Boreal Inland Dune Biophysical Setting

Interior Alaska

Conservation Status Rank: S4 (apparently secure)

Introduction

Active inland dunes occur in areas where wind-deposited silts and sands form expansive deposits. In boreal Alaska and western boreal Canada inland dunes represent remnants of larger dunes systems and sand sheets that developed in the late Pleistocene. Most of these relict sand deposits have been stabilized by vegetation, but areas of active transport and deposition still exist. In Alaska, the Great Kobuk Sand Dunes, Little Kobuk Sand Dunes, and Nogahabara Dunes persist as isolated, active remnants of these extensive sand sheets (Figure 1). These and the western Canada boreal dune fields are strongly linked by their shared floristics, Quaternary origins, and geomorphic processes and landforms. In addition to several plant species of conservation concern, an abundance of Beringian endemics, and disjunct species are known from active inland dunes. This biophysical setting differs from the Arctic Inland Dune biophysical setting as it is not underlain by continuous permafrost. Inland dune systems do not include coastal dune settings such as back beaches, barrier islands, and spits.

Figure 1. The Great Kobuk Sand Dunes, Alaska (photo provided by Kobuk Valley National Park).

Distribution

In boreal Alaska, inland dunes are represented by the Nogahabara Dunes (65 km^2), which exist in a designated wilderness area in the Koyukok River lowlands and Great Kobuk Sand Dunes (62 km^2) (Figure 3) and Little Kobuk Sand Dunes (8 km^2), which are protected National Park lands. The Boreal Inland Dunes

distribution map was developed from bare ground landcover classes of the Alaska Vegetation Map within the areas of interest (Boggs et al. 2015).

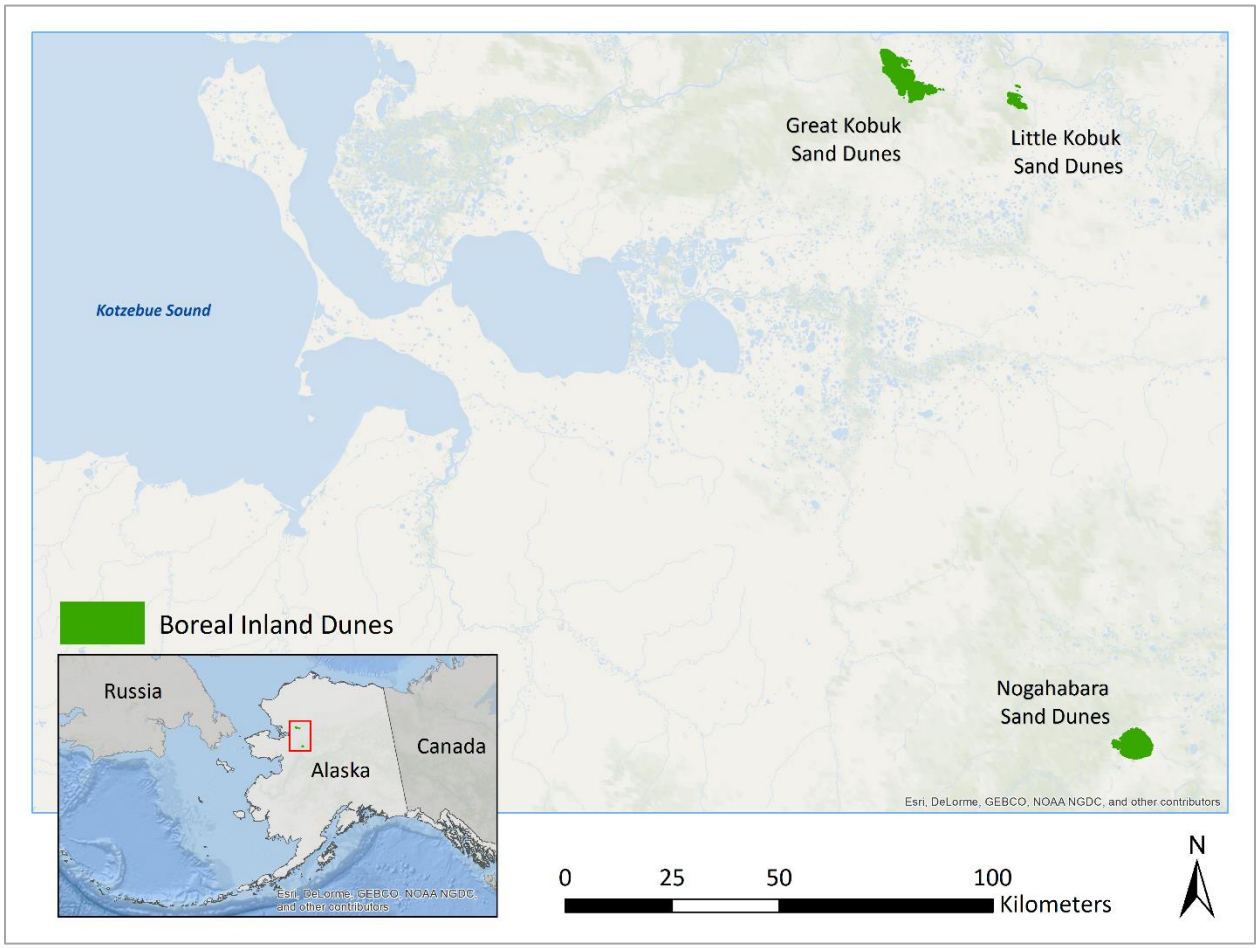

Figure 2. Distribution of the Boreal Inland Dune Biophysical Setting.

Figure 3. The Great Kobuk dunes, Alaska (photo by Kobuk Valley National Park).

Climate

Interior Alaska has short, warm summers and long, cold winters. The average annual precipitation ranges from 25 to 51 cm in valley bottoms and basins. Most precipitation falls as rain between the months of May and September. Average annual snowfall ranges from 165 to 203 cm, and average annual temperature ranges from -6.7 to -5.6 °C. The typical frost-free period ranges from less than 30 to 90 days. Normally,

the temperature remains above freezing in river valleys and basins from mid-June through August (NRCS 2004).

Environmental Characteristics

Inland dunes develop from concentrations of glaciofluvial silts and sands have been deposited by wind. Source material for the three active dune systems in boreal Alaska is derived from sand sheets and dunes that covered over 30,000 km^2 of northern Alaska during the last glacial period (Carter 1981, Hopkins 1982, Lea and Waythomas 1990). The parent material of the sand composing the Kobuk Valley dunes is quartzose bedrock in the Brooks Range that, during the Pleistocene glaciations, was eroded and transported by glaciers and outwash streams into the Kobuk Valley (Fernald 1964, Hamilton 1984, Hamilton et al. 1987). These sands are fine-grained and moderately well-sorted (Dijkmans et al. 1988). Quartz and feldspar are the dominant minerals (78%), accompanied by heavy minerals (10%), and carbonate (7%; Dijkmans et al. 1986). Carbonate grains in the dune sands are a mixture of detrital grains derived from bedrock and calcite precipitated as secondary carbonates within the dune field. Secondary carbonates are widespread in the Great Kobuk Sand Dunes, where they accumulate in frost cracks, around springs and in interdune basins (Cox and Lawrence 1983, Koster et al. 1986, Galloway et al. 1990). Calcretes (carbonate-cemented crusts) also occur and are formed in the Kobuk Valley Dunes primarily by the exposure of cold, carbonate-rich groundwater to warm surface conditions with lower partial pressures of CO_2 (Dijkmans et al. 1986). Calcretes found in the Nogahabara Dunes contain microfeatures that suggest fluvial influences (shallow surface waters) were greater than aeolian or glacial influences prior to concretion (Galloway et al.1990). Very fine sand and silt may be carried beyond the dunes and eventually deposited within the surrounding tundra and forest. This material rains on vegetated surfaces, where it becomes interstratified with soil organic horizons (Mann et al. 2002).

The Great Kobuk Dunes contain a diverse assemblage of aeolian landforms, including parabolic, transverse, longitudinal, and barchanoid dunes, along with sand sheets, blowouts and precipitation ridges (Koster and Dijkmans 1988, Dijkmans and Koster 1990). Precipitation ridges form at the dune field perimeter where bordering forests cause wind speed to drop, resulting in the deposition of sand along a linear crest (Cooper 1967, Raup and Argus 1982, Mann et al. 2002). The Little Kobuk Dunes (8 km^2) are an elongate patch of blowouts and parabolic dunes with barchanoid dunes at their western extremity (Kuhry-Helmens et al. 1985, Hamilton et al.1987). Comparable active dunes outside of boreal Alaska include the Athabasca Sand Dunes in northern Saskatchewan and Carcross dunes in southwestern Yukon.

Vegetation and Succession

The main disturbance process is the erosion, transport and deposition of sand. Sand accumulates at the crest of a dune until the lee slope exceeds the angle of repose and layers slide. Repetition of this process causes migration of the dune. Establishment of plants slows dune migration and leads to stabilization. Vegetation on the lee side of the dune is gradually buried in sand, while vegetation reestablishing on the windward side is subject to excavation. Creeks and interdune depressions, also referred to as slacks, sometimes support wetland and riparian plant communities. Black or white spruce (*Picea mariana* or *P. glauca*) forests surround the dune fields (Racine 1976).

Figure 4. *Oxytropis kobukensis* along the Kobuk River (photo by Rob Lipkin).

The Great Kobuk Sand Dunes are largely barren, supporting widely scattered plants of the grasses *Bromus pumpellianus* and *Festuca rubra,* the willow, *Salix alaxensis,* and the forbs *Artemisia borealis, Oxytropis kobukensis,* and *Plantago canescens* (Figure 4). Dune margins are sometimes stabilized by the grasses *Festuca rubra* and *Leymus mollis,* although cover rarely exceeds 10%. Here, dead leaves of *Leymus* accumulate at the base of the stem and radiate out from it, providing increased cover along the sand surface. Windblown plant and lichen fragments are trapped providing germination sites for additional plants. In time, lichens begin to replace the grasses, and other vascular species, including the forbs, *Plantago canescens* and *Dianthus repens,* become established and may increase plant cover to about 40% in gently sloped areas. Coverage and diversity of lichens and other plants, including the forb, *Silene acaulis* and the dwarf shrub *Dryas integrifolia,* continues to increase. When cover reaches about 90%, spruce may colonize and gradually develop into woodland with widely-spaced trees, a lichen understory and few vascular plants. On well-drained sites within 50–100 m of the active dunes, this forest is dominated by 10–20 m tall *Picea glauca* with subordinate *Betula neoalaskana* and *Populus tremuloides*. Farther from the active dunes, well-drained, stabilized dunes are covered by forest woodlands of *Picea glauca, Betula neoalaskana, Populus tremuloides, Salix* species and *Alnus viridis* ssp. *crispa,* with a ground layer of ericaceous shrubs and foliose lichens (Young and Racine 1977). Lichens identified from the sand dunes and surrounding habitats comprise 63 genera and 160 species, many with circumpolar arctic-alpine and amphiberingian distributions (Dillman et al. 2001).

Active sand may advance on spruce forests, killing them and resetting the successional pattern (Bowers 1982). Fire may also return forest- or tundra-stabilized dunes to activity (Mann et al. 2002). Animals also cause disturbance to dunes; grazing, trampling or burrowing by caribou (*Rangifer tarandus*) or ground

squirrels (*Spermophilus parryi*) disturbs vegetation, thereby facilitating erosion and blowouts (Peterson and Billings 1978).

Conservation Status

Rarity: Cold-climate dune fields in North America, Europe and Asia are estimated to cover an area of over 100,000 km^2 (Koster 1988). Although large systems of dunes and sand sheets developed in Alaska during the late Pleistocene, most deposits have since been stabilized by vegetation. Today active inland dune fields are rare on the landscape; only three large active dune fields: the Great Kobuk, Little Kobuk and Nogahabara Sand Dunes, comprising approximately 100 km^2 are known from boreal Alaska.

Threats: Foot traffic may prevent plants from establishing or persisting in the sandy soil. Thus increased subsistence or recreational use of the dunes could potentially impact the dunes. However, these threats are expected to be minimal due to low human population densities that is concentrated around local villages. Also, the introduction of nonnative plant species could affect establishment of native plants in dune field stabilization.

Trend: A period of dune-field stabilization occurred at Great Kobuk Sand Dunes between 7,000 and 5,000 ybp (years before present). Following this period of stabilization, episodes of dune field expansion occurred at 400 to 1,500 year intervals. Specifically, the Great Kobuk dunes expanded during the Medieval Warm Period (ca. AD 900–1,400), were relatively inactive early in the Little Ice Age (AD 1,400–1,800), and expanded briefly late in the Little Ice Age prior to AD 1,900. The dune field has contracted over the last 80–100 years. Moisture balance appears to be the major control of aeolian (wind driven) activity at dune fields within boreal forests, with increased moisture leading to contraction of the dune fields (Mann et al. 2002, Wolfe et al. 2000). Because vegetation colonization of active dunes is so closely tied to moisture regimes, active dunes currently exist at a threshold wherein a minor change in climate could impact their future direction more strongly than human activity (Parker and Mann 2000).

Species of Conservation Concern

The mammal, bird, and plant species listed below are designated critically imperiled or vulnerable either globally (G1-G3) or within Alaska (S1-S3) and are known or suspected to occur in this biophysical setting (Tables Table 1, Table 2). The Alaska tiny shrew (*Sorex yukonicus*) has been documented to occur at Kobuk Valley National Park, between the Great Kobuk and Little Kobuk dunes (UAM 2015). It primarily inhabits riparian scrub areas, but has also been observed in wetlands and bogs, and at forests and shrub tussock tundra at dune margins. Please visit the Alaska Center for Conservation Science website for species descriptions (ACCS 2016).

Table 1. Mammal and bird species of conservation concern within the Boreal Inland Dune Biophysical Setting.

Common Name	Scientific Name	Global Rank	State Rank	Habitat Description
Mammals				
Alaska tiny shrew	*Sorex yukonicus*	GU	S3	Suspected to occur at Great Kobuk Sand Dunes. Primarily occurs in riparian scrub, and also forests, wetlands, bogs, and shrub tussock tundra.
Birds				
Rusty Blackbird	*Euphagus carolinus*	G4	S3	Documented occurrence in Nogahabara Sand Dunes (Bodony et al. 2011).

Common Name	Scientific Name	Global Rank	State Rank	Habitat Description
Fox Sparrow	*Passerella iliaca*	G5	S3	Suspected to occur within edge habitat of Kobuk Sand Dunes, primarily in wooded understory.
Peregrine Falcon	*Falco peregrinus*	G4	S3	Suspected to occur nearby to the Great Kobuk Sand Dunes- primarily in mountainous cliffs, hunting wetlands nearby the Dunes.
Sharp-shinned Hawk	*Accipiter striatus*	G5	S3	Suspected to occur within edge habitat of Kobuk Sand Dunes, primarily in wooded cover.

Table 2. Plant species of conservation concern within the Boreal Inland Dune Biophysical Setting.

Scientific Name	Global Rank	State Rank	Habitat Description
Carex sabulosa ssp. *leiophylla*	G5	S1	Riverine sand exposures and dune fields in Yukon and Alaska. Also occurs in Kazakhstan, Mongolia, and Russia. Known from less than six sites in North America, this sedge is uncommon at Nogahabara Sand Dunes.
Lupinus kuschei	G3G4	S2	Occurs on sand dunes and glacial rivers. Most of the global population is in southwestern Yukon Territory, with additional occurrences in British Columbia and Alaska.
Oxytropis kobukensis	G2	S2	Narrowly endemic to a small stretch of the middle Kobuk River, where it grows on sparsely vegetated sand on active dunes, in dune slacks and on sheltered dune slopes.
Symphyotrichum yukonense	G3	S3	Known to occur in the Great Kobuk Sand Dunes in damp, sandy dune depressions and creek floodplains.

Plant Associations of Conservation Concern

Of the plant associations that occur at dune field margins, all have a high fidelity for this biophysical setting. However, there are no plant associations of conservation concern (S1-S3) known or suspected to occur within this biophysical setting.

Classification Concept Source

The classification concept for this biophysical setting is based on Racine (1976).

Literature Cited

ACCS (Alaska Center for Conservation Science) 2016. Rare Plant Data Portal. April 28, 2016. http://aknhp.uaa.alaska.edu/maps-js/rare-vascular-plant-portal.

ACCS (Alaska Center for Conservation Science) 2016. BIOTICS Animal Data Portal. April 28, 2016. http://aknhp.uaa.alaska.edu/maps-js/integrated-map/biotics.php.

Bodony, K., D. Bogan and J. Slowik. 2011. Trip Report from July 2010 visit to Nogahabara Sand Dunes and Horner Hot Springs. USFWS.

Bowers J. E. 1982. The plant ecology of inland dunes in western North America. Journal of Arid Environments 5:199-220.

Carter, L. D. 1981. A Pleistocene sand sea on the Alaskan arctic coastal plain. Science 211:381–383.

Cooper, W. S. 1967. Coastal dunes of California. Geological Society of America Memoir 104:1-147.

Cox, G. W., and W. T. Lawrence. 1983. Cemented horizon in Alaskan sand dunes. American Journal of Science 283:369–373.

Dijkmans, J. W. A., E. A. Koster, J. P. Galloway, and W. G. Mook. 1986. Characteristics and origin of calcretes in a subarctic environment, Great Kobuk Sand Dunes, northwestern Alaska, U.S.A. Arctic and Alpine Research 18:377–387.

Dijkmans, J. W. A., and E. A. Koster. 1990. Morphological development of dunes in a subarctic environment, central Kobuk valley, northwestern Alaska. Geografiska Annaler 72A:93–109.

Dijkmans, J. W. A., J. P. Galloway, and E. A. Koster. 1988. Grain-size and mineralogy of eolian and fluvial sediments in the central Kobuk valley, northwestern Alaska. United States Geological Survey Open-File Report 88-369.

Dillman K. L., L. H. Geiser, J. Riley, and G. A. Laursen. 2001. Lichens of the Great Kobuk Sand Dunes of northwestern Alaska. Botany 2001 Plants and People. Albuquerque, New Mexico.

Fernald, A. T. 1964. Surficial geology of the central Kobuk River valley, northwestern Alaska. United States Geological Survey Bulletin 1181-K:k1–k31.

Galloway, J. P., M. Huebner, R. Lipkin, and J. W. A. Dijkmans. 1990. Early Holocene calcretes from the subarctic active Nogahabara dune field, northern Alaska. United States Geological Survey Bulletin 1999:100–109.

Hamilton, T. D. 1984. Surficial geologic map of the Ambler River quadrangle Alaska. United States Geological Survey Miscellaneous Field Studies Map MF-1678, scale 1:250,000, 1 sheet.

Hamilton, T. D., J. P. Galloway, and E. A. Koster. 1987. Late Wisconsin eolian activity and related alluvium, central Kobuk valley. United States Geological Survey Circular 1016:39–43.

Hopkins, D. M. 1982. Aspects of the paleogeography of Beringia during the late Pleistocene. Pages 3-28 *in:* D. M. Hopkins, J. V. Matthews, C. E. Schweger, and S. B. Young, eds. Paleoecology of Beringia. Academic Press, New York, New York.

Koster, E. A. 1988. Ancient and modern cold-climate aeolian sand deposition: A review. Journal of Quaternary Science 3:69-83.

Koster, E. A., and J. W. A. Dijkmans. 1988. Niveo-aeolian deposits and denivation forms, with special reference to the Great Kobuk Sand Dunes, northwestern Alaska. Earth Surface Processes and Landforms 13:153–170.

Koster, E. A., J. P. Galloway, and W. G. Mook. 1986. Characteristics and origin of calcretes in a subarctic environment, Great Kobuk Sand Dunes, northwestern Alaska, USA. Arctic and Alpine Research 18:377–387.

Kuhry-Helmens, K. F., E. A. Koster, and J. P. Galloway. 1985. Photointerpretation map of surficial deposits and landforms of the Kobuk Sand Dunes and part of the Kobuk Lowland, Alaska. United States Geological Survey Open File Report: 85–242.

Lea, P. D., and C. F. Waythomas. 1990. Late-Pleistocene eolian sand sheets in Alaska. Quaternary Research 34:269–281.

Mann, D. H., P. A. Heiser, and B. P. Finney. 2002. Holocene history of the Great Kobuk Sand Dunes, northwestern Alaska. Quaternary Science Reviews 21:709-731.

Nawrocki, T., J. Fulkerson, and M. Carlson. 2013. Alaska Rare Plant Field Guide. Alaska Natural Heritage Program, University of Alaska Anchorage. 352 pp.

NRCS 2004. Land resource regions and major land resource areas of Alaska. United States Department of Agriculture – Natural Resources Conservation Service. Palmer, Alaska.

Parker, C. L., and D. H. Mann. 2000. Floristics and vegetation of active sand dunes in the Kobuk River Valley, northwestern Arctic Alaska. American Association for the Advancement of Science & Yukon Science Institute.

Peterson, K. M., and W. D. Billings. 1978. Geomorphic processes and vegetational change along the Meade River sand bluffs, northern Alaska. Arctic 31:7-23.

Racine, C. H. 1976. Flora and vegetation. Pages 39-139 *in* H. R. Melchior, ed. Biological Survey of the Proposed Kobuk Valley National Monument. Final Report to the United States National Park Service, Alaska Cooperative Park Studies Unit, University of Alaska, Fairbanks, Alaska.

Raup, H. M., and G. W. Argus. 1982. The Lake Athabasca sand dunes of northern Saskatchewan and Alberta, Canada. I. The land and vegetation. National Museum of Natural Sciences Publications in Botany, No. 12. National Museums of Canada, Ottawa, Canada.

UAM (University of Alaska Museum). Fairbanks, AK USA. Available: http://arctos.database.museum/

Wolfe, S. A., D. R. Muhs, P. P. David, and J. P. McGeehin. 2000. Chronology and geochemistry of late Holocene eolian deposits in the Brandon Sand Hills, Manitoba, Canada. Quaternary International 67:61–74.

Young, S. B., and C. H. Racine. 1977. Vegetational and floristic analysis and discussion of the Quaternary environment of the Kobuk valley. Report to the United States National Park Service, Center for Northern Studies, Wolcott, Vermont.