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TUNDRA ESKER SYSTEMS AND DENNING BY GRIZZLY BEARS, WOLVES, FOXES, AND GROUND SQUIRRELS IN THE CENTRAL ARCTIC, NORTHWEST TERRITORIES

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YELLOWKNIFE, NWT

1995

Northwest Territories Renewable Resources

File Report No. 115

ABSTRACT

I investigated den characteristics for grizzly bears (*Ursus arctos*), wolves (*Canis lupus*), red foxes (*Vulpes vulpes*), arctic foxes (*Alopex lagopus*), and arctic ground squirrels (*Spermophilus parryii*) during July and August 1994 in the Lac de Gras region of the Central Arctic, Northwest Territories. All five species established dens almost exclusively on sandy eskers rather than on rocky uplands or on sedge meadows. The estimated proportions of the main habitat types in the study region are upland (54.7%), meadow (10.5%), and esker (1.5%). During helicopter searches the dens of bears ($n = 32$), wolves ($n = 37$), foxes ($n = 39$), and ground squirrels ($n = 2448$) were found on eskers significantly more often than expected by chance ($p \leq 0.025$). The site characteristics measured at four types of den sites (bear, $n = 23$; wolf, $n = 22$; fox, $n = 19$; and squirrel, $n = 18$) and two types of control sites, adjacent and random ($n = 36$) varied significantly. The size of esker materials at den sites was significantly smaller than the size of esker materials at both adjacent control and at random control sites. Esker materials required by industry are on average significantly larger than those used by all four types of denning animals. The slope at bear dens was significantly steeper than the slope at all other types of sites. Dens of both bears and squirrels tended to be on southern slopes. Significant differences were also found in the percentage cover of vegetation between the four types of den sites and the two types of controls. Percentage shrub cover was relatively high at bear dens. Percentage cover of grass, sedge, and fireweed (*Epilobium* spp.) was relatively high at wolf dens. Den sites of wolves, foxes, and ground squirrels were relatively large complexes, usually with numerous burrows. Bear dens had only a single burrow. The biomass of vegetation at den sites of wolves, foxes, and ground squirrels was relatively high and likely resulted from the activities of animals in repeated years. In contrast, vegetation at bear dens undergoes no alteration which suggests a short period of use. There were no significant differences in total nitrogen or in water content among sites. Total carbon content was significantly lower at random control sites compared to den sites. The above results suggest that it may be feasible to evaluate the suitability of habitat for denning of bears, wolves, foxes, and squirrels prior to industrial activities. Preliminary recommendations for further studies and impact mitigation are provided.

ĮKWĘ EDZANÈK'E, HOZI K' E WHAT'À EYITS'Q SAH DEK'O (SAHCHO), DÌGA, NQGÈ, DIENDA HANĮ TICH'ÀDI WEʔQ GQŁĮ

Įkwę hozı Edzanèk'e, Ekà Tı ekìye hagqt'e sı sah dek'o , dìga , nqge`, dıenda hanį tıch'àdı weʔq wendanageeta įle , 1994 ìmbe eko. What'à ewà k'e tıch'àdı k'ahjq hazhǫ t'e weʔq gǫłį eyıts'q ndè whegq , kwenèk'e xè gòzq k'e weʔq gǫłį-le. Dı wet'àʔà hqt'e, ekìye nèk'e sìı nàke percent làanį what'à gǫłį , 55 percent làanį ndè whegq xe kwe nèk'e eyıts'q 11 percent làanį gòzq gǫłį ne. Wekwìt'a ts'aèk'eà t'a tıch'àdı weʔq hak'eets'e t'a sahcho weʔq 32 gots'įʔq , dìga 37, nqgè 39 eyıts'q dıenda weʔq 2,448 gots'įʔq. Edį tıch'àdı weʔq gǫłį sìı wemǫq ndè wek'ats'etq eyıts'q edį tıch'àdı weʔq gǫłį-le sìı ndè t'ahsų ełeht'eh ha wek'ats'eetq. Tıch'adı weʔq gǫłį wemǫq ndè wek'e goįcha-le hqt'e hanìko edį weʔq gǫłį-le t'a hagoįt'e-le.Tıch'àdı weʔq gǫłį wemǫq ndè wek'e goįcha-le hqt'e hanìko sǫmba kwe hageetà gha kǫ hołe , tılı hołe gha sı ndè gıchı hanįdè ełeht'e-le. Shì wemba sah dek'o (sah cho) weʔq gǫłį sı denak'e dehkegoįʔa hqt'e , hanįko tıch'àdı wenda gha hagoįt'e-le. Sahcho eyıts'q dıenda deʔq gehtsį nįdè ekaats'q shì wet'q sazhį ts'qk'e agehʔį hqt'e. Edį tıch'àdı weʔq gǫłį sìı wemǫq įt'ǫà làanì deshe hanìkò weʔq gǫłį-le sı hagot'e-le . Sahcho weʔq k'è įt'ǫà làanì netłq deshe hqt'e; wets'q xo ts'qʔǫ sahcho weʔq yayetǫ làanì. Dìga weʔq weka tł'o eyıts'q gq làanį haʔa netłq deshe ne. Dìga , nqgè eyıts'q dıenda gıʔq yagołį sı netłq gozhì goįʔà. Sacho weʔq t'à įłà zhq gozhì goįʔà. Dìga , nqgè eyıts'q dıenda gıʔq wemǫq įt'ǫą làanì deshe sı , tıch'àdı tsǫ ndè k'e at'į eyıts'q t'asìı ghq shèzhe k'ıàgot'oh xe netłq xo ts'q eyı gıʔq gǫłį ts'įʔq t'asìı deshe hqt'e. Sahcho weʔq t'a įłà zhq get'à at'į làanì eyıts'įʔq wemǫq įt'ǫà deshe sı eładį ade-le. Dı gondı (enįhtł'è) wegha, ndè dàhòt'ı t'à tıch'àdı deʔq eht'sį wek'ehodzq ha, eyıts'q sǫmba kwe hageeta dq edį kǫ gehtsį gha ndè t'a ageht'į gha wek'ehodzq ha.

ᖃᓄᐃᓕᖓᓂᖏᑦ

ᖃᐅᔨᓴᓚᐅᖅᒪ ᑎᓯᒥᔭᐅᖃᑦᑕᖅᑐᓂᒃ ᐊᒃᓚᓄᑦ (*Ursus arctos*), ᐊᒪᕈᖅᓄᑦ (*Canis lupus*), ᑎᕆᒐᓂᐊᓄᑦ ᓯᐊᖅᓇᓄᑦ (*Vulpes vulpes*), ᑎᕆᒐᓂᐊᓄᑦ ᖃᑯᖅᑕᓄᑦ (*Alopex lagopus*), ᐊᒻᒪᓗ ᓯᒃᓯᓄᑦ (*Spermophilus parryii*) ᐊᐅᔭᐅᑎᓪᓗᒍ ᔪᓚᐃᒥᑦ ᐋᒌᓯᒧᑦ 1994-ᒥ ᑕᑐᒪᓂ ᕿᑎᖅᑐᓂ Lac de Gras-ᒥᒃ ᑕᓯᖃᕐᕕᐅᔫᑉ ᓄᓇᖓᓂ, ᓄᓇᓯᐊᒥ. ᑕᒪᐃᑕ ᐆᒪᔪᐃᑦ ᑖᒃᑯᐊ ᑎᓯᖃᐅᖃᑦᑐᒪᑕ ᑖᒪᓂ ᓯᐅᕐᔪᕐᓂ ᑐᐊᐸᖃᕕᐅᔪᓂ ᐅᔾᕈᖃᐅᖏᓐᓂᖅᓴᓂ ᐅᕙᓗᓃᑦ ᒪᖅᓴᐅᖏᑐᓂ ᐃᔾᔪᖃᐅᖏᓐᓂᖅᓴᓂ. ᓇᓗᐅᑦᑖᕈᑎᒋᓪᓗᒋᑦ ᓄᓇᑕᕆᔭᖓ ᑖᒪᓂ ᖃᐅᔨᓴᕐᕕᒋᓗᐅᖅᑕᑎᓐᓂ ᐱᖑᔾᔭᖃᐅᕐᓂᖅᓴᐅᖓᒪᑦ (54.7->ᓴᖏᑦ), ᐃᕕᖃᐅᕐᓃᑦ ᑲᔪᐊᓕᖓᓂᓖᑦ (10.5->ᓴᖏᑦ), ᐊᒻᒪᓗ ᑐᐊᐸᒃᑕᖃᐅᖅᑐᓃᑦ (1.5->ᓴᖏᑦ). ᖁᓕᒥᒎᓕᒃᑯᑦ ᕿᓂᖃᑦᑕᖅᑐᑕ ᓈᓴᔪᕐᒍᑦ ᑎᓯᖏᑦ ᐊᒃᖤᐃᑦ (n = 32), ᐊᒪᕈᐃᑦ (n = 37), ᑎᕆᒐᓂᐊᑦ (n = 39), ᐊᒻᒪᓗ ᓯᒃᓰᑦ (n = 2448) ᐊᓂᓯᔪᔪᒧᑦ ᑐᐊᐸᒃᑕᓕᖕᓈᓐᓂᖅᓴᐅᖃᑦᑕᔪᑦ ᐊᓯᖏᓐᓂᓂᑦ ($p \leq 0.025$). ᓄᓇᐃᑦ ᑎᓯᖃᕐᕕᐅᒐᔪᖕᓂᖅᓴᐅᔪᔪᑦ ᐆᒃᑐᕈᖅᑕᐅᔪᔪᑦ ᓯᑕᒪᓂ ᑎᓯᖃᕐᕕᐅᔪᓂ (ᐊᒃᖤᐃᑦ, n = 23; ᐊᒪᕈᐃᑦ, n = 22; ᑎᕆᒐᓂᐊᑦ, n = 19 ᐊᒻᒪᓗ ᓯᒃᓰᑦ, n = 18) ᐊᒻᒪᓗ ᐊᓯᖏᓐᓂ ᒪᕿᖕᓂ ᖃᓂᒋᔭᖏᓐᓂ, ᐅᖓᓯᒋᔭᖏᓐᓂ ᓇᒥᕈᓘᔭᑐᐃᓐᓇᕐᓗ. ᑐᐊᐸᐃᑦ ᓴᓇᔨᓄᑦ ᐅᑐᖅᑕᕆᐊᖃᖃᑦᑕᖅᑐᑦ ᐊᖏᔫᑕᐅᓂᖅᓴᐅᖃᑦᑕᒪᑕ ᑖᒃᑯᓇᖕᒪᓂᑦ ᓯᑕᒪᓄᑦ ᐆᒪᔪᓄᑦ ᑎᓯᓕᐅᕐᕕᐅᖃᑦᑕᖅᑐᓂᑦ ᑐᐊᐸᒥᔭᐅᔪᓂᑦ. ᐱᖑᐃᑦ ᖃᐃᖅᓱᕐᖏᑦ ᐅᕿᖓᓛᔪᕐᓂᖅᓴᐅᖃᑦᑕᔪᑦ ᐊᒃᖤᓄᑦ ᑎᓯᓕᐅᕕᐅᖃᑦᑕᖅᑐᑦ ᐊᓯᖏᓐᓂᑦ ᐱᖑᖕᓂᑦ. ᐊᒻᒪᓗ ᓯᕿᓂᖕᓚᖓᓃᓐᓗᑎᒃ ᑎᓯᓕᐅᕐᕕᐅᖃᑦᑐᑦ ᐊᒃᖤᓄᑦ ᓯᒃᓯᓄᓪᓗ ᐱᖑᒃ ᓂᐱᖕᓚᖓᓂ. ᐊᒃᓱᒃᑲᓪᓚᒃᑕᐅᖅ ᐊᔾᔨᐅᖏᓐᓂᖅᓴᐅᖃᑦᑕᔪᑦ ᐱᕈᖅᑐᖃᐅᕐᓂᖏᑦ ᑖᒃᑯᐊ ᓄᓇᐃᑦ ᓯᑕᒪᑦ ᐊᔾᔩᖏᓐᓂᖏᑦ ᑎᓯᓕᐅᕐᕕᐅᖃᑦᑕᖅᑐᑦ ᐊᒻᒪᓗ ᐊᓯᖏᑦ ᒪᕿᐃᓕᖓᔪᑦ ᐆᒃᑐᕋᑎᒥᓪᓗᒋᑦ ᓄᓇᐃᑦ. ᕿᔪᒃᑖᖃᐅᕐᓂᖅᓴᐅᖃᑦᑕᔪᑦ ᐊᒃᖤᓄᑦ ᑎᓯᓕᐅᕐᕕᐅᖃᑦᑕᖅᑐᑦ. ᐃᕕᖃᐅᕐᓂᖅᓴᐅᓪᓗᑎᒃ, ᐃᔾᔪᖃᐅᕐᓂᖅᓴᐅᓪᓗᑎᒡᓗ, ᐸᐅᓐᓇᖃᐅᕐᓂᖅᓴᐅᓪᓗᑎᒡᓗ (*Epilobium spp.*) ᐊᒪᕈᐃᑦ ᑎᓯᓕᐅᕐᕕᒥᖃᑦᑕᖅᑕᖏᑦ. ᐊᒪᕈᐃᑦ ᑎᓯᓕᐅᕐᕕᒥᖃᑦᑕᖅᑕᖏᑦ, ᑎᕆᒐᓂᐊᓪᓗ, ᐊᒻᒪᓗ ᓯᒃᓰᑦ ᓄᓇᖃᖃᑦᑕᔪᑦ ᐊᖏᔪᒃᑲᓪᓚᓂᒃ, ᐊᒥᓱᓂᒃ ᑎᓯᖃᐅᖅᑐᑎᒃ. ᐊᒃᖤᐃᓪᓕ ᑎᓯᖏᑦ ᐊᑦᑐᓯᐅᓈᖅᑎᖃᑦᑕᖅᑐᑎᒃ. ᐱᕈᖅᑐᖃᕐᓂᖏᓪᓕ ᑎᓯᓕᐅᕐᕕᐅᖃᑦᑕᖅᑐᑦ ᐊᒪᕈᕐᓄᑦ, ᑎᕆᒐᓂᐊᓄᑦ ᐊᒻᒪᓗ ᓯᒃᓯᓄᑦ ᐊᒃᓱᒃᑲᓪᓚᐅᓂᖅᓴᐅᖃᑦᑕᖅᑐᑦ ᐆᒪᔪᓄᑦ ᓄᓇᑕᖓ ᐱᓕᕆᐊᕆᓇᔭᐅᓯᒪᓂᖓᓈᖅᑯᖅᑐᖅ ᐊᒥᓱᓂ ᐅᑭᐅᓂ. ᐃᓗᐊᒍᖕᖏᓕ ᑕᑯᓪᓗᒋᑦ, ᐊᒃᖤᐃᑦ ᑎᓯᓕᐅᕆᕙᒃᑕᖏᑦ ᐊᔾᔨᖅᓯᒪᓗᐊᔪᖏᑐᑦ ᕿᑐᒥ ᓇᔪᖅᑕᐅᖃᑦᑕᕐᓂᖏᓐᓅᕙᓪᓚᐃᔪᖅ. ᐊᒃᓱᒃᑲᓪᓚᒃ ᐊᔾᔨᐅᖏᓗᐊᔪᖏᑦᑐᑦ ᑲᑎᓯᑦ ᓄᓇᒻᒪᑭᐅᓂᖏᑦ nitrogen ᐃᒪᖃᐅᕐᓂᖏᓪᓗ ᑎᓯᓕᐅᕐᕕᐅᖃᑦᑕᖅᑐᓂ. ᑲᑎᓯᑦ ᕿᔪᒃᑖᖃᕐᓂᖏᓪᓕ carbon ᐊᓯᖕᖏᓐᓂ ᓄᓇᓂ ᒥᕿᓐᓂᖅᓴᐅᔪᔪᑦ ᑎᓯᖃᕐᕕᐅᔪᓂᑦ. ᑖᒃᑯᐊ ᖃᐅᔨᔪᕐᒍᑦ ᓇᓗᓇᐃᖅᓯᔪᑕᐅᔪᔪᑦ ᑐᑭᓯᒍᓐᓇᖅᑎᒍ ᓂᕆᐊᖅᑕᐅᒍᓐᓇᕐᓂᖏᓐᓂᒃ ᓄᓇᒥᓴᐅᔪᒪᔪᑦ ᑎᓯᓕᐅᕐᕕᒥᓴᐅᕙᒃᑐᑦ ᐊᒃᖤᓄᑦ, ᐊᒪᕈᕐᓄᑦ, ᑎᕆᒐᓂᐊᓄᑦ ᐊᒻᒪᓗ ᓯᒃᓯᓄᑦ ᑕᒪᓐᓇ ᓴᓇᕕᐅᓯᒥᐊᓚᐅᖏᓐᓂᖓᓂ. ᓯᕗᓂᖓᓂ ᐅᓕᕐᑯᔭᐅᒥᐊᖃᖅᑐᑦ ᓱᓕ ᖃᐅᔨᓴᕈᑕᐅᒃᑲᓐᓂᓚᐅᖏᓐᓂᖏᓐᓂ ᐊᒻᒪᓗ ᖃᓄᑎ ᓴᓇᔪᖃᓕᖅᐸᑦ ᐆᒪᔪᓄᑦ ᐃᒃᐱᖕᓇᕐᓂᖃᕈᒫᕐᓂᐊᕐᓂᖓᓄᑦ ᓇᓗᐅᑦᑖᕈᑕᐅᓯᒪᔪᑦ ᐃᓚᓕᐅᑎᕙᒍᑦ.

EHIVGIOKHIMAYOT

EHIVGIOKPAKTATKA HEETIT HAPKOAT AKHAIT, AMAGOIT, KAYOKTOT, TIGIGANIAT OVALO HEEHIIT OVANI JULIMI AGAASIMILO 1994-GOTITLOGO HANIANI TAHIKYOAP NUNATIAMI. TAMAITA HOGAAT HEETIKAKTOT HEOGAKMI KINGGAOTAT TALVANIGITTOK OYAGALIAKNI NALIAK NAATINGNAKMI. HAMMA NAONAIKHIMAYOT HEETIKAKVIIT EHIVGIOKHIMAYAPTINGNI IMA TIKVANI (54.7%), NAATINGNAK (10.5%) OVALO KINGGAOTAT (1.5%). HALIKAPTAKOT NALVAKHIOGAPTA HEETIT AGHAIT (N=32), AMAGOIT (N=37), TIGIGANIAT (N=39 OVALO HEEHIIT (N=2448) NALVAKTAOYOT KINGGAOTAKNI KOYAGINAKAT ($P \leq 0.025$). EHIVGIOKTAKOT HITAMAOYOT HEETIT (AGHAK, N=23; AMAGOK, N=22; TIGIGANIAK, N=19; OVALO HEEHIK, N=18) OVALO MALGOK ATTOKTAOYOITTOT, AKIANI HEETIT OVALO TITIGAOHAKHIMAYOMI TIKOAKHIMAYOK. (N=36) TAIMA ALATKIKTOK. KINGGAOTAT HEETINI MEKITKIYAOYOT AKIANIT TALVALO TIKOAKHIMAYONI. KINGGAOTAT HAVAGVIKNI ANGITKIYAOLIKPAKTOT HITAMAINIT HEETIKAKTOT HOGAAT. AGHAIT HEETIKAKVIIT KINGGITKIAT ALANIT. AGHAIT HEEHIITLO HEETIKALIKPAKTOT HIVOANI. NALVAKTOGOTLO ALATKIKTOT NAOHIMAYOT HITAMAINIT HEETIT TALVALO ATTOKTAOHIMAYOITTOT. AGHAIT HEETIANI EVIGIAKTOK. AMAGOIT HEETIT EVIGIAKTOK, NAATINGNAGIAKTOK OVALO NAOSIAGIAKTOK. HEETIT AMIGAITTONIK ANGMAOMAVIKAKTOT AMAGOIT, TIGIGANIAT, OVALO HEEHIIT. AGHAIT ATAOHINAKMIK ETIKTIKVIKAKTOT HEETIT. NAOKATTAKHIMAYOKTOT HEETIANI AMAGOIT, TIGIGANIAT OVALO HEEHIIT ATTOKTAOKATTAKNINGMIK HOGAANIT. ATLAOYOK, AGHAIT HEETIT NAOHIMAYOKATTAYOITTOK ATTOKTAOHAAYOINMATTA. HEETIT NITROGEN-KALOANGITTOT NALIAK EMAAKALOANGITTOT. ANNIHAKTIGOTIKALOAGITTOT TIKOAKHIMAYONI HEETINIT. EHIVGIOKTAHAKOT HEETIKAKVIHAT AGHAIT, AMAGOIT, TIGIGANIAT OVALO HEEHIIT IMA HAVAGVIHALIOKTINAGIT. HAMMALO PITKOYAOHIMAYOT EHIVGIOHIMAGIAMI IMALO KANOGILIOGOTIHAT.

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INTRODUCTION

Little is known about the role of esker systems in the denning ecology of wildlife in tundra regions. To date very few studies of esker ecosystems have been conducted and no studies of the denning requirements of tundra wildlife have been conducted in the Central Arctic of the Northwest Territories. Eskers, ridges of glacially deposited rock material, are prominent topographic features in this vast wilderness region of exposed bedrock and permafrost (Andrews 1975, Aylsworth and Shilts 1989a, Aylsworth and Shilts 1989b, Bone 1992). Eskers can have special biological, geological, cultural, and economic significance (Kay and Kay 1976, Jacobson 1979, Minion 1985, Rajakorpi 1987, Rikkinen 1989, Heikkinen 1991, Vaisanen et al. 1991, Klohn-Crippen Consultants Ltd. 1993).

No studies have examined the den characteristics and den habitat of grizzly bears and foxes in tundra regions of the Canadian Shield. In other northern regions, numerous studies have been conducted on dens of arctic foxes (Chesemore 1969, Eberhardt et al. 1983, Garrott et al. 1983, Smits et al. 1988, Smith et al. 1992, Smits and Slough 1993, Nielsen et al. 1994) and dens of grizzly bears (Harding 1976, Reynolds et al. 1976, Vroom et al. 1980, Nagy et al. 1983, Mychasiw and Moore 1984). A few studies have examined wolf dens and wolf denning habitat in the Central Arctic (Jacobson 1979, Williams 1990, Heard and Williams 1992).

In tundra, the dens of foxes are limited to localized areas where the permafrost is sufficiently deep and soil characteristics allow burrowing (Garrott et al. 1983). No studies have compared the den characteristics and habitat selection of carnivores in tundra regions of the Canadian Shield. The extremely rocky terrain and the permafrost of tundra shield country may seriously limit the availability of suitable habitats for carnivore denning. I hypothesize that, in tundra regions of the Canadian Shield, animals will den almost exclusively on glacio-fluvial habitat, such as eskers, since suitable materials are otherwise rare.

Advanced mineral exploration, construction of mines, and proposed transportation and hydroelectric infrastructures require extensive quantities of granular material. Use of granular materials could lead to alteration or removal of eskers and, consequently, have negative impacts on denning species.

Objectives

The objectives of this study were as follows:

(1) To examine the role of esker habitat in the denning ecology of animals in a tundra region of the Canadian Shield.

(2) To describe and compare the dens and den site characteristics of five species (grizzly bears, wolves, red foxes, arctic foxes, and arctic ground squirrels) on tundra in the Central Arctic.

(3) To compare characteristics of esker den sites with control sites (adjacent and random) to determine whether or not den sites are different from other areas on eskers.

(4) To describe and compare soil and vegetation modifications that take place through faunal activity at den localities.

(5) To begin preliminary mapping of esker systems and wildlife dens in the Lac de Gras region.

(6) To make recommendations for further studies and impact mitigation at den sites.

METHODS

Study Area

During July and August 1994, fieldwork was conducted from the Daring Lake Field Station, Department of Renewable Resources, Government of the Northwest Territories (64°52' N, 111°37' W) and from the BHP Diamonds Inc. Koala Camp (64°42' N, 110°37' W) (Figure 1 and Figure 2). The study area is approximately 18,000 km^2 centred on the two camp sites located near Lac de Gras, the headwaters of the Coppermine River system (Figure 3). The climate is semi-arid and characterized by cool summers, long severe winters, and large annual ranges of temperature. Permafrost is discontinuous. The mean direction of prevailing winter winds (October to April) is 340° at nearby Contwoyto Lake (Canada, Atmospheric Environment Service 1988). Elevation is approximately 400 to 500 meters.

Numerous lakes are found in this rocky upland region of Canadian Shield. This area is within the geological region known as the Slave Geological Province (Figure 1). Continental glaciations created profound impacts on the region's landforms. The most recent, known as the Wisconsinian glaciation, ended in the study region between 11,000 and 9,000 years before present (Aylsworth and Shilts 1989a and 1989b). Glacio-fluvial features such as eskers, kames, drumlins, and raised beaches are numerous (Figure 4).

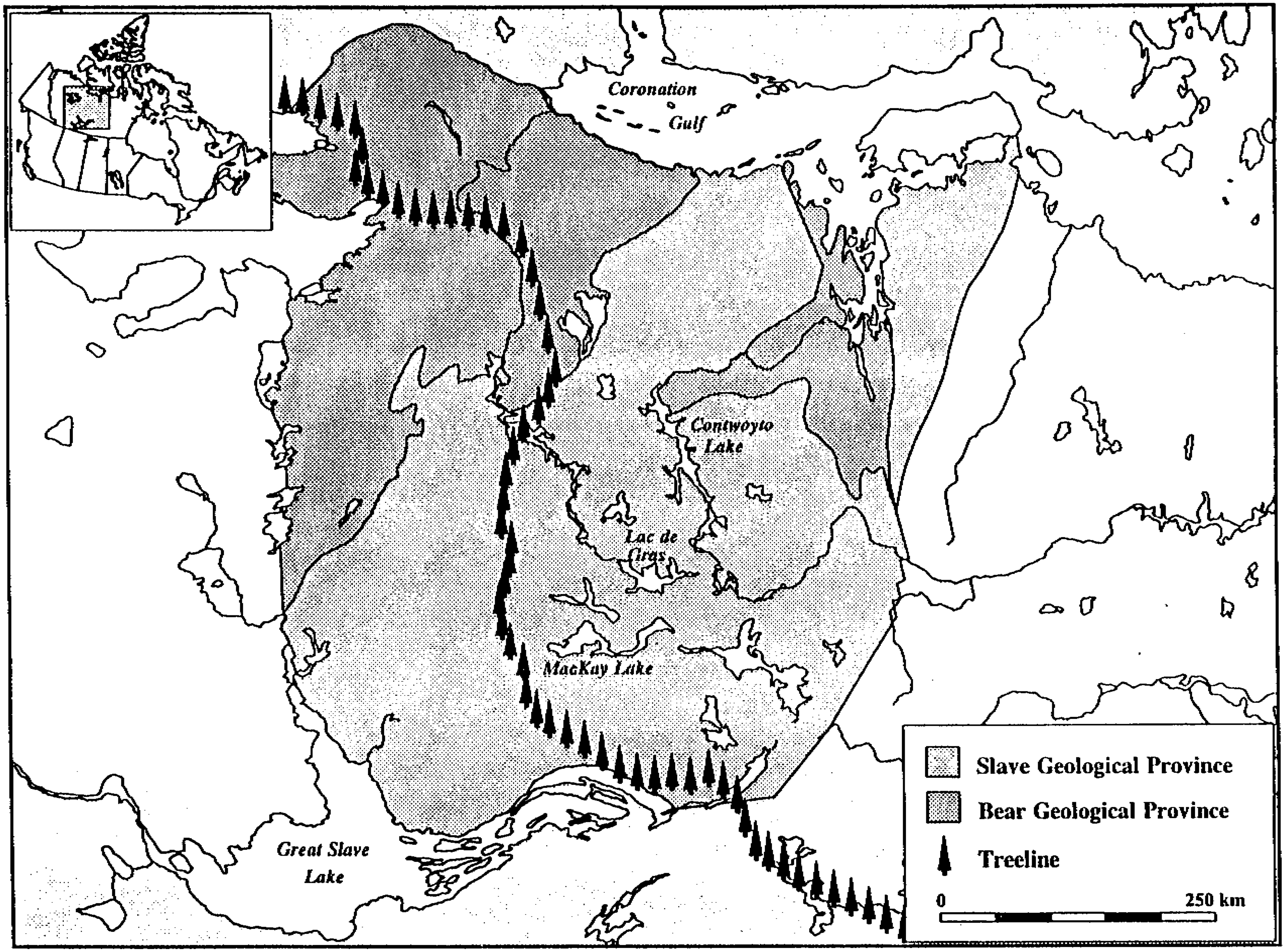

Figure 1. Map of the Central Arctic region of the Northwest Territories showing the location of Lac de Gras in relation to the treeline and the Slave Geological Province.

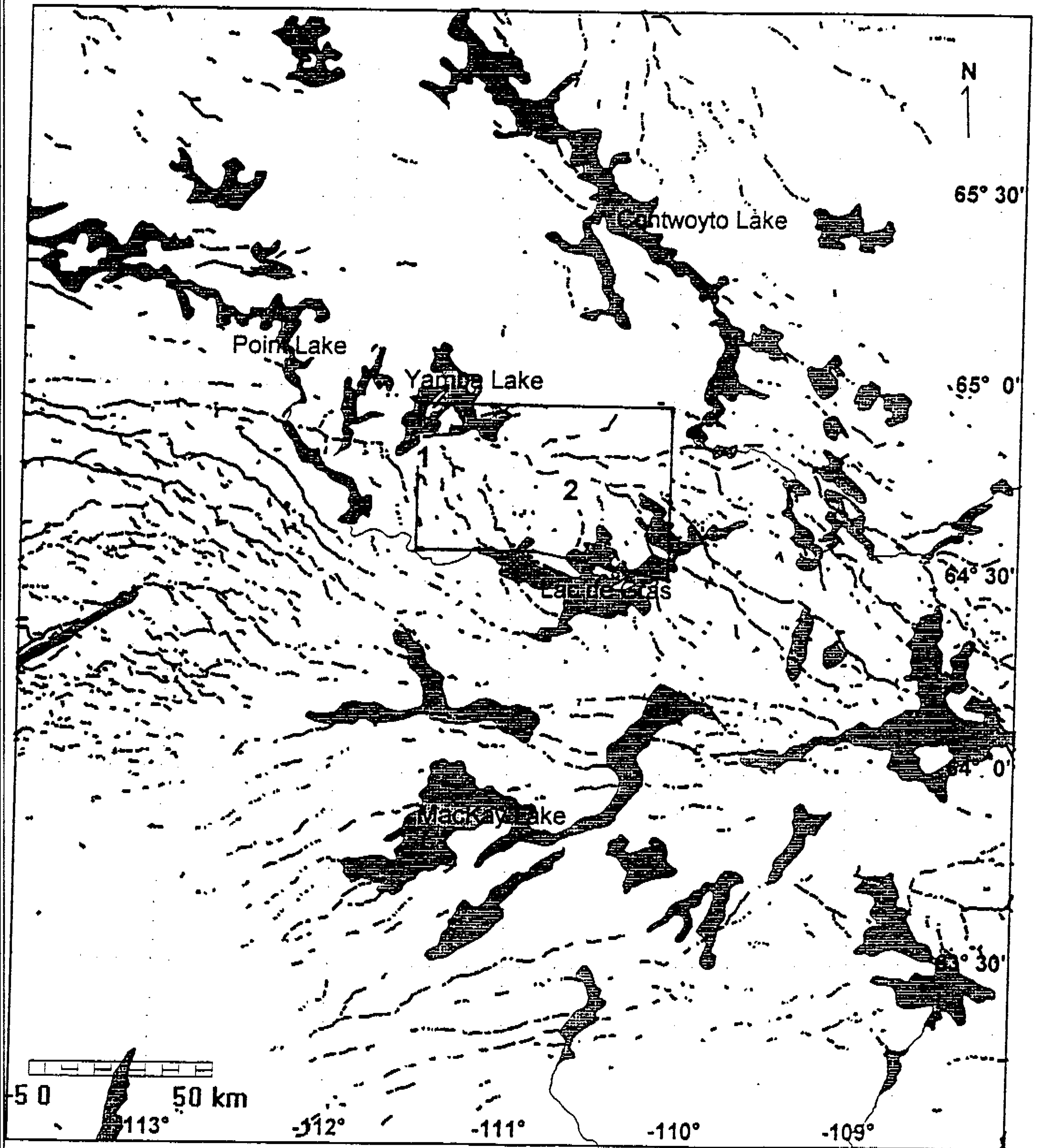

Figure 2. Map of the study area showing esker systems and major lakes in the Lac de Gras region of the Central Arctic, Northwest Territories, Canada. (The locations of the Daring Lake Research Camp and BHP's Koala Camp are indicated by 1 and 2, respectively.)

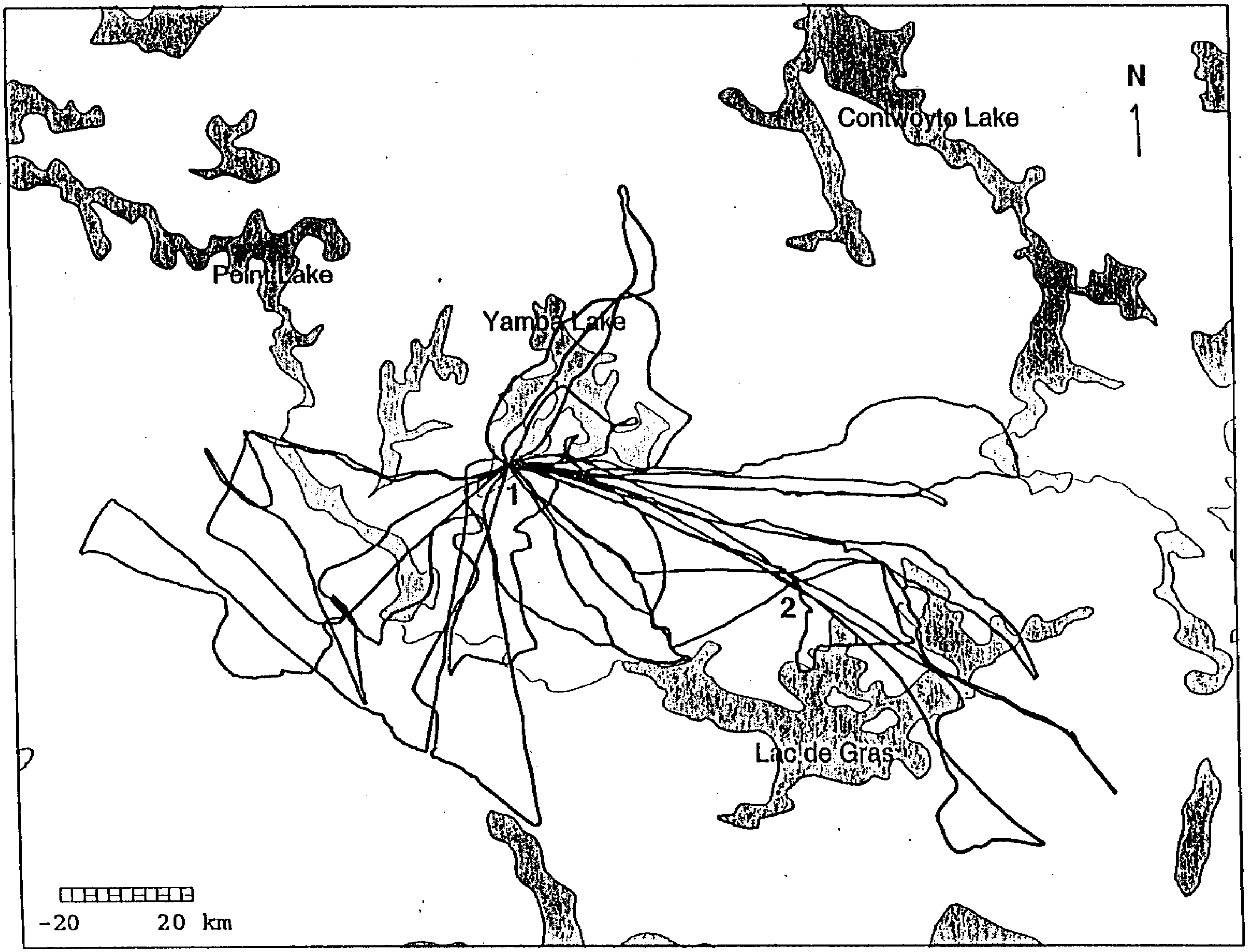

Figure 3. Map showing the helicopter flight path during den searches in the region around Lac de Gras. (The location of the Daring Lake Research Camp is indicated by 1 and the location of BHP's Koala Camp is indicated by 2.)

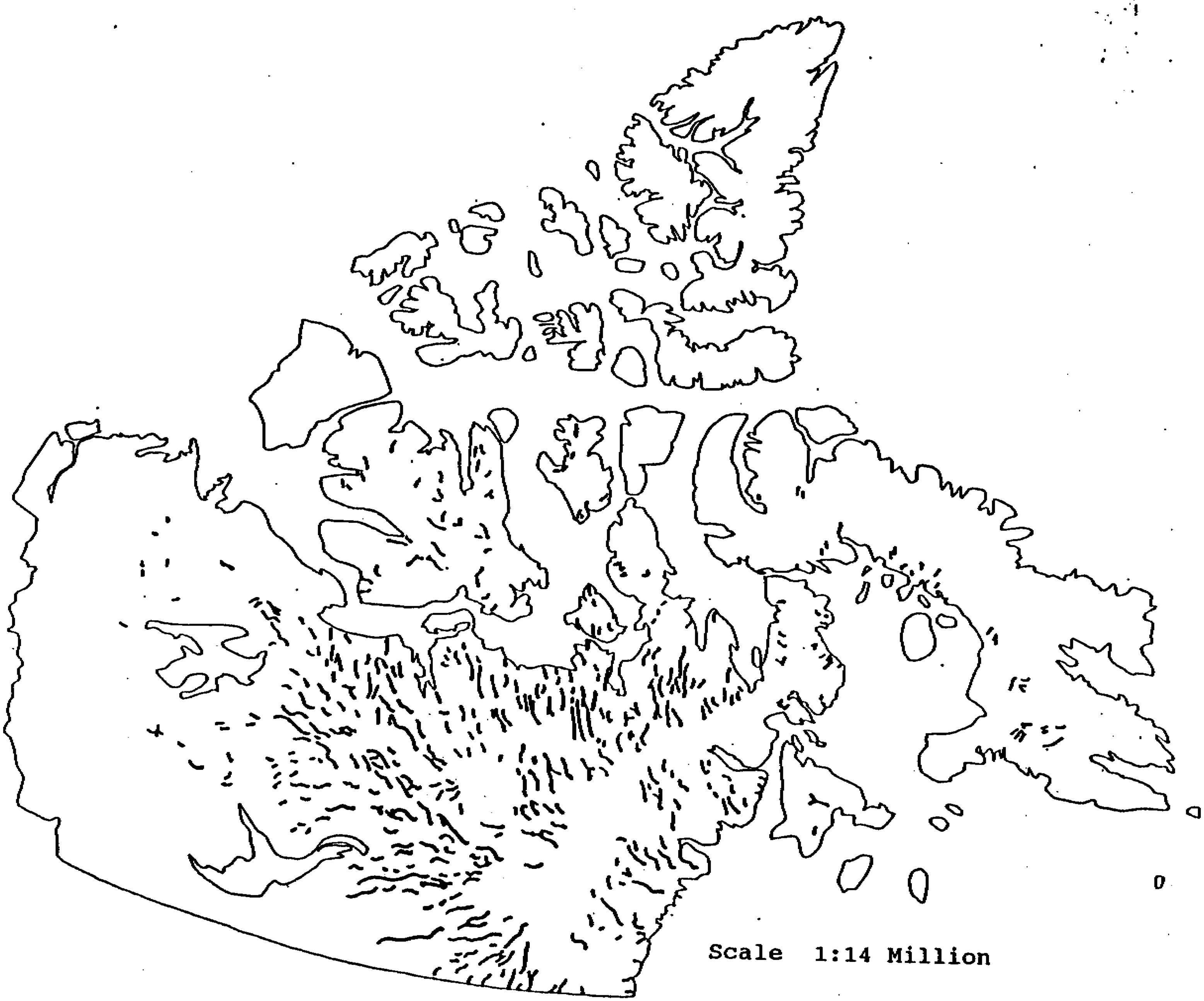

Figure 4. Map of the major esker and kame systems in the Northwest Territories, Canada. (Modified from "Glacial Geology" in Macmillan Company of Canada Limited 1974, pp. 33-34.)

Most of the study area is treeless, although isolated stands of trees are found in the southwestern corner. Arctic willow, dwarf birch, grasses, and sedges are typical tundra vegetation. The area has been classified within the Southern Arctic Ecozone (Ecological Stratification Working Group 1994). This remote region is home to wildlife such as barren-ground caribou (*Rangifer tarandus*) of the Bathurst herd, barren-ground grizzly bear (*Ursus arctos*), tundra wolves (*Canis lupus*), arctic fox (*Alopex lagopus*), and red fox (*Vulpes vulpes*). The area is currently accessible only by air or by winter road over frozen lakes.

Den Identification

Den sites were measured and described for the following five species: grizzly bear, wolf, red fox, arctic fox, and arctic ground squirrel. Four types of dens were recognized (bear = G, wolf = W, fox = F, and ground squirrel = S). The dens of red foxes and arctic foxes were combined into one type (fox), since it was not easy to identify fox dens by species unless live animals were seen at the site.

Den sites were identified using previous den descriptions (e.g., Vroom et al. 1980, Nagy et al. 1983, Heard and Williams 1992, Smits et al. 1988) and using descriptions and photos taken at dens with occupants of known species.

Habitat Types

Three types of tundra habitat were identified: (i) esker habitat, (ii) meadow habitat, and (iii) upland habitat. The first type, esker habitat, consisted of glacio-fluvial materials and hence may have included geological features known technically as eskers, outwash plains, drumlins and raised beaches, among others (Andrews 1975, Goldthwait 1975). In addition, five zones through the profile of esker habitat were identified. Esker zones were given numbers as follows: 1 = top, 2 = top-middle, 3 = middle, 4 = middle-bottom, and 5 = bottom. In general, esker habitat was easily distinguished from the following two habitat types.

The second type, meadow habitat, was distinguished by lush sedge and grass vegetation, flat low-lying topography, and seasonal wetness. Soils in this habitat were relatively dark, moist, and soft.

The third habitat type, upland, ranged from solid rock outcrops to packed till material such as mud boils. Upland habitat included all habitats which were neither esker nor sedge habitat. Upland tended to be extremely rocky with little or no loose materials present.

Site Types

Measurements and samples were collected from three types of sites: (i) den (DN), (ii) adjacent control (AC), and (iii) random control (RC). Den sites were of four species (bear = G, wolf = W, fox = F, and squirrel = S).

Two types of control sites were also used. Adjacent control sites were nearby sites of similar characteristics (e.g., slope, aspect, elevation) not used by wildlife for denning. An adjacent control site was randomly located between 20 and 60 meters (35.7 m $\pm$ 0.7 (1 SE), n = 148) away from each den site. The direction of the adjacent control site from the den site was randomly selected within the same esker zone. Random control sites were selected at random distances down the length of eskers and at random zones on the esker profile.

Den Searches

Searches for dens were conducted from a Bell 206 helicopter and on foot in each of the three habitat types. The helicopter flight path during searches is shown in Figure 3. Search techniques were kept the same between the different habitat types. Helicopter searches were all conducted at approximately 80 km/hour and between 15 and 30 m elevation. Three or four observers were present in the helicopter at all times. During helicopter searches we recorded the location and habitat type of all dens and live animals seen. All dens of uncertain identity from the air were confirmed by ground inspection. The search effort (time) over each habitat type was also noted throughout.

The location coordinates of all sites were taken using either a hand-held Magellan Geographic Positioning System (GPS) or using a GPS mounted in the helicopter.

Den Characteristics

The following additional characteristics were also measured and described at the four den types: entrance width, entrance height, den complex diameter, number of entrance holes in den complex, and current use of den. Also noted was the presence of denning animals, tracks, scats, bones, feathers, other species denning in the same complex, supporting vegetation on den roof, and den roof condition (collapsed or not). Den length and cavity width (width at the back of the den) were measured for bear dens only.

Grass and sedge species found on wolf dens were collected and sent to William Cody, Agriculture Canada, Ottawa for identification.

Site Characteristics

The following variables were measured and described at all den and control sites: location, aspect, slope, soil/rock type, material type, material size, moisture content, nitrogen and carbon content, plant species present, percentage cover, and habitat type. Photos, site sketches, and general descriptions were made at all sites.

Percentage cover was measured at all den and control sites. The following seven types of cover were recognized: shrubs, forbs, grasses, sedges, mosses, lichens, and bare ground. Nine quadrat (25 x 25 cm) samples were taken at each site to estimate percent cover. One quadrat was placed as close as possible to the centre of the den complex, and an additional 2 quadrat samples were taken at 3 and 6 m distances from the centre in each of four (90°) directions. The orientation of each quadrat in relation to the den centre was recorded.

In addition, the percentage cover of the following bush and forb species was recorded: dwarf birch (*Betula glandula*), willow (*Salix spp.*), bearberry (*Arctostaphylos rubra*), crowberry (*Empetrum nigrum*), blueberry (*Vaccinium uliginosum*), cranberry (*Vaccinium vitis-idaea*), labrador tea (*Ledum spp.*), potentilla (*Potentilla spp.*), saxifrage (*Saxifraga spp.*), fireweed (*Epilobium spp.*), cloudberry (*Rubus chamaemorus*), and rhododendron (*Rhododendron lapponicum*). The percentage cover was not estimated for individual species of grass, sedge, moss, and lichen.

Material Collection and Analysis

Materials were collected for physical and chemical analyses from all site types. Between 1.2 and 19.4 kg (mean 8.5 ± 0.2 kg, n = 304) of material were collected from each site. At each site a test pit was dug to a maximum depth of between 0.3 and 1.0 m (mean 0.62 + 0.01 m (1 SE), n = 305). Two separate samples of material were collected at each site. The first sample was collected in the top 10 to 30 cm and any large vegetative material was discarded. The second sample was made up of subsamples (3 to 5 shovels) collected at intervals from between 0.15 and 1.0 m. Care was taken to keep each shovel sample from becoming contaminated with material from other layers. The second sample was collected uniformly throughout the depth of the pit and placed on a tarp where it was carefully mixed. Then a mixed subsample of approximately 8 kg was put in a watertight plastic bag, labelled, and taken from the field for analysis.

The samples collected near the surface were analyzed to compare percentage of nitrogen and percentage of carbon among the different types of sites and among the four species. Soil Total Organic Carbon (% organic matter) and Total Nitrogen were determined with LECO combustion furnace methods by NORWEST Labs in Edmonton, Alberta. Detection limits for the nitrogen and carbon analyses were 0.01% and 0.05%, respectively.

The second set of soil samples, collected throughout the depth of the pit, was analyzed for material size to determine percentages of gravel, sand, and fines using standard sieve analysis. All material size analyses were conducted by EBA Engineering Consultants Ltd. of Yellowknife, NWT. Materials were described using the Unified Soil Classification System. The results of hydrometer analyses on ten samples with the highest percentage of fines during sieve analyses indicated that nearly all of the fines present in these samples were silt rather than clay, therefore, no further hydrometer analyses were conducted.

Esker Mapping

Mapping analyses were conducted with the assistance of the Remote Sensing Centre of Renewable Resources, Government of Northwest Territories, Yellowknife.

Esker systems in the study area were mapped on SPANS Geographic Information System (GIS) using digital 1:250,000 NTS map sheets, an enhanced LANDSAT image (July 28, 1989), and colour aerial photographs (1:20,000) taken August 13 and 14, 1993 by Eagle Mapping Services Ltd., Port Coquitlam, B.C. for BHP Minerals over their entire Lac de Gras claim block (Figure 2). SPANS GIS was used to estimate the total length, area, and percentage cover of eskers in the study area. The percentage cover of the different habitat types in the study area was estimated using a subsample of 50 aerial photographs randomly selected from 740 aerial photos taken across BHP's claim block, giving 6.7% coverage. Percentage cover of lake, upland, and meadow habitat was estimated for each photo.

Data Analyses

ORIANA (Version 1.0) for Windows was used for circular data analyses of den aspect. Circular statistics are discussed in

Batschelet (1981) and Zar (1984). All other computer analyses of data were done with the software SYSTAT for Windows (Version 5.03).

Habitat Selection

Chi-square goodness-of-fit and Bonferroni confidence intervals (Byers et al. 1984, Manly et al. 1993) were used to evaluate significant differences between expected and observed use of esker, upland, and meadow habitats for denning. Upland and meadow habitats were combined into one habitat type for analyses when the expected frequencies in meadow habitat were less than 5 percent. For these analyses the following assumptions were made: (i) observations are independent, (ii) availability and use are equal for all individuals, (iii) there is a relationship between density and relative preference, and (iv) the detectability of dens in different habitats is equal.

Significance of Group Differences

Chi-square goodness-of-fit, Bonferroni confidence intervals, and factorial MANOVA were used to describe how den sites differed from control sites and to compare how den sites differed among species.

RESULTS

Mapping Results

From aerial photographs, the percentage cover of esker, upland, meadow, and lake habitats in the study area are 1.5%, 54.7%, 10.5%, and 33.3%, respectively. Eskers and other glacio-fluvial features represent less than 1.5% of the Central Arctic region.

The locations of all eskers in a 105,000 km^2 region around Lac de Gras are shown in Figure 2. Several things to note from this map are as follows: the high density of eskers in the regions east and west of Lac de Gras; the striking drainage pattern of an ancient river system which appears to have flowed from east to west between Lac de Gras and Yamba Lake; and the near absence of eskers in the north and in the southwestern corner of the mapped region. It can also be seen in Figure 5 that some areas in the Central Arctic have very high densities of eskers while other areas have very few or no eskers.

The spatial distribution of sampled den sites is shown in Figure 6. Bear dens have a tendency to be clustered. Groups of bear dens were found on the northeast side of Lac de Gras and on the north and south sides of Yamba Lake. It is unknown whether this clustering is a result of repeated denning by a single bear in different years or a result of denning by several bears in the same year. By contrast, dens of wolves and foxes appear to be fairly

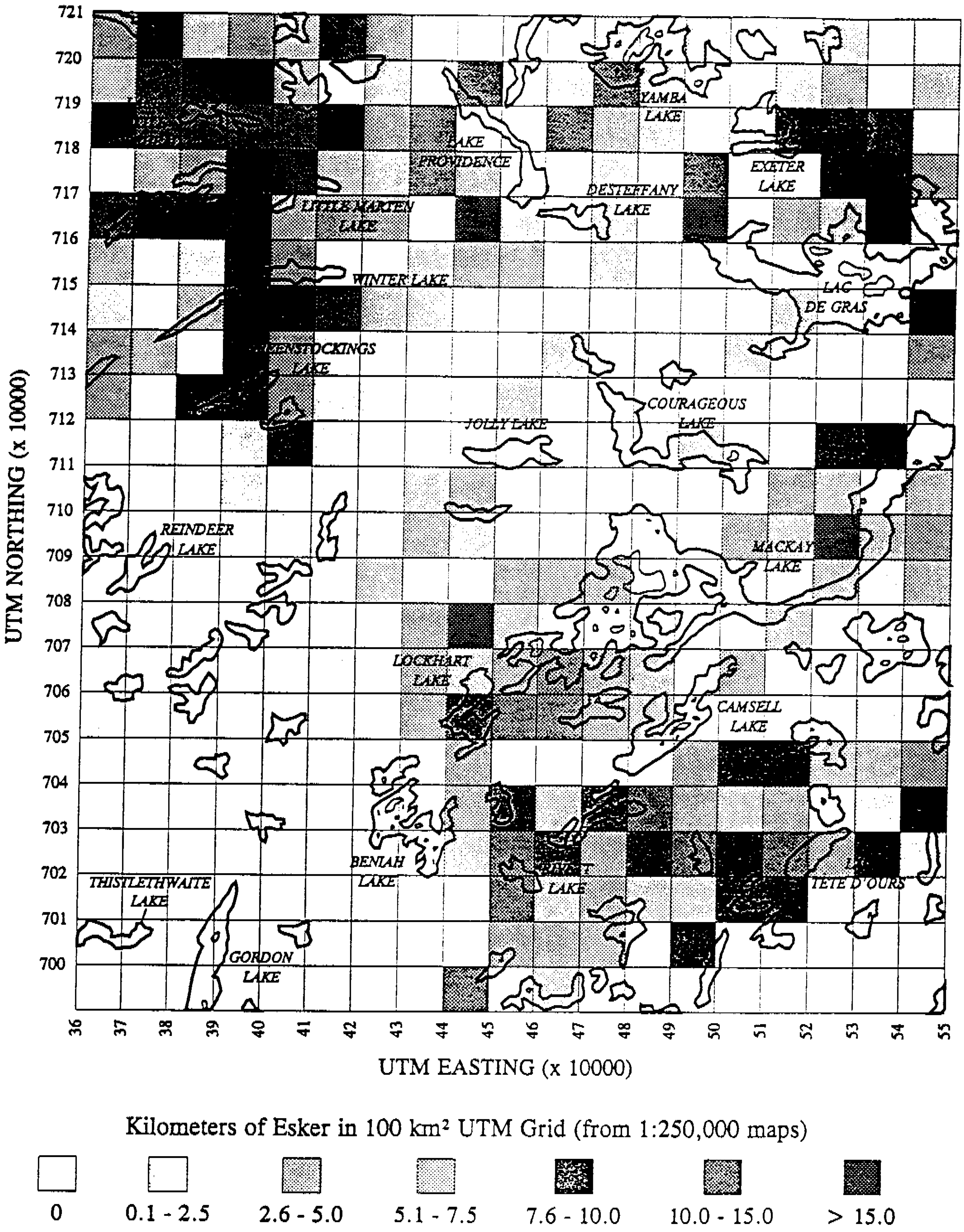

Figure 5. Distribution and relative length of eskers in the Lac de Gras region of the Slave Geological Province. (Used with permission from Ray Bethke, Department of Renewable Resources, Government of the Northwest Territories, Yellowknife.)

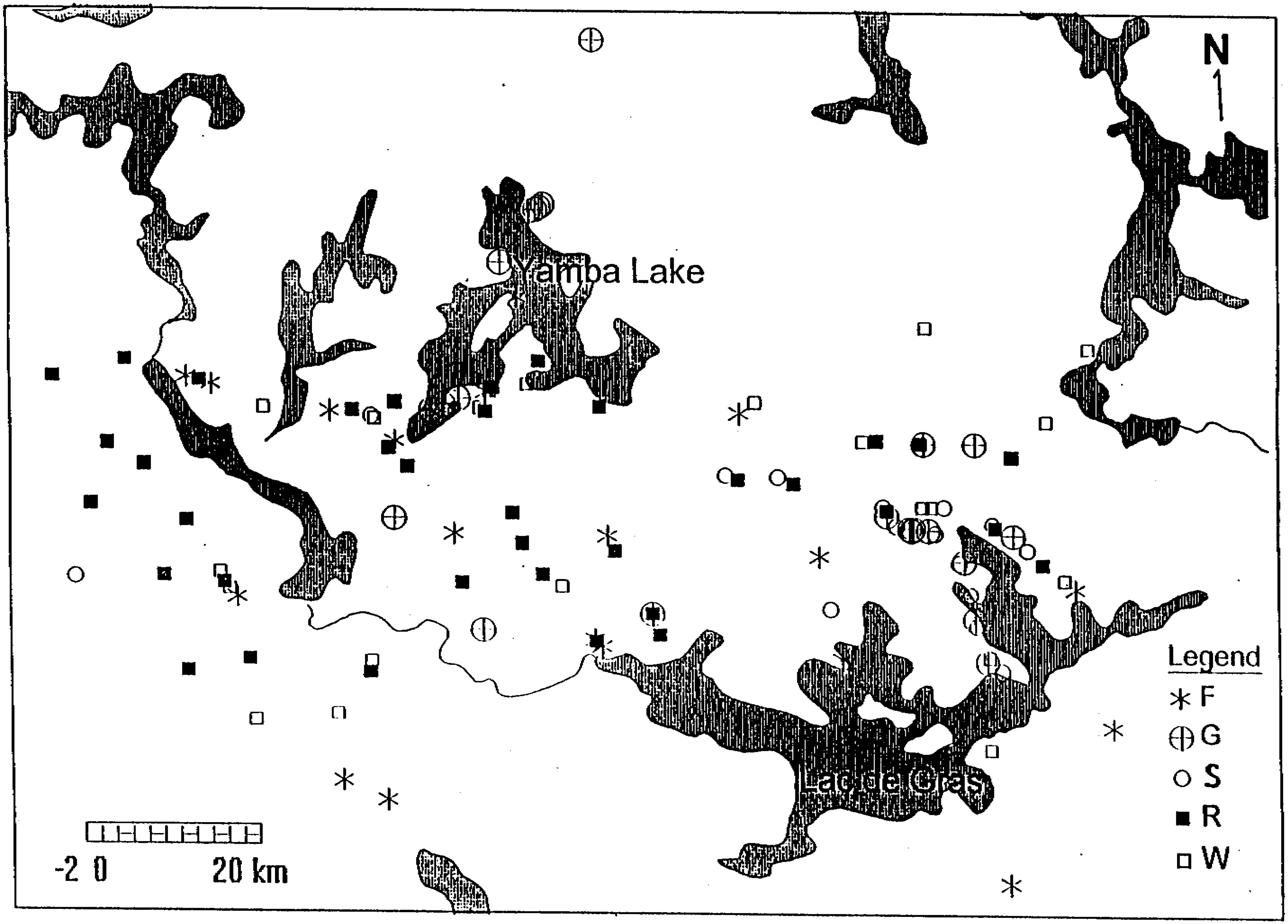

Figure 6. Map showing locations in the Lac de Gras Region of five types of sites sampled during the study. (Sample locations of four types of dens; Bear (G), Wolf (W), Fox (F), and Squirrel (S); and Random Control sites (R).)

uniformly distributed in the intensive study area (Figure 6). Figure 7 shows locations of known wolf dens. Heard and Williams (1992) indicate that wolf dens are concentrated in the region around the treeline.

Den Characteristics

As expected, the mean entrance size decreased from largest to smallest at dens of bears, wolves, foxes, and squirrels (Table 1 and Figure 8). The mean number of entrance holes was highest at squirrel dens, intermediate at fox dens, and lower at wolf dens. All bear dens had only a single entrance. The mean surface area of the den complex was similar for wolf and fox but slightly smaller for squirrel.

Bear Dens

Of the 23 bear dens measured, 19 were "cavity" dens and 4 were "bowl" dens. Cavity dens had a complete roof of material while bowl dens were circular depressions in the ground with only a partial roof. Bowl dens were likely constructed in packed snow and hence would have had a roof of snow. The mean length of bear dens was 181.9 cm (1 SE = 15.3, n = 22) and the mean width at the back of the den was 151.8 cm (1 SE = 22.2, n = 4). Other dimensions of bear dens are given in Table 1.

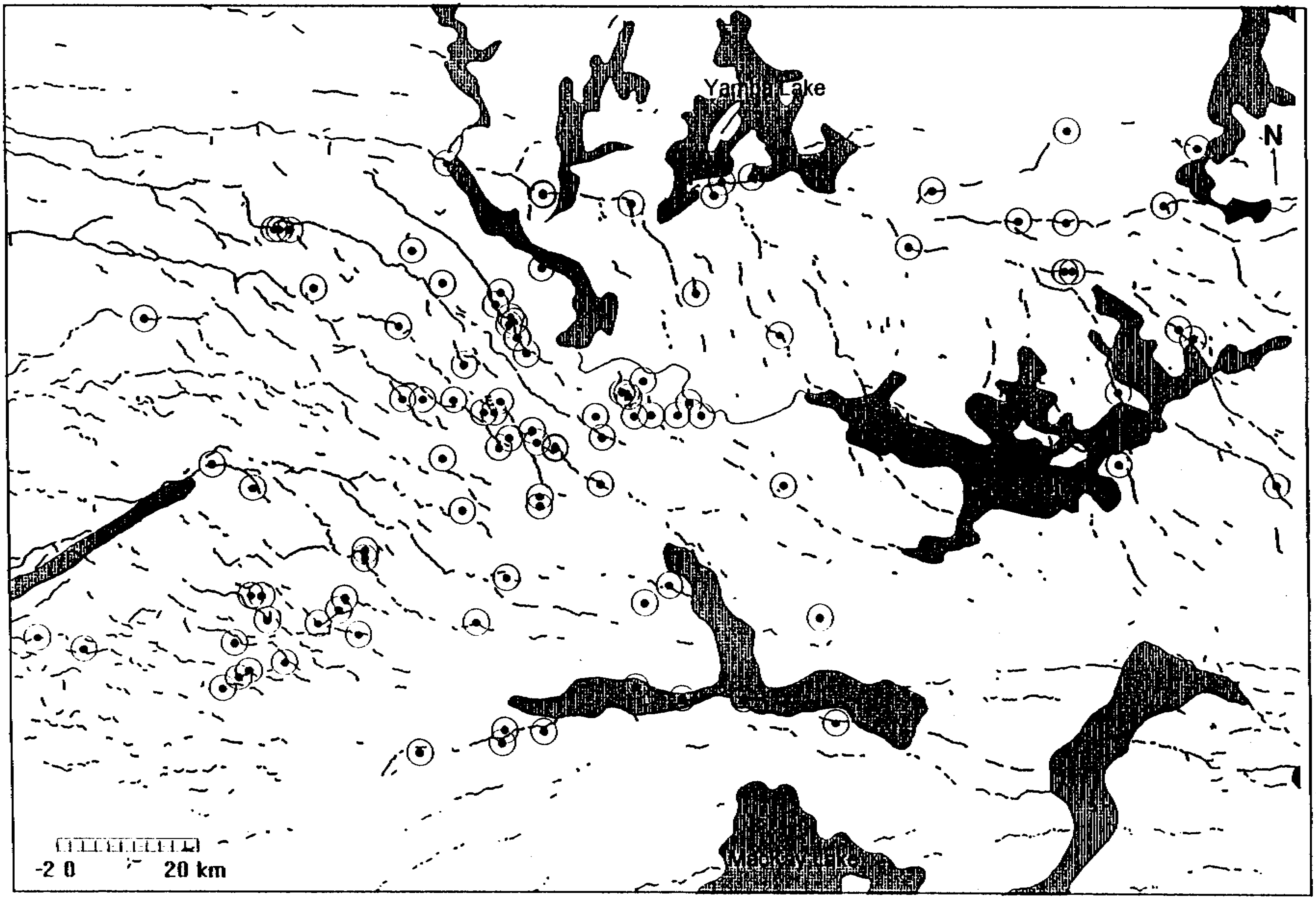

Figure 7. Map showing the distribution of known wolf dens and their locations relative to esker systems in the Central Arctic, NWT.

Table 1. Den characteristics for mammals in the Central Arctic, NWT.

Characteristic	Bear	Wolf	Fox	Squirrel	F	p
Entrance width (cm)	75.3 (3.3,22)	45.9 (2.1,16)	28.6 (1.2,13)	13.6 (1.1,11)	100.171	< 0.001
Entrance height (cm)	66.6[a] (3.0,16)	44.5[a] (5.5,2)	35.0[a] (0.0,1)	--	6.076	< 0.05
Den length (cm)	181.9 (15.3,22)	--	--	--	--	--
Cavity width (cm)	151.8 (22.2,4)	--	--	--	--	--
Number of entrance holes	1.0 (0.0,22)	4.0[a] (0.5,20)	9.7[a,b] (1.4,17)	15.8[b] (2.7,12)	19.252	< 0.001
Diameter of den complex (m)	--	15.3[a] (1.3,15)	15.6[a] (1.8,16)	10.3 (1.0,16)	52.265	< 0.001

Values are means with one standard error and sample size (1 SE, n). Results of one-way ANOVA are shown. Superscript letters indicate non-significant differences ($p > 0.05$) with Bonferroni pairwise comparison. Dashes indicate no measurements were taken.

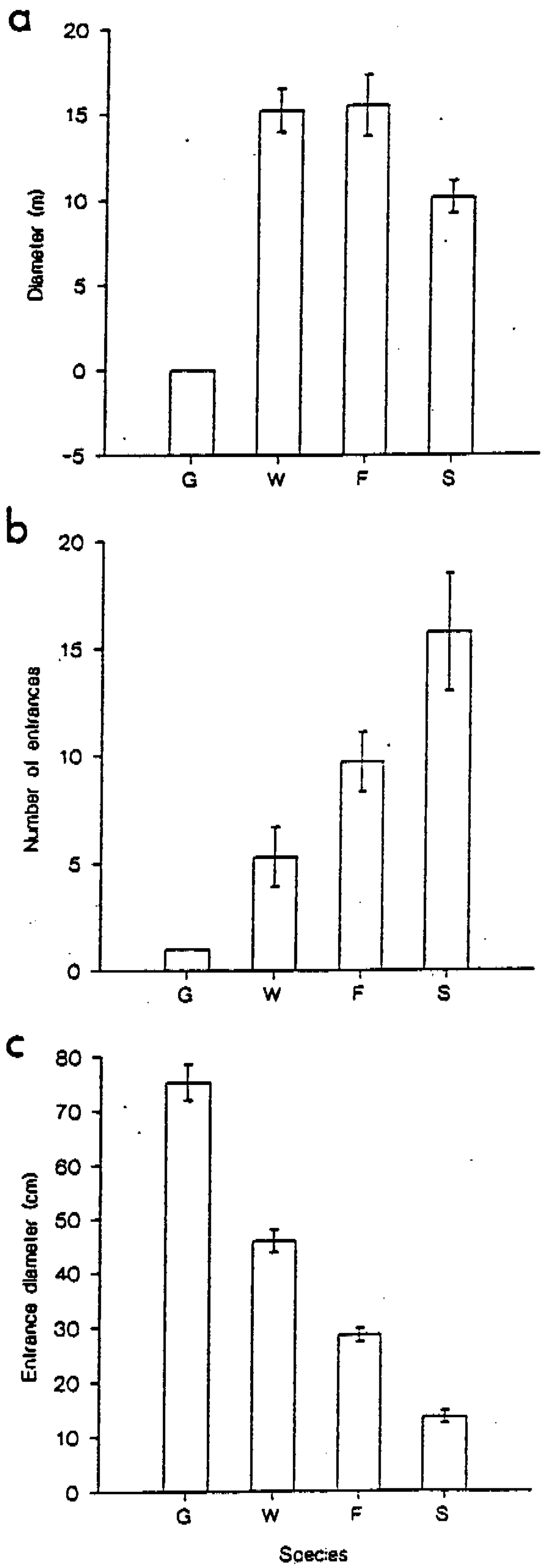

Figure 8. Den characteristics for grizzly bears (G), wolves (W), foxes (F), and squirrels (S). (Den diameter (a), number of entrance holes at den (b), and diameter of entrance holes (c) are shown. Values are means with 1 SE error bars.)

The roofs of 53% of the cavity dens had collapsed. It is possible that most dens collapsed during the first summer after having been used. There were no significant differences in material size between collapsed and intact dens. Of the 23 bear dens measured, 21 (91%) had bushes of either dwarf birch (20) or willow (1) above the den entrance or above the back of the den. The roots of bushes likely help to support the den structure. In collapsed dens, the portion of each den in the immediate vicinity of bushes usually remained intact. Most dens had traces of hairs adhering to vegetation and den walls and most also had a musky smell of bear. One bear den had distinct claw marks on the den walls. No scats or food scraps, such as bones and feathers, were found at any bear dens.

Wolf Dens

Of the 22 wolf dens measured in this study, 15 were found to be active and an additional 4 were unconfirmed. Live wolves were seen near 7 of the studied dens. Scats were found in the vicinity of all dens. Many scats were white from crushed bone fragments. White scats were highly visible from the helicopter and helped to locate wolf dens from the air. Day beds, circular depressions in the ground near dens, were also conspicuous from the air and were present at 20 of 22 (91%) of the wolf dens studied. Bone fragments were found at 95% of wolf dens, and bird feathers and bird bones were present at 9% of the wolf dens. In contrast to bear dens, only 9% of the wolf dens were partially collapsed and no wolf dens had completely collapsed. Supporting birch vegetation was present over entrances of very few wolf dens.

The following six grass and sedge species were identified on wolf dens: *Calamagrostis purpurascens, Calamagrostis strica, Poa glauca, Carex aquatilis, Carex bigelowii*, and *Hierochloe alpina*. The grass species *Poa glauca* was found only at wolf dens and was not found among the other 18 species of grasses and sedges collected in other habitats at Daring Lake during summer 1994. *Poa glauca* is likely fairly common in the region of Daring Lake (Porsild and Cody 1980). We did not collect grasses and sedges from dens of the other species.

Fox Dens

Eighteen of 19 fox dens sampled were active. Live animals were seen at 6 of these dens. Fresh tracks, daybeds, scats, bones, and feathers were at 17, 7, 18, 16, and 8, respectively, of the 19 sampled fox dens. Ground squirrel dens were present within 5 of the den complexes of foxes.

Squirrel Dens

Based on evidence of tracks and scats, all sampled ground squirrel dens (n = 18) appeared to have been recently active. No daybeds, bones, or feathers were found at any of the squirrel dens. Disturbed soil indicated that 11 of the 18 squirrel dens (61%) had at some time been partially dug up by grizzly bears. There was also an old bear den located within the den complex of one ground squirrel. Another ground squirrel den was located in the same place as an old wolf den.

Species Interactions at Den Sites

Interesting interactions between species were evident in the diggings on many dens. For instance, several abandoned fox dens had more recently been used by ground squirrels. In many cases a single den site was found to have been used by more than one species. In several cases, old dens of wolf and fox were found in the same complex. Also, 35 percent of abandoned bear dens were found with active ground squirrel dens inside them. At the same time, over 60 percent of the den complexes of ground squirrels were found to have surface diggings from grizzly bears that were likely searching for food. In one case a grizzly appeared to have denned in the middle of a ground squirrel den complex. In addition, we found 13 of 22 (59%) wolf dens also had ground squirrel dens within the same complex. Even more surprisingly, six (46%) ground squirrel den complexes were known, from fresh tracks and visual sightings, to have been used concurrently with denning wolves.

Den Searches

A total of 1779 minutes (29.7 hours) were spent searching for dens and animals by helicopter in an 18,000 km^2 area surrounding Lac de Gras and Yamba Lake. The search path of the helicopter is shown in Figure 3. The times spent searching for dens in esker habitat, upland habitat, and meadow habitat were 943 minutes, 819 minutes, and 17 minutes, respectively (Table 2). Approximately 1253 km of eskers were searched for dens by helicopter. Relatively little time was spent searching meadow habitat by helicopter. More than 10 hours were spent searching meadow habitat on foot for dens; however, no dens were found during foot searches, so helicopter searches of meadow habitat were discontinued.

Habitat Selection

Habitat Selection for Denning

Chi-square goodness-of-fit and Bonferroni confidence intervals were used to examine significance of differences between expected and observed use of habitats for denning by four types of animals. Dens of bears (n = 32), wolves (n = 37), foxes (n = 39), and squirrels (n = 2448) were all found on esker habitat significantly more often than expected by chance ($p < 0.05$) (Table 3). All Bonferroni confidence intervals were significantly different except for those of fox dens. Percentage use, percentage available, and the ratio of use to availability of three habitat types are compared for four species in Figure 9.

Table 2. Results of helicopter searches for dens of four species in three types of habitat.

	Esker habitat	Upland habitat	Meadow habitat	All habitats
Habitat area (%)	~1.5	54.74	10.46	100
Search time (min)	943.1	818.9	17.2	1779.2
Relative search time (%)	53.01	46.03	0.97	100
Mean search speed (km/hr)	78.7	89.2	98.6	84.1
Distance searched (km)	1252.9	995.6	22.2	2296.5
Bear dens	29	3	0	32
Wolf dens	36	1	0	37
Fox dens	29	10	0	39
Squirrel dens	2082	366	0	2448
Live bear	2	2	0	4
Live wolves	38	0	0	38
Live fox	6	0	0	6
Live squirrel	--	--	--	--
Live wolverine	3	0	0	3
Live caribou	476	268	2	746

These results do not include more than 25 hours of searching in these three habitats during ground searches. The relative areas of the three habitat types were determined using aerial photographs and GIS as described in the methods section.

Table 3. Denning habitat use versus availability data for denning animals.

Habitat type	Expected proportion of use, Pio	Observed proportion of use, Pi	Bonferroni intervals for Pi
Bear dens (n = 32)			
Esker	0.530 (17)	0.906 (29)	0.791 ≤ Pe ≤ 1.000 *
Upland/Meadow	0.460 (15)	0.094 (3)	0.000 ≤ Pu ≤ 0.210 *
	X^2 = 18.071, df = 1, P < 0.001		
Wolf dens (n = 37)			
Esker	0.530 (20)	0.973 (36)	0.913 ≤ Pe ≤ 1.000 *
Upland/Meadow	0.470 (17)	0.027 (1)	0.000 ≤ Pu ≤ 0.087 *
	X^2 = 27.859, df = 1, P < 0.001		
Fox dens (n = 39)			
Esker	0.530 (21)	0.670 (29)	0.501 ≤ Pe ≤ 0.837
Upland/Meadow	0.470 (18)	0.330 (10)	0.161 ≤ Pu ≤ 0.499
	X^2 = 6.603, df = 1, P < 0.025		
Squirrel dens (n = 2448)			
Esker	0.530 (1298)	0.850 (2082)	0.843 ≤ Pe ≤ 0.857 *
Upland	0.460 (1127)	0.150 (366)	0.143 ≤ Pu ≤ 0.157 *
Meadow	0.010 (24)	0.000 (0)	0.000 ≤ Ps ≤ 0.000 *
	X^2 = 1011.402, df = 2, P < 0.001		

* indicates a difference at 0.05 significance level

Number of dens are shown in parentheses.

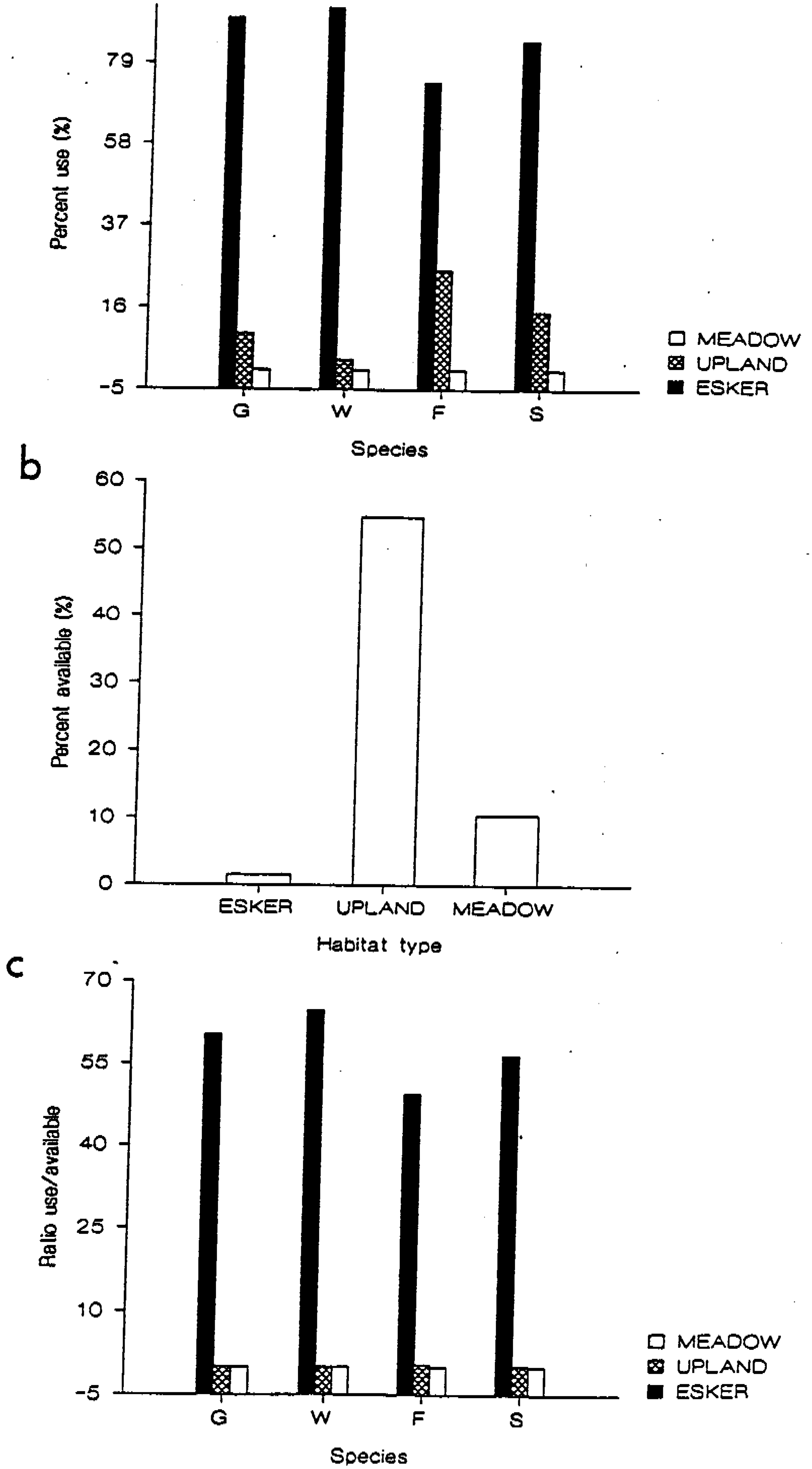

Figure 9. Figures showing (a) relative use, (b) availability, and (c) ratio of use/availability of three habitat types for denning by four animal species. (G = bear, W = wolf, F = fox, and S = squirrel.)

Habitat Use by Observed Animals

Chi-square goodness of fit and Bonferroni confidence intervals were used to examine significance of differences between expected and observed habitat use by live animals (Table 4). During helicopter searches, wolves (n = 38) were found on esker habitat significantly more often (X^2 = 34.200, d.f. = 1, $p < 0.001$) than expected by chance. Caribou (n = 746) were also seen on esker habitat significantly more frequently than expected by chance (X^2 = 36.581, d.f. = 2, $p < 0.001$; Bonferroni confidence intervals shown in Table 4). The numbers of live bears (n = 4) and live foxes (n = 6) seen were too small for statistical comparison of habitat use. Four bears were seen during helicopter surveys, two on esker habitat and two on upland habitat. Six foxes were seen during searches and all were seen on esker habitat.

Table 4. Actual versus expected habitat use for two types of animals in three habitat types.

Habitat type	Expected proportion of use, Pio	Observed proportion of use, Pi	Bonferroni intervals for Pi
Live wolf (n = 38)			
Esker	0.530 (20)	1.000 (38)	1.000 ≤ Pe ≤ 1.000 *
Upland/Meadow	0.470 (18)	0.000 (0)	0.000 ≤ Pu ≤ 0.000 *
	X^2 = 34.200, df = 1, P < 0.001		
Live caribou (n = 746)			
Esker	0.530 (395)	0.638 (476)	0.596 ≤ Pe ≤ 0.680 *
Upland	0.460 (343)	0.359 (268)	0.317 ≤ Pu ≤ 0.401 *
Meadow	0.010 (7)	0.003 (2)	0.000 ≤ Ps ≤ 0.008 *
	X^2 = 36.581, df = 2, P < 0.001		

* indicates a difference at 0.05 significance level

Animals were observed during helicopter searches for den sites. The numbers of live animals seen are shown in parentheses.

Habitat Selection Within Eskers

Comparisons were also made of used and available habitats within eskers. The following characteristics were compared among dens of different species and between control sites:

Percentage Cover

Chi-square goodness-of-fit and Bonferroni confidence intervals were used to compare expected and observed percentage ground cover among dens of four species and among dens and control sites. Results of quadrat estimates of percentage cover are shown in Table 5. For chi-square analyses, percentage cover at adjacent control and random control sites were used as the expected values. Chi-square analyses indicate that the relative percentage cover at all den sites was significantly different from the expected percentage cover measured at adjacent control sites. Also, percentage cover at adjacent control sites for both bear and squirrel are different from expected values at random control sites. Only one Bonferroni confidence interval, for lichen/moss cover at wolf dens, was significantly different (Table 5 and Table 6(a)). The relative percentage cover at different site types is shown graphically in Figures 10, 11, and 12. Of note are (i) the relatively high cover of shrub at bear dens, (ii) the relatively high percentage cover of grass/sedge at dens of wolves and foxes, and (iii) the relatively high cover of fireweed at wolf den sites.

Table 5. Percentage cover at den and control sites in the Central Arctic, NWT.

Cover type	Bear		Wolf		Fox		Squirrel		Random
	DN	AC	DN	AC	DN	AC	DN	AC	RC
Shrub (%)	25.9 (3.1,23)	13.1 (2.5,23)	20.3 (3.2,22)	10.1 (2.2,22)	19.2 (3.8,19)	12.4 (2.2,19)	8.1 (2.2,18)	8.3 (1.6,18)	13.6 (2.0,36)
Forb (%)	35.3 (3.2,23)	34.3 (2.7,23)	20.0 (3.2,22)	23.5 (2.9,22)	21.3 (2.7,19)	26.9 (3.6,19)	27.2 (3.0,18)	21.7 (4.0,18)	32.2 (2.2,36)
Grass/Sedge (%)	5.1 (1.3,23)	2.3 (0.6,23)	25.9 (4.2,22)	3.2 (0.9,22)	15.4 (3.9,19)	1.7 (0.4,19)	12.2 (1.9,18)	2.0 (0.6,18)	1.9 (0.6,36)
Lichen/Moss (%)	12.1 (2.4,23)	28.4 (4.6,23)	2.9* (1.1,22)	15.7 (3.3,22)	3.6 (1.2,19)	11.5 (3.2,19)	3.9 (1.2,18)	4.5 (1.9,18)	9.8 (2.2,36)
Bare ground (%)	21.7 (3.1,23)	21.8 (4.2,23)	30.9 (3.5,22)	47.4 (5.4,22)	40.4 (4.9,19)	47.1 (5.9,19)	44.8 (3.8,18)	60.3 (6.1,18)	42.4 (3.3,36)
RC as expected:									
$X^2_{0.05,4}$	27.458	45.550	319.058	8.282	105.933	1.815	62.525	15.918	--
Probability	P < 0.001	P < 0.001	P < 0.001	P < 0.10 P > 0.05	P < 0.001	P < 0.90 P > 0.75	P < 0.001	P < 0.005	--
AC as expected:									
$X^2_{0.05,4}$	25.300	--	188.030	--	121.681	--	57.483	--	--
Probability	P < 0.001	--	P < 0.001	--	P < 0.001	--	P < 0.001	--	--

DN - Den Sites   RC - Random Control Sites   AC - Adjacent Control Sites

Values are means with one standard error and sample size (1 SE, n). Results of Chi-square goodness-of-fit test with AC and RC as expected values are shown. Asterisk (*) indicates a significant difference from AC expected as indicated by Bonferroni 95% confidence intervals.

Table 6. A. Simultaneous Bonferroni confidence intervals (95%) for percentage cover data.

Cover type	Bear		Wolf		Fox		Squirrel	
	DN	AC	DN	AC	DN	AC	DN	AC
Shrub (%)	0.024 – 0.494	0.000 - 0.312	0.000 - 0.424	0.000 - 0.266	0.000 - 0.425	0.000 - 0.319	0.000 - 0.247	0.000 - 0.250
Forb (%)	0.096 – 0.610	0.088 - 0.598	0.000 - 0.420	0.002 - 0.468	0.000 - 0.455	0.007 - 0.531	0.002 - 0.542	0.000 - 0.467
Grass/Sedge (%)	0.000 – 0.169	0.000 - 0.103	0.018 - 0.500	0.000 - 0.129	0.000 - 0.367	0.000 - 0.093	0.000 - 0.321	0.000 - 0.105
Lichen/Moss (%)	0.000 – 0.296	0.042 - 0.526	0.000 - 0.121	0.000 - 0.357	0.000 - 0.146	0.000 - 0.303	0.000 - 0.156	0.000 - 0.171
Bare ground (%)	0.000 – 0.438	0.000 - 0.444	0.055 - 0.563	0.200 - 0.748	0.114 - 0.694	0.176 - 0.766	0.146 - 0.750	0.306 - 0.900

B. Simultaneous Bonferroni confidence intervals (95%) for material size data.

Characteristic	Bear		Wolf		Fox		Squirrel	
	DN	AC	DN	AC	DN	AC	DN	AC
Gravel (%)	0.000 – 0.315	0.002 - 0.404	0.000 - 0.140	0.000 - 0.297	0.000 - 0.214	0.000 - 0.326	0.000 - 0.236	0.000 - 0.353
Sand (%)	0.392 – 0.874	0.364 - 0.852	0.466 - 0.934	0.482 - 0.944	0.377 - 0.917	0.436 - 0.956	0.444 - 0.972	0.450 - 0.964
Fines (%)	0.017 – 0.435	0.000 - 0.383	0.036 - 0.484	0.000 - 0.347	0.029 - 0.537	0.000 - 0.381	0.000 - 0.451	0.000 - 0.341

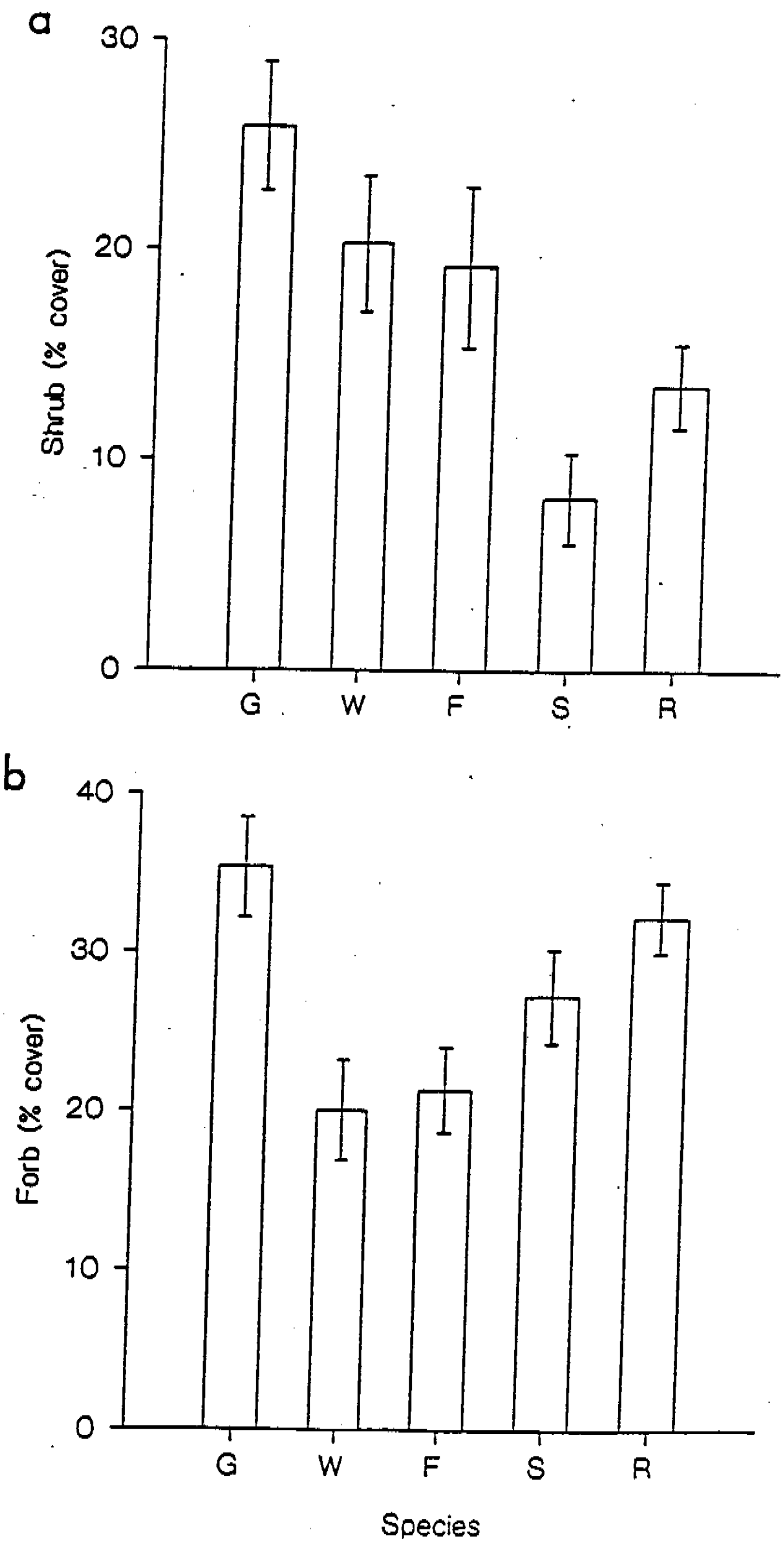

Figure 10. Percentage cover of shrub (a) and forb (b) at five types of sites. (G = grizzly den, W = wolf den, F = fox den, S = squirrel den, and R = Random site. Values are means with 1 SE error bars.)

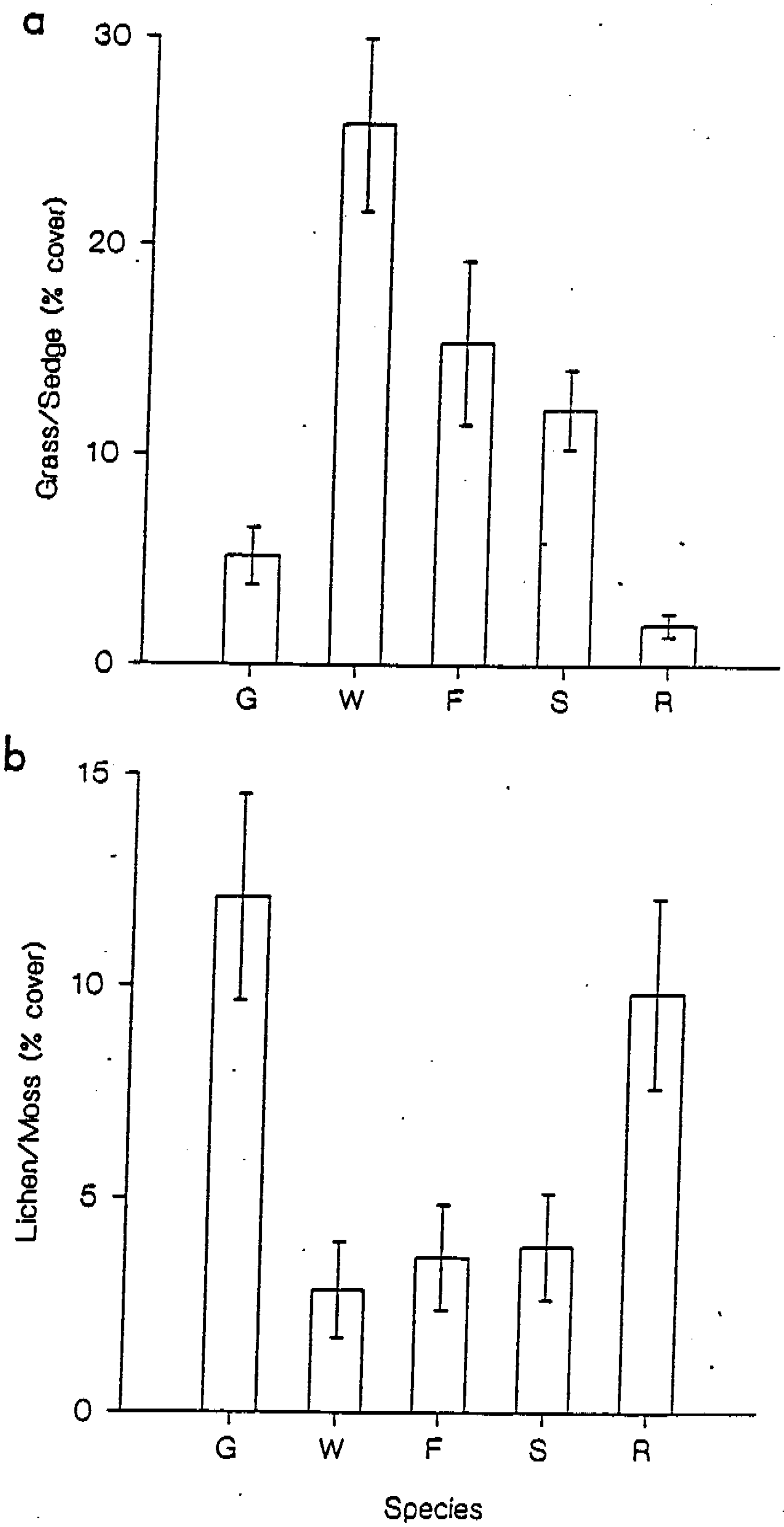

Figure 11. Percentage cover of grass/sedge (a) and lichen/moss (b) at five types of sites. (G = grizzly den, W = wolf den, F = fox den, S = squirrel den, and R = Random site. Values are means with 1 SE error bars.)

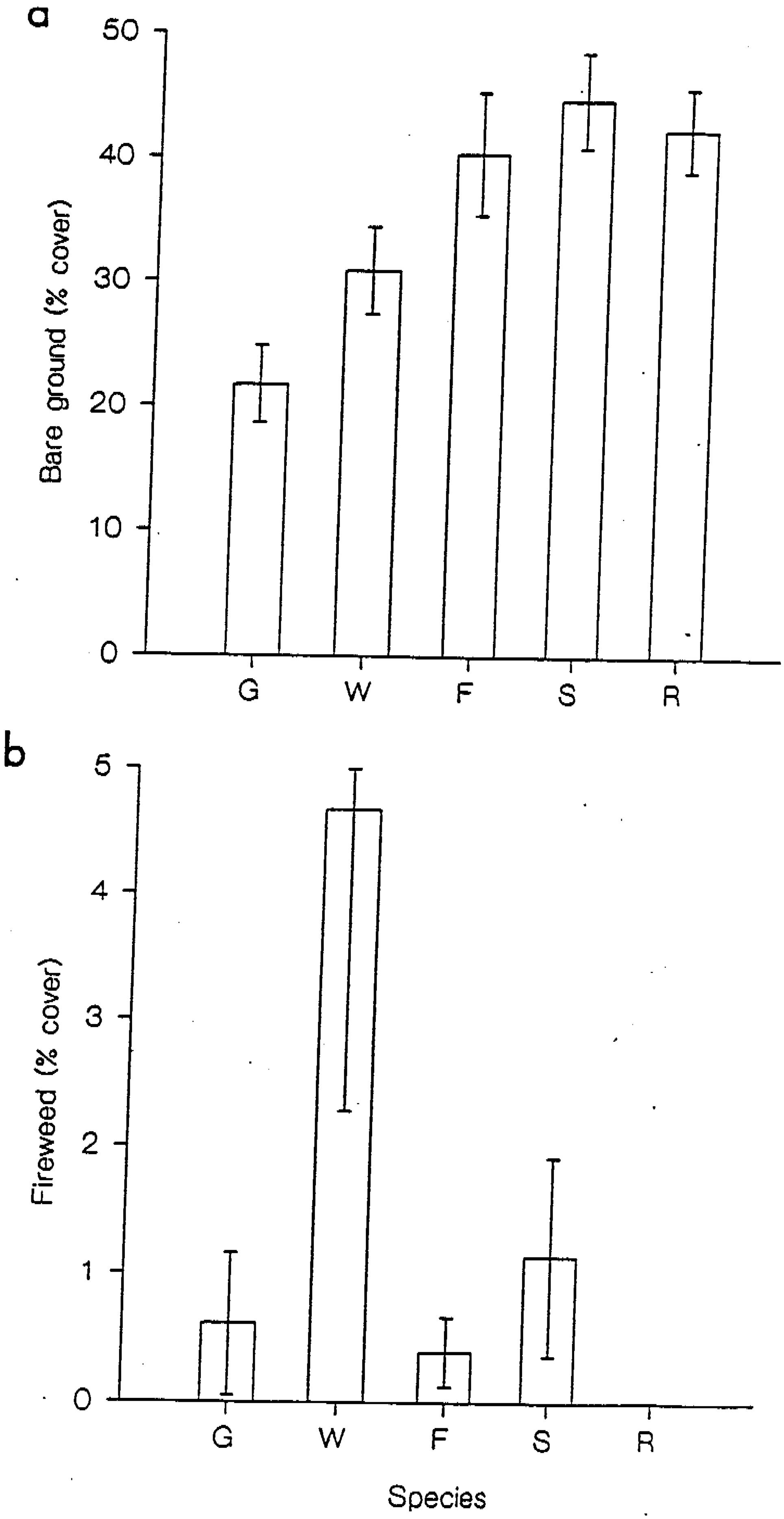

Figure 12. Percentage cover of bare ground (a) and fireweed (b) at five types of sites. (G = grizzly den, W = wolf den, F = fox den, S = squirrel den, and R = Random site. Values are means with 1 SE error bars.)

Chemical Analyses of Materials

Total nitrogen in soil materials collected near the surface of eskers ranged from approximately 0.1 to 0.2 percent. No differences were found in total nitrogen either among species (Table 7) or between site types (one-way ANOVA, $F = 1.979$, $p = 0.140$). Total carbon was lower at den sites than at random control sites (one-way ANOVA, $F = 1.690$, $p = 0.157$). There were no significant differences in total carbon among the den sites of the four species. In addition, no significant differences in C/N ratio were found among species or between site types. There were also no differences in the water content of materials either among species or between site types.

Slope and Esker Zone

The slope at bear dens was significantly steeper than the slope at all other types of sites (Table 7 and Figure 13). No other differences in slope were significant.

The esker zone at squirrel dens was smaller than at all other site types (Table 7 and Figure 13). Sampled squirrel dens were more frequently located near the top of eskers than all other types of sites. No other differences in the esker zone of dens were statistically significant.

Table 7. Chemical analyses of materials and site characteristics at den and control sites in the Central Arctic, NWT.

Characteristic	Bear		Wolf		Fox		Squirrel		Random		
	DN	AC	DN	AC	DN	AC	DN	AC	RC	F	p
Carbon (%)	2.54 (0.54,23)	5.33 (1.08,23)	1.35 (0.26,22)	1.09 (0.23,22)	2.06 (0.94,18)	2.12 (0.95,18)	1.54 (0.34,18)	1.70 (0.42,18)	3.28 (0.72,35)	1.690	0.157
Organic matter(%)	4.52 (0.96,23)	9.48 (1.92,23)	2.40 (0.46,22)	1.94 (0.40,22)	3.67 (1.67,18)	3.76 (1.69,18)	2.74 (0.61,18)	3.02 (0.74,18)	5.84 (1.27,35)	1.689	0.158
Nitrogen (%)	0.12 (0.02,23)	0.21 (0.04,23)	0.08 (0.02,22)	0.06 (0.01,22)	0.11 (0.05,18)	0.11 (0.05,18)	0.11 (0.03,18)	0.09 (0.02,18)	0.14 (0.03,35)	0.851	0.496
C/N ratio	29.89 (4.60,23)	41.07 (18.19,23)	61.92 (20.70,22)	56.33 (17.45,22)	56.49 (20.17,18)	64.03 (22.74,18)	13.66 (0.56,18)	29.95 (5.39,18)	35.82 (13.20,35)	1.585	0.183
Water content (%)	6.4 (1.3,23)	5.2 (1.1,22)	5.0 (0.7,22)	5.3 (0.8,22)	5.7 (0.9,18)	5.7 (1.1,18)	4.1 (0.7,17)	5.5 (1.0,18)	3.5 (0.8,36)	1.817	0.131
Slope (degrees)	34.0* (1.7,23)	19.2 (2.3,23)	11.9 (2.9,22)	6.9 (0.8,22)	15.4 (2.6,19)	10.3 (2.0,19)	9.4 (2.2,17)	11.1 (2.7,18)	10.0 (1.9,36)	20.530	0.000
Esker zone	3.3 (0.2,18)	3.2 (0.2,18)	2.9 (0.3,21)	2.7 (0.3,22)	2.7 (0.2,18)	2.6 (0.2,18)	1.6* (0.3,17)	1.8 (0.3,17)	2.6 (0.2,36)	5.834	0.000

DN - Den Sites AC - Adjacent Control Sites RC - Random Control Sites

Values are means with one standard error and sample size (1 SE, n). Results of one-way ANOVA with adjacent control (AC) excluded are shown. Superscript asterisks indicate significant differences ($p < 0.05$) with Bonferroni pairwise comparison.

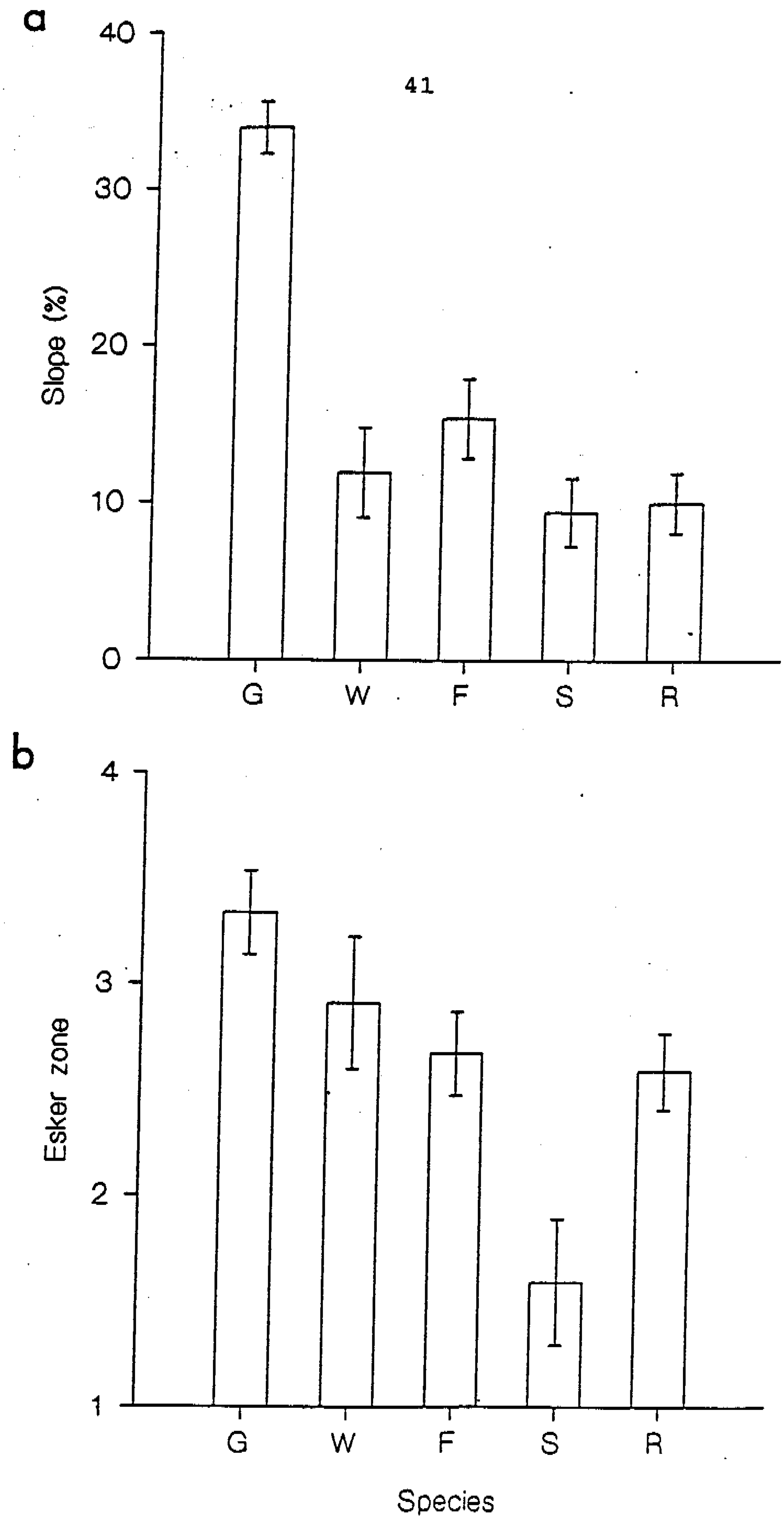

Figure 13. Figures showing slope (a) and esker (b) zone at five types of sites. (G = grizzly den, W = wolf den, F = fox den, S = squirrel den, and R = Random site. Values are means with 1 SE error bars.)

Circular Analyses of Aspect at Dens

The dens of two species, bears and squirrels, had a tendency to face approximately southwards (180°) (Table 8). The aspect at dens of bears and of squirrels was relatively highly concentrated in a southward direction, 197° and 185°, respectively. The aspect at wolf and especially fox dens had a lower concentration in all directions.

The aspect at random control sites was different from the aspect at the other eight site types (both dens and adjacent controls) with Watson's F-test for circular means ($P \leq 0.05$). There were no other significant differences between the aspect of the nine site types.

Table 8. Comparison of aspect among nine types of sites.

Sample	G-DN	G-AC	W-DN	W-AC	F-DN	F-AC	S-DN	S-AC	RC
Observations	23	23	16	20	18	16	15	15	28
Mean vector (u)	196.8°	197.4°	178.4°	198.6°	158.5°	181.2°	184.8°	187.6°	263.9°
Length of mean vector (r)	0.60	0.71	0.30	0.38	0.07	0.36	0.72	0.62	0.13
Concentration	1.50	2.05	0.63	0.81	0.15	0.78	1.75	1.51	0.26
Circular variance	0.40	0.29	0.70	0.62	0.93	0.64	0.28	0.38	0.87
Circular standard deviation	58.19°	47.69°	88.89°	80.18°	131.00°	81.44°	46.10°	56.09°	115.45°
Standard error of mean	12.64°	9.92°	32.95°*	23.22°*	130.20°*	26.84°*	13.15°	15.32°	58.06°*
95% confidence interval (+/-)	172.03°	177.94°	113.81°*	153.11°*	263.29°*	128.54°*	159.06°	157.60°	150.09°*
	221.57°	216.83°	243.00°*	244.14°*	53.76°*	233.79°*	210.63°	217.65°	17.71°*
Rayleigh test of uniformity (p)	0.00	0.00	0.24	0.06	0.91	0.12	0.00	0.00	0.62

Values marked with '*' may be unreliable because of low concentration (i.e., uniform distribution).

G - Grizzly Bear DN - Den Site AC - Adjacent Control W - Wolf
F - Fox S - Squirrel

Material Size

The relative size of esker materials at different site types are compared in Table 9. Chi-square goodness-of-fit and Bonferroni confidence intervals were used to compare differences between observed size and expected size of materials. There was no significant difference in material size between dens and adjacent control sites of grizzly bears. At all other sites, material size was significantly different from expected values. Bonferroni confidence intervals indicate that percentage of gravel was lower at den sites of all species relative to percentage of gravel at random control sites (Table 9 and Table 6(b)). The size of materials at four types of den sites and at random control sites are graphically compared in Figure 14. In Figure 15 the mean sizes of materials are compared at den sites, adjacent control sites, and random control sites. For comparison, the range of material sizes recommended for industrial use in the Central Arctic is also graphed (EBA Engineering Consultants Ltd. 1993). The material size data were also plotted using triangular plots (Figure 16). This allows a different visual comparison of material sizes among different site types.

Table 9. Material size at den and control sites in the Central Arctic, NWT.

Characteristic	Bear		Wolf		Fox		Squirrel		Random
	DN	AC	DN	AC	DN	AC	DN	AC	RC
Gravel (%)	14.1* (2.9,23)	20.3 (3.8,23)	4.0* (1.3,22)	12.7* (4.0,22)	7.0* (2.2,18)	13.4 (4.8,18)	7.9* (2.2,17)	15.1 (4.5,18)	31.9 (4.2,36)
Sand (%)	63.3 (3.7,23)	60.8 (4.1,23)	70.0 (3.3,22)	71.3 (4.4,22)	64.7 (4.1,18)	69.6 (4.4,18)	70.8 (2.8,17)	70.7 (5.6,18)	62.4 (4.4,36)
Fines (%)	22.6 (3.4,23)	18.8 (3.8,23)	26.0 (3.5,22)	16.0 (3.4,22)	28.3 (4.1,18)	16.9 (4.1,18)	21.3 (2.7,17)	14.3 (4.5,18)	5.6 (1.1,36)
RC as expected:									
$X^2_{0.05,2}$	61.552	35.373	99.641	32.140	111.537	34.361	63.203	23.468	--
Probability	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	--
AC as expected:									
$X^2_{0.05,2}$	2.764	--	12.234	--	11.092	--	6.860	--	--
Probability	$P < 0.50$ $P > 0.25$	--	$P < 0.005$	--	$P < 0.005$	--	$P < 0.05$	--	--

DN - Den Sites AC - Adjacent Control Sites RC - Random Control Sites

Values are means with one standard error and sample size (1 SE, n). Results of Chi square goodness-of-fit test with AC and RC as expected values are shown. Asterisks (*) indicate significant differences from RC using Bonferroni simultaneous 95% confidence intervals.

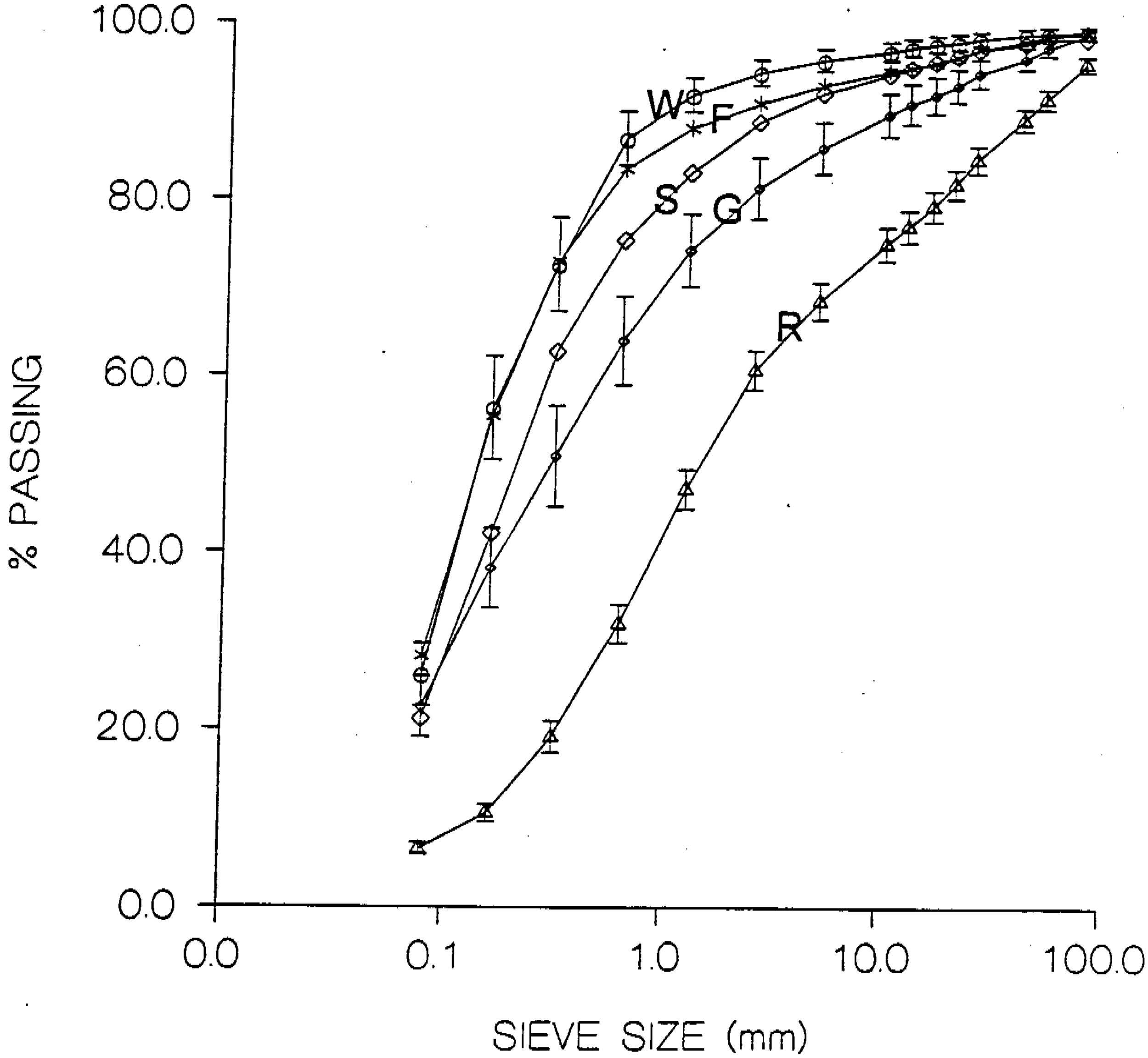

Figure 14. Plot showing the percentage of esker material from five types of sites passing through sieves of 15 progressively smaller sizes. (G = grizzly den, W = wolf den, F = fox den, S = squirrel den, and R = random control. Values are means with 1 SE error bars.)

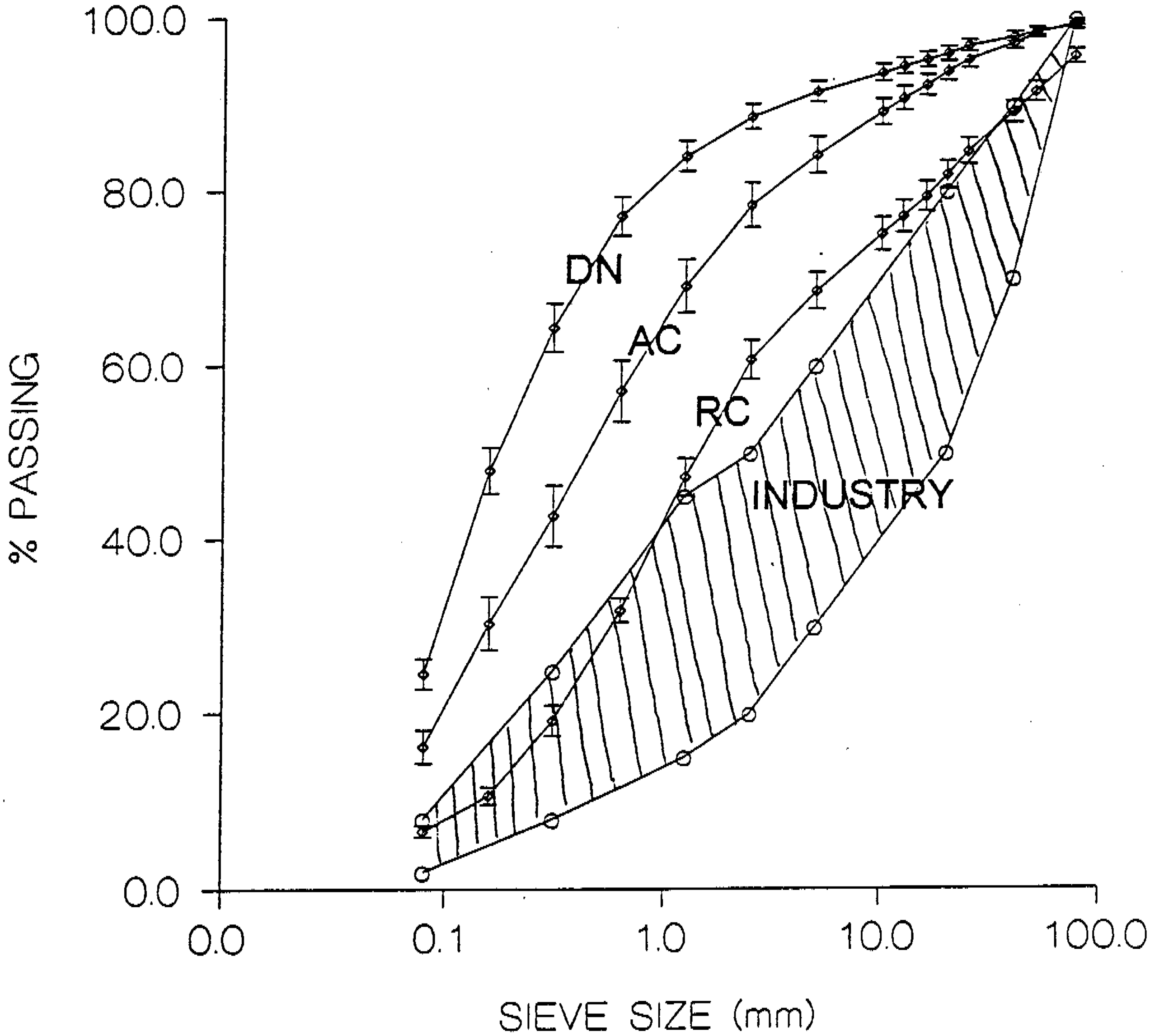

Figure 15. Plot showing the percentage of esker material from three types of sites passing through sieves of 15 progressively smaller sizes. (DN = dens, AC = adjacent control, RC = random control. Recommended material sizes for industry in this area are also plotted. Values are means with 1 SE error bars.)

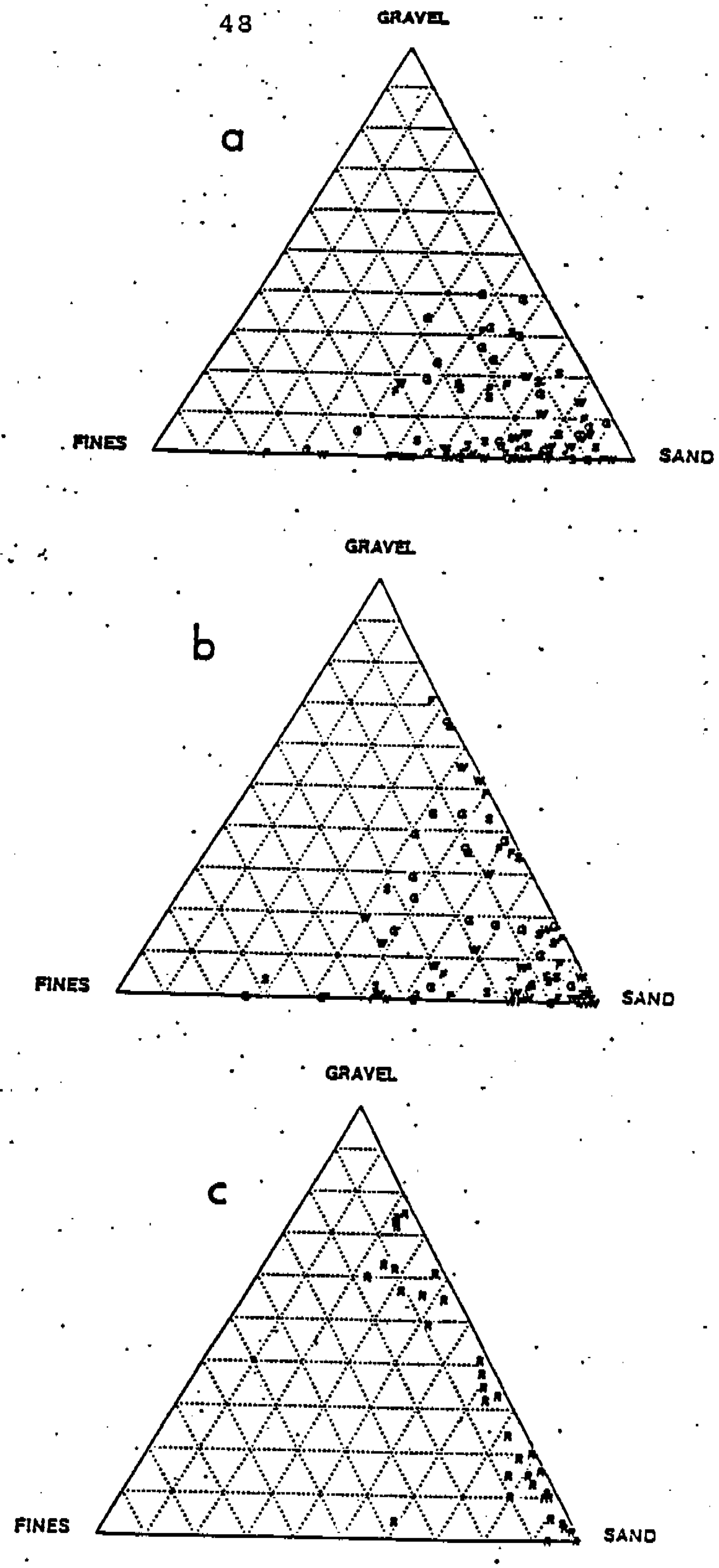

Figure 16. The relative percentages of gravel, sand, and fines in esker materials collected at den sites (a), adjacent control sites (b) and random control sites (c). (Each letter indicates a single sample. G = grizzly den, W = wolf den, F = fox den, S = squirrel den, and R = random control.)

DISCUSSION

Den Characteristics

Dens of wolves, foxes, and squirrels are generally complexes with more than one entrance tunnel. In contrast, grizzly bear dens consist of a single entrance and a den cavity. Dens of wolves, foxes, and squirrels are generally used by several animals and most are used repeatedly for several years (Macpherson 1969, Banfield 1974, Jacobson 1979, Heard and Williams 1992). Grizzly bear dens are used by either a single animal or a mother and her cubs. Bear dens are generally used for a single year and then abandoned (Banfield 1974, Reynolds et al. 1976, Vroom et al. 1980). Of the measured bear dens, 91 percent had shrubs of either dwarf birch or willow growing on the roof of the den entrance. It seems likely that grizzly bears situate their dens just below such vegetation so that the roots of the shrubs will provide additional support for the roof. How bears locate such areas under accumulated snow is unknown.

Almost all of the grizzly bear dens faced southwards (mean = 197°). It is possible that increased inception of solar radiation and/or increased snow accumulation on the south sides of eskers is advantageous for denning grizzly bears. In this region the prevailing winter winds are from the north northwest. Snow drifts, which accumulate on the southern sides of eskers in the study area, may provide important insulation for hibernating bears. Earlier snowmelt on south facing slopes could be important during spring emergence from dens.

Habitat Selection

Observed Animal Use of Esker Habitat

All species were seen to use eskers. Caribou and wolves were seen using eskers significantly more than expected by chance (Table 4). Results of these analyses of habitat use by live animals should be interpreted cautiously. For instance, results could be affected by the time of year and the time of day of the searches. In addition, caribou feeding studies in this area found that caribou selected sedge meadow habitat during summer (Melton et al. 1993).

Are Eskers Limiting Habitat for Denning Animals?

Esker habitat is frequently used by denning arctic wildlife compared with other available habitats. Although infrequent, all four types of animals were also found denning in upland habitat. The three dens of grizzly bears found in upland habitat were located in a region with very low local density of eskers. This may imply that when esker habitat is not available bears will choose upland habitat for denning. In this study we do not know the age, reproductive success, and survival of grizzly bears that den in upland habitat compared with those that den in esker habitat. Such data are needed for bears and for other species in order to understand the role of esker habitat in the population biology of these species. Such data will also be needed to understand any negative effects on wildlife populations of esker use by industry in this region.

Few studies have examined wildlife dens and denning habitat use in shield regions. Developed soils and easily penetrated materials are relatively rare in shield regions compared with other geological regions of Canada. Shield regions are characterized by extensive bedrock outcrops and numerous lakes. In the Central Arctic, exposed bedrock outcrops make up over 50 percent of the land surface. Much of the remaining habitat is wet sedge meadow. Neither outcrop nor sedge meadow is optimal denning habitat for wildlife. Rocky outcrop/upland areas provide difficult and limited digging. Denning is also difficult in sedge meadow habitats which are often flooded during short arctic summers and frozen solid during long arctic winters.

Eskers are the most suitable habitat available for denning. The sands and gravels of eskers provide easy digging for animals. Eskers are also comparatively well drained, so they remain unfrozen year round. This becomes important for animals, such as wolves, which begin denning activities prior to spring snowmelt. At the onset of the breeding season in March and April, foxes and wolves must reoccupy previously established dens because the ground is frozen making excavation of new burrows difficult. Once established, fox and wolf dens may be used for years before being abandoned. Arctic fox dens may be used for longer than 300 years (Macpherson 1969).

The combined factors of Canadian Shield, permafrost, absence of trees and hence lack of suitable alternatives in the Central Arctic likely explain the selection of eskers by denning arctic wildlife. This may also explain the lower importance of eskers to denning wildlife in other regions of the north, such as most of Alaska and northern Yukon, which lack one or more of these characteristics (Reynolds et al. 1976, Nagy et al. 1983, Mychasiw and Moore 1984, Smith et al. 1992).

Aerial Surveys and Aerial Den Identification

Aerial helicopter surveys are a rapid method of locating and identifying dens in the tundra. Wolf and bear dens are distinctive from the air. The number of fox dens may have been slightly overestimated, as the diameter of fox and squirrel entrance holes are similar from the air. For instance, the enlarged entrance holes of squirrel dens which have been dug out by bears may occasionally have been incorrectly identified as the entrance holes to fox dens.

Garrott et al. (1983) had 86% percent accuracy when identifying arctic fox dens from the air with a small airplane (Piper Supercub) flying 40 to 120 m above the ground at speeds of 80-130 km/hour. Incorrectly identified dens were actually arctic ground squirrel dens. Accuracy of den identification should be even greater from a helicopter flying 10 to 105 m lower and as much as 50 km/hour slower than the airplane. Jacobson (1979) also successfully used aerial surveys to search for dens in the Central Arctic, NWT. He also noted vegetation differences on dens of different species.

It is unknown how many dens are missed during low level helicopter searches. Informal comparisons of helicopter searches and foot searches in the same regions suggest that at least 80 percent of dens observed on foot are also observed from the air. The assumption that visibility of dens from the air will be the same in the three habitat types may not be reasonable. For instance, visibility of dens during helicopter searches in rocky upland habitat may have a negative bias relative to other habitats (Nielsen et al. 1994). It is possible that there was under-detection of dens in upland habitat due to the fragmented rocky surface in this habitat. Dens in upland habitat could lack the fan of material characteristically observed below dens in esker habitat. During foot searches in upland habitat, however, we found no evidence that dens in this habitat would differ significantly in either appearance or visibility from the air.

Effects of Animal Activities on Den Site Characteristics

Nutrient Cycling at Den Sites

Denning animals could increase the nutrient pool and soil formation rates by (i) turning and aerating materials with their digging, and (ii) by concentrating their prey remains, feeding and defecation activities around the den openings. Local increases in nutrient cycling rates likely account for the relatively lush growth and diversity of plants seen at many dens of wolves, foxes, and squirrels. The absence of such vegetation at dens of bears supports the suggestion that these dens are not regularly re-used. The relatively high amounts of vegetation seen at many den sites of wolves, foxes, and squirrels may increase substrate stability.

The soil profile of eskers tends to be very shallow (Petaja et al. 1992). Deeper soil profiles were found in soils at den sites compared with adjacent areas. This difference probably also results from the digging, feeding, and defecation activities of animals at den sites.

It was expected that concentration of animal faeces, scraps of food, and animal digging would result in relatively higher nitrogen levels at den sites. However, total nitrogen and total carbon were not significantly higher and may have even tended to be lower at den sites than at control sites. Perhaps nitrogen released from sources such as prey remains and faeces is rapidly taken up by plants and micro-organisms at den sites and hence not detected in the analyses of materials. Further experiments would be needed to test this explanation.

Other Effects of Animal Activities at Den Sites

Animals may trample vegetation and lichen growing in the vicinity of den sites. Trampling could change the percentage cover of different plant and lichen species. Animal activities could also change the size of materials at den sites over long periods of time. For instance, large materials could be rolled away from the den area by routine activities of animals. Also, thick vegetation resulting from animal activities on den sites, may trap fine air-born materials hence increasing the amount of fines at den sites.

Species Interactions on Eskers

Eskers are important to many arctic species including grizzly bears, wolves, foxes and ground squirrels as denning and foraging habitat, as well as for providing relief from insects for caribou and nesting sites for birds. Eskers are used extensively by denning wildlife. Eskers become an importance source of food for tundra animals especially in early spring and late fall. For instance, early snowmelt on eskers in spring attracts migrating waterfowl. Vegetation communities on eskers are complex (Rikkinen 1989, Rajakorpi 1987, Heikkinen 1991) and may share similarities with plant communities found on raised beaches in arctic regions (Svoboda 1977). In addition, the abundance of ground squirrels on eskers may be a critical source of food for hungry grizzly bears just prior to denning and just after emergence from dens in the spring. Eskers are used by all wildlife, including caribou, as travel corridors (Jakimchuk and Carruthers 1983) and as important habitat for relief from insects. Especially during July, large groups of caribou can be seen milling about on eskers to obtain relief in the wind from numerous biting insects. In the Central Arctic eskers play an integral role in traditional cultures. They are frequently used for travelling, hunting, and camping. Historically, they were also used as burial sites.

CONCLUSION

Grizzly bears, wolves, foxes, and squirrels established dens almost exclusively on esker habitat rather than on rocky upland habitat or on meadow habitat. Within esker habitat, a number of characteristics were significantly different between den sites and control sites. This suggests that it may be feasible to evaluate the suitability of habitat for denning of bears, wolves, foxes, and squirrels prior to industrial activities, that might include esker use.

RECOMMENDATIONS

Although further work is required, the following preliminary recommendations for impact mitigation are provided. A number of questions are also posed for future studies of eskers in the Central Arctic.

Significant diamond, gold, and base metal deposits have been discovered in the Central Arctic region known as the Slave Geological Province. Several diamond, gold, and base metal mines, as well as all-weather roads, hydro projects, and port sites are being considered for this region (Hayley and Valeriote 1994, Klohn-Crippen Consultants Ltd. 1993). All of these developments will require extensive quantities of granular resources and eskers will be their main source. Given the possibility of extensive esker use, it becomes imperative that guidelines be developed to minimize both the amount of granular material extracted from eskers and the disturbance to denning wildlife.

Currently, the impacts to ecological communities in the Central Arctic resulting from extensive extraction of granular materials from eskers for road and mine construction are poorly understood. Cumulative disturbance and extraction of material from eskers in the Central Arctic could negatively effect the long-term viability of grizzly bear, wolf, and fox populations in the region.

Gravel extraction will result in direct loss of denning habitat and feeding habitat for grizzly bears, wolves, foxes, and squirrels. Harding and Nagy (1980) have documented cases where grizzly bear dens on Richards Island, NWT, were partially destroyed by vehicular activity or totally destroyed by quarry operations. A decrease in the amount of denning habitat may have a significant impact upon carnivore populations. For example, loss of traditional denning areas could reduce the reproductive success of these species. Suitable denning sites on the barrens may already be a limiting factor for carnivore populations.

Indirect habitat loss may also occur due to gravel extraction activities which may displace animals from denning and feeding habitat. For instance, noise from vehicles may displace animals from a region even if the habitat is not directly altered.

Operating guidelines need to be developed and summarized so that recommendations and regulations regarding esker use can be effectively and easily implemented in the field by industry. Existing guidelines do not consider arctic eskers in detail (Svedarsky and Crawford 1982; Canada, Indian and Northern Affairs 1989; Katona and Szoke 1993; Stanley Associates Engineering Ltd. and Sentar Consultants Ltd. 1993). Possible management options/operating guidelines to reduce impacts of industrial esker use include:

1. Identify and Avoid Den Sites

Den sites should be identified before major development or exploration activities are initiated. Dens of all species studied are conspicuous and can be identified by conducting aerial surveys. The dens of wolves and foxes are traditional sites and are used for many years in succession. Such sites should be avoided during development. Grizzly bears likely do not re-use existing dens. Grizzly bears, however, do require habitat with certain characteristics for denning. Suitable habitat for future denning should be identified and protected. Protected areas of habitat should be large enough that animal populations are not negatively affected either by extraction of granular materials or by displacement away from development activities. Early identification combined with guidelines or regulations limiting den disturbance would reduce the impacts of resource development on carnivores.

2. <u>Minimize Use and Disturbance of Eskers</u>

Use of eskers should be minimized. For instance: (i) construct winter roads when possible, (ii) make road beds as narrow and as thin as possible, (iii) make roads as direct as possible to shorten length, (iv) use mine or exploration waste rock as alternative road fill, and (v) recycle granular materials from abandoned road beds.

In general, roads should not be constructed on eskers. Constructing roads away from eskers using fill material is a favoured option and minimizes the amount of esker materials required by a project. This prevents the granular material within the esker from becoming "capped" and no longer available for use as a future source of granular resources. Fill material should come from identified quarry sites. However, it is possible that in some instances putting a road on an esker of low denning value will have less overall impact than placement of esker material across a nearby more productive habitat. Therefore, off-esker road routes also need careful evaluation.

Timing (e.g., winter versus summer) of material removal from eskers may also reduce impacts, but will vary for different species.

3. Identify Quarry Sites

Use and disturbance of eskers should, therefore, mainly occur at identified quarry sites. Guidelines for selection of quarry sites and for extraction of materials need to be developed. Quarry sites should be chosen to avoid material types favoured by denning animals. Furthermore, consideration should be given to location in relation to important animal movement corridors, such as animal crossings and animal den sites. The volume of granular material required and available from identified esker quarry sites should be carefully determined so potential impacts are known before a project is initiated.

4. Reclaim Materials After Industrial Use

Revegetation of disturbed eskers occurs slowly in arctic tundra regions. Roads, pads and other granular developments should be reclaimed during the termination of development projects. For instance, scarification of road beds after use will increase microhabitat availability and possibly decrease the time required for revegetation. After abandonment, road beds constructed from esker materials may be suitable denning habitat for some species such as the ground squirrel; however, comparison of material size requirements of wildlife and industry suggests that materials in road beds and other developments will be too coarse to be suitable for animal denning.

5. Study Impacts of Future Use of Eskers

In future when eskers are used by industry, studies of the direct and indirect impacts to arctic plants and wildlife should also be conducted. Such information could be used to improve future decision making regarding esker use and impact mitigation.

Questions for Future Esker Research

(1) Are eskers a limiting/regulating resource for tundra wildlife and plant populations?

(2) Does local esker abundance and quality correlate with parameters such as the reproductive success, overwinter survival, and density of a species population?

(3) How can we improve our ability to predict which eskers or portions of eskers are of greatest ecological value?

(4) Does the frequency of denning activity on an esker increase as the density of surrounding eskers decreases?

(5) Can aerial photography and satellite imagery analysis be used to predict animal use of esker habitat?

(6) Does the presence of a den of one species allow prediction of use by another species? For example, can aerial surveys for ground squirrel dens be used as an index of esker "quality" for denning carnivores?

(7) How long does it take for plants and animals to recolonize a disturbed esker in the Central Arctic?

ACKNOWLEDGEMENTS

I especially thank David Livingstone, Steven Matthews, and Derek Melton for making this project possible and for providing assistance throughout. Ricki Hurst, Steven Harrison, Carey Ogilvie, Rene Brule, Meghan Steward, Rob Gau, Ed Struzik, Chris O'Brien, and Brenda McNair helped with field work. Rene Brule with Ultra Helicopters, was our pilot. Dave Taylor, Dean Cluff, Ray Bethke, Helmet Epp, and Norm McLean assisted with computer analyses and graphics. Figures 1 and 5 were used with the permission of Ray Bethke. Mark Williams freely shared his expertise and data on wolves. I am grateful to Derek Melton, Anne Gunn, Ray Case, Bob Gowan and Alison Welch for their comments on drafts of this paper. Financial and logistical support for this study was provided by Indian and Northern Affairs, Canada; Department of Renewable Resources, Government of the Northwest Territories; DeBeers Centenniary Ltd.; and BHP Diamonds Inc.

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