WETLAND INFORMATION FOR SOUTHERN ALASKA: WETLAND ENVIRONMENTAL INDICATORS, BIBLIOGRAPHY, AND WETLAND COMMUNITIES

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ABSTRACT

The purpose of this project was to provide State and Federal land managers and environmental regulators information that could be applied to evaluating wetland degradation. The development of 'hydrogeomorphic functional profiles' and other wetland evaluation methods depend on understanding the response of wetlands to human disturbance. To address this need, this project provides descriptions of the response of wetlands to human disturbance, a list of wetland community types, and a bibliography of wetland literature for southeast-, southcentral- and southwest-Alaska.

The wetland communities provide the baseline information needed for describing non-degraded wetland systems for Alaska. Wetland community classifications are developed by land management and regulatory agencies concerned with wetland issues. They are based on ground sampling of vegetation, soils, landform, and other wetland characteristics. Approximately 563 communities were listed during the literature review. Our findings show that there is substantial vegetation-based information available for describing non-degraded wetlands.

A complete bibliography of wetland literature within southern Alaska was developed by searching on various library and government computer databases and contacting individuals working in the field. The search topics included rapid ecological assessment, disturbance, pollution, community types, ecosystem studies, biodiversity, hydrology, soils and vegetation. The results were entered into a database that is maintained by The Nature Conservancy and State Heritage Programs. Key search words were entered for each source. The bibliographic information is also retrievable based on Alaska's Hydrologic Unit Codes (HUC).

Studies of human-disturbed wetlands are rare to nonexistent for much of southern Alaska. Even where wetlands have been disturbed on a regional basis—such as the Anchorage bowl and timber harvests in watersheds of southeast Alaska—few studies have been funded to describe wetland response to disturbance. The paucity of studies on the response of wetlands to disturbance leaves the land manager and environmental regulator at a great disadvantage for understanding wetlands in Alaska.

INTRODUCTION

Implementation of watershed plans typically entails an inventory of a watershed's wetlands and an evaluation of wetland health. The ability to recognize a degraded or healthy wetland is necessary before proceeding with the evaluation. To address this need, the report provides a list of wetland community types, bibliography of wetland literature and information on indicators of wetland degradation for southeast, southcentral and southwest Alaska (see Map). The information is given as both a hard-copy report and an Internet product (http://aknhp.uaa.alaska.edu/).

The wetland communities listed in this report (Appendix 3) provide the baseline information needed for describing non-degraded wetland systems for Alaska. This initial step of describing non-degraded communities is necessary for developing mitigation methods, and complements the development of Hydrogeomorphic (HGM) functional profiles (Brinson 1993). The vegetation component of HGM is typically based on plant communities whether they are degraded or not (Alaska Department of Environmental Conservation 1996).

To evaluate wetland health one needs to be able to also recognize degraded wetlands. This entails knowing how wetland systems react to anthropogenic disturbance in terms of geomorphology, vegetation (habitat), soils and hydrology. Studies describing how wetland communities react to disturbance are available throughout North America including Alaska. Indicators of wetland health are then extracted from these studies. Examples of wetland environmental indicators used in North America include community species composition, soil characteristics and stream bank stability (Padgett et al. 1989, Hansen et al. 1995). The use of these wetland indicators provides a means to conduct rapid ecological assessments on a broad basis. This report provides a summary of the available information on disturbed wetlands by reviewing the wetland literature southern Alaska.

Classifications

Several wetland classifications or wetland-oriented classifications are available within the contiguous USA and Alaska including the USDI National Wetlands Inventory (NWI), the Hydrogeomorphic (HGM; Brinson 1993) method, and the National Vegetation Classification System (NVCS; Grossman et al. 1998). The following brief description of each system is provided to clarify each classification's uses and differences. The National Vegetation Classification System is emphasized because of its value to baseline wetland information.

Figure 1, map of study area.

National Wetlands Inventory. The USDI National Wetlands Inventory is the official National system for mapping wetlands, and is an effective means of delineating wetland boundaries and acreages (Cowardin et al. 1979). The NWI system, however, does not provide a robust method for evaluating wetland health, and, consequently other methods have been developed for this purpose such as HGM and community classifications.

Hydrogeomorphic system. The HGM system was developed primarily for wetland mitigation and evaluation purposes. Although not the only evaluation system—see Hansen et al. (1995)—it has become popular due to its comprehensive approach. HGM's greatest strength is that it is based on "the best Science available" (Brinson et al. 1998) but is only as accurate as the information used to develop it. Critical components of HGM include identification of wetlands with the "highest sustainable functional capacity," and the "least-altered wetlands" (Brinson et al. 1998, Brown and McLeod 1966, Smith et al. 1995). The information for these critical components is primarily derived by compiling and reviewing the existing literature as for this report. The information is then incorporated into the wetland evaluation method.

National Vegetation Classification System. Vegetation-based community classifications have been developed throughout North America, and NVCS is the hierarchy used to store this information. These community descriptions are based on ground sampling of vegetation, soils, landform, and other wetland characteristics much like the methods for HGM. The end result is a classification describing all wetland communities within the geographic range of study. This system is developed for both descriptive, management and mitigation purposes.

The following is a description of a vegetation community described for southeast Alaska, the Sitka Spruce/Peat Moss (*Picea sitchensis/Sphagnum*) community type (Shephard 1995).

> This community type is rare on a global basis (G2). Vegetation is composed of dwarf Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) with a total cover of less than 25%. Limited regeneration is common for both conifer species, and downed logs are uncommon. The shrub layer is dominated by sweetgale (*Myrica gale*), crowberry (*Empetrum nigrum*) and bog cranberry (*Oxycoccus microcarpus*). Typical forbs are bunchberry (*Cornus canadensis*) and nagoonberry (*Rubus arcticus*). The two most common graminoids are Sitka sedge (*Carex sitchensis*) and cotton grass (*Eriophorum angustifolium*). Bryophytes, including peat moss (*Sphagnum*) species, blanket the ground.
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> This type occupies old undisturbed sites of distal outwash plains, floodplains and uplifted marshes. These are ombrotrophic fens, or bogs, typically dominated by peat moss species. The water table is close to the surface most of the year, and the surface topography is level with minor hummock formation.
>
> The soils are usually classified as Histic Cryaquepts and Terric Cryofibrists, and have an average organic matter depth of 41 centimeters over the mineral horizon (fine gravel to silt).
>
> This type was also reported from Dixon Harbor in Glacier Bay National Park (Worley 1977) and by Boggs (1995) on the Copper River Delta.

Wetland community classifications are developed by land management and regulatory agencies concerned with wetland issues, such as the USDA Forest Service, Environmental Protection Agency and the USDI Bureau of Land Management. The ability to evaluate wetland health is typically provided in wetland community classifications. The development of HGM and other systems like it depend on reviewing the information contained within these classifications.

Objectives
This report summarizes the following wetland information for southwest, southcentral and southeast Alaska.

- List of wetland vegetation communities for the description of non-degraded wetlands
- A concise review of environmental indicators of wetland degradation
- Bibliography of all wetland information related to degradation and vegetation, soil or ecosystem description

The results of this project are meant to be built on and, consequently, they are being incorporated into systems that are periodically updated. The list and descriptions of community types are placed into the NVCS hierarchy that is updated annually and is partially funded by both the national network of Heritage Programs (including the Alaska Natural Heritage Program), the EPA, The Nature Conservancy and many other agencies.

METHODS

A complete bibliography of wetland literature within southwest-, southcentral- and southeast-Alaska was developed by searching on various library and government computer databases and contacting individuals working in the subject. The search topics included rapid ecological assessment, disturbance, pollution, community types, ecosystem studies, biodiversity, hydrology, soils and vegetation. The results were entered into the Source Abstract section of the Biological Conservation Database that is maintained by The Nature Conservancy and State Heritage Programs. Key search words were entered for each source. The bibliographic information is also retrievable based on Alaska's Hydrologic Unit Codes (HUC). Within a HUC region all available wetland citations are listed.

A list of wetland communities for southern Alaska was compiled by summarizing communities described in the wetland literature. This information was also identified by HUC unit and entered to the Source Abstract fields of the Biological Conservation Database. Environmental indicators of health were developed by reviewing wetland literature for southern Alaska.

The results were incorporated into the AKNHP web page. The web page includes the environmental indicators document, wetland community list, and bibliography. The wetland bibliography is graphically displayed and downloadable via HUC subregions (total of three HUC regions in southern Alaska).

RESULTS

The results are given in this hard-copy report and as an Internet product.
http://www.uaa.alaska.edu/enri/aknhp_web/index.html

On the web page the following products are given and are downloadable and read using Acrobat Reader:

- Introduction, methods, results, discussion, tables, figures and appendices
- List of vegetation based community types for southern Alaska
- Bibliographic list divided into the three Hydrologic Unit Code regions of southern Alaska

Wetland Community Types
The list of wetland community types and the bibliography provide baseline information on non-degraded wetland systems for Alaska. Wetland community type descriptions are relatively comprehensive for the

southern half of Alaska given the size of the area. Baseline descriptions of undisturbed community types, consequently, are readily available. See Appendix 3 for a full list of community types.

Environmental Indicators of Wetland Disturbance

The following is a summary of the environmental indicators of degraded wetlands that were extracted from the literature. Abstracts of all the studies are provided in Appendix 2. The results of the HGM studies were not included because they are in draft form (Alaska Department of Environmental Conservation 1996). The results are broken into coarse scale landscapes because landscapes—tidal marshes, floodplains—tend to function as ecological units (Brinson 1993). Table 1 lists wetland species indicative of human-caused disturbance. These species are considered increasers because they thrive at the expense of other plants after disturbance.

Tidal Marshes. In tidal marshes, seeding and transplants of Lyngbye's sedge (*Carex lyngbyaei*) and seashore arrowgrass (*Triglochin maritinum*) rapidly recolonized a human-disturbed marsh near Girdwood to a relatively pristine nature (Table 1; Wright et al. 1995). This study suggests that tidal marshes can be restored within a few years to a relatively pristine condition following disturbances such as removal of vegetation or vegetation crushing by vehicles. Exotic plants and plant species unusual to tidal marshes did not invade. Rapid colonization of tidal mud-flats was also noted for natural tidal systems (Boggs 1998, Shephard 1995).

Floodplain. Densmore (1994) studied the response of vegetation on a floodplain rehabilitated after mining. The species composition on the rehabilitated floodplain was similar to successional communities found on a nearby-unmined stream (Densmore 1994). This pattern of vegetation responding as natural communities was also observed by Zasada et al. (1981) in the earliest stages of succession on a logged floodplain. The only species that showed a major increase in cover in the earliest stage of succession following timber harvesting was horsetail (*Equisetum arvense*; Zasada et al. 1981; Table 1). Demeo et al. (1992) also gave general descriptions of vegetation response to logging in wetlands, but the descriptions are not detailed enough to describe environmental indicators.

Table 1. Wetland species indicative of human caused disturbance. Species listed are considered increasers because they thrive at the expense of other plants after disturbance.

Wetland type	Disturbance	Species (common name)
Tidal marsh	Crushing	*Carex lyngbyaei* (Lyngbye's sedge) *Triglochin maritinum* (seashore arrowgrass)
Floodplain (subalpine)	Mine reclamation	*Alnus* (alder)
Floodplain forest	Logging	*Equisetum arvense* (horsetail)
Wet tundra	Reindeer grazing	*Eriophorum callithrix* (cotton grass) *Equisetum* (horsetail) *Arctagrostis* (polar grass) Moss
Peatland types:	Lower water table	
dwarf spruce woodland		*Potentilla fruticosa* (cinquefoil) *Sphagnum* (peat moss) *Carex* (sedge) Moss
dwarf tree scrub		Mixed forest
sedge bog meadow		*Carex* (sedge) Moss
lowland-sedge-wet meadow		*Andromeda polifolia* (bog rosemary) *Scirpus* (tufted club rushes) haircap cranesbill mosses *Cladonia* lichens
lake shore		*Alnus* (alder) *Betula papyrifera* (paper birch) *Salix* (willows) *Calamagrostis canadensis* (bluejoint grass) *Scirpus* (tufted club rushes)

Grazing. On Nunivak Island, Palmer and Rouse (1945) conducted a clipping study to simulate Reindeer grazing on wet tundra. Their study found that an increase in cotton grass (*Eriophorum callitrix*) might be a reliable indicator of overgrazing. Recovery of the wet tundra to more natural conditions took up to nine years, depending on the degree of disturbance.

Palmer and Rouse (1951) also demonstrated that wet tundra dominated by willows and *Arctagrostis* (polar grass) withstood intense grazing without impairing its productivity (Table 1). Intense grazing, however, initiated the invasion of moss, horsetail (*Equisetum*), and polar grass (*Arctagrostis*). In time these species were replaced by weedy genera and species such as wormwood (*Artemisia*), *Coelopleurum*, seabeach sandwort (*Honkeneya*), and horsetail (*Equisetum*) and a decline in mosses.

Peatlands: Water level changes. Hogan and Tande (1983) made observations of changes in species composition in Anchorage area peatlands as a result of artificial water level changes. In a peatland where water level was lowered, a dwarf spruce woodland community was invaded by a cinquefoil-sphagnum open low shrub type (Table 1). Open dwarf tree scrub changed to closed mixed forest. Both dwarf tree woodland and sedge bog meadow changed to sedge-moss-wet meadow.

A lakeshore with a lowered water level was pioneered by alder (*Alnus*), paper birch (*Betula papyrifera*), willows (*Salix*), bluejoint grass (*Calamagrostis canadensis*) and rush (*Juncus*). A lowland-sedge-wet meadow was invaded by bog rosemary (*Andromeda polifolia*), tufted club rushes (*Scirpus*), haircap and cranesbill mosses, and *Cladonia* lichens. Raising of water level drowned mature black spruce (*Picea mariana*) trees on raised ridges and bog islands. On Turnagain Bog survey lines, power and sewer rights of way crisscross the area. These disturbed sites were covered by pioneering sedge-grass vegetation with scattered shallow ponds.

DISCUSSION

The purpose of this project was to provide State and Federal land managers and environmental regulators information that could be applied to evaluating wetland degradation. The development of HGM and other wetland evaluation methods depend on understanding the response of wetlands to human disturbance. Our findings show that there is substantial vegetation-based information available for undisturbed wetlands (Appendix 3), however, studies describing disturbed wetlands are limited (Appendix 2).

We expect the HGM wetland guides to help fill the gap—at certain geographic scales—to understanding the response of wetlands to anthropogenic disturbance. Until these guides are published, the paucity of studies on the response of wetlands to disturbance leaves the land manager and environmental regulator at a great disadvantage for understanding wetlands in Alaska. There is little perceived need for wetland studies due to the scarcity of disturbed wetlands distributed across large areas.

For wetlands that have been studied, anthropogenically disturbed sites tend to follow a natural successional pathway at least in terms of vegetation. Densmore (1994), for example, reported that species composition on a rehabilitated floodplain in Denali National Park and Preserve was similar to successional communities on nearby unmined natural streams (Densmore 1994). Another example is a harvested forest site on well-drained floodplains that responded with alder species. Alder is what would be expected under natural conditions following such disturbances as blowdown or disease-killed trees. This lack of departure from natural succession is due to the type of human-disturbance that predominates in Alaska. These disturbances are typically short-term such as timber harvesting and wetland reclamation following mining, and not continual as for grazing and pollution.

These findings make a quick and easy analysis of the degree of anthropogenic-disturbance difficult. Typically a departure from a non-natural status can be identified using hydrology, geomorphology or vegetation; however, this is not necessarily the case for Alaskan systems. Understanding the stage of succession may be a more accurate method of evaluating a departure from normal.

The subject of exotic species (nonnative) invasion of wetlands is important because of their possible persistence and spread. The literature suggests that human-disturbed sites in Alaska currently do not have any aggressive exotic species except along roadways. Reclaimed wetlands that are seeded or planted with exotics, however, show that these plants can dominate the site and persist indefinitely by resisting the reinvasion of native species. Due to this persistence Elliot (1984) suggests seeding of exotics at low level to allow reinvasion of native species.

It could be argued that studies conducted in southern Canada and the contiguous USA be used to evaluate Alaska's floodplain systems. These non-Alaskan wetland systems, however, are unique enough to not be applicable to Alaska. Much of Alaska's wetland systems are influenced by either glacial-fed streams or permafrost whereas most wetland studies conducted outside of Alaska are on non-glacial-fed systems or lack permafrost.

Following the publication of the HGM guides, we recommend that baseline studies be conducted to evaluate the response of wetlands to human disturbance at a finer time and space scale that those developed for HGM. In most regions of the USA, developers of HGM functional profiles can draw from the accumulated knowledge of studies on wetland succession, nutrient inputs and outflows, hydrology, geomorphology, vegetation succession, and a wetland's response to various disturbance factors. The development of HGM in Alaska is hampered by this lack of information.

The new studies should be conducted in regions of Alaska with the greatest amount of disturbance to wetlands such as the Cook Inlet Watershed, and timber harvested areas of southeast Alaska. The baseline information should include changes in hydrology, geomorphology and vegetation in response to human disturbance. These are purposively the same factors used to develop HGM in order that the information is incorporated into HGM's coarser-scale wetland evaluation method.

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Appendix 2. Descriptions of types of degradation

Wetlands in the Southern part of Alaska have been impacted in many ways. Construction projects, fuel oil spills, wetland filling, overgrazing by reindeer, mining, all-terrain vehicle use, and logging are just some of the ways wetlands have been degraded. This appendix summarizes wetland mitigation projects and studies by general geographic area, followed by more detailed descriptions, including citations, by type of degradation.

Construction

Girdwood. Chugach Electric Association, Inc. (CEA) disturbed a wetland during the rebuilding of a transmission line from Girdwood to Twenty Mile River. The University of Alaska Fairbanks' (UAF) Plant Materials Center rehabilitated various sites within the construction area (Wright et al. 1995). Native plants were used as the seed source and seeds were collected mechanically from three CEA right-of-way areas in 1994 (Wright et al. 1997, Wright et al. 1997). Lyngby's sedge (*Carex lyngbyaei*) was the primary species used for this restoration. In addition, hairgrass (*Deschampsia beringensis*), beach wildrye (*Leymus mollis*), yarrow (*Achillea borealis*), spear bluegrass (*Poa eminens*), lupine (*Lupinus nootkatensis*), bluejoint (*Calamagrostis canadensis*) and sorrel (*Rumex fenestratus*) were used at some sites. Heavy rates of 8-32-16 fertilizer were also applied.

A special mitigation using transplanting of three species (*Carex lyngbyaei*, *Potentilla egedii*, and *Triglochin maritimum*) was conducted in an area considered an eyesore by local residents. *Carex* was the most successful transplant. Wright (1997) notes that although the transplantation activities were successful, seeding accounted for approximately 80% of the vegetation composition by the end of the 1996 season. Native plants that had not been seeded also occurred, suggesting that the fertilizer applications played an important role in revegetation. Wright (1997) notes that seashore arrowgrass (*Triglochin maritimum*) may be more important than Lyngby sedge in regards to initial reinvasion. In addition, short squirrel tail (*Hordeum brachyantherum*) and seaside plantain (*Plantago maritima*) may be important components in future restorations (Wright et al. 1997). Wright (1997) suggests that future projects attempt using seeds of seashore arrowgrass.

Kenai. The UAF Plant Materials Center assisted with the clean up of an illegal wetland fill on the Kenai Peninsula (Wright 1991). They used a seed mix of species native to the area (Wright 1993a) and adapted for wet sites, that consisted of 'Egan' American sloughgrass (*Beckmannia syzigachne*), 50% by weight, 'Sourdough' bluejoint (*Calamagrostis canadensis*), 25%, and 'Norcoast' Bering hairgrass (*Deschampsia beringensis*), 25% (Wright 1992). Subsequent evaluation in August 1991 found a "well established wetland community" (Wright 1992). Both sloughgrass and hairgrass performed well. Percent cover of the area was 98% in 1992 and reinvasion by forbs and sedges was excellent (Wright 1993a).

Fish Creek, Anchorage. Anchorage Water and Wastewater Utility (AWWU) disturbed a wetland along Fish Creek during a construction project. They brought in the Plant Materials Center to assist in the restoration. In August 1990, sprigs of beach wildrye *(Leymus mollis)* were transplanted to higher elevation sites, and low elevation or flooded areas were planted with native sedges (*Carex*), rushes (*Juncus*) and arrowgrass (*Triglochin*). The transplants were harvested from adjacent donor communities. Work resumed in May 1991 with plantings of beach wildrye (*Elymus arenarius*) sprigs and seeded with a hairgrass (*Deschampsia*) mix on three dikes and also on higher ground. In addition, sedges and rushes were transplanted in lower areas (Wright 1992). Wright (1997) stated that "coastal wetlands with silty soils and tidal inundation, require higher than usual fertilizer applications", and that "transplanting proved somewhat ineffective" on this project.

Additional areas needing attention were identified in early 1992 and plantings occurred on June 3, 1992. Seedlings of greenhouse grown sedges, plantain and arrowgrass were planted in areas flooded by high tides. A compacted dike was rototilled and sprigs of beach wildrye *(Leymus mollis)* were planted, in addition to seeding with 'Norcoast' Bering hairgrass (*Deschampsia beringensis*) (Wright et al. 1995). Evaluation was to be conducted in 1995.

Trans-Alaska Pipeline System. Construction of the Trans-Alaska Pipeline System (TAPS) created disturbed areas—including wetlands—that needed revegetation, rehabilitation and restoration. Johnson, Quinn and Brown (1977) discussed the preliminary revegetation of sites revegetated during the 1975 summer construction season. No follow-up of these sites was found in the literature review. Johnson (1984) observed that the TAPS relied mostly on introduced grasses to control erosion and "preliminary observation of (the) seeded areas reveal little erosion but also very low reinvasion by species of native plants." Densmore (n.d.) summarized previous reports on the results of revegetation along the Trans-Alaska Pipeline and noted that many sites were not adequately prepared and that seeded non-native grasses inhibited the invasion of native plants.

Susitna River basin. Helm et al. (1987) studied the effects of fertilizers on ryegrass (*Lolium temulentum*) in a wet-sedge site that was to be used for a base camp for the Susitna hydroelectric project. The "site was selected....because revegetation or mitigation of disturbances to the site may be required after the camp is removed" (Helm et al. 1987). Soils were deficient in N, P and K. The best fertilizer combination seemed to be "low levels of N, high levels of P, and low levels of K" (Helm et al. 1987). They found that both N and P were necessary for a positive plant response. Ryegrass response was better with low levels of both N and P than with high levels of either N or P. They wrote "the best treatment to achieve good aboveground biomass (forage production) or height might be different from the best treatment for cover (reclamation, soil protection)" (Helm et al. 1987).

Palmer Hay Flats and Knik Arm. Sanville (1988) studied the effects of nutrient addition to an Alaskan freshwater wetland to assess the effects of nutrient enrichment on plant production, and to determine nutrient distribution with the *Sphagnum*/sediment substrate. One location was a low bog dominated by peat moss (*Sphagnum*) and ericaceous shrubs and the other was a higher site with *Sphagnum*, ericaceous shrubs and a dispersed alder (*Alnus tenuifolia*) overstory. Plots were treated singly or with combinations of N, P or secondary treated sewage. Sanville reports that herb production increased with nutrient addition, but that sewage addition had no effect. There were no changes in community composition. He also notes that nutrients added singly had minimal effect.

Construction of the Glenn Highway and the Alaska Railroad across wetlands in Knik Arm in the early 1980's changed the hydrology of wetlands and wetland species composition. The Glenn Highway "between the Parks Highway cutoff and the Matanuska River has prevented cross slope drainage, significantly altering water depths and vegetative communities" (Ritchie et al. 1981). Mitigation for these construction projects included culverts to allow for water flow and fish passage, avoidance of important wildlife habitat, and reduction of access to sensitive habitats.

In addition, a waterfowl enhancement project was conducted on the Palmer Hay Flats in a joint agreement by the Alaska Department of Fish and Game and Ducks Unlimited, Inc. Thirteen ponds were constructed with one to three islands within each pond. Islands were seeded and fertilized with seed mixes that included sloughgrass (*Beckmannia syzigachne*), Bering hairgrass (*Deschampsia beringensis*), red fescue (*Festuca rubra*), polar grass (*Arctagrostis latifolia*), bluejoint grass (*Calamagrostis canadensis*), Bebral rye (*Lolium multiflora*) and weal barley (*Hordeum vulgare*) (Campbell et al. 1987). In addition, sprigs of willow (*Salix* spp.) were planted in August. Interim and final reports were not found during this literature search.

Mining

Valdez Creek Mine. Valdez Creek Mine, 55 miles east of Cantwell, was reclaimed by Cambior USA Inc. over a number of years beginning in 1992. Recontouring occurred on upland sites and former settling ponds were reclaimed as wetlands (Alaska Business Monthly 1997). Bob Fisk (Anchorage Area Office of Bureau of Land Management) has photographs of the reclaimed areas.

Nyak. Durst (1984) studied mammal ecosystem interactions on gold mine tailings at Nyac. He examined both the effect small mammals had on the natural revegetation process and whether there was a difference in species composition and mammal abundance between mined and unmined areas. In addition, Durst compared the plant species composition of the valleys, the slopes surrounding the abandoned mine and the tailings. He found that when trees and stumps with their soil, or just the soil, were deposited on the tailings, the community more resembled a riparian community than areas without soil, trees, or stumps.

Moose (*Alces alces*) and beaver (*Castor canadensis*) had the most effect on revegetation (Durst 1984). Moose browsed willow and alder shrubs beside mining roads, keeping the vegetation to about 1m in height. Beavers cut trees for dam and lodge construction, increasing the water-tailing interfaces. They favor balsam poplar (*Populus balsamifera*) and to a lesser extend alder (*Alnus* sp.) for dams and lodges. Willow (*Salix* sp.) were their preferred food source, followed by paper birch (*Betula papyrifera*), balsam poplar and alder. Beaver activity favored white spruce (*Picea glauca*) establishment by removing all competitors. Beaver-cut pieces of balsam poplar and willow washed into ponds and streams, allowing them to colonize from sprouts (Durst 1984, Rutherford and Meyer 1981).

Rutherford and Meyer (1981) also discussed the aquatic vegetation found in and along intertailing channels, ponds and beaver ponds. They noted that beaver-dammed areas allowed for settling of organic material and silt, which initiated the build up of sediments. Beaver dam building also increases the extent of aquatic habitats, and traps naturally occurring silt. This favors revegetation of footslope areas.

A higher density of beaver was found in the mined areas, and red-backed voles (*Clethrionomys rutilus*) had highest densities in areas with a mix of herbaceous and low shrub vegetation and preferred areas with berries (Durst 1984). Bunchberry (*Cornus canadensis*) was the major berry producing plant on the tailings. Voles (Arvicolidae) were found mostly in areas that were densely herbaceous, and meadow voles (*Microtus pennsylvanicus*) were in highest abundance in immature unmined communities. Meadow jumping mice (*Zapus hudsonius*) had similar requirements as the meadow voles, but preferred damp areas to drier ones. Shrews (*Sorex* spp.) preferred dense vegetation – either herbaceous or woody, but few were captured beneath dense alder thickets.

Durst (1981) also studied the vegetational responses to gold dredging. He noted two results from mining gold that affected revegetation of tailings. The first was that the tailing surface consisted of large, washed gravel which was a poor seedbed. Second, there was a low area between tailings, that due to the porosity of the tailings, was frequently moist or filled with water. Rutherford and Meyer (1981) stated that fine textured materials had a greater percentage of voids than coarse textured materials and, therefore, had a greater water holding capacity and a greater availability of water for plant growth.

Reshaping tailings reduced heterogeneity of the tailings and moved the surface above the water table (Durst 1984). Both heterogeneity and water was needed for reestablishment of plant and animal communities. Applying topsoil saved from mining helped revegetation of tailings, and subsequent mammal invasion. Durst also noted that mining methods have changed over the last century. Tailings deposited prior to the 1960's often had strips of unmined land between the mined land. Overburden and stumps were piled onto these tailings and this promoted revegetation. Areas mined after 1963 had less unmined land between the mined land, with less overburden deposited on them. He recommended setting up mining operations so that one year's overburden could be placed on the prior year's tailings, or saved to be placed back on the current year's tailings. Revegetation of the herbaceous understory should "be given as high a priority as woody revegetation" (Durst 1984).

Rutherford and Meyer (1981a) discussed two different methods for encouraging revegetation of gold dredged tailings. The first method was to fill the water-filled trench caused by dredging by regrading the tailing pile. Then the overburden debris was bulldozed from that area (and the area adjacent to it) onto the tailing surface. They estimated that this would increase the area able to support revegetation by about 15% to 30%. A second method was "to pump a portion of the flue discharge into the surface of the tailings", but noted that this method had many disadvantages. In addition, they state "because of the concentration of silts, organic nutrients, and stem and root pieces, overburden material promises to be more effective than flue pumped sand as a fine textured material for enhancing regrowth on tailings." They added "leaving corridors of unmined ground between tailings would also increase habitat diversity by increasing the amount of natural vegetated areas within the tailings area."

Glen Creek, Denali National Park and Preserve. Placer mining for gold occurred on Glen Creek in what is now Denali National Park and Preserve from 1906 through the 1970's. A study of reclamation techniques at two sites on the creek floodplain was begun in 1988 (Densmore and Karle 1998?, Karle 1993, Karle and Densmore 1994, 1994a). The floodplain was stabilized using bioengineering techniques such as anchoring alder (*Alnus crispa*) and feltleaf willow (*Salix alaxensis*) brush bars laterally to the channel and planting willow cuttings along the channel. In addition, methods based on the type of streambed substrate materials, and geomorphic, hydraulic and hydrologic principles were used to design slope and sinuosity for the creek (Karle and Densmore 1994, 1994a). Most of the brush bars survived a flood in 1992, and protected the unvegetated floodplains, but the flood eroded the feltleaf willow cuttings. A difference in sediment deposition and bed material between the two sites was noted after the flood. Karle (1993) observed that the brush bars trapped sediments, as did small, circular ridges left by the bulldozer.

Densmore and Karle also experimented with time released fertilizers. They found that fertilizer-treated feltleaf willows provided a band of vegetation within four years, and recommend the use of time-released fertilizer on nutrient-poor placer mine tailings in subarctic riparian areas (Densmore and Karle 1998?).

Military Sites

Adak. The UAF Plant Materials Center assisted with rehabilitation of a wetland site adjacent to a fish stream on Adak. They seeded with hairgrass (*Deschampsia beringensis*), and transplanted sedge (*Carex* spp.) and beach wildrye (*Elymus arenarius*), and fertilized the undisturbed area next to the site to enhance seed production. By September 1994, "the site supported 90% vegetative cover, comprised of species identical to the surrounding area" (Wright et al. 1995).

King Salmon Airport. Wetland contamination by petroleum seeps from storage tanks and heavy metal contamination from drums and other debris has occurred at and near the King Salmon Airport (KSA). Fluor Daniel Environmental Services, Inc. and their subcontractors have evaluated contamination in human food (berries and mushrooms), in the aquatic biota in four creeks, and the wetlands adjacent to the seeps and debris. OASIS Environmental, Inc. (1997) analyzed berries and mushrooms for "contaminants previously detected at sites during the remedial investigations." OASIS Environmental, Inc. 1997 lists three primary objectives for the project. One was to determine "whether berries and mushrooms are accumulating contaminants that would pose a risk to humans that ingest these foods." A second was to "determine if aquatic species present in the study streams are accumulating contaminants at levels that would pose a risk to humans that ingest these species." The third was "to establish baseline characteristics of the wetlands and to collect the data to evaluate the managed wetlands remediation alternative." As part of this project, wetlands were mapped and characterized at four sites. This is an ongoing project and a final report has not been produced at this time.

Reindeer and Caribou Range Conditions (Overgrazing)

St. Matthew Island. Reindeer (*Rangifer tarandus*) were introduced to various areas in Alaska in the early part of the 20th century. Studies of reindeer ranges have centered on natural recovery of the vegetation, in particular lichens, after grazing. In is unclear as to whether these sites were wetlands or not. Klein (1987, 1959) compared lichen stands on two Bering Sea islands: St. Matthew Island where reindeer were introduced in 1944, and Hall Island where there are no reindeer. In 1964 the reindeer on St. Matthew Island underwent a crash die-off. In 1957, Klein began an investigation of the population dynamics of vegetative species on St. Matthew Island using exclosures to look at vegetation changes due to reindeer grazing and recovery after the die-off. The vegetation was examined in 1957, in 1963 at the peak of the reindeer population, and in 1985 (Klein 1987). Mosses increased 120% by 1963 and 3109% by 1985. Lichens had decreased 83% in 1963 from the 1957 cover but increased 140% by 1985. The species composition of lichens changed compared to Hall Island and to what had been on St. Matthew Island previously. *Cetraria delisei* dominated on St. Matthew Island with 19.1 (g/m^2) percent composition, whereas on Hall Island *Cladina stellaris* and *C. arbuscula* were the dominant species with a total biomass of 400 g/m^2 (Klein 1987).

Bering Sea Islands. Swanson and Barker (1992) studied the condition of reindeer ranges in various areas of Alaska. They reported that wildfire had the greatest impact on the depletion of lichen on the mainland, but overgrazing by reindeer was the greatest cause of depletion on the Bering Sea Islands and some localized areas on the mainland. They noted that indicators of poor condition in low- to mid-elevation tundra are the lichens *Thamnolia*, *Stereocaulon*, *Sphaerophorus* and areas in which crustose forms of *Icmadophila* and *Ochrolechia* are increasing.

Nunivak Island. Wet-sedge-lichen tundra sites on Nunivak Island were intentionally disturbed in such a way as to mimic grazing by reindeer (Palmer and Rouse 1945). At some sites the vegetation was cut to the ground with knives, at others the vegetation and soil were spaded. The degree of disturbance affected the length of time it took for the vegetation to recover. Cotton grass (*Eriophorum callithrix*) was the main species to appear after a disturbance and Palmer and Rouse (1945) suggest it may be a reliable indicator of overgrazing.

Nelchina Caribou Herd. The range of the Nelchina caribou herd includes many vegetation types including what Pegau and Hemming (1970) designated the “shrub birch type”, the “water sedge type”, and the “bog type.” They discussed indications of range deterioration for all vegetation types on the Nelchina caribou range. They also summarized previous reports of studies on the Nelchina caribou herd into one report covering population size fluctuations, range conditions and experiments with exclosures. They noted that “trampling plays a very important role in affecting the vegetation.” In addition, “from the exclosure studies it appears that lichens on the Nelchina range need almost total protection for lengthy periods of time (over 25 years?) to recover fully, yet it only takes 5 to 8 years of use to destroy climax lichen stands."

All-Terrain Vehicles

Wrangell-St. Elias National Park and Preserve. Ahlstrand and Racine (1993) looked at the effects of all-terrain vehicles (ATV) on a shrub tussock community in the Wrangell-St. Elias National Park and Preserve. The study site was an open, low, mixed shrub-sedge tussock bog community. Tests of ATV use occurred on two hundred 2.5 m x 30 m lanes. The vehicles used were the same or similar to vehicles used for subsistence and recreation in Wrangell-St. Elias National Park and Preserve. Tests were run at various time periods in late spring, summer and early autumn. Repeat tests were also run in midsummer. Crowberry (*Empetrum nigrum*) and lowbush cranberry (*Vaccinium vitis-idaea*) were least affected by ATV activity. Dwarf birch (*Betula nana*) was the most impacted. Compression and flattening of the tussocks helped speed the transition to green strips of vegetation. These strips had warmer temperatures and higher soluble nutrient levels when compared to the adjacent tundra.

Racine and Ahlstrand (1991) researched the impact of successive passes of ATV's on thawing of permafrost. The study was conducted concurrently with the research on a shrub-sedge tussock bog community. Four types of ATV's and a 1200-kg Weasel were tested. Early spring passes of ATV's had a greater effect on thawing than later in the season, as well as a greater effect than the Weasel later in the year. Number of passes (or traffic intensity) also had a greater impact in the spring than in the fall.

Forestry/Logging

Southeast Alaska. Alaback (1982) studied changes in the forest community structure after an ecosystem perturbation such as logging, fire or windthrow. He did not discuss whether there were differences in succession depending on the type of disturbance. Three stages were discussed. The first was the Early Successional Stage, followed by the Depauperate Understory Stage, and ending with the Understory Reinitiation (Mature Even Age or Uneven-Aged Old Growth) Stage. The only information gleaned from this articles on wetland sites was that wet microsites with forests less than 30 years old were dominated by ferns such as lady fern (*Athyrium felix-femina)* or shield fern (*Dryopteris dilatata* Hulten) and trailing black current (*Ribes laxiflorum*). In addition, mountain hemlock (*Tsuga heterophylla)* and western red cedar (*Thuja plicata*) had the highest proportion of biomass on the wettest sites and on those sites with the least soil disturbance.

Susitna River Floodplain. Zasada et al. (1981) studied natural revegetation of balsam poplar (*Populus balsamifera*) on a Susitna River floodplain. The area had been clear-cut between 1973 and 1975. A stand adjacent to the clear-cut was used as a control. The type of instrument used for logging (chainsaw or shears) and the season (summer, fall or winter) in which logging occurred influenced the source of regeneration. Sources of revegetation were from seedlings, stump sprouts, branch segments broken and buried during harvesting, and root suckers. They found that surface disturbance increased regeneration for seeds, root suckers and broken branches. Broken branches were more likely to produce new trees if they were buried, seeds reproduced better on mineral soils, and removal of the forest floor benefited root sucker production. In addition, they found that stump sprouting did not produce tree for tree replacement.

Chichigof and Baranof Islands. Responses to clear-cutting by vegetation on Chichigof and Baranof Islands were studied by Schrader (n.d.). Eight successional communities within the Sitka spruce zone were identified along a moisture and disturbance gradient. The investigator was not able to determine whether the water table in the skunk cabbage (*Lysichitum americanum*) sites had been high before clear-cutting or was a result of timber harvest. Spruce seeds germinated on both mineral and organic soils, but most spruce regenerated on logs. Where tractor-yarding occurred, alder (*Alnus* spp.) was taller than spruce (*Picea sitchensis*) and shrubs. Recommendations were: 1) Retaining woody debris on the forest floor, 2) Partial cutting of alluvial sites, 3) Leave windthrow trees instead of salvaging because the root wads are important to the community structure, 4) Single tree harvest by helicopter, 5) Analyze skunk cabbage sites more carefully since they are difficult to regenerate, and 6) Pile small diameter slash in large clumps, or chip the slash and leave it on the site.

Oil Related Activities

Lewis River. The UAF Plant Materials Center assisted Unocal with restoration of a wetland after a fuel spill on the west side of Cook Inlet (Wright 1993). The wetland was adjacent to the Lewis River (Wright 1993a), a major fish stream. Most damage was due to surface excavation from cleanup of the spill. Site cleanup was completed and a seedbed prepared by the end of August. The site was planted with a grass mix that consisted of sloughgrass (*Beckmannia syzigachne*), Bering hairgrass (*Deschampsia beringensis*), bluejoint grass (*Calamagrostis canadensis*) and alpine bluegrass (*Poa alpina*), and then fertilized with 20-29-10 fertilizer. A site evaluation was conducted in September 1991, and August 1992, by which time the site was almost 100% covered by vegetation, with approximately 80% hairgrass, 15% sloughgrass, and 3% bluejoint (Wright 1993a).

Fire

Interior Alaska. Lutz (1956) wrote about the effects of both natural and anthropogenically-caused forest fires and described the communities that resulted after a burn. He looked at different forest types and characterized the "climax" communities found after a burn depending on the type of fire. Black spruce forests on poorly drained soils returned to black spruce forest after a single moderate fire, or several light fires, or to a sedge-rush-grass or low shrub community after several severe fires. After a single severe fire, a black spruce forest will regenerate itself (Lutz 1956). Viereck (1983) also described the revegetation sequence following fire in both upland and wet or mesic black spruce forests.

Wetland Manipulation for Birds and Wildlife

Copper River Delta. Mickelson (1978) described techniques used to manipulate wetlands to enhance habitat for wildlife in the Copper River Delta Wildlife Management Area. Both pond drawdown and fertilization were used to improve the abundance of aquatic plants and invertebrates eaten by ducks, swans and shorebirds. Lowering pond levels enhanced submergent species, especially *Potamogeton pectinatus* and *P. perfoliatus*. Mickelson concluded the drawdown technique was useful "to obtain a better interspersion and higher composition of emergent cover species and submergent food species for waterfowl." Drawdown also increased the availability of invertebrates for shorebirds and waterfowl by concentrating the invertebrates in the water column and by lowering the water level, thus increasing the ability of birds to reach invertebrates in the sediments.

Ponds were also fertilized in late June 1977, but no difference was found in the density of plants between the control and fertilized ponds. Fertilizer may have been applied too late in the season to affect production. Invertebrates, on the other hand, were found at greater numbers in the fertilized ponds.

Environmental Factors

Alaska-cedar (*Chamaecyparis nootkatensis*) underwent a decline in southeast Alaska in about 1880, with the decline most often seen in bog or semibog sites (Hennon et al. 1990). Using aerial photographs from 1927, 1948, 1965 and 1976, Hennon et al. (1990) examined seven stands for evidence of mortality and expansion. Mortality was found at all sites by 1927, and that the boundaries had expanded less than 100m beyond the 1927 limit by 1976. They wrote "development patterns of spreading mortality has followed an ecological gradient, with slow encroachment from bogs to better drained sites." They explained that their data "suggest(s) that bogs, and therefore bog plant communities, were in place well before the onset of Alaska-cedar decline." They discussed a number of causes for the decline and mortality of Alaska-cedar such as paludification, increase in average winter temperatures, poor protection from weather events and cohort senescence.