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Minnesota Moose Population: Using Forest Inventory Data to Assess Changes in Habitat

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Abstract: A preliminary analysis of changes in forest habitat in northeastern Minnesota suggests reduced acreage in recently disturbed and young forest as a contributing factor in moose population decline. This report also describes how available data can be used to characterize habitat conditions.

Introduction: A January 2013 aerial survey of moose living in the primary habitat zone of the Arrowhead Region of northeastern Minnesota (Figure 1), suggests that numbers have declined from more than 4,230 individuals in the 2012 census to just 2,760 individuals in 2013, a 35% loss (DelGiudice 2013). The Minnesota Department of Natural Resources (MN DNR) has indicated causal factors of potential interest include disease, parasites, and habitat change.

While there is no recent evidence to suggest that habitat alone has limited moose numbers in Minnesota, habitat quality and spatial arrangement can limit the population within a smaller geographic area (Moose Advisory Committee Report [MAC] 2009). This study examines the relationship between recent changes in Minnesota's moose population and changes in forest and related aquatic habitat.

The literature indicates new growth in young and regenerating forests is an important summer food source contributing to the success of moose over the winter months when available food sources are typically insufficient to maintain body mass (Franzmann et al. 2007, Lenarz et al. 2011, Peek et al. 1976). Peek et al. (1976) found that the leaves of young quaking aspen, willows, and paper birch were the most important food sources for moose in northeast Minnesota from June to September; almost 60% of moose nutrition was gained from eating leaves of these three species during the summer. Other species, including aquatic vegetation and small diameter twigs and shoots, are also important at various times of the year.

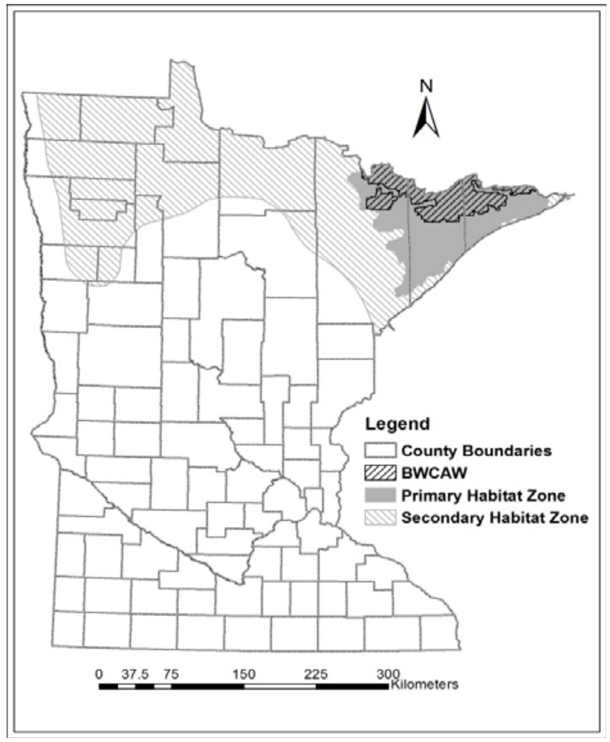

Figure 1: Moose Habitat Zones in northern Minnesota. Primary habitat zone data (circa 2010) courtesy of MN DNR Data Deli. Secondary habitat zone adapted from MAC (2009).

Methods and Results: The US Forest Service Forest Inventory and Analysis (FIA) unit gathers data from 1,258 permanent sample plots within the primary moose habitat zone over a 5-year cycle. The current annual inventory began in 1999, with one-fifth of the field plots measured each year. The first full sampling cycle was completed for the 2003 inventory year. Thus, FIA data are an average of conditions over the reporting year plus the previous 4 years. Each FIA plot includes four subplots covering 0.0415 acres per subplot (O'Connell et. al. 2012). For the cycle ending in 2011, there were 224 FIA plots in the primary moose habitat zone with a nonforested condition code. Of these

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plots, 92 occurred on nonforested land (152,675 acres), 132 fell on open water, i.e., census and noncensus water bodies (348,271 acres), and 37 others were not sampled for various reasons. The FIA database provides numerous variables which can be related to the development or existence of sufficient feeding habitat for the moose population. This report examines disturbed acres (e.g., areas one acre or greater in size, with damage or mortality to 25% or more of the trees on a plot), total acres of 0- to 10-year old forest land, total acres of 0- to 10-year old aspen, birch, and willow forest land and area of open water, with respect to the northeast Minnesota moose population (Table 1). We also compare moose population trends with the quantity of timber harvested from the Superior National Forest (SNF)[2], a related, but separate dataset (Table 2).

Table 1: Moose population estimates and corresponding FIA estimates of forest land in the 0- to 10-year age class, acres disturbed by harvest, wind, weather, fire, flood (includes beaver damage), human, and unknown causes, and acres of open water. Disturbances due to insects, disease, drought and domestic/wild animal browsing are excluded.

Moose survey year	Moose population estimate	Acres 0- to 10-year old forest land	Acres 0- to 10-year aspen-birch-willow	Harvested acres	Acres harvested or disturbed	Open water
2003	---	227,632	129,527	91,503	352,299	394,589
2004	---	236,889	136,712	89,629	343,311	405,490
2005	8,160	250,817	140,855	91,651	303,238	427,147
2006	8,840	241,238	126,853	89,405	236,019	393,319
2007	6,860	236,149	113,228	81,747	180,647	389,109
2008	7,890	241,834	117,737	67,467	126,584	386,185
2009	7,840	209,084	101,818	58,966	123,015	351,370
2010	5,700	206,087	106,983	71,346	194,748	349,247
2011	4,900	203,766	107,976	71,468	236,007	348,271
2012	4,230	---	---	---	---	---
2013	2,760	---	---	---	---	---

Table 2: Volume of timber harvest from the Superior National Forest.

Federal fiscal year	Volume harvested (MBF)
FY 00	66,633
FY 01	71,408
FY 02	56,509
FY 03	46,507
FY 04	55,147
FY 05	48,590
FY 06	32,445
FY 07	27,930
FY 08	32,330
FY 09	50,163
FY 10	49,851
FY 11	40,152
FY 12	50,907

We used the 2011 FIA database (Microsoft™ Access version) and geographic information system (GIS) techniques described by Miles (2009) to examine changes in variables related to the amount of primary feeding habitat available to the moose population. Findings indicated Minnesota's northeast moose habitat zone has lost 47,041 acres, or 18.8%, of 0- to 10-year old forest land from the 2005 maximum (2005 = 250,817 acres, 2011 = 203,766 acres). Similarly, disturbed acres have fallen from a 2003 high of 352,299 acres to a 2009 low of just 123,015 acres, a 65% decline. Aspen, birch, and willow forest types combined lost 39,037 acres of 0- to 10-year old forest land between 2005 and 2009 (2005 = 140,855 acres, 2009 = 101,818 acres), nearly a 28% loss. A similar trend can be seen with respect to the area of open water available to the moose population. From a 2005 high of 427,147 acres, the area of open water has declined to 348,271 acres in 2011, potentially indicating a loss of 18.5% of the moose population's aquatic feeding habitat.

The downward trend in total acres of young forest land in Table 1 is not surprising considering the aging demographics of Minnesota's forests (Kigore and Ek 2013). Figure 2 shows the age-class distribution of forest land within the primary moose habitat zone in 2005 and 2011. Although measured over a short time span, these changes reflect the long-term statewide trend toward aging forests reported by Kilgore and Ek (2013).

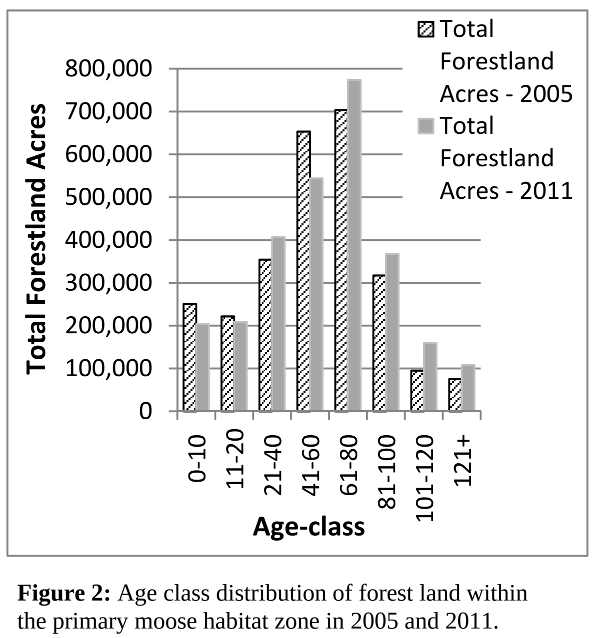

Figure 2: Age class distribution of forest land within the primary moose habitat zone in 2005 and 2011.

[2] SNF harvest data courtesy of Tim O'Hara, Minnesota Forest Industries, Duluth, MN

Importantly, estimates of changes in potential feeding habitat area do not coincide precisely with the steep decline in the moose population. Instead, a period of time would be needed for the moose population to respond to changes in its habitat. Because moose depend on body mass gained, and hence food availability, from the preceding summer to survive the winter, we assumed a 1 year expected response time to changes in the area of young forest land and aquatic feeding habitat recorded by FIA. For example, to determine the effect of forest conditions from 2005 on the moose population with an assumed response time of 1 year, we compare FIA data from 2005 with moose population data from 2006. For changes in harvested and disturbed forest land area, we assumed a longer response time. For example, the time required for disturbed areas to develop in to young forest and serve as a food source for moose will, of course, vary depending on forest type and type of disturbance. Here we assume that aspen will produce abundant suckers 1 or 2 years following harvest/disturbance (Bates et al. 1991). We further assumed an additional year for these suckers to become small saplings, and the technical passing of another year between the FIA field season and the January moose survey. Hence, for comparisons of the moose population with FIA estimates of area disturbed and/or harvested, we assumed an overall response time of 4 years.

Harvest data from the SNF is reported by FY rather than as a summary of conditions over the preceding 5 years as in FIA. Thus for comparison of the moose population with volume harvested from the SNF, we added another year to the response time assumed for disturbances reported by FIA. The response time assumed for disturbances quantified in the SNF harvest data was thus 5 years. Importantly, different numbers of comparisons (see Figures 3-7) become possible depending on the datasets used and the assumed response time.

Although trends observed in the forest and aquatic habitat of the northeast moose population appear to correspond with the downward trend in the moose population, we cannot assume a direct functional relationship. Instead, further analysis was conducted to aid in identifying potentially important relationships between the moose population and factors assumed related to availability of critical feeding habitat. A correlation matrix comparing trends in the moose population with corresponding changes in its habitat is shown in Table 3.

Table 3: Correlation matrix showing the strength of relationships (r-values) between Minnesota's primary moose population and four FIA habitat variables and one SNF variable.

Variable	Moose population estimate	0- to 10-year forest land (acres)	0- to 10-year aspen-birch-willow	Cut + disturbed acres	Open water (acres)	SNF harvested volume (MBF)
Moose population	1.0000	0.9425	0.7787	0.9321	0.9344	0.8829
0- to 10-year forest land	0.9425	1.0000	0.7925	0.9252	0.9341	0.8598
0- to 10-year aspen-birch-willow	0.7787	0.7925	1.0000	0.7109	0.9324	0.8548
Cut + disturbed acres	0.9321	0.9252	0.7109	1.0000	0.9359	0.8131
Open water (acres)	0.9344	0.9341	0.9324	0.9359	1.0000	0.9042
SNF harvested volume	0.8829	0.8598	0.8548	0.8131	0.9042	1.0000

This matrix shows a high degree of relationship between the moose population and several of the variables of interest. Of these, acres of 0- to 10-year old forest land (r = 0.94), area of open water (r = 0.93) and acres of harvested or otherwise disturbed forest land (r = 0.93) show the highest degree of correlation. Both acres of 0- to 10-year aspen-birch-willow forest land (r = 0.78) and timber harvest on the SNF (r = 0.88) also exhibit high correlation with the moose population, but to a lesser degree than the other variables.

Given the apparent relationships between the moose population and several habitat-related variables, we characterized these relationships using linear regression analysis. A regression of the moose population estimate on total acres of young forest land is shown in Figure 3. In brief, the moose population appears to be closely related to acres of all forest land in the 0- to 10-year age class reported by FIA.

Similarly, a regression of estimated moose population on total acres of forest land harvested and/or disturbed (Figure 4) also shows a close relationship between habitat conditions reported by FIA and moose population changes. This regression potentially explains more than 80% of year-to-year variation in the moose population.

The apparent relationships between the moose population and area disturbed or harvested is further strengthened though examination of changes in the moose population with respect to thousand board feet (MBF) harvested on the SNF for federal fiscal years 2000 to 2009 (Figure 5).

Regression of the moose population estimate on total acres of 0- to 10-year old aspen-birch-willow (Figure 6) also indicates a substantial relationship, potentially explaining 61% of the observed variation in the moose population. Interestingly, this is almost exactly the same dietary importance value found by Peek et al. (1976) for aspen, birch, and willow during the summer months of June to September.

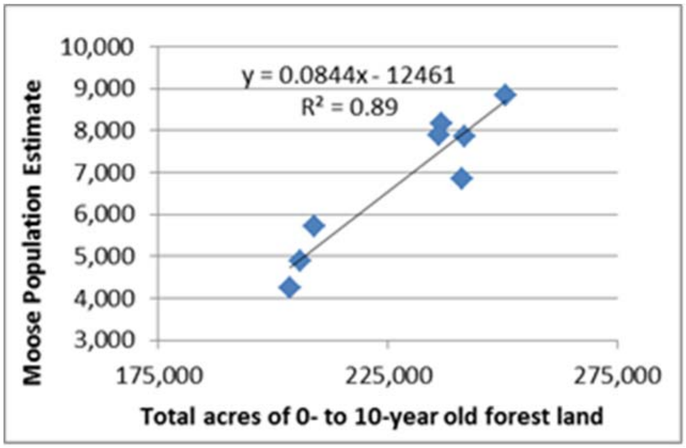

Figure 3: Regression of moose population estimate on acres of young forest land.

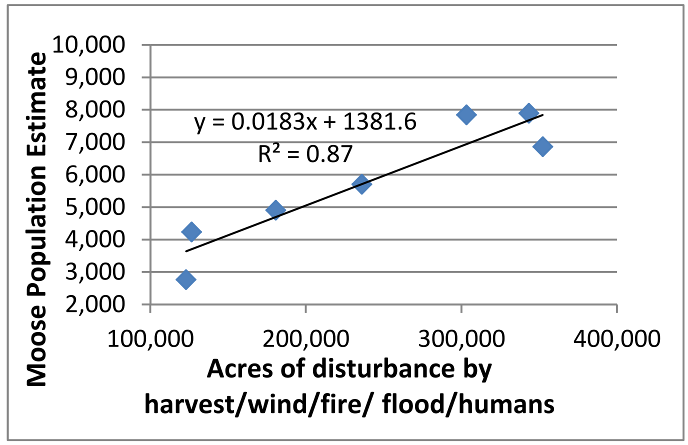

Figure 4: Regression of moose population estimate on acres of harvested and/or disturbed forest land.

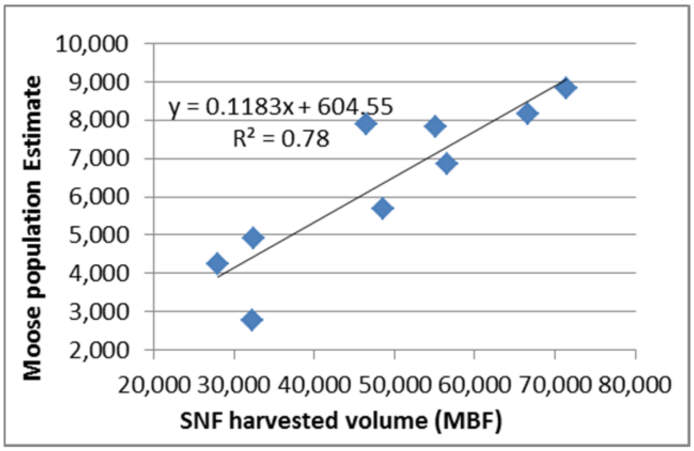

Figure 5: Regression of moose population estimate on volume harvested from Superior National Forest.

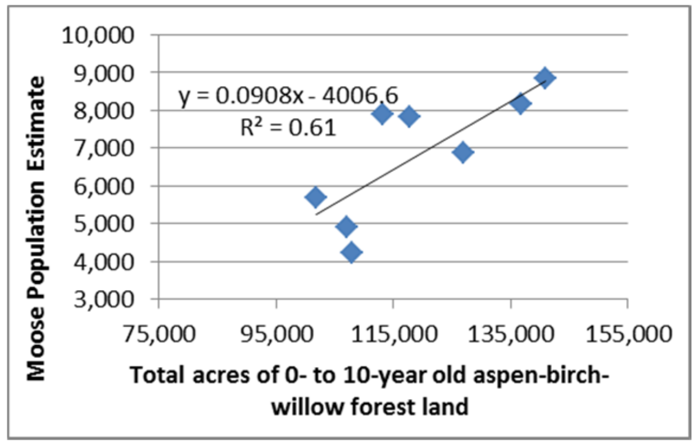

Figure 6. Regression of moose population estimate on total acres of aspen-birch-willow forest land reported by FIA 1 year prior to the moose survey.

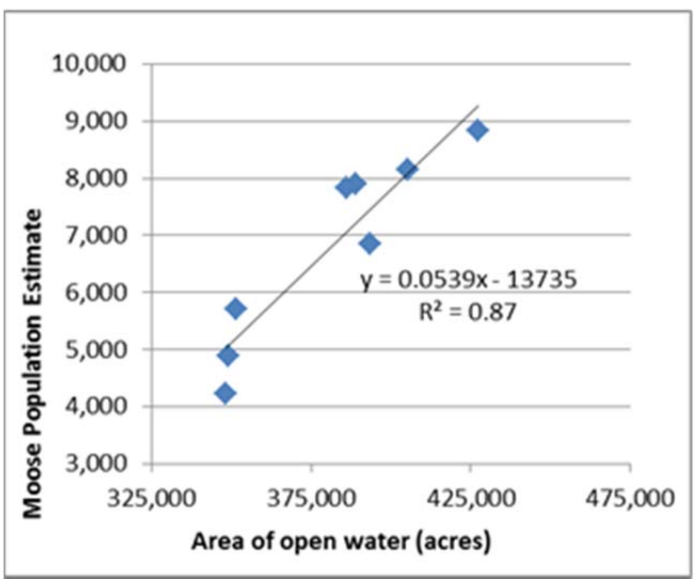

Figure 7: Linear regression of estimated moose population with respect to area of water greater than 1 acre in size or 30-feet wide.

Important aquatic feeding habitat might also be expected to show a relationship with the moose population. Regression of the moose population estimate on area of open water recorded by FIA (Figure 7) also indicates a close relationship. Minnesota's Moose Research and Management Plan (MN DNR 2011) reiterates the MAC (2009) assertion that there is no evidence habitat alone limits the moose population in Minnesota. However, this analysis of changes in the primary habitat zone suggests that such limitations are playing a role in this smaller geographic area over the time period examined.

Given the substantial loss in total area of summer feeding habitat between 2003 and 2011, it is possible that Minnesota's Moose population is experiencing pressure due to food resource limitations. Clearly, this type of reduction in available food resources will reduce the carrying capacity of a population. Hence, the situation we are observing with respect to loss of summer feeding habitat might be expected to result in a population decline. A precipitous reduction in food resources would likely exacerbate problems of disease, parasites, inclement weather, and other stressors.

Alternatively, this habitat change might also lead to greater use of less effective food resources, greater encounters with pathogens, etc. A recent study involving mortality of 89 radio-collared moose between 2002 and 2010 shows that about 74% of moose mortalities resulted from either “unknown” or “unknown-health related” causes (MN DNR 2011). Given the trends observed for summer feeding habitat, these unknown causes of mortality could be related to pressure from resource limitations.

Discussion: Given these preliminary results, it is prudent to re-examine the historical response of moose populations to forest age and age class distributions, disturbance such as fires, harvesting, and loss of wetlands and other aquatic habitat. Assuming these are important drivers of changes observed in the moose population, the logical conclusion would be that additional disturbance on the landscape would benefit the moose population. This includes increasing management of the forest age class distribution to foster more young forest and including the creation of food resources through planned disturbance. Additionally, examination of how moose use recently burned, harvested, or otherwise disturbed areas may help to establish the nature of the relationships indicated here. Recent large fire and windstorm events occurring within Minnesota’s primary moose habitat may also serve as test areas in that examination.

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