ECOSYSTEM CONSERVATION STRATEGY FOR IDAHO PANHANDLE PEATLANDS

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PREFACE

The National Forest Management Act of 1976 and Forest Service policy require that Forest Service land be managed to maintain populations of all existing native animal and plant species at or above the minimum viable population level (USDA Forest Service 1991). In the past, this type of biodiversity conservation took place on a species by species basis. More recently, the value of other aspects of biodiversity have been recognized as important conservation elements (Toth et al. 1986; Patton 1992; Marcot et al. 1994). Redirecting conservation efforts from the traditional single-species approach to an ecosystem or unique habitat-based system, such as has been done with coastal Pacific Northwest old-growth forests and associated rare and threatened plant and animal species, can greatly increase the efficiency and effectiveness of biodiversity conservation. Barkham (1993) outlines the conservation strategy put forth by a consortium of ten conservation organizations which has been successful in initiating a comprehensive protocol for the protection of remaining pristine lowland bog habitats in the British Isles. Some of what we propose here follows the criteria established by Barkham.

In Idaho, low and mid-elevation peatlands have been recognized as important habitats characterized by a unique suite of environmental conditions and hosting more than 40 rare plant and animal species (Bursik and Henderson 1995; Conservation Data Center 1994). Idaho peatlands are disjunct by more than 1,000 kilometers from the largely unbroken peatlands in the north. Peatlands are rare in Idaho, particularly low elevation valley peatlands, which are separated from each other by vast stretches of upland. The study of the biota of Idaho's peatlands is much like the discipline of island biogeography where long-distance dispersal and persistence of relict populations must account for their flora and fauna. The isolated nature of peatland habitats in Idaho creates a laboratory for the evolution of ecotypes of more wide-ranging, disjunct species that are uniquely adapted to local conditions.

Our research has shown the peatlands of Idaho's Panhandle region to be very sensitive to subtle changes in water levels and nutrient status brought on by human activities within the peatlands and on adjacent uplands. The health and stability of unique habitats, such as peatlands in Idaho, can reflect the overall health of the greater ecosystem of which they are a part. On the other hand, loss of species within peatlands may reflect poor ecosystem health or improper management schemes. This is why a comprehensive management strategy for peatlands in the Panhandle region is critical. With implementation of the outlined monitoring plan, this conservation strategy will not only aid in the conservation of sensitive peatland habitats, but it can also provide an ongoing valuable critique of prevailing management paradigms and their effects on sensitive species, rare habitats, and the surrounding forested landscape. As F. Dale Robertson, former Forest Service Chief, reflected in a 1991 management directive on the importance of wetlands and riparian areas: "Riparian areas and wetlands are some of the most diverse and productive areas of the National Forest System. Often these key areas visibly reflect the quality and success of land management activities in tributary watersheds... (therefore) I am calling on each of you to strengthen and clarify forest plan standards, where needed, to protect riparian areas and wetlands."

It is in this light that we propose a comprehensive conservation strategy for peatlands in the Idaho Panhandle, with special reference to sites on the Idaho Panhandle National Forests. We discuss the critical peatland sites, the ecology of these sites, their important physical and biotic features, threats to their integrity, existing and recommended protection for the sites, conservation strategy prescriptions, and monitoring and research needs. It is our objective to develop a comprehensive strategy that will assure the protection and maintenance of this unique habitat in the Panhandle region and the rare species that it supports. We believe this strategy can serve as a model for protecting other unique habitats in this region and elsewhere.

We have prepared most of this strategy in manuscript form compatible with the style of the Natural Areas Journal where we plan to submit it for publication. Following the manuscript, Appendix 1 contains specific information about each peatland site, including: (1) a map; (2) the Site Basic Record from the CDC's Biological and Conservation Data System; and (3) CDC occurrence records for all rare species occurring at each site.

Ecosystem Conservation Strategy for Idaho Panhandle Peatlands

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ABSTRACT: Peatlands are rare in the Panhandle region of Idaho and adjacent Washington. They are disjunct by nearly 1000 kilometers from the largely unbroken peatlands occurring at boreal latitudes of North America. As elsewhere, Panhandle peatlands are characterized by species adapted to the unique suite of conditions associated with these habitats. Nearly 10 percent of Idaho's rare flora are disjunct boreal species found in these peatlands. Due to the rarity and sensitive nature of peatlands in northern Idaho we propose a comprehensive conservation strategy that will protect and maintain them and the ecological factors responsible for their occurrence and persistence. We identify critical peatlands of the Panhandle region, discuss the ecology of these sites, their important physical and biotic features, existing and potential threats, recommend conservation designations and management prescriptions, and outline public education, research, and monitoring needs.

INTRODUCTION

Peatlands are generally defined as wetlands with waterlogged substrates and at least 30 cm of peat accumulation. Peatlands are an important terrestrial habitat worldwide, occupying one percent of ice-free continental land masses, including nearly 15 percent of Canada. Peatlands exert an enormous influence on the world's climate. Anaerobic respiration within peat soils may account for nearly 40 percent of the methane released into the biosphere annually. They also act as immense sinks of carbon dioxide, storing an estimated 15 to 20 percent of terrestrial carbon reserves, more than twice the amount in all living northern latitude forests (Breining 1992). Others have estimated the amount of carbon tied up in peatlands is 3 - 3.5 times that present in moist tropical forests, despite covering half the land area (Barkham 1993).

Peatlands contain a unique biota adapted to saturated, oxygen-free, nutrient-poor, and acidic conditions, which limit microbial breakdown of plant tissues and lead to the accumulation of peat (Crum 1988). They are archives of the past, containing plant spore, pollen, and macrofossil remains which allow paleoecologists to infer physical and biotic dynamics of the postglacial landscape. This biological record has direct application to understanding the capabilities and limitations of current and future land management (Miller 1990; Schoonmaker and Foster 1991; Barber 1993). Peatlands are also important economically as a source of horticultural amendment, fiber, and energy.

Historically, peatlands were considered forbidding and worthless lands. Every attempt was made to drain them for afforestation and agriculture or to mine them for fuel. Finland has drained more than half of its 25 million acres of peatland for forestry. Less than five percent of Ireland's three million acres of peatland remain untouched (Breining 1992) and an estimated 91.5 percent of lowland raised bogs in the British Isles have been destroyed (Barkham 1993). Although North American peatlands have fared far better, the continued threat of direct peatland development exists. Indirect impacts from land-use activities in surrounding uplands can be of equal threat to peatland biodiversity because most species are sensitive to small changes in water chemistry and hydrology (Vitt and Slack 1975; Damman and French 1987; Glaser 1987; Bursik and Moseley 1992a; 1992b).

Floristic and ecologic studies of peatlands have been conducted throughout boreal and temperate parts of the world (Gore 1983), including numerous studies in Canada and the eastern United States (Glaser 1987; Crum 1988; Damman and French 1987). Few studies, however, have been conducted in the northern Rocky Mountains of the United States (Rumley 1956; Lesica 1986). During the 1980's, peatlands in northern Idaho became widely recognized as important habitats for rare plants (Rare and Endangered Plants Technical Committee of the Idaho Natural Areas Council 1981) leading to numerous floristic inventories of peatlands around the state, largely by the Idaho Department of Fish and Game's Conservation Data Center (CDC) (Caicco 1987; 1988; Moseley 1989; 1990; 1992; Bursik 1990; 1992; Moseley et al. 1991; 1994a). More recently, we've shifted our focus to understanding community- and landscape-level patterns and processes in Idaho peatlands, at both spatial and temporal scales (Bursik and Moseley 1992a, 1992b; Bursik 1993; Bursik et al. in prep.; Moseley et al. 1992; 1994a).

Peatlands of northern Idaho are largely intact when compared to those in Europe. Our challenge for maintaining the diversity of peatland communities and biota in the region, however, is no less daunting. The rarity and isolation of peatlands on the landscape is coupled with increasing, often incompatible use of adjacent uplands. These small, overlooked sites support the richest rare plant diversity of any habitat in Idaho, containing 10% of the state's rare flora (Bursik and Moseley 1992c). We have identified 45 sites that we consider critical to conservation of the full array of peatland biota and communities of the Idaho Panhandle region. Our objectives in preparing this ecosystem-level conservation strategy are to: (1) describe important biotic and physical features of each site and (2) put forth a comprehensive, ecosystem-level conservation strategy that will assure the long term maintenance and protection of Panhandle peatland biota, communities, and ecological processes. This strategy for the Panhandle is part of a state-wide peatland conservation planning effort being undertaken by the CDC (Moseley et al. 1991; Bursik and Moseley 1992c; Moseley 1992; Moseley et al. 1994a).

STUDY AREA

Climate

The Panhandle region of Idaho is influenced by prevailing westerly airmasses from the Pacific Ocean during the winter and spring, creating an "inland maritime" climate. These airmasses bring prolonged, gentle rains, deep snow accumulation at higher elevations, cloudiness and frequent fog, high humidity, and winter temperatures 8 to 14^{o}C warmer than continental or East Coast areas at similar latitudes (Cooper et al. 1991). Data from the Priest River Experimental Forest, in the Priest River valley, best express the climate of peatland-supporting valleys in northern Idaho, where the average annual precipitation is 80 cm and the average annual temperature is 6.8^{o}C. Although no weather stations exist, subalpine peatland sites in the Selkirk Mountains [Smith Creek Research Natural Area (RNA), Bog Creek, Grass Creek, Cow Creek; Table 1] probably have much higher annual precipitation and lower temperatures. Most of the precipitation occurs in the winter (November through March) as snow. July and August are typically very dry, generally averaging less than 2.5 cm per month (Ross and Savage 1967).

Table 1

Table 1 cont

Geology

Prominent rock types in northern Idaho include granites of the Kaniksu batholith and low-grade metamorphic Precambrian "belt" metasediments (Rabe et al. 1986; Cooper et al. 1991). Cordilleran ice sheets covered much of the Panhandle during the Pleistocene, covering all but three of the southernmost peatland sites. The four subalpine peatland sites in the Selkirk Mountains were influenced more by recent late-Pleistocene and possibly Holocene alpine glaciation, as is the case with subalpine peatlands elsewhere in Idaho (Rabe et al. 1986). Most Panhandle peatlands occur on glacially-influenced topographic features, such as cirques, kettles, scours, and outwash channels. Others, such as Kaniksu Marsh RNA, occur in abandoned meander channels of rivers.

Terrestrial Vegetation

Northern Idaho falls within the western temperate coniferous forest ecosystem, which covers the northern Rocky Mountains of the United States (Daubenmire 1969). Typically, lower-elevation forests in northern Idaho are covered by mixed coniferous forests dominated by Thuja plicata, Tsuga heterophylla, Abies grandis, Pinus ponderosa, P. monticola, Larix occidentalis, and Pseudotsuga menziesii, while higher- elevation forests are dominated by Abies lasiocarpa, Picea engelmannii, and Pinus contorta [Cooper et al. (1991); plant nomenclature follows Bursik and Henderson (1995) for most peatland taxa and Hitchcock and Cronquist (1973) for all others].

SIGNIFICANT SITES

Bursik (1990) recognized two types of peatlands in Idaho, based on vascular floristic composition: (1) valley peatlands are rare and generally occur around lakes and ponds at relatively low elevations in major river valleys from near the Canadian border in the north, to near Driggs in eastern Idaho; (2) subalpine peatlands are common throughout the same portion of Idaho, but form along low-gradient, subalpine streams. Subalpine peatlands are characterized by species common throughout the western cordillera of North America, while valley peatlands are characterized by numerous boreal species whose Idaho populations are disjunct by hundreds of miles from the main portion of their range in boreal Canada. The highest concentration of valley peatlands in Idaho is in the Panhandle region (Figure 1). Only four of the Panhandle sites are subalpine peatlands (Bog Creek, Grass Creek, Cow Creek Meadows, and Smith Creek RNA), all of which are located in the Selkirk Mountains near the Canadian border. These subalpine peatlands are transitional toward valley peatlands based on the presence of numerous boreal species in addition to the typical Cordilleran species. Subalpine peatlands in the Panhandle range in elevation from 1311 to 1666 m, while valley peatlands range from 641 to 1154 m (Table 1).

We have identified 42 significant peatland sites in the Idaho Panhandle and three in adjacent Pend Oreille County, Washington (Table 1; Figure 1; Appendix 1). We included the three Washington sites because they occur along the western edge of the Priest River valley, which contains the densest concentration of peatland sites in the Panhandle, and are managed by the Idaho Panhandle National Forests. The 45 sites represent most of the diversity of flora, communities, and ecological features known in peatlands of the region. The peatlands occur from 48^{o} 59' N latitude, along the Canadian border (Bog Creek), south to 47^{o} 29' in the lower Coeur d'Alene River valley (Thompson Lake). In addition to the three Washington sites, 21 occur in Bonner County, 14 in Boundary County, and five

Figure 1

in Kootenai County. As stated above, the Priest River valley contains the most sites with 19, 11 sites occur in the Kootenai River valley, eight sites in the Pend Oreille River drainage, five are located in the Spokane/Coeur d'Alene drainage, and two in the Moyie River drainage (Table 1).

A majority of the peatland sites are entirely or partially on publicly-owned land. The U.S Forest Service, Idaho Panhandle National Forests, is the primary land manager, managing part or all of 25 sites. Other federal and state agencies, including the U.S. Bureau of Land Management, Idaho Department of Lands, and Idaho Department of Fish and Game, are also peatland managers. Ten of the sites are entirely private land, while portions of 14 others are privately-owned (Table 1). Few of these private sites have any legal or voluntary protection.

ECOLOGY AND FLORA

The term peatland encompasses all wetlands occurring on peat soils. Peatlands can be further subdivided into bogs, which are ombrotrophic, receiving water and mineral nutrients only from rain water, and fens, which are minerotrophic, receiving nutrients from water that has percolated through mineral soil and bedrock, or which has run off from terrestrial lands into a surface source such as a creek. All peatlands are on a trophic gradient from nutrient-poor (bog and poor fen) to mesotrophic (intermediate fen) to relatively nutrient-rich (rich fen) and one type can grade imperceptibly into another. Bogs are dominated primarily by Sphagnum mosses. Fens range from poor fens, which tend toward bog conditions and are dominated predominantly by bryophytes (especially Sphagnum spp.) and some vascular species (sedges and ericads), to rich fens, which are dominated by sedges, other graminoids, and true mosses. Because the greatest distinguishing factor among peatlands appears to be whether they are Sphagnum-rich (bog/poor fen) or Sphagnum-poor (rich fen), Horton et al. (1993) suggested adopting these terms to replace the traditional, often misapplied terms, bog and fen. We agree, but have also identified northern Idaho peatlands and features in the traditional sense.

Northern Idaho supports both Sphagnum-rich and Sphagnum-poor peatlands, often within the same site. Almost all of Panhandle peatland habitat is fen. Only very scattered microsites, in the form of hummocks no more than 10 m^2, constitute ombrotrophic bog. These hummocks contrast sharply in form and floristic composition from surrounding minerotrophic fen where they occur at Chase and Huff lakes. The few peatlands supporting bog microsites occur in the northern portion of the study area, which on average receives the most summer precipitation. Lack of summer precipitation has been shown to limit the geographic extent of raised bog formation (Crum 1988). This appears to be the case in Idaho where, under prevailing patterns of precipitation, poor fen is the likely endpoint of peatland succession.

In his initial study of the peatland flora of Idaho and northwestern Montana, Bursik (1990) found 327 vascular species occurring at both valley and subalpine sites, with only 205 species occurring in the valley peatlands. Subsequent study has revealed the presence of 291 vascular and 20 bryophyte species in the valley peatland flora of Idaho alone (Bursik and Henderson 1995), the majority of which are found in Panhandle peatlands. Subalpine peatland plant diversity is not as high in the Panhandle region as it is elsewhere in Idaho. Two of the four subalpine peatlands included in this conservation strategy are well-inventoried floristically, Cow Creek Meadows and Smith Creek RNA (Bursik 1993). These sites contain a combined 115 species (15 bryophyte and 100 vascular). The floristic composition of the other two sites (Bog Creek and Grass Creek) appear similar.

RARE FLORA

Thirty-eight vascular plant species are considered rare in Panhandle peatlands (Table 2; Appendix 1), representing 10% of the state's rare flora (Conservation Data Center 1994). One species, Tofieldia glutinosa var. absona, is globally known from only one site, while several are restricted to a single known site in Idaho, including Andromeda polifolia, Cypripedium parviflorum, Iris versicolor, and Maianthemum dilatatum. Several others occur exclusively within our study area, including Betula pumila, Carex chordorrhiza, C. comosa, C. paupercula, Comandra livida, Diphasiastrum sitchense, Dryopteris cristata, Gaultheria hispidula, Ludwigia polycarpa, Lycopodium dendroideum, Lycopodiella inundata, Salix pedicellaris, Scirpus fluviatilis, S. hudsonianus, Trientalis arctica, Vaccinium oxycoccos, and Vallisneria americana. The remaining species occur in peatlands elsewhere in Idaho.

Maianthemum dilatatum is a coastal disjunct species in Idaho (Lorain 1988). The remaining rare species are boreal or north-temperate in distribution, disjunct in Idaho from more continuous ranges in the north (Bursik 1990). The most widely occurring rare species include Cicuta bulbifera (15 sites), Epilobium palustre (16 sites), Hypericum majus (14 sites), Scirpus subterminalis (17 sites), and Trientalis arctica (18 sites). The three richest sites, relative to rare flora, are Mosquito Bay Fen, Chase Lake, and Kaniksu Marsh RNA, containing 21, 15, and 13 rare plant populations, respectively (Table 2).

RARE FAUNA

The northern bog lemming (Synaptomys borealis), a rodent restricted largely to peatland habitats, is found at Cow Creek Meadows and is considered rare in Idaho (Conservation Data Center 1994). The grizzly bear (Ursus arctos), a federally listed Threatened species, and the woodland caribou (Rangifer tarandus caribou), an Endangered species, are known to utilize the four subalpine peatlands of the Selkirk Mountains. Grizzly bears have also been recently sighted at valley peatland locations in the Priest River valley.

ECOLOGICAL FEATURES

Ombrotrophic Bog

True bog habitats exist in scattered microsites in Panhandle peatlands (Table 3). The best example is at Chase Lake where distinctly raised hummocks, dominated almost exclusively by Sphagnum spp., have formed over areas up to 10 m^2. Similar hummocks exist at Huff Lake Fen, Armstrong Meadows, and Mosquito Bay Fen over old stumps. Ombrotrophic bogs are dominated by Sphagnum fuscum, S. magellanicum, S. centrale, S. angustifolium, and Polytrichum strictum.

Poor Fen

Extensive poor fen exists at many sites (Table 3). Poor fens are characterized by a solid mat of Sphagnum and scattered stems of vascular plants such as Scheuchzeria palustris, Vaccinium oxycoccos, Carex limosa, C. lasiocarpa, Dulichium arundinaceum, Potentilla palustris, and Lycopus uniflorus.

Table 2

Table 2 cont

Table 3

These habitats are often identified as "bogs" by laymen and ecologists alike, particularly when they occur on floating mats. They are nonetheless minerotrophic and therefore distinguished from true bogs. Some of the most extensive poor fens occur at Hager Lake Fen, Chase Lake, Perkins Lake, Bottle Lake RNA, Kaniksu Marsh RNA, Upper Priest Lake Fen, Lee Lake, and Twin Lakes Fen.

Intermediate Fen

Intermediate fen habitats contain an equal abundance of bryophytes and vascular species. Characteristic bryophytes include Sphagnum spp., particularly S. subsecundum and S. angustifolium, and the brown mosses Calliergon stramineum and Aulacomnium palustre. Vascular species characteristic of intermediate fens include Carex lasiocarpa, C. cusickii, Dulichium arundinaceum, and Potentilla palustris. Intermediate fens grade into poor fens under more nutrient-poor conditions, and into rich fens, dominated by denser stands of sedges, shrubs, and other graminoids with little or no Sphagnum, under more nutrient-rich conditions. Intermediate fens would generally be considered a Sphagnum-rich peatland in the recently proposed, simplified classification of Horton et al. (1993). Most of the Sphagnum-rich habitats of subalpine peatlands (Bog Creek Fen, Grass Creek Fen, Cow Creek Meadows, Smith Creek RNA), for example, are intermediate fens with equal prominence of bryophyte and vascular species. Valley peatlands with extensive intermediate fen habitat include Armstrong Meadows, Huff Lake Fen, Chase Lake, Kaniksu Marsh RNA, Twin Lakes Fen, Hauser Lake Fen, Rose Lake, and Thompson Lake.

Rich Fen

Sphagnum spp., with the exception of S. teres, are conspicuously absent from rich fen habitats. Valley peatland rich fens are dominated by dense stands of certain sedge species, such as C. lasiocarpa, C. rostrata, and C. chordorrhiza, other graminoids, including Typha latifolia, Calamagrostis canadensis, and Scirpus microcarpus, and shrubs, such as Spiraea douglasii, Betula glandulosa, and Salix geyeriana. Rich fens in subalpine peatlands are typically characterized by Carex scopulorum, C. aquatilis, Calamagrostis canadensis, Deschampsia cespitosa, Betula glandulosa, and Salix commutata. Brown mosses, including Aulacomnium palustre and Calliergon stramineum, may be common in rich fens, although the growth of vascular plants is often dense enough to shade out most bryophytes.

Rich fens are the most diverse of the peatland types in northern Idaho, and cover the most area. All Panhandle peatlands contain rich fen communities (Table 3). Three rich fen types occur in valley peatlands. Dense rhizomatous monocultures of C. lasiocarpa occur at Mosquito Bay Fen, Sinclair Lake, Rose Lake, Chase Lake, and Dubius Creek Fen. A marsh-like Typha latifolia/C. lasiocarpa rich fen occurs on floating mats at McArthur Lake WMA, Chase Lake, Blue Lake, Gamlin Lake, Beaver Lake (South), Shepherd Lake, Hoodoo Lake, Kelso Lake, and Rose Lake. Many of the shrub carr habitats (described below), dominated by dense stands of Spiraea douglasii, Betula glandulosa, and Salix spp., are classified as rich fens (Table 3).

Floating Mat

Floating mats are a classic feature of peatlands throughout their range. Any of the above peatland types can occur on floating mats. Floating mats are largely restricted to valley peatlands containing ponds or lakes (Table 3). Indeed, floating mats may provide the proper substrate for growth of many boreal peatland species. Their absence from subalpine peatlands may be the greatest contributing factor to floristic differences with valley peatlands (Bursik 1990). On floating mats the living vegetation occurs on a mat of peat that floats on water or very unstable muck below.

Floating mats contain the most ecologically stable communities within peatlands because they adjust with fluctuating water levels by as much as 0.75 meters annually, hence maintaining constant contact with water while never becoming inundated like fixed mats (Crum 1988). Changes in the composition of floating mat communities are generally a function of trophic status changes, making them ideal monitoring sites to ascertain the effects of human activities that may contribute to nutrient runoff into peatlands (Bursik and Moseley 1992a). Extensive Sphagnum-dominated floating mats occur at Bottle Lake RNA, Perkins Lake, Huff Lake, Three Ponds RNA, Hager Lake Fen, Lee Lake, Chase Lake, and Kaniksu Marsh. Examples of extensive intermediate and rich fen floating mats dominated by shrubs, cattails, and sedges occur at Dawson Lake, Blue Lake, Gamlin Lake, Beaver Lake (South), Lost Lake, Shepherd Lake, and Thompson Lake.

At some sites, small, floating mats dominated by various bryophyte and vascular species have formed on partially submerged logs in lakes and ponds. Particularly good examples of these pioneer mats are at Robinson Lake, Huff Lake Fen, and Beaver Lake (North). Monitoring these mats (as we are doing at Huff Lake Fen) can shed light on the mode and rate of mat expansion in the Panhandle region and environmental factors that affect it.

Shrub Carr

Shrub carr habitats are shrub-dominated fens and are classified as intermediate or rich fen, depending on the prominence of Sphagnum spp. This type of habitat occurs at most Panhandle peatlands (Table 3). Most commonly one or several shrubs dominate vast areas of moist to wet, sometimes seasonally flooded fen. Spiraea douglasii, Alnus incana, Betula glandulosa, and several willows, including Salix bebbiana, S. drummondiana, and S. geyeriana, are of widespread or local prominence in shrub carr habitats in northern Idaho. Many shrub carrs are dominated by dense monocultures of Spiraea douglasii. Betula pumila, a rare species in Idaho, is prominent in shrub carrs of the Moyie River and Kootenai River valleys (Table 2).

Paludified Forest (Peatland Swamp)

As peat accumulates in a lake basin, the water level tends to rise and "flood" adjacent uplands; a process known as paludification. These paludified uplands are subsequently colonized by sphagnum mosses and other peatland species. Paludified forests are associated most closely with valley peatlands whose lake basins are almost entirely filled with peat. These sites include Upper Priest Lake Fen, Mosquito Bay Fen, Armstrong Meadows, Deerhorn Creek Meadows, and Lee Lake (Table 3).

Cool, moist climatic conditions are conducive to paludification, while hotter, drier climatic periods favor afforestation of paludified areas. Paludification in some areas precedes the formation of poor fen and bog habitats (Crum 1988). It is unknown how paludification fits into broad peatland successional trends in northern Idaho, due to the prolonged summer droughts that characterize this region. A cyclic sequence of moist coniferous forest to forested Sphagnum rich fen to open Sphagnum/Carex fen and back to paludified forest may characterize the areas we have identified as paludified. The intermediate conditions (forested Sphagnum fen) prevails now in paludified sites which are characterized by the odd combination of conifers, including Pinus contorta, P. monticola, Abies grandis, A. lasiocarpa, Picea engelmannii, Thuja plicata, and Tsuga heterophylla growing with Sphagnum centrale, Vaccinium oxycoccos (bog cranberry), and other poor fen species in the understory.

Lake/Pond

Significant standing bodies of water occur at a majority of the sites (Table 3). Some sites occur around ponds [<8 ha; Rabe and Chadde (1994)], while others have formed around the margins of lakes [>8 ha; Rabe and Chadde 1994)]. Hager Lake Fen, Huff Lake Fen, Three Ponds RNA, Potholes RNA, and Chipmunk Potholes are examples of the former situation, while Mosquito Bay Fen on Priest Lake and Twin Lakes Fen exemplify the latter. Where present, ponds and lakes affect the successional dynamics of a peatland with periodic water level fluctuations that can flood fixed mats, deposit sediment and nutrients during high water, or leave floating mats stranded during low water. Cyclic drought and wave action on lakes and ponds are responsible for the formation and expansion of floating mats. Open water also attracts birds and mammals that may be dispersal vectors for peatland species or which may influence physical conditions of the site, as in the case of beavers. The soft, acidic waters of peatlands are also the habitat for numerous invertebrate species, several of which are strictly adapted to such conditions (Rabe et al. 1986).

Littoral and Limnetic Vegetated Aquatic Zones

All of the Panhandle peatlands with lakes or ponds contain vegetated littoral (<2 m deep) and/or limnetic zones (>2 m deep) (Rabe and Chadde 1994). More than 15 percent of the valley peatland flora of Idaho consists of aquatic species, while a similar percentage are facultative aquatic species (Bursik and Henderson 1995). Most of the lake sites have extensive vegetated littoral and limnetic zones with a high diversity of aquatic plant species (Table 3).

Stream

Several stream types described by Rabe et al. (1994) are found in Panhandle peatlands (Table 3), including spring streams with very short runs (e.g., at Kaniksu Marsh RNA, Upper Priest Lake Fen, and Mosquito Bay Fen), spring streams with long reaches (Potholes RNA), and meandering glide streams in broad valleys (all four subalpine peatlands, Packer Meadows, Deerhorn Creek Meadows, Bear Creek Fen, and Dubius Creek Fen). Several lake sites serve as the headwaters for creeks (e.g., Bottle Lake RNA and Chase Lake). Streams are the main feature allowing for beaver activity, which is a significant part of Panhandle peatland ecology. Some streams host a handful of vascular and bryophyte plant species, adapted to life in slow-moving water. All are the habitat for an array of invertebrate species and several contain populations of rainbow, cutthroat, and eastern brook trout (Rabe and Savage 1977).

Beaver Activity

Beavers exert an enormous influence on Panhandle valley peatlands (Table 3). Beaver activity is responsible for the initial formation of fen habitats at two of the RNA peatlands, Bottle Lake and Potholes. Damming at Packer Meadows, Beaver Lake (North), Kaniksu Marsh RNA, Beaver Lake (South), and Dubius Creek Fen is responsible for the formation of large ponds or the periodic expansion of ponds into lakes. During inactivity the dams break and large mudflats are colonized by a host of pioneer marsh and fen species. Over time, perennial, rhizomatous sedges, such as Carex lasiocarpa, colonize these mudflats. When water levels rise again, the rhizomatous mats can become buoyant, forming floating mats which provide substrate for the colonization of Sphagnum spp. and other fen species.

Wholesale changes brought on by beavers in Idaho peatlands was illustrated by the study of Rabe and Savage (1977) at Bottle Lake RNA. Aerial photographs of Bottle Lake from 1932 and 1956 bear little resemblance to each other. Apparently 1932 was near the end of a long period without beavers at Bottle Lake. In 1932, the central doughnut-shaped, Sphagnum-dominated mat was surrounded by a sedge fen with scattered trees. The mat rested on the basin bottom allowing the growth of Thuja plicata, Tsuga heterophylla, and other conifers. The lake within the mat supported emergent (Nuphar polysepalum) and submergent aquatic plants. By 1956, beaver damming had flooded the sedge fen surrounding the floating mat, replacing it with littoral plant communities and killing the scattered trees. The doughnut-shaped mat once again had become a buoyant island, the conifer trees that had been established on it during low water were dead, and the lake within the mat had become too deep to support Nuphar. These conditions persisted until today.

Artificial manipulation of dynamic hydrological regimes at Bottle Lake RNA or any other sites with significant beaver activity could significantly disrupt processes at play for millennia that have allowed the long-term persistence of a wide array of species adapted to various successional stages within the peatland. Long-term stability (maintenance of water level and nutrient status) in peatlands leads toward poor fen formation and a gradual depauperization of the flora as sphagnum takes over and guides the course of succession autogenically (Crum 1988). Episodic beaver activity creates and maintains a mosaic of successional stages within a site and contributes to the habitat and floristic diversity of Panhandle peatlands (Bursik and Henderson 1995).

Site-Feature Evaluation

Several peatlands stand out as having the greatest ecological diversity. Chase Lake contains all twelve of the ecological features discussed above. It contains the most extensive floating mats known in the region and the largest bog microsites in the state. Additionally, extensive poor, intermediate, and rich fen communities occur around beaver ponds upstream along the inlets and downstream along Chase Creek. Potholes RNA and Kaniksu Marsh RNA contain ten of the twelve ecological features. Both of these sites lack bog microsites and lake habitats, although each contains a large pond. Rose Lake has ten of the features, lacking only bog habitat and paludified forest. Mosquito Bay Fen also supports ten of the ecological features, only lacking a floating mat and beaver activity. These five sites are among the most floristically diverse peatlands in Idaho, each containing more than 100 plant species (Bursik and Henderson 1995). With the exception of Rose Lake, these sites also contain the densest concentrations of rare plant populations (Table 2).

CONSERVATION OF PANHANDLE PEATLANDS

Threats

As stated earlier, the two most critical factors affecting the abundance and distribution of peatland species in northern Idaho are water level and the nutrient concentration of incoming water. Wildfires, drought, and beaver activity bring periodic changes in these two factors and consequent shifts in location and abundance of peatland species. The abrupt, large-scale, and often irreversible nature of changes in hydrology and nutrient concentrations that result directly or indirectly from human activities, however, may be beyond the tolerance level of resident populations to relocate and persist.

Several large areas of former peatland in the Panhandle have been totally altered by major ditching, filling, and development, and are barely recognizable as peatlands today. An area near Coolin, in the Priest River valley, was identified as a "cranberry bog" in surveyor records from the late-1800's. The site no longer supports Vaccinium oxycoccos (bog cranberry) and has little peat substrate remaining. The disappearance of fourteen species at Hager Lake Fen during the last 40 years, including four rare species, was likely caused by ditching, which eliminated flooding around the lake (Bursik and Moseley 1992a). Without flooding, shrub growth in the surrounding Spiraea douglasii carr simply became too dense to support the species in the understory (Bursik et al. in prep.). Eventually the proper niche for these species was eliminated.

Ground disturbance around Hager Lake Fen following homesteading near the turn of the century had profound affects on the flora by causing temporary eutrophication. We documented an increase in weedy wetland species in the pollen and macrofossil record and changes in the composition of vegetation zones within the fen that would be expected with eutrophication (Rumely 1956; Bursik and Moseley 1992a; Bursik et al. in prep.). Ground disturbance associated with home building, road building, logging, and grazing is the most widespread threat to Panhandle peatlands. Only a handful of the sites, including the five RNAs have adequate upland buffers to eliminate this threat.

At Huff Lake Fen, the only other peatland where we have pre-1990's data on floristic composition, we found a similar level of change over the last 20 years (Bursik and Moseley 1992b). Thirteen species have disappeared, including three rare species, several of which has also disappeared from Hager Lake. Altered hydrology and increased nutrient inputs from adjacent road building and maintenance seem the most likely causes (Bursik and Moseley 1992b).

Peatlands around lakes with regulated water levels (Twin Lakes Fen, Hauser Lake Fen, Robinson Lake) could be threatened with a loss of species dependent on naturally fluctuating water regimes. Beavers have been removed from several sites because they have caused flooding on nearby roadways. Beaver activity is critical to the maintenance of habitat diversity that allows numerous species adapted to various seral stages to survive in Panhandle peatlands. Long-term maintenance of water levels can lead to the gradual depauperization of the flora in peatlands (Crum 1988). Such "unnatural" changes could be underway at sites with regulated water levels.

Grazing takes place within and around peatland communities at several of the privately owned sites and in two managed by the Forest Service (Cow Creek Meadows and Hoodoo Lake). We have implemented a vegetation monitoring study and made management suggestions to protect sensitive peatland communities at Cow Creek Meadows from direct grazing threats (Bursik 1993). It is too early to assess the impacts of cattle on the peatland communities of Cow Creek Fen, but 20- and 40-year changes in plant populations and vegetation at Huff Lake Fen (Bursik and Moseley 1992b) and Hager Lake Fen (Bursik and Moseley 1992a) indicate that subtle changes in hydrology and nutrient regimes that can result from cattle grazing could lead to changes in community composition and structure.

Little peat mining has taken place in Idaho, and only one site on private land in the Panhandle is known to be semi-actively mined. This type of habitat destruction may be increasing, however, as private landowners and mining companies are becoming increasingly interested in exploiting peat deposits in southeastern Idaho (J. Lukens, Idaho Department of Fish and Game, Pocatello, personal communication, 1994).

Site Boundaries

We have delineated the boundaries of each Panhandle peatland to include all peatland habitat, lake and pond, adjacent marsh and other wetland habitats, and adequate upland buffers. Adequate upland buffer zones are critical to the maintenance of species and community diversity in these sites. The boundary of the upland buffer zones vary depending on slope, aspect, and vegetation but generally extend 200 meters from wetland/water margin into the adjacent upland. Ground-disturbance within site boundaries should be avoided or minimized. Road maintenance activities within the sites should be done in such a manner to avoid impacts on water quality. We suggest the 200 meter buffer zone extend the entire reach of inlet streams to protect incoming water quality.

Site Protection

All 45 peatland sites addressed in this strategy are critical for the maintenance of a diverse peatland ecosystem in northern Idaho. We have stratified the sites into two protection classes based on the richness of ecological features (Table 3) and rare plant species (Table 2) and on the human disturbance history (site quality).

Class I Sites

Nine peatlands meet richness and site quality criteria to qualify them as Class I sites. Five of these sites have already been protected as Research Natural Areas by the Idaho Panhandle National Forests: Smith Creek RNA, Bottle Lake RNA, Three Ponds RNA, Potholes RNA, and Kaniksu Marsh RNA (Hilty and Moseley 1991). The RNA designation used by federal agencies, including the Forest Service and BLM, is an ideal protection vehicle for relatively small, unique habitats such as Panhandle peatlands. These peatland RNAs represent most of the ecological and floristic diversity known in northern Idaho peatlands (Table 3). Several features, however, are not well-represented, including bog microsites (absent from the five sites), paludified forest (poorly represented), and Typha latifolia/Carex lasiocarpa rich fen found on floating mats (absent from these sites, despite all supporting a rich fen).

Four additional peatland sites should receive the maximum protection available: Perkins Lake, Mosquito Bay Fen, Rose Lake, and Chase Lake. Assuring the long-term protection of these important sites would result in representation of virtually all known Panhandle peatland habitat and floristic diversity within a protected-areas system. The requirement for the RNA-eligible habitats being "pristine" or largely unaltered by humans (Federal Committee on Ecological Reserves 1977) is met at these sites because the minor attempts to ditch and drain these peatlands failed. All four sites are only partially publicly-owned, and Chase Lake has no federal land necessary for RNA protection. Because of the mixed ownership, which includes significant private land, these four sites should be high priorities for land acquisition, land exchange, and conservation easement programs of The Nature Conservancy, Forest Service, and BLM.

Perkins Lake would be the easiest site to designate as a RNA because the Forest Service owns all but the western end of the site. Land exchange efforts of the Forest Service could focus on this privately owned area along the inlet to achieve full public ownership and protection of the site. RNA designation could proceed now without acquisition of the west end, however.

The Forest Service manages 10% of the nearly 50 ha of peatland habitat at Mosquito Bay Fen. This land is incorporated into the Upper Priest Lake Scenic Area, which is protected in an agreement between the USFS and Idaho Department of Lands. Two private parties own the majority of Mosquito Bay Fen. Both are currently involved in a lawsuit regarding Mosquito Bay Fen and water level management on Priest Lake. Future acquisition of this land would seem promising after the lawsuit is settled and should be considered the highest land acquisition priority of any privately owned peatland in Idaho. RNA designation could proceed following acquisition.

Fen habitats along Rose Creek on the southwestern side of Rose Lake are managed by the Forest Service and the Idaho Department of Fish and Game. Large tracts of the peatland habitat on the east, west, and north sides of the lake and further upstream along Rose Creek, now privately owned, should be acquired and incorporated into Coeur d'Alene River Wildlife Management Area, which is cooperatively managed by Fish and Game and other agencies. The peatland areas on Forest Service land surrounding Rose Lake could then be designated RNA.

The largest portion of Chase Lake is managed by the Idaho Department of Lands. The Nature Conservancy should approach the department regarding the cost of safeguarding this diverse site. The Department of Lands' mission is to maximize return to the public school endowment, regardless of the source. This can be done with conservation money as well as from exploitation of resources. In addition, land protection efforts of the Conservancy, BLM, and Forest Service should focus on the south end and northwestern corner of the lake, which are currently under private ownership.

Class II Sites

The remaining 36 peatlands are all Class II sites and should be afforded some level of protection, if they are not already. Upper Priest Lake Fen is protected as part of the Upper Priest Lake Scenic Area by the Forest Service and Idaho Department of Lands. Several sites, including Rose Lake, Hidden Lake, Thompson Lake, and McArthur Lake WMA, are wholly or partially managed by the Idaho Department of Fish and Game as Wildlife Management Areas, where they are largely protected from inappropriate development activities. Most of the peatlands around Gamlin Lake are being protected by the BLM and The Nature Conservancy. One tract at the north end of the lake remains in private ownership. The Nature Conservancy owns a conservation easement on an important tract at Hager Lake Fen. The Forest Service manages a small, but important tract, while the third tract is privately owned. One of the two private owners of Rose Fen is voluntarily protecting part of this important site in the Kootenai River valley.

Cow Creek Meadows has been nominated as a Special Interest Botanical Area (Bursik 1993), but has yet to be established as such. The Special Interest Area (SIA) is a Forest Service designation that recognizes special botanical, zoological, or geologic features, protects them without eliminating many management options, and encourages public education (Shevok 1988). It is a less restrictive land use designation than a RNA. All other Class II peatland sites on Forest Service land qualify for the SIA designation.

Public Education

It is doubtful that a person exists who is not captivated by the carnivorous adaptations of sundews and bladderworts to the nutrient-poor environs of peatlands, or who has not been shocked at the quaking underfoot when traversing a floating mat for the first time. In the past, knowledge of the whereabouts of Panhandle peatlands and their intriguing constituents have been restricted to locals who forage for cranberries in the fall, a few adventuresome fishermen, and a handful of biologists, teachers, and their students. If we can make the public aware of the incredible aesthetic, recreational, and pragmatic values of peatlands as habitat for numerous unique and unusual organisms, as sites of landscape monitoring, as archives of landscape history, and as carbon sinks in the battle against global warming, we will achieve public support for their long-term protection.

Privately owned peatlands and those around popular recreation lakes require special attention. Lake Associations should be informed of the sensitive nature of the peatland habitats on their lakes. These associations, comprised of lakefront homeowners, are generally very concerned about maintaining water quality and preserving pristine habitats around their lakes. Educating residents about the potential detrimental effects that sewage, fertilization, and ground disturbance within the buffer zones could have on peatlands should be a priority.

Because of the out-of-the-way or hard-to-get-to nature of many of the 45 critical sites, no special protection measures aside from those outlined here are required to keep them in pristine, undisturbed conditions. Thanks to the comprehensive nature of the peatland inventory in the Panhandle region we can select certain representative easy-to-get-to sites among the peatland SIAs to expose and educate the public without resulting in significant resource damage. Interpretive facilities are generally not compatible with RNA objectives and should be discouraged from established or proposed RNAs, except under special circustances, such as at Perkins Lake and Rose Lake Fen, where raods and boat docks already provide reasonable access to peatland communities.

Two sites on the Priest Lake Ranger District of the Idaho Panhandle National Forests have great interpretive potential. Dubius Creek Fen is located just east of Highway 57, approximately half-way between Priest River and Priest Lake. The extensive nature of peatland communities coupled with easy access make this area an excellent candidate for a visitor center and interpretive walkways. Huff Lake Fen is the site of our recent floristic and vegetation study (Bursik and Moseley 1992b) and an ongoing paleoecological study (Moseley et al. 1992). It is located just off the main road accessing the northern part of the Ranger District. A short wooden plank walkway could be built to access the lake and a portion of the floating mat community, which hosts several rare plant populations and a population of round-leaf sundew (Drosera rotundifolia), one of several carnivorous plants that inhabit Panhandle peatlands. Interpretive information could include discussions of floristic and vegetational changes at the site, the human activities that may have contributed to them, and the value of our monitoring and paleoecological studies in learning how to properly manage forest resources in the area.

Other easily accessible sites with interpretive potential include Sinclair Lake and Perkins Lake on the Bonners Ferry Ranger District of the Idaho Panhandle National Forests. Perkins Lake has an extensive floating dock for angler access that was built through the floating mat in the late 1980's. This dock could be used for interpretive purposes. A well-maintained road skirts the edge of the lake and fen communities, offering access to a considerable amount of habitat for similar purposes. Sinclair Lake also has an angler dock and excellent access to fen communities surrounding the lake where a wooden plank walkway could be constructed.

An Idaho Fish and Game boat launch at Rose Lake provides a staging and parking area for an interpretive walkway that could extend into the fen communities along the east side of the lake, if this area is acquired by a public agency or The Nature Conservancy. Upper Priest Lake Fen occurs along a portion of the Idaho Centennial Hiking Trail. A boardwalk system through the extensive fen and paludified forest communities could provide a peatland wilderness experience for hikers enjoying the state's natural heritage.

Peatlands are important for wildlife of all types. At least two Panhandle peatlands (Dawson Lake and McArthur Lake) are part of the state's Watchable Wildlife Program, complete with wildlife viewing areas. Coordination of development of interpretive walkways in Panhandle peatlands could be done through the Watchable Wildlife Program. Forest Service, BLM, and CDC botanists and wildlife biologists can work together in design and placement of trails, and in development of interpretive programs appropriate for each site. Education of Lake Associations could also be done through the Watchable Wildlife Program.

Research and Monitoring Needs

Inventory

Although it is likely that other significant sites will be discovered, we believe that after two decades of inventory the most important peatland sites in the Panhandle are included in this conservation strategy. Inventory of the peatland habitats themselves then, can be considered largely complete in the Panhandle region.

Biotic inventory in Panhandle peatlands has focused almost exclusively on the vascular flora (Bursik 1990; Bursik and Henderson 1995) and, to a lesser extent, on bryophytes (Bursik and Henderson 1995) and aquatic invertebrates (Rabe and Savage 1977; Rabe et al. 1986). Further inventory work is needed on terrestrial vertebrate and invertebrate fauna, fungi, and bryophytes of Panhandle peatlands. Scattered trapping of small mammals has revealed the presence of disjunct populations of bog lemmings in at least one Panhandle peatland (Groves and Yensen 1989). Similar finds are likely among the lesser known portions of the peatland biota with further inventory.

Classification

Classification is often considered the first step in understanding the nature and dynamics of habitats in order to properly manage them. When the CDC began studying Idaho's valley peatlands in 1987, we tried to discern repeating patterns of vegetation that could be used in a classification of habitats, similar to other wetland classification schemes in the region (e.g., Tuhy 1981; Mutz and Queiroz 1983; Boggs et al. 1990). This habitat classification was to form the basis of our peatland ecosystem conservation efforts (Bursik and Moseley 1992c). We have since come to the conclusion that the only pattern in the state's peatland habitats is that there is no pattern. Typical classification methods would yield a large number of community types of small size occurring in a fine-grained mosaic. Classification of other wetland systems can yield similar results (Winward and Padgett 1989). In addition, few repeatable units occur over more than just a localized area of the state.

Others have observed that peatland classifications based exclusively on vegetation dominance can be relatively meaningless except in a localized context (Gore 1983; Crum 1988). The widely accepted peatland classification that recognizes bog, poor fen, intermediate fen, and rich fen is sufficient for the region and relatively easy to apply in the field. No additional classification work is necessary or recommended.

Monitoring

The establishment of long-term studies, including monitoring programs have been recommended for a variety of ecological systems (Leopold 1962; Likens 1983). Through carefully designed monitoring studies we can begin to understand the magnitude and direction of change in dynamic landscapes and alter human activities and management paradigms appropriately (Noss 1990; Mueggler 1992). Our recent reanalysis of previous studies of Panhandle peatlands have revealed a disturbing level of change that is likely attributed directly or indirectly to human activities (Bursik and Moseley 1992a; 1992b; Bursik et al. in prep.).

Periodic reanalysis of water chemistry, flora, and vegetation along permanent transects and within permanent plots established at Cow Creek Meadows, Smith Creek RNA, Hager Lake Fen, and Huff Lake Fen must be continued. Additionally, we recommend placing at least two permanent monitoring plots in all Class I peatlands following protocol we developed for peatland community monitoring in the Sawtooth Valley (Moseley et al. in prep.). We used the methods of Bourgeron et al. (1992), which are compatible with Forest Service ECODATA methods (Jensen et al. 1994).

Routine vegetation and water chemistry monitoring is recommended for peatlands where management activities such as grazing or timber harvest occur within or immediately adjacent to site boundaries. Determination of effects on the flora or vegetation should result in alteration of the management activity accordingly or avoidance of that management option in or near peatlands in the future.

Monitoring of surface water quality and invertebrate populations, which have been studied for many years by Fred Rabe, professor emeritus, University of Idaho (Rabe and Savage 1977; Rabe et al. 1986; Rabe and Chadde 1994), should be continued. The volumes of data amassed by Dr. Rabe from Panhandle peatlands over the past several decades should be cataloged and organized for future use in monitoring.

Research

Hager Lake Fen is the best-studied of the Panhandle peatlands. It has been the subject of several paleoecological studies, some of which are still in progress (Hansen 1939; Rumely 1956; Mack et al. 1978; Bursik et al. in prep.). Rumely (1956) carried out a detailed vegetational study of Hager Lake Fen, which we used to ascertain 40-year vegetational and floristic changes at the site (Bursik and Moseley 1992a). The report of Karg (1973) was used to detect floristic and vegetation changes at Huff Lake Fen (Bursik and Moseley 1992b). Vegetation and floristic monitoring studies have also been initiated at Cow Creek Meadows and Smith Creek RNA to ascertain the effects of cattle grazing on fen communities and rare plant populations along Cow Creek (Bursik 1993). Peat cores were extracted from Huff Lake Fen in 1992, although no funds are currently available to study them (Moseley et al. 1992).

Further synecological research on peatland communities and autecological studies of particular peatland species (particularly those considered rare) should be encouraged among graduate students and researchers at regional universities. Other areas of research interest include peatland habitat values and uses for wildlife, terrestrial vertebrate and invertebrate population dynamics in peatlands, plant dispersal mechanisms via wildlife, gradients responsible for plant distribution within peatlands, population genetics of rare peatland species, the history of paludified forests in the region, and the role of beavers in successional dynamics within Panhandle peatlands.

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LITERATURE CITED

Andrus, R.E., and E.F. Layser. 1976. Sphagnum in the northern Rocky Mountains of the United States. The Bryologist 79:508-511.

Caicco, S.L. 1987. Field investigations of selected sensitive plant species on the Idaho Panhandle National Forest. Conservation Data Center, Idaho Department of Fish and Game, Boise. 44 p.

Caicco, S.L. 1988. Studies in the genus Carex on the Idaho Panhandle National Forest. Conservation Data Center, Idaho Department of Fish and Game, Boise. 44 p.

Barber, K.E. 1993. Peatlands as scientific archives of past biodiversity. Biodiversity and Conservation 2:474-489.

Barkham, J.P. 1993. For peat's sake: conservation or exploitation? Biodiversity and Conservation 2:556-566.

Boggs, K., P. Hansen, R. Pfister, and J. Joy. 1990. Classification and management of riparian and wetland sites in northwestern Montana. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula. 217 p.

Bourgeron, P.S., R.L. DeVelice, L.D. Engelking, G. Jones, and E. Muldavin. 1992. WHTF site and community survey manual, version 92B. Western Heritage Task Force, The Nature Conservancy, Boulder, Colorado.

Breining, G. 1992. Rising from the bogs. Nature Conservancy (July/August):24-29.

Bursik, R.J. 1990. Floristic and phytogeographic analysis of northwestern Rocky Mountain peatlands, U.S.A. M.S. Thesis, University of Idaho, Moscow. 37 p.

Bursik, R.J. 1992. Field investigation of sensitive plant taxa occurring on the Priest Lake Ranger District, Kaniksu National Forest, Idaho Panhandle National Forests. Conservation Data Center, Idaho Department of Fish and Game, Boise. 141 p.

Bursik, R.J. 1993. Fen vegetation and rare plant monitoring in Cow Creek Meadows and Smith Creek Research Natural Area, Selkirk Mountains, Idaho. Conservation Data Center, Idaho Department of Fish and Game, Boise. 25 p.

Bursik, R.J., and R.K. Moseley. 1992a. Forty-year changes in Hager Lake Fen, Bonner county, Idaho. Conservation Data Center, Idaho Department of Fish and Game, Boise. 31 p.

Bursik, R.J., and R.K. Moseley. 1992b. Forty-year changes in Huff Lake Fen, Kaniksu National Forest. Conservation Data Center, Idaho Department of Fish and Game, Boise. 26 p.

Bursik, R.J., and R.K. Moseley. 1992c. Prospectus - Valley peatland ecosystems project, Idaho. Conservation Data Center, Idaho Department of Fish and Game, Boise. 16 p.

Bursik, R.J., and D.M. Henderson. 1995. Low elevation valley peatland flora of Idaho. Madrono in press.

Bursik, R.J., P.J. Mehringer, and R.K. Moseley. In prep. Recent paleoecological history of Hager Lake Fen with special regard to rare plant population management.

Conservation Data Center. 1994. Rare, threatened, and endangered plants and animals of Idaho. Third edition. Idaho Department of Fish and Game, Boise. 39 p.

Cooper, S.V., K.E. Neiman, and R. Steele. 1991. Forest habitat types of northern Idaho: a second approximation. General Technical Report INT-236, U.S. Department of Agriculture, Forest Service, Ogden, Utah. 135 p.

Crum, H. 1988. A focus on peatlands and peat mosses. University of Michigan Press, Ann Arbor. 306 p.

Damman, A.W.H. and T.W. French. 1987. The ecology of peat bogs of the glaciated Northeastern United States: a community profile. U.S. Fish and Wildlife Service Biological Report 85(7.16).

Daubenmire, R. 1969. Ecological plant geography of the Pacific Northwest. Madrono 20:111-128.

Federal Committee on Ecological Reserves. 1977. A directory of Research Natural Areas on federal lands of the United States of America. U.S. Department of Agriculture, Forest Service, Washington D.C. 280 p.

Glaser, P.H. 1987. The ecology of patterned boreal peatlands of northern Minnesota: a community profile. U.S. Fish and Wildlife Service Report 85(7.14).

Gore, A.J.P. 1983. Introduction. Pp. 1-34 in A.J.P. Gore, ed., Ecosystems of the World, Part 4A, Mire: Swamp, Bog, Fen, and Moor. Elsevier, Amsterdam.

Groves, C.R. and E. Yensen. 1989. Rediscovery of the northern bog lemming (Synaptomys borealis) in Idaho. Northwest Naturalist 70:14-15.

Hansen, H.P. 1939. Pollen analysis of a bog in northern Idaho. American Journal of Botany 26:225-228.

Hilty, J., and R.K. Moseley. 1991. Idaho Natural Areas directory. Conservation Data Center, Idaho Department of Fish and Game, Boise. 212 p.

Hitchcock, C.L., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle. 730 p.

Horton, D.G., N. Malmer, and D.H. Vitt. 1993. Peatland classification: how important are bryophytes? Abstract. Supplement to the American Journal of Botany 80(6):1-2.

Jensen, M.E., W. Hann, R.E. Keane, J. Caratti, and P.S. Bourgeron. 1994. ECODATA-A multiresource database and analysis system for ecosystem description and evaluation. Pp. 192-205 in M.E. Jensen and P.S. Bourgeron, eds., Volume II: Ecosystem Management Principles and Applications. General Technical Report PNW-GTR-318, U.S. Department of Agriculture, Forest Service, Portland, Ore.

Karg, K. 1973. Huff Lake bog. Kaniksu National Forest, Coeur d'Alene, Idaho. 27 p.

Lawton, E. 1971. Moss flora of the Pacific Northwest. Hattori Botanical Laboratory, Nichinan, Miyazaki, Japan. 362 p.

Leopold, L.B. 1962. A national network of hydrological bench marks. Geological Survey Circular 460-B, U.S. Geological Survey, Reston, VA.

Lesica, P. 1986. Vegetation and flora of Pine Butte Fen, Teton County, Montana. Great Basin Naturalist 46:22-32.

Likens, G. 1983. A priority for ecological research. Bulletin of the Ecological Society of America. 64:234-243.

Lorain, C.C. 1988. Floristic history and distribution of coastal disjunct plants of the northern Rocky Mountains. M.S. Thesis, University of Idaho, Moscow. 221 p.

Mack, R.N, N.W. Rutter, V.M. Bryant Jr., and S. Valastro. 1978. Reexamination of postglacial vegetation history in northern Idaho: Hager Pond, Bonner Co. Quaternary Research 10:241-255.

Marcot, B.G., M.J. Wisdon, H.W. Li, and G.C. Castillo. 1994. Managing for featured, threatened, endangered, and sensitive species and unique habitats for ecosystem sustainability. General Technical Report PNW-GTR-329, U.S. Department of Agriculture, Forest Service, Portland, Ore. 39 p.

Miller, N.G. 1990. The management of rare plants: suggestions derived from paleoecological studies of late-pleistocene floras. Pp. 159-162 in R.S. Mitchell, C.J. Sheviak, and D.J. Leopold, eds., Ecosystem Management: Rare Species and Significant Habitats, New York State Museum, Bulletin 471, Albany.

Moseley, R.K. 1989. Field investigations of 16 rare plant taxa occurring in wetlands on the Bonners Ferry Ranger District, Idaho Panhandle National Forests. Conservation data Center, Idaho Department of Fish and Game, Boise. 75 p.

Moseley, R.K. 1990. Field investigations of eight rare plant taxa occurring in wetlands on the Sandpoint Ranger District, Idaho Panhandle National Forests. Idaho Department of Fish and Game, Conservation Data Center, Boise. 42 p.

Moseley, R.K. 1992. Ecological and floristic inventory of Birch Creek Fen, Lemhi and Clark counties, Idaho. Idaho Department of Fish and Game, Conservation Data Center, Boise. 29 p.

Moseley, R.K., R. Bursik, and M. Mancuso. 1991. Floristic inventory of wetlands in Fremont and Teton counties, Idaho. Conservation Data Center, Idaho Department of Fish and Game, Boise. 60 p.

Moseley, R.K., R.J. Bursik, and P.J. Mehringer. 1992. Paleoecology of peatlands at Huff and Hager Lakes, Idaho Panhandle National Forest: FY92 year-end summary. Conservation Data Center, Idaho Department of Fish and Game, Boise. 5 p.

Moseley, R.K., R.J. Bursik, F.W. Rabe, and L.D. Cazier. 1994a. Peatlands of the Sawtooth Valley, Custer and Blaine counties, Idaho. Conservation Data Center, Idaho Department of Fish and Game, Boise. 66 p.

Moseley, R.K., R.J. Bursik, F.W. Rabe, and L.D. Cazier. In prep. Long-term ecological monitoring of peatlands: An example from Idaho.

Mueggler, W.F. 1992. Cliff Lake Bench Research Natural Area: Problems encountered in monitoring vegetation change in mountain grasslands. Research Paper INT-454, U.S. Department of Agriculture, Forest Service, Ogden, UT.

Mutz, K.M., and J. Queiroz. 1983. Riparian community classification for the Centennial Mountains and South Fork Salmon River, Idaho. Meiiji Resource Consultants, Layton, Utah. 106 p.

Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology 4:355-364.

Patton, D.R. 1992. Wildlife habitat relationships in forested ecosystems. Timber Press, Portland, Ore.

Rabe, F.W., and N.L. Savage. 1977. Aquatic natural areas in Idaho. Idaho Water Resources Research Institute, University of Idaho, Moscow. 109 p.

Rabe, F.W., R.C. Biggam, R.M. Breckenridge, and R.J. Naskali. 1986. A limnological description of selected peatland lakes in Idaho. Journal of the Idaho Academy of Science 22:63-89.

Rabe, F.W., and S.W. Chadde. 1994. Classification of aquatic and semiaquatic wetland natural areas in Idaho and western Montana. Natural Areas Journal 14:175-187.

Rabe, F.W., C. Elzinga, and R. Breckenridge. 1994. Classification of meandering glide and spring stream natural areas in Idaho. Natural Areas Journal 14:188-202.

Rare and Endangered Plants Technical Committee of the Idaho Natural Areas Council. 1981. Vascular plant species of concern in Idaho. Bulletin 34. Forest, Wildlife and range Experiment Station, University of Idaho, Moscow. 161 p.

Ross, S.H., and C.N. Savage. 1967. Idaho earth science geology, fossils, climate, water, and soils. Idaho Bureau of Mines and Geology, University of Idaho, Moscow, ID. 271.

Rumely, J.H. 1956. Plant ecology of a bog in northern Idaho. Ph.D. Dissertation, Washington State University, Pullman. 85 p.

Schoonmaker, P.K. and D.R. Foster. 1991. Some implications of paleoecology for contemporary ecology. The Botanical Review 57:204-245.

Shevok, J.R. 1988. Native plant diversity and special area designations on the National Forests in California. Fremontia 16:21-27.

Toth, E.F., D.M. Solis, and B.G. Marcot. 1986. A management strategy for habitat diversity: using models of wildlife-habitat relationships. Pp. 139-144 in J. Verner, M.L. Morrison, and C.J. Ralph, eds., Wildlife 2000: modeling habitat relationships of terrestrial vertebrates, University of Wisconsin Press, Madison.

USDA Forest Service. 1991. Threatened, endangered and sensitive plants and animals. Forest Service Manual. Chapter 2670. Washington, D.C.

Vitt, D.H. and N.G. Slack. 1975. An analysis of the vegetation of Sphagnum-dominated kettle-hole bogs in relation to environmental gradients. Canadian Journal of Botany 53:332-359.

Winward, A.H., and W.G. Padgett. 1989. Special considerations when classifying riparian areas. Pp. 176-179 in D.E. Ferguson, P. Morgan, and F.D. Johnson, compilers, Proceedings - Land classification based on vegetation: Applications for resource management, General Technical Report INT-257, U.S. Department of Agriculture, Forest Service, Ogden.

Appendix 1

Maps, Site Basic Records, and Occurrence Records for rare species occurring at each of the 45 significant peatland sites in the Idaho Panhandle region.

NOTE: This voluminous appendix is not included in all copies, AND IS NOT INCLUDED ON THE CDC HOMEPAGE VERSION.