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SMALL MAMMALS IN RELATION TO NATURAL REVEGETATION OF GOLD DREDGE TAILINGS AT NYAC, ALASKA

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SMALL MAMMALS IN RELATION TO NATURAL REVEGETATION OF GOLD DREDGE TAILINGS AT NYAC, ALASKA

A

THESIS

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SMALL MAMMALS IN RELATION TO NATURAL REVEGETATION

OF GOLD DREDGE TAILINGS AT NYAC, ALASKA

RECOMMENDED:

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ABSTRACT

Small mammal and vegetation communities were studied during 1980 and 1981 in areas affected by, and adjacent to, gold dredging at Nyac, Alaska. Northern red-backed voles (*Clethrionomys rutilus*) and masked shrews (*Sorex cinereus*) were the most common small mammals and exhibited generalized habitat preferences. *Microtus* spp. and meadow jumping mice (*Zapus hudsonius*) showed specific habitat preferences. Diversity, richness, and abundances of small mammals were generally higher in unmined than mined areas. Beaver (*Castor canadensis*) were found in greater densities in mined areas. A variety of carnivore species occurred in both mined and unmined areas.

Natural revegetation appeared to be limited primarily by water stress and secondarily by nutrient availability. Saving and redepositing topsoil during mining operations is believed the best way to promote natural revegetation. Revegetated tailings with topsoil present mimicked natural riparian vegetation. Habitat heterogeneity and tailing-water interfaces are of major importance to wildlife species.

. . .[T]his involves the deeper questions of <u>why</u> a species occurs in one place and not in another, which is probably the same as why it persists at all. No living man can answer that question fully in even one single instance.

-- Aldo Leopold

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My debt to the people of Nyac and Brand X is greater than can be adequately covered here. Their acceptance of a mouse trapper (of all things!) in their midst with companionship, stories, and warm coffee will always be remembered.

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This thesis is dedicated to the memory of John T. Bloomquist -- miner, pilot, friend.

INTRODUCTION

This study was undertaken to document some of the short- and long-term terrestrial effects of placer mining in subarctic Alaska. Both government and industry have had insufficient data to make knowledgeable decisions concerning responsible use of public land for mineral extraction. In conjunction with other recent studies of placer mining effects in northern regions (Hardy Associates 1979; Rutherford and Meyer 1981; Singleton et al. 1981; Weir et al. 1981; Holmes 1981, 1982), this study provides a data base upon which land management and industry personnel can draw during the planning and decision processes.

Information concerning the effects of mining is needed when legal guidelines require some sort of post-mining treatment of affected lands. An example of such a guideline is U.S. Bureau of Land Management Rulemaking 43 CFR 3800, Subpart 3809, the stated goal of which "is to afford adequate protection to Federal lands from unnecessary and undue degradation at the least possible burden to the mining industry and to the United States."

Prior to the 1970s, northern revegetation literature was largely limited to studies concerning colonization of gravel bars (Viereck 1970), glacial moraines (Crocker and Major 1955, Viereck 1966), or other natural disturbances. Johnson and Van Cleve (1976) and Peterson and Peterson (1977) have reviewed the literature of both assisted and natural revegetation in the north, and Holmes (1982) substantially reviewed that pertaining to natural revegetation. Woodward-Clyde Consultants (1980) studied natural revegetation of gravel removal sites in subarctic and arctic Alaska.

With exception of studies done in the Klondike region of Canada (Singleton et al. 1981, Weir et al. 1981), virtually nothing has been published regarding the effects of surface mining upon terrestrial animals in the north. Hansen and Warnock (1978) and Brennen et al. (1982) examined small mammal communities on strip mined areas of mid-latitudes. Ferns (1979) examined succession of mammalian species in a British larch plantation, while Moulton et al. (1981) looked at mid-latitude old field succession. Most work at northern latitudes has been in relation to either fire (West 1974, Fox 1983) or logging (Martell and Radvanyi 1977; West et al. 1980; Van Horne 1981, 1982a,b) in coniferous forests.

Dredging of placer gravels is a severe form of land disturbance. The vegetation mat and silt (overburden) overlying stream gravels must be stripped away, frequently with a bulldozer. Next a bucketline dredge (Figure 1) is used. Daily (1968) described such a dredge as

> a combined floating excavating machine and a gravity concentration system. Material is excavated at the forward end of the buckets, elevated, washed and screened, concentrated for recovery of valuable minerals, and discharged off the stern as coarse and small fractions.

The washing and sorting of gravels, together with the physical relationship of tail flumes and stacker, result in a tailing (waste) pile with the finer components (typically 10-15 mm diameter or less)

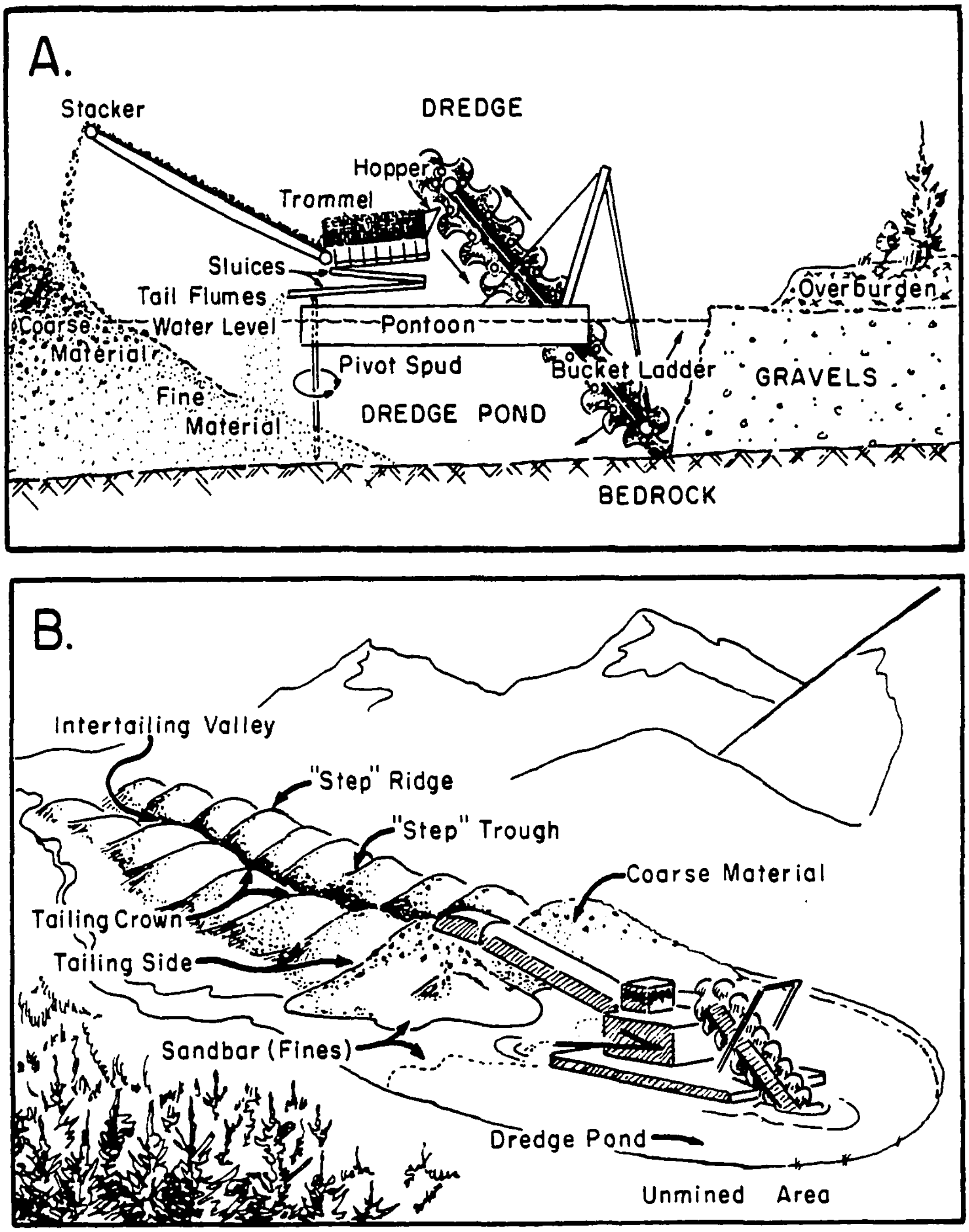

Figure 1. Terminology relating to portions of a bucketline dredge operation, and to tailings formed by such an operation. A - stylized cross-section of a dredge and dredge pond. B - Topography associated with an area mined by a bucketline dredge; distance between successive step ridges exaggerated for clarity.

being overlain by several meters of freshly washed coarse materials. Terminology is explained further in Figure 1.

Specific objectives of this project were to

(1) identify the seral vegetation that invades after mining has ceased and compare the seral vegetation to that of undisturbed sites,

(2) assess the effect of various dredging procedures upon revegetation,

(3) assess use by key mammal species of vegetation communities,

(4) determine relative abundances of terrestrial mammals, including small mammals, carnivores, and ungulates, associated with the seral and undisturbed vegetation communities, and

(5) establish baselines for future studies.

STUDY AREA

Physical location

The study area is located in a valley system in the foothills of the Kilbuck Mountains on the eastern edge of the Yukon-Kuskokwim Delta in southwestern Alaska (Figure 2). Positioned at about 61°N,160°W, the area lies in portions of both the Bethel and Russian Mission USGS Quadrangles, approximately 105 km east of Bethel, Alaska. Elevations of the valley floors of the Tuluksak River and Bear Creek range from 100-300 m in the study area; the surrounding ridges range from 455-760 m in elevation, with peaks to 1150 m.

Extensive studies were made along the Tuluksak River and adjoining creeks (Figure 2) from the water to surrounding ridge tops. Intensive sampling was limited to portions of the active and inactive floodplains identified in Figure 2.

Geology and soils

Bedrock is largely composed of cretaceous andesitic and basaltic flows, with layers of interbedded graywacke, siltstone, and pebble conglomerate (Hoare and Coonrad 1959a,b). Tertiary granitic intrusions are prominent on the ridges. Valley floors and associated benches are composed of Quaternary alluvial and colluvial deposits. Along upper Bear Creek, 90% of the gravel passed through a 63.5 mm (2.5 in) ring (Holzheimer 1926).

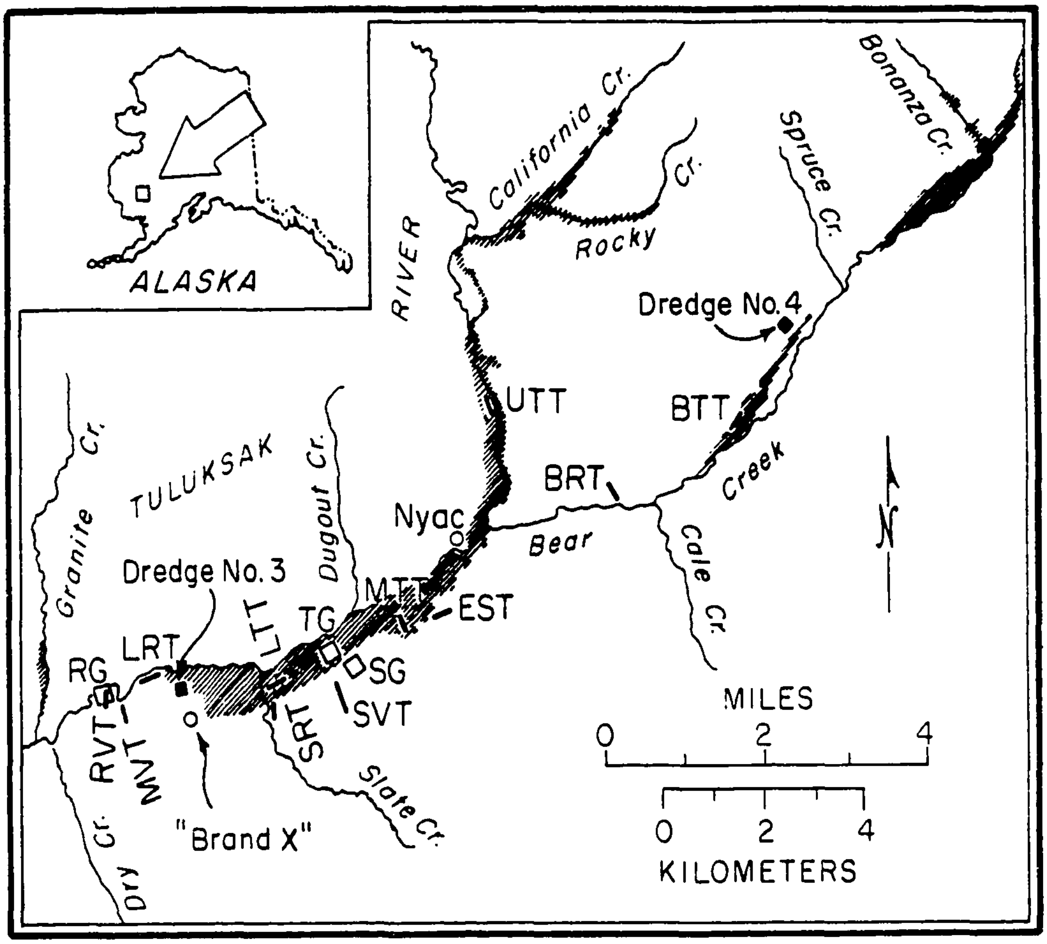

Figure 2. Map of the Nyac study area showing locations of mining camps (open circles), active dredges as of 1981 (solid squares), and sampling sites (lines and open squares). Shaded areas were mined between 1913 and 1979.

Floodplain and terrace soils along the Tuluksak River are composed of a thin, partially decomposed organic layer overlying a thin white horizon. Beneath the white horizon is a 0.10-0.25 m thick layer of reddish brown sand or loam. Between the loam and bedrock is a layer of course gravel and larger alluvial material typically 3-6 m thick (Rutherford and Meyer 1981).

Isolated areas of the floodplain contain a water table at or near the surface. Apparently this results from subsurface damming of water flow by clay lenses, ice wedges, or some other, undetermined, natural levee. Soils in these areas consist of 0.50-0.75 m of partially decomposed sedges and peat moss overlying permanently frozen alluvial material (Rutherford and Meyer 1981).

Climate

The Nyac climate is classified as transitional between continental and marine. Meteorologic records from the area are summarized in Selkregg (1976). Summer temperatures typically range from 3° to 19°C, winter temperatures from -45° to -11°C, and recorded extremes are -45° and 31°C. Mean date of last spring freeze is 14 June, and that of first fall freeze 29 August, resulting in a mean growing season of 76 days. Mean annual precipitation is 560 mm, including 1800 mm of snow. The area is in the zone of discontinuous permafrost, although mining records show only small, scattered bodies of ice in the placer gravels. Holzheimer (1926) reported no frozen ground found in the initial dredging of Bear Creek.

Considerable variation occurs from year to year with regard to winter thaws and summer conditions. L. J. Peyton (pers. comm.) experienced about 150 mm of snow on 4 and 5 June in 1963, and 10 mm of ice formed on ponds 4 July 1981 during my field work. The summer of 1980 was deemed among the wettest and coldest of the past decade by the local miners, while summer 1981 was the driest and one of the warmest.

History

Gold was discovered in the gravels of Bear Creek near Bonanza Creek prior to 1910. Although many claims were staked in the area, mining activity was limited to small, hand-powered operations, and most miners soon left the area. Consolidation and leasing of claims was begun in 1915, resulting in the New York based New York Alaska Gold Dredging Corporation controlling the claims in the areas by the early 1920s. The town of Nyac (deriving its name from the Corporation's initials) received a post office in 1926 (Orth 1971), the same year dredging was begun (Holzheimer 1926).

Up to three dredges at a time operated on the Tuluksak River, and Bear, California, and Rocky Creeks from 1926 until 1963. Dredge operations were begun again under new management in 1973, and a second dredge began digging in 1981.

METHODS -- VEGETATION

Mapping

Several series of aerial photographs of the study area were available for mapping and study site selection. Black and white series from pre-1941, 1941, and 1954 were used in conjunction with a false color infrared series taken in 1979. I took 360° photographic panoramas every 1-2 km of the valley floor while verifying the aerial photos in 1980 and 1981, and these panoramas also served as photo points for future reference. Mining company records and maps enabled me to date most disturbances in the valley system to a given 2-week period.

Groundwork

Access to valley bottom portions of the study area was generally excellent, involving a short walk from the system of mining roads. Qualitative notations were made at 15 m intervals (stations) along several transects throughout the valleys. Six of these transects (sites LRT, MTT, EST, UTT, BRT, and BTT; 257 stations) (Figure 2) were primarily snaplines for small mammal sampling. Site descriptions can be found in the Mammal Methods section (page 38). Three transects (sites MVT, SVT, and RVT; 77 stations) were established strictly for vegetation sampling. Site MVT (muskeg vegetation transect) was across a section of low shrub and herb bog (muskeg) resulting from natural damming of surface runoff. Site SVT (shrubland vegetation transect) was chosen as representative of nonriparian valley bottom communities, while RVT (riparian vegetation transect) was riparian. The area around site RVT was extensively resampled as site RG, discussed below. At each station, predominant plants under 1.5 m tall were noted, as were the genera of woody vegetation greater than 1.5 m tall within a 1-m radius of the station.

Relevés (Mueller-Dombois and Ellenburg 1974) were made at various locations throughout the study area by C. Rutherford, and her methods are presented in Rutherford and Meyer (1981).

Intensive sampling of both vegetation and small mammals was carried out on grids at sites TG, SG, and RG. See page 40 in the Mammal Methods section for descriptions of these sites. At each of the 100 stations on the 3 10X10 grids, cover by plants less than 1 m tall was sampled. Cover was ocularly estimated for moss, herb, and low shrub layers, and also for percent of the quadrat occupied by dead and down woody material greater than 25 mm diameter. Herbaceous and low shrub species, and lichen growth form classes (fruticose, foliose, crustose) were assigned cover class values in agreement with Rutherford's work (Rutherford and Meyer 1981): Class 1, <5%; 2, 5-20%; 3, 20-40%; 4, 40-60%; 5, 60-80%; 6, 80-100%. A 0.25 m^2 quadrat was used in 1980 when grids TG and SG were sampled, and a 1 m^2 quadrat was used on site RG during 1981. Color slides taken during the quadrat sampling were used in the laboratory for cover estimation of species noted only as present or absent in the field. A comparison of this technique with values obtained in the field showed it to be a valid means of estimating cover values ($r = 0.81$), with a linear regression correction applied to values obtained from slides.

Initially, tall shrub cover (greater than 1 m tall) and tree cover were estimated using a point-centered quarter method based on Ohman and Ream (1971). However, the nonrandom distribution of species within the areas sampled made the method unsuitable (Oldemeyer and Regelin 1980), and I resampled in 1981 using stratified random sampling of 4 m^2 quadrats. In each quadrat, tall shrubs and trees were separated into 1-3 m and over 3 m height classes. In each class, total cover for that layer was estimated, as was cover for each species. Numbers of stems at breast height (1.5 m) were noted for each species. Tall shrubs and trees were combined in each height class during 1981 sampling, as they appeared to be functinally the same in the communities sampled.

For sampling, each grid was stratified on the basis of vegetation height or history. Site TG was stratified on the basis of regrowth height: low (<2 m), medium (2-2.5 m), and tall. Site SG had low shrub, tall shrub, and white spruce/shrub strata. Site RG was stratified using historical factors: unlogged, road (once cleared for drilling), and logged (of white spruce). Thirty quadrats were sampled on each grid.

Cluster analysis was performed using all 300 cases (3 grids of 100 quadrats each) in order to evaluate the understory communities sampled by quadrat without using _a priori_ assumptions. Clusters were formed using centroid linkage. Several runs were made including one in which 65 species were entered by cover class for each case. The most biologically interpretable clustering came from a run using the following cover variables: fruticose lichens, crustose lichens, total mosses, total herbs, total low shrubs, and amount of dead and down material. Note that all variables used refer to vegetation less than 1 m tall, as such vegetation was deemed of greatest importance to small mammals.

Discriminant functions analyses were run to check the resolving power of the above 6 variables, grouping on the 3 grids one time, and on the cluster analysis derived communities a second time. Ordination of the data was accomplished using principal components analysis. All statistical analyses were done using BMDP81 programs (Dixon 1981).

Voucher specimens are located at the University of Alaska Museum, Fairbanks. Herbaceous vascular plant nomenclature follows Hultén (1968), woody vascular plant nomenclature follows Viereck and Little (1972), and that for willows follows Argus (1973). Appendix A lists species collected in the study area.

RESULTS -- VEGETATION

Mapping

A vegetation community map was completed for the study area from site RG upstream. Communities mapped followed Viereck and Dyrness (1980) and various levels of description judged to be ecologically meaningful were used. Approximate scale was 1:18,000, with a resolution of about 7 m. Units mapped were: water, bare rock/bare ground, Low shrubland, Wet sedge-grass herbaceous, Closed mat and cushion tundra, Open mat and cushion tundra, Tall shrubland, Conifer forest, Deciduous forest (balsam poplar [*Populus balsamifera*] predominant), Mixed conifer and deciduous forest (balsam poplar predominant), and Deciduous forest/Mixed conifer and deciduous forest (balsam poplar not dominant). An overlay to the vegetation map shows areas and year of disturbance. Both the map and overlay are on file with the Wildlife Biologist, McGrath Resource Area, U.S. Bureau of Land Management Anchorage District Office.

Vegetation descriptions

Pre-mining vegetation was partially reconstructed from observations made at the time (various Nyac residents; pers. comm.) and by a report written by Holzheimer (1926), which notes that "small spruce, cottonwood, and willows are found along the river banks." Photographs in Holzheimer's report show the New York Alaska dredge during its initial months of operation, and unstripped areas of Bear Creek in the background appear the same as the portions of that drainage that still remain unmined. D. Weir (pers. comm.) believes that the only community completely removed by mining has been a marsh community once found in small areas among the riparian forests just downstream of Nyac.

Valleys

At present, riparian vegetation is a mixed deciduous and coniferous forest, with balsam poplar predominant and white spruce (Picea glauca) scattered throughout. Along rocky cutbanks, thinleaf alder (Alnus tenufolia) occurs. Some riparian areas have small stands of American green alder (Alnus crispa) among the balsam poplar. With the exception of highbush cranberry (Viburnum edule), the understory is herbaceous. Bluejoint (Calamagrostis canadensis), meadow horsetail (Equisetum arvense), oak-fern (Gymnocarpium dryopteris), and nagoonberry (Rubus arcticus) are major components.

As one progresses away from the active river channel, the white spruce component of the overstory becomes more dominant, in places reaching essentially pure stands. The understory becomes less herbaceous and more shrubby. Some valley bottom areas are ericaceous low shrubland with scattered white spruce. Frequent species include dwarf arctic birch (Betula nana), narrow-leaf Labrador-tea (Ledum decumbens), Vaccinium spp., and various fruticose lichens. Still other patches are a mix of tall shrubs, often including feltleaf willow (Salix alaxensis), littletree willow (S. arbusculoides), and alder.

Balsam poplar and white spruce saplings may or may not be present. Such tall shrub areas are usually sites disturbed by man, either cleared for some purpose such as temporary storage, or logged. Most of the study area and adjoining valleys were logged of large white spruce during the 1930s and 1940s. Up to 200 cords a year were cut for firewood, and many buildings were made of local wood sawn at an onsite mill.

Surrounding slopes

Valley bench vegetation is typically ericaceous low shrubland with scattered white spruce. South facing sides of ridges are covered with closed forests of white spruce and paper birch (Betula papyrifera) with an understory of scattered grasses. Occasionally, pure stands of paper birch are found on both north and south facing hillsides.

At the upper tree limit, thickets of alder are interspersed with ericaceous shrubs and species typical of alpine areas. The tops of the higher ridges appear to be at the limit of vegetation and tend to be largely loose rock with scattered lousewort (Pedicularis spp.) and willow (e.g., Salix arctica) species.

Tree limit occurs at about 275 m in the upper sections of the study area, approximately at the confluences of Rocky and California Creeks and Bonanza and Bear Creeks. Above this, the valleys are narrower, with no appreciable inactive flooplain. Hillside vegetation is as described above. Riparian species are mostly willow and alder tall shrubs, with some stunted balsam poplar.

Black spruce (Picea mariana) and quaking aspen (Populus tremuloides) had scattered distributions. Black spruce occurred in a handful of small stands in the lower Tuluksak River valley. These stands were on north facing slopes with poor drainage, possibly underlain by permafrost. Quaking aspen was found in a small stand along site MVT. A single individual was found on a gravel bench above Spruce Creek.

Tailings

Revegetation ranged from nonexistent, to balsam poplar stands having 0.15-0.20 m dbh trees, with white spruce approaching the canopy. Tailings with rock exposed generally had at least some crustose lichen cover, and frequently had small clumps of the nitrogen-fixing lichen Stereocaulon spp.. Moss cover (species of genera such as Polytrichum, Rhacomitrium and Ceratodon) was seen frequently on the sides of tailings at least 30 years old. Scattered individuals of tree and shrub species at times colonized tailings. Thinleaf alder could be found as a dense shrub 1-2 m tall on a barren, rocky tailing, with the nearest woody neighbor on the tailing perhaps 100 m away. Balsam poplar, white spruce, and willows (particularly littletree willow) could be found in similar situations, although woody neighbors were more on the order of 10 m away.

Dense stands of thinleaf alder are frequent wherever roads have been cut along or across tailings. These stands are usually 2-3 m tall, and have essentially no ground cover except alder litter. White spruce seedlings are occassionally found in older, more open stands. A few roads were seen that had little or no alder, but rather were nurseries for white spruce and balsam poplar seedlings.

Whenever tree and shrub stumps with their accompanying soil, or just soil, (i.e., overburden) have been deposited on the tailings, the results are markedly different from above. The resulting community is largely riparian in nature, with balsam poplar up to 10 m tall and 0.20 m dbh, white spruce approaching the lower canopy, feltleaf and littletree willows occurring as or becoming single stem plants 7 m tall, and small clumps of thinleaf alder. The understory is essentially herbaceous, with common species including bluejoint, nagoonberry, bunchberry (*Cornus canadensis*), and starflower (*Trientalis europaea*). In a few areas where tailings were 35 years old or older, shrubs such as highbush cranberry and prickly rose (*Rosa acicularis*) were found scattered in the understory.

Revegetation patterns

At the beginning of this project, a common assumption was that a strong correlation existed between the age of a tailing (i.e., how long since that spot had been mined) and the degree of revegetation. This simply was not the case. With rare exceptions, tailing age mandated the maximum age of any plant on its surface; but the age of most of the cover, and the amount of that cover, was related more to factors discussed below.

Age did play an indirect role, however, by correlating with mining method. Older mining (pre 1950 or so) was more geared toward reclamation of gold from areas identified by drilling as high value.

Strips and islands of unmined ground were left, as dredges essentially "connected the dots" between high-dollar drill holes. Overburden was often pushed onto the sides and crowns of adjacent tailings, and roads were frequently bulldozed along or across the tailings. All such modifications to the tailings increased the chances of revegetation.

By contrast, more recent mining has totally mined large areas of lower quality gravels, and consequently tended not to leave unmined sections scattered among the tailings. Overburden appears to have been washed downstream more completely or dumped into old dredge ponds, as it is less in evidence on the tailings themselves.

Roads built across or along the crowns of tailings are often more densely revegetated than undisturbed sections of the same tailing. They often had more compacted surfaces than unaltered tailings and a smaller average particle size. Litter sometimes collected at the edges if the road was cut down into a tailing.

The rock type at the lower depth limit of the gold had a major effect upon revegetation, as this is the material on the surface of each tailing. Sometimes, bedrock was not reached, and the tailing surface is composed of cobbles of harder portions of country rock: sandstones, hard shale, volcanic agglomerate, and siliceous and basic intrusives (Maddren 1915). Such materials are well rounded, leaving much space between cobbles, and chemically stable. Soil development from such materials is extremely slow.

In other locations, gold was trapped in cracks of the top layer of bedrock, and this material is the surface of the tailing. Bedrock is partially decomposed in the study area, and breaking it and bringing it to the surface aids in its decomposition. Although often in cobble sized pieces, these surfaces have some visible deterioration after 30 years, and cover, particularly of mosses, was noticeably higher here than on tailings with surfaces of alluvial materials.

Location of the water table in relation to the bottom of intertailing valleys (Figure 1) is important to revegetation. In cases where the water table is well below the valley bottom, little vegetation difference is seen between the valleys and crowns. If, on the other hand, there is a body of water between tailings, a narrow band of alder and/or willow frequently grows along at least part of the pond edge.

Particle size of the surface material did not appear to make a difference in revegetation in most cases, unless organic materials or silt were included. Several sandbars at the ends of tailings created in 1947 had water tables less than 0.20 m below the surface and were largely naked except where the coarse tailings met the sand. At this line, the coarse sand would sometimes support a few alder or fireweed (Epilobium spp.) plants. Occasionally fireweed, crucifers, or other weedy species had invaded a sandbar, but this was not the norm.

The presence of silt or mineral soil on tailings had profound effects upon revegetaion. Whenever stumps and shrubs were pushed onto a tailing, soil was carried along and deposited as well. Data from aging a few trees on such tailings and from looking at aerial photos, suggest that substantial woody cover is present 5-10 years after such depostion. For the 49 quadrats on site TG without a soil or organic substrate, the mean herbaceous cover was 2.2% (s.e. = 0.6); those with soil substrate had a mean of 28.5% (s.e. = 4.1, n = 41); and those with stumps deposited along with soil a mean of 45.7% (s.e. = 10.2, n = 10). A few tailings were found that had silt deposition along their sides where silty water from upstream mining had deposited part of its sediment load. Vegetation on these tailings was difficult to distinguish from riparian areas of the same age that had been stripped but not mined and therefore still had a silt substrate.

Slope and aspect of the tailings and their step ridges were expected to influence revegetation. Some tailings oriented east-west with bedrock surfaces had greater moss and alder growth on their north side than on their south. A few tailings, again with bedrock surfaces, had greater growth on the north sides of step ridges than on the south sides, but this was interrelated with particle size. When the stacker is depositing a tailing, smaller rocks and fragments (but still too large to pass through the holes in the trommel screen) tend to stick somewhat to the wet belt. The result is a partial grading of materials on a step ridge, with the side facing the dredge being finer than that away from the dredge. When the fine side of a ridge also faces north, it may have increased moss and lichen cover, but rarely were more woody species found.

Finally, the altitude of the area mined plays an important role. Tailings created in the early 1950s above tree limit along California Creek or dragline piles deposited in the 1940s along Bear Creek above Bonanza Creek are consistently less vegetated than areas mined below Nyac during the same period in the same manner.

Community descriptions

Nine understory communities were selected from the cluster analyses, and these were named on the bases of dominant cover and predominant sampling grid on which the communities were found (Table 1 and Figure 3). Descriptions follow.

Crustose Tailing: essentially no vascular plant cover on bare rock with modal 2 crustose lichen cover (i.e., cover class 2 was the modal class), modal 1 fruticose lichen cover, and some moss cover. Found only on tailings.

Mossy tailing: rocky substrate with modal 1 fruticose and crustose lichen covers, and an increased moss cover over Crustose Tailing. Although these quadrats were more barren than Crustose Tailing quadrats because of the lowered lichen cover, a few quadrats had small amounts of herbaceous cover such as grasses or fireweed.

Herby Tailing: usually rocky substrate with little or no lichen cover but some moss and herb cover, particularly of nagoonberry and grasses. Usually found under a closed canopy, often of tall shrubs.

Fruticose Shrubland: ericaceous low shrubland with modal 6 fruticose lichen cover. Open areas with scattered white spruce; soil substrate. Usually some sedge (Carex spp.) cover, with dwarf arctic birch, narrow-leaf Labrador-tea, bog blueberry (Vaccinium uliginosum), and lowbush cranberry (Vaccinium vitis-idaea).

Ericaceous Low Shrubland: similar to Fruticose Shrubland in locale, but with much less (modal 1) lichen cover and greater herb and low shrub cover. Typical herbs include sedges and grasses; low shrubs

Table 1. Number of quadrats assigned to 9 understory communities derived from cluster analysis, on each of 3 100-station sampling grids at Nyac, Alaska, during 1980 and 1981.

community	tailing grid	shrubland grid	riparian grid	total (% N)
crustose tailing	7	0	0	7 (2)
mossy tailing	46	1	0	47(16)
herby tailing	19	3	3	25 (8)
fruticose shrubland	0	23	0	23 (8)
ericaceous low shrubland	2	59	0	61(20)
moderate herbaceous riparian	0	0	25	25 (8)
dense herbaceous riparian	10	0	57	67(22)
mossy mixed	12	12	13	37(12)
fallen log	4	2	2	8 (3)

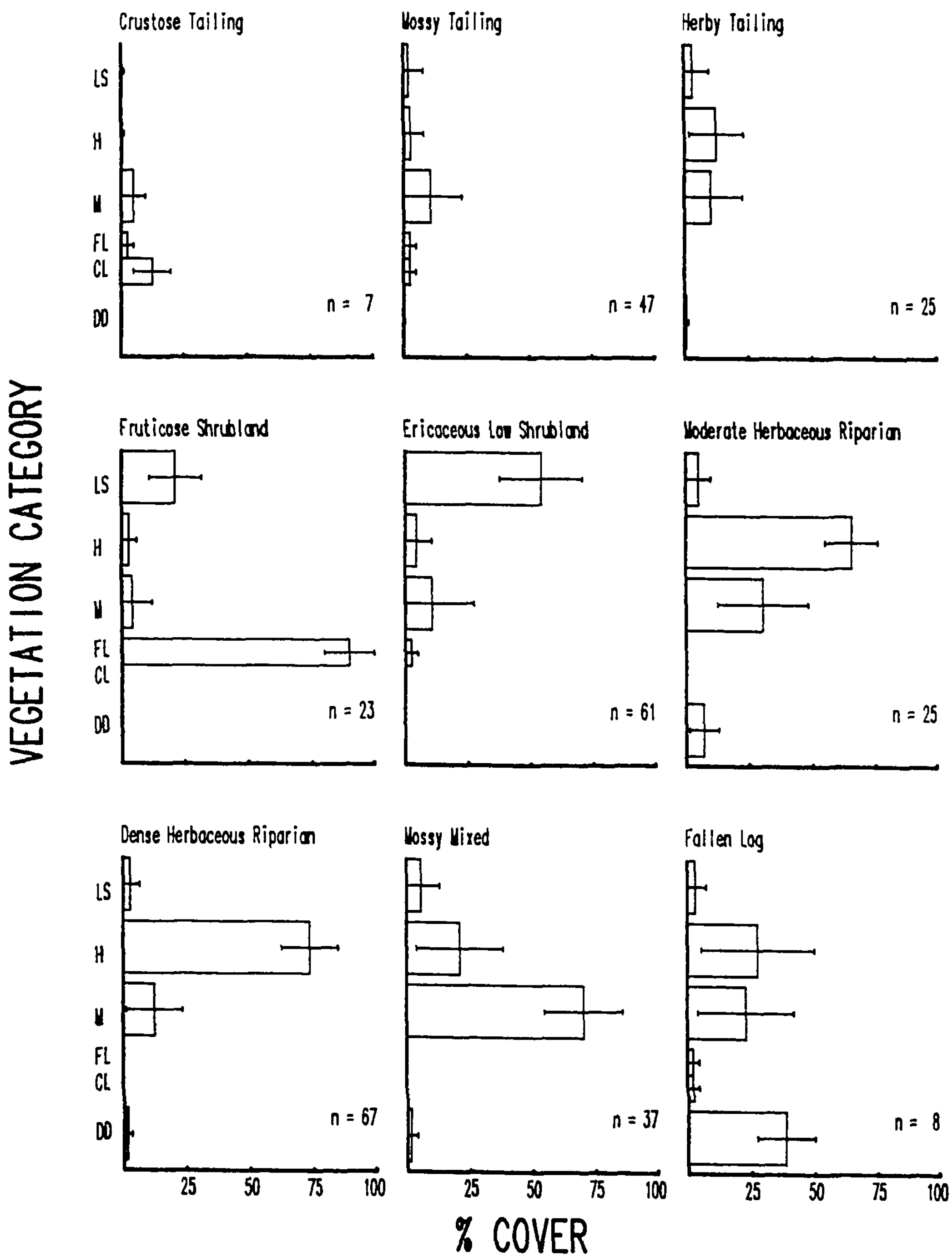

Figure 3. Mean cover values (± s.d.) for 9 understory vegetation communities derived from cluster analysis of 300 quadrats at Nyac, Alaska, during 1980 and 1981. LS - low shrubs, H - herbs, M - mosses, FL - fruticose lichens, CL - crustose lichens, DD - dead & down.

are those present in Fruticose Shrubland, plus crowberry (*Empetrum nigrum*).

Moderate Herbaceous Riparian: found only in unmined riparian areas. Fairly dense groundcover of herbs, with some cover of low shrubs (prickly rose, highbush cranberry) and dead and down materials. Typical herbs include oak-fern, nagoonberry, bunchberry, bluejoint, and tall bluebell (*Mertensia paniculata*).

Dense Herbaceous Riparian: found in unmined riparian areas and on tailings where overburden had been deposited. Similar species composition to Moderate Herbaceous Riparian, but with denser bluejoint, less oak-fern, and more horsetail cover.

Mossy Mixed: found almost equally throughout the 3 sampling grids. Moss cover substantial, frequently with small amounts of lichens. Horsetail, grass, and nagoonberry cover is variable. Low shrubs are usually present, composed mainly of thinleaf alder on the tailings grid, dwarf blueberry and bush cinquefoil (*Potentilla fruticosa*) on the shrubland grid, and prickly rose and highbush cranberry on the riparian grid. This understory community is usually beneath a canopy of tall shrubs.

Fallen Log: dominated by the presence of dead and down material. Found on all 3 grids; soil substrates. Other cover is light, with varying amounts of lichens, nagoonberry, and grasses.

Using only total herb and total low shrub covers, the discriminant functions program could correctly predict the site allegiance of 83.3% of the 300 quadrats sampled. This was raised to 88.7% with the inclusion of fruticose lichen cover, moss cover, and crustose lichen cover, entered in that order. The 9 communities from the cluster analysis could be discriminated correctly for 78.7% of the quadrats using 4 variables (in order of entry): total herb cover, dead and down, crustose lichen cover, and total low shrub cover. When the 2 remaining variables (moss cover and fruticose lichen cover) were entered, this increased to 94.0% corrrectly classified.

The principal components analysis, using the same 6 variables as the discriminant functions analysis, yielded 2 meaningful factors. Factor 1 loads heavily negative on herb cover and heavily positive on low shrub and fruticose lichen cover (Table 2); it is a measure of the "herbiness" or "low shrubbiness" of a quadrat. Factor 2 loads heavily negative on low shrubs and herbs, and heavily positive on crustose lichens, thereby describing the amount of "vegetatedness" or "barrenness" of a quadrat (Figure 4).

Tall shrubs and trees

Tall shrub and tree characteristics were different for each grid. Site TG had the highest cover in the 1-3 m class and moderate cover in the 3+ m class. Such averages over the whole grid somewhat obscured the heterogeneity between strata (Table 3). Cover on portions of TG tended to be either low or high, with few intermediate values.

Site SG had the lowest means for both height classes, although its tall shrub stratum had the highest 1-3 m class mean of any. Some 3+ m cover was present in all strata, but was consistently low. Site RG had a 1-3 m class mean essentially identical to that of SG's, but its values

Table 2. Unrotated principal components factor loadings for 300 vegetation quadrats sampled at Nyac, Alaska, during 1980 and 1981.

cover variable	Factor 1	Factor 2
crustose lichens	0.190	0.928
fruticose lichens	0.806	-0.122
mosses	-0.436	0.062
total herbs	-0.789	-0.397
total low shrubs	0.711	-0.445
dead & down	-0.290	0.165
total variance explained	35%	20%

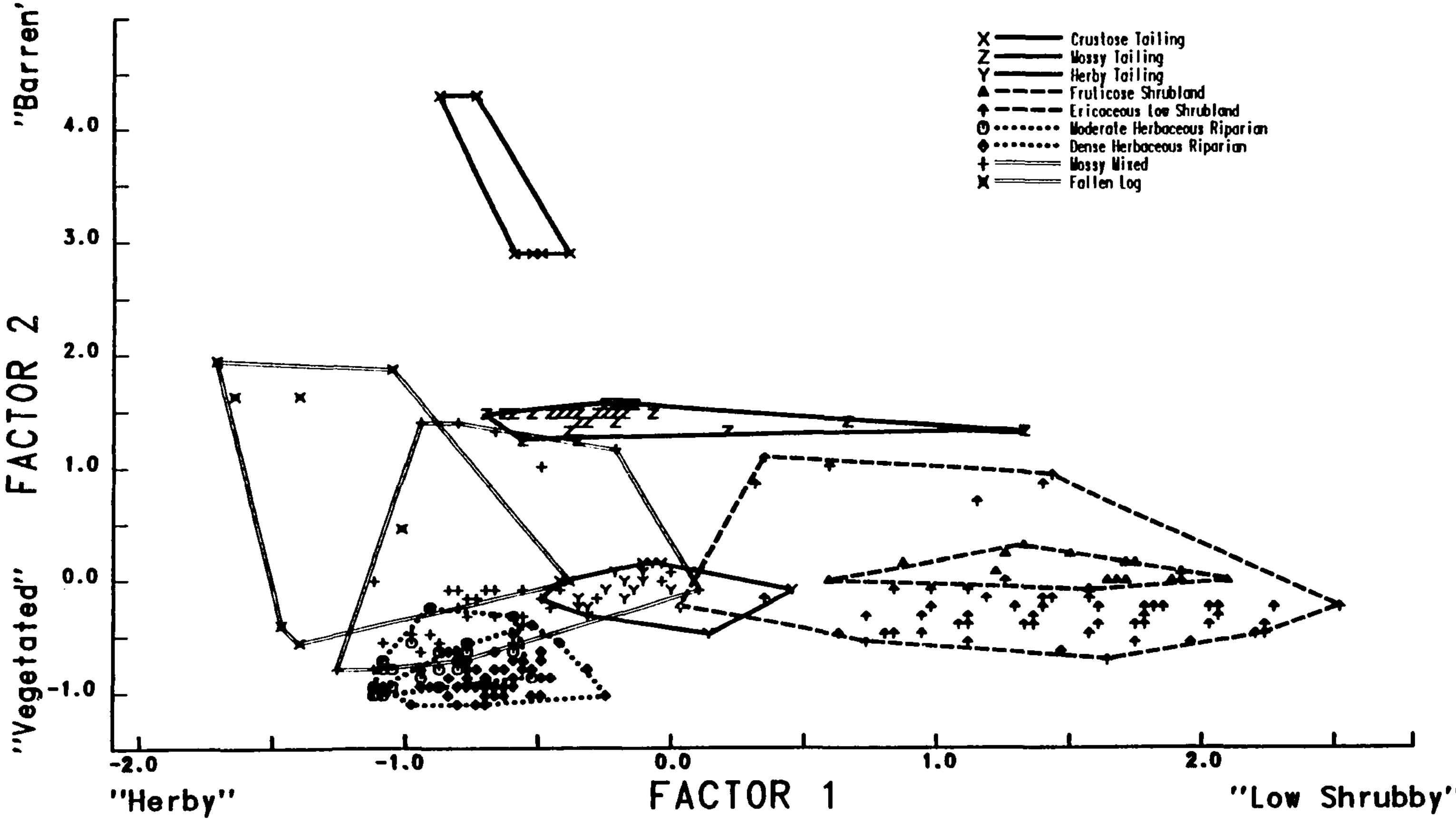

Figure 4. Scatter plots of PCA Factor 1 and 2 scores for 300 quadrats sampled at Nyac, Alaska, during 1980 and 1981. Polygons enclose points assigned to each of 9 cluster analysis derived understory communities.

Table 3. Percent cover of trees and tall shrubs in various strata of sampling grids at Nyac, Alaska, during 1981. TG - tailing grid, SG - shrubland grid, RG - riparian grid.

			1-3 m tall		3+ m tall	
site	stratum	n	$\hat{Y}$	95% C.I.	$\hat{Y}$	95% C.I.
	low	12	5.4	± 5.0	0.0	± 0.0
	medium	2	25.0	*	1.3	*
TG	tall	16	22.7	± 14.3	39.4	± 12.0
	water		0	**	0	**
	total	30	15.0	± 7.7	20.1	± 6.1
	low shrubland	20	1.3	± 1.4	3.8	± 3.5
	tall shrubland	2	30.0	*	8.8	*
SG	spruce/shrub	8	13.1	± 3.7	2.2	± 2.5
	total	30	7.1	± 1.4	3.7	± 2.5
	unlogged	7	12.9	± 13.0	45.7	± 19.1
	road	8	1.3	± 1.3	70.0	± 12.3
RG	logged	15	7.7	± 3.7	42.5	± 12.4
	total	30	7.6	± 3.7	48.8	± 8.7

* Confidence interval was not calculated for n<5.

** This stratum was censused.

for the 3+ m cover class were higher in each stratum than for any other grid, and the total mean in that class was more than double that for TG. Stem density figures for the 3 grids (Table 4) show patterns similar to those shown by the mean cover values.

Site TG's 1-3 m class was mostly thinleaf alder, with some willow, while its 3+ m class was balsam poplar, and littletree and feltleaf willows. The lower class on site SG was grayleaf willow (Salix glauca) and white spruce, with white spruce essentially the only species over 3 m tall. Riparian (site RG) 1-3 m shrubs and trees were largely highbush cranberry, with some balsam poplar, American green alder, and feltleaf willow. Site RG cover over 3 m was a mix of white spruce, balsam poplar, American green alder, and feltleaf willow.

Taxonomy

Taxonomic problems arose with the birches and the willows. Site SG had short birch cover largely made up of dwarf arctic birch, but with scattered individuals which more closely resembled resin birch (Betula glandulosa) or a hybrid of the 2. Since the questionable individuals appeared to be functionally dwarf arctic birch, I have lumped them as such.

Nonfruiting willows whose vegetative characters did not lead to confident identification were often present in small amounts in sample units. Since the vast majority of willow biomass in the valleys was composed of feltleaf willow, littletree willow, and grayleaf willow, all other species were lumped under the heading Salix spp..

Table 4. Number of stems/ha of trees and tall shrubs in various strata of sampling grids at Nyac, Alaska, during 1981. TG - tailing grid, SG - shrubland grid, RG - riparian grid.

site	stratum	n	1-3 m tall $\hat{Y}$	1-3 m tall 95% C.I.	3+ m tall $\hat{Y}$	3+ m tall 95% C.I.
TG	low	12	3950 ±	4410	0 ±	0
	medium	2	21,250	*	0	*
	tall	16	12,030 ±	9080	11,560 ±	5475
	water		0	**	0	**
	total	30	8800 ±	5275	5875 ±	2775
SG	low shrubland	20	1875 ±	2950	500 ±	450
	tall shrubland	2	50,000	*	3750	*
	spruce/shrub	8	14,375 ±	10,135	625 ±	800
	total	30	9350 ±	4200	775 ±	700
RG	unlogged	7	9640 ±	10,220	3930 ±	1455
	road	8	935 ±	1835	7500 ±	3705
	logged	15	10,000 ±	5680	7000 ±	4120
	total	30	8075 ±	4000	6400 ±	2475

* Confidence interval was not calculated for n<5.

** This stratum was censused.

DISCUSSION -- VEGETATION

Communities

Assessment of natural revegetation of tailings in the Klondike region of the Yukon Territory (Weir et al. 1981) showed tall shrubs, dominated by willows, to comprise the initial communities. In general, revegetated areas had higher canopy cover and decreased ground cover compared to undisturbed areas. Broadleaved trees, particularly willows, tended to replace spruce in both shrub (<0.40 m tall) and tree layers. These results are consistent with those from Nyac if one recognizes that the undisturbed vegetation in the Klondike was frequently black or white spruce dominated, with a moss or ericaceous shrub dominated understory (Singleton et al. 1981).

When comparing Fruticose Shrubland or Ericaceous Low Shrubland communities with Herby Tailing or Dense Herbaceous Riparian communities occurring on the Nyac tailings, a similar pattern appears to that found in the Klondike. However, if Nyac tailing communities are compared with the 3 predominant riparian communities (Mossy Mixed, Moderate Herbaceous Riparian, Dense Herbaceous Riparian), the tailing communities have lower canopy cover and lower ground cover. The proportion of ground cover that was herbaceous versus that which was low shrub cannot be determined from the Klondike reports.

Comparisons with Holmes' (1981, 1982) work on dredge tailings at Fox, Alaska, again show revegetation containing higher broadleaf and tall shrub cover, in this case in an area originally dominated by communities with sedge tussock and moss understories and black spruce or tall shrub overstories. Herbaceous cover was quite low in all of Holmes' study plots, most frequently 2-5% and only once exceeding 10%.

Holmes' herbaceous cover values were surprisingly low, since paper birch dominated forests with up to 90% cover were found on the Fox tailings. Such forests are found on south facing hillsides in the Nyac area; there they have a much denser grass dominated herbaceous understory. The Fox tailings supporting such forests had a high percentage (up to 50%) of fines in the surface, but were devoid of any organic material or mineral soil throughout the tailing cobbles. The amount of herbaceous cover on Nyac tailings devoid of organic matter was nearly identical to that in Fox.

Revegetation patterns

Hardy Associates (1979), Holmes (1981, 1982), and Singleton et al. (1981) all point to moisture availability as the major limiting factor to revegetation in the north. At both Fox and Nyac, increased moisture or presence of standing water in intertailing valleys promoted revegetation. Taylor and Gill (1974) and Taylor (1976) discuss natural revegetation on hardrock gold tailings at the Discovery Mine near Yellowknife, Northwest Territories. They found little or no revegetation for 1-10 year old tailings except along gullies in the tailings.

Clayballs found at low densities on Nyac tailing surfaces were nearly barren, even after lying about for 45 years. Some lichens and mosses were associated with many of these clayballs, but vascular plants were almost never found growing on them or at their periphery. Moisture availability does not seem to be limiting, as these clayballs were generally quite moist just below their surface whenever examined.

Similarities other than those associated with the presence of water exist between the Fox and Nyac tailings. Aspect did not appear to be a major factor in the revegetation observed at either location. Roads along or across tailings were frequently more vegetated at both locations than were the surrounding tailings (Holmes 1982), and there was essentially no correlation between age of tailing and percent woody cover.

Holmes (1981, 1982) repeatedly found strong correlations between surface material size and woody cover. That is, the smaller the cobbles or the greater the percentage of fines at the surface of a tailing, the greater the woody cover. Since no sand elevators were used on the dredges at Nyac, I had no tailings with high fines content for comparison, but the previously noted sandbars in my study area can be thought of as 100% fines. As noted, these sandbars were usually very unproductive unless later overlain with silt.

In light of the sandbar observations and the greater rainfall at Nyac than at Fox, I feel that the presence of silt, organic material, or mineral soil is a major factor in revegetation at Nyac. Taylor (1976) found that 20-30 year old tailings had woody (willow, birch, alder) and herbaceous (horsetail, fireweed, sedges) cover only where organic material had been incorporated onto or into the tailings. Although the water retention properties of the organic materials were important, moisture alone (e.g., irrigation, standing water) did not promote revegetation nearly as well as did the organic material.

Nutrient availability may be partially responsible for patterns of revegetation at Nyac. Certainly, the alluvial and bedrock materials are quite hard and largely resistant to weathering of the sort that quickly produces finer materials or mineral soil. Sandbars are largely siliceous in nature and might not be expected to be fertile in an area such as Nyac where the ground water is low in dissolved ions (R. Hunsinger; pers. comm.). Clayballs, being decomposed country rock, might be mostly siliceous, or might not have a nutrient regime conducive to seedling growth.

Analyses for pH, nitrogen, phosphorus, potassium, and particle size distribution were conducted upon samples from Nyac sandbars, clayballs, overburden piles, and tailing surfaces (Rutherford and Meyer 1981). The results show no consistent differences between substrate groups (K. Meyer; pers. comm.). Particularly puzzling about these data is why overburden is so effective in revegetation while sandbars (i.e., high fines concentration) are so ineffective even though the 2 substrates showed similar nutrient levels. This points to moisture availability as the major limiting factor, at least in the sense of a few days a year when seedlings are stressed beyond recovery, resulting in no establishment.

Evidence from aerial photos and from aging stems suggests that alder, if present on a tailing, colonizes within the first 5 years after disturbance. Because alder individuals die after 40 or 50 years (J. C. Zasada; pers. comm.), dense stands of alder such as grow on cobble substrates have a very finite lifespan. Tailings laid down in 1926 currently have stands of dead alder on them, and many examples were seen of 40-year-old alder with most stems dead or dying and low vigor in those stems still growing. In both cases, little or no woody vegetation grew among the alder (including alder seedlings), suggesting that competition had a minor role in the death of the alder, if any. In such instances, apparently revegetated tailings become barren, and must be colonized again.

Plant-mammal interactions

Most mammals in the study area had minimal effects upon revegetation, but moose (*Alces alces*) and beaver (*Castor canadensis*) locally caused great change. Moose apparently walk the mining roads in the winter (their tracks were infrequently seen on the roads in summer), browsing on willow and alder shrubs growing beside the roads. In places, this has kept the shrubs down to a height of about 1 m.

Beaver have had a profound impact near their den sites among the tailings. Dams have been built, increasing the area of the water-tailing interface and trapping any silt in the flowing water. The latter may be important in times of high water, when silt laden river water may percolate through the tailings.

The cutting done by beaver for food and construction materials can drastically alter the plant species composition in an area. Balsam poplar appeared to be the favorite construction material, followed by alder. Food caches are largely willow, with some paper birch and balsam poplar, and a cap of alder. In the majority of cases, beaver assist white spruce establishment by systematically removing all woody competitors. It is probable that the sprouting abilities of balsam poplar and willow allow cut pieces washed into shallows or piled onto beaver lodges with one end in the water to colonize these areas of the tailings.

Snowshoe hares were seen in moderate numbers in both mined and unmined areas. They did not appear to have a large effect upon vegetation patterns once woody species were established, except for a few severely browsed white spruce seen among the tailings. The possibility exists that hare numbers greatly affect sapling establishment, but remains of such browsing were not looked for in this study.

METHODS -- MAMMALS

Scent stations

Scent stations were established along roads in both mined and unmined areas during 1981. R. D. Roughton (pers. comm.) provided valuable advice and a manuscript copy of Roughton and Sweeney (1982). Lines were of a 10x1 design (Roughton and Sweeney 1982), with 0.16 km spacing between stations, and greater than 4 km between pairs of lines. Synthetic fatty acid scent (FAS) was delivered as 1 ml of liquid to the center of each 1 m diameter station. Time and weather constraints limited sampling to 2 lines on 1 night, 5 August.

Beaver survey

The only aquatic species addressed by this project was beaver. I decided to assess the number of overwintering beaver in mined and unmined portions and use this as an index of habitat utilization. Counts of dams, lodges, and trails have all been shown to be inferior indices to the aerial cache count method (Hay 1958, Murray 1961, Koontz 1968, Machida 1982). Each cache is assumed to represent an overwintering family group of 1-14 beaver, with an average of 5 beaver usually used for population extrapolations in Alaska (Koontz 1968, Boyce 1974).

Surveying was done on 30 September 1981, a few days before freeze-up. A Bell 206 helicopter was used, flying at an average height of 30 m above treetop, with a speed of 65-95 km/h.

Initially the data were analyzed by relating the number of caches found in a portion of the valley system to the linear length of that portion. In an effort to remove possible confounding effects due to changes in the width of the riparian areas brought about by mining, the data were also analyzed by comparing the number of caches to the area of "potential beaver habitat" in the various portions of the surveyed area. "Potential beaver habitat" was defined using aerial photos; it included valley bottom on both sides of a watercourse out to the limit of standing or flowing water bodies adjoining the main channel.

Small mammals

Eight snaplines and 3 grids were established for sampling small mammals (Table 5). Site LRT was stripped in preparation for mining between the 2 years' sampling. In 1980, it was riparian vegetation; in 1981, it consisted of a 2 m wide strip of trees and shrubs along a river channel, with an adjoining berm of stripped vegetation and stumps. The snaplines were sampled for 3 nights each during 1980 and 1981. Sampling sites were chosen to encompass a wide variety of unmined communities and areas in differing stages of recovery from mining.

All snaplines were parallel lines with approximately 15 m between lines and stations. Of the approximately 44 stations per site, two-thirds had 2 Museum Special traps, while every third station was set with 1 Museum Special and 1 Victor Rat trap. Bait consisted of peanut

Table 5. Small mammal traplines sampled at Nyac, Alaska, during 1980 and 1981. See Figure 2 for locations. U - unmined, possibly logged but never stripped; S - stripped of vegetation, but not mined; M - mined.

site	name	dates	history	description
SRT -	Slate Cr. riparian trapline	22-25 June 1980 15-18 July 1981	U	riparian; beside Slate Cr.
LTT -	lower Tuluksak R. tailing trapline	27-30 June 1980 12-15 July 1981	M (1947)	tailing crown in dense alder; sides with grasses and tall shrubs.
LRT -	lower Tuluksak R. riparian trapline	13-16 July 1980	U	riparian; adjacent to mining.
		12-15 July 1981	S (1981)	berm of stripped overburden.
MTT -	middle Tuluksak R. tailing trapline	19-22 July 1980 18-21 July 1981	M (1947)	tailing crown barren; regrown overburden berm beside.
EST -	ericaceous shrub-land trapline	19-22 July 1980 18-21 July 1981	U	mostly ericaceous low shrub-land, with one end in tall shrubland.
UTT -	upper Tuluksak R. tailing trapline	13-16 July 1980 15-18 July 1981	M (1940)	partially barren tailing; no understory; tall shrubs.
BRT -	Bear Cr. riparian trapline	16-18 July 1980	U	riparian; bissected by power-line and associated clearing.
BTT -	Bear Cr. tailing trapline	16-19 July 1980	M (1947)	tailing crown barren; regrown overburden berm beside.

butter and oatmeal in about equal proportions, a mixture appropriate for capture of a wide variety of species (Bear 1964, Golley et al. 1975). Bacon grease was not included in the bait for fear of attracting carnivores.

Snap traps were checked daily. Animals captured were individually bagged with labels. Data noted in the field included site and station of capture, date, and species or genus. Collected animals were frozen in the field, and species, sex, breeding condition, weight, and body measurements were determined in the laboratory.

Two 10x10 station grids were established for live trapping in 1980, and a third in 1981. Site TG (tailings grid) was located in partially revegetated tailings created between 1935 and 1945. Site SG (shrubland grid) was established to represent nonriparian unmined valley bottom. As such, both undisturbed ericaceous low shrubland and once-logged tall shrubland communities were present. Site RG (riparian grid) was only trapped 1 year, and represented relatively unaltered riparian communities, although some logging and clearing had been done in the 1940s. A single large, aluminum Sherman live trap was placed at each station. Trap spacing was 15 m, an accepted compromise value for most species (Golley et al. 1975).

Every two weeks, the traps were rebaited, fresh cotton balls were added for nest material, and 3 nights of trapping begun (a trap period). Traps were set in the evening, and checked twice a day. The morning after the third night, all traps were closed. Bait used was the same as for snap traps, with uneaten bait left in the traps between periods. Site TG was trapped for 6 periods each in 1980 and 1981, site SG for 5 periods in 1980 and 6 in 1981, and RG for 6 periods in 1981. See Table 6 for dates of trap periods. Pizzimenti (1979) reviewed the conflicting literature concerning the relative effectiveness of live and snap traps and issued a warning against using live traps when trying to capture all species using an area. Therefore, in period 6 of 1981, snap traps were set on the 3 grids in place of the Shermans. Protocol followed that used for snaplines.

Animals captured were handled and released at the site of capture. Species, sex, breeding condition, weight, and individual number were noted. Toe clipping was used for identification during 1980 and most of 1981. Early in the 1981 trapping season, numbered fingerling fish tags were used, but this was discontinued after several animals repeatedly lost the tags. Animals which died in the traps or during handling were frozen in the field for later laboratory analysis.

The presence of "trap happy" individuals violated the equal catchability assumptions of open population models of population density (Seber 1965), while closure was violated by recruitment of young into the trappable population (Otis et al. 1978). Therefore, I decided to use the known minimum number alive (MNA) estimate of total numbers, realizing that such an estimate is biased low.

Population densities were calculated using the MNA and an area based on home range. Stickel (1954) and Hansson (1969), among others, have shown that the effective area trapped by a grid is the area of the grid plus a border strip around the grid. This strip has a width of half the average home range length of the species involved and is

Table 6. Dates of small mammal trapping periods on sampling grids at Nyac, Alaska. Period 6 in 1981 was snap trapped; all other periods were live trapped. TG - tailing grid; SG - shrubland grid; RG - riparian grid.

	period	dates	sites
1980	1	8 June - 14 June	TG,SG
	2	22 June - 28 June	TG,SG
	3	6 July - 12 July	TG,SG
	4	20 July - 26 July	TG,SG
	5	3 Aug. - 9 Aug.	TG,SG
	6	17 Aug. - 20 Aug.	TG
1981	1	31 May - 9 June	TG,SG,RG
	2	14 June - 23 June	TG,SG,RG
	3	28 June - 8 July	TG,SG,RG
	4	12 July - 21 July	TG,SG,RG
	5	25 July - 4 Aug.	TG,SG,RG
	6	9 Aug. - 19 Aug.	TG,SG,RG

species specific. I have adopted this technique, realizing that the homogeneous habitat assumption (Hansson 1969) is not met on any of my grids.

Home range was calculated using the exclusive boundary strip method, which was shown by Stickel (1954) to be the most accurate of several examined. Range lengths were measured at the extreme points of the boundary strips. Only individuals captured at least 5 times were used for home range and length calculations. In addition, no more than 2 captures were allowed to have been on the periphery of a grid. Single captures which appeared to be travels outside an animal's home range (Stickel 1954), and which would have increased the range length more than 50%, were generally excluded. Time between captures and sequence of locations was also taken into account when considering outlying points.

It would be desireable to compare relative abundances found by both live and snap trapping, but a means of standardizing catch per effort of snap traps (checked and emptied once a day) and live traps (checked and emptied twice a day) would be needed. I was unable to resolve this problem without hand tallying on a case by case basis. Therefore, abundances are presented separately for the 2 types of traps, the snap traps yielding captures per 100 trap nights (C/100TN), and the live traps producing captures per 100 trap half-nights (C/100THN). The latter, of course, is a partial misnomer, as a 12-hour trap check during the day is also counted as a trap half-night.

Large numbers of traps were found either closed and empty (Shermans) or snapped with no animal caught. In an effort to account for such lost opportunities for capture, I followed the reasoning of Nelson and Clark (1973) and Quinlan (1978) by subtracting half the number of unavailable traps from the calculation of trap nights and trap half-nights. Since there were no nontarget species, no adjustment was made for traps with animals in them. Nelson and Clark (1973) raises concerns about the assumption that a trap was open for exactly half the trap interval, but the theory developed by Johnson (1979) when examining the Mayfield estimator for bird nest success showed that this assumption could be totally relaxed without substantially altering the results.

Using the criteria set forward in Poole (1974), I decided that the Shannon-Weiner H' diversity index was the most appropriate for these data. The Hutcheson bias correction (in Poole 1974) was used.

Although body size criteria have often been used to assign small mammals to age classes, such methods are subject to great error and tend to be population and season specific (Pucek and Lowe 1975). I followed the tooth root closure method of Martell and Fuller (1979) on 17 northern red-backed voles (*Clethrionomys rutilus*) (hereafter referred to as RBVs) and compared these data to growth curves plotted for RBVs captured in at least 3 trap periods.

Voucher specimens are located at the University of Alaska Museum, Fairbanks. Nomenclature follows Honacki et al. (1982). Appendix B lists species present in the study area.

Habitat preference

Capture data from snaplines that sampled different vegetation communities on 1 line than on the other (as determined from qualitative vegetation transects noted earlier) were examined for small mammal habitat preferences. Since the spacing between lines and between stations along lines was the same (15m), greater captures along 1 line were taken to indicate habitat preferences.

Live trapping data were evaluated for habitat preferences in a more quantitative manner. Trap successes were plotted on scatter plots of principal components factors, the result being a descriptive account of vegetation qualities near successful traps. Trap successes were also related to cover classes and percent cover for various groupings of 65 habitat variables using BMDP81 discriminant functions and all possible subsets regression programs (Dixon 1981). In addition to vegetation cover at the trap station, weighted and unweighted mean cover values for each trap station and its 4 nearest neighbors, as well as measures of the heterogeneity surrounding each station, were related to trap successes.

In an effort to examine the relationship between vegetation communities and mammal habitats, I looked at the mean captures per trap for traps in each of the 9 understory vegetation communities derived from cluster analyses. If indeed vegetation communities and small mammal habitats are the same, the mean capture rates for each community should be quite different, with fairly low variances. Kruskal-Wallis pairwise comparisons were made to test whether the means were statistically different.

RESULTS -- MAMMALS

Scent stations

Only a small amount of data was collected due to problems with logistics and weather. I was unable to distinguish between some mustelid species visiting the stations due to similar track sizes and the availability of suitable habitat for most species close to the scent stations. I therefore grouped the species into pairs based upon track size: marten (Martes americana) and mink (Mustela vison); and ermine (M. erminea) and least weasel (M. nivalis). Although I did not observe these 4 mustelids in the study area, I believe they were present (Appendix B). Table 7 lists the species found on each line. Tracks of smaller species were more in evidence after 1 night, while larger species' tracks were more in evidence after many nights. This may be due to rain washing out smaller tracks, and/or to lower population densities of larger carnivores.

Beaver survey

The survey covered portions of the floodplains of the Tuluksak River, and Granite, Slate, Dugout, Bear, Cale, and Bonanza Creeks. A total of 45.2 km of linear valley was surveyed, with an area of 18.5 km^2. Of this, 18.9 km (8.1 km^2) had not been mined, and 26.3 km (10.5 km^2) had. Table 8 gives the distribution of the 65 caches found.

Table 7. Number of scent stations containing tracks of a given carnivore species (or species group). Ten stations each for mined and unmined areas. Data for 5 August 1981 after 1 night; 20 August 1981 data after 2 weeks of attracting, with some rain during the period.

	unmined		mined	
species	5 Aug.	20 Aug.	5 Aug.	20 Aug.
black bear	0	1	0	0
wolf	0	6	0	2
red fox	3	1	1	2
medium mustelid	2	0	3	1
small mustelid	1	0	0	0

Table 8. Beaver food cache densities found by aerial surveying on 30 September 1981 at Nyac, Alaska. See text for explanation of "potential habitat" analysis. Sample sizes (in parantheses) are numbers of km or km^2 surveyed, as appropriate.

	# caches/km of linear valley		# caches/km^2 of potential habitat	
stream & type	unmined	mined	unmined	mined
main river & creek (Tuluksak, Bear)	1.3(11.1)	1.7(24.6)	2.6(6.1)	4.0(10.2)
broad-valleyed creeks (Granite, Slate, Cale)	0.8 (5.1)	4.0 (1.1)	2.6(1.5)	19.6 (0.2)
narrow-valleyed creeks (Dugout, Bonanza)	0.0 (2.7)	0.0 (0.5)	0.0(0.4)	0.0 (0.1)
all types combined	1.0(18.9)	1.8(26.3)	2.5(8.1)	4.3(10.5)

Small mammals

Snap trapping

A total of 116 animals from 6 genera was captured in 1980, and 648 animals from 6 genera and 13 species were captured in 1981 (Table 9). Specimens from 1980 were destroyed in a freezer malfunction before they could be identified to species and measured.

Table 10 presents relative abundance of data for the sites. Shown are C/100TN calculated in 2 ways: corrected for traps that failed to catch an animal (see Methods section, page 43) and without such correction. The latter is included for comparison with other studies and because correction data are missing for part of 1980. Note that many more captures were made in 1981 than in 1980. In 1980 only 1 trapline exceeded 10 C/100TN, while all lines and grids sampled in 1981 exceeded that value. In fact, several genera had abundances greater than 10 C/100TN in 1981. With the exception of meadow jumping mice (Zapus hudsonius) and red squirrels (Tamiasciurus hudsonicus), all species and genera increased in abundance from 1980 to 1981.

Site richness and diversity values did not necessarily increase along with abundance (Table 11). There did not appear to be any pattern as to which sites had increased or decreased richness. In general, diversity increased from 1980 to 1981, although a decrease was seen for the pooled categories of all sites. Site LRT (Methods section, page 38) showed a decrease in both diversity and richness, although it was still among the most diverse sites.

Table 9. Number of animals captured in snap traps during the summers of 1980 and 1981 at Nyac, Alaska. See Table 5 for site abbreviations. TG - tailing grid, SG shrubland grid, RG - riparian grid, rbv - northern red-backed vole, mv - meadow vole, tv - tundra vole, uv - unknown vole, nbl - northern bog lemming, bl - brown lemming, mjm - meadow jumping mouse, rs - red squirrel, sh - snowshoe hare, ms - masked shrew, ts - tundra shrew, ds - dusky shrew, ps - pygmy shrew, us - unknown shrew, "-" - category not used during that year of trapping.

		rodents									shrews						
year	site	rbv	mv	tv	uv	nbl	bl	mjm	rs	sh	ms	ts	ds	ps	us	total	trapnights
1980	SRT	4	-	-	14	-	-	2	0	0	-	-	-	-	1	21	228
	LRT	3	-	-	5	-	-	1	2	0	-	-	-	-	6	17	264
	BRT	0	-	-	0	-	-	1	1	5	-	-	-	-	2	9	264
	EST	17	-	-	9	-	-	0	0	1	-	-	-	-	2	29	264
	LTT	1	-	-	3	-	-	0	0	1	-	-	-	-	0	5	180
	MTT	16	-	-	0	-	-	0	0	0	-	-	-	-	0	16	228
	UTT	13	-	-	0	-	-	0	0	1	-	-	-	-	0	14	264
	BTT	2	-	-	1	-	-	2	0	0	-	-	-	-	0	5	240
	total	56	-	-	32	-	-	6	3	8	-	-	-	-	11	116	1932
1981	SRT	20	51	0	0	0	0	1	0	1	37	1	3	0	-	114	260
	LRT	13	13	2	0	0	0	0	0	0	17	0	0	0	-	45	256
	RG	16	13	0	2	0	0	3	1	6	96	6	3	1	-	147	598
	EST	28	3	0	0	0	0	0	0	0	16	0	0	0	-	47	264
	SG	40	0	0	0	1	0	0	0	7	22	0	0	0	-	70	600
	LTT	12	0	13	0	0	0	0	0	0	11	1	0	0	-	37	262
	MTT	15	1	0	0	0	0	0	0	0	8	1	2	0	-	27	264
	UTT	42	0	0	0	0	1	0	0	6	10	0	1	0	-	60	264
	RG	41	4	1	0	0	0	0	0	4	45	6	0	0	-	101	600
	total	227	85	16	2	1	1	4	1	24	262	15	9	1	-	648	3368

Table 10. Relative abundance of animals snap-trapped during the summers of 1980 and 1981 at Nyac, Alaska, expressed as captures/(100 trapnights). Captures in parentheses are corrected for failed traps. See text for explanation of correction method. See Tables 5 and 9 for abbreviations. "-" - unable to calculate corrected capture rate.

year	site	rbv	uv	mjm	rs	sh	us	total
	SRT	1.75 -	6.14 -	0.88 -	0	0	0.44 -	9.21 -
	LRT	1.14 (1.17)	1.89 (1.95)	0.38(0.39)	0.76(0.78)	0	2.27 (2.34)	6.44 (6.64)
	BRT	0	0	0.38(0.39)	0.38(0.39)	1.89(2.13)	0.76 (0.85)	3.41 (3.83)
	EST	6.44 (6.91)	3.41 (3.66)	0	0	0.38(0.41)	0.76 (0.81)	10.98(11.79)
1980	LTT	0.55 -	1.67 -	0	0	0.55 -	0	2.79 -
	MTT	7.02 (7.31)	0	0	0	0	0	7.02 (7.31)
	UTT	14.92 (5.26)	0	0	0	0.38(0.40)	0	5.30 (5.67)
	BTT	0.83 (0.84)	0.42 (0.42)	0.83(0.84)	0	0	0	2.08 (2.09)
	total	2.90 -	1.66 -	0.31 -	0.16 -	0.41 -	0.57 -	6.00 -
	SRT	7.69 (8.73)	19.61(22.27)	0.38(0.44)	0	0.38(0.44)	15.77(17.90)	43.85(49.78)
	LRT	5.08 (5.47)	5.86 (6.31)	0	0	0	6.64 (7.16)	17.58(18.95)
	RG	2.68 (2.73)	2.51 (2.56)	0.50(0.51)	0.17(0.17)	1.00(1.02)	17.73(18.08)	24.58(25.08)
	EST	10.61(12.36)	1.14 (1.32)	0	0	0	6.06 (7.06)	17.80(20.75)
	SG	6.67 (7.42)	0	0	0	1.17(1.30)	3.67 (4.08)	11.67(12.90)
1981	LTT	4.58 (5.06)	4.96 (5.48)	0	0	0	4.58 (5.06)	14.12(15.16)
	MTT	5.68 (6.22)	0.38 (0.41)	0	0	0	4.17 (4.56)	10.23(11.20)
	UTT	15.91(19.18)	0	0	0	2.27(2.74)	4.17 (5.02)	22.73(27.40)
	TG	6.83 (8.26)	0.83 (1.01)	0	0	0.67(0.81)	8.50(10.27)	16.83(20.34)
	total	7.40 (8.70)	3.36 (3.95)	0.13(0.15)	0.03(0.04)	0.78(0.92)	9.35(11.00)	21.12(24.83)

Table 11. Diversity and richness of small mammal captures on snap lines and grids at Nyac, Alaska, with species lumped within genera. The Hucheson modification of Shannon-Weiner H' was used for diversity (Poole 1974).

	1980		1981	
site	H' genus diversity	genus richness	H' genus diversity	genus richness
SRT	1.0265	4	1.0985	5
LRT	1.3344	5	1.0704	3
BRT	0.9824	4	. . .	. . .
RG	. . .	. . .	0.9370	6
EST	0.9250	4	0.8297	3
SG	. . .	. . .	0.9531	4
LTT	0.7503	3	1.0709	3
MTT	0.0000	1	0.7774	3
UTT	0.02206	2	0.8342	4
BTT	0.8549	3	. . .	. . .
TG	. . .	. . .	0.9728	4
unmined	1.4617	6	1.2078	7
mined	0.5627	4	1.0799	5
all	1.3408	6	1.2085	8

Live trapping

One hundred eighty-five individuals from 3 genera were captured on sites TG and SG in 1980, and 502 individuals from 5 genera were taken on sites TG, SG, and RG in 1981 (Table 12). It should be noted that live trapping totals for masked shrews (Sorex cinereus) possibly contain small numbers of dusky (S. monticolus) and pygmy shrews (S. hoyi) because the latter species occurred in the live trapping areas, as determined by snap trapping, but were indistinguishable when live in the hand. In some tables, all shrew genera have been lumped into "unknown shrew" in order to facilitate comparisons between 1980 and 1981. The majority of the unknown vole counts are due to meadow voles (Microtus pennsylvanicus), with smaller numbers of tundra voles (Microtus oeconomus), and possibly a few northern bog lemmings (Synaptomys borealis) included for reasons mentioned above.

Several striking differences between 1980 and 1981 are evident (Table 12). Excluding snowshoe hares (Lepus americanus) and red squirrels, 94% of 1980 captures were RBVs, with a few masked shrews captured in the latter half of the summer. In 1981, RBVs made up 62% of the captures on sites TG and SG; they comprise 32% of the captures if site RG is included. Shrews, particularly masked shrews, made up the majority (59%) of the catch, with unknown voles also contributing substantially. In general, species captured in 1980 were captured in 1981 in greater numbers, and species caught only in 1981 were less abundant than those captured both years. A major exception is the RBV capture on site TG, which declined markedly in 1981 if one looks only

Table 12. Number of individual animals captured in Sherman live traps at Nyac, Alaska, during the summers of 1980 and 1981. See Tables 5 and 9 for abbreviations. Capture numbers shown for masked shrews may contain small numbers of dusky shrews as well, as they are indistinguishable on the basis of pelage. Snowshoe hares captured were juveniles.

		rodents					shrews			
	site	rbv	uv	mjm	rs	sh	ms	ts	total	trapnights
1980	TG	122	0	0	0	2	8	0	132	2960
	SG	50	0	0	0	0	3	0	53	2500
	total	172	0	0	0	2	11	0	185	5468
1981	TG	59	7	0	0	0	29	1	96	2475
	SG	57	2	0	0	0	31	0	90	2496
	RG	45	28	5	2	0	227	9	316	2498
	total	161	37	5	2	0	287	10	502	7469

at numbers of individuals captured. If recaptures are included, the 2 years are nearly identical in numbers of RBVs in traps.

Relative and absolute abundances of species captured in live traps are shown in Tables 13 and 14. These data include recaptures as well as first-time captures (in contrast to Table 12), and more clearly show the trends of increased abundances and species richness in 1981 captures. Again, C/100THN are shown both with and without correction for traps that were sprung without capturing animals.

As expected from the differences noted above, genus richness and diversity for each grid increased from 1980 to 1981 (Table 15). Diversity increased dramatically for sites TG and SG, and site RG was the most diverse of the 3.

Mean home range and range lengths are given in Table 16. Although none of the means were statistically different ($p = 0.10$), note that RBVs on site SG had larger home range areas and lengths in both 1980 and 1981 than did RBVs on site TG, and that those on site RG had still larger values. The smaller values for site TG may be related to the relatively small patch size of this heterogeneous habitat.

Activity patterns

Live trapping data were examined for evidence of changing patterns of small mammal activity as the length of daylight (sunlight plus civil twilight) (Selkregg 1976) changed. During trap period 1 in early June, there was nearly 22 hours of daylight. Continuous daylight occurred in the latter half of June (period 2), and shortened to 17 hours by the end

Table 13. Relative abundance of small mammals captured in Sherman live traps during the summers of 1980 and 1981 at Nyac, Alaska, expressed as captures/(100 trap half-nights). Capture rates in parentheses are corrected for closed but empty traps. See text for explanation of correction method. See Tables 5 and 9 for abbreviations.

site & period		rbv	uv	mjm	ms	ts	total	trap half-nights
	1	0.81 (0.81)	0	0	0	0	0.81 (0.81)	495
	2	2.83 (2.85)	0	0	0	0	2.83 (2.85)	495
	3	16.57(16.91)	0	0	0	0	16.57(16.91)	495
TG	4	21.50(22.20)	0	0	0	0	21.50(22.50)	495
	5	24.68(28.75)	0	0	0	0	27.68(28.75)	495
	6	27.68(28.87)	0	0	1.62 (1.69)	0	29.29(30.56)	495
	total	15.77(16.16)	0	0	0.27 (0.28)	0	16.44(16.85)	2968
1980								
	1	0.40 (0.40)	0	0	0	0	0.40 (0.40)	500
	2	3.00 (3.01)	0	0	0	0	3.00 (3.01)	500
SG	3	5.00 (5.10)	0	0	0	0	5.00 (5.10)	500
	4	9.00 (9.27)	0	0	0.20 (0.21)	0	9.20 (9.47)	500
	5	12.40(12.63)	0	0	0.60 (0.61)	0	13.00(13.24)	500
	total	5.96 (6.03)	0	0	0.16 (0.16)	0	6.12 (6.14)	2500
1980 total		11.50(11.72)	0	0	0.22 (0.22)	0	11.72(11.95)	5468

Table 13. Continued.

site & period			rbv	uv	mjm	ms	ts	total	trap half-nights
		1	1.62 (1.64)	0	0	0	0	1.62 (1.64)	495
		2	10.51(10.63)	0.20 (0.20)	0	0	0	10.71(10.84)	495
	TG	3	15.15(15.77)	0.20 (0.21)	0	1.62 (1.68)	0	16.77(17.45)	495
		4	18.59(19.49)	0.61 (0.64)	0	2.02 (2.12)	0	21.21(22.25)	495
		5	22.02(24.09)	1.41 (1.55)	0	5.45 (5.97)	0.40 (0.44)	29.70(32.49)	495
		total	13.58(14.12)	0.48 (0.50)	0	1.82 (1.89)	0.08 (0.08)	16.00(16.64)	2475
		1	3.43 (3.47)	0	0	0	0	3.43 (3.47)	496
		2	8.80 (9.02)	0	0	0	0	8.80 (9.02)	500
	SG	3	11.40(11.63)	0	0	2.00 (2.12)	0	13.40(13.67)	500
1981		4	17.40(17.55)	0.40 (0.40)	0	1.60 (1.61)	0	19.60(19.78)	500
		5	19.00(19.33)	0	0	3.40 (3.46)	0	22.40(22.79)	500
		total	12.02(12.22)	0.08 (0.08)	0	1.40 (1.43)	0	13.54(13.77)	2496
		1	0	0	0	0	0	0	500
		2	2.20 (2.24)	0.20 (0.20)	0	7.00 (7.14)	0.20 (0.20)	9.60 (9.80)	500
	RG	3	11.65(12.12)	4.02 (4.18)	1.61 (1.67)	23.09(24.03)	0.80 (0.84)	41.57(43.26)	498
		4	13.40(13.71)	1.60 (1.64)	0.20 (0.20)	15.80(16.17)	0.60 (0.61)	31.60(32.34)	500
		5	16.00(16.34)	2.20 (2.25)	0	16.00(16.34)	0.20 (0.20)	34.80(35.55)	500
		total	8.65 (8.82)	1.60 (1.63)	0.36 (0.37)	12.37(12.61)	0.36 (0.37)	23.50(23.96)	2498
1981 total			11.41(11.70)	0.72(0.74)	0.12 (0.12)	5.21 (5.34)	0.15 (0.15)	17.63(18.08)	7469

Table 14. Small mammal abundance on 3 trapping grids at Nyac, Alaska, expressed as minimum number alive (MNA) on the 1.96 ha grids, and as densities (animals/ha). Density calculations based upon a boundary strip addition equal to half the average home range length for that genus. See text for range length methods. There were too few unknown vole recaptures for density calculations. See Tables 5 and 9 for abbreviations.

			rby		uv	mjm		us		total	
grid & period			MNA	dens.	MNA	MNA	dens.	MNA	dens.	MNA	dens.
	TG	1	3	0.78	0	0		0		3	0.78
		2	8	2.08	0	0		0		8	2.08
		3	36	9.38	0	0		0		36	9.38
		4	49	12.77	0	0		0		49	12.77
		5	54	14.07	0	0		0		54	14.07
1980		6	56	14.59	0	0		7	1.61	63	16.42
	SG	1	1	0.21	0	0		0		1	0.21
		2	6	1.25	0	0		0		6	1.25
		3	11	2.30	0	0		0		11	2.30
		4	22	4.59	0	0		1	0.23	23	4.80
		5	31	6.47	0	0		2	0.46	33	6.89

Table 14. Continued.

grid & period			rby		uv	mjm		us		total	
			MNA	dens.	MNA	MNA	dens.	MNA	dens.	MNA	dens.
1981	TG	1	2	0.49	0	0		0		2	0.49
		2	24	5.92	1	0		0		25	6.17
		3	25	6.17	1	0		8	1.84	34	8.39
		4	32	7.90	2	0		12	2.76	46	11.35
		5	33	8.14	4	0		27	6.22	64	15.79
		6	41	10.12	5	0		51	11.74	97	23.94
	SG	1	7	1.55	0	0		0		7	1.55
		2	17	3.75	0	0		0		17	3.75
		3	19	4.20	0	0		10	2.30	29	6.40
		4	30	6.62	2	0		9	2.07	41	9.05
		5	38	8.39	0	0		14	3.22	41	9.05
		6	40	8.83	0	0		22	5.06	62	13.69
	RG	1	0		0	0		0		0	
		2	9	2.23	1	0		30	8.07	40	9.93
		3	23	5.71	16	4	1.17	99	26.64	142	35.26
		4	24	5.96	8	3	0.88	82	22.06	117	29.06
		5	26	6.46	10	3	0.88	78	20.99	117	29.06
		6	16	3.97	15	3	0.88	105	28.25	139	34.52

Table 15. Diversity and richness of small mammal captures in live traps at Nyac, Alaska, with species lumped within genera. Hucheson's modification of Shannon-Weiner H' (Poole 1974) was used for diversity.

	1980		1981	
site	H' genus diversity	genus richness	H' genus diversity	genus richness
TG	0.0826	3	0.4958	3
SG	0.1184	2	0.3681	3
RG	. . .	. . .	0.9627	5
all	0.1095	3	0.8171	5

Table 16. Mean home range areas and lengths for small mammal species captured at Nyac, Alaska, during the summers of 1980 and 1981. See Table 9 for abbreviations. "-" - s.d. not calculated for n<5.

		1980					1981				
		area (ha)			length (m)		area (ha)			length (m)	
species	site	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.
rbv	TG	0.123	0.060	16	60.9	21.5	0.120	0.054	14	66.3	26.0
rbv	SG	0.153	0.076	6	83.8	30.9	0.156	0.106	7	77.8	36.1
rbv	RG	. . .	. . .		. . .	. . .	0.176	-	3	86.8	-
mjm	RG	. . .	. . .		. . .	. . .	0.084	-	2	59.5	-
ds	RG	. . .	. . .		. . .	. . .	0.116	0.024	6	73.4	20.4

of period 6 in the third week of August. Capture rates for the nighttime sets (roughly 1900 to 0800 hours) were compared to those for the daytime sets using an X^2 test (Sokal and Rohlf 1981, p. 708) with H_0: p(capture during nighttime sets) = p(capture during daytime sets). Table 17 presents the results of that analysis.

In 1980, H_0 could not be rejected for either sites TG or SG through mid-July. Periods 4-6 showed marked signs of diurnal activity patterns for total captures. In 1981, a similar pattern appeared, although sites TG and SG showed changes in the degree of significance of their departures from H_0. In both years, the shrews showed the greatest tendency to key activity into darker hours, RBVs a lesser tendency, and unknown voles and meadow jumping mice had no significant departures from H_0.

Nighttime sets tended to have a higher percentage of newly captured animals than did daytime sets. Meadow jumping mice were mostly captured in nighttime sets, and tundra shrews (Sorex tundrensis) were only captured in nighttime sets.

Growth curves and breeding status

Plots of body weights of RBVs captured in at least 3 trapping periods showed that breeding and nonbreeding individuals formed 2 distinct cohorts, with individuals rarely changing status during the time I trapped (Figures 5 and 6). In general, animals lighter than 20 g were nonbreeding, and some individuals stayed so from mid-June through mid-August with no change in weight exceeding 2 or 3 g. Breeding individuals were generally greater than 20 g in body weight,

Table 17. Diurnal activity patterns of small mammal species captured in Sherman live traps at Nyac, Alaska, during the summers of 1980 and 1981. Kruskal-Wallis pairwise comparisons used to test H_0: p(capture during nighttime trap set) = p(capture during daytime trap set). See Table 9 for abbreviations. "-" - none captured, n - n<5, + - p>0.05, * - p<0.01, *** p<0.001.

site & period		1980			1981				
		rbv	us	total	rbv	uv	mjm	us	total
TG	1	n	-	n	+	-	-	-	+
	2	+	-	+	+	-	-	-	+
	3	+	-	+	+	n	-	+	+
	4	***	-	***	+	n	-	+	+
	5	**	-	**	+	+	-	*	*
	6	***	+	***			. . .		
SG	1	n	-	n	+	-	-	-	+
	2	+	-	+	+	-	-	-	+
	3	+	-	+	+	-	-	+	+
	4	+	n	*	*	n	-	*	***
	5	*	n	*	*	-	-	*	***
RG	1		. . .		-	-	-	-	-
	2		. . .		+	n	-	+	*
	3		. . .		+	+	+	+	+
	4		. . .		*	+	+	*	+
	5		. . .		+	+	-	***	**

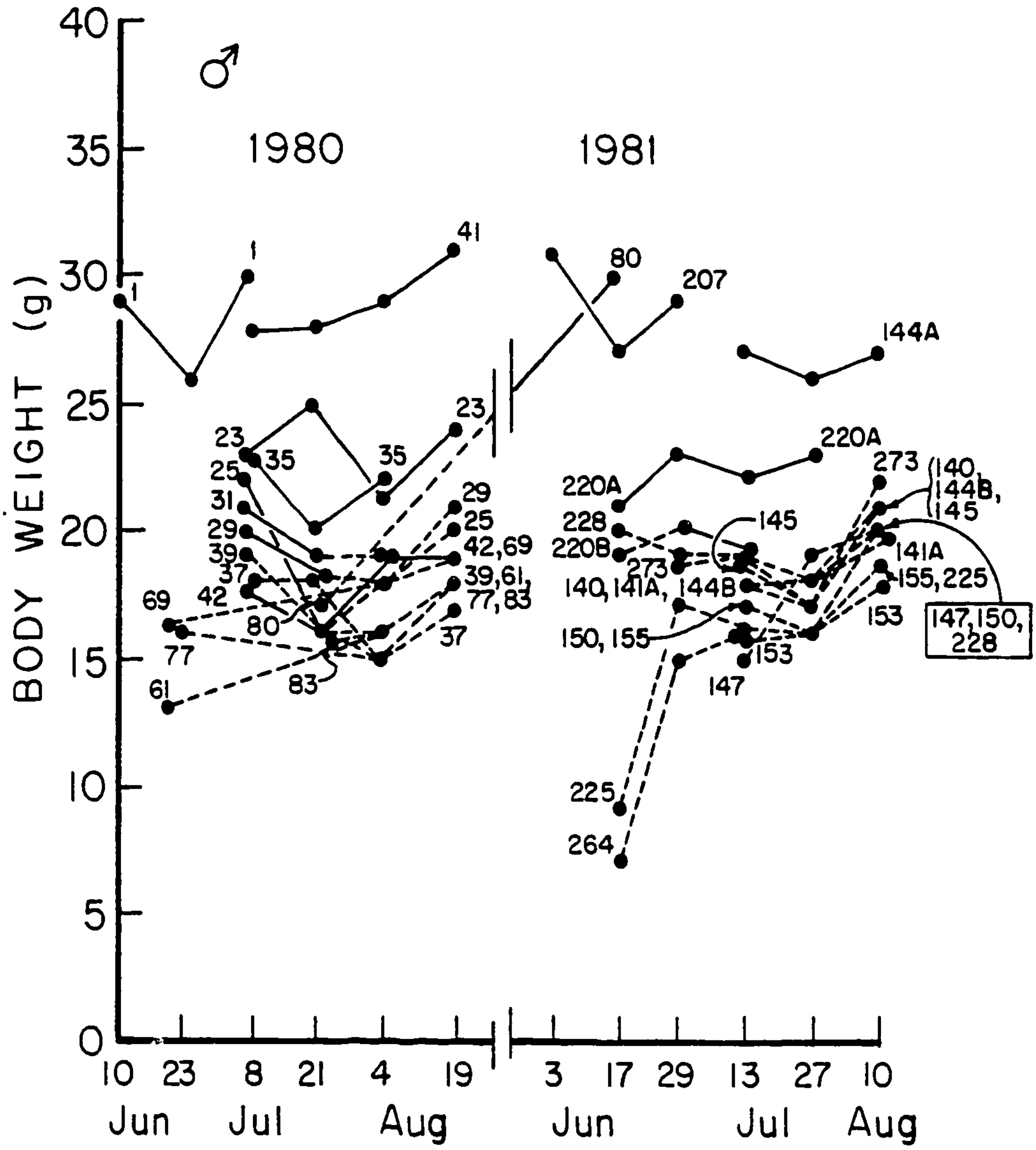

Figure 5. Body weights over time for male northern red-backed voles captured in live traps on site TG at Nyac, Alaska. Type of line denotes breeding (solid) or nonbreeding (dashed) status as determined from external examination.

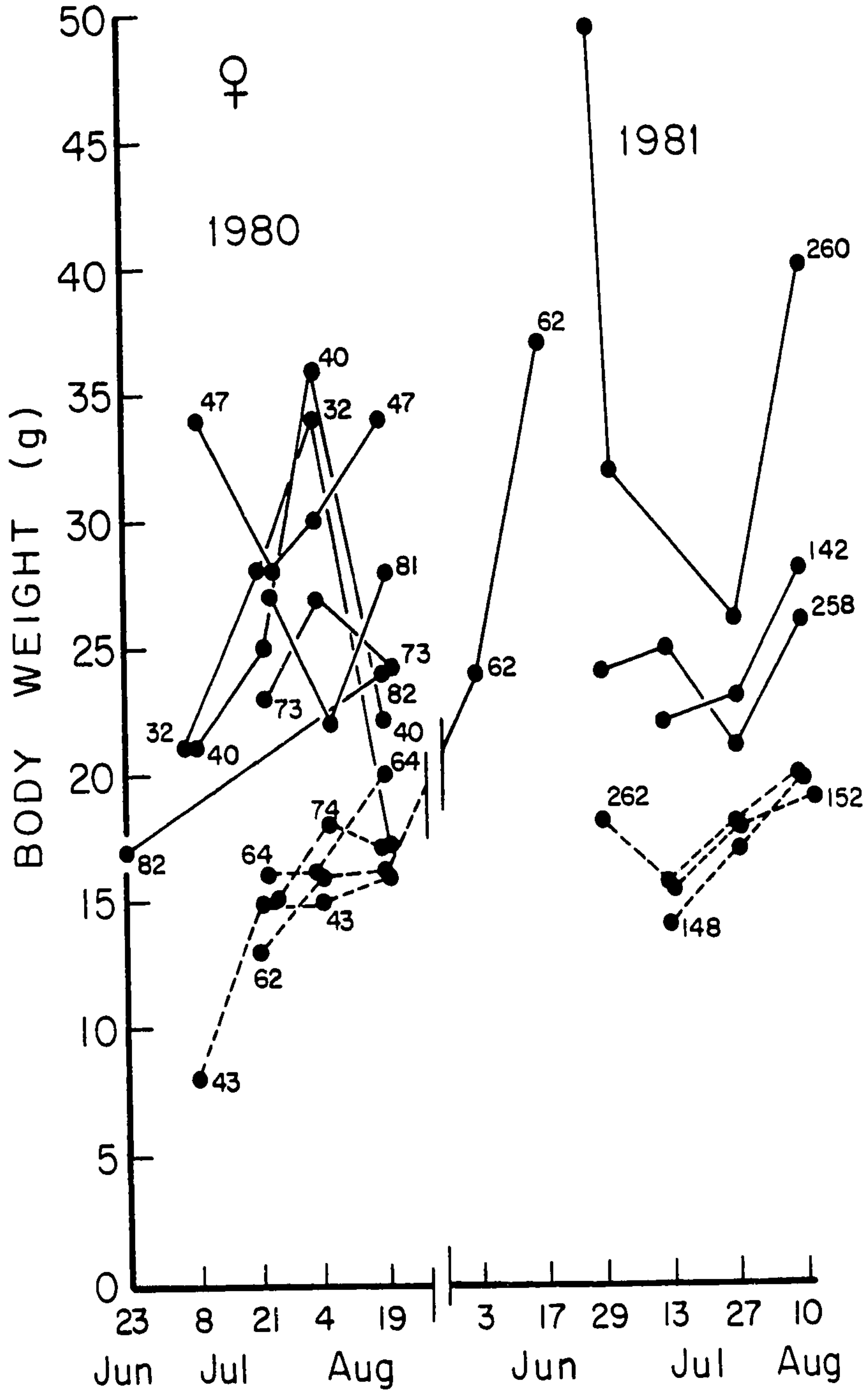

Figure 6. Body weights over time for female northern red-backed voles captured in live traps on site TG at Nyac, Alaska. Type of line denotes breeding (solid) or nonbreeding (dashed) status as determined from external examination.

and were breeding from first capture onward. Two individuals were captured in both years: #62 (female) and #80 (male). Number 80 was only captured twice (once each year), so his growth in 1980 is unknown. Both were breeding the second year, but not the first. Males on site TG (Figure 5) were the only group in which breeding animals lost weight and became nonbreeding. Whether or not the nonbreeding status was a result of weight loss is unknown.

This 2-cohort scenario was corroborated by tooth aging. Of the 17 skulls examined, breeding was restricted to, and universal among, overwintered animals (roots $\geq$ 1.0 mm long). The mean body weight for these 9 individuals was 31.7 g. All RBV young-of-the-year were nonbreeding, with a mean weight of 19.8 g.

Habitat preference

Based upon snap trapping data, small mammals showed strong preferences for some vegetation communities and a near-total avoidance of others (Table 18). All species, and unknown voles in particular, showed strong preferences for vegetated sites in general and sites with large amounts of herbaceous understory cover in particular.

Scatter plots of the principal components analysis Factor 1 and 2 scores for all 300 live trap stations were generated, resulting in a graphical representation of habitats available. Onto these plots I drew irregular polygons enclosing domains of points corresponding to given levels of trap success. Figures 7-10 show these domains for each genus captured. The larger the domain, the less specific the vegetation

Table 18. Habitat preferences shown by small mammal captures along parallel trap lines at Nyac, Alaska. Paired lines (a site) were 15 m apart, each sampling a different community. See Tables 5 and 9 for abbreviations.

year & site		vegetation community	rbv	uv	mjm	us	total
1981	LRT	alder/balsam poplar/ grass/herbs	13	13	0	14	40
		stripped soil/stump pile	1	1	0	3	5
1980	LTT	alder thicket; little or no understory	8	0	0	2	10
		grass/low shrub, and alder/willow/grass	4	13	0	11	28
1981	LTT	alder thicket; little or no understory	0	0	0	0	0
		grass/low shrub, and alder/willow/grass	1	3	0	0	4
1980	BTT	bare tailings	0	0	0	0	0
		tall shrubs, grass/ herb understory	2	1	2	0	5
1980	MTT	bare tailings	0	0	0	0	0
		tall shrubs, grass/ herb understory	16	0	0	0	16
1981	MTT	bare tailings	2	1	0	4	7
		tall shrubs, grass/ herb understory	13	0	0	7	20

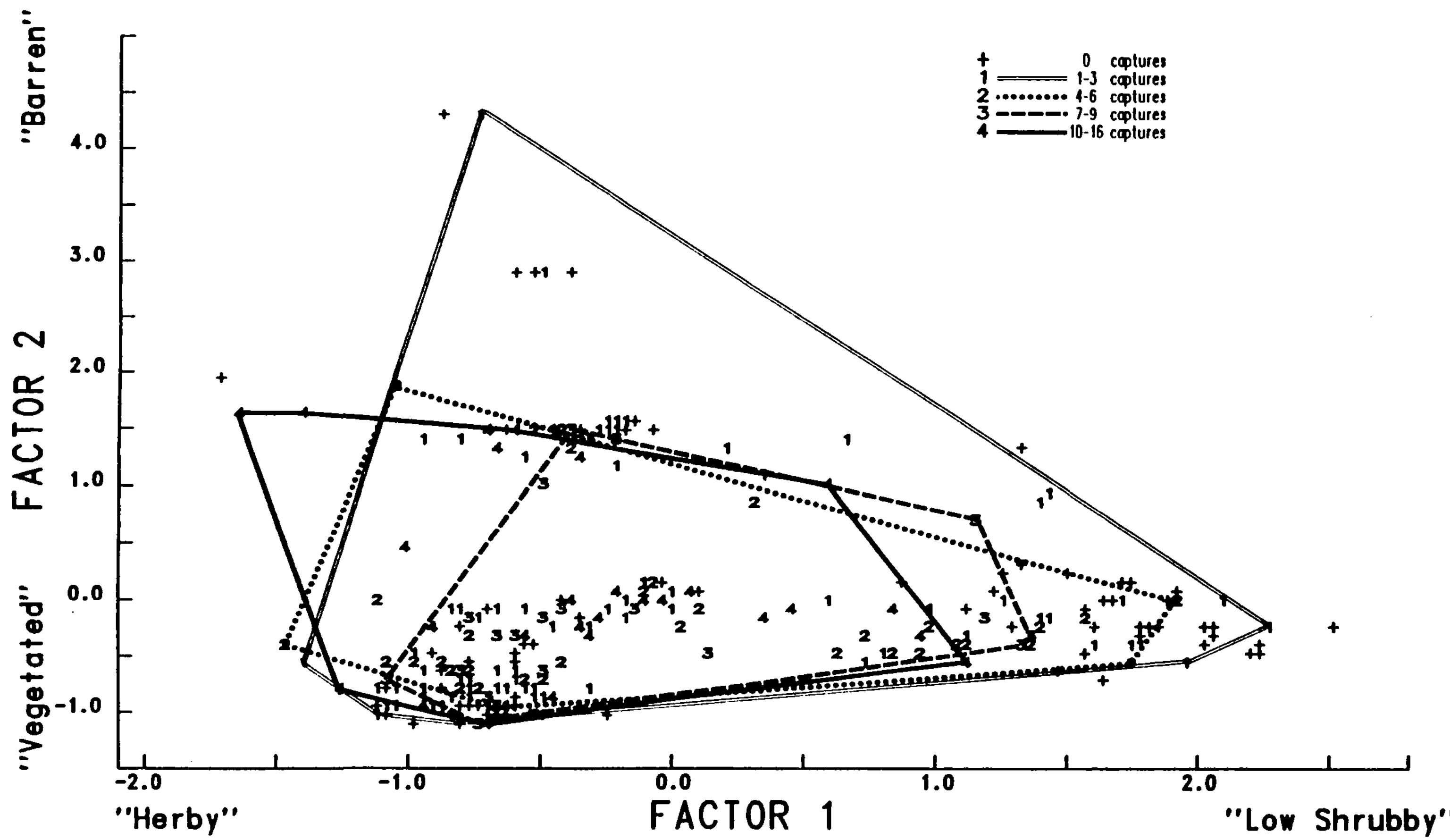

Figure 7. Habitat preferences shown by northern red-backed voles on the basis of increasing capture success with Sherman live traps at Nyac, Alaska, during 1981. Polygons enclose sample locations grouped by success.

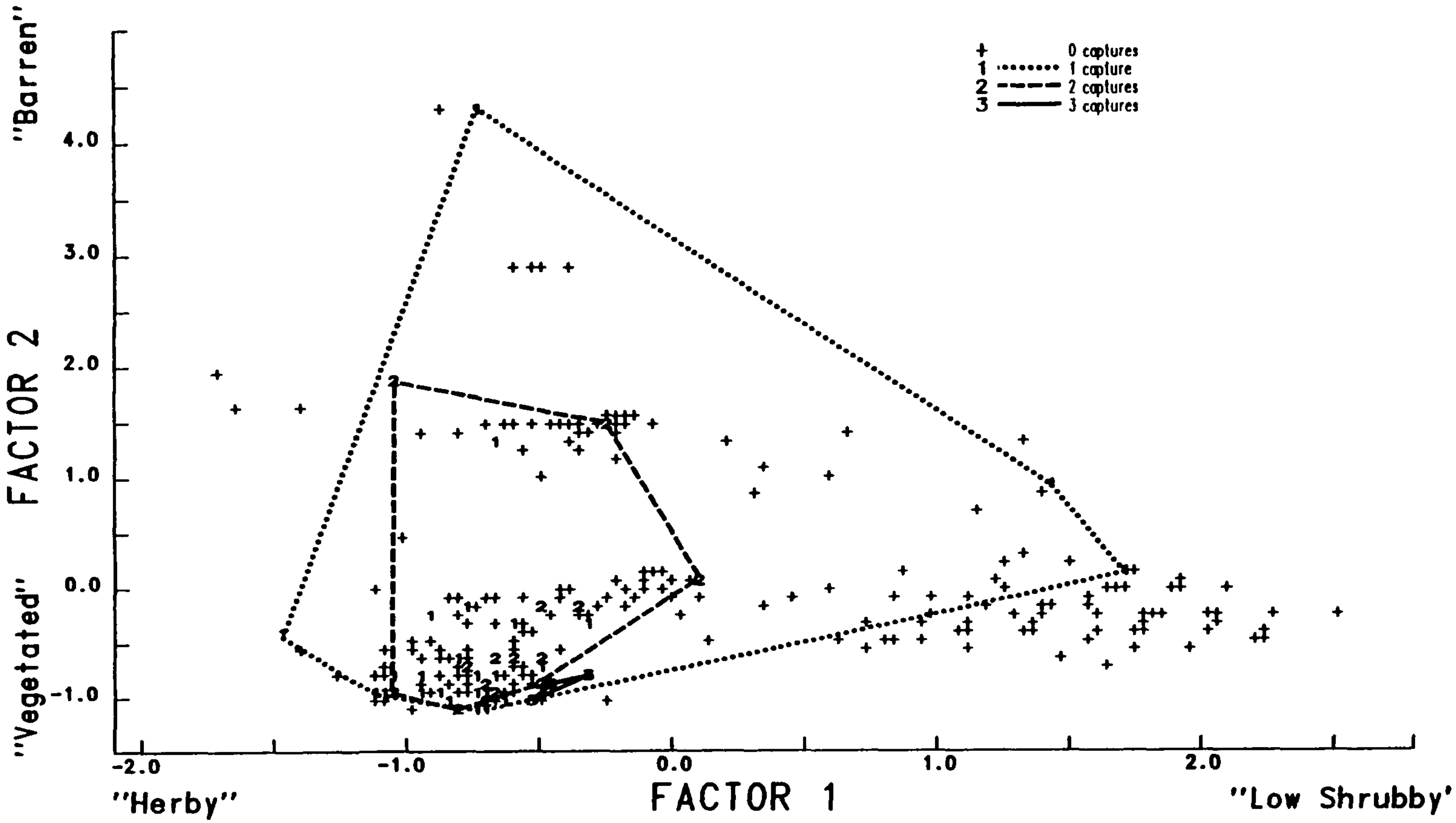

Figure 8. Habitat preferences shown by Microtus spp. on the basis of increasing capture success with Sherman live traps at Nyac, Alaska, during 1981. Polygons enclose sample locations grouped by success.

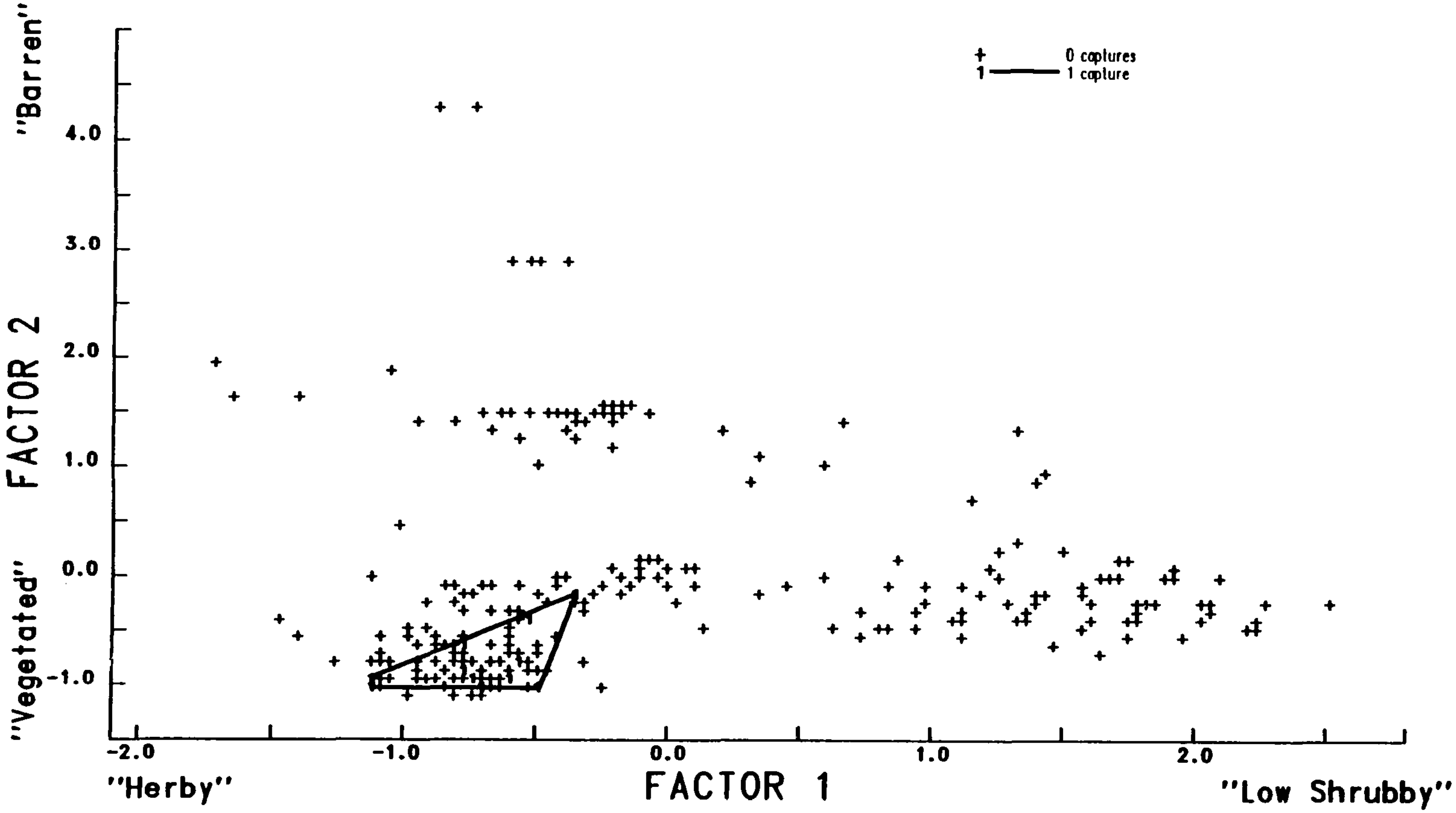

Figure 9. Habitat preferences shown by meadow jumping mice on the basis of increasing capture success with Sherman live traps at Nyac, Alaska, during 1981. Polygons enclose sample locations grouped by success.

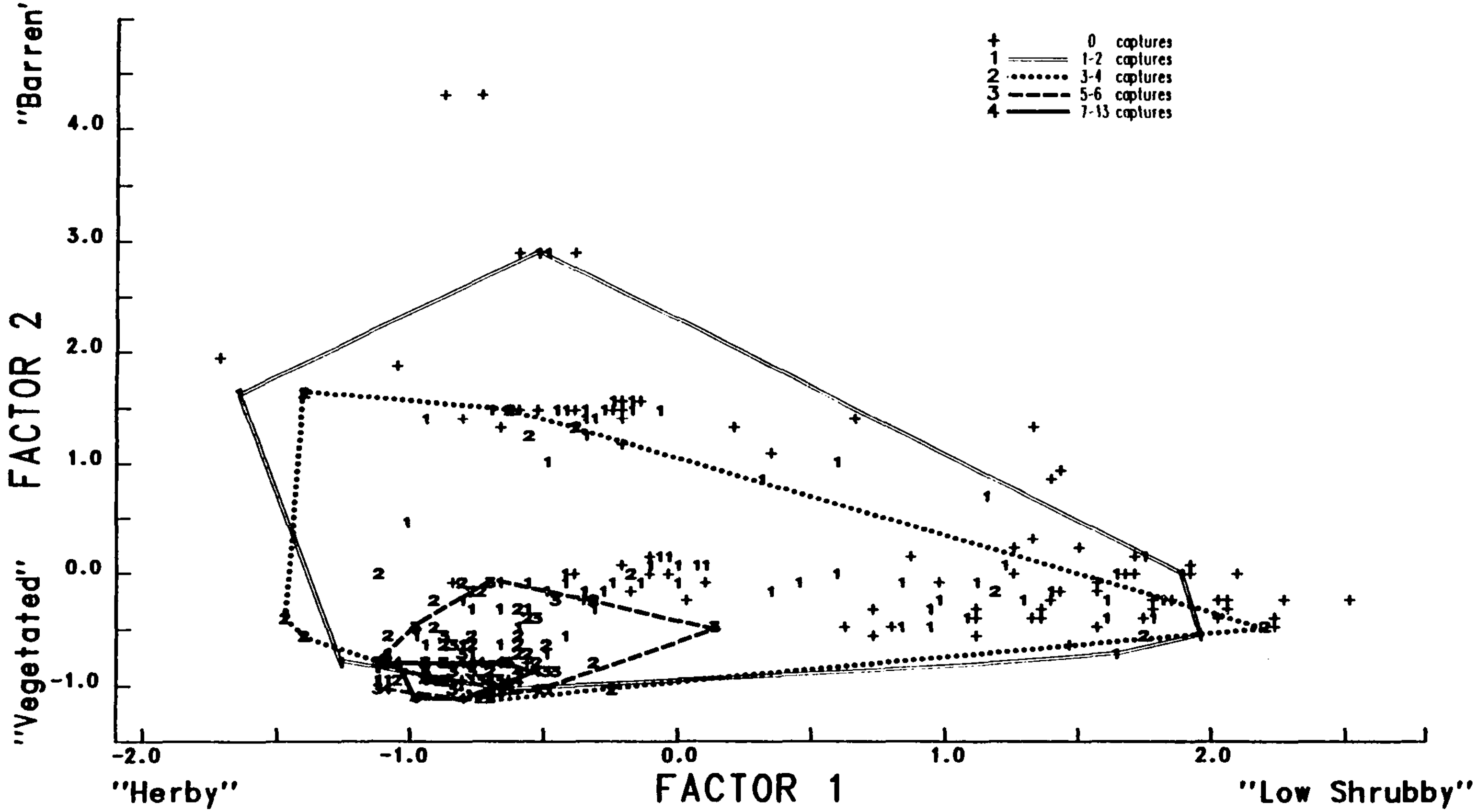

Figure 10. Habitat preferences shown by shrews on the basis of increasing capture success with Sherman live traps at Nyac, Alaska, during 1981. Polygons enclose sample locations grouped by success.

community characteristics associated with capture of a particular species or genus.

The polygons for RBV captures showed fairly large domains. With increasing trap success, a slight shift towards more herby and less low shrubby was seen. Unknown vole domains tended to be smaller and more restrictive than those of RBVs, but again suggested a preference for herbaceous vegetation. Meadow jumping mice were never captured more than once in any one trap, but the traps that were successful were in very densely vegetated, herby habitats. Shrews showed a more generalized preference for vegetation than did the genera above. Moderate numbers were captured in dense low shrubby habitats, although maximum shrew captures were associated with densely herbaceous habitats.

It should be noted that "preference" as used here is meant to imply that communities possessing the mentioned characteristics were preferred habitats, not that the animals were selecting for the actual characteristics themselves.

Discriminant functions analyses had varied successes. RBVs were difficult to classify. With the entry of 2 variables, about one-third of the traps were correctly classified (Table 19). Addition of more variables did not substantially improve the discrimination. Discrimination among unknown vole successes was over two-thirds, reached in 1 step. Meadow jumping mouse captures were discriminated for 90% of the traps using 2 variables. Less than half of the traps were correctly classified for shrew captures, with only slight gains after step 1.

Table 19. Percentage of trap locations correctly classified as to small mammal live trap success at Nyac, Alaska, by discriminant functions analysis. 36 habitat variables (each with cover ≥5% in at least 1 trap location) were potential predictors. n = 300. See Table 9 for abbreviations.

	rbv		uv		mjm		us	
step	variable	% corr.	variable	% corr.	variable	% corr.	variable	% corr.
1	fruticose lichens	17.3	grasses	66.7	oak-fern	74.7	total herbs	43.7
2	unknown herbs	32.0	highbush cranberry	70.3	northern beech-fern	90.0	bunchberry	46.3
3	white spruce	32.7	prickly rose	70.7	prickly rose	84.7	fruticose lichens	48.3
4	dead & down	33.0	oak-fern	73.0	American green alder	84.3	oak-fern	47.7
5	oak-fern	32.3	northern bluebell	73.7	grasses	88.3	highbush cranberry	48.7
6	bunchberry	35.3	bunchberry	74.3	highbush cranberry	86.3	spiked saxifage	50.3
7	mosses	33.7	total herbs	76.7			grasses	48.7
8	horsetails	34.7	spinulose shield-fern	77.3			horsetails	51.3

All possible subsets regressions did not explain greater than about 35% of the variance, so those results are not presented.

Figure 11 presents mean captures of small mammals per trap for each of the 9 identified plant communities; variances were quite high, and several means were similar. The Fallen Log and Herby Tailing communities were the most productive for RBVs; Moderate Herbaceous Riparian and Dense Herbaceous Riparian were the most productive for the other genera. Figure 12 shows the results of testing for equal means among the communities at $p \leq 0.10$ and $p \leq 0.05$.

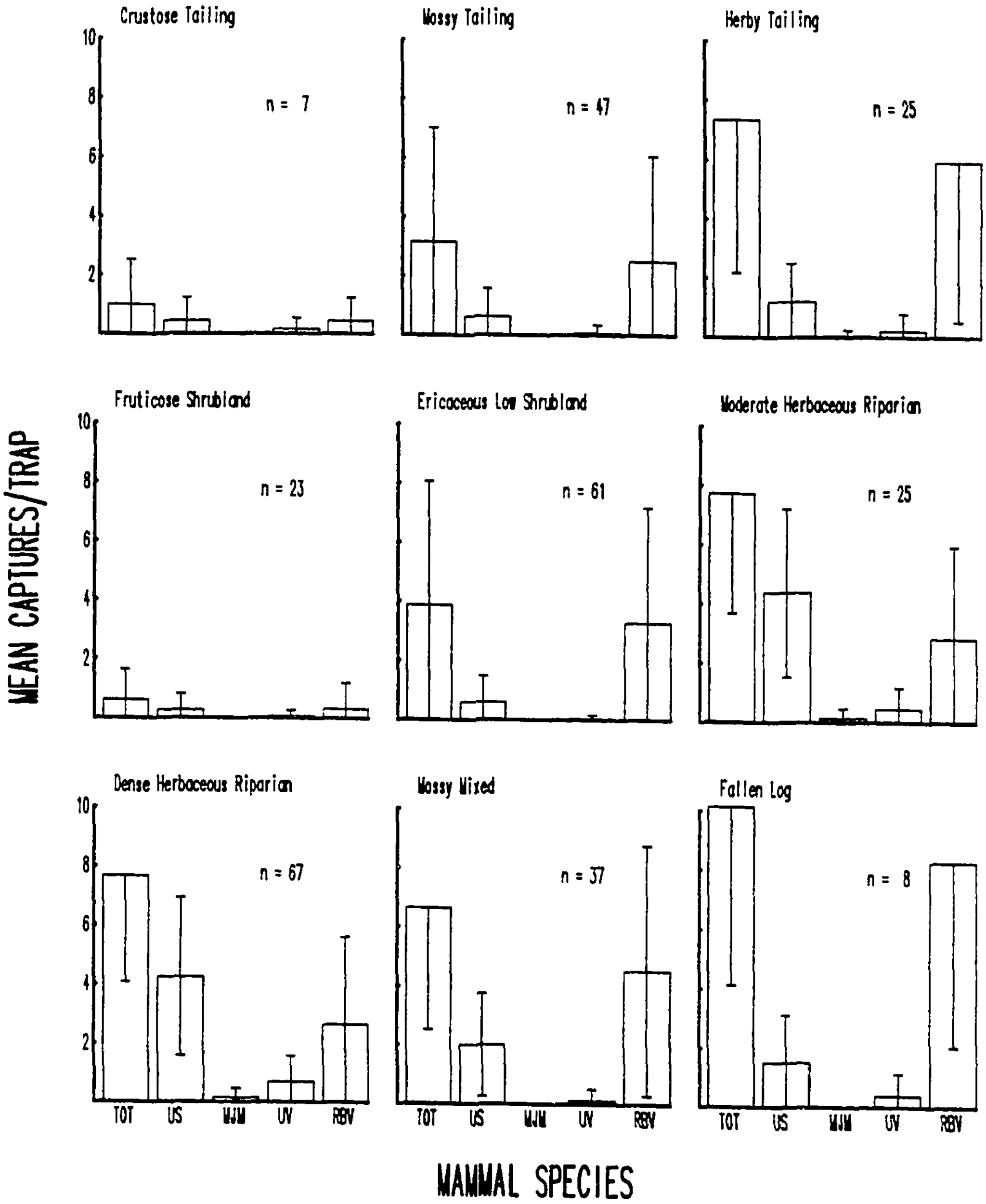

Figure 11. Mean capture rates (± s.d.) of small mammals for traps located in 9 understory communities derived from cluster analysis of 300 sampling locations at Nyac, Alaska, during 1981. See Table 9 for abbreviations.

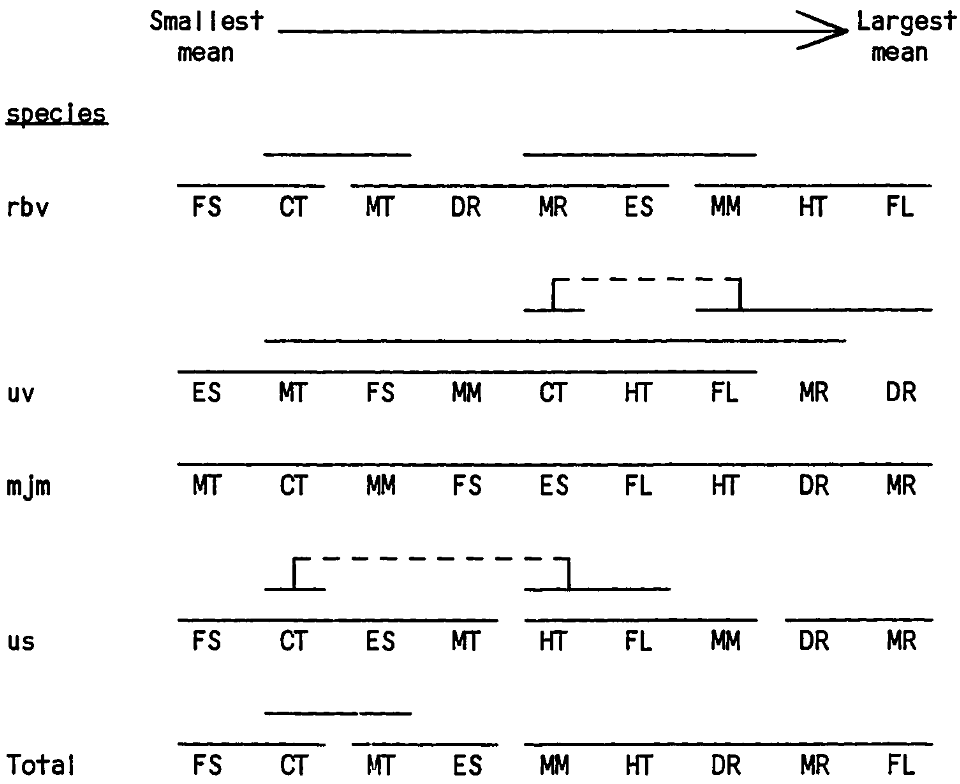

Figure 12. Results of Kruskal-Wallis pairwise comparisons of equal mean capture rates between small mammal traps located in different vegetation communities at Nyac, Alaska, during 1981. Bars join communities with means not statistically different at $p \leq 0.05$. See Table 9 for abbreviations. FS - Fruticose Shrubland, CT - Crustose Tailing, MT - Mossy Tailing, DR - Dense Herbaceous Riparian, MR - Moderate Herbaceous Riparian, ES - Ericaceous Low Shrubland, MM - Mossy Mixed, HT - Herby Tailing, FL Fallen Log.

DISCUSSION -- MAMMALS

Beaver

The higher beaver densities observed in the mined versus unmined portions of the study area can be explained in terms of the habitat provided by Nyac tailings. Beaver prefer slow moving water bodies with fairly stable water levels, a low gradient, and noneroding banks (Retzer 1955, Slough and Sadlier 1977). Water depths greater than 1 m are required to avoid winter freezeout (Hakala 1952, Boyce 1974), and food should be within a foraging range of 100 m (MacDonald 1956, Slough and Sadlier 1977). Besides highly favored willows, beaver consume large amounts of herbaceous vegetation in early summer (MacDonald 1956).

All of these requirements and preferences are met at present by the Nyac tailings, with their combination of water bodies between tailings and vegetation growing on soil deposited onto the tailings. Note that succession to a white spruce valley bottom forest will decrease the woody food supply markedly and that dense alder revegetation with little herbaceous understory is nearly useless to beaver.

Small mammals

In the only small mammal study directly comparable to this one (Weir et al. 1981), similar trends were found in regard to species presence and abundance. Disturbed areas had fewer individuals of fewer species than did undisturbed areas. Many species in low abundances on undisturbed sites were absent on disturbed sites. In both cases (Weir et al. 1981 and this study), however, there were portions of the disturbed areas that had small mammal densities (particularly RBVs) that exceeded those in the undisturbed areas. A decrease in the small mammal faunal diversity accompanied these drops in richness and abundance. Elliott (1984) found a similar drop in diversity on a revegetated coal strip mine at Healy, Alaska.

In general, small mammal abundances at Nyac were as high as or higher than those found by workers comparing disturbed and undisturbed sites in interior Alaska (West 1974), the Kenai Peninsula (Bangs 1979), the Klondike (Weir et al. 1981), and Healy, Alaska (Elliott 1984). RBV abundances were similar at Nyac and both the Klondike and Kenai Peninsula, while I captured many more than were found in Healy or in burned interior Alaska forests. Abundances for voles at Nyac were greater by up to 2 orders of magnitude than in the Klondike, and were higher than those found on undisturbed sites at Healy. Shrew abundances at Nyac were slightly lower than those in Kenai Peninsula crushed black spruce forests, greater than was found in crushed Kenai Peninsula birch forests and old Klondike mine sites, and much greater than those in undisturbed Kenai Peninsula and Klondike sites.

Although my data point out the potential yearly variability of small mammal populations, they are in line with annual fluctuations observed in Martell and Fuller's (1979) work on RBVs in northern Yukon Territory. All comparisons in the above paragraph have taken into account such variability, and I feel that the differences noted are indeed real.

Martell and Fuller (1979) found that in at least 1 of their 4 study years, there was essentially no breeding by young-of-the-year, a situation similar to that I observed. Other years, some breeding by young-of-the-year was seen in mid-August. They further found, as I did, that a very small proportion of the fall population successfully overwinters and that those individuals that do are in prime breeding condition by snow melt. Those authors suggest that the date of the onset of spring determines the fall abundances. If spring is early, animals born in early June can produce litters by August, providing a large population in the fall.

Habitat preference

The results of the discriminant functions and domain mapping analyses provide us with coherent pictures of the habitat preferences of the mammalian species involved, with preferences related to food habitats.

RBVs were found in a variety of densely vegetated areas. Highest densities were in areas where a mix of herbaceous and low shrub vegetation was present, but the RBV reputation as a generalist was supported. Primarily omnivorous, RBVs depend largely upon fruits and mosses, with some populations also taking arthropods and other animal items (Dyke 1971, West 1982, Elliott 1984). Monocots are apparently avoided, even when available in abundance. Two hypothermic RBVs taken from live traps were warmed up and released in areas where they had a wide variety of monocot and dicot food items to choose from. Both animals began eating leaves of tall bluebell immediately upon release.

The discriminant functions analysis for RBV habitat also suggests a berry preference. The first variable included is fruticose lichen cover, which correlates with berry producing plants such as dwarf blueberry (r = 0.5502), lowbush cranberry (r = 0.6040), and cloudberry (Rubus chamaemorus) (r = 0.0207) in the study area, particularly on site SG. In 1980, there was a near total failure of the berry crop, and few RBVs captured were near these berry plants. In 1981, a moderate berry crop was produced, and many more RBVs were captured in the vicinity of the same plants. On the tailings, bunchberry is the major berry producing plant.

In addition, RBVs were infrequently captured in traps without some nearby tall shrub or tree cover, no matter how adequate the potential food supply. This is reflected in the 3rd variable entered in the discriminant functions analysis, white spruce cover. It is unknown whether RBVs at Nyac eat animal items, but such items are undoubtedly present in their preferred habitats, as evidenced by the presence of shrews.

Unknown voles (primarily meadow and tundra voles) were rarely captured in areas not densely herbaceous. This preference is shown by their restricted habitat domains and by the success of the discriminant function using only grass cover. Elliott (1984) reported 60-75% of tundra vole diets consisting of monocots, with another 10-19% being mosses. Tundra voles were frequently found under dense bluejoint cover.

Weir et al. (1981) reported meadow voles in highest abundance in immature unmined communities, which had the densest herbaceous cover. Hallett et al. (1983) also emphasize the dependence of meadow voles upon dense grass cover.

Meadow jumping mice have habitat requirements similar to those of meadow voles (Hallett et al. 1983) but seem to prefer damp areas to drier areas of equally dense herbaceous cover. Their habitat domain shows such a specialization, as do the variables chosen by the discriminant functions analysis. Ferns were found only in areas of damp soil and were usually accompanied by lush monocot and dicot growth. It is interesting to note that Weir et al. (1981) never captured any jumping mice in their Klondike plots, even though they have been captured in that area in the past. This may be because Weir et al. did not trap in any areas with dense herbaceous cover (C. Babcock; pers. comm.)

Shrews preferred dense vegetation, be it herbaceous or, to a lesser extent, woody. This is presumably because the animal matter making up a majority of shrews' diets (Quay 1951) is found in the litter beneath such vegetation. Litter alone is not sufficient for shrew habitat, however, as seen by the few shrew captures beneath dense alder thickets on site LTT. Such locations had dense litter but little vascular cover less than 1 m tall. The importance of seeds and berries as supplements to shrews' meat diets was shown by Terry (1978). Variables entered in the discriminant function suggest the importance of damp herbaceous vegetation and berry producing plants, or of some factor related to these characteristics.

SYNTHESIS

Habitat considerations

At present, the tailings at Nyac provide habitat for 80% of the 31 mammalian species occurring in the study area. Taken as a whole, these tailings represent a very heterogeneous cover type, with bare rock, water, tall shrubs, herbaceous cover, and stands of trees in close juxtaposition. Leopold (1933) recognized the value of such situations to wildlife species that do not range widely on a regular basis. Areas containing such interspersed communities support larger populations of wildlife than do more homogeneous areas. Patten (1975) and Taylor (1977) also examined this concept and reaffirmed Leopold's conclusions.

The younger vegetation communities currently on the tailings seem to have greater habitat value than the mature valley bottom communities of white spruce and ericaceous low shrubland. It is difficult, however, to envision a scenario in which the tailings would not undergo successional changes, eventually approaching the present mature communities. Such succession to more mature communities may be seen in areas of heavy beaver cuttings. Therefore, the current value of the tailings to wildlife is likely to change in the future, but the time frame of such change is unknown.

The complexities of heterogeneous cover types may help explain difficulties encountered correlating trap success with measured plant community variables, and hint that the concepts of plant community and wildlife habitat may not be nearly the same thing. During the data analyses of this study, I tried to account for the contributions of surrounding communities to the heterogeneity of a given trap location, but could not account for more than about 10% of the variability of trap success. Some of this failure may be because I did not design this study to explicitly measure heterogeneity.

The fact that an experienced trapper can walk through an area and often say whether or not it is "good" habitat for a species with which s/he is familiar tends to indicate that it is possible to predict animal species' habitats from some complex combination of plant community characteristics. Results of this study suggest that extrapolation from vegetation type maps is a less than satisfactory approach.

Management considerations

Two portions of U.S. Bureau of Land Management Rulemaking 43 CFR 3800, Subpart 3809, deserve direct mention, for they bear on the results of this study. Section 3809.1-3(d)(4) deals with required reclamation measures. One measure specifically required is reshaping of mined areas. I feel this is inappropriate at Nyac for several reasons.

From a practical standpoint, reshaping dredge tailings to original contour is essentially impossible, as the fines that originally filled the cobble interstices are segregated as a distinct layer in the tailing, and there is now air between the cobbles. The result is an increase in the volume of material (the "swell rate") up to about 30%, which cannot be put back into the original space. Reshaping will not result in greatly enhanced revegetation, as explained in earlier comments on particle size. Dense stands of alder might develop in places, but they are not desireable types of revegetation for mammalian species.

Detrimental effects from reshaping are very real. Not only would reshaping reduce the heterogeneity of the tailings, but the resulting surface would be above the water table, eliminating the water-tailing interface. As noted in the Results sections, both heterogeneity and water appeared important to establishment of plant and mammal species on the tailings.

Another measure called for is saving of topsoil, and application of same to the disturbed areas. This is extremely beneficial to both revegetation and mammals. This study corroborates others (Johnson and Van Cleve 1976, Taylor 1976, Woodward-Clyde Consultants 1980, Rutherford and Meyer 1981, Singleton et al. 1981) which have shown that topsoil and/or organic material (collectively, overburden) is crucial to revegetation with appreciable herbaceous cover. Such cover containing a mix of monocots and dicots is highly selected for by mammals. In addition, such substrates at Nyac promote revegetation by woody species closely resembling the undisturbed communities in the area. Reshaping of tailings is unnecessary in this case, as is application of a thick layer of overburden. Several cases were seen on Nyac tailings where the soil layer beneath dense herbaceous and woody revegetation was about 0.1 m thick.

Reclamation is often undertaken as a means of reducing erosional processes following land disturbances. In the present case, this appears unnecessary. For the most part, the finer components of the dredged ground are overlain with a thick layer of cobbles, an arrangement highly resistant to erosion. Only scattered instances of any erosion of tailings were seen, and in only 2 cases were up to one-third of the width of a tailing eroded. In each of these instances, the Tuluksak River had been impinging upon the tailing on the outside of a bend, or at a right angle, for 30-40 years.

It is unknown how much erosion of overburden occurs if applied to tailings, but conditions at locations in the study area where this was done in the past seem to indicate that the material may wash down some into surface interstices, but is generally held quite well by the tailing surface.

It bears repeating here that mining methods have undergone a change during the 55 years of operation in the study area. Tailings deposited in the first half of the period often have strips or islands of unmined land interspersed throughout them. A relatively large amount of overburden and stumps was piled onto these tailings. These factors tended to promote natural revegetation. More recent tailings, on the other hand, tended to have few areas of unmined land interspersed throughout, and much less overburden has been deposited onto them. The net result is that tailings created in 1963, for example, will probably not be nearly as naturally revegetated when 45 years old as tailings are today which were deposited in 1935.

In order for mining to remain an economically viable land use, reclamation measures need to be devised which require a minimum of labor and energy, both of which are very expensive in most Alaskan mining areas. Creative methods of depositing overburden cheaply onto tailings as mining progresses are needed. One possible method has been suggested by a soil scientist of the U.S. Bureau of Land Management Anchorage District Office in an internal report following a visit to the Nyac area. In this report, he suggests that mining be planned so that 1 year's mining is largely parallel to that of the previous year, facilitating the spreading of overburden from the current year's stripping onto the previous year's tailings (K. Meyer; pers. comm.). Whenever recommendations as to reclamation methodology are being developed, the site specific nature of such procedures must be condsidered.

The question of whether gold dredging is a "good" or "bad" land use cannot realistically be answered unless a set of criteria are provided. If one wishes an area unaltered aesthetically, then dredging is probably undesirable. If beaver are desired, perhaps dredging should be encouraged. If historical evidence is important, perhaps revegetation should be neither undertaken nor promoted. The aquatic effects of the mining need to be considered as well, but they are not being specifically addressed in this study. What appears to be needed is coherent land use planning, so that miners know the planned post-mining uses of claims and can operate accordingly. An important aspect of such plans would be the time frame chosen for the amount of reclamation desired; for example, a productive, self maintaining cover in 10 years versus the "instant green" of hydroseeding.

Recommendations

On the basis of this study, I recommend that

(1) any reclamation undertaken be consistent with providing habitat heterogeneity and tailing-water interfaces,

(2) removed overburden be applied to tailings past or future,

(3) herbaceous understory revegetation be given as high a priority as woody revegetation,

(4) the site specific nature of reclamation procedures, and of many results of this study, not be overlooked,

(5) land use planning goals be available to miners so that they may plan operations accordingly, and

(6) ongoing research be established at Nyac, based upon the present baselines and directed towards cooperative, sensible approaches to eliminating "unnecessary and undue degradation" due to surface mining.

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APPENDIX A: Scientific and common names of plant species collected near Nyac, Alaska, during 1980 and 1981. Nomenclature follows: herbaceous vascular, Hultén (1968); woody vascular, Viereck and Little (1972); willows, Argus (1973). Many common names from Welsh (1974).

Lichens

Cladina alpestris (L.) Rabh.	
Cladina (*mitis* ?)	
Cladina rangiferina (L.) Wigg.	
Cladonia c.f. *deformis* (L.) Hoffm.	
Cladonia spp.	
Nephroma arcticum (L.) Torss.	
Stereocaulon c.f. paschale (L.) Fr.	

Mosses

Ceratodon purpureus (Hedw.) Brid.	purple horntooth
Climacium dendroides (Hedw.) Web. & Mohr.	tree moss
Pleurozium schreberi (Brid.) Mitt.	Schreber's moss
Polytrichum juniperinum Hedw.	juniper haircap
Polytrichum piliferum Hedw.	awned haircap
Rhacomitrium canescens (Hedw.) Brid.	gray frayed-cap moss
Scorpidium scorpioides (Hedw.) Limpr.	
Sphagnum rubellum Wils.	peat moss

Aspidiaceae

Dryopteris dilatata (Hoffm.) Gray	spinulose shield-fern
Gymnocarpium dryopteris (L.) Newm.	oak-fern

Athyriaceae

Athyrium filis-femina (L.) Roth	lady fern

Betulaceae

Alnus crispa (Ait.) Pursh	American green alder
Alnus sinuata (Reg.) Rydb.	Sitka alder
Alnus tenuifolia Nutt.	thinleaf alder
Betula nana L.	dwarf arctic birch
Betula papyrifera Marsh.	paper birch

Boraginaceae

Mertensia paniculata (Ait.) G. Don.	tall bluebell

Campanulaceae

Campanula lasiocarpa Cham.	mountain harebell

Caprifoliaceae

Linnaea borealis L.	twin-flower
Viburnum edule (Michx.) Raf.	highbush cranberry

Caryophyllaceae

Cerastium beeringianum Cham. & Schlecht.	Bering chickweed
Minuartia arctica (Stev.) Aschers. & Graebn.	arctic sandwort
Moehringia laterifolia (L.) Fenzl	blunt-leaved sandwort
Silene acaulis L.	moss campion
Stellaria laeta Richards.	
Stellaria longipes Goldie	long-stalked sandwort
Wilhelmsia physodes (Fisch.) McNeill	merckia

Compositae

Achillea borealis Bong.	yarrow
Arnica frigida C.A. Mey.	
Artemisia arctica Less.	
Artemisia globularia Bess.	
Artemisia tilesii Ledeb.	
Aster sibiricus L.	Siberian aster
Matricaria matricarioides (Less.) Porter	pineapple weed
Petasites frigidus (L.) Franch.	arctic sweet coltsfoot
Senecio congestus (R. Br.) DC.	marsh fleabane
Taraxacum officinale Weber	common dandelion

Cornaceae

Cornus canadensis L.	bunchberry

Crassulaceae

Sedum rosea (L.) Scop.	roseroot

Cruciferae

Arabis lyrata L.	rockcress
Barbarea orthoceras Ledeb.	wintercress
Cardamine pratensis L.	cuckoo flower
Parrya nudicaulis (L.) Regel	

Cyperaceae

Carex aquatilis Wahlenb.	water sedge
Carex buxbaumii Wahlenb.	Buxbaum sedge
Carex laeviculmis Meinsh.	smooth-stem sedge
Carex rhynchophysa C.A. Mey.	
Eriophorum brachyantherum Trautv. & Mey.	
Eriophorum scheuchzeri Hoppe	white cottongrass
Eriophorum vaginatum L.	tussock cottongrass

Diapensiaceae

Diapensia lapponica L.	diapensia

Droseraceae

Drosera rotundifolia L.	round-leaf sundew

Empetraceae

Empetrum nigrum L.	crowberry

Equisetaceae

Equisetum arvense L.	meadow horsetail
Equisetum silvaticum L.	woodland horsetail

Ericaceae

Andromeda polifolia L.	bog rosemary
Ledum decumbens (Ait.) Small.	narrow-leaf Labrador-tea
Loiseleuria procumbens (L.) Desv.	alpine azalea
Vaccinium oxycoccus L.	bog cranberry
Vaccinium uliginosum L.	bog blueberry
Vaccinium vitis-idaea L.	lowbush cranberry

Fumariaceae

Corydalis pauciflora (Steph.) Pers.	few-flowered corydalis

Geraniaceae

Geranium erianthum DC.	cranesbill

Gramineae

Agrostis scabra Willd.	tickle grass
Arctagrostis latifolia (R. Br.) Griseb.	polar grass
Arctophila fulva (Trin.) Anderss.	pendent grass
Beckmannia erucaeformis (L.) Host	slough grass
Calamagrostis canadensis (Michx.) Beauv.	bluejoint

Iridaceae

Iris setosa Pall.	wild iris

Juncaceae

Luzula multiflora (Retz.) Lei.	woodrush
Luzula parviflora (Ehrh.) Desv.	small-flowered woodrush

Juncaginaceae

Triglochin palustris L.	marsh arrowgrass

Leguminosae

Astragalus alpinus L.	alpine milk-vetch
Oxytropis nigrescens (Pall.) Fisch.	blackish oxytrope

Lentibulariaceae

Pinguicula villosa L.	hairy butterwort

Liliaceae

Fritillaria camschatcensis (L.) Ker-Gawl.	chocolate lily
Lloydia serotina (L.) Rchb.)	alp lily
Tofieldia coccinea Richards.	northern asphodel

Lycopodiaceae

Lycopodium selago L.	fir clubmoss

Myricaceae

Myrica gale L.	sweetgale

Onagraceae

Epilobium angustifolium L.	fireweed
Epilobium latifolium L.	dwarf fireweed

Orchidaceae

Platanthera obtusata (Pursh.) Lindl.	small bog-orchid
Spiranthes romanzoffina Cham.	ladies' tresses

Papaveraceae

Papaver lapponicum (Tolm.) Nordh.	arctic poppy

Pinaceae

Picea glauca (Moench)Voss	white spruce
Picea mariana (Mill.) B.S.P.	black spruce

Polemoniaceae

Polemonium acutiflorum Willd.	blue Jacob's-ladder
Polemonium boreale Adams	northern Jacob's-ladder

Polygonaceae

Polygonum alaskanum (Small) Wight	Alaska wild rhubarb
Polygonum bistorta L.	bistort
Polygonum viviparum L.	alpine bistort

Portulacaceae

Claytonia sarmentosa C.A. Mey.	Alaska spring beauty

Primulaceae

Trientalis europaea L.	starflower

Pyrolaceae

Moneses uniflora (L.) Gray	shy maiden
Pyrola grandiflora Radius	large-flowered wintergreen
Pyrola minor L.	lesser wintergreen

Ranunculaceae

Actaea rubra (Ait.) Willd.	baneberry
Aconitum delphinifolium DC.	monkshood
Anemone narcissiflora L.	
Anemone richardsonii Hook.	yellow anemone
Caltha palustris L.	yellow marsh marigold
Ranunculus confervoides (E. Fries) E. Fries	water crowfoot
Ranunculus hyperboreus Rottb.	arctic buttercup
Thalictrum sparsiflorum Turcz	

Rosaceae

Dryas octopetala L.	white mountain-avens
Potentilla fruticosa L.	bush cinquefoil
Potentilla palustris (L.) Scop.	marsh cinquefoil
Potentilla uniflora Ledeb.	one-flowered cinquefoil
Rosa acicularis Lindl.	prickly rose
Rubus arcticus L.	nagoonberry
Rubus chamaemorus L.	cloudberry
Sanguisorba stipulata Raf.	Sitka burnet
Spiraea beauverdiana Schneid.	beauvered spirea

Rubiaceae

Galium boreale L.	northern bedstraw

Salicaceae

Populus balsamifera L.	balsam poplar
Populus tremuloides Michx.	quaking aspen
Salix alaxensis (Anderss.) Cov.	feltleaf willow
Salix arbusculoides Anderss.	littletree willow
Salix arctica Pall.	arctic willow
Salix barclayi Anderss.	Barclay willow
Salix glauca L.	grayleaf willow
Salix phlebophylla Anderss.	skeletonleaf willow
Salix reticulata L.	netleaf willow
Salix spp.	

Saxifragaceae

Chrysosplenium tetrandrum (Lund) T. Fries	northern water-carpet
Parnassia palustris L.	northern grass-of-parnassus
Saxifraga bronchialis L.	spotted saxifrage
Saxifraga hieracifolia Waldst. & Kit.	hawkweed-leaf saxifrage
Saxifraga hirculus L.	yellow marsh saxifrage
Saxifraga punctata L.	brook saxifrage
Saxifraga spicata D. Don	spiked saxifrage

Scrophulariaceae

Castilleja elegans Malte	elegant Indian paintbrush
Euphrasia disjuncta Fern. & Wieg.	arctic eyebright
Pedicularis capitata Adams	capitate lousewort
Pedicularis kanei Durand	Kane lousewort
Pedicularis oederi M. Vahl	Oeder lousewort
Pedicularis sudetica Willd.	
Pedicularis verticillata L.	whorled lousewort
Rhinanthus minor L.	yellow rattle

Sparganiaceae

Sparganium hyperboreum Laest.	northern burreed

Thelypteridaceae

Thelypteris phegopteris (L.) Slosson	northern beech-fern

Umbelliferae

Angelica lucida L.	
Cicuta douglasii (DC.) Coult. & Rose	water hemlock
Heracleum lanatum Michx.	cow parsnip

Valerianaceae

Valeriana capitata Pall.	capitate valerian

Violaceae

Viola biflora L.	two-flower violet
Viola epipsela Ledeb.	marsh violet

APPENDIX B: Scientific and common names of mammal species trapped, tracked, or seen near Nyac, Alaska, during the summers of 1980 and 1981. Nomenclature follows Honacki et al. (1982).

Soricidae	
Sorex cinereus Kerr	masked shrew
Sorex hoyi Baird	pygmy shrew
Sorex monticolus Merriam	dusky shrew
Sorex tundrensis Merriam	tundra shrew
Leporidae	
Lepus americanus Erxleben	snowshoe hare
Lepus timidus Linnaeus	northern hare
Sciuridae	
Marmota caligata (Eschscholtz)	hoary marmot
Spermophilus parryi (Richardson)	arctic ground squirrel
Tamiasciurus hudsonicus (Erxleben)	red squirrel
Castoridae	
Castor canadensis Kuhl	beaver
Arvicolidae	
Clethrionomys rutilus (Pallas)	northern red-backed vole
Microtus pennsylvanicus (Ord)	meadow vole
Microtus oeconomus (Pallas)	tundra vole
Ondatra zibethicus (Linnaeus)	muskrat
Lemmus sibiricus (Kerr)	brown lemming
Synaptomuys borealis (Richardson)	northern bog lemming
Dicrostonyx nelsoni Merriam*	collared lemming
Zapodidae	
Zapus hudsonius (Zimmermann)	meadow jumping mouse

Erethizontidae

Erethizon dorsatum (Linnaeus)	porcupine

Canidae

Canis lupus Linnaeus	wolf
Vulpes vulpes (Linnaeus)	red fox

Ursidae

Ursus americanus Pallas	black bear
Ursus arctos Linnaeus	brown bear

Mustelidae

Martes americana (Turton)+	marten
Mustela erminea Linnaeus+	ermine
Mustela nivalis Linnaeus+	least weasel
Mustela vison Schreber+	mink
Gulo gulo (Linnaeus)	wolverine
Lutra canadensis (Schreber)	river otter

Felidae

Lynx canadensis Kerr	lynx

Cervidae

Alces alces (Linnaeus)	moose

* Included for completeness. Known from a specimen collected by L. J. Peyton in 1963 and from great horned owl pellets from the study area.

+ Tracks are ambiguous in the summer. Species presence based upon descriptions from trappers and miners believed knowledgeable. Suitable habitat for each species was present.

APPENDIX C: Notes on wildlife species not studied intensively.

<u>Mammals</u>

snowshoe hare -- very common throughout the study area, especially in shrubs on tailings. Appear to be food base for foxes and goshawks inhabiting tailings.

river otter -- seen infrequently, but during both summers. All sightings were among tailings in areas directly connected to creeks.

red fox -- many sightings, the majority of which were among tailings. Tracks indicate presence throughout study area. Use road system extensively. At least 2 dens believed among tailings.

wolf -- numerous sightings adjacent to lower dredge in 1981. Tracks indicate wide use of road system by several animals.

lynx -- infrequently seen, but always in vicinity of tailings. Location of only probable den in study area was among tailings.

black bear -- common throughout valley bottoms and on benches.

brown bear -- present on ridges, and in valley bottoms during spring movements to fishing areas west of study area.

moose -- small population present in unmined riparian areas. Limited evidence of use of mined areas except roads.

caribou -- not present in study area, although reindeer herd maintained in upper Bear Creek during 1920s.

Birds

raptors -- common throughout study area and surrounding hills. Species hunting among tailings include goshawk, kestrel, great horned owl, boreal owl,and marsh hawk.

shorebirds -- spotted sandpipers common, much more so among tailings than elsewhere. Common snipe and phalaropes limited to unmined marshy areas.

harlequin duck -- extensive use of ponds and slow-moving water among tailings, apparently as breeding and rearing habitat.