Yellowstone Science

volume 16 • number 1 • 2008

Moose Population History on the Northern Yellowstone Winter Range

Plants Exposed to High Levels of Carbon Dioxide

Economics of Wolf Recovery in Yellowstone

NPS/JIM PEACO

Three moose in the snow at Round Prairie, May 1997.

Counting Moose

I am especially fond of the moose article in this issue by Dan Tyers, as years ago I helped count moose for this project while commuting from Cooke City to Mammoth. Those early spring mornings I would occasionally count more than 20 moose between Cooke City and Round Prairie. We are pleased to be able to reprint his article on moose population history on the northern Yellowstone winter range that reports on the results of that study. This is the first article on moose that has been printed in *Yellowstone Science,* and we hope to see more.

Mike Tercek et. al's article reports on the first concerted effort to study and characterize plant communities exposed to high levels of CO_2 in Yellowstone. Their findings support the idea that Yellowstone is a valuable resource for studying the long-term effects of impending global climate change on plants and plant communities.

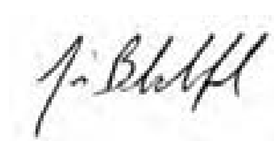
The article by John Duffield et. al reports on two primary results from a 2005 visitor survey: preferences for wildlife viewing among Yellowstone visitors and the regional economic impacts attributable to wolf presence in the park.

I want to take this opportunity to point out the announcement and Call for Papers for the 9th Biennial Scientific Conference on the Greater Yellowstone Ecosystem on page 2. *The '88 Fires: Yellowstone and Beyond* will be held September 22–27, 2008 (please note this change in dates if you have received previous information), in Jackson Hole, Wyoming. Detailed conference information is available on the International Association of Wildland Fire's website at http://www.iawfonline.org/yellowstone/.

Please also visit the redesigned Greater Yellowstone Science Learning Center website at www.greateryellowstonescience.org. It has been restructured and is now resource-centric, and we are interested in feedback. You can send comments to Tami_Blackford@nps.gov or call me at 307-344-2204.

Alert readers may have noted that *Yellowstone Science*, usually a quarterly magazine, skipped an issue in 2007. Unexpected delays put us well behind our normal production schedule and we decided to omit Vol. 15(4).

We hope you enjoy the issue.



Yellowstone Science

a quarterly devoted to
natural and cultural resources

volume 16 • number 1 • 2008

Yellowstone Science is published quarterly. Support for *Yellowstone Science* is provided by the Yellowstone Association, a non-profit educational organization dedicated to serving the park and its visitors. For more information about the association, including membership, or to donate to the production of *Yellowstone Science,* visit www.yellowstoneassociation.org or write: Yellowstone Association, P.O. Box 117, Yellowstone National Park, WY 82190. The opinions expressed in *Yellowstone Science* are the authors' and may not reflect either National Park Service policy or the views of the Yellowstone Center for Resources.

For back issues of *Yellowstone Science,* please see www.nps.gov/yell/planyourvisit/yellsciweb.htm.

Submissions are welcome from all investigators conducting formal research in the Yellowstone area. To submit proposals for articles, to subscribe, or to send a letter to the editor, please write to the following address: Editor, *Yellowstone Science,* P.O. Box 168, Yellowstone National Park, WY 82190. You may also email: Tami_Blackford@nps.gov.

Yellowstone Science is printed on recycled paper with a soy-based ink.

on the cover:
Silhouette of moose in pond.
Photo by Dan Tyers.

BOB WESELMANN

Winter visitors watch a wolf in Hayden Valley.

FEATURES

DEPARTMENTS

Call for Papers, Posters, and Special Sessions

http://www.iawfonline.org/yellowstone/call_papers.php

Fourth Announcement

International Association of Wildland Fire

The '88 Fires: Yellowstone and Beyond

And, 9th Biennial Scientific Conference on the Greater Yellowstone Ecosystem

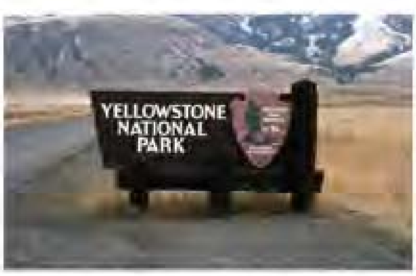
Jackson Hole, Wyoming
Sept. 22-27, 2008

For more information, visit:
www.iawfonline.org/yellowstone

International Association of Wildland Fire
P.O. Box 261
Hot Springs, SD 57747
E-Mail: iawf@iawfonline.org
888-440-IAWF (4293)
605-890-2348

The International Association of Wildland Fire and the Association for Fire Ecology in association with the 9th Biennial Scientific Conference on the Greater Yellowstone Ecosystem is sponsoring a conference to remember the events of the Yellowstone area fires of 1988. These history-making fires will provide springboards for discussions and presentations about lessons learned, fire effects, large fire management, wildland fire policy, research related to the fires, the use of fire as a management tool, and many other issues. Post-conference field trips will be scheduled as well as companion and family-friendly activities. The Co-Incident Commanders are Paul Woodard and Don Despain. Visit our web site for more details at www.iawfonline.org/yellowstone

Grand Teton National Park



Yellowstone National Park

Current Co-Sponsors

- International Association of Wildland Fire
- 9th Biennial Scientific Conference on the Greater Yellowstone Ecosystem
- Association for Fire Ecology
- Canon U.S.A.
- Grand Teton Association
- Grand Teton National Park
- Haub School & Ruckelshaus Institute of Environment & Natural Resources
- Joint Fire Science Program
- National Park Service (US)
- Tall Timbers Research Station
- The Nature Conservancy
- University of Alberta
- University of Idaho
- U. S. Forest Service
- University of Wyoming
- Wildland Firefighter Foundation
- Wildland Fire Lessons Learned Center
- Wyoming State Forestry Division
- Yellowstone Association
- Yellowstone National Park
- Yellowstone Park Foundation

12-20-2007

NPS and Bill Gabbert Photos

Moose Population History on the Northern Yellowstone Winter Range

Daniel B. Tyers

This article has been adapted with permission from Alces*, a journal devoted to the biology and management of moose* (Alces alces). *It was originally published in* Alces *42:133–149 (2006).*

OBTAINING RELIABLE demographic information on any free-ranging ungulate population is difficult, but moose are among the most difficult ungulates to monitor because they are the least social North American deer and frequently occupy habitats with poor observability (Houston 1974). In 1985, I initiated a study (Tyers 2003) to identify moose habitat needs and population status on the northern Yellowstone winter range (NYWR). I also searched agency files and archives for statements on moose populations specific to the study area. Documents not considered by other authors that provided a historical context for population monitoring were of special interest.

NPS photo by John Brandow

Figure 1. Map of the Northern Yellowstone Winter Range study area showing prominent features and sampling areas. BCSU =Bear Creek Study Unit; YPSU=Yellowstone Park Study Unit; SCSU=Slough Creek Study Unit; SBSU=Soda Butte Study Unit.

Moose population size is typically assessed in three ways: total area counts, sample estimates, and indices (Timmermann and Buss 1998). I used multiple population monitoring methods, including aerial surveys, horseback surveys, road surveys, and spatially restricted counts, to determine if vegetation changes associated with the massive 1988 wildfires in the Yellowstone ecosystem precipitated changes in moose population size. My monitoring efforts during 1985–2001 allowed me to evaluate the efficacy of several techniques for developing moose population indices and to identify reasonable techniques for monitoring future trends.

Study Area

The boundary of the NYWR is based on winter distribution of elk (Houston 1982); it includes parts of Yellowstone National Park, Gallatin National Forest, and mixed private and state lands (Fig. 1). During this study, elk were the dominant ungulate species (10,000–25,000), but mule deer (2,000–3,000), bighorn sheep (100–200), bison (500–1,000), and pronghorn antelope (100–300) also occupied the NYWR. Moose numbers were unknown, but they wintered throughout the study area in scattered areas of suitable habitat, usually at higher elevations than elk.

Vegetation on the NYWR varies from low elevation (<2,000 m) sage (*Artemisia* spp.) steppe to high elevation (3,000 m) coniferous forests. Willow (*Salix* spp.) stands occur along streams and in wet areas within forests. Lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudostuga menziei-sii*), and whitebark pine (*P. albicaulus*) are the most common conifers in the NYWR. The 1988 fires burned approximately 43,000 ha of mature conifer forest in the NYWR, converting about 30% of the NYWR's mature forest to early seral stages (Tyers 2003).

Population Monitoring Techniques

Horseback transect index. In 1947, 1948, and 1949, Montana Fish and Game Biologist Joe Gaab looked for moose each September on about 177 km of trail in what is now the Absaroka-Beartooth Wilderness. Other observers repeated his route through the Hellroaring, Buffalo Fork, and Slough Creek drainages 34 times between July and late October from 1985 to 2001 while carrying out other tasks (trail maintenance, hunter compliance checks, and outfitter camp inspections). Like Gaab, they recorded the age (calf or >1 year of age) and gender (for moose >1 year of age) of all moose sighted during daylight hours; sightings were reported as number of moose seen per day per observer group. Observer group size varied from one to six.

Road transect index. Moose sightings along the 89-km stretch of road from Gardiner to Cooke City (elevation 1,585–2,134 m), one of only two roads in the park maintained for wheeled vehicles year-round (the other is a section of U.S. Highway 191 that runs from Bozeman to West Yellowstone, Montana, through the park), were used as an index of moose distribution and abundance. Each trip was considered one sample regardless of the direction of travel. The estimated likelihood of sighting a moose each year was calculated by dividing trips with moose sightings by the total trips in a calendar year. Seasonal likelihoods of seeing a moose were determined from analysis of two-month periods (November/December, January/February, etc.). No attempt was made to standardize time of day, but at least four trips were completed every month. Data collected January 1987–December 1992 and January 1995–December 1997 were used to determine if there were differences in the number of moose seen seasonally and before and after the 1988 fires. To determine if changes between pre- and post-fire counts were consistent across the NYWR, the road was divided into five sections, each of which traversed similar vegetation and topography: (1) Gardiner to Mammoth (8.0 km), broken topography with arid grasslands and dry sagebrush unaffected by the 1988 fires; (2) Mammoth to Tower Junction (29.1 km), diverse topography where a mosaic burn pattern left open grasslands and Douglas-fir, but also mature spruce-fir forests, isolated stretches of stunted willow and aspen, and one small area of insect-killed Douglas-fir; (3) Tower Junction to Round Prairie (30.9 km), mostly a broad open valley with expanses of grasslands and sagebrush along the Lamar River where the 1988 fires did not cause much change in vegetative structure; (4) Round Prairie to Warm Creek (13.2 km) through mature lodgepole pine that was reached by the fires; (5) Warm Creek to Cooke City (8.0 km), which follows Soda Butte Creek through the largest willow stands in the transect, mature lodgepole pine and spruce-fir; only the area north of the road burned in 1988.


NPS/JIM PEACO

Bull moose near upper Soda Butte Creek.

Willow stand overflight index. Barmore (1980) identified several willow stands where moose were frequently observed during 1968–1970 aerial elk counts on the NYWR. Two of the largest, Frenchy's Meadow in the Slough Creek drainage and the willow stands along Soda Butte Creek outside the park's east boundary (Fig. 1), were sampled using fixed-wing aircraft between first light and 9 AM twice a month year-round from June 1987 to December 1990. All moose visible in and adjacent to the willow stands were counted, and seven radio-collared animals were located to determine what proportion of radio-marked animals in the drainage were in the willow stand.

Two indices of abundance were calculated for each flight: (1) the number of moose observed; and (2) the percent of available radio-collared moose seen. There were too few radio-collared animals to make valid estimates of total moose numbers in willow stands using mark-recapture methodology, but they did provide an estimate of the proportion of animals in the vicinity of the willow stands that were visible. The moose counts in willow stands were used to determine if moose numbers in favored willow stands varied among months or among years.

Daily willow stand observations. Because over-flights of willow stands were limited in number and were restricted to morning hours, ground observations were used to better delineate the time of year and time of day that moose were most easily observed in willow stands. From April 1996 through June 1997, moose were counted every half-hour daily, from first light until dark, in the willow stand between Silver Gate and Cooke City. Observations were limited to a standardized segment of the stand. These data allowed me to determine if counts from fixed-wing aircraft were optimally timed (diurnally and seasonally) and provided another potential population index. To account for the changes in number of daylight hours during the year and occasional gaps in data collection, data were standardized as number of moose seen per number of observation attempts.

Census flights. Data collected from road transects and willow stand flights suggested that moose were most observable around December 1 and May 1. Two fixed-wing aircraft were scheduled for eight survey nights in December and May 1988–1992. For the first two flights, pilots were instructed to follow transects (0.4-km parallel spacing on flat terrain and contour flying on slopes) as suggested by Gasaway et al. (1986), but this method was subsequently abandoned because of difficulties following transects due to wind and topography, limited visibility created by dense forest canopy, and observer frustration along unproductive sections. In the last six flights, searches were limited to areas where moose were most likely to be seen: the major willow stands along the park's north boundary. These stands were covered carefully on all eight flights, with one plane covering the north half and the other plane the south. Aircraft were flown about 97–113 kph at 61–152 m above the ground, depending on obstacles.

Results

Historical Documents. The earliest reports on moose located in agency files did not have consistent assessments of population status in areas immediately north of and within the park during the early 1900s (Tyers 1981). McDowell and Moy (1942) reported that "old timers" regarded moose as a rarity in drainages along the park's north boundary between 1907 and 1915, while Rush (1942) reported that moose were considered "fairly common" by 1913 in the same area. In 1920, Stevenson (1920) noted that 13 moose were wintering in two drainages currently designated as prime moose winter habitat in the NYWR (12 in Hellroaring and 1 in Buffalo Fork) and that the habitat could support more wintering moose.

In 1921, the U.S. Forest Service began more extensive patrols (non-systematic snowshoe surveys conducted December to April) to deter poaching and monitor wildlife near the park's north boundary. Crane (1922) counted 16 moose during the winter of 1921–1922. Uhlhorn (1923) estimated 25 moose the winter of 1922–1923. Johnson's (1925) report for 1924–1925 accounted for 65 moose. He noted that calf survival was high and he believed the population was increasing. By 1936, U.S. Forest Service reports (USDA 1936, McDowell and Moy 1942) expressed concern over the long-term status of willow stands in the area and with the moose population that used them. These reports noted that willow condition was positively related to elevation and negatively related to access by elk and moose. The moose population wintering along the park's north boundary in 1935–1936 was estimated at 193 (54 in the Hellroaring, 80 in the Buffalo Fork, and 60 in the Slough Creek drainage). Over-winter utilization of willow in stands used by moose was estimated at 90%, and 75% of the willows in moose winter range were described as recently dead.

Montana Fish and Game Department personnel surveyed drainages north of the park from June to October 1942 (McDowell and Moy 1942). They covered 341 miles (549 km) on foot and 1,341 miles (2,158 km) on horseback. They reported 194 unduplicated moose and suggested that moose had expanded their range into the area from the park and that the population was increasing. They noted that more than 50% of willow plants were severely damaged in some areas where ungulates wintered while little or no degradation in willow stands was observed at elevations above ungulate winter range. They called for a controlled harvest of moose to prevent further willow damage. Cooney et al. (1943) reported an increase in moose numbers in 1943 over that reported for an area covered by McDowell and Moy (1942) during their 1942 survey.

In 1942 and 1944, Montana Fish and Game Department employees conducted winter moose surveys north of the park (Parsell and McDowell 1942, McDowell and Page 1944). They found 10–15 moose utilizing major willow stands in and around Frenchy's Meadow, but were surprised at the large number of moose occupying forested slopes adjacent to the willow stands. Parsell and McDowell (1942) estimated that elk and moose had utilized 90% of current willow growth by December 1942 and reported moose foraging on alder (*Alnus incana*), Engelmann spruce, lodgepole pine, and subalpine fir.

The 1945 Montana State Legislature authorized the Montana Fish and Game Commission to "remove and dispose of moose increasing in numbers and damaging property by the limited license method" (Montana Fish and Game Department 1945). McDowell (1946) reported that 40 permits were issued to hunters who killed 35 moose in autumn 1945 across an area that included the Hellroaring, Buffalo Fork, and Slough Creek drainages north of the park and the Cooke City area (McDowell 1946). Reports of the impacts on moose varied. A Forest Service employee reported 18 moose on a survey the following winter (McDowell 1946), where Cooney et al. (1943) had counted 31 in winter 1943. McDowell believed this decrease was likely due to moose moving to the Slough Creek drainage because willow production had declined in the Hellroaring drainage. In a 1945 winter survey, McDowell and Smart (1945) noted that 90% of the current year's willow production in some stands had been utilized despite the harvest. Only 20 of 30 permits were filled in 1946 and, at the request of hunters and guides concerned about declining moose numbers, permits were further reduced in 1947 (Couey 1947).

Montana Fish and Game biologist Joe Gaab traveled about 110 miles (177 km) of trail by horseback in September of 1947, 1948, and 1949 to count moose, using the same trails each year, and recorded 106, 71, and 30 independent moose sightings, respectively (Gaab 1948, 1949, 1950). In his opinion, the moose population was in a decline that he attributed, in part, to a continued deterioration of willow stands.

NPS, YELLOWSTONE NATIONAL PARK, YELL 28637

A man holding a moose calf at Silvertip Ranch, 1929.

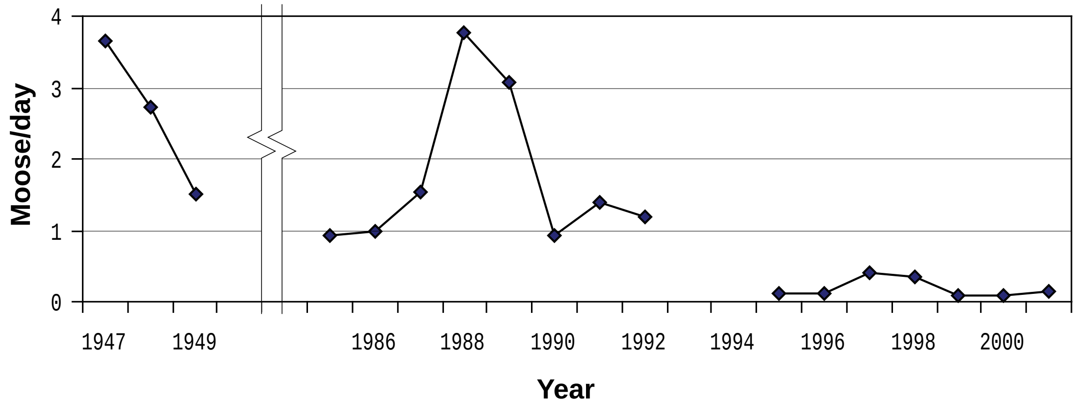


Figure 2. Average number of moose seen per party per day in horseback surveys in the Yellowstone ecosystem 1947–1949, 1985–1992, and 1995–2001. In years with more than 1 survey (1992, 1995–2001), values are the mean of multiple surveys.

Gaab stated in a 2000 interview that during the first years of quota hunting, hunters shot "many more" moose than permits allowed; he could recall anecdotes but not actual numbers (J. Gaab, Montana Fish and Game Department, personal communication).

Agency reports on moose population surveys and hunting seasons were scarce during most of the 1950s and 1960s. In 1963, Montana Fish and Game regulations listed a moose harvest quota of 45 in districts along the park's north boundary with no restrictions on age or gender. A 1964 wildlife management plan for the Gardiner Ranger District in the Gallatin National Forest noted that addressing the "moose problem" in the Hellroaring-Slough Creek area (declining moose populations and deteriorating willow stands) was a management priority (Kehrberg 1964).

A different perspective on moose population/habitat trends from the 1920s to the 1960s was provided by Tony Bliss, co-owner of a small parcel in Slough Creek near the large willow stand in Frenchy's Meadow. He summarized his observations of moose population trends (Kehrberg 1964): "1926 to 1935—lots of tall willow and few moose, elk and moose fed hay by Yellowstone Park in lower Slough Creek; 1935 to 1945—more moose, still lots of willow, feeding ended about 1936; 1941 to 1945—away at war; 1955 to 1962—fewer and fewer moose and extensive loss of tall willow."

Indices of hunter effort (such as hunting days per moose harvested) suggest that the moose population remained relatively stable through the 1970s and early 1980s (T. Lemke, Montana Fish, Wildlife and Parks, personal communication). When this project began in 1985, the moose quota for hunting districts north of the park was 55 with no restriction on age or gender. Quotas were reduced and restrictions implemented following extensive fires in the Yellowstone area in 1988. In 1990, the Montana Department of Fish, Wildlife and Parks issued 42 harvest permits (23 antlered and 19 antlerless) (T. Lemke, Montana Fish, Wildlife and Parks, personal communication). The quota was reduced to 21 (13 antlered, 8 antlerless) in 1991 in response to population declines observed during this study and to 13 in 1996 (all antlered).

Population Indices

Horseback transect index. The number of moose observed per day on the 177-km transect in the Absaroka-Beartooth Wilderness declined between 1947 and 2001 (Fig. 2). Only in 1988 and 1989 did sighting rates approach those reported by Gaab (1948, 1949, 1950). The total number of moose seen on surveys also declined. Gaab's counts averaged 69.0 (SD = 38.0, $n = 3$). Total counts in the 1980s prior to 1988 averaged 15.0 (SD = 4.4, $n = 3$). Post-fire counts in the late 1980s averaged 44.5 (SD = 6.4, $n = 2$). Counts in the 1990s averaged 6.0 (SD = 5.8, $n = 20$), and counts in 2000–2001 averaged 2.0 (SD = 2.8, $n = 9$).

Road transect index. The overall likelihood of seeing at least one moose while traveling the Gardiner to Cooke City road ($n = 1{,}020$) was 0.26 during the nine years data were collected (1987–1992 and 1995–1997). The likelihood of seeing at least one moose per trip was highest during May/June, when moose were observed on 50.4% of trips, and lowest during September/October, when moose were observed on only 7% of trips. Because numbers of trips were relatively consistent across seasons and years, analysis by section and of pre- and post-fire effects were based on pooled data for individual years.

The likelihood of sighting a moose during a drive between Gardiner and Cooke City was highest in 1989 (49%) and lowest in 1995 (2%). There was a statistically significant decline in moose sightings after the 1988 fires when a lag effect of a year was included in the test. No moose were seen in the Gardiner to Mammoth section either before or after the 1988 fires (Fig. 3). In the Mammoth to Roosevelt Junction section, moose were observed on 15% of trips before the fires but only 4% after the fires. In the Roosevelt Junction to Round Prairie section, the sighting incidence was 8% pre-fire compared to 1% post-fire. In the Round Prairie to Warm Creek section, incidences of sighting were similar before and after the 1988 fires (5% and 6%, respectively). The percentage of trips in which moose were observed in the Warm Creek to Cooke City section declined from 19% pre-fire to 14% post-fire, but this difference was not significant.

Figure 3. Likelihood (%) of seeing at least 1 moose while traveling the five sections of road between Gardiner and Cooke City, Montana, prior to and after the 1988 Yellowstone fires. Section 1 = Gardiner to Mammoth (8.0 km); Section 2 = Mammoth to Tower Junction (29.1 km); Section 3 = Tower Junction to Round Prairie (30.9 km); Section 4 = Round Prairie to Warm Creek (13.2 km); Section 5 = Warm Creek to Cooke City (8.0 km).

Willow stand over-flight index. The average number of moose seen per flight did not vary significantly among the four survey years (1987–1990). The highest average number seen per flight was in 1988 (4.9), followed by 1989 (3.1). Results were the same for 1987 and 1990 (1.9 moose per flight). The month with the highest average number seen per flight was November (9.3), followed by December (8.6), and May (7.6). The percent of radio-collared moose available for observation (i.e., alive in the drainage with operational radio-collars) seen per flight was not significantly different among years. Means for years varied from 0 (1987) to 12% (1988). Although no significant differences in the percent of collared moose observed by month were detected, the highest percent seen was in May (18.0%), followed by December (13.8%), and November (13.1%). This implies that in the late spring and early winter periods when moose were most visible, less than 20% of moose in a drainage were likely to be seen in fixed-wing surveys.

Daily willow stand observations. Daily counts of moose in a willow stand near Cooke City were made at half-hour intervals for 15 months. The mean number of moose seen per half-hour of daylight varied significantly among months. The highest average number seen per half-hour was in June 1997 (0.9), followed by December 1996 (0.6), and May 1996 (0.6). Average counts were highest between 0600–0930 hours and 2030–2130 hours. When times were adjusted for seasonal changes in daylight, moose were most visible in the hours near sunrise and sunset. In late spring and early winter when most moose per half-hour were recorded, the optimum times for observation were: May, 0600–0700; June, 0600 and 2130; November, 0730; and December, 0830.

Census flights. The north and south halves of the study area could not be covered on all flights, but moose sightings decreased sharply between November 1989 and May 1990 (Fig. 4). The highest number seen on a single survey was 59 in November 1989. The lowest count (13) occurred in May 1992.

Discussion

Population History

Long-term studies in North America support the idea that moose populations erupt, crash, and then stabilize at various densities depending on prevailing ecological conditions. Geist (1974) attributed this pattern to a response by moose populations to changes in habitat quality. In his opinion, over the species' evolutionary history, moose have typically occupied limited areas of permanent habitat in low densities. When fire has created transient habitat, they have rapidly colonized these areas and reached comparatively high densities. Population eruptions can also be triggered by plant succession following logging or by reduction of hunting or predation pressure if these were holding a population at low densities (Mech 1966, Peek et al. 1976, Messier 1991).

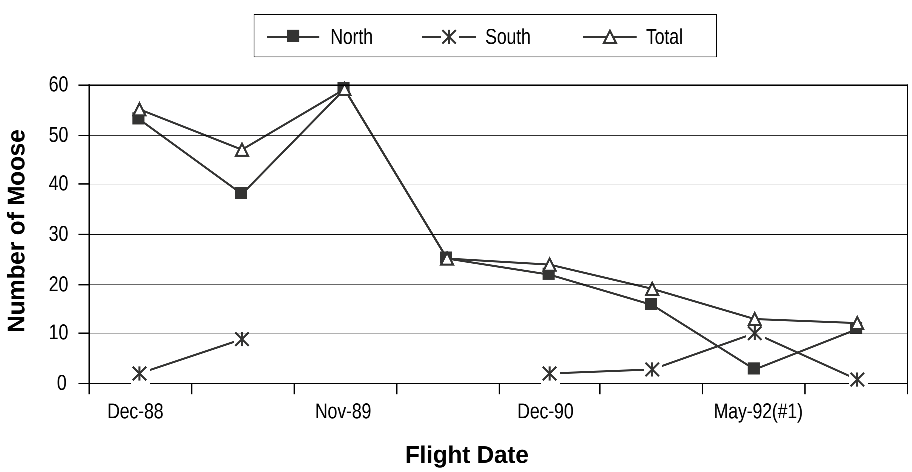


Figure 4. Number of moose seen during aerial surveys of the complete Northern Yellowstone Winter Range (NYWR) and in two segments of the NYWR (north and south of the Yellowstone River) from December 1988 to May 1992.

NPS/BRAIN HARRY

Moose evidently colonized the NYWR in the 1800s and initially increased in numbers in a manner similar to that occurring in other areas in North America, but the population did not respond positively to the 1988 forest fires as might have been expected based on Geist's (1974) theory and moose population responses to fire in Alaska (Schwartz and Franzmann 1989).

When moose arrived on the NYWR, they encountered an environment in transition due to European settlement. Human predation was initially important and then curtailed. Forest succession was altered with attempts to suppress fires. Agency reports suggest that moose had expanded into all suitable habitats on the NYWR by the middle of the twentieth century. Reports of negative impacts on willow stands (USDA 1936, McDowell and Moy 1942) indicate that at least in some drainages moose numbers may have stabilized or over-populated the area by the late 1930s. Regulated hunting, introduced in the 1940s to alleviate damage to willow stands on the NYWR, may have ended a population eruption triggered by a ban on hunting that dated from the early 1900s and by concerted efforts to eliminate predators from the Yellowstone ecosystem during the 1910s–1930s. Because no systematic monitoring of moose populations was done from 1950 to 1985, the population trends during that period will never be known, but the horseback surveys conducted from 1985 to 1987 produced similar moose sighting rates as Gaab's 1949 survey, perhaps indicating that the population remained relatively stable from 1949 to 1987.

The 1988 Yellowstone fires negatively affected moose habitat and population levels at a landscape scale. In the winter of 1988–1989 and the summer of 1990, some indices produced exceptionally high values for moose numbers. By the winter of 1990–1991, however, all indices indicated substantial declines in moose. In areas where fire effects were severe, the reduction in numbers was greater than in areas where fire impacts were minimal. No sign of population recovery was evident through 2001, the last year in which data for one or more indices was collected.

Population Monitoring

The horseback surveys, road transects, and aerial surveys identified a decline in moose numbers following the 1988 fires. The willow over-flight index did not reveal any significant decline from 1987 to 1990, but indicated a similar pattern of change (relatively low in 1987, high in 1988 and 1989, low in 1990) to that provided by the horseback survey and the road transect.

The horseback transect index had high sighting numbers per day in 1988 and 1989 and consistent, very low sighting rates from 1995 to 2001. The high numbers of moose seen in 1988 and 1989 were probably due to increased sightability resulting from the burning of climax forests and to the movement of moose into unburned willow stands along the route. Data on moose movement and survival (Tyers 2003) collected from 1996 to 2001 reflect a real decrease in moose numbers. The horseback transect index probably under-represented actual moose numbers before 1988.

The road-transect index generally mirrored results from the horseback survey; an increase in sighting likelihood in 1988–1989 and a decline thereafter. The decrease was most pronounced on the section where forests were most affected by fire (Mammoth to Round Prairie) and least pronounced where areas bisected by the road were not burned. The post-fire decline on the road transect was apparent as early as 1990 while values from the horseback survey for 1990–1992 were similar to values for 1985–1987. This may indicate that the road survey was more sensitive to population changes than was the horseback survey or it may be only an artifact of sampling greater areas of burned terrain or more marginal habitat on the road transect than on the horseback survey.

Systematic aerial surveys were not initiated until the winter after the 1988 fires and were discontinued in 1992, when moose sightings were extremely low and limited to a few large willow stands. Variability of moose counts on flights within the same stand, season, and year was so high that no significant decline was detected until 1990.

The efficiency of indices employed in this study could potentially be improved by timing sampling to optimize moose sightability. February and March are considered the most difficult months to find moose because they are more likely to be in dense cover. Sightability in November and December may be higher because moose form larger groups and have stronger preferences for vegetation with low, open canopies. This has been found in Alaska (Peek et al. 1974, Gasaway et al. 1986), Minnesota (Peek et al. 1974, Mytton and Keith 1981), Michigan (Peterson and Page 1993), Alberta (Lynch 1975), and Ontario (Bisset and Rempel 1991). However, 34 consecutive years of aerial surveys in Saskatchewan were successfully conducted in January and February (Stewart and Gauthier 1988).

In Yellowstone, Barmore (1980) found seasonal variation in moose sightability during attempts to count moose incidental to elk distribution flights from 1968 to 1970. He concluded that moose were difficult to observe in this environment. Most of the moose Barmore saw were associated with willow, and he was most successful at finding them there in May, early June, and December. In my study, moose were more likely to be observed from fixed-wing aircraft in early winter (November and December) and May than at other times of year. A similar seasonal pattern was observed during intense ground sampling in willow stands near Cooke City.

Time of day also may influence visibility of moose (LeResche and Rausch 1974). Timmermann (1974) suggested from 1000 to 1400 hours as the optimal time for moose aerial surveys in Ontario. Peterson and Page (1993) preferred to survey moose in Minnesota just after sunrise. Data from half-hour counts in a willow stand near Cooke City for this study indicated that moose sightings in the Yellowstone area were most likely in early morning (0600–0930 hours) and late evening (2030–2130 hours).

Would aerial surveys in early winter or late spring, concentrated in early morning hours, provide an efficient means of monitoring moose associated with the NYWR at current population levels? Aerial surveys of moose have produced mixed results (LeResche and Rausch 1974, Stevens 1974, Novak 1981), but counting moose on winter ranges from aircraft is still considered the most practical method for estimating moose numbers over large areas in North America (Timmermann and Buss 1998). In some areas, aerial surveys are very efficient. Edwards (1954) reported that 78% of moose located during intense ground surveys were seen from the air. Evans et al. (1966) reported that observers in fixed-wing aircraft saw 94% of moose observed by crews in helicopters. Gasaway et al. (1978) noted that 91% of radio-collared moose available to be seen were found during intensive searches from the air.

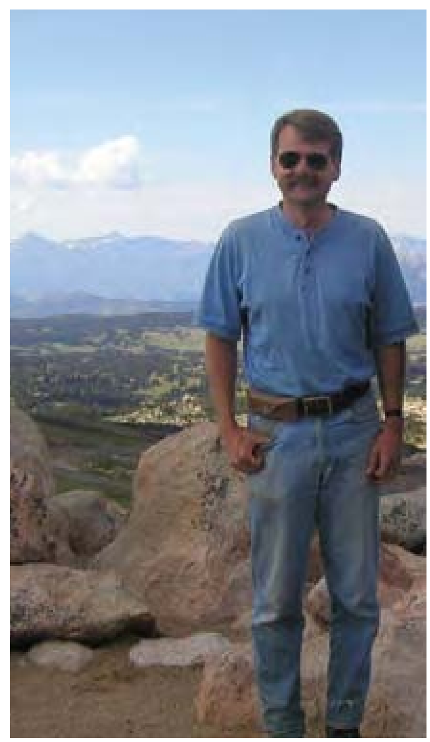
It is unlikely that fixed-wing aircraft used in a systematic survey of the NYWR would locate a high proportion of the moose population. Even in the months with highest sightability (November, December, and May), less than 20% of radio-collared moose known to be in drainages containing preferred willow stands were observed from fixed-wing aircraft. High variability in both percent of radio-collared animals observed and in total animals observed indicates that using a large number of radio-collared moose to develop a sightability model, an expensive option that has had utility in estimating elk numbers (Samuel et al. 1987), is not likely to yield good results given the low density and low visibility of moose associated with the NYWR. Low density and low sightability would also limit the utility of helicopter surveys.

Developing an index of moose abundance using fixed-wing counts in early winter or late spring and limited to early morning hours, or perhaps even ground counts of moose in specific willow stands, does have potential for tracking changes in the moose population associated with the NYWR. Boundaries of key willow stands are easily identified from the air or ground and cover relatively small areas (most are <40 ha). Counts of moose along the highway between Gardiner and Cooke City during early winter and late spring may also provide a relatively cheap means of monitoring population trends. Summer–autumn horseback surveys, especially when costs can be mitigated by combining counts with required tasks such as trail maintenance and hunter management, may also be useful in tracking trends in moose populations. Although indices are less intellectually satisfying as a base for management of moose than are statistically valid population estimates, they may provide a reasonably reliable mechanism for determining population trends in situations where logistical constraints preclude accurate estimates of moose numbers.

YS

Acknowledgements

This project was conducted at the request of the Northern Yellowstone Cooperative Wildlife Working Group, which includes Montana Fish, Wildlife and Parks, Yellowstone National Park, Gallatin National Forest, and the U.S. Geological Survey Northern Rocky Mountain Research Center. Funding was provided by Gerry Bennett, Dick Ohman, Jim Wood, John and Kathryn Harris, Safari Club International Montana Chapter, Gallatin National Forest, Montana Fish, Wildlife and Parks, and Yellowstone National Park. I also wish to thank those who helped make this study possible by providing essential help in the field, office, or in analysis: Phyllis Wolfe, Tami Blackford, John Varley, Frank Singer, Tom Lemke, Sam Reid, Patrick Hoppe, Steve Yonge, Jeremy Zimmer, Par Hermansson, Sarah Coburn, Reyer Rens, Kim Olson, Maria Newcomb, Tom Nelson, Rob St. John, Tris Hoffman, Ellen Snoeyenbos, Anna Carin Andersson, Bill Chapman, Tom Drummer, Bill Gasaway, Emma Cayer, Vanna Boccadori, Mark Petroni, Tom Puchlerz, Lynn Irby, Jack Taylor, Tom McMahon, Harold Picton, Peter Gogan, Kurt Alt, Harry Whitney, Mike Ross, Kelsey Gabrian, and Randy Wuertz.



COURTESY OF AUTHOR

Dan Tyers is the Gardiner District wildlife biologist for the U.S. Forest Service in Gardiner, Montana. He holds a PhD in wildlife biology from Montana State University–Bozeman.

References

Barmore, W. J. 1980. Population characteristics, distribution, and habitat relationships of six ungulate species in Yellowstone National Park. Final Report. National Park Service, Yellowstone National Park, Mammoth Hot Springs, Wyoming, USA.

Bisset, A. R., and R. S. Rempel. 1991. Linear analysis of factors affecting the accuracy of moose aerial inventories. *Alces* 27:127–139.

Cooney, R. F., W. K. Thompson, and L. E. McDowell. 1943. Montana moose survey Slough Creek-Hellroaring Unit, Supplement No. 2. Montana Fish and Game Department, Wildlife Restoration Division. Unpublished Report. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

Couey, F. M. 1947. Summary of Montana's 1946 moose kill. Montana Fish and Game Department, Wildlife Restoration Division. Unpublished Report. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

Crane, H. M. 1922. Report on game protection and patrol of winter elk range, winter of 1921–1922. Unpublished Report. U.S. Forest Service, Gallatin National Forest, Gardiner Ranger District, Gardiner, Montana, USA.

Edwards, R. Y. 1954. Comparison of aerial and ground census of moose. *Journal of Wildlife Management* 18:403–404.

Evans, C. D., W. A. Trover, and C. J. Lensink. 1966. Aerial census of moose by quadrant sampling units. *Journal of Wildlife Management* 30:767–776.

Gaab, J. E. 1948. Absaroka Unit moose survey-1947. Montana Fish and Game Department, Wildlife Restoration Division. Unpublished Report. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

___. 1949. Absaroka Unit moose survey-1948. Montana Fish and Game Department, Wildlife Restoration Division. Unpublished Report. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

___. 1950. Absaroka Unit Moose Survey-1949. Montana Fish and Game Department, Wildlife Restoration Division. Unpublished Report. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

Gasaway, W. C., S. D. Dubois, S. J. Harbo, and D. G. Kelleyhouse. 1978. Preliminary report on accuracy of aerial moose surveys. Proceedings of the North American Moose Conference and Workshop 14:32–55.

___, ___, D. J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska. Number 22. University of Alaska, Fairbanks, Alaska, USA.

Geist, V. 1974. On the evolution of reproductive potential in moose. *Naturaliste Canadien* 101:527–537.

Houston, D. B. 1974. Aspects of the social organization of moose. Pages 690–696 in V. Geist and F. Walther, editors. *The Behavior of Ungulates and Its Relation to Management.* Volume II. Publication 24. Union of Conservation, Nature, and Natural Resources, Morges, Switzerland.

___. 1982. The Northern Yellowstone Elk: Ecology and Management. McMillian, New York, New York, USA.

Johnson, C. H. 1925. Report of game studies and game protection on the Park District of the Absaroka National Forest, winter of 1924–25. Unpublished Report. U.S. Forest Service, Gallatin National Forest, Gardiner Ranger District, Gardiner, Montana, USA.

Kehrberg, E. V. 1964. Wildlife management plan, Gardiner Ranger District. Unpublished Report. U.S. Forest Service, Gallatin National Forest, Gardiner Ranger District, Gardiner, Montana, USA.

LeResche, R. E., and R. A. Rausch. 1974. Accuracy and precision of aerial moose censusing. *Journal of Wildlife Management* 38:175–182.

Lynch, G. M. 1975. Best timing of moose surveys in Alberta. Proceedings of the North American Moose Conference and Workshop 11:141–152.

McDowell, L. E. 1946. Report on 1945 moose season to date. Montana Fish and Game Department, Wildlife Restoration Division. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

___, and M. Moy. 1942. Montana moose survey, Hellroaring-Buffalo Fork-Slough Creek unit. Montana Fish and Game Department, Wildlife Restoration Division. Unpublished Report. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

___, and P. Page. 1944. Montana moose Survey Slough Creek-Hellroaring Unit. Supplement No. 3. Montana Fish and Game Department, Wildlife Restoration Division. Montana Department of Fish, Wildlife, and Parks, Region 3, Bozeman, Montana, USA.

___, and R. Smart. 1945. Montana moose survey Slough Creek-Hellroaring Unit. Supplement No. 4. Montana Fish and Game Department, Wildlife Restoration Division. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

Mech, L. D. 1966. The wolves of Isle Royale. Fauna Service No. 7. National Park Service. U.S. Government Printing Office, Washington, D.C., USA.

Messier, F. 1991. The significance of limiting and regulating factors on the demography of moose and white-tailed deer. *Journal of Animal Ecology* 60:377–393.

Montana Fish and Game Department. 1945. Foreword to moose hunter harvest surveys. Unpublished Report. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

Mytton, W. R., and L. B. Keith. 1981. Dynamics of moose populations near Rochester, Alberta, 1975–1978. *Canadian Field-Naturalist* 95:39–49.

Novak, M. N. 1981. The value of aerial inventories in managing moose populations. *Alces* 17:282–315.

Parsell, J. and L. McDowell. 1942. Montana Moose Survey Slough Creek-Hellroaring Unit. Supplement No. 1. Montana Fish and Game Department, Wildlife Restoration Division. Montana Department of Fish, Wildlife and Parks, Region 3, Bozeman, Montana, USA.

Peek, J. M., R. E. LeResche, and D. R. Stevens. 1974. Dynamics of moose aggregation in Alaska, Minnesota, and Montana. *Journal of Mammalogy* 55:126–137.

___, D. L. Urich, and R. J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. *Wildlife Monographs* 48.

Peterson, R. L., and R. E. Page. 1993. Detection of moose in mid-winter from fixed-wing aircraft over dense forest cover. *Wildlife Society Bulletin* 21:80–86.

Rush, W. 1942. Agency correspondence: W. M. Rush to L. McDowell and M. Moy. U.S. Forest Service, Gallatin National Forest, Gardiner Ranger District, Gardiner, Montana, USA.

Samuel, M. D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. *Journal of Wildlife Management* 51:622–630.

Schwartz, C. C., and A. W. Franzmann. 1989. Bears, wolves, moose, and forest succession, some management considerations on the Kenai Peninsula, Alaska. *Alces* 25:1–10.

Stevens, D. R. 1974. Rocky Mountain elk-Shiras moose range relationships. *Naturaliste Canadien* 101:505–516.

Stevenson, D. H. 1920. Hellroaring-Slough Creek game patrols, 1919–20. Unpublished Report. U.S. Forest Service, Gallatin National Forest, Gardiner Ranger District, Gardiner, Montana, USA.

Stewart, B. R., and D. A. Gauthier. 1988. Temporal patterns in Saskatchewan moose population, 1955–1988. *Alces* 24:150–158.

Timmermann, H. R. 1974. Moose inventory methods: a review. *Naturaliste Canadien* 101:615–629.

___, and M. E. Buss. 1998. Population harvest and management. Pages 559–616 in A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington D.C., USA.

Tyers, D. B. 1981. The condition of the northern Yellowstone winter range in Yellowstone National Park: A discussion of the controversy. MSc Thesis, Montana State University, Bozeman, Montana, USA.

____. 2003. Winter ecology of moose on the Northern Yellowstone Winter Range. PhD Thesis, Montana State University, Bozeman, Montana, USA.

Uhlhorn, C. F. 1923. Winter game conditions of the Hellroaring, Buffalo Fork, and the Slough Creek drainages, Absaroka National Forest, winter of 1922–1923. Unpublished Report. U.S. Forest Service, Gallatin National Forest, Gardiner Ranger District, Gardiner, Montana, USA.

(USDA) U.S. Department of Agriculture. 1936. Absaroka winter game studies 1935–1936. Unpublished Report. U.S. Forest Service, Gallatin National Forest, Livingston Ranger District, Livingston, Montana, USA.