Alaska Department of Fish and Game
Division of Wildlife Conservation
Federal Aid in Wildlife Restoration
Research Progress Report

Lower Susitna Valley Moose Population Identity and Movement Study

Illustration by Sue Arthur

by
Ronald D. Modaferri
Project W-23-4
Study 1.38
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SUMMARY

I counted numbers of moose and studied movements of moose radio-marked in 7 alpine habitat postrut concentration areas in the lower Susitna River Valley in Southcentral Alaska from October 1985 to October 1990. Moose count and movement data gathered from April 1980 to May 1986 during other moose studies I conducted in lowland riparian winter concentration areas along the Susitna River floodplain were updated with moose movement data gathered through October 1990. Data provided by the U.S. National Climatic Data Center on snowpack depth at Wasilla, Willow, Talkeetna, Skwentna and Chulitna River Lodge in the lower Susitna River Valley were selectively summarized trimonthly for October-April, 1970-71 and 1981-90. Data provided by the Alaska Railroad Corporation (ARC) on moose killed by train collisions over 470 miles of railway from Seward to Fairbanks, between 1963 and 1990 were analyzed for year, season, month and location. This report interrelates data on moose numbers in alpine postrut concentration areas, moose numbers in lowland riparian winter concentration areas, movements of radio-marked moose, snowpack depth, and numbers of moose killed by trains. Management implications of findings are discussed.

Movement data obtained from 5,740 point locations of 69 radio-marked moose indicated that migration patterns of moose populations in Game Management Subunits 14A, 14B and 16A differed significantly from migration patterns previously assumed by the Alaska Department of Fish and Game (ADF&G). Moose fall-winter migrations exceeding 25 km were not uncommon; some migrations exceeded 45 km. Easterly fall-winter migrations of Subunit 16A fall resident moose to winter concentration areas in the Susitna River floodplain and the transportation corridor in Subunit 14B, commonly traversed north-south oriented drainages where other moose concentrated in winter. Fall-winter migrations resulted in "mixing" of Subunits 14A, 14B and 16A moose populations in winter. Radio-marked fall resident Subunit 16A moose migrated to Subunits 14A and 14B in

winter. Marked fall resident Subunit 14B moose migrated to Subunit 14A during winter; marked females migrated to Subunit 16A before calving.

Movement patterns for groups of moose marked in 7 alpine habitat postrut concentration areas between Bald Mountain Ridge in Subunit 14A and Sunshine Mountain in Subunit 14B exhibited similarities within groups and differences between groups. Many moose from the Willow Mountain postrut area in Subunit 14B and all moose from the Bald Mountain Ridge and Moss Mountain postrut areas in Subunit 14A migrated south to winter concentration areas near Palmer and Wasilla in Subunit 14A. Moose from postrut concentration areas north of Willow Mountain generally migrated west toward less remote, low elevation winter concentration areas in human settlements, the Susitna River floodplain and the transportation corridor in Subunit 14B. Marked moose from Brownie Mountain postrut area did not migrate west to low elevation winter concentration areas near the transportation corridor in winter. They generally remained near that postrut area or migrated east to more remote areas up the Kashwitna drainage in Subunit 14B.

Moose count data collected in 7 alpine habitat postrut concentration areas on 37 surveys in the Talkeetna Mountains during October 1985-March 1990 exhibited seasonal and yearly variation in moose numbers that could affect quality of data obtained on standardized ADF&G moose sex/age composition and population trend surveys conducted in Subunits 14A and 14B. Number of moose in postrut concentration areas was related to snowpack depth which affected onset and magnitude of moose fall-winter migrations to winter areas. In general, moose numbers in alpine habitat postrut concentration areas increased during October. Numbers peaked between late October and early December and then decreased to low levels between late December and mid-April. Large seasonal and yearly differences in moose numbers were documented and were related to snowpack depth. Early and late snowpack accumulations were associated with early and late declines in moose numbers at postrut concentration areas. Large numbers of moose remained in alpine habitat postrut concentration areas during a winter when snowpack rarely exceeded 40 cm. Few moose were counted in postrut areas in mid-November following an exceptionally early and deep snow.

Number of moose counted on 34 surveys in winter concentration areas in the Susitna River floodplain between Talkeetna and Devil Canyon during December 1981-April 1985 varied by season and year and were related to snowpack depth data. Timing and magnitude of moose fall-winter migrations affected numbers of moose in winter concentration areas. Moose migrations were associated with snowpack depth. Early and late snowpack accumulations, respectively, correlated with early and late arrival of migratory moose in winter concentration areas. Small and large numbers of moose were counted in winter concentration areas when snowpack was relatively shallow and deep. Few moose were counted in winter concentration areas during a winter when snowpack depth seldom exceeded 40 cm.

Data on timing and location of 3,075 moose reported killed by collisions with trains in 470 mi of Alaska railroad right-of-way between Seward and Fairbanks during 1963-90 were analyzed in relation to data on timing and depth of snowpack accumulation, moose occurrence in postrut and winter concentration areas and location of moose winter concentration areas. Number of moose killed by trains, timing and depth of snowpack accumulation, and number of moose in postrut and winter concentration areas were analyzed for interrelationships. Most moose were killed by trains in winter, January-March. Trains killed few moose during May-October. However, few moose were killed by trains in winter when snowpack depth was less than 40 cm. As with number of moose in postrut and winter concentration areas, number of train killed moose also varied in relation to snowpack depth. Train moose kill rates were highest in years with early and deep snowpack and lowest or insignificant when snowpack was shallow. Moose kill rates were always highest in locations where moose winter concentration areas overlapped the railway corridor. Relative to the entire railway, moose kill rates were exceptionally high in the 90 mi section of railway in Subunit 14B. In Subunit 14B, the railway overlaps major moose winter concentration areas in the Susitna River floodplain, among human developments and settlements and in the Parks Highway and Alaska Railway corridors. Moose killed by trains in Subunit 14B in winter included migratory Subunit 16A and 14B fall resident moose.

Numbers of moose counted on 17 surveys in winter concentration areas in the Susitna River floodplain between the Yentna River and Talkeetna during October 1982-March 1984 were analyzed in relation to data on snowpack accumulation and number of moose killed by trains. Early and late yearly peaks in number of moose in winter concentration areas were associated with early and late snowpack accumulation and elevated rates for moose killed by trains during November-December and April.

Snowpack depth was identified as an important factor affecting moose fall-winter migrations and moose use of winter concentration areas. In other studies, winter concentration area snowpack depth correlated with calf recruitment in migratory and non-migratory female moose. In this study, fall resident radio-marked moose in Subunits 14B and 16A migrated long distances to winter concentration areas in the Wasilla vicinity in Subunit 14A where trimonthly snowpack depth was commonly less than 40 cm and seldom exceeded 70 cm. In addition to relatively light snowfall, strong winds and occasional above freezing temperature lessened snowpack depth in this area. Perennial shallow snow conditions make the Wasilla vicinity a highly desirable moose winter concentration area in the lower Susitna Valley. I hypothesized that migratory and non-migratory female moose that use the Wasilla vicinity in winter have higher calf recruitment rates than females that use other winter areas in the lower Susitna River Valley where snowpack is deeper. Because snowpack depth is an important quality of moose winter concentration areas, land managers should consider managing lands in regions where snowpack depth is shallow as moose winter concentration areas.

If moose numbers in alpine postrut concentration areas are used as an index to assess moose population trends in Subunits 14A and 14B, then surveys must be conducted before the onset of moose fall-winter migrations. Likewise, the status of Subunits 14A, 14B and 16A fall hunted moose populations cannot be assessed accurately by surveys in winter concentration areas because these moose populations are "mixed" after fall-winter migrations.

Some marked fall resident Subunit 14B female moose migrated to Subunit 16A before calving. Movement of female moose from Subunit 14B to Subunit 16A in spring will affect subunit specific data obtained on "parturition" counts.

Subunit 16A fall resident moose migrated to the transportation corridor in Subunit 14B in winter and were vulnerable to hunters and trains. Consequently, fall-winter migrations of moose from Subunit 16A to 14B must be considered when implementing winter moose hunts and designing management plans to reduce the number of train-killed moose.

In Subunits 14A and 14B, moose fall-winter migration patterns varied with postrut concentration area. Consequently, vulnerability of moose to collisions with trains and to hunters in winter were also related to postrut concentration area. Site specific data on fall-winter moose migration patterns are a prerequisite for knowledgeably designing management plans to reduce the train moose kill or to harvest moose in winter.

Key Words: Moose, *Alces alces*, Susitna Valley, radiotelemetry, habitat, movements, aerial survey, counts, population identity, Southcentral Alaska, subunits, snowpack depth, concentration areas, railroad, migration.

CONTENTS

BACKGROUND

Before statehood (1959), the Susitna River Valley was ranked as the most productive moose (*Alces alces*) habitat in the territory (Chatelain 1951). Today, the innate potential of this area as moose habitat is unsurpassed throughout the state.

The lower Susitna Valley is the focal point of more development than any other region in the state. Proposed and progressing projects involving grain and crop agriculture, dairy and grazing livestock, commercial forestry and logging, personal-use cutting of firewood, mineral and coal mining, land disposals, wildlife ranges and refuges, human recreation, human settlement, urban expansion, development of the highway and railway systems, and increased railroad traffic in the region may greatly detract from the area's potential to support moose.

Although development and associated activities may reduce the moose population in the Susitna Valley, resource users have demanded increased allocations to satisfy consumptive and nonconsumptive uses. This conflict created a tremendous need by local, state, and federal land and resource management agencies for timely and accurate knowledge about moose populations in Subunits 13E, 14A, 14B, 16A, and 16B. These informational needs will intensify in response to (1) increased pressures to develop additional lands, (2) increased numbers of users and types of resource use, and (3) more complex systems for allocating the resource to potential users.

The Division of Wildlife Conservation lacks necessary information about moose populations in the lower Susitna Valley to accurately assess the ultimate impacts from these increasing resource demands. The Division is unable to dispute or condone specific demands, or provide recommendations to regulate and minimize negative impacts on moose populations or habitat. The Division must be knowledgeable about moose population behavior to mitigate unavoidable negative impacts to moose populations or their habitat.

Because major decisions on land use and resource allocation in the lower Susitna Valley are being made, the Division should consolidate the existing database for moose populations there and initiate studies to augment that database so that activities impacting moose and their habitat may be promptly recognized, evaluated, and minimized and/or mitigated. Habitats and environmental conditions of the lower Susitna Valley vary greatly. Because many resource use conflicts require site-specific knowledge, numerous interrelated substudies must be conducted to adequately understand movement patterns and identities of the area's major moose populations. Initial substudies will be conducted in areas where immediate conflicts exist.

When I evaluated conflicts in resource use for the entire lower Susitna Valley, it was apparent that research efforts should begin in Subunits 14A and 14B in the western foothills of the Talkeetna Mountains for the following reasons: (1) this area possesses the largest densest postrut aggregation of moose in the region and, perhaps, the state; (2) it is the nucleus of development activities and resource use; (3) it provides recreation and resources to over half of Alaska's human population; (4) it has unique problems involving railroad and highway systems; and (5) recent information obtained from Susitna River hydroelectric environmental studies and a habitat suitability assessment project has pointed out a lack of basic knowledge about moose in the area.

Historical information available on moose populations in the Susitna Valley is limited to (1) harvest statistics (ADF&G files), (2) inconsistently conducted sex-age composition surveys (ADF&G files); (3) inconsistently collected data for train- and vehicle-killed moose (ADF&G files), (4) an outdated population movement study based on resightings of "visually collared" moose (ADF&G files), (5) studies on railroad mortality and productivity of the railbelt subpopulation (Rausch 1958, 1959), (6) a sporadically monitored radiotelemetry population identity study in the Dutch and Peters Hills (Didrickson and Taylor 1978), (7) an incomplete study of moose-snowfall relationships in the Susitna Valley, and (8) a study of extensive moose mortality in a severe winter (1970-71) for which there is no final report.

Recent studies designed to assess the impact of a proposed hydroelectric project on moose provided substantial amounts of data on populations in areas adjacent to the Susitna River downstream from Devil Canyon (Arneson 1981; Modafferi 1982, 1983, 1984, 1988b). Circumstantial evidence and cursory examination of data in these studies suggest that traditional sex-age composition counts conducted in widely spaced alpine areas of Subunits 14A and 14B were biased, excluding samples from large segments of hunted moose subpopulations. These data also suggested that moose killed in Subunit 14B by collisions with trains and during open hunting seasons in winter were fall residents of Subunit 16A. Moose killed during fall hunting seasons in Subunit 16A were included in Subunits 14A and 14B population composition and trend surveys.

Traditional moose sex/age composition and trend surveys in Subunits 14A and 14B have remained relatively insensitive to large annual changes in mortality rates. These data suggest that assumptions about movements and identities of moose subpopulations in Subunits 14A and 14B (western foothills of the Talkeetna Mountains) may be incorrect or too simplistic.

Subunit 16A fall moose populations remain largely unsurveyed because they occur in forest habitat. I believe that these moose populations could be surveyed during winter when they occur in shrub dominated riparian winter concentration areas common to Subunit 16A and 14B.

A recent joint study conducted by the Divisions of Wildlife Conservation and Habitat designed to evaluate methods for assessing moose population status and habitat suitability began to identify important moose wintering areas and to document moose-snowfall relationships in the lower Susitna River Valley (Albert and Shea 1986). Previous progress reports on lower Susitna Valley moose population identity and movement studies have been published (Modafferi 1987, 1988a, 1990).

OBJECTIVES

Primary

Identify and delineate major moose populations in the lower Susitna Valley.

Delineate moose annual movement patterns and location, timing, and duration of use of seasonal habitats more precisely.

Assess the effects of seasonal timing on results of annual fall sex-age composition and population trend moose surveys.

Relate findings to moose population management in lower Susitna Valley.

Peripheral

Identify habitats and land areas that are important for maintaining the integrity of moose populations in the lower Susitna Valley.

Locate moose winter concentration areas and calving areas in the lower Susitna Valley.

Identify moose populations that sustain "accidental" mortality in highway and railroad rights-of-way and hunting mortality during open seasons.

Determine moose natality rates and timing of calf and adult mortality.

STUDY AREA

The study area was located in the lower Susitna Valley in Southcentral Alaska (Fig. 1). The roughly 50,000-km^2 area bordered on the north and west by the Alaska Mountain Range, on the east by the Talkeetna Mountains, and on the south by Cook Inlet encompasses all watersheds of the Susitna River downstream from Devil Canyon and includes all or portions of Subunits 14A, 14B, 16A, 16B, and 13E (Fig. 2).

Monthly mean temperatures vary from about 16 C in July to -13 C in January; maximum and minimum temperatures of 25 and -35 C are not uncommon. Total annual precipitation varies from about 40 cm in the southern portion to over 86 cm in the area's northern and western portions. Maximum snow depth on the ground in winter can vary from less than 20 cm in the southern portion to over 200 cm in the northern and western portions. Climatic conditions generally become more inclement away from the maritime influence of Cook Inlet. Elevations within the area range from sea level to rugged mountain peaks well above the 1500 m. Vegetation in the area is diverse, and varies depending on the elevation: wet coastal tundra and marsh, open low-growing spruce forest, closed spruce hardwood forest, treeless bog, shrubby thicket and alpine tundra (Viereck and Little 1972). Dominant habitat and canopy types in the area are characterized as: (1) floodplains dominated by willow (*Salix spp.*) and poplars (*Populus spp.*), (2) lowland dominated by a mixture of wet bogs and closed or open mixed paper birch (*Betula papyrifera*)/white spruce (*Picea glauca*)/aspen (*Populus tremuloides*) forests, (3) mid-elevation dominated by mixed or pure stands of aspen/paper birch/white spruce,

(4) higher elevation dominated by alder (*Alnus spp.*), willow, and birch shrub thickets or grasslands (*Calamagrostis spp.*), and (5) alpine tundra dominated by sedge (*Carex spp.*), ericaceous shrubs, prostrate willows, and dwarf herbs. Fall-winter postrut concentration area moose surveys were conducted above timberline in higher elevation and alpine tundra habitats, between elevations from 600 to 1200 m. Winter concentration area moose surveys were conducted in lowland floodplain riparian habitats between elevations of 30 to 300 m.

METHODS

Individual moose were captured and marked with ear tags and radio collars (Telonics, Inc., Mesa, AZ). Each ear tag featured a discrete numeral, and each radio collar featured a discrete radio-transmitted frequency and a highly visible number.

Moose were immobilized with 4-6 mg carfentanil (Wildlife Laboratories, Ft. Collins, CO) dissolved in 2-3 cc H_20 and administered with Palmer Cap-Chur equipment by personnel aboard a hovering Bell 206B or Hughes 500D helicopter. While immobilized, moose were marked with ear tags and radio collars and aged by visual inspection of wear on incisor teeth. Antler size and conformation were considered when assessing age of males. Moose were assigned to the following age categories: calves, yearlings, 2- to 5-year-olds, 6- to 12-year-olds, and >12-year-olds. Sex of marked moose and their association with young of the year were noted. Immobilized moose were revived with an intramuscular injection of 90 mg naloxone hydrochloride (Wildlife Laboratories, Ft. Collins, CO) per mg of carfentanil administered.

Forty-four moose were captured and marked in 7 Talkeetna Mountain alpine habitat postrut concentration survey areas (Fig. 3) from 23 December 1985 to 4 February 1986. Marking procedures began after 18 November 1985, when aerial surveys indicated peak numbers of moose present in alpine habitat postrut concentration areas (Modafferi 1987). Distribution of sampling effort between postrut concentration areas roughly paralleled moose distribution observed on aerial surveys. On 14 December 1987 and 21 December 1988, 6 and 2 moose, respectively, were captured and radio-marked to replace those that had shed transmitting collars or died.

On 28 January 1987, 7 moose were captured and marked in lowland forest habitat (Fig. 4, Area H) located between Little Willow Creek and the Kashwitna River. Sampling effort paralleled distribution of moose observed on a survey conducted between Willow Creek and the Kashwitna River on 7 January 1987 (Modafferi 1988a). This area is included within the Kashwitna Corridor Forest, where the State of Alaska, Department of Natural Resources (DNR), Division of Forestry (DOF), initiated a forest management program in 1988 by providing access and conducting sales to make timber available for commercial harvest. On 9 February 1989, 5 moose were captured and marked near timber sale sites between Willow Creek and Iron Creek in the southern portion of the Kashwitna Corridor Forest (Fig. 4, Area H).

During February and March 1988, 6 moose were captured and marked in the Coal Creek area (Fig. 4, Area I), where personal-use cutting of firewood had been permitted by DNR. Captured moose frequented this area to feed on buds, catkins, and twigs that had been trimmed off mature birch trees cut for firewood.

In April 1991, 7 moose were captured and marked at 5 different sites near the Parks Highway between the Little Susitna River and Sheep Creek (Fig. 1). On 16 April 1990, 6 moose were captured, marked, and released at sites where supplemental food was provided for moose nutritionally stressed by an exceptionally deep snowpack. One, 2, 1, and 2 moose, respectively, were captured at sites near the Deshka Landing, Long Lake, Capitol Speedway, and Caswell Creek, where the ADF&G provided supplemental moose food. On 19 April 1990, 1 moose accidentally caught in a snare trap was tranquilized, marked, and released at the Houston landfill.

In 1988 and 1989, parallel moose population identity and movement studies were initiated in other areas of the lower Susitna River Valley (Faro 1990. Appendix B. in Modafferi 1990). In March 1987, 23 moose were captured and radio-marked along the Alexander Creek floodplain (Fig. 4, Area J). In February 1988 and 1989, 21 and 6 moose, respectively, were captured and radio-marked in the Lake Creek-Skwentna area (Fig. 4, Area K). Marked moose with operational radio transmitters were radio-located during this study.

Moose captured and marked during previous studies along the Susitna River floodplain (Arneson 1981; Modafferi 1982, 1983, 1984, 1988b) ranged within the lower Susitna Valley study area. Information gathered from these marked moose was incorporated into the database. Moose marked during these studies were radio-located until the transmitters failed.

Survey flights in Cessna 180 or 185 and Piper PA-18 aircraft equipped with 2-element "H" or 3-element yagi antennas (Telonics, Mesa, AZ) were conducted at 2- to 4-week intervals to radio-locate radio-marked moose. Moose location points (audio-visual or audio) were noted on USGS topographic maps (1:63,360) and later transferred to translucent overlays of those maps for computer digitization and geoprocessing. A maximum of 200, 70, 55, 39, 27, and 13 point locations were recorded through 20 October 1990 for moose radio-marked in the Susitna River floodplain, Talkeetna Mountain, northern Kashwitna Corridor, Coal Creek, southern Kashwitna Corridor, and Parks Highway area, respectively.

During this study, radio transmitters on some individuals marked along the Susitna River in March 1981 and February 1982 exhibited either weak, infrequent or no signals. These transmitters were presumed to be weakening and expiring from battery failure.

Moose distribution, abundance, and herd composition were assessed by aerial surveys conducted at different times and locations. Each fall/winter from October 1985 to March 1990, aerial moose count surveys were conducted to determine timing, magnitude, and duration of moose use of alpine habitat postrut concentration areas in the western foothills of the Talkeetna Mountains. Aerial surveys were periodically conducted at 2- to 3-week intervals as weather permitted and snowcover was sufficient to observe moose. Antlered yearlings, antlered adults, non-antlered adults, and calves were counted on each survey. Survey data were tallied for 7 discrete alpine habitat moose postrut concentration areas (Fig. 3, Areas A—G) separated by lower-elevation river drainages.

The ARC provided the ADF&G with location and date data on moose killed by collisions with trains in the 470 mi section of ARC railway between Seward and Fairbanks during 1964-90. These data were analyzed for year, season, month and location and related to data on snowpack depth and numbers of moose in alpine habitat postrut and winter concentration areas, location of moose winter concentration areas and movements of marked moose.

Snowpack depth data for Wasilla, Willow, Talkeetna, Skwentna, and Chulitna River Lodge (Fig. 1) were obtained from *Alaska Climatological Data Reports*, U.S. Department of Commerce, NOAA, National Environmental Satellite, Data and Information Service, National Climate Data Center, Asheville, NC. Tabular data for daily measurements of depth of snow on the ground were summarized by selecting maximum depths recorded during each of 3 periods (1-10, 11-20 and 21-31 days) in each month. Willow and Talkeetna snowpack data were used as indices of snowpack depth in alpine habitat moose postrut survey areas.

This progress report primarily contains analyses of movement data collected from moose captured and marked from 23 December 1985 through 14 February 1990 in 7 alpine habitat postrut concentration areas in the western foothills of the Talkeetna Mountains in southcentral Alaska where the ADF&G annually conducts Subunit 14A and 14B moose population sex-age composition and population trend surveys. Pertinent movement data gathered from radio-marked moose captured between 17 April 1980 and 1 January 1985 in previous studies in winter concentration areas on the Susitna River floodplain from the Yentna River to Talkeetna in Subunit 16A and monitored through October 1990 were included in the database. This report also contains analyses of count data from 37 moose surveys in the 7 alpine habitat moose postrut concentration areas where moose were marked and from 34 moose surveys in 2 lowland riparian habitat moose winter concentration areas. Relevant data and findings from previous studies (Modafferi 1982, 1983, 1984, and 1988b) of moose movements in the lower Susitna Valley were re-analyzed. Interrelationships of data on moose movements, moose counts, train-killed moose and snowpack depth were assessed. Findings were related to moose surveys, hunting seasons, subunit boundaries, moose calf recruitment, habitat management, and moose mortality a transportation corridor.

RESULTS AND DISCUSSION

Movements of Radio-Marked Moose

Movement patterns for moose radio-marked in Subunits 14A, 14B and 16A of the lower Susitna River Valley documented in this study differed significantly from movement patterns previously assumed by the ADF&G (Fig. 5). Convex polygons encompassing point locations for 69 individual radio-marked moose that provided data for deriving generalizations about moose movement patterns appear in Appendices 1-8.

Subunit 16A Fall Resident Moose:

Data from moose marked in winter concentration areas on the Susitna River floodplain suggest that fall resident moose from Subunit 16A commonly cross several north-south oriented drainages in east-west migrations to and from winter concentration areas in Subunits 14A and 14B. Data from marked moose also indicated that many Subunit 16A fall resident moose migrated to winter concentration areas in the transportation corridor between Willow and Talkeetna in Subunit 14B. Previously, the ADF&G assumed that Subunit 16A fall resident moose populations migrated short distances to winter areas within Subunit 16A. My data indicated that it was not uncommon for Subunit 16A fall resident moose to migrate distances greater than 30 km and to traverse subunit boundaries. Fall-winter migrations of individual marked moose were generally oriented in east, north-, or south-east directions. Several Subunit 16A fall resident marked moose migrated distances greater than 45 km to winter concentration areas near Palmer, Wasilla and Knik Arm. In contrast, several other moose marked in winter concentration areas on the Susitna River floodplain where large islands were present, maintained small annual ranges seldom more than 10 km from winter concentration areas during other seasons.

Subunit 14A Fall Resident Moose:

All moose marked in the Bald Mountain Ridge postrut concentration area in Subunit 14A migrated south toward the Palmer-Wasilla area in winter. Westerly fall-winter movements toward the transportation corridor and the Susitna River floodplain that were assumed common for moose in this area (ADF&G files), were not recorded. Fall-winter migrations for moose from the Bald Mountain Ridge postrut area were generally less than 20 km. Moose marked on Moss Mountain, the next alpine postrut concentration area north of Bald Mountain Ridge, also migrated south toward the Palmer-Wasilla area in winter.

Subunit 14B Fall Resident Moose:

Moose marked in the Willow Mountain postrut concentration area exhibited several different fall-winter migratory patterns. Many Willow Mountain fall resident moose migrated south, 35-40 km, to winter concentration areas in the Palmer-Wasilla area. Some moose from the Willow Mountain postrut area migrated west short distances to forest habitats. Other moose migrated longer distances to the transportation corridor. Two moose marked several km northeast of Willow Mountain on Witna Mountain, migrated west toward the transportation corridor.

All moose marked in the Brownie Mountain postrut concentration area remained near that area or migrated east up the Kashwitna River drainage during winter. In contrast to moose from other Subunit 14B postrut concentration areas, moose marked on Brownie Mountain did not exhibit extensive westerly fall-winter movements to the transportation corridor as was previously assumed (ADF&G files). Moose from this postrut area generally remained in remote parts of Subunit 14B year-round.
Marked moose in the Wolverine and Sunshine postrut concentration areas exhibited westerly fall-winter migrations toward the transportation corridor. Fall-winter migration distances greater than 20 km were not uncommon for moose from these postrut areas.

Movements of Female Moose Before Calving

In May, prior to calving, most female moose in Subunits 14A and 14B moved from lowland winter concentration areas to higher elevations near timberline (Modafferi, in press). However, some marked female moose from each postrut concentration area in Subunit 14B were known to migrate to lower elevations in Subunit 16A before parturition. Data in this study suggest that the tendency for female moose to migrate to lower elevations and into Subunit 16A increased from Bald Mountain Ridge postrut area (south) to Sunshine Mountain (north) in Subunit 14B.

During calving, many marked fall resident Subunit 16A female moose were located in wet, open black spruce forests on the periphery of mixed conifer-hardwood forest "islands" which were widely spaced among extensive wet treeless bogs (Modafferi 1988:42-43). Several weeks after parturition, marked females were more commonly located in more closed mixed forest "islands". At that time, some fall resident Subunit 14B female moose returned to higher elevations near alpine habitat postrut concentration areas while others remained in lowland area mixed forest "islands" until late summer or fall (Modafferi, in press).

Moose Occurrence in Alpine Habitat Postrut Concentration Areas in Subunits 14A and 14B

Number of moose observed in alpine habitat postrut concentration areas from Bald Mountain Ridge in Subunit 14A to Willow Mountain in Subunit 14B varied seasonally. October-April and seasonal patterns differed yearly (Figure 6A). Generally, numbers of moose in alpine habitat postrut concentration areas increased during October, peaked between late October and early December, and declined between late December and mid-April. However, because the number of moose in alpine postrut concentration areas was affected by fall-winter migrations and moose fall-winter migrations were associated with snowpack depth, moose occurrence in postrut areas was indirectly related to snowpack depth (Figure 6B). In 1985-86, a year with little snowfall and shallow snowpack, more than 50% of the peak number of moose observed in postrut areas remained through late March. In the subsequent 5 winters, 1986-91, moose numbers in postrut areas decreased about 80 percent from peak levels to yearly low levels in January, February or March. Moose numbers in postrut areas decreased rapidly and earliest in 1989-90 following an early accumulation of snow and record depth snowpacks in most of the Susitna River Valley. During 1986-89 and 1990-91, when seasonal timing and depth of accumulated snow were intermediate relative to 1985-86 and 1989-90, numbers of moose in postrut areas declined at intermediate seasonal times. In contrast to other years, moose numbers in postrut areas in 1989-90 increased from a low level in late December to higher levels later that winter even though the snowpack remained exceptionally deep (Figure 6A).

Moose Occurrence in Winter Concentration Areas in Subunit 13E

Number of moose observed in winter concentration areas on the Susitna River floodplain between Talkeetna and Devil Canyon in Subunit 13E varied seasonally October through April, and seasonal patterns varied yearly (Figure 7A) (Modafferi 1988b). Generally, moose in winter concentration areas increased after October, reached peak levels in January-February and declined in mid-April. Because the number of moose in winter concentration areas was affected by moose fall-winter migrations and moose fall-winter migrations were correlated with snowpack depth, moose occurrence in winter concentration areas was indirectly related to snowpack depth (Figure 7B). In 1982, an exceptionally early movement of large numbers of moose to winter concentration areas on the Susitna River floodplain in late November was preceded by a snowpack accumulation of 40 cm in late October. In 1983 when snowpack depth did not exceed 40 cm until late December, comparable numbers of moose were not observed in winter concentration areas until mid-February. In 1981-82, when snowpack depth seldom exceeded 40 cm, large numbers of moose were never observed in winter concentration areas. In 1984-85 when extraordinarily deep snowpacks occurred in late December, exceptionally large numbers of moose were counted in winter concentration areas in late-January.

Numbers of moose in winter concentration areas correlated with snowpack seasonal timing and depth. Small and large numbers of moose in winter concentration areas in 1981-82 and 1984-85 were associated with shallow and deep yearly snowpacks (Figures 7A and B). Seasonally early and late moose concentrations in winter areas in 1982-83 and 1983-84 were associated with seasonally early and late accumulations of snow.

Moose Mortality From Collisions with Trains

Data provided by the ARC indicated that 3,075 moose were killed by collisions with trains in the 375 mi section of railway between Seward and Fairbanks between 1963 and

1990. Number of moose reported killed by train varied greatly annually (Figure 8). Most moose were killed during winter, November-April (Figure 9) and high moose kill rates were documented in the 90 mi section of railway located between Willow and Chulitna Pass (Figures 10 and 11). Annual variation in moose kill rates may be attributed to several factors, including: (1) differences in moose population size, (2) differences in accuracy and consistency of recording and reporting of moose kills (Rausch 1958), and (3) differences in timing and depth of snow accumulation which affect timing and number of moose that migrate to winter concentration areas. Moose kill rates were highest in winter because large numbers of migrating moose concentrate at locations near the railway corridor. Finer grain seasonal differences in moose kill rates are related to the yearly differences in timing of moose fall-winter migrations which are affected by snowpack depth. Moose kill rates were highest at locations in the railway corridor where moose winter concentration areas overlap the railway corridor.

Data provided by the ARC on number of moose killed by trains yearly were related to snowpack depth and moose numbers in winter concentration areas in 1981-85 and moose numbers in alpine postrut concentration areas in 1985-90 (Figures 6C and 7C). Many moose were killed by trains in 1984-85 and 1989-90 when accumulated snowpacks were relatively deep. Few moose were killed by trains in 1981-82 and 1985-86 when accumulated snowpacks were relatively shallow. Over 70% of the train moose kill occurred in winter (January-March), whereas, less than 7% of the reported train moose kill occurred May through October (Figure 9). Early and late snowpack accumulation in 1982-83 and 1983-84 were associated with seasonally early and late moose migrations to lowland moose winter concentration areas and early and late yearly peaks in moose killed by trains (Figure 12). Consequently, unseasonably early or late snowpack accumulations probably account for slightly elevated moose kill rates reported for November-December and April, respectively (Figure 9).

<u>Moose Migrations, Snowpack Accumulation and Calf Recruitment</u>

Data indicate that migrations of moose were closely related to snowfall and accumulated snowpack. Timing and depth of snow accumulation varied greatly seasonally, yearly and locally in the lower Susitna River Valley (Figure 13). Onset of moose fall-winter migration in Sweden was correlated with 40 cm of accumulated snow (Sandegren et al. 1985). My data suggest that significant fall-winter migration of moose in Alaska did not occur until after the snowpack accumulated to a similar depth of 40 cm (Figures 6, 7, and 12). Data I gathered indicated that when seasonal snowpack remained below 40 cm in winter 1985-86 few moose migrated from postrut concentration areas (Figure 6) and in 1981-82 few moose were observed in winter concentration areas (Figure 7). These data suggest that year to year moose migration patterns vary and that the distance and terminus of moose fall-winter migrations are partly influenced by snowpack depth. In another study, moose fall-winter migration patterns remained consistent from year to year (Sweanor and Sandegren 1987). However, during later study, snow depth exceeded 40 cm, the threshold snow depth that initiated migrations (Sandegren et al. 1985), in all years. Consequently, data in that study do not contradict my findings that moose are not rigidly philopatric to a single winter concentration area.

Other studies in Sweden, demonstrated a correlation between calf recruitment and the region cow moose ranged in during winter (Sweanor and Sandegren 1987). Calf recruitment was higher for cow moose that used areas which had highest moose densities, greatest percent of browse-damaged forests and shallower snowpacks. Calf recruitment success of cows using different regions in summer did not vary. Both migratory and non-migratory cow moose that ranged in winter areas where snowpack was shallow exhibited higher rates of calf recruitment than cows that used other areas. Snowpack depth in the "most productive" winter area exceeded 70 cm on 12 days, whereas, in the 2 other "less productive" areas, snowpack depth exceeded 70 cm for 90 and 118 days. This study points out the importance of moose winter concentration area "location" and indicates that other environmental factors in moose winter areas, such as snowpack depth, may be of greater importance than browsing damage in limiting calf recruitment of cow moose.

Although the seasonal snow accumulation pattern at Wasilla paralleled that at other locations in the lower Susitna Valley, the former location consistently exhibited a significantly shallower yearly snowpack (Figure 13). Even during the winters 1970-71, 1984-85 and 1989-90, when exceptionally deep snowpacks were recorded in lower Susitna Valley, snowpack depth at Wasilla did not exceed 70 cm (Fig. 14). In addition to the Palmer-Wasilla area typically receiving less snowfall than other areas in the lower Susitna Valley, strong northerly winds that blow snow clear from exposed sites and occasional periods of above freezing temperatures are other local features that lessen the region's snowpack depth. Other environmental factors being equal, relatively shallow snowpack conditions should make the Palmer-Wasilla area the most desirable moose winter concentration area location in the lower Susitna Valley. It is not surprising that fall resident marked moose from Subunits 16A and 14B migrated long distances to winter concentration areas in the Palmer-Wasilla area. Additionally, as documented in other studies (Sweanor and Sandegren 1987), I suspect that calf recruitment rates of female moose that migrate to winter concentration areas near Palmer-Wasilla are higher than calf recruitment rates of females that range elsewhere in the lower Susitna Valley where snowpack is deeper.

MANAGEMENT IMPLICATIONS

Subunit Moose Herd Composition Trend Surveys

In many subunits the ADF&G conducts moose population sex/age composition and trend surveys in alpine habitat postrut concentration areas. Ideally, moose should be surveyed when maximum numbers are most observable. Large proportions of moose populations are most observable when they concentrate in alpine habitat postrut areas before fall-winter migrations. Therefore, moose populations should be surveyed in fall, before fall-winter migrations, when large numbers of moose are readily observable in alpine habitat postrut concentration areas. My data indicated that early timing of moose surveys was important because onset of moose fall-winter migrations in the lower Susitna Valley was related to snow accumulation. However, in years when snowfall occurred exceptionally early, I found smaller numbers of moose in alpine postrut areas in early October than I found in late October. Therefore, moose sex/age composition and population trend surveys should be conducted as soon after 20 October that snow conditions are adequate for counting moose. In most years, numbers of moose in postrut areas decreased significantly by early December. Area wildlife managers must place high priority on conducting trend surveys after moose migrate to alpine habitat postrut areas in mid-October and before onset of migration to winter concentration areas in early December. Rapid accumulation of early deep snowpack, as in 1989-90, could initiate an immediate, early emigration of large numbers of moose from postrut areas and preclude ideal survey conditions.

Subunit Moose Population Census Surveys

Random stratified census (Gasaway et al. 1984) and random stratified trend survey (ADF&G files) techniques are employed by the ADF&G to evaluate moose population status. Because sex-age composition is not always a necessary component of moose population censuses, these surveys are frequently conducted during late winter or early spring when snowcover is most desirable and moose are located in shrub-dominated winter concentration areas where observability is high. My data indicated that Subunits 16A and 14B fall resident moose traverse subunit boundaries into Subunit 14A during fall-winter migrations. Consequently, Subunits 14A, 14B and 16A moose populations were "mixed" during late winter-early spring. Therefore, winter survey data should not be used to make judgements about "resident" fall moose populations in Subunits 14A, 14B and 16A.

Train Moose Kill

The ADF&G assumed that moose killed by collisions with trains in the railway corridor in Subunit 14B were solely Subunit 14B fall resident moose. My data indicated that Subunit 16A fall resident moose migrated to the railway corridor in Subunit 14B during winter and were vulnerable to collisions with trains. Therefore, moose mortality from collisions with trains in Subunit 14B in winter must be partitioned between Subunits 14B and 16A moose populations. Similarly, management plans to reduce train moose kill in Subunit 14B must also consider the fall-winter migration of moose from Subunit 16A to 14B.

Winter Season Moose Hunts

The ADF&G desires to distribute the hunter moose kill equally throughout the Subunit 14B moose population. The ADF&G assumed that much of the Subunit 14B moose population ranged in remote areas inaccessible to hunters during fall hunting seasons. It was also assumed that moose in high elevation remote areas in Subunit 14B migrated to lower elevations near the highway and railway transportation corridors and were vulnerable to hunters in winter. The ADF&G implemented winter hunts to harvest migrant moose that ranged in remote areas of Subunit 14B and were inaccessible to hunters during fall hunts. My data indicate that Subunit 16A fall resident moose were vulnerable during winter hunts in Subunit 14B. Moose in some remote areas in Subunit 14B in fall remained inaccessible to hunters in winter. Other moose in Subunit 14B migrated to Subunit 14A and were not vulnerable in Subunit 14B during winter hunts. Winter hunts in Subunit 14B resulted in the harvest of Subunit 16A fall resident moose and failed to harvest components of the Subunit 14B moose population that remained in remote areas or migrated to Subunit 14A.

Altering Habitat For Moose Winter Range

The ADF&G wants to alter habitat to improve its quality as moose winter range. My study demonstrated that moose fall-winter migration patterns may not be obvious and can be complex. Without adequate knowledge about moose migration patterns it is not possible to identify specific moose populations that will be affected by altered habitat or where affects of moose population increases will ultimately be realized. Habitat alteration could increase moose densities in areas where additional moose are not desirable; i.e., transportation corridors, residential developments or locations inaccessible to hunters. Improvement of moose winter habitat in lowlands west of the Talkeetna Mountains near the transportation corridor would not benefit large numbers of moose from Bald Mountain-Willow Mountain postrut areas that migrate south or moose from the Brownie Mountain postrut area that remain in that vicinity or migrate east. Whereas, moose winter habitat improvement in this same area would benefit Subunit 16A fall resident moose that migrate to Subunit 14B in winter and result in increases to the moose population that migrates to the transportation corridor in winter. Site specific knowledge about moose movement patterns is a necessary prerequisite to select sites for moose habitat improvement.

Snowpack Depth and Land Management

In Sweden, onset of moose migration was related to a snowpack depth of ca. 40 cm (Sandegren et al. 1985) and calf recruitment rate of cow moose was correlated with winter area snowpack depth (Sweanor and Sandegren 1987). In the later study, migratory and non-migratory female moose that ranged in a region where snowpack exceeded 70 cm for 12 days exhibited higher calf recruitment rates than females that ranged in regions where snowpack exceeded 70 cm for more than 90 days. I hypothesize that Subunits 14B and

16A fall resident female moose that migrate to the Palmer-Wasilla vicinity in Subunit 14A where snowpack seldom exceeds ca. 40 cm in winter have higher calf recruitment rates than Subunits 14B and 16A winter resident females.

Data I collected suggested that onset of moose fall-winter migration in the lower Susitna Valley was also triggered by ca. 40 cm of accumulated snow. Small numbers of moose were observed in winter concentration areas when snowpack seldom exceeded 40 cm and large numbers of moose remained in postrut concentration areas in winter when snowpack rarely exceeded 40 cm. Geographical locations where snowpack does not exceed 40 cm probably "attract" moose from migrating populations and preclude winter emigration of fall resident moose. Moose probably emigrate from locations where snowpack commonly exceeds 40 cm. Consequently, geographical locations where snowpack seldom exceeds 40 cm, such as the Palmer-Wasilla vicinity are ecologically important moose winter areas. Land planners and resource managers should be encouraged to manage lands in these locations for moose, as winter concentration areas.

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I thank D. McAllister, Alaska Department of Fish and Game, for logistic assistance, help with "radio-tracking" surveys, assistance drafting figures and who along with B. Taylor, Alaska Department of Fish and Game, assisted in the capture, handling and radio-marking of moose. K. Schneider, Alaska Department of Fish and Game, is acknowledged for providing support and helpful suggestions throughout this study, reviewing drafts of this report, and for willingly providing assistance in administration procedures. J. Didrickson, C. Grauvogel, and H. Griese, Area Management Biologists, Alaska Department of Fish and Game, are acknowledged for "area" support, comments on all aspects of the study, and for sharing their experiences and knowledge about moose. B. Wiederkehr, Wiederkehr Air Inc., Palmer, L. Rogers, Southcentral Air Inc., Kenai, and C. Soloy, Soloy Helicopters, Wasilla, deserve special thanks for safely piloting Super Cub, 185 and helicopter aircraft used in this study. Becky Strauch, Alaska Department of Fish and Game, is acknowledged for updating and maintaining the computerized data file for radio-marked moose, for providing compilations of data on marked moose and for producing the computer generated data, products and Figures included in this report. In spite of her very busy work schedule, Ms. Strauch, always managed to find time to provide computer generated products that I requested.

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Prepared by:

Ronald D. Modafferi
Wildlife Biologist

Submitted by:

Karl B. Schneider
Research Coordinator

Approved by:

David G. Kelleyhouse, Director
Division of Wildlife Conservation

Steven R. Peterson, Senior Staff Biologist
Division of Wildlife Conservation

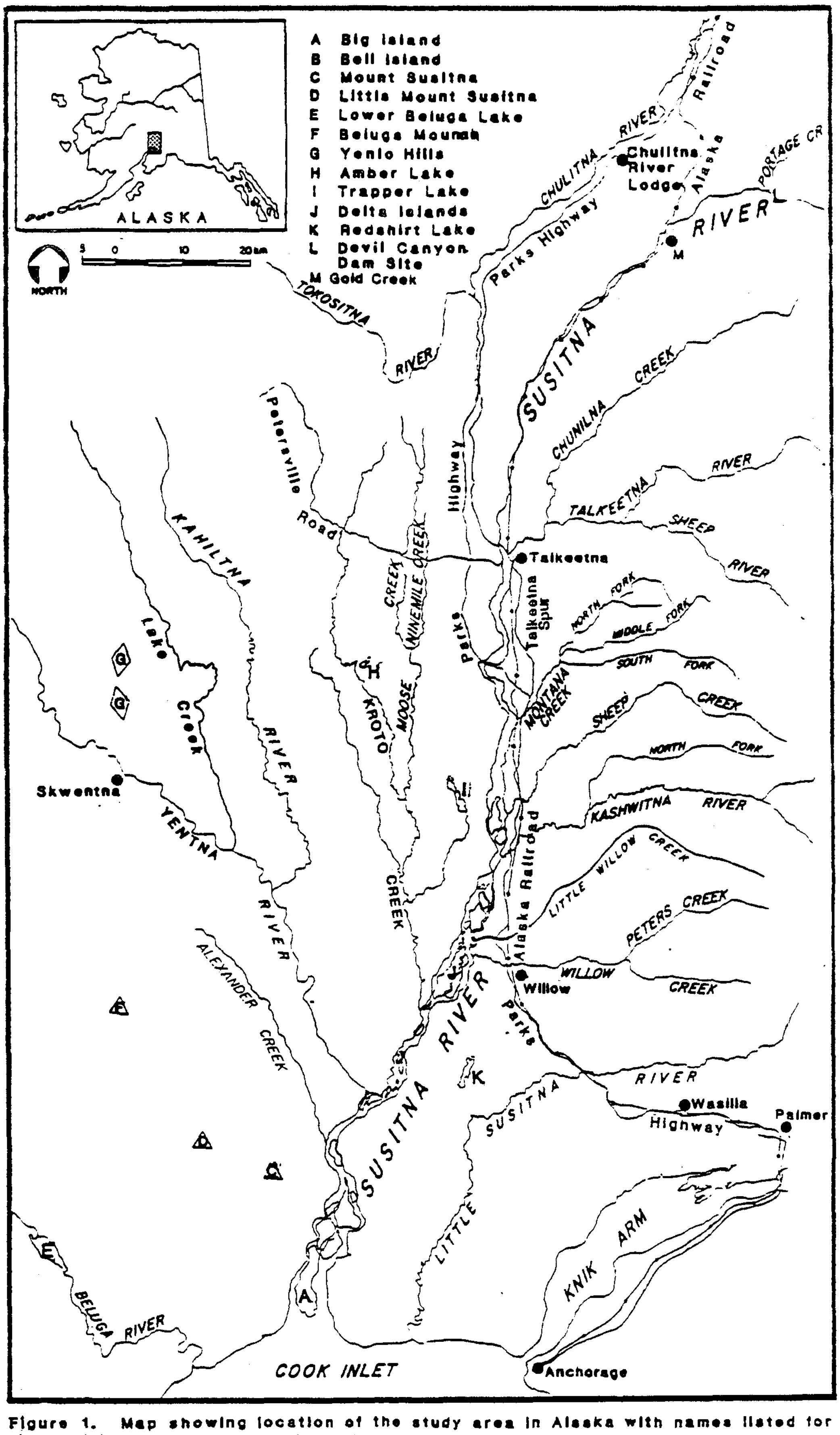


Figure 1. Map showing location of the study area in Alaska with names listed for rivers, lakes and other prominent landscape features.

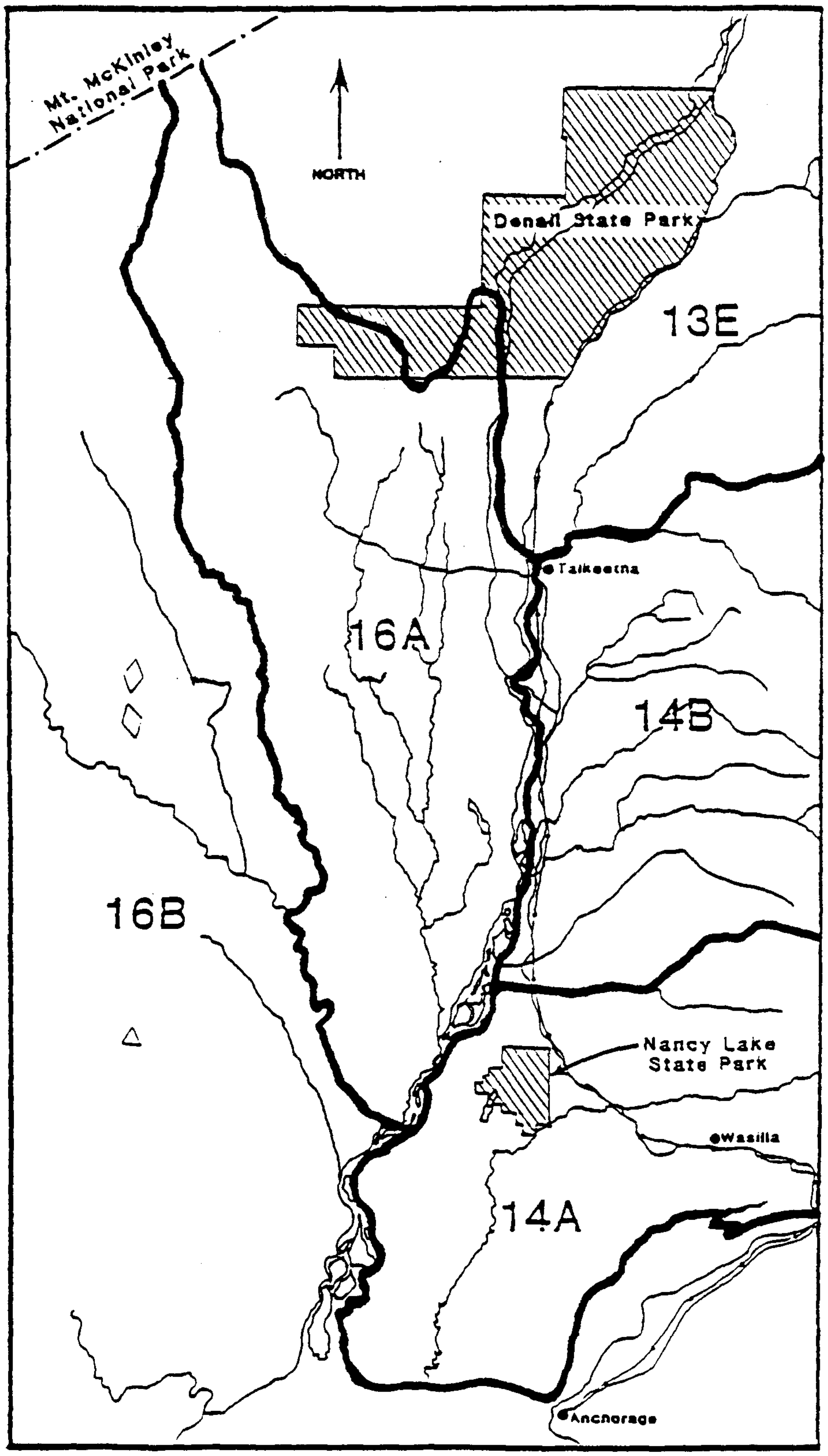


Fig. 2. Location of Game Management Subunits (13E, 14A, 14B, 16A and 16B) and state and national parks in the study area.

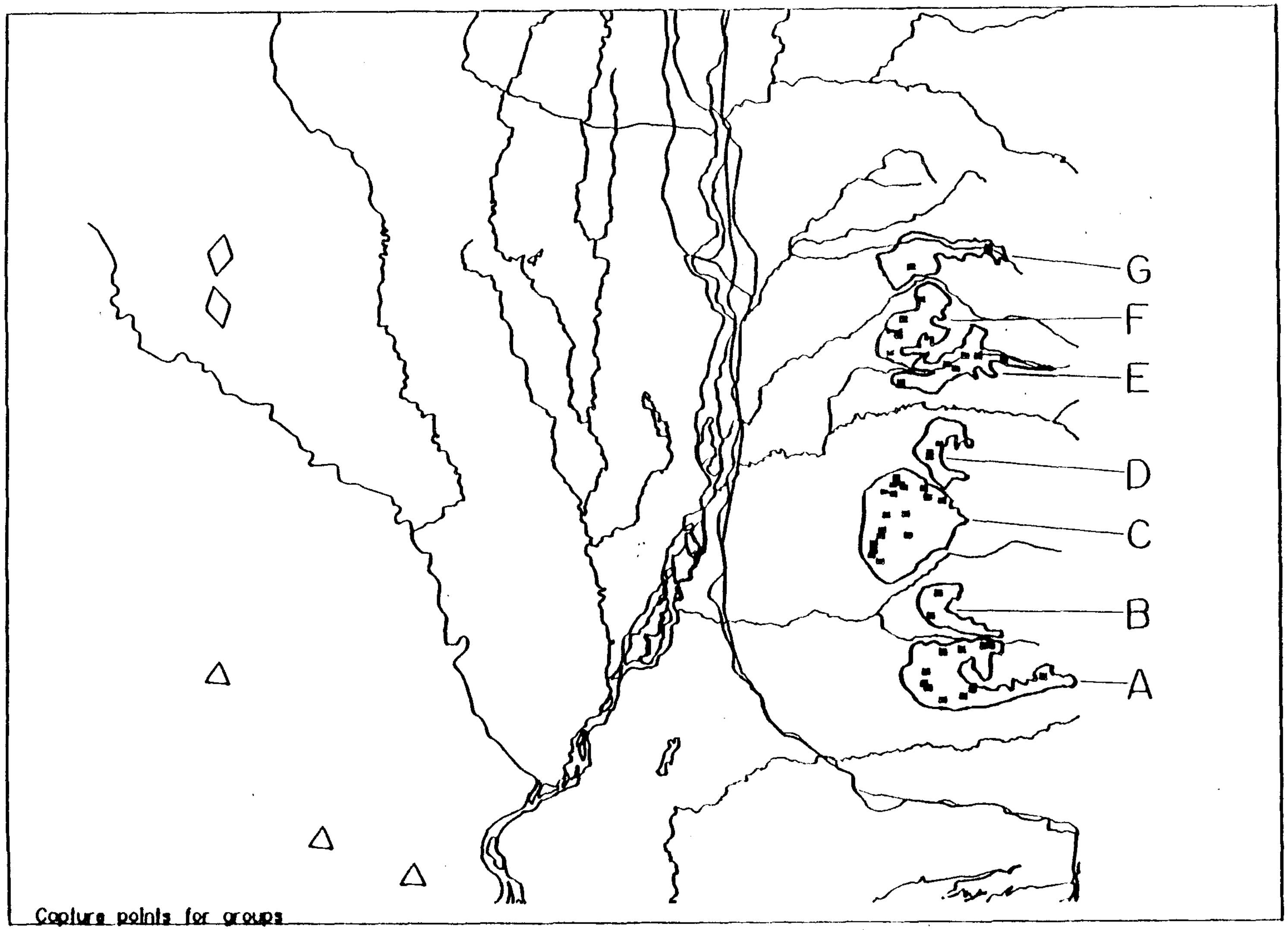


Fig. 3. Point locations where individual moose were captured and radio-marked in 7 alpine habitat postrut areas in game management Subunits 14A and B in the western foothills of the Talkeetna Mountains in southcentral Alaska. A = Bald Mtn., B = Moss Mtn., C = Willow Mtn., D = Witna Mtn., E = Brownie Mtn., F = Wolverine Mtn., and G = Sunshine Mtn.

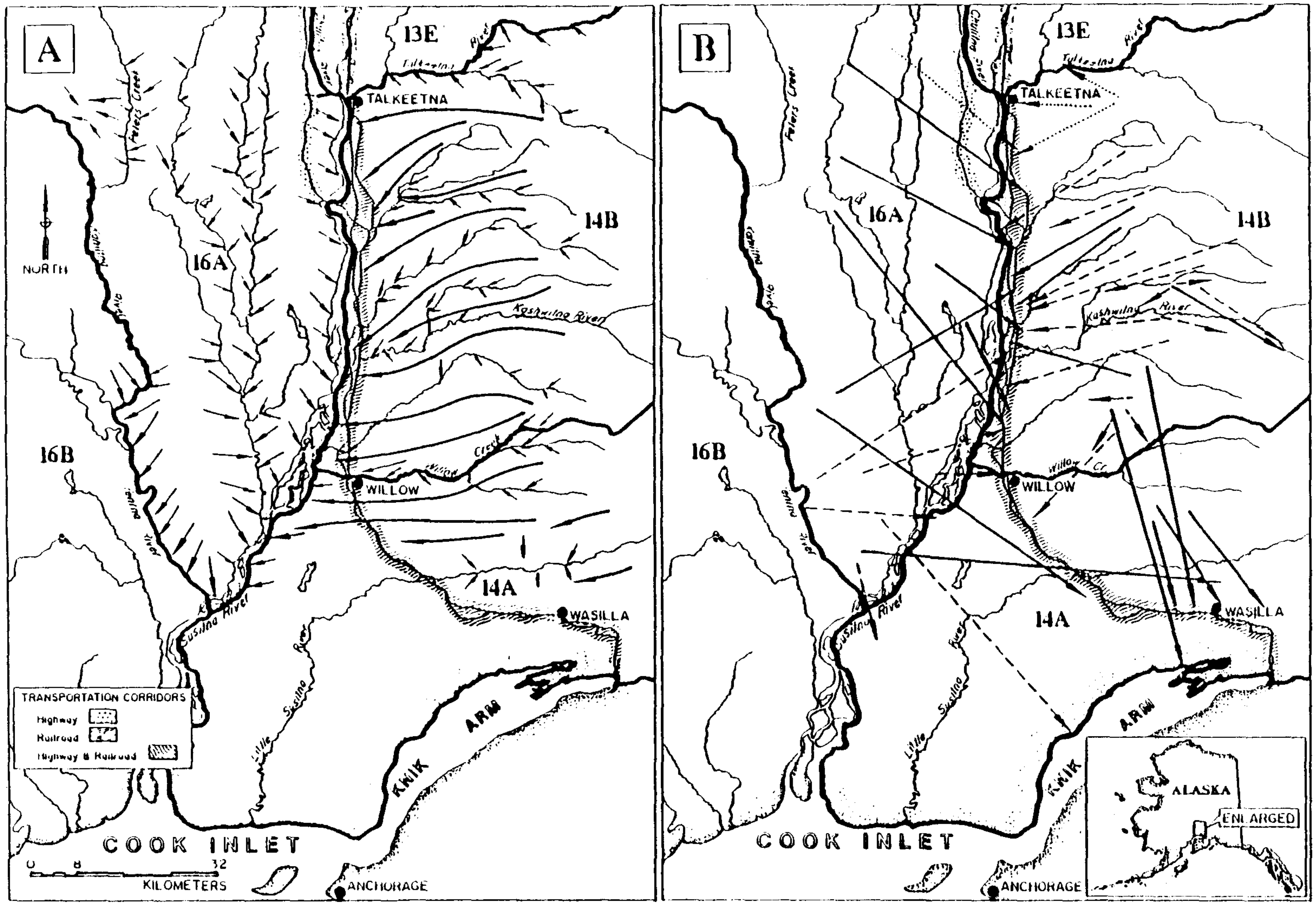


Fig.4. Location of study area showing locations of Game Management Units 13E, 14A, 14B, 16A and 16B, highway and railroad transportation corridors, towns, prominent drainages and major assumed (A) and prevalent documented (B) routes for fall winter moose migrations (arrows). Documented migration routes were derived from study of 32 and 34 moose radio-marked in winter and postrut concentration areas, respectively, southcentral Alaska, 1980 90. Arrow length and width are related to migration distance and number of moose involved in specific migratory patterns. Thick and long arrows, respectively, indicate that relatively large numbers of moose were involved in long distance migrations. Dotted lines indicate undocumented movements. Dashed lines indicate lines of smaller thickness.

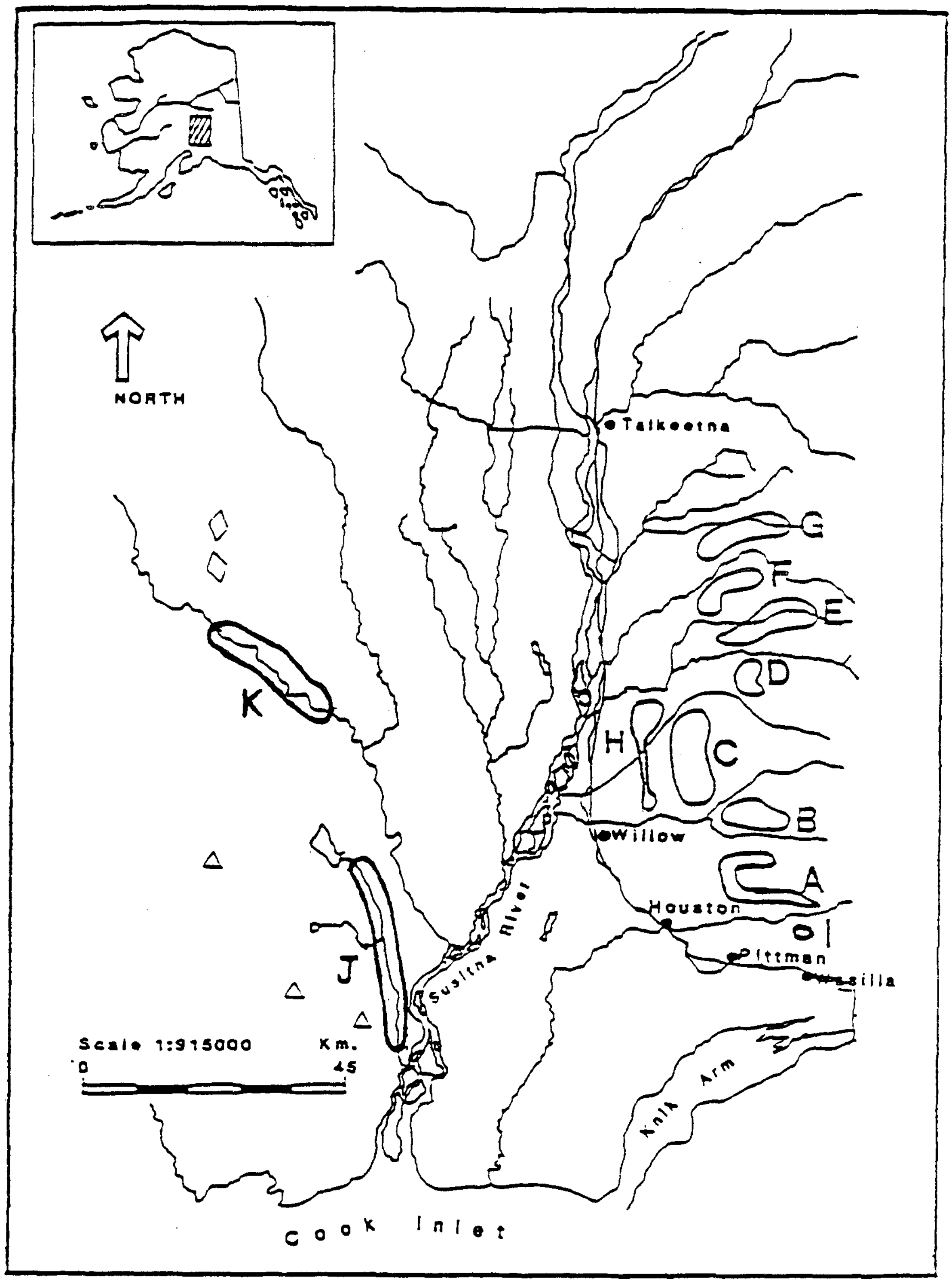


Fig. 5. Locations of Talkeetna Mountains alpine habitat moose postrut areas (A-G), Kashwitna Corridor Forest (H), Coal Creek timber cut area (I), Alexander Creek (J) and the Lake Creek/Skwentna area (K) where moose were captured and radio-marked. A = Bald Mountain, B = Moss Mountain, C = Willow Mountain, D = Witna Mountain, E = Brownie Mountain, F = wolverine Mountain, and G = Sunshine Mountain.

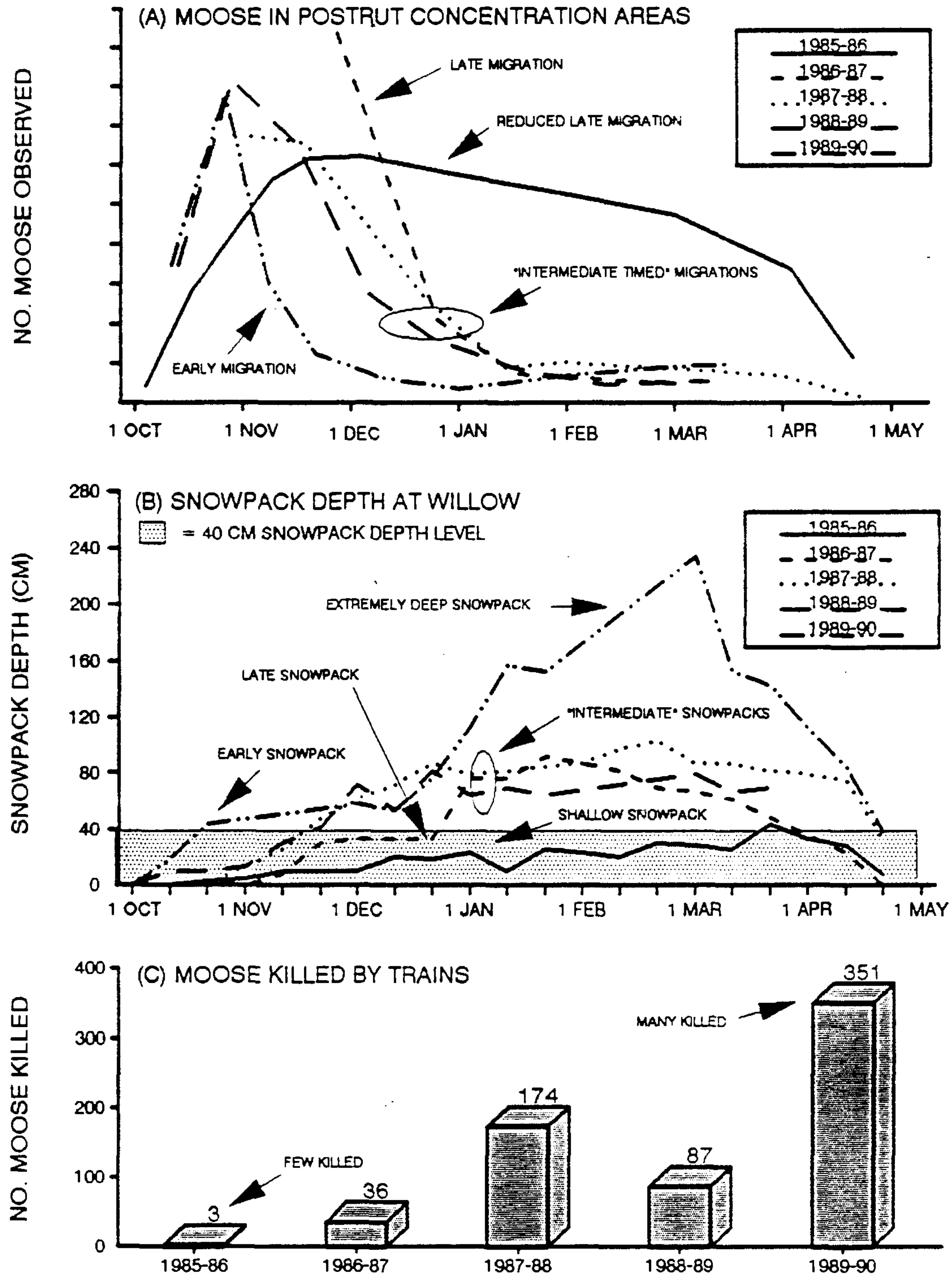


Fig. 6. Number of moose counted on surveys in alpine postrut concentration areas (Bald Mountain-Willow Mountain) in the western foothills of the Talkeetna Mountains (A), trimonthly snowpack depth measured at Willow (B) and the number of moose killed by trains in Game Management Subunit 14B (railroad milemarks 187-225) during November-April (C), 1985-90, southcentral Alaska. Numerals above bars indicate no. moose killed. In other studies, moose fall-winter migration onset coincided with ca. 40 cm of accumulated snow.

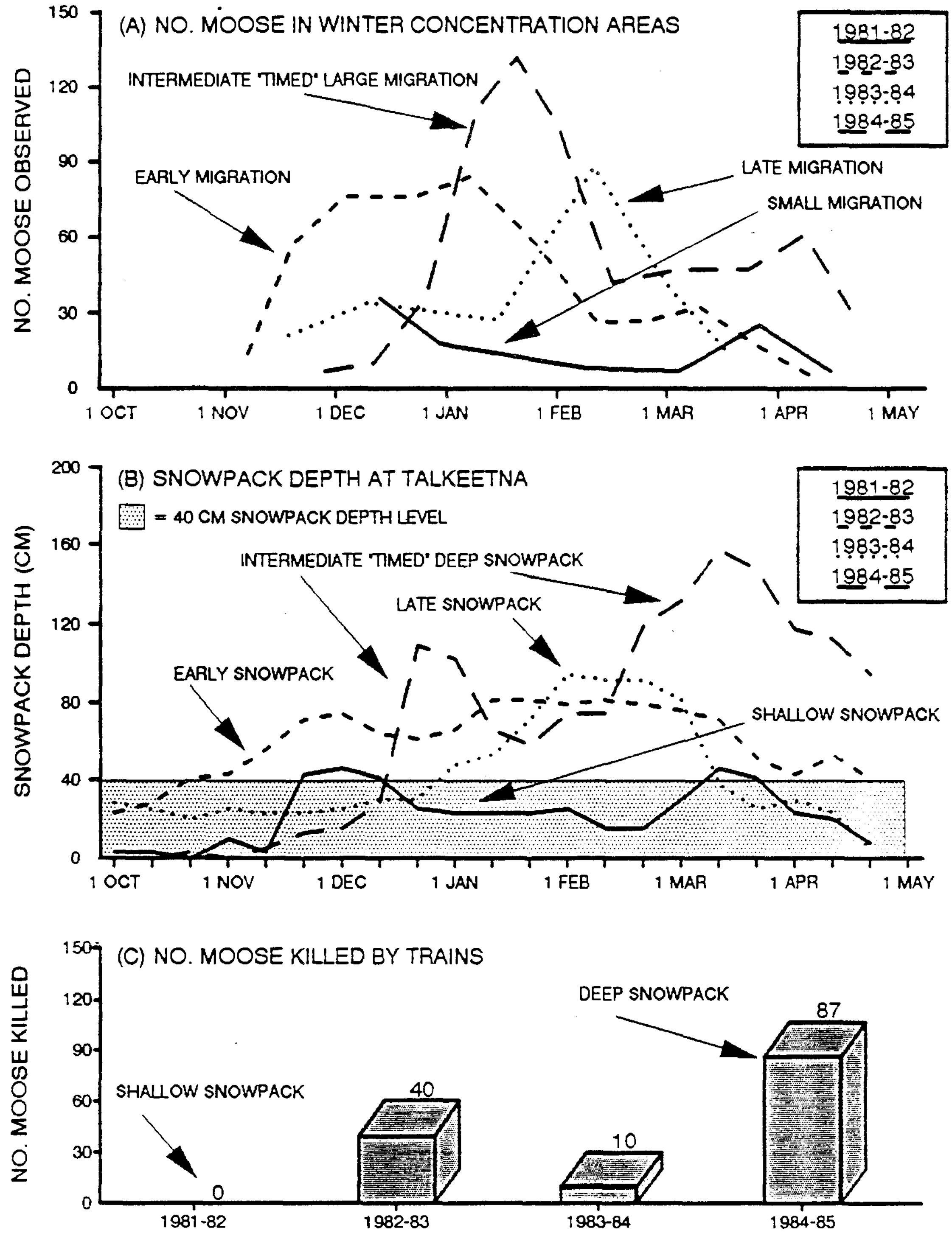


Fig. 7. Number of moose counted on surveys in winter concentration areas on the Susitna River floodplain between Talkeetna and Devil Canyon (A), trimonthly maximum snowpack depth measured at Talkeetna (B) and number of moose killed by trains in Game Management Subunit 13E (railroad milemarks 225-274) during October-April (C), 1981-85, southcentral Alaska. Numerals above bars indicate no. moose killed. In other studies, moose fall-winter migration onset coincided with ca. 40 cm of accumulated snow.

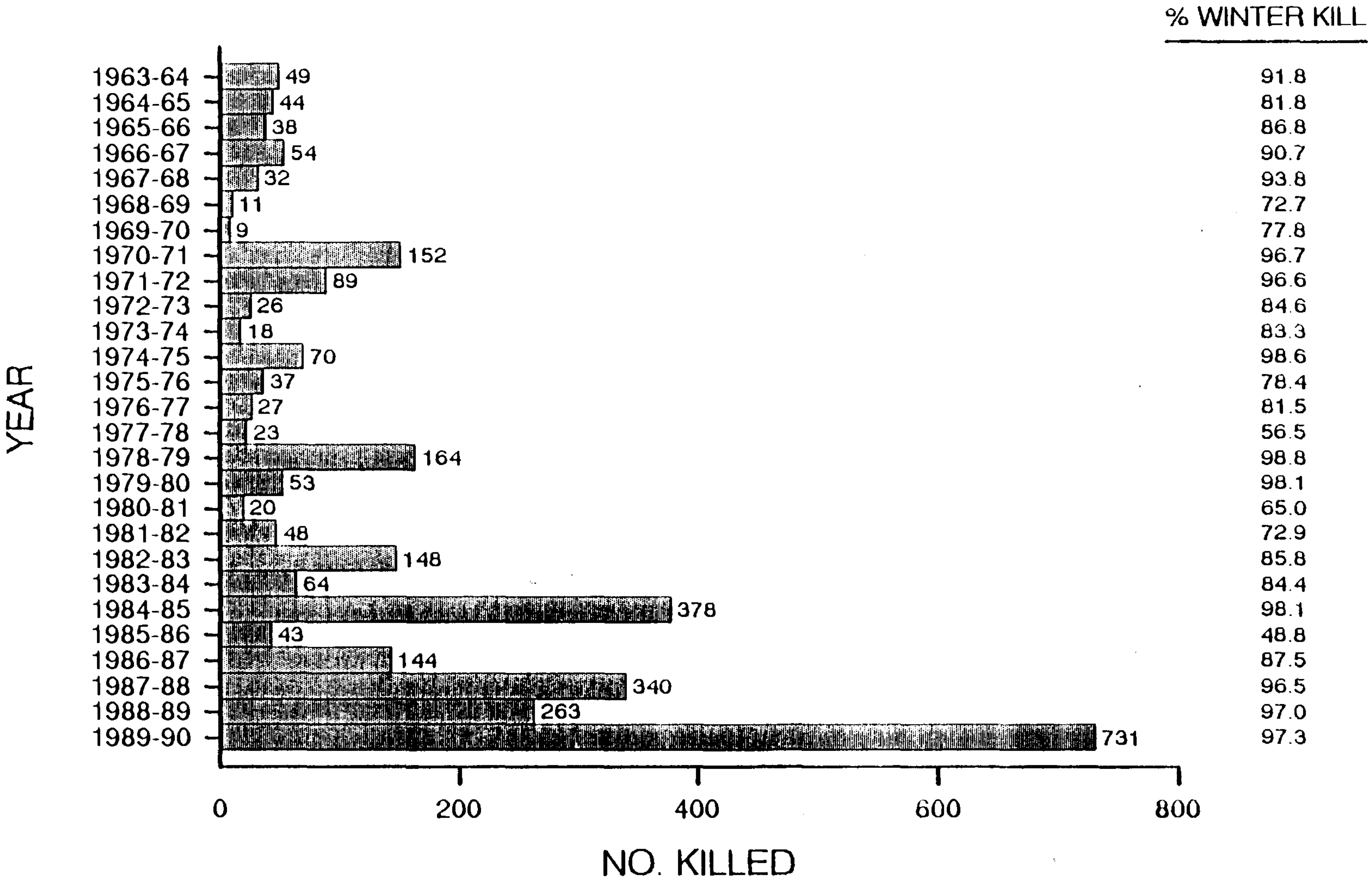


Fig. 8. Number of train killed moose, May-April (n=3075) and percent killed during winter, November-April (n=2866), by year, in 470 mi of railway between Seward and Fairbanks, Alaska, 1963-90. Numerals at end of bars indicate no. moose killed yearly.

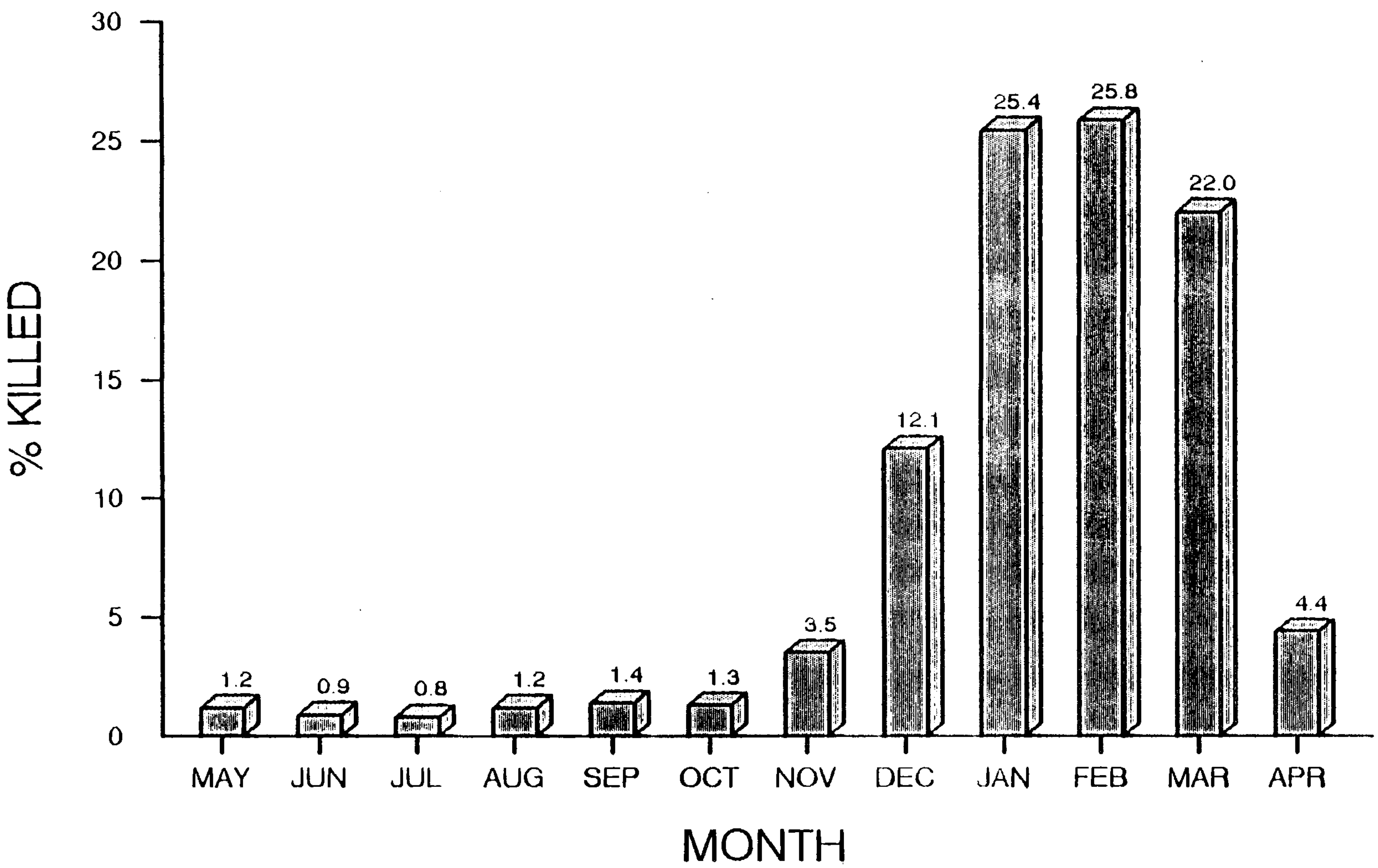


Fig. 9. Percent distribution of train killed moose by month for 470 mi of railway between Seward and Fairbanks, Alaska, 1963-90 (n=3075). Numerals above bars indicate % train killed moose.

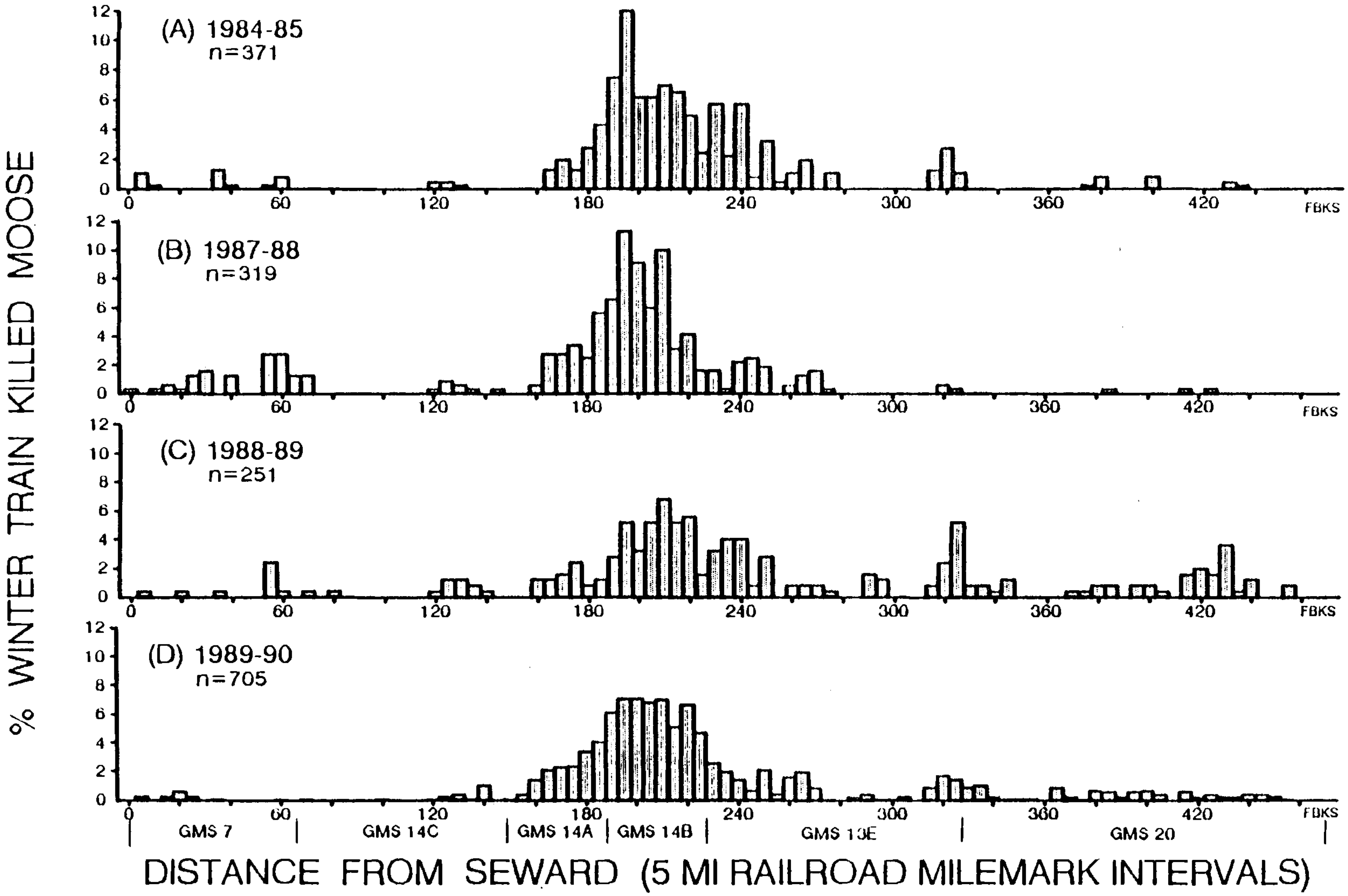
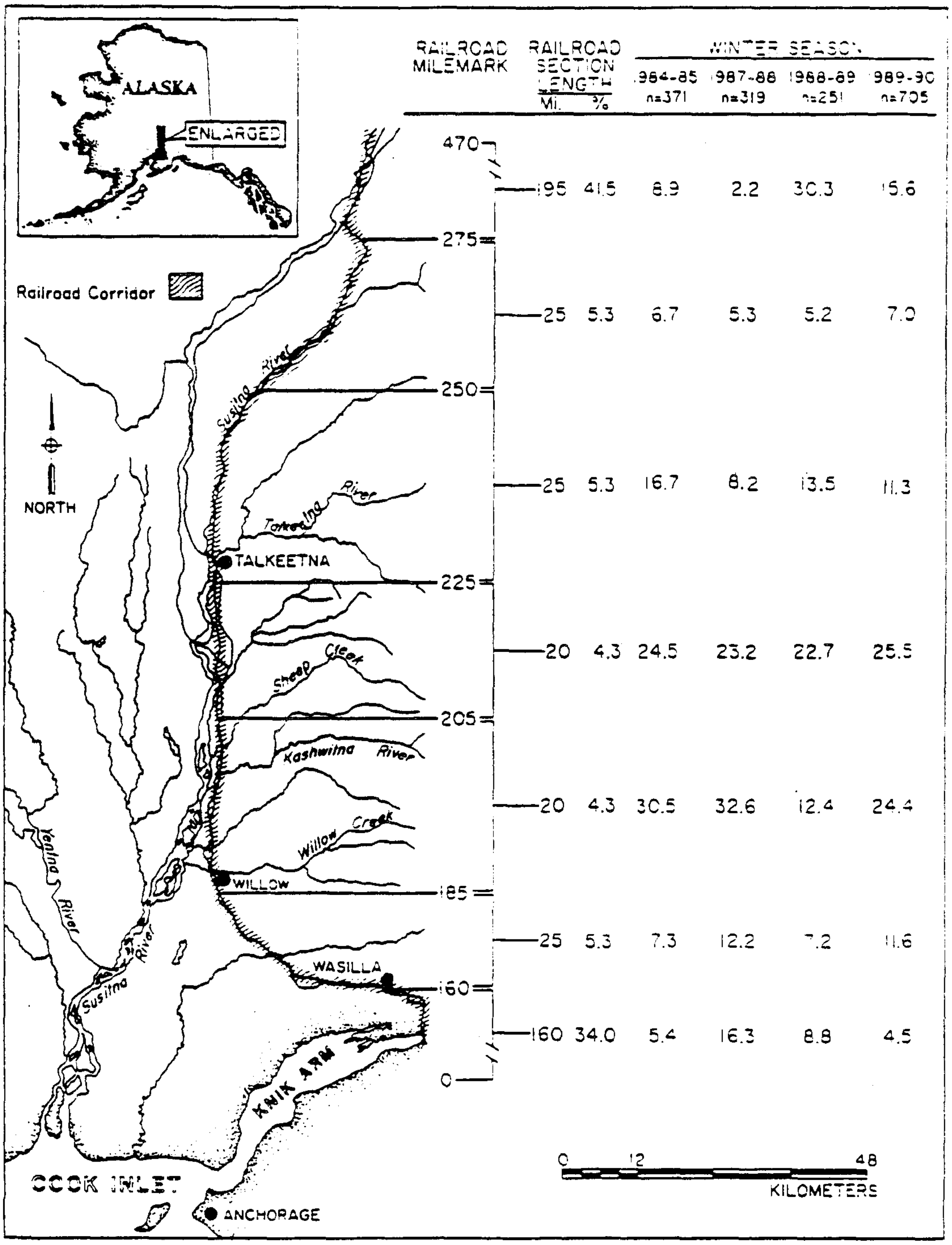


Fig. 10. Percent winter, November-April, train killed moose for 5 mi railroad milemark intervals from Seward (mi 0) to Fairbanks (mi 470) during 1984-85 (A), 1987-88 (B), 1988-89 (C) and 1989-90 (D), Alaska. Vertical lines below x-axis indicate milemark locations of Game Management Subunit (GMS) boundaries. FBKS=Fairbanks.



Railroad Milemark	Railroad Section Length Mi.	%	Winter Season 1984-85 n=371	1987-88 n=319	1988-89 n=251	1989-90 n=705
470–275	195	41.5	8.9	2.2	30.3	15.6
275–250	25	5.3	6.7	5.3	5.2	7.0
250–225	25	5.3	16.7	8.2	13.5	11.3
225–205	20	4.3	24.5	23.2	22.7	25.5
205–185	20	4.3	30.5	32.6	12.4	24.4
185–160	25	5.3	7.3	12.2	7.2	11.6
160–0	160	34.0	5.4	16.3	8.8	4.5

Fig.11. Percent of moose killed by trains in 7 sections of railway between Seward (milemark = 0) and Fairbanks (milemark 470), Alaska, during 4 winter seasons (November-April), 1984-85, 1987-88, 1988-89 and 1989-90.

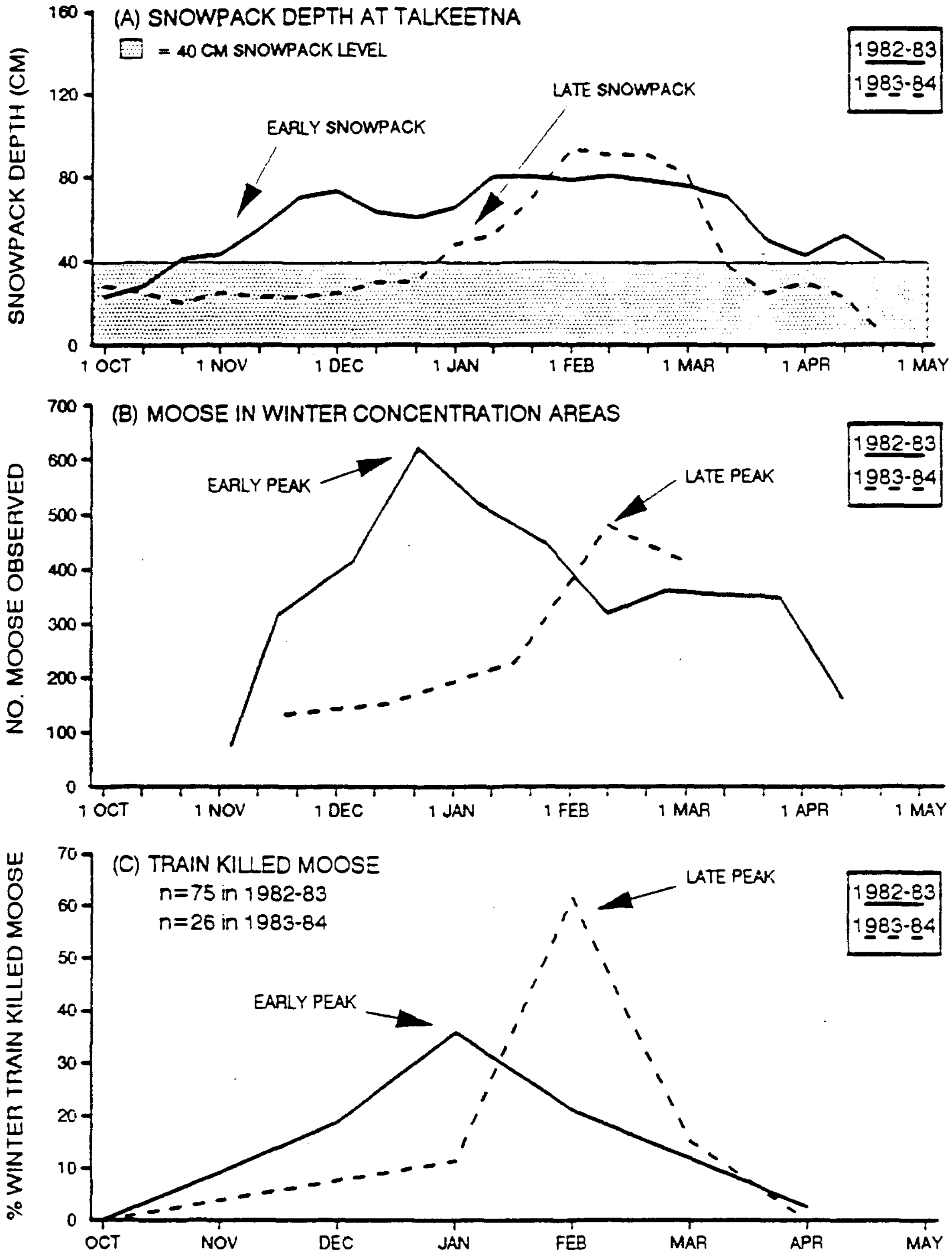


Fig. 12. Maximum snowpack depth measured trimonthly at Talkeetna (A), number of moose counted on surveys in winter concentration areas on the Susitna River floodplain from the Yentna River to the Talkeetna River (B), and number of moose killed by trains in Game Management Subunit 14B (railroad milemarks 187-225) during November-April (C), 1982-84, southcentral Alaska. In other studies, moose fall-winter migrations coincided with ca. 40 cm of accumulated snow.

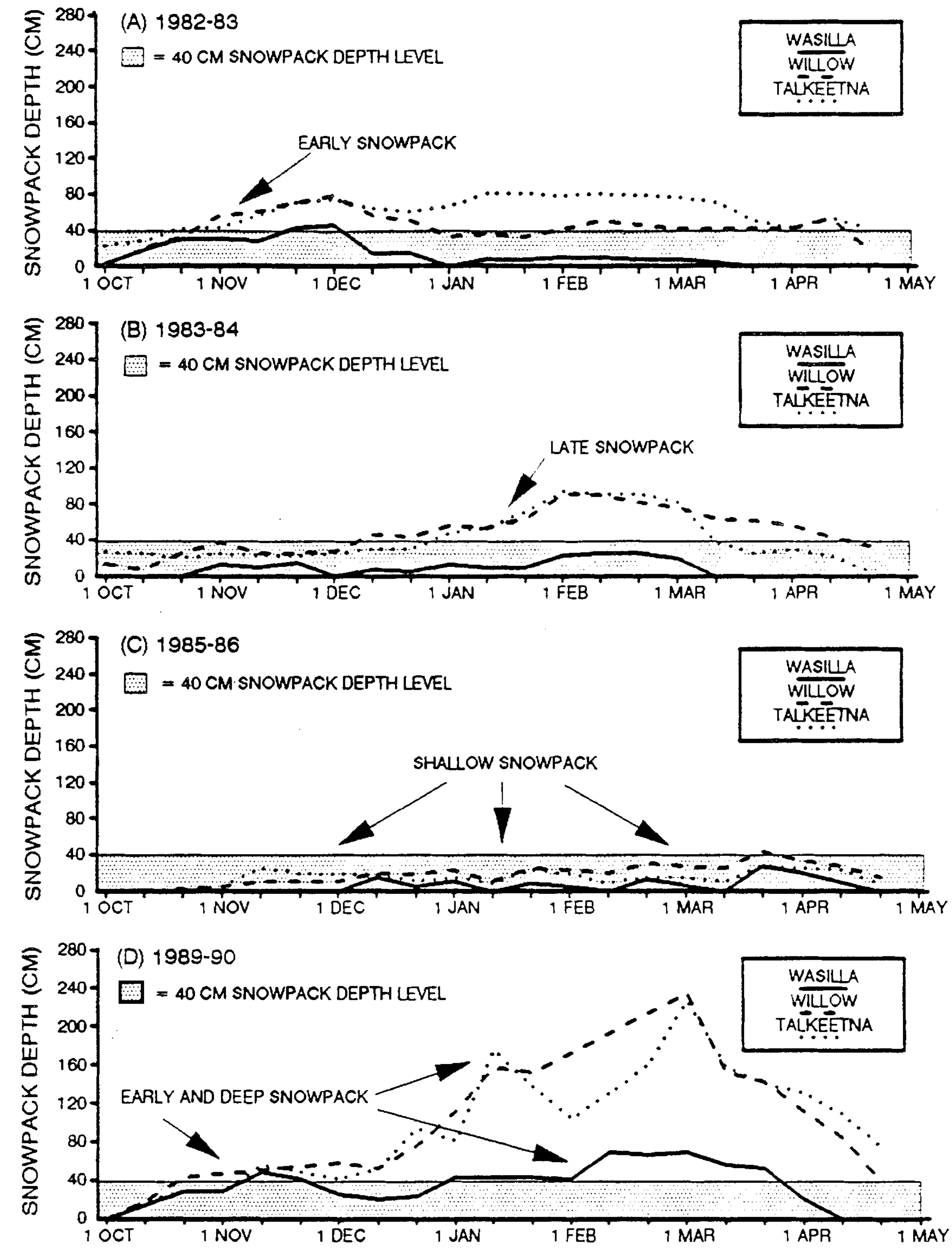


Fig. 13. Maximum snowpack depth measured trimonthly, October-April, at Wasilla, Willow and Talkeetna during 1982-83 (A), 1983-84 (B), 1985-86 (C), and 1989-90 (D), years with early, late, shallow, and early and deep snowpacks, respectively, in southcentral Alaska. In other studies, moose fall-winter migration onset coincided with ca. 40 cm of accumulated snow.

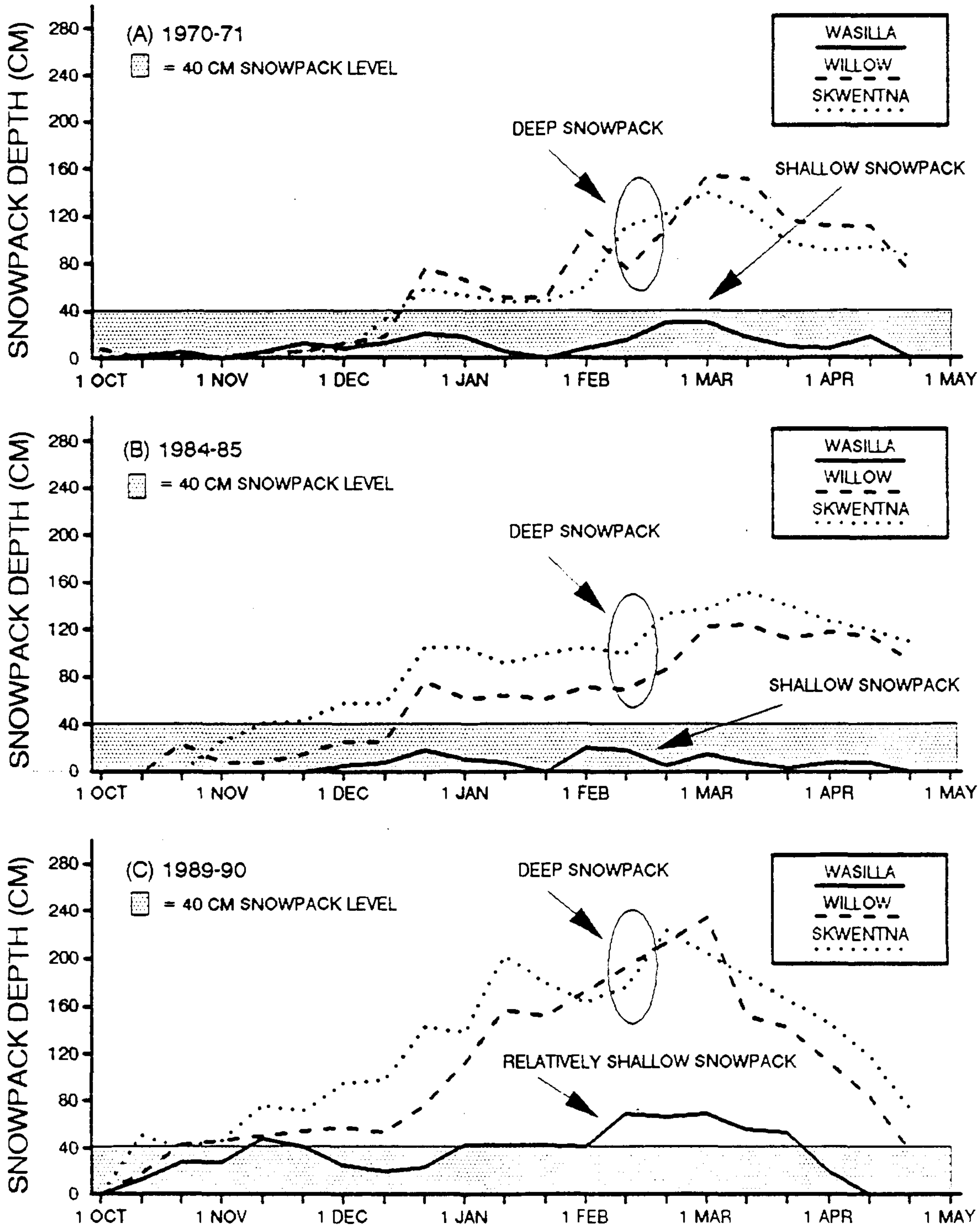
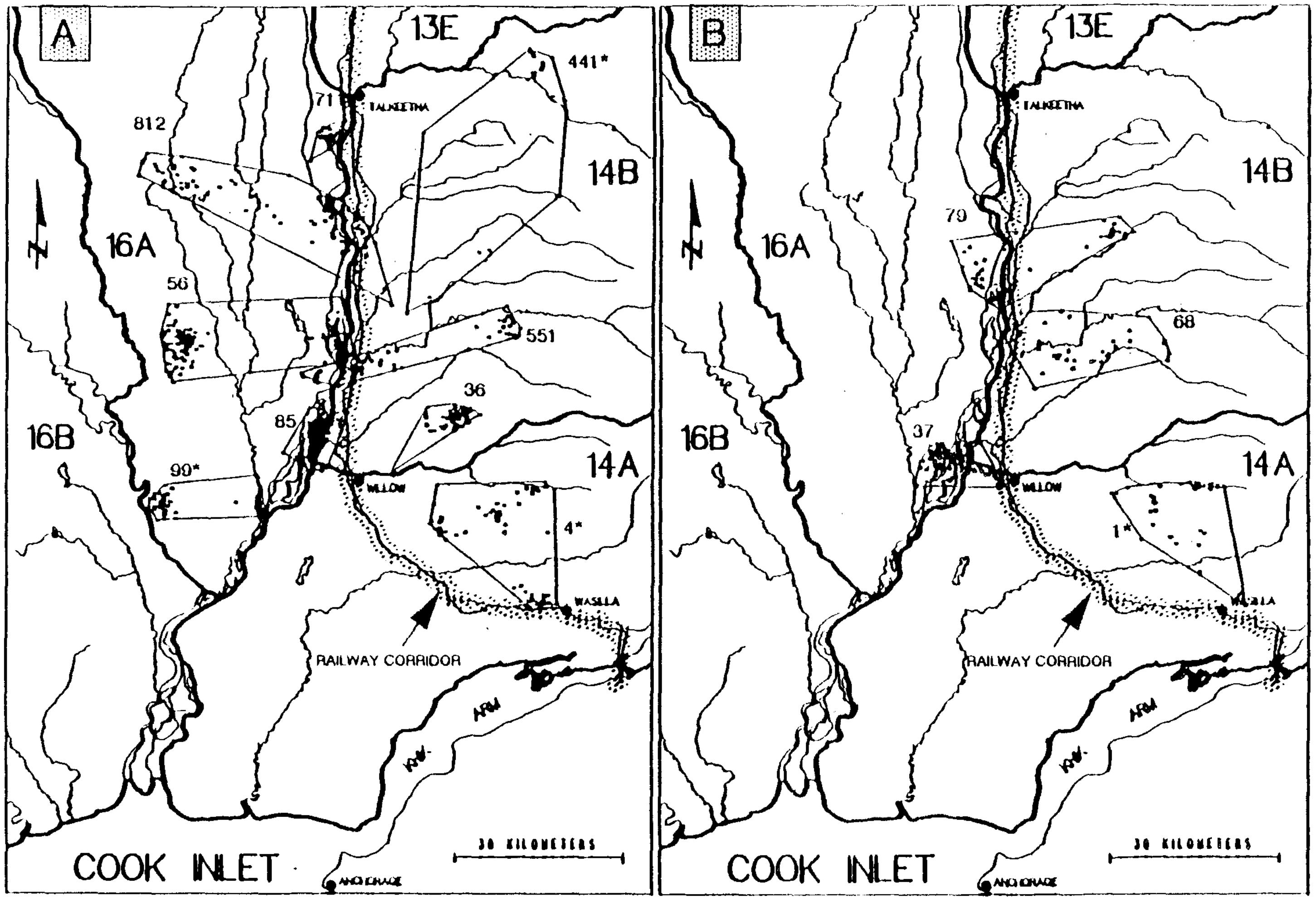


Fig. 14. Maximum snowpack depth measured trimonthly, October-April, at Wasilla, Willow, and Skwentna during 1970-71 (A), 1984-85 (B) and 1989-90 (C), years with exceptionally deep snowpacks, southcentral Alaska. In other studies, moose fall-winter migration onset coincided with ca. 40 cm of accumulated snow.

APPENDIX A. Convex polygons encompassing point locations for 22 male and 47 female radio-marked moose studied in lower Susitna Valley, southcentral Alaska, 1980-90. Numerals identify individual moose. Males are indicated (*).



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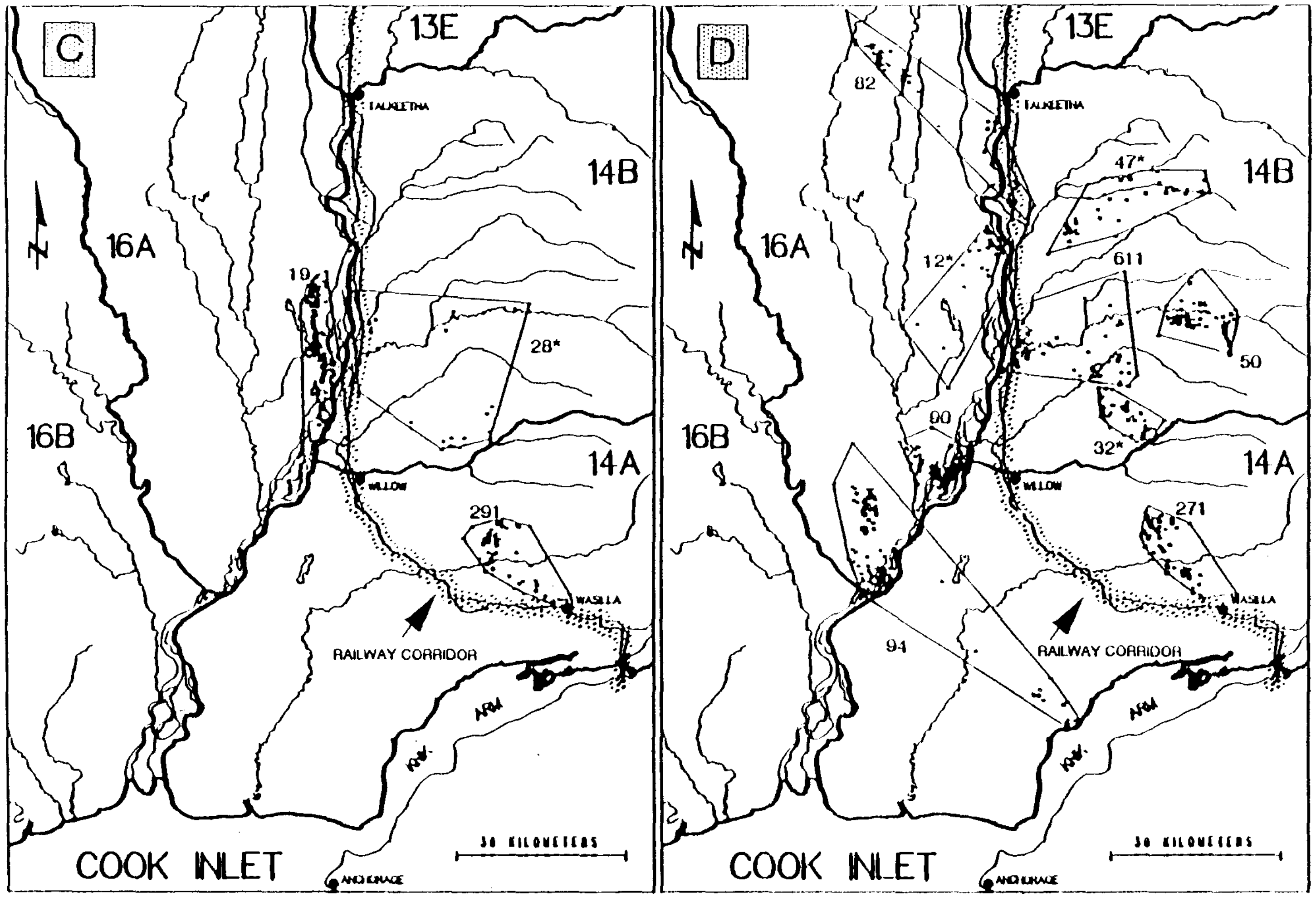

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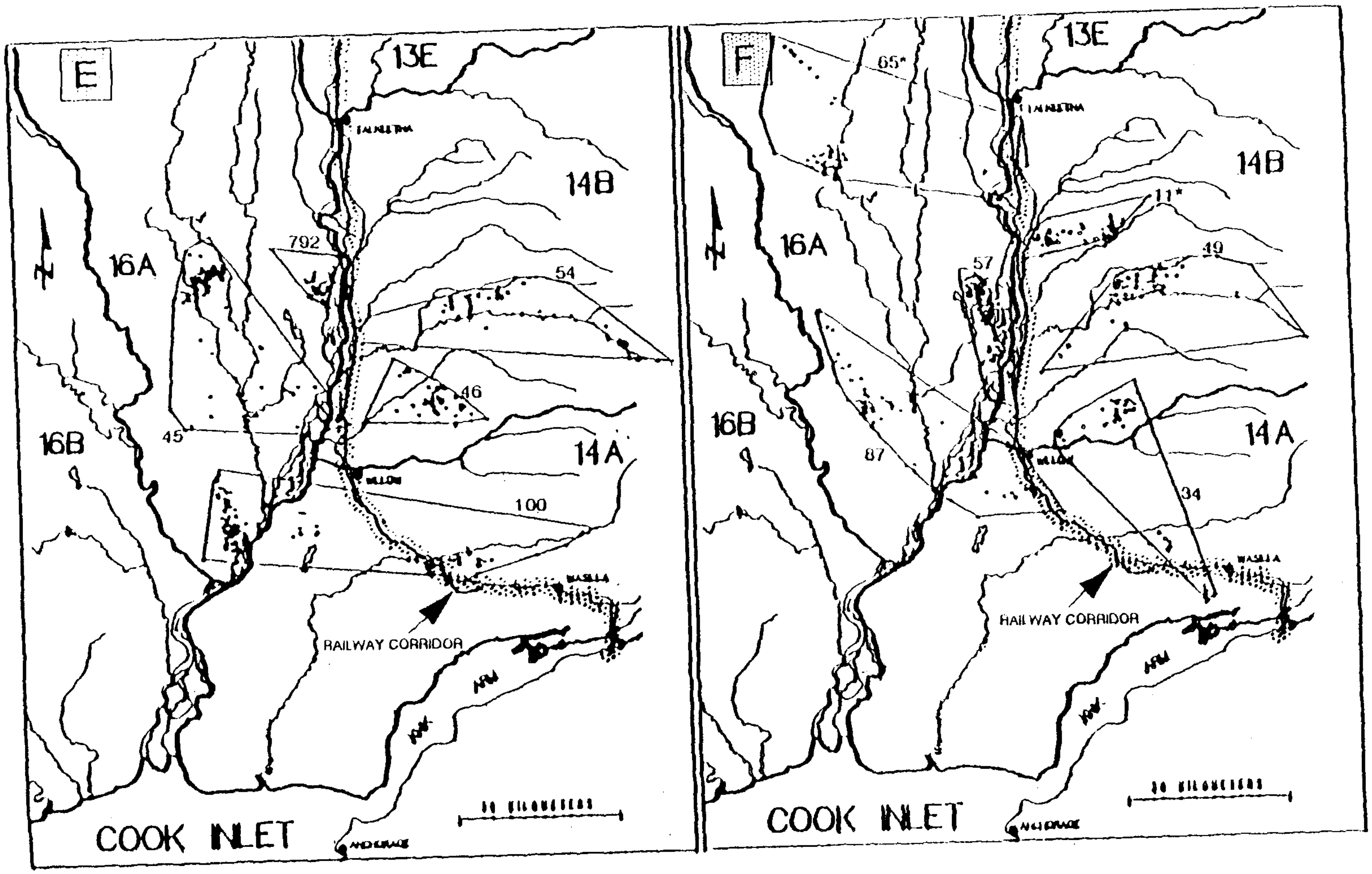

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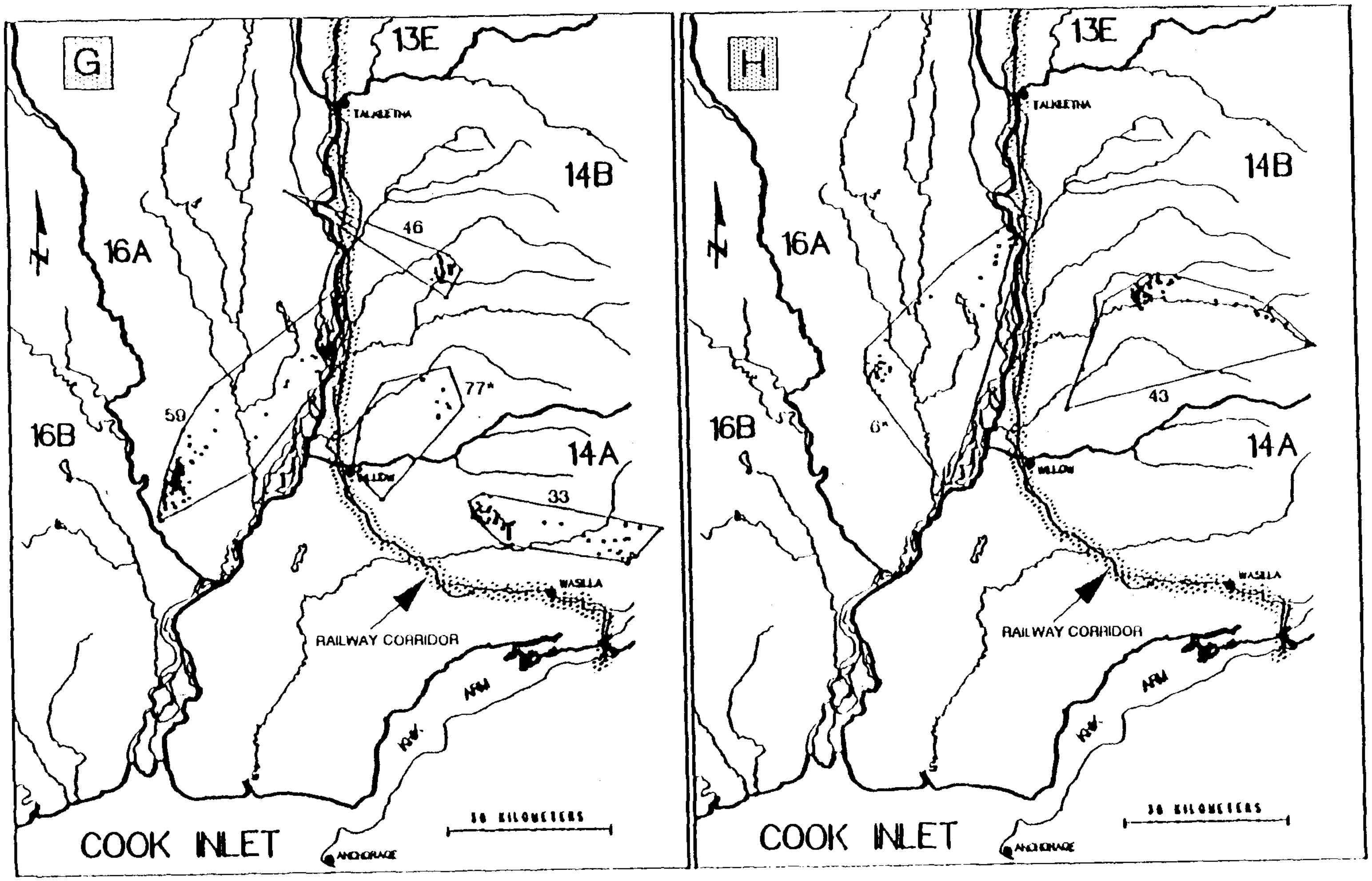
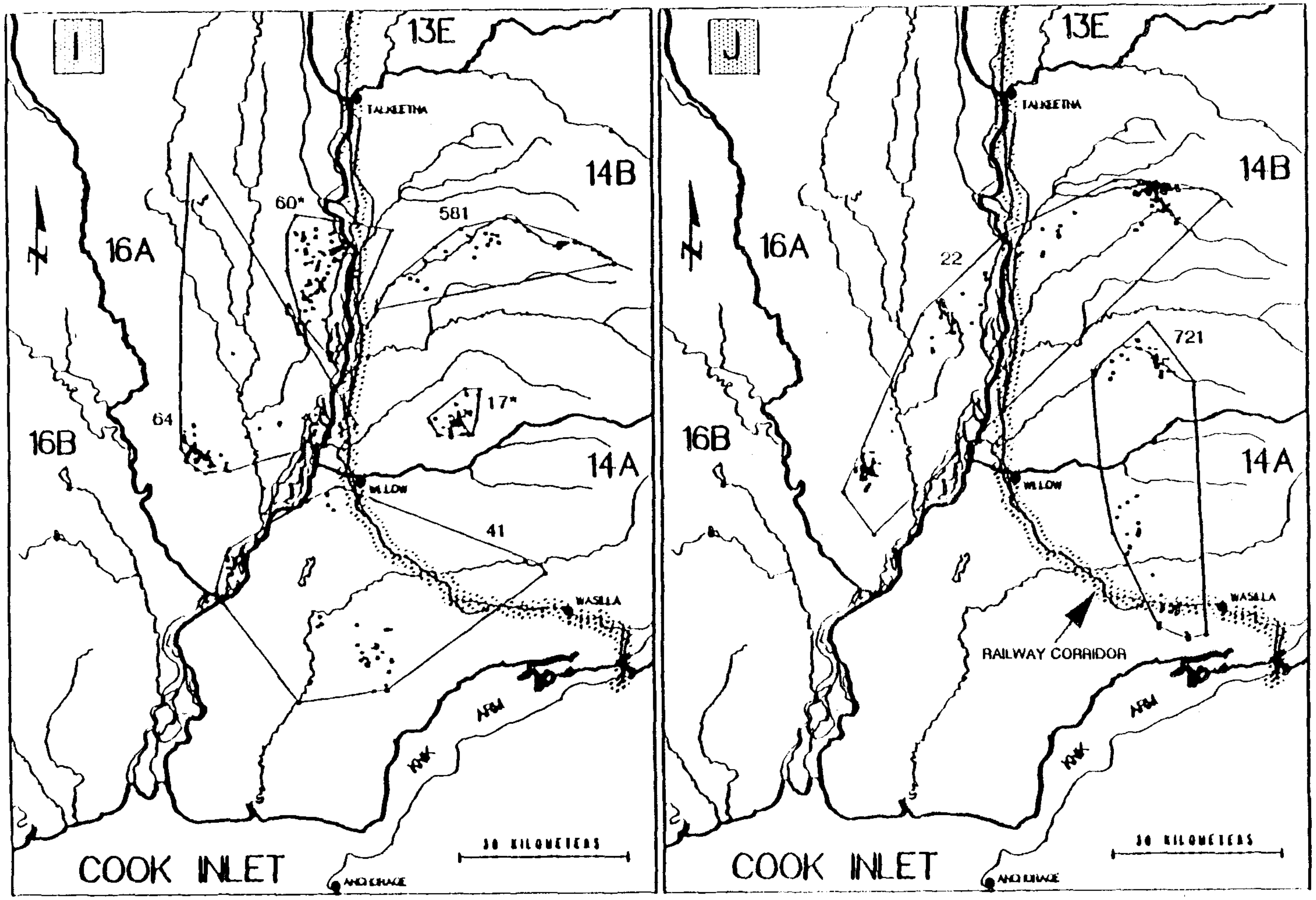
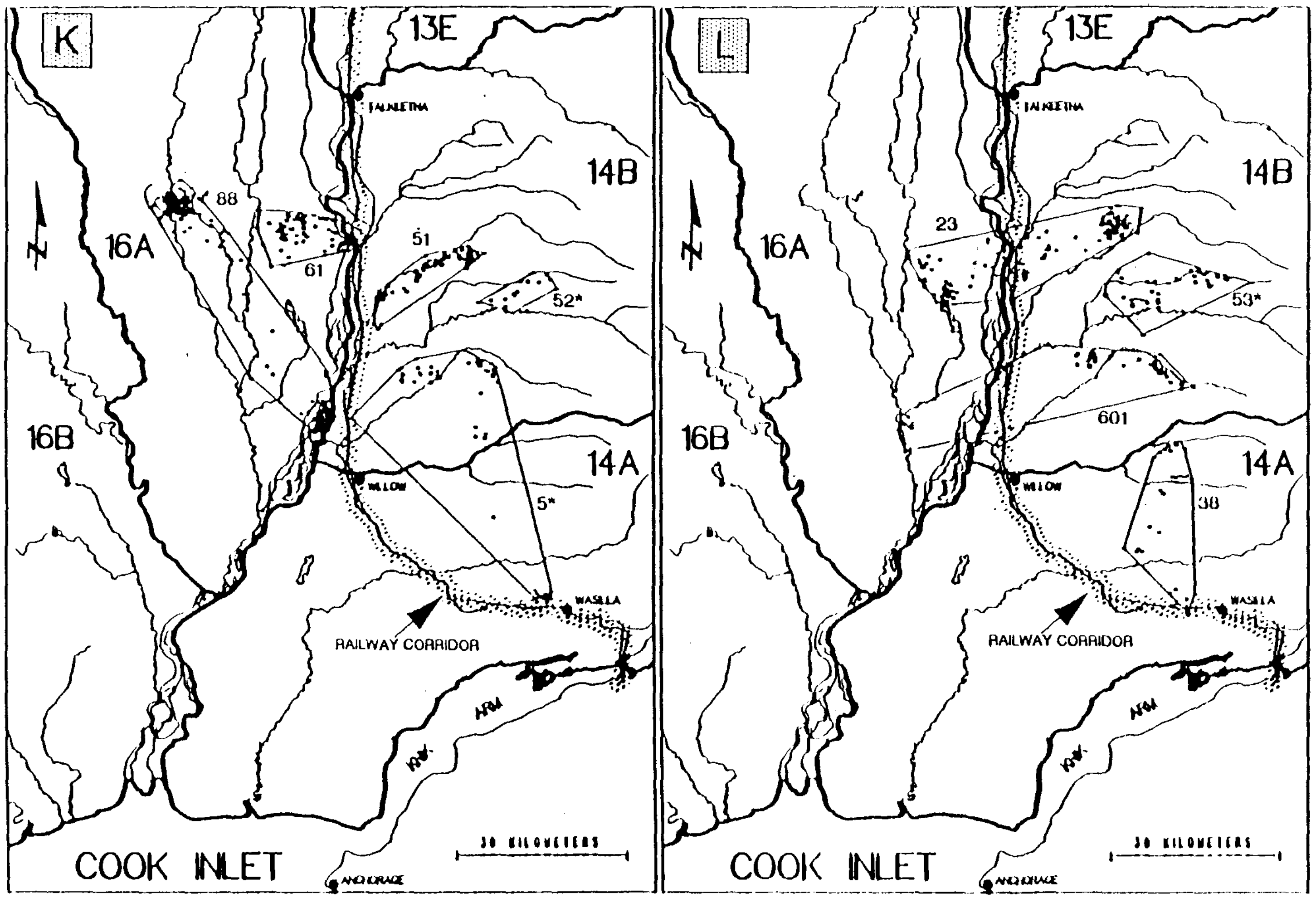


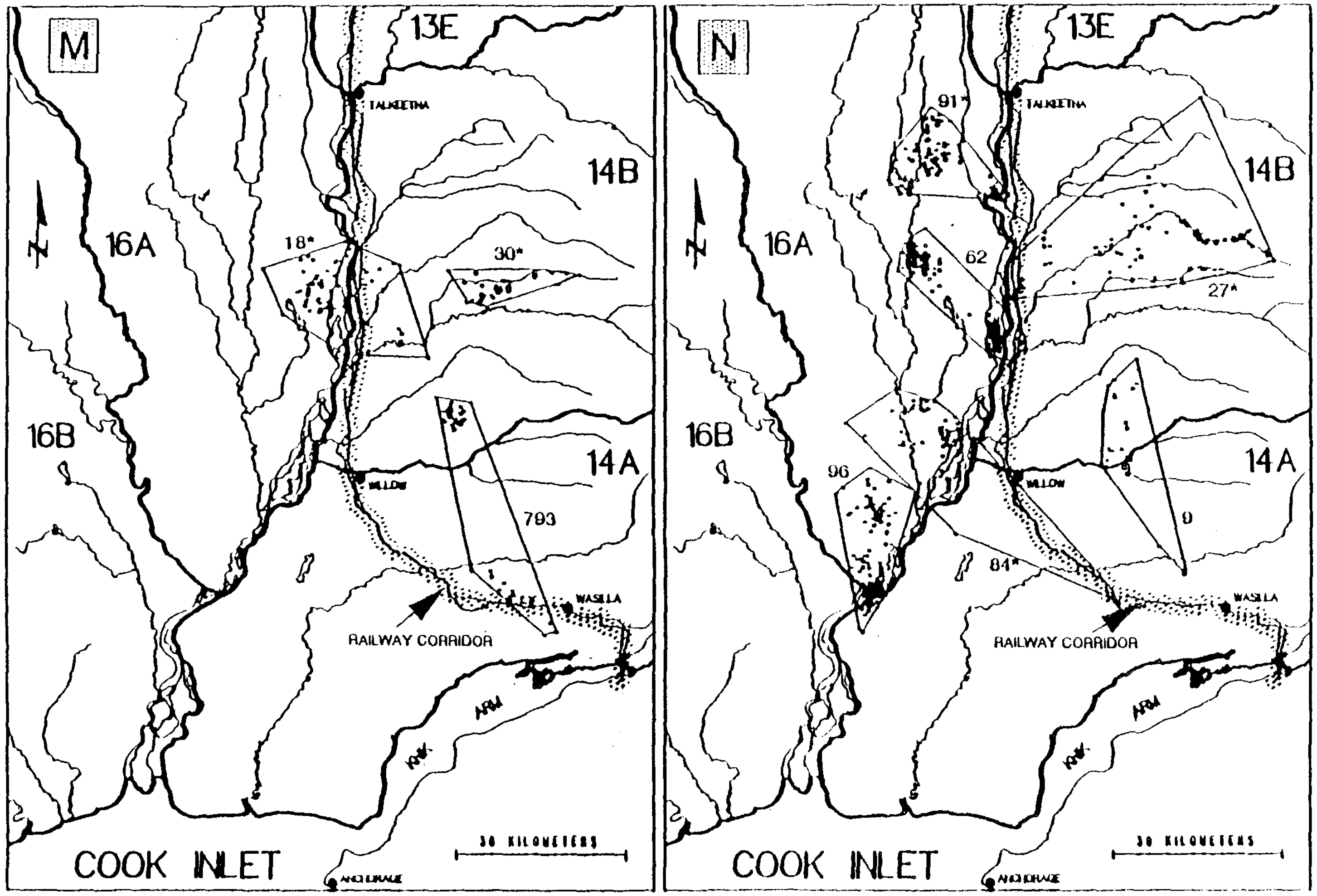
APPENDIX A. (Continued.)



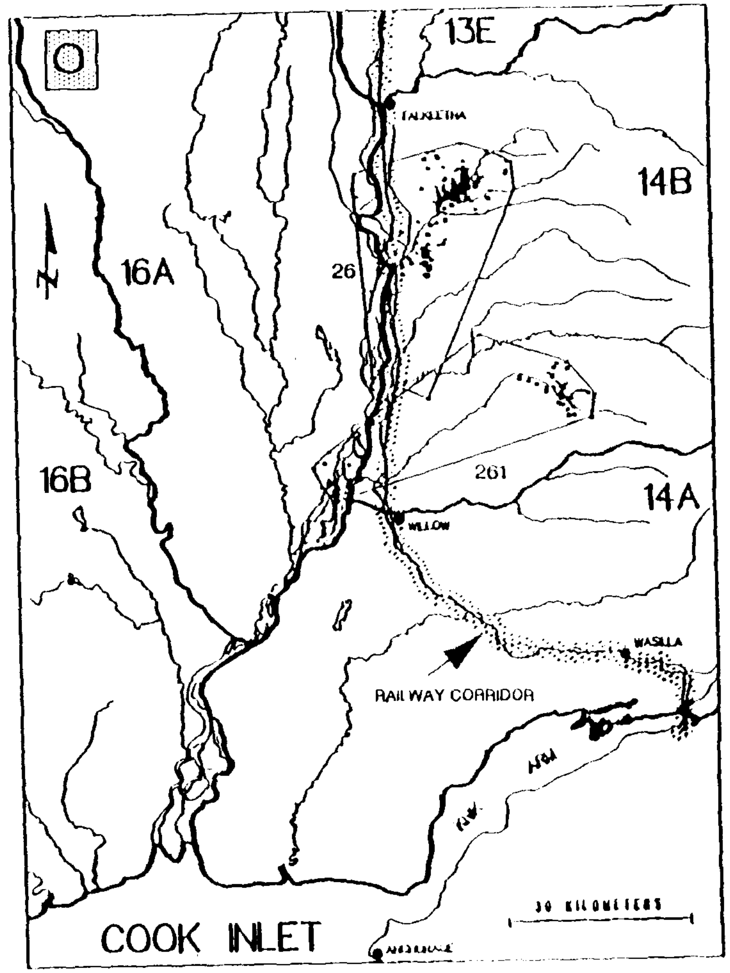
APPENDIX A. (Continued.)



APPENDIX A. (Continued.)



APPENDIX A. (Continued.)



WILDLIFE RESTORATION

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