Haggstrom 2007) where tree growth is more robust (authors' observation). The tradeoff on sites cleared of debris is more forage to attract moose and improved moose viewing during initial years; but faster tree growth means the current annual twigs desired as browse will extend more rapidly above the reach of moose (10 feet), and moose will become harder to see by hunters unless tree stands are utilized.

Once mature trees are top killed by fire or cutting, repeated coppice silviculture of winter dormant stems on a rotation of 2–3 decades can be used to maintain patches of early seral forest in desirable locations (e.g., fuel breaks, hunting areas). This practice is not expected to reduce soil nutrients on rotations >15 years based on research that included fiber removal (Perala 1979), which would not occur with crushing or shearing in Alaska that leaves small stems on the site. Crushing or shearing portions of large burns as forest succession occurs will maintain a mix of shrub and tree species and stand age classes for wildlife habitat. Forest age diversity also reduces the risk of pathogen or insect infestation (Nyland 2002:498–500).

<u>Conversion of Coniferous Forest to Early Seral Deciduous Plants</u>

Under certain conditions, disturbance in spruce-dominated forest can result in early seral dominance by hardwoods whether by fire (Johnstone et al. 2010) or by logging (Wurtz and Zasada 2001, Allaby et al. 2017). Scarification exposes mineral soil that provides a nutritional medium for seed germination and often reduces competing vegetation that could hinder seedling establishment. Natural scarification occurs when high severity fire consumes organic duff, when trees fall and soil is exposed beneath root balls, or after ice scouring removes vegetation. Using prescribed fire to convert spruce forests to hardwood requires drying of the duff by later in June, when fires often present a containment risk, thereby competing with wildland fires for suppression resources. Mechanical scarification is sometimes done with a dozer or skidder blade, ripper plow, or disk trencher (parallel angled wheels with teeth) after logging to enhance seedbeds or create a favorable planting environment. Narrow exposure of mineral soil to the proper depth (a horizon of soil) is desirable to allow the roots of establishing seedlings to benefit from organic soils that are laterally within a few inches (Collins 1996). These shallow soils hold moisture and slowly release nutrients and enable herbaceous and other vegetation to provide some shade in hot weather (Collins 1996). Scarification to a depth that damages the existing clonal roots of aspen should be avoided because it can reduce sprouting (Allaby et al. 2017). In active floodplains, mineral soil accretion occurs when flooding deposits silt for primary succession.

Forage Quality

Most prescriptions for forage enhancement focus on increasing biomass of current annual growth (Seaton et al. 2011) or its proxy of stem density. Forage quality of browse can be described in terms of digestible energy, nutrient content (nitrogen, protein, minerals, etc.), and degree of fiber or secondary compounds that hinder digestion or assimilation (Regelin et al. 1987, Schwartz and Renecker 1997:442–444, Spalinger et al. 2010). Digestibility and protein content of woody forages used by moose generally increases for 2–3 growing seasons after disturbance but typically returns shortly thereafter to pretreatment conditions, whether after fire (DeByle et al. 1989) or mechanical treatments (Bowyer et al. 2001, Rea and Gillingham 2007). Treatment at such a high frequency would likely require artificial fertilization. The primary location of such frequent disturbance is mowing brush along roadsides, which especially during periods of deep snow, attracts moose and increases potential for vehicle collisions. Mowing shrubs in summer is done to increase sight distance for drivers, especially around corners. DWC should recommend to road maintenance crews that mowing of roadside brush should also occur just prior to senescence to prohibit growth height that exceeds mean snow depth by mid-winter which could attract moose to roadsides. Early fall mowing will also reduce roadside forage and concealment cover during the rut when collision risk is high due to an increase in moose movement (Noordeloos 2016; McDonald et al. 2018). Where fuel breaks also serve as habitat enhancement sites, maintenance of the site is generally on a longer rotation such as 20–30 years, depending on degree of conifer regeneration.

Guidelines for Treatment Configuration

The size, shape, and position of treatment sites should be based on regeneration ecology of desired plants and spatial scale and dispersion of habitat features affecting moose habitat selection. Birch seeds predominantly disperse within 200 m during fall and winter unless driven further by prevailing wind (Safford et al. 1990) or along the snow surface. For birch harvest, the shape of clearcut boundaries should consider proximity to mature trees as seed sources (or retain seed trees within larger cuts) and prevailing wind direction in fall and winter (Allaby et al. 2017). Willow, aspen, and poplar fruits have a dehiscent capsule with numerous small seeds each with a tuft of long silky down that allows long distance dispersal in spring and early summer. Where grass (most commonly bluejoint grass, *Calamagrostis canadensis*) competition can hinder hardwood establishment, fall scarification disrupts the rhizomatous mat and exposes mineral soil allowing tree seeds (including conifer) to land in fall and winter and germinate in spring, prior to re-establishment of dense grass.

Juxtaposition of habitat attributes may be as important as the amount of any single attribute. Creating a large monoculture of a browse species may be an efficient use of heavy equipment and maximize aspen coppice. However, uncut islands (harvest retention) create patches of mature security cover in a matrix of browse. This matrix is attractive to moose seeking to optimize nutrient intake through selective foraging (Weixelman et al. 1998, Shipley 2010) and more aesthetically pleasing to the public. Enhancing the diversity of woody forage species in proximity may be more beneficial to moose than enhancing a large patch of a single species. Moose tend to select different species over short periods of foraging to reduce species-specific secondary compounds that inhibit nutrient assimilation in the gut (W. Collins, DWC Physiologist, Palmer, personal communication, August 2017). Another consideration is that large openings with full sunlight may produce forages that are lower in nitrogen and less digestible than those grown in the shade of adjacent vegetation (Molvar et al. 1993).

Thompson and Stewart (1997:392–393) reviewed guidelines for moose habitat configuration in Alaska and other parts of North America. The optimal width of treatment examined at multiple study areas was about 200 yards (farthest point to cover of 100 yards), and no further than about 600 yards. Forage offtake by moose tends to decline in amount or selection for preferred species with increasing distance from cover (Nellemann 1990, Weixelman et al. 1998, Nichols 2005). Percentage concealment in horizontal and vertical cover for moose can vary substantially among seasons for deciduous wood species (Collins and Helm 1997). Collins (1996:3) reviewed the large variation in the reported distance from cover within which moose are reported to selectively feed and attributed it to rapid growth of horizontal cover in some clear cuts, including that of browse species.

For crushing, Oldemeyer and Regelin (1987) recommended that treated areas have pole-size trees or smaller, be large enough to not be over browsed by moose, the width of crushing be narrow enough to ensure seed entry from mature trees, and a 4:1 browse-to-spruce (*Picea* spp.) ratio. Recent roller chopping efforts in Tok and Delta (2017–2022) confirmed that the ideal upper size limit when roller chopping live aspen is 4- to 5-inches in diameter at breast height. However, slightly larger diameter trees may be feasible if snow is not deeper than 12–15 inches because this allows tree boles to break into segments from the weight of roller chopper blades for lesser debris height. Oldemeyer and Regelin (1987) also recommended leaving approximately 40% of the larger management unit undisturbed to provide cover, which can be accomplished by leaving steeper hillsides and mature timber stands untreated. Interception of snow by mature conifers of moderate-to-full canopy closure can reduce the energy expenditure for moose while traveling. This is optimal when abundant forage in burns, timber sales, or active floodplains are bordered by such forest (Hundertmark et al. 1990, Weixelman et al. 1998). Collins and Helm (1997) additionally surmised that moose frequently lying in the shade of white spruce (*Picea glauca*) in March and April avoided thermal stress. However, experimental manipulation remains to be done to confirm that proximity or access to mature conifers is critical for winter survival of moose (Balsom et al. 1996).

It is unlikely that mechanical treatments will be of a sufficient scale to cause a numeric response in moose unless supported by economic drivers such as wood fiber value. If the disturbed area is likely to expand to more than 5,000 acres of a landscape within a few years, planning should include conservation of habitat features other than cover and winter forage, such as aquatic areas with summer forages (Thompson and Stewart 1997).

Logistics and Costs

Techniques that require action during vegetation dormancy may occur from mid-Sept to mid-May. Working with frozen ground to reduce soil compaction or scarification and access wetlands requires prolonged cold which is rarely possible before November. Extreme cold ($<-20^{o}$F) increases potential for equipment failure, and short days surrounding winter solstice provide less time to work in sufficient light. During the spring period of active layer thaw, the Alaska Department of Transportation places weight restrictions on road traffic to reduce damage to paved roads; therefore, timing of equipment demobilization may require calculated costs for rental or idle time vegetation treatments in late winter.

Crushing, shearing, or roller chopping of standing forests can bring fine wood debris and dry vegetation into contact with the exhaust system of heavy equipment. Operators should be cautioned to frequently inspect debris accumulation to reduce the risk of fire. This is particularly important if a hydraulic hose or oil seal ruptures during extreme cold.

Cost per acre can vary widely for both mechanical and fire methods (Collins 1996, Paragi and Haggstrom 2007, 2015). Fixed costs for a given project scale (e.g., equipment mobilization and demobilization) and planning costs for prescribed fire are added to operational costs (labor, fuel, expendable materials, etc.). A variety of mechanical treatments have been used in Alaska, and bidding costs vary by equipment type, local availability, and competing projects in the public and private sectors. Seek a balance between treatment patch size (e.g., 10–40 acres) and the number of patches clustered in each area creating the mosaic of cover that is best suited for moose habitat for efficiency in the logistics of mobilizing and demobilizing equipment and crews.

**Appendix G. Conceptual models of habitat project benefits.**

Figures depicting prey population response from Crowe (1983:63, 65) show scenarios of (a) potential for increased abundance with habitat enhancement and (b) potential for decline that is mitigated by habitat enhancement. Reprinted with permission from Wyoming Game and Fish.

**a**

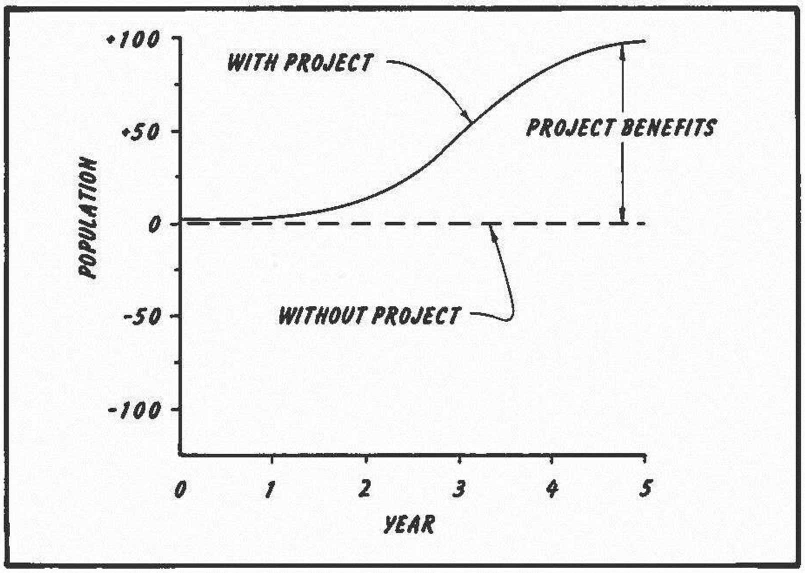



Figure 30. Anticipated deer population increase resulting from habitat improvement.

**b**

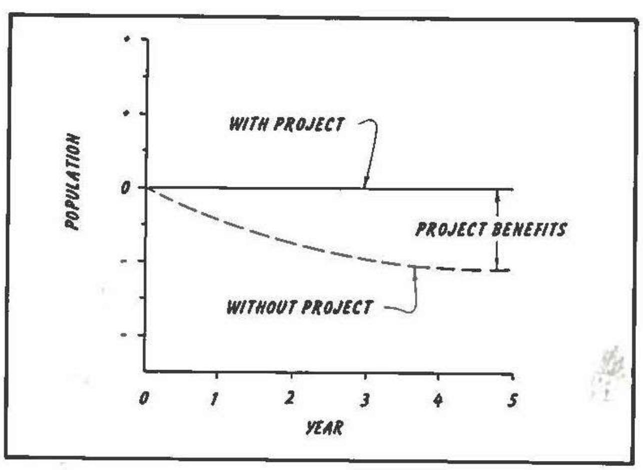



Figure 32. Anticipated project benefits resulting from habitat improvement.

## Appendix H. Feasibility assessment for intensive management

In defining whether an intensive management action is feasible, the assessment must address the potential to achieve ungulate population and harvest objectives (Alaska Department of Fish and Game 2011).

| | | |
|---|---|---|
| A. | Population increase in ungulates is required to reach population objective (may be represented as comparable density) | [number] |
| B. | Increase in average estimated harvest (last 3 regulatory years [RY]; RY = 1 July–30 June) to reach harvest objective [if applicable, clarify for IM areas at low density how many prey animals are needed to meet local needs as an initial means of contributing toward IM objective for that unit] | [number] |
| C. | Potential to mitigate biological habitat limitations in proposed IM area | [low/moderate/high] |
| D. | Potential to reduce or moderate hunting conflicts | [low/moderate/high] |
| E. | Anticipated public participation based on factors of access | [low/moderate/high] |
| F. | Data availability for designing an effective operational plan and evaluation design | [low/moderate/high] |
| G. | Potential to measure or demonstrate progress in ungulate population recovery or an increased harvest within a defined period | [low/moderate/high] |
| H. | Potential to document cause and effect for success or failure in population recovery or harvest increase | [low/moderate/high] |

**Appendix I. Prescribed fire planning for moose habitat enhancement.**

Using prescribed fire to enhance wildlife habitat requires ADF&G to consult with those agencies who have the authority and expertise to implement them, which include member agencies of the Alaska Wildland Fire Coordinating Group (AWFCG). Implementation may be arranged through outside entities with expertise, per approval of the protecting agency. Through guidance from the National Wildfire Coordinating Group (NWCG), common practices and requirements are established that "enable efficient and coordinated national interagency wildland fire operations." This leadership group "enables interoperable wildland fire operations among federal, state, local, tribal, and territorial partners" (National Wildfire Coordinating Group 2023).

*NWCG Standards for Prescribed Fire Planning and Implementation* (National Wildfire Coordinating Group 2023; search for PMS 484) provides guidance for writing and executing a site-specific, legal, prescribed-fire plan. Associated documents that complete the Prescribed Fire Plan Template (PMS 484-1) include the Prescribed Fire Summary, Final Complexity Worksheet (PMS 424-1), and Prescribed Fire Complexity Rating System Guide (PMS 424). The Smoke Management Guide for Prescribed and Wildland Fire (PMS 420-2) supports the plan with smoke management techniques and mitigation measures. There are classes associated with these guidance documents that are offered in both Alaska and in the Lower 48 through the NWCG Wildland Fire Learning Portal.

The prescribed burn plan must be authorized by the protecting agency[30]; this authorization serves as the "burn permit" for a landscape-scale fire. An open-burn permit through ADEC is also required. Land-management fires are regulated through Open Burning Policy & Guidelines per ADEC[31]. ADF&G staff can request assistance from member agencies of AWFCG such as DOF&FP or the BLM Alaska Fire Service to develop a prescribed burn plan. Expertise in prescribed fire varies across agencies over time; requesting information and support can be accomplished through any agency fire management officer. Building a team that includes a fire behavior analyst, burn boss, and fire operations forester (if applicable) is a first step in determining the feasibility of a project proposed by DWC.

The feasibility assessment (Appendix B) is designed to ensure that necessary steps are addressed in the planning process, especially stakeholder engagement. Consulting with experts in fire management is necessary to fully appreciate and account for risks, unintended results, and the many uncontrollable variables associated with fire applications. Assessing the feasibility of the project within this partnership sets the parameters needed for establishing a Memorandum of Understanding or Cooperative Agreement to engage the operational expertise needed to complete a burn plan. Expect to pay for staff time when engaging a partner agency for this expertise. However, much of the documentation, research, and context can be prepared by ADF&G staff. In the initial stages of assessing a prescribed burn's feasibility, agencies must critically evaluate whether implementation is clearly endorsed by all agency partners and there is

[30] Map of wildland fire protection areas:
https://fire.ak.blm.gov/content/maps/aicc/Large%20Maps/Alaska_Fire_Management_Zones.pdf
[31] https://dec.alaska.gov/air/air-permit/open-burn-info/

support at the local level, including adjacent landowners. The complexities involved in implementation range from federal laws such as the Bald and Golden Eagle Protection Act and NEPA to accessing burn units through private land. Addressing these complexities at the beginning of the process may save months or years of time collecting data to fulfill a permit application and negotiating agreements.

**Appendix J. Considerations in evaluating vegetation, moose response, and moose harvest.**

Evaluation strategy should reflect the degree of project complexity and information needs. Detailed review and recommendations on evaluation design is beyond the scope of this bulletin. Holthausen et al. (2005) and Rowland and Vojta (2013) provide guidance in design of monitoring programs for habitat and wildlife in forested environments. We limit our discussion here to the scope and tradeoffs of monitoring and research and consideration of metrics for each of the 3 outputs: vegetation, moose, and harvest.

Monitoring

Monitoring of relatively simple treatments can be incorporated into moose S&I projects[32]. An example might be manipulating a single factor (habitat) without changes in harvest opportunity or incentive (e.g., stable regulations for predator and prey removal, no changes in hunter access) and monitoring the response variable(s) and environmental variation that could influence response (e.g., winter severity) in the treated site and a similar nontreated site. This design, with a defined statistical power, could isolate treatment effects from potential confounding factors. Biometric assistance in study design and sample size requirements occurs in operational planning (Appendix C).

S&I projects are intended to evaluate wildlife response to management actions and harvest among game management units, with harvest at the resolution of UCUs (usually in the tens to hundreds of square miles[33]). S&I projects use a suite of proven techniques defined in "project statements" under 5-year Federal Aid matching grants[34] and described in species management reports and plans[35]. Metrics are monitored for the purpose of informing a routine management or regulatory decision and are often chosen based on long-affirmed value as an appropriate indicator (e.g., Fraser 1985). Evaluating habitat treatments should be focused on demonstrating the estimated magnitude of effect (e.g., area, stem density, or biomass of vegetation type), its variance (Anderson et al. 2001), or strengths of correlation to gauge treatment efficacy and potential for output response in vegetation, wildlife abundance, or game harvest.

Research

Addressing questions using unproven methodology or monitoring confounded situations where multiple factors were manipulated simultaneously (on purpose or by chance) should be under the guidance of a research operational plan. Confounding among habitat treatments, stochastic environmental effects, and (potentially) simultaneous predator treatments ideally require a research design, replication sites, and nontreatment sites to isolate treatment effects and demonstrate causation (discussed below, this section). However, a reductionist approach in such situations may be impractical, with evaluation limited to acceptance of confounding and simply

[32] Reports and plans: https://www.adfg.alaska.gov/index.cfm?adfg=librarypublications.wildlifepublications&sort=all&species=Moose&publicationtype=Species+Management+Report+%28and+Plan%29&submit=Search

[33] https://alaska-department-of-fish-and-game-adfg.hub.arcgis.com/datasets/adfg::game-management-units-subunits/about

[34] As of March 2024, the Office of Conservation Investment.

[35]https://www.adfg.alaska.gov/index.cfm?adfg=librarypublications.wildlifepublications&sort=all&species=Moose&publicationtype=Species+Management+Report+%28and+Plan%29&submit=Search

evaluating outcomes of multiple simultaneous factors in a management application. The following review summarizes perspectives, challenges, and opportunities in considering approaches to habitat research for moose management.

Managing wild systems for outputs of large herbivore abundance and harvest involves understanding relationships among habitat, disturbances to vegetation, free-ranging herbivores and carnivores, preferences of hunters, technological aids for hunters, annual weather, and land managers that control access. Ballard et al. (1991:37) noted in a case study on attempting recovery of a reduced moose population that “when several factors that may be independent of each other are limiting the population, the risk of management error greatly increases.” Planning manipulations of 1–2 factors with the intent to achieve specified outputs requires recognition that many potential outcomes could occur because of unanticipated interactions among factors (Dörner 1996:192). Further, changes in land management policies and regulatory actions for game harvest are outside the control of field biologists and make precise or consistent treatment designs challenging, especially over longer periods associated with forest succession.

Thompson and Stewart (1997:382) described the importance of evaluation: “There remains a need for management-level, cause-and-effect experimentation to test the effectiveness of intentional moose habitat alteration.” They further noted, as did Eastman and Ritchey (1987:115), that demonstrating a numeric response by moose to habitat enhancement requires an experimental design to discern confounding factors (legal and illegal harvest, predation, weather) that may have been operating simultaneously. However, design of large field experiments is challenging (Sinclair 1991, NRC 1997). Prescribed fires large enough to affect moose populations are time consuming and expensive and are only one sample (nonreplicated). The cost and scale of habitat enhancement typically limits replication of independent treatments, and caution should be applied in statistical analysis comparing treatments to controls (Hurlburt 1984). Mechanical treatments are limited in size by cost and treating units of a few hundred acres will not cause a population level response in moose. Several articles in *Ecology* (Vol. 71, No. 6, 1990) discuss natural experiments following large disturbances. Wildland fires provide an opportunity to monitor effects after the fact, but the “treatment” precedes the evaluation design and precludes the ability to randomize beforehand (Garton et al. 2005). Additional guidance in design of field experiments is provided by Eberhardt (1978) and Eberhardt and Thomas (1991).

Wildlife scientists have long recognized the potential value of evaluating management actions in an experimental design with testable hypotheses and nontreatment controls to gain “reliable knowledge” for broad application beyond the study site to other sites (Romesburg 1981, MacNab 1983, Nudds and Morrison 1991). Without reliable knowledge on ecosystem and hunting system response to treatments, spurious inference on cause and effect from the unique situation of a case study could result in misapplication of future treatments (resulting in failure to achieve desired response) or failure to apply the appropriate future treatment where it might work. Study design should include monitoring the appropriate response metrics before and after treatment and on nontreated sites to account for confounding effects (NRC 1997:122–125), such as greater overwinter survival of young because of mild winters coincident with habitat enhancement or reduced predation.

Walters and Holling (1990) asserted the need to prioritize research, management, and monitoring activities to permit learning from typical management actions (e.g., timber sales, prescribed fires, reduced predation) that can serve as large-scale field experiments. They advised accepting tradeoffs in sampling precision for replication by the following: monitoring a greater number of management actions in a less intensive manner than conventional field research; using remote sensing technology where appropriate; and encouraging institutional arrangements that foster studies spanning periods longer than the working careers of the scientists who initiate them.

Thompson and Stewart (1997:398) proposed adaptive management to gain understanding of the many hypothetical relationships commonly assumed to occur in moose hunting systems. "Active" adaptive management is a strategy to gain reliable knowledge from management actions. Unlike trial and error, it is predicated on being able to evaluate strength of evidence for alternative hypotheses. Walters and Holling (1990:2066) noted that "A critical antecedent to the use of adaptive management experiments and to decisions of where to invest effort is a small number of credible hypotheses to explain the patterns perceived." Rather than detailed studies of single habitat projects, managers would gain a broader geographic inference on vegetative response (and associated moose response and moose harvest) by applying a standardized evaluation at multiple habitat projects that both document efficacy and contribute toward testing hypotheses of ecosystem and hunting system dynamics. Clarifying public expectations prior to implementation would be important in this type of systems approach (see adaptive management sections in Alaska Department of Fish and Game 2011). This type of experimental undertaking can be a long-term commitment for habitat succession that might be approached through multiple short-term efforts at appropriate time intervals.

<u>Response in Vegetation, Moose, and Harvest</u>

A) Vegetative response to fire or mechanical treatments

Mueller-Dombois and Ellenberg (1974), Hays et al. (1981), and Krebs (1999) describe techniques for vegetation and habitat sampling using plot-based and plotless methods. There are several metrics for quantifying progress toward vegetation objectives:

- Cover type (graminoid, shrub, forest, etc.) at the landscape scale for large, prescribed burns or wildland fires.
- Concealment cover, both horizontal and vertical (Collins and Becker 2001, using a 90-degree sighting scope for vertical estimates).
- Forage biomass production and offtake for large study areas that is a population-level assessment (Seaton et al. 2011) sensitive to changes in moose density and nutritional condition (Paragi et al. 2015), or plot data by vegetation type for smaller treatments; either approach accommodates targeted interest in selected forage species.
- Plant stem density as a proxy for forage biomass (Collins 1996).
- Forage nutritional quality (digestibility, protein content; McArt et al. 2006, 2009).

Vegetative response for browse and cover enhancement is assumed to be measured over relatively short periods where treatment effect is not confounded with longer-term climatic trends. If longer response times are assessed (several decades), utilize a before-after-control-impact design for the strongest evidence of a treatment effect (Krebs 1999) that reduce confounding by a change in moisture or temperature regime affecting plant growth. Permanent plots enable a time series for monitoring change but are a constrained sampling method and require attention to statistical analysis (Rowell and Walters 1976).

Time efficiency will be important as the number of implemented projects to monitor increases (cumulatively) over time in a region. Immediate posttreatment responses need to be documented in the short term of forest stand initiation for recent programs, whereas measuring slower responses on older treatments can be staggered in appropriate successional stages of stem exclusion through late seral (Nyland 2002:204–206, 345–347). The tradeoff of time requirements and data gain from various plant sampling methodologies (e.g., Oldemeyer and Regelin 1980) should be considered to plan staff workload for a monitoring program. Training observers in ocular estimates of stem density with a subset of quantified responses in plots can be useful to increase efficiency (Collins 1996:34). Portable technology platforms (e.g., electronic tablets) that can integrate georeferenced images on remote sensing layers with data or field notes can greatly reduce time spent in treatment layout and data entry. GPS polygons of treatment boundaries and retention patches therein can then be provided to operators of machinery to avoid the labor of marking with flagging or paint that can be hard to see in poor light during winter or when obscured by snow.

Stakeholder engagement may benefit from using categorical descriptions of vegetative conditions (e.g., Ottmar and Vihnanek 1998, 2001) or show desired outcomes or demonstrate changes with vegetation treatments. This can be done using before-after images for a category of treatment, such as hazardous fuel reductions[36], or it can be site specific using formal methods (Hall 2001a,b).

B) Moose response to vegetative changes (increased opportunity for viewing or harvest)

An actual or perceived increase in moose abundance in a habitat treatment area creates greater opportunity for harvest or viewing. A demonstrated spatial response by ungulates may identify opportunities to create or improve ground, water, or air access for hunters that allow an intended increase in harvest (e.g., Young and Boertje 2011).

For large (>50 mi$^2$) treatments or wildland fires, numeric responses by moose can be estimated with precision using abundance surveys at the population scale (Kellie and DeLong 2006). This type of estimate may be suitable for pre- and post-treatment assessment, with the former ideally larger than the intended treatment to encompass the greatest area expected to burn. Geospatial population estimators that utilize sampling have the advantage of estimating abundance in portions of a larger survey area (Kellie and DeLong 2006:13). These portions may be conducive to comparison (treatment versus nontreatment) before the treatment occurs but may require new stratification by moose density in the treated portion after vegetation changes.

Moose harvest is reported by drainage, so spatial correspondence among large treatment areas, moose survey areas, and UCU boundaries optimizes the strength of scientific inference on treatment effect. Typically, only large wildland fires are of sufficient scale to demonstrate an increase in hunter use and moose harvest by proportion of UCU burned. The 2004 Boundary fire

[36] https://www.frames.gov/afsc/partners/frdac/activities-products (Alaska Fire Science Consortium).

along the Steese Highway in Units 20B and 25C (837 $mi^2$) provided a unique opportunity to illustrate harvest within the burn being greater in road-accessible areas than in roadless areas (Schmidt and Dial 2017). An increase in calf recruitment (calf-to-cow ratio in early winter) in burned areas, when isolated from confounding effects of reduced predation or mild winters, can corroborate numeric response where abundance estimates have not occurred. Paired calf weights in fall and spring might illustrate short-term habitat benefits of recently burned areas over older successional stages.

If geospatial surveys have been done, but with inadequate scale, spatial overlap, or intensity of sampling for abundance estimates, count data from sample units could be compared among categories of proportion of area burned (e.g., 0%, 1–50%, 51–100%) using burn perimeters <30-years old where higher moose density is expected (Maier et al. 2005). Assuming forage biomass is enhanced, average moose counts are expected to be higher in cells with higher percentage of area burned. Presently, the perimeters include areas not burned, which typically is a higher proportion for larger fires (Eberhardt and Woodard 1987, DeLong and Tanner 1996, Kolden et al. 2012).

Higher severity fires tend to result in type conversion of spruce-dominated forest to deciduous stands during early succession (Lord and Kielland 2015). Therefore, a greater understanding of burn severity allows for more robust inference of moose response to habitat changes observed during aerial surveys. Methods for estimating fire severity have been developed for Alaska forest and tundra (Alaska Interagency Fire Effects Task Group 2007) to calibrate estimated severity classifications from remote sensing (e.g., Parks et al. 2019).

Habitat treatments to date in Alaska, even large, prescribed burns, may be too small for readily discerning numeric response by moose from geospatial sampling techniques. Perceived increase in localized moose abundance can be gauged by counts or indices (e.g., tracks, pellet groups) in habitat selection designs. Intensive aerial census counts in treatment and nontreatment areas of moderate size (5–50 $mi^2$) can be sufficient to demonstrate an increase in use of a treated area if sightability correction occurs to estimate percentage of animals present but not detected (Gasaway et al. 1986). Fresh pellets collected from transects cleared just prior to hunting season can be used as a source of DNA for estimating abundance of moose by sex (Brinkman and Hundertmark 2009) as an alternative to aerial surveys on small (<5 $mi^2$) treatments. This allows an estimate of hunting opportunity before and after habitat enhancement and could be particularly useful if male moose were more inclined to use larger open crushing areas than females with young as suggested by Bowyer et al. (2001). Another technique to quantify sex-specific use of smaller treatment sites during the relatively short hunting seasons are time-specific images acquired with motion-sensitive cameras (Hughson et al. 2010, Trolliet et al. 2014, Newby et al. 2015).

Indirect measures of season-specific use include pellet groups deposited or tracks in snow. Collection of pellets just prior to and just after hunting season is most instructive to gauging change in harvest opportunity. However, understanding the basis of habitat use is important to avoid confounded inference. For example, Collins and Urness (1979) found that travel by elk was greatest in the poorest habitats, resulting in the highest defecation rates and overestimation of habitat value. Elk were most likely to move about in search of preferred forages when they are in less productive and species-diverse habitats, thereby contributing to the highest defecation rates and overestimation of value. Nellemann (1990:30) discussed how moose preference for edge habitats confounds factors of spatial scale when comparing treated sites having sharp boundaries with adjacent nontreated sites.

C) Harvest of moose or viewing success (ultimate objective of habitat enhancement).

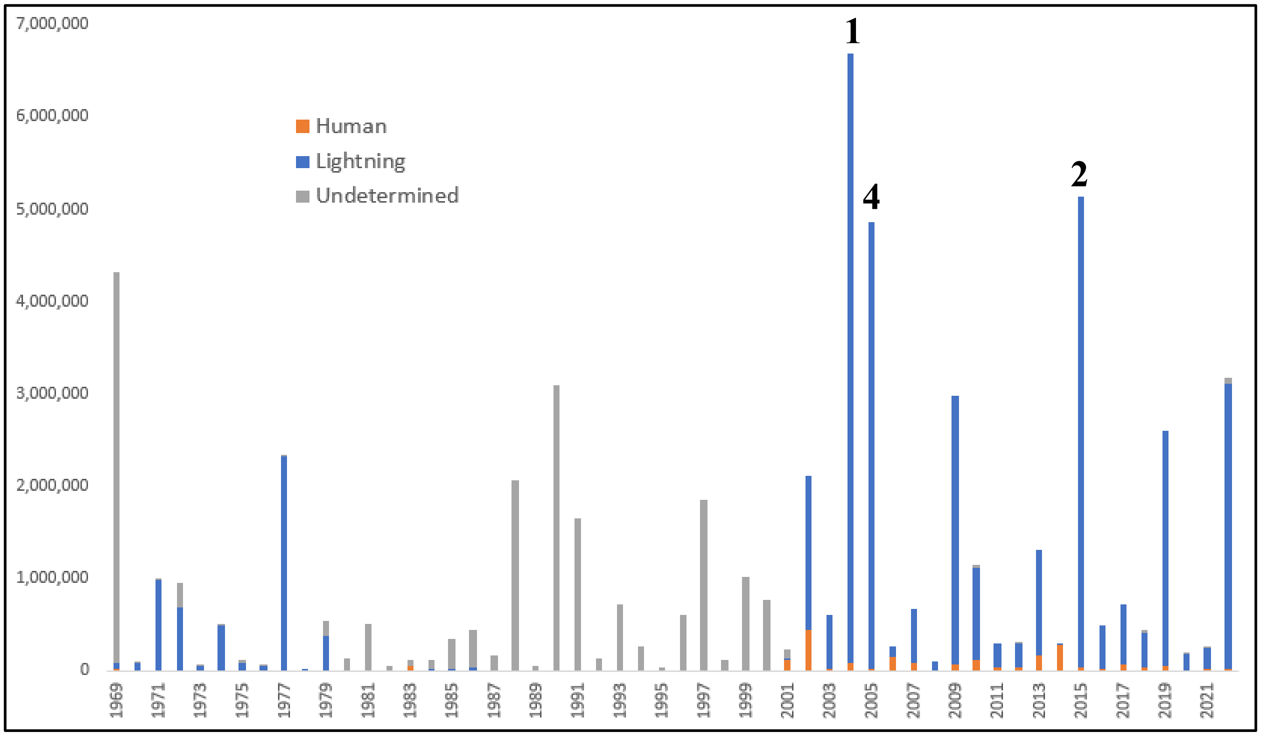
Assessing moose harvest success (number of hunters reporting a kill/total number that reported hunting), kill-per-unit effort (or days hunted until harvest), or wildlife viewing achievement (moose seen per unit time) for habitat enhancement requires matching the resolution of reporting scale to the habitat area. It would be rare for a wildland fire or prescribed burn boundary to largely coincide with UCU, so the evaluation will likely incorporate fractional portions among multiple UCUs. At smaller scales of treatment where harvest magnitude may be masked at the UCU scale, access roads provide kiosk or check station opportunities to sample public use specific to treatment sites (Paragi and Haggstrom 2004:23–24). An ideal situation is where a road system exists to allow pretreatment inference on public use to gauge harvest opportunity (e.g., sightings of moose per hour hunted as an abundance index) and harvest success, followed by a posttreatment evaluation where change can be attributed to the new treatment. Creating new access that coincides with habitat treatments precludes separation of access from treatment effect unless precise locations of moose sightings or harvest are obtained. It may be efficient to design an evaluation to include outcomes of nontarget species that may be positive externalities to moose habitat enhancement, such as small game and furbearer harvest or songbird viewing.

A critical output in the hunting system management is how much elevated harvest opportunity translates into elevated harvest. Harvest is often influenced by the degree of hunter access by land vehicle, boat, or fixed-wing aircraft. Increased mechanized access for hunters or wildlife viewers on forest roads or trails is often a byproduct of mechanical treatments done with large machinery. Access can be increased separately from habitat enhancement, or it can be done to reach into areas improved for habitat by natural disturbances, such as wildland fires. Increased access for hunting can be construed as positive or negative depending on whether a hunter already has personal knowledge of access or animal use of the area that confers a competitive advantage, in some instances because of a long history of use or a fixed hunting base. Biologists should incorporate local knowledge and public experience regarding wildlife behaviors, hunting patterns, and other pertinent information into the evaluation of hunting system outputs.

Creation, expansion, or improvement of access from the existing road or trail system or new ramps for launching boats can be an experimental treatment. New access provides an opportunity to collect information for evaluating whether the objective of a net increase in goods or services (public participation in harvest or viewing opportunity and success rate) was achieved and the degree to which it has been sustained since implementation. Contact stations with hunters can be used to estimate public effort for standardizing success rate, obtain biological specimens, provide outreach on management and research activities, and enforce regulations. Acquiring information on human uses of treatment sites can be done anonymously by traffic counting devices along access roads or motion-sensitive cameras of vehicles (but not license numbers), although ‘purpose of access’ would need to be confirmed through hunter contact, likely by sampling use. Information specific to wildlife abundance and harvest with the option of precise location can be gained through anonymous reporting cards at kiosks along access roads. Gaining information from specific individuals requires consent to preserve privacy. Individuals may be contacted in the field using “creel census” methods in a spatial and temporal design, potentially at sites where vehicles are parked or at check stations along limited access routes. Willing participants might consent to using a smart phone app for self-reporting of georeferenced wildlife information and hunting or viewing effort (e.g., Boyce and Corrigan 2017) that could include images for validation of spoor and sightings.

Evaluating whether the number of people viewing wildlife increases because of habitat enhancement (or concurrent predator control) could be accomplished through contact stations or reporting kiosks near fixed viewing locations, such as promontories on a highway, before and after the habitat enhancement occurs. Internet surveys of individual experiences could be a broader survey of residents and nonresidents to gauge participation and success rate. The agency could use moose abundance estimates as an index to sighting opportunity, recognizing that viewing can occur throughout the year and be greatly affected at specific locations by seasonal habitat use or behaviors, such as rutting or winter range concentration.

**Appendix K. Wildland fires caused by lightning and humans in Alaska.**




Extent of acres burned by ignition source for 1969–2022, Alaska. Area burned was critically evaluated to the degree possible for fires >1,000 acres prior to 1988 and >100 acres since 1988 (source: Alaska Fire Service, large fire database, March 2023[37]). Numbers above bars are the rank in peak years of area burned since record keeping began in 1940. Aircraft detection and mapping of fires became more consistent by the late 1960s (Todd and Jewkes 2006).

[37] Zipped geodatabase of fire polygons at https://fire.ak.blm.gov/predsvcs/maps.php.

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