ECOSYSTEM ANALYSIS AND CONSERVATION PLANNING FOR THE CLEARWATER REFUGIUM, CLEARWATER AND NEZ PERCE NATIONAL FORESTS

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ABSTRACT

The Clearwater refugium is a unique ecosystem occurring in low-elevation tributary canyons of the Clearwater River in north-central Idaho. Since the plants and plant communities of this ecosystem reflect a climate more characteristic of coastal forests, they are thought to be relicts of Miocene vegetation that survived regional climatic changes in these protected canyons. Because numerous rare plants are associated with the refugium, in habitat that is itself rare, this landscape-level study was conducted to survey for rare plants and to describe the range of habitats they occupy. A Gradsect (gradient section) approach was used to sample the range of bioenvironments present. Target species consisted of all Forest Service Sensitive species associated with the canyon refugia: Blechnum spicant (deerfern), Botrychium spp. (moonworts), Cardamine constancei (Constance's bittercress), Carex hendersonii (Henderson's sedge), Cornus nuttallii (Pacific dogwood), Polypodium glycyrrhiza (licorice fern), Thelypteris nevadensis (Sierra woodfern), and Trientalis latifolia (western starflower). Habitats of the four most common species (B. spicant, C. constancei, C. hendersonii, and T. latifolia) were described using Ecodata methods. Data on community composition were subjected to a combination of classification and ordination methods for descriptive purposes and to examine underlying environmental variables. Field observations were used as the basis of a discussion of metapopulation structure and its relationship to population viability. Occurrences of Sensitive plant species were entered into an ARC/INFO geographic information system database.

Core habitats of the target species are closely tied to the range of the Thuja plicata/Adiantum pedatum (western redcedar/maidenhair fern) habitat type and inclusions of wetter fern understory unions. Sensitive species and disjunct coastal species are tied in varying degrees to certain canyon sections where this habitat is expressed. Although ranges of the target species overlap to a large degree, optimum habitats differ as indicated by an ordination of plant community samples. In this report we describe the ranges and habitats of four commonly encountered Sensitive species and discuss their metapopulation structure. We then divide the study areas into "conservation units" - large, cohesive land units that can be used as a basis for management and planning-and address biological values and conservation planning for each land unit.

INTRODUCTION

Low-elevation canyons on the west slope of the Bitterroot Mountains in northern Idaho harbor a forest ecosystem that is unique (Daubenmire 1969). While it bears many similarities to those west of the Cascade crest, it also contains Rocky Mountain biotic elements that make it globally unique. Researchers who have studied this ecosystem consider it a relict or refugium of conditions that were once more widespread in the Rocky Mountains during the Miocene and Pliocene, but became restricted as the climate became drier during the Pliocene and Pleistocene (Steele 1971; Crawford 1980; Lorain 1988).

The refugium ecosystem is most strongly expressed in two somewhat separate areas: along the lower North Fork Clearwater River, and at the confluence of the Lochsa and Selway Rivers. These river canyons provide habitat for almost 40 disjunct coastal plant species, some of which are rare, occurring nowhere else in the Rocky Mountains (Roper 1970; Johnson 1973, Lorain 1988). *Trientalis latifolia* (western starflower), *Carex hendersonii* (Henderson's sedge), *Thelypteris nevadensis* (Sierra woodfern), *Cornus nuttallii* (Pacific dogwood), and *Blechnum spicant* (deerfern) exhibit this type of distribution. This moist-canyon ecosystem also contains plants and animals endemic to northern Idaho, such as the mustard *Cardamine constancei* (Constance's bittercress; Crawford 1980) and bryophagous beetles of the family Byrrhidae (Johnson 1987). The regional endemic *Mimulus clivicola* (bank monkeyflower) is also restricted to this ecosystem in the Clearwater basin (Lorain 1992). All seven plant species mentioned above are Forest Service Sensitive Species (Moseley and Groves 1992) and the habitats in which they occur can also be thought of as rare and sensitive. Although certain areas and species associated with the refugia have received considerable attention in the last two decades, the ecosystem as a whole has not been studied in any integrated or comprehensive way.

A considerable portion of the ecosystem was inundated by the filling of Dworshak Reservoir in the early 1970's and much of the remaining habitat has been impacted by construction of roads, campgrounds and administrative sites. The ecosystem also contains large timber volumes and its long-term conservation is becoming a concern on the Clearwater and Nez Perce National Forests which manage most of the lands involved.

Historically, biological conservation efforts have focused on single species. Recently however, more attention has focused on ecosystem- or landscape-level approaches (Hunter 1991) which may be especially pertinent to ecosystems with numerous rare elements. This study combines aspects of both approaches by targeting a group of species of overlapping ranges and attempting to define and describe the ecosystem as a whole. This study is part of a proactive approach by the Clearwater and Nez Perce National Forests to planning for the long-term conservation of the Clearwater refugium ecosystem.

Policy and direction

Section 6(g) of the National Forest Management Act (NFMA) states that distinct biological communities or ecosystems that are unique, rare, or highly productive warrant management attention. Section 5 of the Endangered Species Act (ESA) directs the Secretary of Agriculture to establish a program to conserve fish, wildlife, and plants. In order to comply with this act the Forest Service developed a Threatened, Endangered, and Sensitive species program, as stated in Chapter 2670 of Title 60 of the Forest Service Manual, to assure that National Forest lands are managed to maintain viable populations of all native plant and animal species. A viable population is defined as the number of individuals of a species necessary to perpetuate that species' existence in a natural, genetically stable, self-sustaining condition. Sensitive species are defined as species in need of special management consideration to prevent their decline.

THE CLEARWATER REFUGIUM ECOSYSTEM

Origins of Coastal Disjunction

High numbers of Pacific coastal disjuncts are part of the flora on seaward slopes of the Rocky Mountains from southeastern British Columbia to the Salmon River in eastern Idaho (Roper 1970, Steele 1971, Johnson and Steele 1978, Lorain 1988). A thorough review of the vegetational history of the region is presented by Daubenmire (1975) who was first to explain the presence of these "oceanic elements" as relic populations of a once widespread mesic-temperate Miocene flora. The eastward extent of this Miocene forest in Northern Idaho was isolated by changing climatic patterns resulting from the gradual uplifting of the Cascades, complete in the Miocene. At least forty plant species occurring in the Clearwater River basin exhibit such coastal-disjunct distributions. The relatively high number of endemic plant taxa associated with the Clearwater Mountains, including *Cardamine constancei* (Constance's bittercress), *Synthyris platycarpa* (evergreen kittentails), *Dasynotus daubenmirei* (dasynotus), *Corydalis caseana var. hastata* (Case's corydalis), and *Waldsteinia idahoensis* (Idaho barren ground strawberry), may represent descendants of Miocene elements that were better adapted to the developing Rocky Mountain climate than to that of the coast (Daubenmire 1975).

Several low-elevation river canyons of the Clearwater basin contain coastal biota that are particularly rare inland, including plants, animals, and plant communities. During glacial advances of the Pleistocene, these canyons–the first deep canyons south of the extent of glaciation–may have provided a refugium for plants with relatively high heat requirements. Plant communities in these canyons reflect the warm-moist extreme of northern Idaho habitats (The Nature Conservancy et al. 1987). These canyons probably also provided essential upstream and downstream migration pathways during several major climatic fluctuations that occurred between the Pleistocene and the present (Steele 1971).

Location

The North Fork Clearwater, Lochsa, and Selway rivers drain the Bitterroot divide westward and eventually unite to form the Clearwater River (Map A1). Canyon refugia occur at the lowest-elevation canyon sections. Based on floristic elements present, the refugium environment is most strongly expressed along the lower North Fork Clearwater River and at the confluence of the Lochsa and Selway Rivers where they meet to form the Middle Fork Clearwater River. Most of the lands involved are administered by the US Forest Service, including portions of both the Clearwater and Nez Perce National Forests.

Physical setting

Gradual uplifting of the Clearwater Mountains, which continued into the Pleistocene, resulted in an estimated 4000-ft (1200-m) rise in elevation. This uplift greatly increased stream gradients, producing rapid downcutting that continues to the present. The resulting landscape is characterized by steep, high-relief landforms and oversteepened, unstable slopes (Wilson et al. 1983). Rolling to mountainous uplands separating major canyons rise to peaks of 6000-7000 ft (1800-2100 m). The refugium ecosystem occupies v-shaped, unglaciated valleys where elevations at the river bottom are 1400 to 1800 ft (430-550 m). Slopes rise abruptly from the valley bottom to form very steep, highly dissected breaklands with a dense network of high-gradient streams. Landforms of the river breaks vary from cliffs and talus to small benches formed by past slumping.

Geology and soils

Surficial geology of the Clearwater Mountains is primarily a result of granitic intrusions of the Idaho Batholith, primarily quartz monzonite, into overlying Precambrian metamorphic rocks. This activity, accompanied by a gradual uplifting of the entire region, resulted in severe warping and folding of bedrock dating from the Mesozoic period (Ross and Savage 1967). Metamorphics are primarily gneiss, quartzite, and coarse- to medium-grained schists (Rember and Bennett 1979). Steep slopes underlain by schist bedrock are very unstable and mass-wasted slopes are common topographic features.

Soils are formed predominantly from coarse-grained crystalline rock types. In addition, volcanic ash, probably resulting from the cataclysmic eruption of Mt. Mazama (6700-6800 YBP), mantles much of the region. Thickness of the ash mantle varies from over 10 inches (25 cm) in depositional and undisturbed sites, to a complete absence of ash where it was lost to erosion (Steele 1971). The comparatively high water-holding capacity of ash-influenced soil relative to that of soil derived from coarse-grained crystalline rock implies an importance of ash content to plant growth.

Climate

The canyon refugia are thought to express a unique climate resulting from a combination of low elevation, mountainous terrain, and the dominant influence of Pacific-maritime weather patterns (Daubenmire 1975). Temperatures within the canyons are moderate due to the low elevation. Although the mouth of the North Fork Clearwater River lies some 300 miles inland, the elevation is only 980 ft (300 m). At the same, time these deeply incised canyons lie at the western edge of a great mountain mass receiving abundant orographic precipitation and oriented to maximally intercept prevailing weather patterns which bring warm, moist coastal air masses inland. This combination of high precipitation and moderate temperatures closely parallels Pacific coastal climates (Crawford 1980).

In the Clearwater basin, over 90 percent of annual precipitation occurs during fall, winter, and spring months resulting from a succession of eastern-moving frontal systems. These events tend to produce long-duration, low intensity precipitation. Low clouds, fog, and high humidity are also characteristic during the non-summer months. Snow accounts for about 40 percent of annual precipitation at low elevations. Summers are typically dry due to stationary high pressure systems over the northwest coast. Summer precipitation is associated with convectional storms (Wilson et al. 1983).

No detailed, long-term weather record exists for the North Fork study area. Annual precipitation of 36.3 inches (922 mm) has been measured at Bungalow Ranger Station along the North Fork, approximately 20 miles (32 km) upstream of what is generally considered the zone of maximum maritime affinity. Weather station data from Fenn Ranger Station, within the Lochsa/Selway refugium, indicates average annual precipitation of 38 inches (965 mm) and an average temperature of 50 degrees F (10 degrees C; US Weather Bureau 1989).

Vegetation

Canyon refugia lie at the southern extent of the cedar-hemlock forest zone, south of the main range of western hemlock (*Tsuga heterophylla*) which occurs only rarely along the North Fork. Upland forests are dominated by grand fir up to about 5500 ft (1670 m) where it is replaced by subalpine fir (*Abies* *lasiocarpa*) and mountain hemlock (*Tsuga mertensiana*). In places, forests above the refugia have been significantly fragment by ongoing timber harvest.

Vegetation of the river breaklands is strongly influenced by aspect, with western redcedar the climax tree species in valley bottoms, on north-facing slopes, and in side drainages. On south aspects, grand fir habitat types extend down nearly to the valley bottom and usually support seral stands of Ponderosa pine or Douglas-fir. Mixed stands of western redcedar and grand fir form the predominant cover type on the river breaks, reaching to 4000 ft (1200 m) in the deepest canyon sections. Extensive shrubfields cover some areas where conifers have not regenerated following fire or logging. Old-growth forest is scarce as a result of fire history and timber harvest. Some of the oldest stands occur on river terraces in the main drainage bottoms. Red alder (*Alnus rubra*), a coastal disjunct tree species, forms a persistent seral type on unstable slopes and along major drainages that are occasionally flooded. The oldest, most extensive inland stands of red alder occur along the North Fork Clearwater River and have been used to define the North Fork refugium (Steele 1971). Paper birch (*Betula papyrifera*) is a consistent component of forests along the Middle Fork and its tributaries, but is more limited along the North Fork.

The lush understory vegetation of lower slopes and valley bottoms is characterized by the *Adiantum pedatum* (maidenhair fern) understory union and includes an unusually high diversity of fern species. Maidenhair fern occurs here at the southern end of its Idaho range. Many disjunct coastal plants are associated with the *Thuja plicata/Adiantum pedatum* (western redcedar/maidenhair fern) habitat type and wetter fern understories. Twelve disjunct coastal species and three endemics are associated with the Clearwater canyon refugia (Table1). Eight of these are Forest Service Sensitive species.

The existing mosaic of vegetation types in the Clearwater River canyons is the result of extensive stand-replacing fires in the first half of the twentieth century. Catastrophic fires swept through the area in 1910, 1919 and, along the Lochsa River, again in 1934 (Maps G1-G3). The prevalence of fire during this time period was due in part to human causes including the setting of fires to expose ore veins. Some areas, such as the lower Lochsa River canyon, have burned repeatedly.

Table 1. Rare and disjunct plant species associated with the Clearwater refugia.

	Distribu-tion	USFS status*	Fed. status*	North Fork	Selway/ Lochsa
Target study species**					
Blechnum spicant	disjunct	s	-	x	x
Botrychium, subgenus *Botrychium*	circumboreal	s	-	x	
Cardamine constancei	Idaho endemic	s	3c	x	x
Carex hendersonii	disjunct	s	-	x	x
Cornus nuttallii	disjunct	s	-		x
Polypodium glycyrrhiza	disjunct	s	-	x	
Thelypteris nevadensis	disjunct	s	-	x	
Trientalis latifolia	disjunct	s	-	x	
Other					
Alnus rubra	disjunct	-	-	x	x
Corydalis caseana var. hastata	Idaho endemic	-	3c	x	x
Cypripedium fasciculatum	western US	s	C2	x	x
Equisetum telmatiea	disjunct	-	-	x	x
Festuca subuliflora	disjunct	-	-	x	x
Juncus effusus var. pacificus	disjunct	-	-	x	
Mimulus clivicola	regional endemic	s	3c	x	x
Rubus ursinus	disjunct	-	-	x	x
Viola sempervirens	disjunct	-	-	x	x

* s (Forest Service Sensitive); C2 (Category 2: Listing as threatened or endangered may be appropriate, but more data are needed); 3c (former candidate, found to be more abundant or less threatened than previously thought)

** For more information see Appendix B.

METHODS

Delineation of study areas

A study area was delineated in each of the two core refugia areas based on the known distribution of disjunct coastal species on Forest Service lands. The distribution of *Blechnum spicant* was not considered in delineating the study areas because of its lack of overlap with other disjunct species. The North Fork study area extends from the western boundary of the Clearwater National Forest, near the upper end of Dworshak Reservoir, upstream to Kelly Forks Ranger Station–a distance of approximately 50 river miles (80 km; Maps A2 and A3). The study area includes both sides of the river and tributary streams to the 3400-ft (1040 m) contour, encompassing roughly 42,000 acres (17,000 ha). The upper elevation of 3400 ft is approximately the upper limit of the known distribution of target species within the study areas. The largest tributary streams–Isabella, Skull, Quartz, and Weitas Creeks–were truncated at their first major tributary as a practical consideration. Elevation at the river ranges from 1600 ft (490 m) at Dworshak Reservoir to 3000 ft (915 m) at Kelly Forks.

The Lochsa/Selway study area extends from the National Forest boundary along the Middle Fork Clearwater River, upstream on the Lochsa to Split Creek, and upstream on the Selway to Selway

Falls, for a total of 45 river miles (72 km; Maps A4 and A5). The study area encompasses the main river corridor and tributaries to the 3400-ft contour. Included are lower portions of O'Hara Creek and Meadow Creek–two major, low-elevation tributaries of the Selway. Elevation at the river ranges from 1400 ft (430 m) along the Middle Fork Clearwater River to 1800 ft (550 m) at both Selway Falls and Split Creek. The study area encompasses roughly 68,000 acres (27,500 ha).

Target species

Species targeted for study were *Blechnum spicant* (deerfern), *Cardamine constancei* (Constance's bittercress), *Carex hendersonii* (Henderson's sedge), *Cornus nuttallii* (Pacific dogwood), *Polypodium glycyrrhiza* (licorice fern), *Thelypteris nevadensis* (Sierra woodfern), *Trientalis latifolia* (western starflower), and species of moonworts (*Botrychium* subgenus *Botrychium*). All are Forest Service Sensitive species and all except *Botrychium* were known to be associated with the canyon refugia (Table 1). Rare ferns in the subgenus *Botrychium* were suspected to occur in the study areas because of their association with moist western redcedar understories. All of the target species listed above are disjunct coastal species, with the exception of *C. constancei*, an Idaho endemic, and *Botrychium* spp. which are circumboreal. While *Mimulus clivicola* (bank monkeyflower) is a Sensitive species associated with the refugia, it is an annual that dries up in early summer making it difficult to locate for most of the field season.

Ecosystem sampling design

Our objective was to conduct an unbiased, representative survey of the two study areas by attempting to sample each bioenvironment relative to its extent within the area, in a modified version of the Gradsect sampling design (Austin and Heyligers 1989). Gradsect sampling is a gradient-directed vegetation sampling method intended to provide a description of the full range of floristic variation on a regional scale. By incorporating significant environmental gradients found in the study area, this sampling strategy ensures that the widest possible range of bioenvironments is sampled given reasonable constraints on traveling time and costs. Two types of easily available data were used to represent the four significant environmental variables: (1) Landtype inventories for the Clearwater and Nez Perce National Forests (Wilson et al. 1983; Green 1987) to reflect soils and geology, and (2) elevation, to reflect temperature and precipitation.

Through photogrammetric interpretation the land area of each Forest has been mapped into individual management units or "stands". A stand is the smallest land unit for which biophysical data exist. Each stand is given a landtype classification that indicates landform, parent material and soil type (Wilson et al. 1983, Green 1987). To obtain a manageable number of units for our sampling design we grouped stands at the level of the landtype association, which indicates landform and parent material only. Twenty-five different landtype associations are represented in the study area on the Clearwater National Forest and fourteen on the Nez Perce National Forest (Table 2).

Table 2. Landtype associations occurring within study areas on the Clearwater and Nez Perce National Forests (Wilson et al. 1983; Green 1987). Horizontal lines indicate how units were grouped for analysis.

Clwtr. NF	Nez Perce NF	Landform	Geologic parent material
10A	10A	Floodplains and terraces	alluvium
13A	13A	High terraces	alluvium
-	15U	Colluvial toeslopes and fans	undifferentiated
23K	24A	Dissected uplands	granite grus
-	24C	Moderate relief uplands	hard crystalline rocks
24G	-		granitics
24K	-		granite grus
24S	-		mica schist
-	31C&D	Mountain slopelands	hard crystalline rocks
31G	-		granitics
31K	-		granite grus
31Q	-		quartzites
31S	-		mica schist
31U	-		undifferentiated
-	32A&C	Convex mountain slopes	hard crystalline rocks
50	50C	Mass-wasted slopes	
-	50E		
-	60E	Undissected stream breaklands	hard crystalline rocks
60G	-		granitics
60K	-		granite grus
60Q	-		quartzites
60S	-		mica schist
60U	-		undifferentiated
-	61E	Dissected stream breaklands	hard crystalline rocks
61G	-		granitics
61K	-		granite grus
61Q	-		quartzites
61S	-		mica schist
61U	61E48	Dissected stream breaklands	undifferentiated
63G	63E38	Stream headlands	hard crystalline rocks
63U	-		undifferentiated
T	-	Talus	-

A matrix of landtypes x elevation zones was used to define the different bioenvironments present and choose a representative array of sample sites. Study areas were stratified into four, 500-ft (150-m) elevation zones between 1400 and 3400 ft (430-1040 m). Acreages were then obtained for each landtype association x elevation zone combination from the TSMRS (Timber Stand Management Record System) database. These acreages were only estimates because the database contains only the midpoint elevation of each stand and stands are quite variable in size.

In order to sample the range of geographic variation present, study areas were divided into river segments of similar sizes. The sampling design was then imposed on each segment individually and each segment was sampled relative to its proportion of the study area.

Elevation zones within stands were used as the basic units for survey and sampling. For each stand x elevation zone unit visited the following stand attributes were documented:

- Habitat type
- Cover type (overstory species and dominant size class)
- Stand history
- List of dominant species by canopy stratum
- Coastal-disjunct species present
- Presence of target species

Occurrences of Sensitive species were mapped on 7.5-minute quad maps and standard element occurrence (EO) forms used by the CDC (Conservation Data Center) were used to record population and habitat data. Element occurrence data are stored in the CDC database (ICDC 1993).

Community descriptions

Vigorous populations of target species were considered indicators of optimum habitat. Vigor, for our purposes, was subjectively assessed based primarily on population numbers and secondarily on areal extent. Optimum habitats were described using 0.1-acre circular plots and Ecodata methods (USDA-FS 1992). Form PC was used to record species composition, and modified versions of Forms LL and GF were used to record location and site data. Appendix C shows fields used on Forms LL and GF. A complete species list was recorded along with percent cover based on a 12-class cover scale with class midpoints of 0.5, 3,10, 20,.....90, and 97.

A total of 114 Ecodata plots were sampled. Normally, only a single sample was described per stand. Two samples were sometimes taken if a stand included both slope and valley-bottom positions or contrasting community types. *Trientalis latifolia* occupied such a wide range of habitats, often occurring with another target species, that we did not attempt to sample it in every stand but tried to capture as much of the variation in habitat as possible in a small number of samples.

Data analysis

Community classification. A combination of classification and ordination techniques were used to group and characterize community samples and to identify variation in species composition along environmental gradients. The program TWINSPAN (TWo-way INdicator SPecies ANalysis; Hill 1979) was used to perform a hierarchical classification of all samples. TWINSPAN carries out a series of dichotomous divisions of the samples based on similarity of their species composition, and creates an ordered, samples x species abundance table in which similar samples are grouped together.

The order of samples in the table usually reflects an environmental gradient across the area studied.

Prior to the analysis it was specified that target species would not be used as indicator species for groups. Since every plot contained one or more target species, this would have resulted in an artificial segregation of samples based on these species instead of focusing on their community associates as habitat indicators. Any species that occurred in less than five samples was omitted.

In performing the calculations TWINSPAN treats different abundance levels of a species as separate species or "pseudospecies". Five pseudospecies levels are possible and can be set by the operator. To coincide with the abundance scale used by Ecodata, pseudospecies cut-off levels were set to 0, 2,10, 11 and 31. Like the default levels, these prohibit the most abundant species from dominating the analysis. The levels used here lump all coverages greater than 35% instead of all coverages greater than 25%.

Ordination. Canonical correspondence analysis (CCA) was used to ordinate samples. CCA is a widely used ordination method that overcomes many problems associated with previous methods (Palmer 1993). CCA uses reciprocal averaging (Pielou 1984) to compute sample scores based on species abundance. Unlike previous ordination methods CCA is a direct gradient method that analyzes any measured environmental variables along with abundance values and plots them together in the ordination space. The CANOCO computer package (ter Braak 1988) was used to run CCA. All default settings were used and data were not transformed.

Mapping

All target-species occurrences in the study areas were digitized and entered into an ARC/INFO Geographic Information System (GIS) database. Other map layers include cartographic features, 40-ft contour intervals, stand x elevation zone polygons surveyed during 1993, and ground strata from the TSMRS database which include landtype, cover type and timber management activities.

Data analysis

Only four target species were encountered frequently enough to provide a sufficient number of sample plots for analysis. Forty-nine of the 114 Ecodata samples taken describe habitat of *Cardamine constancei*, fifty-two of *Carex hendersonii*, seven of *Blechnum spicant*, and twenty-two of *Trientalis latifolia*. Only nine samples contained both *C. constancei* and *C. hendersonii* and in most of these cases *C. hendersonii* was incidental within a major population of *C. constancei*. Since *Trientalis* occurred in a relatively wide range of habitats including those also occupied by *C. constancei* or *C. hendersonii*, we did not attempt to sample every stand in which it occurred, but tried to capture in our samples the range of habitat variation present. A combination of classification and ordination techniques was used to organize the data for description, discussion and evaluation of underlying environmental relationships.

Classification of plant communities

Table 5 is a subset of the complete table created by TWINSPAN. Several species of low frequency were omitted to save space. Species are ordered such that those at the top show the strongest preference for samples to the left of the table, and those at the bottom for samples on the right. Species in the middle of the table are non-preferential. Samples are grouped by similarity of species composition, with vertical lines separating community types identified by a combination of TWINSPAN analysis and visual inspection. Some samples were rearranged after analysis to give more weight to ecological indicator species such as *Oplopanax horridum* (devil's club) and *Athyrium filix-femina* (ladyfern). Community types are described later in this section.

All samples in Table 5 represent rare plant habitat. Of the 114 samples taken, 47 had greater than 5% cover of *Adiantum pedatum*, indicating the *Thuja plicata/Adiantum pedatum* habitat type or wetter understory unions. Grand fir almost always forms a significant portion of the canopy and forbs of the *Asarum caudatum* union are present with high constancy.

The ordering of samples in the table represents a complex gradient with cold/moist *Blechnum spicant* sites at the left, and drier sites with lower cover of western redcedar toward the right. However, at the far right are *Cardamine* sites in successional stands, at the upriver extreme of the North Fork study area, which are not likely the driest sites. Gradients represented in the table probably include moisture, temperature, and seral stage and are better examined by the ordination described later.

Table 5 illustrates the habitat separation between *Carex hendersonii* and *Cardamine constancei*, which segregate within the table even though they were not used as indicator species in the analysis. *Carex hendersonii* samples are concentrated in two separate locations in the table–with the moist *Athyrium* understory union (Type 2), and also with more mesic sites in the Lochsa/Selway study area characterized by *Pseudotsuga menziesii*, *Betula papyrifera*, and *Holodiscus discolor* (ocean spray; Types 4 and 5). *Cardamine* samples occupy a position between these groups in Types 3 and 4. *Cardamine* also occurs in Type 6, which is characterized by drier stands of mostly *Thuja/Asarum* habitat types, often located outside the range of *C. hendersonii*. Samples containing *Trientalis latifolia* strongly cluster within community type 2 (THUPLI/ATHFIL).

Figure 1 shows indicator species for each division of the samples performed by TWINSPAN. The initial division separated the entire data set into two major groups of samples based on the presence of *Pseudotsuga menziesii* (Douglas-fir) vs that of *Gymnocarpium dryopteris* (oak fern). *Gymnocarpium dryopteris* is an indicator species for the driest fern understory found with western redcedar. Based on a visual inspection of the TWINSPAN table, Types 3 and 4 were combined.

Table 5. Sample x species matrix ordered by TWINSPAN. Samples grouped by similarity of species composition. Numbers in body of table indicate canopy cover based on five cover classes. Vertical lines indicate groupings at the third level of hierarchy. Indicator species and other species mentioned in the text are underscored.

Figure 1

TWINSPAN helped recognize the following six community types, reflecting different environmental conditions, at the third level of hierarchy .

Type 1 (THUPLI/VACMEM/BOYMAJ): This group consists of all seven *Blechnum spicant* samples. These represent the cold/moist extremes of all environments sampled and occur at the extreme left side of the sample x species matrix (Table 5). These samples do not contain any Sensitive species other than *B. spicant*. They are characterized by the presence of wet-site species *Glyceria elata* (tall mannagrass), *Boykinia major* (boykinia), and *Senecio triangularis* (arrowleaf grounsel), and by *Menziesia ferruginea*, an indicator species for the coldest *Thuja plicata* habitat types. Most are in mixed stands of *Abies grandis* and *Thuja plicata*. *Tsuga mertensiana* (mountain hemlock), which rarely occurs at such low elevations, was recorded at three of these sites.

Type 2 (THUPLI/ATHFIL). These samples represent one of several distinct communities associated with *Carex hendersonii*. *Trientalis latifolia* is also strongly associated with this type. This group consists of twenty-three samples representing *Thuja plicata/Athyrium filix-femina* (western redcedar/lady fern) and *T. plicata/Oplopanax horridum* (western redcedar/devil's club) habitat types–the wettest understory unions in the western redcedar series. This Type is well-differentiated by 5% or more of *Adiantum pedatum* (maidenhair fern), *Athyrium filix-femina* (ladyfern), *Circaea alpina* (enchanter's nightshade), and *Asarum caudatum* (wild ginger); and the presence of *Viola glabella* (pioneer violet), *Dryopteris austriaca* (mountain woodfern), and *Gymnocarpium dryopteris* (oak fern). *Tiarella trifoliata* (foam flower) occurs in every sample and is usually greater than 5%. The analysis did not, at any level, group samples containing *Oplopanax* which is an indicator for cool, low-elevation *Thuja plicata* sites (Cooper et al. 1981). Seventeen of the samples in this group represent *Carex hendersonii* habitat; seven represent *Cardamine* habitat and fifteen contain *Trientalis*.

Type 3 (THUPLI/ADIPED-LINBOR). These eleven samples represent slightly more mesic sites than Type 2, and all but two are associated with *Cardamine constancei*. They are distinguished from Type 2 by the absence of *Athyrium filix-femina, Oplopanax horridum*, and *Dryopteris austriaca* –all moist-site indicators. *Gymnocarpium* and *Circaea* are either absent or less than 1%. *Linnaea borealis* (twinflower) and *Tiarella trifoliata* are constant. These samples were separated from Type 4 in the analysis because of the absence of *Pseudotsuga menziesii* but the two groups are more conveniently combined into one community type, based on a visual inspection of species composition and the extent to which they were intermixed in the ordination (Figure 2).

Types 4, 5, and 6 arise from the half of the data set characterized by the presence of *Pseudotsuga menziesii* and absence of *Gymnocarpium dryopteris* and wet-site ferns. *Pteridium aquilinum* (bracken fern) is often present, sometimes with high cover.

Type 4 (THUPLI–PSEMEN/forb). This is a poorly distinguished, widespread community type based more on absence of species than presence. It consists of 22 samples with consistently high cover of western redcedar and an absence of *Betula papyrifera* (paper birch). Sixteen of these samples represent *Cardamine constancei* habitat, three of which have both *Cardamine* and *Carex hendersonii*, and five contain only *C. hendersonii*. Understories are not distinctive. *Cornus canadensis* (bunchberry dogwood) and *Clintonia uniflora* (queencup beadlily) are constant, and *Arnica latifolia* (mountain arnica) is often abundant. This type is very similar to Type 3 except for the presence of Douglas-fir, bracken fern and much lower representation of *Tiarella*.

Figure 2

Type 5 (THUPLI-PSEMEN-BETPAP): Twenty-three of the twenty-four samples in this group represent *Carex hendersonii* habitat. *Betula papyrifera* (paper birch) is constant and usually greater than 5%; *Holodiscus discolor* (ocean spray), *Acer glabrum* (mountain maple), and *Fragaria vesca* (wild strawberry) are common and *Pteridium aquilinum* is highly constant but usually low in cover. *Montia sibirica* (miner's lettuce) is common and sometimes abundant. This group is unique in its paucity of *Cornus canadensis*. These samples represent more mesic sites than Type 2 and probably an earlier seral stage than Type 4, with higher cover of Douglas-fir and paper birch. Paper birch, the indicator species for this type, is a successional species that establishes after fire.

Type 6 (PSEMEN/shrub): This Type is characterized by consistent and usually high cover of *Rubus parviflorus* (thimbleberry), *Holodiscus discolor* (ocean spray), and *Symphoricarpos albus* (snowberry). There is an unusual lack of *Polystichum munitum* (swordfern), and *Tiarella trifoliata* is mostly absent. *Cornus stolonifera* (red-osier dogwood) and *Arnica latifolia* (mountain arnica) are common. Ten out of the 13 samples describe *Cardamine* habitat. A distinctive subset of this group (6b, Figure 2) consists of all *Cardamine* sites along the upper North Fork (upriver of Quartz Creek), which are in various stages of succession following a 1919 fire.

Type 7 consisted of an additional group of four, poorly distinguished plots and was not included in Table 5.

Ordination of samples

An ordination plots samples on a pair of axes based on species composition of the samples. In the ordination diagram (Figure 2) similar samples are placed close together and dissimilar far apart. Canonical correspondence analysis (CCA) combines direct gradient analysis with ordination so that community composition can be related to any measured environmental variables. After calculation, sample scores are subjected to linear regression and plotted as linear combinations of environmental variables.

Blechnum spicant samples were omitted from the ordination because the TWINSPAN analysis indicated them to be outliers. A first run of CANOCO indicated that sample #39 was also an outlier. This sample is a very large, high-elevation *Cardamine* population on a south aspect. Sample #39 was made passive in subsequent runs so that it was not used in calculating the ordination axes but was plotted afterward. The use of such outliers in the analysis severely limits the resolution of the rest of the data set.

The CCA ordination of plant community samples is shown in Figure 2. Each sample is indicated by a number indicating the TWINSPAN group to which it belongs. The four samples making up Type 7 were very diverse; three were deleted from the diagram and one was subjectively combined with Type 6. Environmental variables analyzed include slope (%), aspect (degrees), elevation, and landtype (Appendix E). Because landtype is a nominal environmental variable it is represented by points (+) rather than arrows in the ordination diagram, each point coinciding with a different landtype classification. These points are the centroids of the sample scores belonging to that landtype. The centroid is essentially the mean of the sample scores for a given landtype.

The length of the arrow for an environmental variable indicates the degree to which it affects species composition of the samples. Within each general landtype group samples are spread along an axis related to elevation, which is the environmental variable most highly correlated with species composition. Sample points perpendicularly projected onto the arrows provide a rank ordering of the sites along that environmental variable. The mean of an environmental variable is the origin so that the arrowhead side is above average and the tail (not shown) is below average. Interestingly, aspect is insignificant in influencing species composition of the samples. The very short aspect vector may be due to the fact that few samples were taken on southerly aspects where differences in plant composition would be expected to be most pronounced.

Because samples are plotted as linear combinations of environmental variables, samples from the same community type may form separate clusters in the ordination space. For example, samples representing the *Thuja/Athyrium* community type (2) and occupying terraces and toeslopes with gentle to flat slope gradients, form a distinct cluster in the upper left quadrant, segregated from other samples of the same community type along a slope gradient. The samples representing steeper slopes are spread across a wide range of elevations, and are weakly clustered around the centroid for mass-wasted slopes (MWS).

The most distinctive feature of the ordination is the segregation of samples into two distinct groups along a gradient of slope and geomorphic position (valley bottoms vs mountain slopes). This segregation reflects the physiography of these canyon systems. In the upper left quadrant are samples representing river terraces (TE) and toeslopes (FT), both valley-bottom landforms characterized by gentle to flat slope gradients. In the lower right quadrant are samples on mountain slopes which, in the river breaks, are generally steep to very steep.

A lack of distinct clustering within these two main groups is probably indicative of the relatively low amount of environmental variation that was actually sampled, eg., 93 out of 105 samples were in the *Thuja plicata* series and 47 were in the *Thuja plicata/Adiantum pedatum* habitat type or wetter. The landforms encountered in the study were few, due more to the scale of the landtype classification used rather than the actual landscape diversity.

Cardamine populations along the upper North Fork form a distinctive group in the ordination (6b). These are mostly early-successional stands on river terraces and toeslopes with relatively high shrub cover. Note that *Cardamine* occupies similar habitats on mountain slope landforms (MS) and dissected stream breaklands (DSB) as indicated by 6s in quadrants I and II.
These latter samples represent major populations in both study areas.

The intermixing of Types 3 and 4 in the ordination reinforces our combining of these types as indicated in Figure 1. A large cluster of these samples, centered around mass-wasted slopes, represent *Cardamine* habitat along the south side of the Middle Fork–Selway corridor where the species exhibits its best development. Lochsa/Selway *Carex hendersonii* sites are primarily represented by Type 5, corresponding in the diagram almost exclusively to moderate to steep slopes. This supports our speculation, discussed later, that metapopulation structure of *C. hendersonii* differs between the two study areas.

RESULTS

Distributions and Habitats of Target Species

Survey work confirmed that the ranges of *Cardamine constancei*, *Carex hendersonii* and, on the North Fork, *Trientalis latifolia*, overlap to a large degree. The latter two are the most restricted in range and probably indicate areas of optimum expression of the maritime-like climate. *Cardamine constancei* has a larger range than *T. latifolia* or *C. hendersonii* but occurs unpredictably and is scarce within most of the area surveyed. Our sampling design was effective in expanding the known distribution of *Cardamine* and *Blechnum spicant* in particular. Ranges of *T. latifolia* and *C. hendersonii*, while understood fairly well before this study, are now more accurately defined. Maps D1-D10 show the distributions of target species based on our 1993 survey and CDC records. Population and habitat data for each occurrence reside in the CDC database. Distribution and habitat of each species is discussed below.

***Trientalis latifolia* (western starflower)**

Trientalis occurs only in the North Fork study area where it appears to be limited to a particular section of the North Fork canyon rather than to any specific site factors. Within the study area it is almost continuous from the western Forest boundary upstream to Skull Creek (Map D10) and extending 3 miles (5 km) up the Isabella Creek drainage to Goat Creek. It was only observed in one site upriver of the mouth of Quartz Creek. Its range apparently extends downstream of the study area all the way to the main Clearwater River on non-Forest Service lands, where its abundance has not been documented.

Habitat. Within the range described above, *Trientalis* is abundant and nearly continuous in the forest understory in habitat types of both the *Thuja plicata* and *Abies grandis* series to an elevation of 3400 ft (1040 m). *Trientalis* occurred in every Ecodata sample taken within this range and was sometimes the most abundant forb present. The species appears to be well adapted to the range of soil and site conditions found along the North Fork. It occurs in old-growth stands as well as areas that burned in 1910, and was observed in a 12-yr-old stand regenerating after harvest. Its confinement to the lower North Fork canyon, primarily downstream of Canyon Work Center, may reflect an optimum combination of climatic factors.

***Carex hendersonii* (Henderson's sedge)**

Carex hendersonii is probably the best indicator of core maritime conditions. It is most abundant, and reaches its highest elevations, at the downstream end of each study area in a pattern paralleling those of *Cornus nuttallii* (Map D10) and *Trientalis latifolia* (Map D5). These valley- bottom sites are the lowest elevations within the *Thuja plicata* series. *Carex hendersonii* is rare along the Lochsa upriver of Lowell Creek and along the Selway upriver of Glover Creek (Maps D8-D9).

In the North Fork study area, the upstream limit of *C. hendersonii* is approximately the mouth of Quartz Creek (Map D4). It is most abundant on the north side of the river from Salmon Creek to Isabella Creek and in the Isabella Creek drainage upstream to Goat Creek.

Habitat. *Carex hendersonii* is associated primarily with forests of the *Thuja plicata* series, sometimes extending into moist understory unions of the *Abies grandis* series on upper slopes. It is common from the valley bottom to 3600 ft (1100 m) on the north side of the Middle Fork. Habitat characteristics of *C. hendersonii* are shown in Table E3; associated species are shown in Table F3.

The most well-developed populations of *C. hendersonii* occur on low-elevation river terraces and lower slopes in moist, fern-dominated understories–often in old-growth stands. On such sites plants form dense populations up to 0.5 acre in size. These often occur on level grades or in slight depressions, but without standing water. Plants also occur up slope in *Thuja plicata/Asarum caudatum* and *Thuja plicata/Clintonia uniflora* habitat types to 2800 ft (850 m), in smaller sub-populations and as scattered individuals. There is a strong association between *C. hendersonii* populations and elk trails and, in three instances, populations were strictly associated with "rot pockets"–openings created by fungus-killed Douglas-fir.

***Cardamine constancei* (Constance's bittercress)**

There is a great deal of variation in the distribution and abundance of *Cardamine* within the two study areas that coincides with the three Ranger Districts involved. Consequently, it is easiest to discuss the distribution of *Cardamine* by Ranger District.

Selway Ranger District–Our survey work supports the conclusion of Crawford (1980) that *Cardamine* is most abundant along the south canyon face bordering the lower Selway and upper Middle Fork Clearwater Rivers. It occurs downstream along the Middle Fork at least as far as the Forest boundary, near the forest-grassland ecotone (Map D6). Populations are usually discrete and mostly limited to less than 5 acres (2 ha), but occur more commonly here than in any other area surveyed. Several populations are continuous for more than 10 acres. The most extensive, nearly continuous *Cardamine* population recorded is at the mouth of the Selway opposite the town of Lowell (160 acres; EOR no. 065). *Cardamine* becomes scarce after Meadow Creek but occurs at the mouths of tributaries for 5 miles (8 km) upstream.

Large populations of *Cardamine constancei* also occur on the north side of the Selway in tributary bottoms, and on upper slopes to 3200 ft (980 m) on east or west aspects. On both sides of the river populations occur unpredictably, i.e., they do not seem to be correlated with any obvious habitat factor. Populations frequently occur in cool, shaded sites at the mouths of streams–often in stands missed by the last stand-replacing fire. These populations are usually restricted to within 300 ft (90 m) of the stream bottom. However, even larger populations can often be found on upper slopes, on east or west aspects, often near a ridge or shoulder (eg., EOR nos. 010, 002; Table 3). Surprisingly, these were never found to be continuous with steam-bottom sites in the same drainage.

Lochsa Ranger District–*Cardamine* was not found anywhere in the Lochsa River corridor including three tributaries surveyed on the south (north-facing) side. Lochsa and Selway River corridors have experienced distinctly different fire histories. Slopes along both sides of the lower Lochsa were exposed to repeated and widespread fires from 1910 to 1934 (Map G2). The south side, which burned in the 1934 Pete King fire, is now forested on all but south-facing slopes while the north side is a mosaic of shrubfields and seral forest. Soil temperatures, which reflect air temperature on a seasonal rather than a diurnal scale, are similar between the canyons (Odegard, pers. comm.). Because climate, parent materials and landforms are comparable in the two canyons, it seems possible that *Cardamine* was eliminated from the Lochsa canyon by repeated, large fires. *Cardamine* occurs at several locations along the north side of the Middle Fork Clearwater River (EOR no. 008) and in the Little Smith Creek drainage (EOR no. 062), on the Lochsa Ranger District (Map D6).

Table 3. Population data for *Cardamine constancei* sites sampled using Ecodata methods. Sample numbers can be used to reference site data in Table E2.

EOR#	Ecodata Sample Number	Ranger District*	EO Rank**	Site name***	Number of ramets	Area	Veg.:Repro	TWIN-SPAN Group
.088	L014	NF	D	Isabella Ck	40	0.1 ac	:0	2
.084	L018	NF	C	Quartz	130	2 ac	3:1	2
.041	K025	NF	D	Fern Ck 1	30	0.1 ac	:0	2
.041	S006	NF	D	Fern Ck 3	20	5 sq yd	:0	2
	L002	NF	D	Aquarius south	60-80	0.25 ac	50:1	2
.085	L016	NF	D	Collins Ck	50	0.25 ac	50:1	3
.083	L017	NF	B	Skull Ck-E	100-200	1 ac	:0	3
.088	L021	NF	B	Goat Ck	100-200	3 ac+	100:1	3
.088	L022	NF	D	Isabella-W	20	30 sq yd	:0	3
.022	L026	NF	A	Washington Ck	500-1000	10 ac	100:1	6
.082	R001	NF	A	Bates Ck	500-1000	20 ac	100:1	6
.084	L023	NF	B	Upper Quartz	150	2 ac	150:1	6
.086	L024	NF	A	Flat Ck	300-500	3 ac	:0	6
.017	L027	NF	B	Cub Ck	200	0.25 ac	10:1	6
.042	L028	NF	D	Trail Ck	17	20 sq yd	:0	6
.021	L029	NF	C	Gilfillian Ck	100	0.25 ac	100:1	6
.021	L031	NF	D	Cold Spgs Ck	50	0.1 ac	25:1	6
.021	L032	NF	D	Gilfillian 2	60	1 ac	:0	6
.041	K029	NF	A	Fern Ck 2	500	5 ac	:0	7
.025	K015	NF	B	Larson Ck	300-500	0.25 ac	:0	4
.065	****	S	A	Swiftwater	5000-10,000	30 ac	10:1	2,3,4,5
.063	L045	S	B	Sob Ck	500-1000	10 ac	:0	3
.063	O005	S	A	Sob Ck-W	500	1 ac	:0	3
.071	L057	S	A	Wash Ck 1	100-200	3 ac	:0	4
.071	L058	S	A	Wash Ck 2	300-500	7 ac	20:1	4
.010	L046	S	D	Glover Ck	40	1 ac	3:1	4
.010	K026	S	A	Glover 2	1000-2000	10 ac	:0	4
.004	L038	S	A	Slide/Boyd	500-1000	5 ac	:0	4
.003	L055	S	A	Nineteen Mile Ck.	1000+	20 ac		4
.070	L053	S	A	Dave Ck.	200-500	5 ac		4
.062	K009	L	C	Little Smith Ck.	100	0.25 ac	70:30	4
.008	L060	L	C	Three Devils Ck.	100-200	0.25 ac		5
.001	S001	S	C	Stillman Pt. Tr.	60-100	0.5 ac	:0	5
.077	O009	S	A	Number One	2000-5000	6 ac	:0	5
.080	L047	M	A	Bait Ck	500-1000	1 ac	:0	
.050	K011	S	B	Gedney Ck	100-200	2 ac	:0	6
.002	K002	S	A	Rackliff burn	3000+	20 ac	25:75	7

* NF (North Fork), L (Lochsa), S (Selway), M (Moose Ck)

** Based primarily on number of ramets: A (>300), B (100-300), C (60-100), and D (<60) and secondarily on areal extent.

*** Each site is a separate population; populations are often grouped under the same element occurrence record (EOR) to keep the number of EORs manageable.

**** Sample no. (TWINSPAN no.): L034 (2), L036 (4), L054 (3), L059 (3), K003 (4), K004 (4), K005 (5)

North Fork Ranger District–In the North Fork study area, large *Cardamine* populations are rare, and the species forms smaller, more discrete populations of several square yards to 1 acre (0.4 ha), with one exceptionally large population of up to 30 acres (12 ha). Populations are widely scattered along the main canyon to elevations of 3600 ft (1100 m) and extending 3 to 5 miles (5-8 km) up Isabella, Skull, and Quartz Creeks (Map D2). The species appears to be more common in tributary drainages than along the main canyon. *Cardamine* extends farther upstream on the North Fork and its tributaries than do most of the coastal disjuncts, with isolated, valley-bottom populations occurring from Weitas Creek to Cold Springs Creek at the upriver extreme of the study area. These populations are isolated from the core refugium by large unforested expanses resulting from a 1919 fire.

Habitat. Although the range of *Cardamine constancei* coincides to a large degree with those of *Trientalis latifolia* and *Carex hendersonii*, optimum habitat differs. While all three species are strongly associated with the *Thuja plicata/Adiantum pedatum* (western redcedar/maidenhair fern) habitat type, *Cardamine* often occurs in 70 to 80-yr-old seral stands of mixed western redcedar and grand fir (Table 3, EOR# 022, 025, 086) and extends into the grand fir series above. *Cardamine* was observed in stands representing a wide variety of disturbance regimes including: old-growth western redcedar and grand fir (EOR no. 082), a high-graded stand dominated by shrubs (EOR no. 084), 70-yr old post-fire seral stands (EOR nos. 022, 025), and a 2-yr-old stand-replacing burn (EOR no. 002). A dense population was observed in a 1-yr-old clearcut along Isabella Creek, but plants were contorted, had rubbery foliage, and had not flowered. Like many rhizomatous understory forbs, *Cardamine* may survive for a period following canopy removal, but cannot be expected to persist or reproduce.

Cardamine attains its best development on the river face along the south side of the Selway- Middle Fork River corridor, which is almost continuously forested. The river breaks in this section are dominated by western redcedar with stands varying from 80 to more than 125 years old (Warofka pers. comm.). Two age classes of trees are evident in much of the area with Douglas fir and grand fir representing a younger class (50-90 yrs) and western redcedar greater than 125 yrs.

North Fork *Cardamine* populations in late-seral and old-growth western redcedar stands are usually small. However, this observation is based largely on stands of river terraces where moisture and community composition are not comparable to upper slopes. On the moister river terraces competition may be a limiting factor. *Cardamine* does not usually flower under shaded conditions, but may be able to maintain itself indefinitely by vegetative growth as long as competitive pressures are not too great. The largest known population in the North Fork refugium (Table 3, EOR# 082) is in an old-growth grand fir stand where white pine die off and natural decadence have created openings in the canopy. However, no *Cardamine* was found on slopes along the south side of the North Fork canyon where there are extensive stands of mixed western redcedar and grand fir more than 100 years old.

Cardamine can be vigorous under high canopy closer where ground cover is very sparse, or in lush understories of forbs and ferns. Cover of *Rubus parviflorus* (thimbleberry) is often high and *Pteridium aquilinum* (bracken fern) is often present. Habitat characteristics of *Cardamine* are shown in Table E2 and associated species in Table F2. Associated species are further discussed under "Community Classification".

As proposed by Crawford (1980) it seems likely that populations of *Cardamine* are maintained by periodic underburns that open the canopy. Plants may be able to withstand a canopy fire if microsites or surviving trees exist to provide shade. Two populations affected by a 1991 fire along the Selway produced unusually prolific ramets that flowered profusely in both 1992 and 1993 (Map D6, EOR no. 002). Several sites indicate that *Cardamine* can survive removal of the tree canopy if microsites are available. This may explain its association with downed logs, rock overhangs and the bases of trees. However, such small populations are vulnerable to extinction and may represent only a sample of the genetic variation of the original population. *Cardamine* appears capable of colonizing disturbed soils via vegetative spread from adjoining habitat, but there is no evidence that such sites can be colonized by seed.

Cardamine populations occur on a range of soil types derived from metamorphic, granitic and mixed alluvial parent materials, either with a distinct volcanic ash mantle or without ash. *Cardamine* often occurred without *Asarum caudatum* (wild ginger), a species indicative of sites with an ash layer (Mital, pers. comm.). Table 4 shows textures and sodium fluoride pH of surface soils associated with major *Cardamine* populations. A sodium fluoride pH greater than 9.4 indicates significant volcanic ash influence (Fieldes and Perrott 1966).

Table 4. Surface soil characteristics from optimum *Cardamine constancei* habitat; top 6 inches (15 cm) of soil.

EOR#	Study Area *	Site Name	Textural class	NaF pH**
.070	L/S	Dave Ck	sandy loam	10.49
.003	L/S	Nineteen-mi Ck	loam	8.96
.071	L/S	Wash Ck	loam	10.01
.065	L/S	Swiftwater Rd	loam	10.63
.008	L/S	Three Devils Ck	loam	10.42
.010	L/S	Glover Ck	silt loam	8.81
.022	NF	Washington Ck	loam	8.56
.086	NF	Flat Ck	sandy loam	10.63
.041	NF	Fern Ck	loam	9.70
.025	NF	Larson Ck	sandy loam	10.06

* L/S (Lochsa/Selway); NF (North Fork)
** Sodium fluoride pH as indication of volcanic ash influence.

Twenty out of the 46 *Cardamine* sites sampled were on mica schist parent material, and soils were often shallow with rock at the surface (Table E2). Schist rock types are associated with slumping and landslides throughout both study areas. At 12 sites an association with slumping or unstable soils was noted. Populations were often associated with landforms created by mass wasting such as slumps or stabilized talus. *Cardamine* clones will colonize shaded cut slopes such as along trails, and can grow in somewhat compacted soil. Slope gradient is probably not a factor in habitat suitability for *Cardamine*. South aspects are generally unfavorable but may be mitigated by forest canopy.

***Blechnum spicant* (deerfern)**

Although a disjunct coastal species, the range of *B. spicant* barely overlaps core refugia areas. While it is associated with the same drainage systems, it occurs at higher elevations than other disjuncts and generally much farther upstream. The lowest-elevation sites coincide with the upper elevational limit of the study area along tributaries to the North Fork (Map D1). Large populations are known from Black Canyon and Independence Creek, 4-14 miles (6-23 km) upstream of the study area. *Blechnum* *spicant* also occurs just outside the Lochsa/Selway study area at 3400 ft (1040 m).

Habitat of *B. spicant* is colder and wetter than that of the core coastal disjuncts. Populations as low as 3400 ft are in sites affected by cold air drainage, possibly allowing the species to persist at lower-than-normal elevations. Habitat may also be related to duration or depth of snowpack. Habitat types are the moist, *Oplopanax* (devil's club) and *Athyrium* (ladyfern) understory unions of the western redcedar series. The plant community is distinctive from that of the other target species by the presence of *Vaccinium membranaceum* (blue huckleberry), *Menziesia ferruginea* (menziesia), and *Glyceria elata* (tall mannagrass). Wetness of sites is indicated by high cover of *Boykinia major* (boykinia) and the presence of *Senecio triangularis* (arrow-leaf groundsel). Although understory composition is very consistent, forest overstory is quite variable, ranging from old-growth *Thuja plicata* to seral *Pinus contorta* (lodgepole pine). Habitat characteristics of *B. spicant* are shown in Table E1. The extent of this type of habitat in the study areas is not known.

Thelypteris nevadensis **(Sierra woodfern)**

The only two inland sites known for this disjunct fern species are in the Isabella Creek drainage (Map D1). Although separated by 1.5 air miles (2.4 km), both occur at 3200 ft (980 m). Both sites are small in extent and are part of the *Thuja plicata/Athyrium filix-femina* (western redcedar/ladyfern) habitat type.

Botrychium **ssp.** ***Botrychium*** **(moonworts)**

Fern allies in the subgenus *Botrychium* (*B. minganense, B. crenulatum, and B. pinnatum)* are generally associated with moist understories of western redcedar old-growth but are not considered coastal disjuncts. None of the species listed above are known from either study area. *Botrychium minganense* occurs upriver of both study areas, in tributary drainages at elevations of 4500 to 4900 ft (1370-1500 m; ICDC 1993).

Cornus nuttallii **(Pacific dogwood)**

Cornus nuttallii is known only from the Lochsa/Selway study area, extending from the town of Syringa upriver to Black Canyon on the Lochsa and to Boyd Creek on the Selway (Map D10). Along the Lochsa and Selway Rivers it is fairly restricted to the main river bottom, but along both sides of the Middle Fork scattered populations have been found to 3200 ft (980 m). *Cornus nuttallii* is in severe decline due, at least in part, to a fungal disease known as dogwood anthracnose (Hibben 1992). Population numbers may have decreased 75-90% over the past 10-15 years (Lichthardt 1991). Scattered individuals and one large, but mostly decadent population were discovered during 1993 surveys. Several seedlings were also recorded that are assumed to be *C. nuttallii* but are difficult to differentiate from *C. stolonifera*.

METAPOPULATION STRUCTURE

Metapopulation structure refers to the spatial and temporal distribution of populations and their relationship to landscape features, habitat patches and each other. In plants, little gene flow occurs between populations separated by unoccupied or unsuitable habitat and, unless seed are dispersed by the wind or animal vectors, establishment of new populations may be a rare event. Therefore the amount of genetic variability present may be related in part to the geographic structure of the metapopulation (Gilpin

1987). In terms of species viability it is generally very important to maintain this overall geographic structure (Shelly1994). Only four species–*Cardamine constancei, Carex hendersonii, Blechnum spicant*, and *Trientalis latifolia*–were abundant enough in the study areas to assess metapopulation structure.

Cardamine constancei often occurs in isolated, small populations, especially along the North Fork. Average population size is not reflected by Table 3 which lists only the largest, most vigorous populations. Populations are reproductively isolated due to distance and paucity of sexual reproduction. Flowering is a rare event, occurring only when the canopy is opened up, and seed production is low (Crawford 1980). Due to this reliance on clonal reproduction, within-population genetic variablity is expected to be low. A system of such localized populations, considered at the landscape level may have more genetic variance than a single large population of the same total size (Gilpin 1987).

Because of their limited extent, and probable low level of intra-population genetic variability, most *Cardamine* populations are extremely susceptible to random environmental events as well as human impacts. Although flowering, and possibly the production of ramets (aboveground stems of a clonal plant), are stimulated by increased light, plants cannot tolerate prolonged direct sun following complete canopy removal. Microsites appear to be extremely important in allowing plants to survive and flower where the canopy has been removed by fire, disease or logging. From these relict populations the species may expand as forest succession proceeds. Vigorous populations of *Cardamine* occur on mesic slope positions in 70 to 100-yr old stands of mixed western redcedar-grand fir. These populations may still be expanding, via seed and/or vegetative spread, following the last stand-replacing fire. Four previously documented *Cardamine* sites were searched with no success, indicating that small populations may be ephemeral, even in the absence of disturbance.

Carex hendersonii. In valley-bottom sites *C. hendersonii* forms dense populations, up to 0.5 acre in size, often on level gradients and in slight depresssions, but without standing water. Genets form large clumps, produce many reproductive culms, and enlarge by producing short rhizomes, such that it can be difficult to distinguish individual plants. It is likely that such stable "source" populations (Pulliam 1988) supply seed to replace ephemeral populations and individuals in surrounding, less optimum habitat. Source populations usually occur in near-climax forests of river and stream bottoms, and less well-developed populations and scattered individuals occur upslope in drier *Thuja plicata/Asarum caudatum* and *Thuja/Clintonia uniflora* habitat types. Ungulates or rodents may be important vectors for seed dispersal, since seedheads are commonly nipped off just below the flag leaf. Populations are often found associated with elk trails.

Viability of *Carex hendersonii* metapopulations may be dependent on this system of stable "source" and ephemeral "sink" populations (Pulliam 1988). There may even be genetic differences between plants on mesic vs moist sites. Threats to source populations include logging, wildfire, roadbuilding, and the development of campgrounds and recreational sites. Although plants may persist for some time following canopy removal, reduced vigor will likely decrease their contribution to metapopulation viability.

Blechnum spicant. Most of the *B. spicant* populations observed during this study were in discrete locations associated with small perennial drainages, often around seeps. The exception is the Elizabeth Lake Trail site at which the species occurs extensively along the slope break above the river for 0.5 mile where it occupies several different microsites. Within the North Fork study area, *B. spicant* occurs as isolated populations living on the low-elevation margins of the species' inland range. Habitat is fairly specific as indicated by a fairly consistent group of indicator species. Populations are dense and include a range of plant sizes and both vegetative and reproductive individuals. Prolific spore production should allow plants to colonize any suitable nearby habitat, but such habitat may be scarce at the lower end of the species elevational range.

Genetic studies on one North Fork population of *Blechnum spicant* indicate a lack of intrapopulation genetic variation consistent with a "founder effect" in which ancestry of the population can be traced back to a small group of individuals or even a single individual (Soltis and Soltis 1988). However, it is possible that genetic differences exist between isolated populations such as those observed in 1993, in which case these represent important sources of genetic variation for the species in its inland range. Because of their peripheral nature, *B. spicant* populations along the North Fork, downstream of Kelly Forks, should be protected.

Trientalis latifolia occurs so continuously within the major portion of its range that it is difficult to discern any metapopulation structure. Gaps in its distribution are produced by rock outcrops, shrubfields, developments, and clearcuts. The highest density of ramets seems to occur where understory competition is not too great and filtered light is available. Most ramets produce flowers and abundance of the species would seem to indicate successful reproduction by seed as well as by rhizomes.

Toward the margins of its range *Trientalis* becomes scarce rather abruptly, and then disappears altogether. This transition is not related to any observable habitat factor. A few peripheral populations occur outside the main range that may be indicative of a once-larger distribution that has been reduced by wildfire. However, correlation between the ranges of *Trientalis* and *Carex hendersonii* seems to indicate a unique microclimate that is limiting to both species.

DISCUSSION AND RECOMMENDATIONS

The Clearwater Refugium Ecosystem

It appears that the Clearwater refugium ecosystem can be fairly well defined by the occurrence of the *Thuja plicata*/*Adiantum pedatum* habitat type within the North Fork, Lochsa, Selway, and Middle Fork Clearwater River canyons. The inland range of red alder is also tied to this habitat type and is a good indicator of the North Fork refugium (Steele 1971). The refugium ecosystem as defined here, should not be confused with a broader zone of maritime influence expressed to varying degrees throughout the Northern Rockies (Lorain 1988). Coastal-disjunct and endemic plants also occur at the higher elevations separating canyons of the refugium.

Disjunct coastal plant species differ in their relationship to core refugium areas. *Polypodium glycyrrhiza*, *Trientalis latifolia*, *Carex hendersonii*, and *Cornus nuttallii* appear to be tied to a central or core area (only the latter two occur in the Lochsa/Selway area). *Festuca subuliflora, Viola sempervirens, Alnus rubra,* and the endemic *Cardamine constancei*, have a wider range that is centered around this area. *Blechnum spicant* occurs on the periphery of the refugium as we have defined it, but its association with the same drainage systems further supports the role these canyons have played as refugia and migration routes during past climatic changes. *Blechnum spicant, Cardamine constancei* and *Viola sempervirens* also occur in the St. Joe river drainage to the north.

Cumulative impacts to rare plant populations must consider the reduction of habitat that has already taken place, for example through unnatural fire regimes and the use of private and public lands for timber harvest and development. The largest impact to refugium habitat resulted from the filling of Dworshak Reservoir in 1974. Steele (1971) estimated that the *Thuja plicata/Adiantum pedatum* habitat type on the North Fork was reduced by 18%, from 32,400 acres (13,100 ha) to about 26,400 acres (10,700 ha). Permanent alteration of much of the Lochsa/Selway refugium resulted from the construction of State highway 12 and settlement of the river corridor.

The basis for any conservation plan for the Clearwater refugium ecosystem must be an alternative approach to forest management–from one rooted in timber production to one rooted in ecosystem sustainability. The two objectives need not be exclusive, but within such an outstanding biological area the planning process must be guided by the biodiversity objective since it is the one over which we have little or no control. A failure to maintain intact ecosystem structure and function can lead to loss of both biodiversity and commodity production.

A landscape approach to conservation considers the full regime of natural disturbances and processes responsible for the mosaic of habitats present (Urban et al. 1987). Vegetation patterns in the refugium ecosystem are related to climate, soils, landforms, and a history of fire and disease. Management that seeks to preserve natural processes and structure within this system will have the greatest potential for ecosystem sustainability and, as a result, for maintaining viability and future evolutionary potential of rare plant species. Such an approach involves consideration of the entire ecosystem, not just of habitat currently occupied by rare species.

General Recommendations:

This report does not represent final documentation of the potential effects of human activities on viability of the refugium ecosystem. Rather, it is a first step–the gathering of rare plant distribution and habitat data, and a working definition of the ecosystem itself. From this picture, we have tried to draw conclusions about successional relationships and disturbance tolerance of some Sensitive plant species, but these are largely speculative. More information is needed on the response of individual species to disturbance and on species biology. Monitoring studies currently underway may provide helpful information, but expansion of these studies is essential if we are to manage the ecosystem and its biological elements with any confidence.

The following recommendations are made with the objective of maintaining viable populations of Sensitive plant species by preserving intact ecosystem structure and function. More specific recommendations are made under individual Conservation Units below. Because of the multiple- use mandate of National Forest lands, the points addressed are strongly management oriented. No amount of scientific knowledge will be sufficient to allow us to draw specific lines around "critical habitat", make exact quotas for compatible resource extraction, or determine some minimum number of populations required. Instead, management must be guided by current scientific knowledge, while allowing a significant margin of safety for the integrity of the ecosystem. Conservation planning must also consider the cumulative effects of past human-induced impacts to the ecosystem.

- Identify management units based on areas that differ in expression of inland maritime environment, rare elements, habitats, threats, and disturbance history (see "Conservation Units" below). Such units will allow finer tuning of land management within the refugium ecosystem.

- Utilize maps of Sensitive species occurrences, habitat types, and old growth during the Forest planning process to avoid conflicts with timber harvest.

- Conduct project-level biological surveys to avoid impacts to Sensitive species. The current study was designed to provide initial information on Sensitive species' distributions, habitat associations, and disturbance relationships; it is not to be construed as a final, District or Forest-wide biological evaluation for these species. Site-specific evaluations for specific projects should be tiered to this broad analysis in order to make accurate determinations of cumulative effects on population viability. Sensitive species occurring in project areas must be documented so that the impacts of management can be assessed.

- Expand clearance surveys to include areas peripherally affected by proposed projects. Biological surveys should be based on some meaningful ecological unit on a scale at least as large as the entire project. This might require sampling the area using a Gradsect or some other meaningful approach, rather than trying to cover every inch of ground.

- In general, a "no impact" policy should be applied with regard to sensitive species and, ideally, also with rare plant communities. Exceptions may be made on a case-by-case basis using guidelines given for specific Conservation Units and specific species.

- Minimize timber harvest in core refugium areas. For the North Fork this includes Aquarius-Dworshak, Isabella Creek, Grasshopper-Twin and Beaver-Sneak Conservation Units, generally below 2800 ft. For the Lochsa-Selway, it is generally equivalent to the study area (Map H3) excluding Meadow Creek on the Selway.

- Use forestry methods that emulate natural disturbance regimes (i.e., fire) and optimize chances of successful conifer regeneration. Logging practices should minimize physical disturbance of the ground surface, and result in a patchy environment including downed and standing timber. Clearcutting methods will have the most adverse effects on all target species. Allow forested corridors along drainages, including ephemeral drainages, that tie into rare plant habitat. Plan entry to create a multi-age stand mosaic. Do not harvest timber on sites that may be unsuited to conifer regeneration.

- Timber harvest should not isolate populations of rare plants on habitat "islands".

- Preserve old growth stands where these are of size and condition to support a natural understory and intact ecological processes. It is important to preserve the old-growth component because of its relatively small representation in the landscape as a whole.

- Care should be taken not to sacrifice peripheral populations of rare species (e.g., the higher elevation extents of *Trientalis latifolia* or *Carex hendersonii*) or isolate them from core habitat. Peripheral populations lying outside core refugium areas should be protected by 200- to 300-ac habitat patches, based as much as possible on natural features with which the population is associated such as a drainage, river terrace, or interfluve. Such tracts should be linked to the river bottom or, when that is not possible, to a major tributary.

- Consider the role of unoccupied (by Sensitive species) habitat in potential expansion and migration of nearby populations, and in protection of occupied habitat.

- Consider past reductions of refugium habitat when assessing cumulative impacts to Sensitive species populations during the Environmental Assessment process.

- Conduct monitoring of known populations to expand our knowledge of the tolerance of Sensitive species to various impacts and disturbance levels that have already occurred.

Conservation units

A great deal of vegetational diversity exists within the refugium ecosystem due to differences in successional status, disturbance history, and microclimate. In order to simplify discussion and implementation of conservation planning, study areas were divided into the following conservation units based on physiognomy of the vegetation, disturbance history, and representation of refugium elements (Maps H1-H3). Botanical values and management guidelines will change as more information becomes available. For each unit, both human and natural factors that have shaped the landscape are discussed. These units reflect primarily differences in fire history and microclimate. All of these units with the exception of Lowell–Gedney on the Selway District, are under analysis for timber management. All of the lands involved, with the exception of two established RNAs, are open to timber harvest.

North Fork Ranger District

Aquarius–Dworshak Conservation Unit

This unit includes Aquarius RNA and areas between the RNA and the Forest boundary on both sides of the river. The RNA comprises roughly a third of the area.

Botanical values: This unit represents core refugium habitat as evidenced by the abundance of *Trientalis latifolia* and *Carex hendersonii*, extensive *Adiantum pedatum* understory, and occurrence of the rare *Thuja plicata/Dryopteris* spp. (western redcedar/woodfern) habitat type (Steele 1971). *Cardamine* is not well-represented in the RNA; two known occurrences along the river trail on the north side of the river were not relocated in 1993 and only one population is known from the south side of the river. *Carex hendersonii* is particularly abundant on the north side of the river, occurring both in dense, source populations and scattered up slope as high as 2800 ft (850 m). *Cypripedium fasciculatum* is also known from several sites. Large river terraces on both sides of the river support old-growth cedar with fern understories. Extensive mass-wasted slopes beneath Thompson Point support persistent stands of red alder, which also occur at stream mouths.

Disturbance history: Most of this unit burned in 1910 and downstream portions on the north side burned again in 1931 (Map G1). Some valley-bottom forest escaped both fires. Recent clearcutting in the Lower Salmon timber sale impacted habitat of *Trientalis latifolia*,*Cypripedium fasciculatum*, and *Carex hendersonii* along the western edge of the RNA, north of the river.

As much as two-thirds of the core refugium habitat was lost when Dworshak reservoir was filled in 1974, including many occurrences of disjunct coastal species (Steele 1971). Very little survey has been done on the south side of the river downstream of the RNA because of the remote, unroaded nature of this area. Because it has been largely unaffected by fire, this area may contain the best examples of old-growth cedar and communities most like those lost beneath the reservoir.

Proposed management guidelines: Monitoring of both plant communities and rare plant populations has been initiated within Aquarius RNA and a management plan for the RNA is scheduled for 1994. The most critical rare habitat outside the RNA should be preserved by allowing a significant corridor, to at least the 2200-ft (670-m) contour, along the south side of the river, west to the forest boundary. This habitat would be most similar to that lost beneath the reservoir. In addition, a thorough field survey of lands between the RNA and the Forest boundary would allow planners to avoid conflicts with old growth and Sensitive plant populations.

Large areas of bracken glade on the north side of the river in the vicinity of Milk Creek, represent a potential for permanent loss of habitat, as these can expand into adjacent areas of timber harvest. Pre-harvest planning should determine suitability of lands for regeneration to avoid permanent loss of refugium habitat.

Isabella Creek Conservation Unit

Botanical values: The Isabella Creek drainage appears to represent core refugium habitat with optimum conditions for coastal disjuncts as well as for *Cardamine constancei*. Because of this, habitat in Isabella Creek drainage can be considered core habitat critical to integrity of the ecosystem and therefore to the viability of Sensitive target species. With the exception of *Botrychium* spp., all target species occur in this drainage. *Trientalis latifolia*, *Carex hendersonii*, and *C. constancei* exhibit numerous, well developed populations. It is highly probable that more *Cardamine* populations exist in the drainage than are currently known. In addition, this drainage contains the only known sites of the two rarest plant species on the

Clearwater National Forest–*Thelypteris nevadensis* (Sierra woodfern) and *Polypodium glycyrrhiza* (licorice fern). *Blechnum spicant*, a species normally associated with higher elevations, occurs in three different sites. The floodplain of Isabella Creek is rich in disjunct species with scattered occurrences also of *Cypripedium fasciculatum.*

A combination of optimum inland-maritime climate, a well-developed stream floodplain, and extensive old-growth forest probably contribute to the canyon's unique biological character. Seral forest types, especially on the west side of Isabella Creek, contribute to habitat diversity. This unit borders on Aquarius RNA, which increases its habitat value.

Disturbance history: Most of the west side of Isabella Creek burned in 1910 (Map G1). Patches of old-growth remain, especially in the valley bottom. Probably the largest recent impacts within the watershed have been timber sales on both sides of the drainage within or at the periphery of the core refugium area. Impacts to one known *Cardamine* population may be significant because of the sparse nature of its distribution in this drainage. Other Sensitive species have probably not been significantly affected.

Proposed management guidelines: The outstanding botanical characteristics of the Isabella Creek drainage warrant official recognition through establishment of Special Interest Areas (SIA). The Clearwater National Forest should consider expanding the Heritage Cedar Grove Special Interest Area to include the Elmer Creek populations of *Thelypteris nevadensis, Blechnum spicant,* and *Cypripedium fasciculatum*. Remaining floodplain habitat at the mouth of Isabella Creek, adjacent to the RNA should be protected from development and could be the basis of an additional SIA. The Goat Creek drainage also offers an outstanding opportunity for a botanical SIA which would include vigorous populations of *Cardamine constancei* in addition to *Cypripedium fasciculatum, Carex hendersonii*, *Trientalis latifolia,* and old-growth stands of western redcedar. Other important features of the Goat Creek area include a lack of forest fragmentation, and representation of a mixture of successional stages.

Because the Isabella Creek watershed seems to represent optimum refugium conditions, management of this unit should place highest priorities on conservation of Sensitive plants and plant communities. Old-growth forest should be maintained below 3000 ft (900 m) and in the stream floodplain. Any *Cardamine* populations adjacent to cutting units should be monitored to assess their response to canopy opening. However, populations should not opened up to southern exposure. Sixty- to one hundred-year old conifer stands may represent optimum habitat for *Cardamine*.

Beaver–Sneak Conservation Unit

This unit consists of river breaks on the south side of the North Fork River upstream of Aquarius RNA. Except for the Beaver Creek drainage this area is unroaded.

Botanical values: Several significant populations of *Carex hendersonii* occur on shoulder slopes and terraces near the river (Map D4). *Trientalis latifolia* is abundant in the Beaver Creek drainage and east to Sneak Creek, becoming patchy and scarce further east. One historical location of *Cardamine constancei* exists but was not relocated during surveys made in 1992. The coastal species *Festuca subuliflora* is common.

Disturbance history: This area has not been affected by fire in this century. It is almost uniformly forested with late-seral mixed western redcedar and grand fir very similar to the south side of Aquarius RNA. White pine snags are scattered throughout. Seed-tree cuts and clearcuts have impacted populations and habitat of *Trientalis latifolia* and *Carex hendersonii* and have resulted in bracken fern and exotic weed invasion of the river terrace in at least one site (Lichthardt 1992b). Timber harvest has been primarily restricted to the west end of this unit in and near the Beaver Creek drainage.

The Steep Creek Timber sale area, on the west side of Beaver Creek, included populations of *Carex hendersonii, Trientalis latifolia* and *Cypripedium fasciculatum*. Monitoring plots established prior to the start of the project will increase our knowledge of direct affects of ground disturbance and canopy opening (Lichthardt 1992a). The project utilized selective cutting and sky-line methods which should minimize direct effects on rare plant populations. However, if stands become dominated by shrubs after logging they will represent a loss of habitat.

Proposed management guidelines: Protect stable, "source" populations of *Carex hendersonii* (Map D4, and see pg. 23) during planning of timber sales and allow continuity with upslope areas of unoccupied or sparsely occupied habitat. Undisturbed patches should be large relative to project areas. Core refugium habitat occurs downstream of Sneak Creek, generally below 2800 ft (850 m). This area, represents one of the largest patches of late-seral forest within the core refugium. Ideally, timber harvest should be restricted to areas above 2800 ft. Fragmentation of this area would represent a relatively large contribution toward cumulative effects on the ecosystem.

Grasshopper–Twin Conservation Unit

In this unit south-facing slopes above the North Fork are a mosaic of forest, shrubfield, and grassy rock outcrop. Open stands of grand fir and Douglas-fir extend nearly to the river in some places. *Trientalis latifolia* is common in the forest understory. *Carex hendersonii* is restricted to lower slopes and five, steeply graded tributaries of the North Fork. Several large populations of *Mimulus clivicola* occur below 2000 ft (600 m). Logging has been insignificant in this unit. The noxious weed spotted knapweed (*Centaurea maculosa*) is abundant, especially along the road and on roadcuts.

No imminent threats to sensitive plant populations are anticipated in this unit. An old-growth stand representing the rare *Thuja plicata*/*Dryopteris* spp.(western redcedar/wood fern) habitat type, just across the road from Aquarius campground, should be protected from recreational and road development.

Skull Creek and Quartz Creek Conservation Units

These two large, low-elevation tributaries of the North Fork bear many similarities. Physiography is of extremely steep canyon slopes with some well-developed stream terraces and gentle toe slopes in the valley bottom. There are many cliffs and rock outcrops on upper slopes, especially on the west side of Skull Creek. The comments below apply to both drainages.

Botanical values: *Cardamine constancei* appears to be more common in these tributary canyons than along the North Fork itself. It occurs in mostly small populations and is commonly found associated with microsites within open stands of mixed conifers and shrubs. Microsites in which *Cardamine* populations were found included a rock overhang, a flush of saplings in a slight gully, and a pile of cut cedar boles. These may be remnants of larger populations that were able to survive opening of the canopy only in these microsites.

Few disjunct coastal species were observed in either drainage. However, a large population of *Blechnum* *spicant* occurs near the mouth of Collins Creek, a tributary of Skull Creek, and extends upslope to 4400 ft (1400 m).

Disturbance history: Both drainages were largely unaffected by stand-replacing fires in this century. Primary processes affecting vegetation patterns have been disease (white pine blister rust) and timber harvest. Both drainages are characterized as "heavily cut over, with high concentrations of dead and dying timber" (USFS–North Fork RD 1994). In the past, white pine and other large trees were selectively harvested with no post-harvest treatment, resulting in extensive shrubfields with scattered or patchy mature trees. Recently, low elevations along Quartz Creek have been fragmented by clearcuts. Approximately 18% of the study area within Quartz Creek has been harvested in the last 23 years and 7% has been clearcut within the last 4 years.

Proposed management guidelines: Project-level surveys should be done for all sales including salvage sales. Retention of any remaining live trees is important where *Cardamine* exists. Disturbance of the ground surface would also be detrimental.

Quartz Creek-Kelly Forks Conservation Unit

Canyon vegetation changes markedly upstream of the mouth of Quartz Creek, coinciding with an abrupt change in orientation of the canyon. Physiography of the canyon remains largely unchanged, and large stands of red alder are still prominent on alluvial fans. Quartz Creek was arbitrarily chosen to divide the study area into two segments of roughly equal length but it coincides with real changes in species distribution and vegetation patterns.

Disturbance history: Upstream of Quartz Creek both sides of the canyon experienced a stand-replacing fire in 1919 (Map G1). Much of the west side is still shrubfield with little or no conifer regeneration. The east side is uniformly forested with 60-70 yr-old stands of mixed *Thuja-Abies* as is the west side of the river south of Little Washington Creek. The river breaks on both sides of the river are roadless and only a small area of timber harvest overlaps the study area in the Washington Creek drainage.

Castle Rock marks another change in orientation of the canyon. Still part of the 1919 fire, slopes on the north side of the river are dominated by shrubfields where conifers have not regenerated. Shrubfields dominate the north-side canyon face all the way to Kelly Forks. Coldsprings Creek is roaded and has been the site of recent timber harvest.

Botanical values: In this canyon section, differences in habitat, possibly related to micro-climate in addition to disturbance history, are reflected in the absence of *Trientalis latifolia* and *Carex hendersonii*. Species such as *Pyrola secunda* and *Chimaphila umbellata* occur near river level, marking a transition to understory unions drier than *Adiantum pedatum* (Steele 1971). Even river terraces that escaped the fire do not support *C. hendersonii*. A notable exception is a well-developed population 0.5 mile (0.8 km) upstream of the mouth Quartz Creek in an area unaffected by the 1919 fire. This occurrence is important because it appears to be a stable, persistent population peripheral to the core range of the species (Map D4). As such, it is important to geographic viability of the metapopulation and may also be somewhat genetically distinct.

Trientalis latifolia was observed at only one location in this unit, in the Bates Creek drainage below 3400 ft (Map D5). It occurs in an area of old-growth timber on the margin of the 1919 burn, possibly indicating that its range was reduced by the 1919 fire.

Cardamine is rare in this canyon section, but several populations occur, on both sides of the North Fork, that are equal to or larger than those downstream. The largest population known from the North Fork Refugium occurs in the Bates Creek drainage at 3600 ft (1100 m; Map D3). Additional populations will likely be found. It is possible that the species was more extensive here, on both sides of the canyon, prior to the catastrophic 1919 fire. Because of the isolation of *Cardamine* populations in this unit each one may represent an important source of genetic variation to the species as a whole (Gilpin 1987). Stands searched unsuccessfully for *Cardamine* are shown in the GIS Map Supplement to this report.

Several coastal disjuncts are common in this unit including *Alnus rubra* (red alder), *Festuca subuliflora* (crinkle-awn fescue), *Viola sempervirens* (redwoods violet), and *Rubus ursinus* (white-stemmed blackberry). These species have a wider ecological amplitude than the Sensitive disjuncts and are thus not as rare. *Festuca subuliflora* was previously classified as Sensitive but was declassified when its distribution became better understood. Two isolated populations of *Blechnum spicant* are also known from this canyon section and *Mimulus clivicola* (bank monkeyflower) is known from two valley-bottom sites.

Based on the presence of coastal disjuncts and *Cardamine*, it appears that this upper section of the study area is a zone of maritime affinity and rare habitat, possibly without the optimum combination of warmth and moisture required by the more restricted disjuncts. However, soil temperatures measured at the mouth of Orogrande Creek over the growing season were within two degrees centigrade of those in the lower Selway River canyon (Odegard, pers. comm.). Fire may have been a factor in eliminating some of the rarer disjuncts from this unit.

Proposed management guidelines: Maps showing Sensitive species occurrences and stands searched should be used in initial planning of timber sales in this conservation unit to avoid conflicts with rare plant conservation. The large *C. hendersonii* population south of the mouth of Quartz Creek (Map D4) should be protected as a *high priority occurrence*, ideally by maintaining a continuous tract of late-seral forest between it and the mouth of Quartz Creek. One large and one small *Cardamine* population are known from the West Pot analysis area and more likely exist. The area between the river and 3400-ft (1040 m) should be considered habitat for *Cardamine* and peripheral habitat for coastal species.

The Bates Creek *Cardamine* population (Table 3) on the west side of the North Fork is an important peripheral population because of its size and the fact that it occurs at the upper elevational limit of the species. Since this population occurs on a south aspect, further loss of canopy cover would likely cause a downward trend in numbers and vigor. On the west side of the river, where little regeneration has occurred, maintenance of any forested corridors between the river and uplands is especially important to allow migration of plant populations.

The Bates Creek *Trientalis* population is also a high-priority population because of its peripheral location. This may represent one of the only seed sources for expansion of this species into the North Fork canyon above Quartz Creek.

Project-level analyses will be required in areas affected by timber harvest and should not be limited to cutting units. The status of *Cardamine* in this unit, as currently known, allows no impacts to populations unless future data indicate a tolerance for certain impacts. Any occurrences of *Blechnum spicant* also represent peripheral populations and must be protected within large undisturbed patches which include unoccupied habitat. The plant community with which *Blechnum* is associated should represent a small proportion of the undisturbed patch to allow a significant buffer against changes in insolation and drainage patterns. Blechnum will be particularly sensitive to changes in hydrology. This habitat should be linked to the river bottom.

The amount of forested buffer required between a cutting unit and a *Cardamine* population will be dependent on aspect of the site, direction of the unit from the population (i.e., potential for increased insolation), and the potential for blowdown. Managers should keep in mind that, although plants may flower in response to increased insolation, they will probably not set seed if soil moisture is inadequate (Crawford 1980).

Lochsa Ranger District

Smith–Three-devils Conservation Unit

The canyon face along the north side of the Middle Fork does not make a very homogeneous unit due to differences in cover type and timber cutting, but is quite cohesive in terms of botanical values and environmental variables.

Botanical values: Both the abundance and elevational amplitude of coastal disjuncts in this unit indicate a core refugium environment. This is particularly well expressed in the large drainage basin formed by Little Smith, Big Smith, and Syringa Creeks. In this drainage *Carex hendersonii* is unusually common in the forest understory, occurring up to 3600 ft (1100 m), primarily in western redcedar habitat types. *Cornus nuttallii* is known historically from the vicinity around the town of Syringa, at the mouth of Smith Creek and scattered, live individuals still occur as high as 3400 ft (1040 m). The area also represents a particularly high concentration of *Cypripedium fasciculatum*. Uniqueness of this habitat is further supported by the presence of numerous other coastal disjunct species including *Alnus rubra* (red alder), *Collomia heterophylla* (varied-leaf collomia), *Festuca subuliflora* (crinkle-awn fescue), *Juncus effusus* var. *pacificus* (soft rush), *Chimaphila menziesii* (Menzie's prince's pine), *Rubus nivalis* (snow dewberry), *Rubus ursinus* (blackberry), *Symphoricarpos mollis* (creeping snowberry), the District's only known population of *Viola sempervirens* (redwoods violet), and the highest concentration of *Equisetum telmateia* (giant horsetail) on the District. Several moss species characteristic of the coastal environment have also been identified (Karen Gray, pers. comm.).

The river face east of Syringa supports drier forest types and extensive shrubfields. Here *C. hendersonii* is restricted to microsites on lower slopes and in stream bottoms, seldom forming well developed populations like those along the North Fork. *Cardamine constancei* occurs in two widely separate sites, with one population in upper Little Smith Creek and several more near the mouths of Three Devils and Two Shadows Creeks (Map D6). *These* Cardamine *populations are extremely important since they are the only known occurrences of the species on the north side of the Lochsa–Middle Fork corridor*.

The river terrace at the mouth of Two Shadows Creek is one of only a few remaining undeveloped cedar terraces in the Lochsa/Middle Fork corridor. It supports populations of both *Carex hendersonii* and *Cardamine constancei* and should be protected from development.

Disturbance history: While the dominant tree age class is greater than 100 years, little of the forest has developed old-growth characteristics, probably due to a stand-replacing fire ca 1880. The drainage basin formed by Little Smith, Big Smith, and Syringa Creeks has been the site of extensive road-building and portions are highly fragmented by clearcuts, mostly in early stages of regeneration. Approximately 650 acres have already been harvested within the study area, representing 13% of this unit. Most of the river terrace habitat has been lost to highway and campground construction and to the townsite of Syringa. Because of the wide distribution of *Carex hendersonii* and *Cypripedium fasciculatum* in the Smith Creek drainage, any timber harvest using clearcuts or seed-tree cuts is likely to have either direct impacts to populations or indirect effects via habitat availability.

Proposed management guidelines: This unit should be considered high-priority refugium habitat. Dense "source" populations of *Carex hendersonii* (those that appear stable and long-lived) should be identified and protected. A reserve system should be designed to link such stream-bottom populations with more mesic slope habitat, possibly in conjunction with old-growth reserves. SIA or other official designation should be considered for part of this reserve. Outside this reserve system timber harvest should utilize methods that result in patchy canopy. Source populations of *C. hendersonii* should still be protected as they will be necessary to populate adjacent, managed areas. The two known populations of *Cardamine* should be protected. Any suspected *Cornus nuttallii* seedlings should be carefully protected as they may represent offspring of disease-resistant trees. River terrace habitat at two-shadows Creek should not be considered for development of any kind.

Lochsa Conservation Unit

Although the two sides of the Lochsa River from Split Creek to Lowell are sharply contrasting in physiognomy, they are similar with respect to Sensitive species. Disturbance history is comparable between the two sides because the entire canyon, with the exception of a few small areas, has burned extensively and repeatedly over the past 90 years (Map G2), resulting in the loss of much refugium habitat on the north side.

Botanical values: On the south side of the Lochsa River *Carex hendersonii* is relatively common to about 2600 ft (800 m) on densely forested river breaks. Populations are small and scattered, occurring unpredictably on ridges as well as slopes, often along elk trails. One relatively large *Cypripedium fasciculatum* population was found in the Handy Creek drainage. *Cardamine* was not found anywhere in this canyon section even though habitat appears suitable and microclimate and soils are comparable to the Selway Canyon.

On the north side of the river *C. hendersonii* is mostly restricted to drainage bottoms and moist, shaded microsites. The mouth of Canyon Creek is the site of a *Calochortus nitidus* population of high conservation value because of its position on the periphery of the species' range. *Mimulus clivicola* (bank monkeyflower) also occurs at this site, which is adjacent to the Lochsa RNA. Numerous *Mimulus clivicola* and *C. fasciculatum* sites have been recorded between Deadman and Tick Creeks in an area that has remained largely unburned.

The once-vigorous *Cornus nuttallii* populations that once populated canyon slopes and river bottoms have mostly succumbed to disease. Little if any successful sexual reproduction has occurred in recent years (Lichthardt 1991). Numerous *C. nuttallii* trees are still alive in several locations, most notably at Bimerick and Split Creeks. *Cornus nuttallii* is still more abundant along the lower Lochsa than along the Selway or Middle Fork .

Disturbance history: Fire has been the dominant ecosystem process in this canyon section, shaping the vegetation and possibly altering the soils by accelerating erosion. Most of the forest on the south side of the river has regenerated following fires in the first half of this century. Several recent clearcuts have impacted *C. hendersonii* populations in Lowell Creek, on the north side of the Lochsa, but most of this unit is roadless and, on the south side, only the Lottie Creek drainage is being considered for timber harvest. River terrace habitat on the north side of the river has largely been lost to road construction.

Proposed management guidelines: Aside from the implications of dogwood anthracnose in *C. nuttallii* populations, threat to sensitive species in this unit can be considered minor. Management practices such as fire or conifer thinning might be applied to *C. nuttallii* populations but injury to individual trees should be avoided when planning timber sales and road and trail maintenance. Since most of this unit burned only 60 years ago, *Carex hendersonii* is likely still expanding in range and developing more stable populations. Its scattered, common occurrence seems to indicate good dispersal characteristics.

Selway Ranger District

Lowell–Glover Creek Conservation Unit

Botanical values: Along the north side of the Selway River western redcedar forest quickly gives way to open stands of Douglas-fir and Ponderosa Pine as you move upslope. The combined effects of fire and aspect have created a patchy landscape. Upstream from Rackliff Creek the *Adiantum pedatum* understory union is restricted to lower drainages and *Carex hendersonii* becomes restricted to drainage bottoms where it occurs rather consistently as far as Selway Falls. Downstream from Rackliff Creek it is scattered and common in the forest understory to 2600 ft (800 m; Map D8).

Several populations of *Mimulus clivicola* (bank monkeyflower) occur in forest openings just above the river. Significant populations of *Cornus nuttallii* once occurred at Rackliff Creek and Twenty-mile Bar but mortality has been extremely high and few live individuals remain. A population of *C. fasciculatum* at Rackliff Creek is exceptionally vigorous.

Cardamine constancei is associated with tributary drainages upstream from Rackliff Creek. Several exceptionally vigorous populations occur here (EO nos. 002, 003, 004, 010; Map D6-7) that are significant because they extend to the upper elevational range for *Cardamine*. Two of these were also exposed, in varying degrees, to wildfire two years prior to this study. Plants did not appear to be hurt by the fire; two years later both ramet and flower production were extremely vigorous.

Disturbance history: Vegetation on the river face represents a patchwork of overlapping burns of varying ages and intensities (Map G3). Fire has probably been instrumental in maintaining open stands of Ponderosa pine and shrubfields. In the mid-1980s the Forest Service began a program of controlled burning to enhance wildlife habitat. In 1991 one such burn escaped and was responsible for underburns and canopy fires that affected *Cardamine* populations in Rackliff and Nineteen-mile Creeks. Populations of *Cardamine constancei*, *Carex hendersonii*, *Cypripedium fasciculatum* and *Cornus nuttallii* at the mouths of both Rackliff and Boyd Creeks have been impacted to some extent by campground developments.

This unit is a roadless area along a recreational river corridor with many campgrounds and several well-developed trails. Values are primarily for recreation and wildlife. The timber in several of the areas burned in 1991 was sold and harvested by helicopter, affecting at least three *Cardamine* populations. It is not clear how much canopy cover will remain after logging. If too little tree canopy remains, invasion by shrubs will be a threat.

Proposed management guidelines: *Cardamine* populations in the 1993 salvage sale should be monitored to assess the effects of canopy removal and fire. This information could be very useful in devising a conservation plan for the species. *Cardamine* is much more limited on the north side of the Selway than on the south. Special considerations should be made for reducing surface disturbance and maintaining an upper tree canopy. Where the canopy is lost to fire it may be especially important to maintain microsites, for example, by leaving large downed logs.

Number One–Meadow Conservation Unit

Botanical values: From the eastern Forest boundary on the Middle Fork to the mouth of Meadow Creek on the Selway, slopes on the south side of the canyon are predominantly northerly in aspect and almost continuously forested with mixed western redcedar and grand fir. Western redcedar is at the southern edge of its range here. This area supports the highest concentration of *Cardamine constancei* known. Populations of various sizes are frequent along the breaks from river level to 2600 ft (800 m). At the Lochsa-Selway confluence the species is particularly abundant, with numerous, large subpopulations occurring throughout a160-acre area (Map D6).

Carex hendersonii is common in some drainages and rare in others. It is not as widespread here as on the north side of the Middle Fork. In the areas surveyed no well-developed subpopulations were observed–most were what appeared to be ephemeral populations and scattered individuals, similar to the Lochsa Conservation Unit. It becomes scarce upstream of O'Hara Creek but small populations of 1-20 individuals occur as far as 5 miles (8 km) up O'Hara Creek and 2 miles (3.2 km) up Meadow Creek. Throughout this range it is found in western redcedar/maidenhair fern habitat types along with *Festuca subuliflora* (crinkle-awn fescue), a grass species characteristic of the refugium ecosystem.

Disturbance history: Much of this unit has not burned since European settlement. The largest western redcedar are 100-125 years old and Douglas-fir and grand fir are mostly younger (50-90 yrs; Warofka pers. comm.). This younger age class may be replacing diseased or decadent trees. Along the Middle Fork stands are younger and burnt-out shells are common. Douglas-fir rot pockets are common throughout the area.

Very little timber has been harvested from this unit. Timber harvest has been restricted to areas just above the study area. Most of this unit is roadless and has very high value as viewshed for the recreational river corridor, which extends for the length of the study area.

Proposed Management Guidelines: If future timber harvest is restricted outside the designated recreational river corridor impacts to the large *Cardamine* population at Number One Creek should be minimized. Any timber harvest in upper Decker Creek is likely to affect populations of *Cardamine*. A combination of selective cutting, and the retention of large (_) continuous tracts of habitat can help mitigate cumulative effects to the species.

Monitoring the responses of populations affected by timber harvest will be important to future management. This unit represents the core range of *Cardamine constancei*–a globally rare plant species. Human impacts in this corridor should be minimized and set-aside areas should be designated to protect the largest populations until the species' response to disturbance is better understood. Excellent opportunities now exist on the Selway Ranger District to learn more about the ecology of *Cardamine*. New information could indicate ways in which timber harvest and/or controlled burns could be used to improve habitat and manage for future viability of the species.

Research needs

Monitoring–Very few population monitoring sites have been established to date in either of the study areas. Monitoring of *Carex hendersonii* has been initiated in the Little Smith Creek drainage (Lochsa Ranger District) where populations will be affected by timber harvest (K. Gray, pers. comm.). Three years of monitoring data for *Cardamine constancei*, *Trientalis latifolia*, *Cypripedium fasciculatum*, and *C. hendersonii* are available for Aquarius RNA (Lichthardt 1992c), but thus far only one site has been established for each species. Two years of data exist for *C. hendersonii*, *T. latifolia*, and *Festuca subuliflora* populations in units of the Steep Creek timber sale just outside Aquarius RNA; the first post-harvest data will be collected in 1994 (Lichthardt 1992a). More population and ecological data are needed for *Cardamine* in order to assess its reaction to disturbance. Additional monitoring of *Cardamine* populations should be initiated in a series of stands representing a gradient of successional stages to augment that already established in Aquarius RNA.

Site-specific projects–The following opportunities exist to acquire additional information about the ecology of Sensitive plant species, that would allow better long-range planning for their conservation:

1) Initiate monitoring of a large *Cardamine* population in a clearcut along Isabella Creek (North Fork RD). This easily accessible population in a 1-yr old clearcut could provide valuable data on flowering, seed production, and population response to canopy removal. Natural microsites could be simulated using snow-fence or piled logs, with enough height to partially shade plants.

2) Initiate quantitative monitoring in spring of 1994 in *Cardamine constancei* populations on the Selway Ranger District affected by the 1991 fire and subsequent salvage timber sales.

3) Using data in this report, identify *Cardamine* populations associated with different seral stages and initiate demographic monitoring which will complement that already available for Aquarius RNA.

4) Establish additional *Carex hendersonii* monitoring to test our assumptions about metapopulation structure of the species.

Genetic studies such as those already underway for *Cornus nuttallii*, could be used to achieve a better understanding of metapopulation structure in *Cardamine constancei* and *Carex hendersonii*. Information about inter- and intra-population genetic variation is required to protect the species' evolutionary viability.

GIS. The GIS database established by this study could be used to model effects of both natural and human disturbance on population viability.

REFERENCES

Austin, M.P. and P.C. Heyligers. 1989. Vegetation survey design for conservation: Gradsect sampling of forests in north-eastern New South Wales. Biological Conservation 50: 13-32.

Caicco, S.L. 1987. Field investigations of selected sensitive plant species on the Clearwater National Forest. Unpublished report by Idaho Department of Fish and Game, Conservation Data Center, Boise, for US Forest Service. 21 pp plus appendices.

Cooper, S.V., K.E. Neiman, R. Steele, and D.W. Roberts. 1987. Forest Habitat Types of Northern Idaho: a Second Approximation. General Tech. Rep. INT-236. USDA Forest Service Intermountain Research Station, Ogden, UT.

Crawford, R. 1980. Ecological investigations and management implications of six northern Idaho endemic plants on the proposed endangered and threatened lists. Unpublished M.S. Thesis, University of Idaho, Moscow. 200 p.

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

Daubenmire, R. 1975. Floristic plant geography of eastern Washington and northern Idaho. Journal of Biogeography 2:1-18.

Fieldes, M. and K.W. Perrott. 1966. The nature of allophane in soils. Part 3–rapid field and laboratory test for allophane. New Zealand Journal of Science 9: 623-629.

Gilpin, M.E. 1987. Spatial structure and population vulnerability. In: M.E. Soule (Ed.). Viable Popula tions for Conservation. Cambridge University Press, Cambridge. pp 125-139.

Gray, Karen. Biological technician with the Lochsa Ranger District, Clearwater National Forest. Personal communication, 3 Feb. 1994.

Green, P. 1987. Soil Survey, Nez Perce National Forest Area. USDA Forest Service, Northern Region, Grangeville, ID.

Hibben, C.R. 1992. Anthracnose in a coastal disjunct population of Pacific dogwood in Idaho: an evaluation based on comparisons with the disease in eastern flowering dogwood. Unpublished report for the USDA Forest Service, Intermountain Research Station, Missoula, MT. 16 pp

Hill, M.O. 1979. TWINSPAN–a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell Ecology Programs, Cornell University, Ithaca, NY.

Hunter, M.L. 1991. Coping with ignorance: the coarse filter strategy for maintaining biodiversity. In K.A. Kohn (Ed.), Balancing on the brink of extinction. Island Press. 318 pp.

ICDC. 1994. Idaho Conservation Center Database. Idaho Department of Fish and Game.

Johnson, F.D. and R. Steele. 1978. New plant records for Idaho from Pacific coastal refugia. Northwest Science. 52(3):205-211.

Johnson, P.J. 1987. Larval taxonomy, biology, and biogeography of the genera of North American Byrrhidae (Insecta: Coleoptera). Unpublished M.S. Thesis, University of Idaho, Moscow. 268 pp.

Lichthardt, J. 1991. Initiation of long-term population monitoring of Pacific dogwood, *Cornus nuttallii*, on the Clearwater and Nez Perce National Forests. Unpublished report by Idaho Fish and Game, Conservation Data Center, Boise, ID for US Forest Service.1 6 pp plus appendices.

Lichthardt, J. 1992a. Monitoring plan for US Forest Service Region 1 Sensitive plants in the Steep Creek timber sale area, North Fork Ranger District, Clearwater National Forest. Unpublished report by Idaho Fish and Game, Conservation Data Center, Boise, ID for US Forest Service. 6 pp plus appendices.

Lichthardt, J. 1992b. Rare plant survey of the Sneaky-Sheep timber sale area. Unpublished report by Idaho Fish and Game, Conservation Data Center, Boise, ID for US Forest Service.

Lichthardt, J. 1992c. Monitoring of Sensitive plant populations in Aquarius Research Natural Area, Clearwater National Forest. Unpublished report by Idaho Fish and Game, Conservation Data Center, Boise, ID for US Forest Service. 12 pp.

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

Lorain, C.C. 1992. Conservation strategy, *Mimulus clivicola* (bank monkeyflower). USDA Forest Service, Northern Region, Missoula, MT. 22 p., plus appendices.

Mital, James. Forest Ecologist, Clearwater National Forest. Personal conversation, Sept. 1993.

Moseley, R.K. and C. Groves. 1992. Rare, Threatened and Endangered Plants and Animals of Idaho. Idaho Department of Fish and Game, Conservation Data Center. 33 pp.

Odegard, Craig. Graduate student in Botany, University of Idaho. Personal communication on December 2, 1993.

Palmer, M.W. 1993. Putting things in even better order: the advantages of canonical correspondence analysis. Ecology 74:2215-2230.

Pielou, E.C. 1984. The interpretation of ecological data: a primer on classification and ordination. Wiley, New York, New York.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. American Naturalist 132: 652-661.

Rember, W.C. and E.H. Bennett. 1979. Geologic map of the Hamilton Quadrangle, ID. Geologic Map Series. Moscow, ID: Bureau of Mines and Geology. 1:250,000.

Roper, L.A. 1970. Some aspects of the synecology of *Cornus nuttallii* in northern Idaho. Unpublished

M.S. Thesis, University of Idaho, Moscow. 71 p.

Ross, S.H. and C.N. Savage. 1967. Idaho earth science: geology, fossils, climate, water, and soils. Idaho Bureau of Mines and Geology, Idaho Earth Science Seies No. 1. 271 p.

Shelly, S. 1994. Population viability assessments for TES plants. Draft document. USDA Forest Service Region 1. Missoula, MT. 14 pp.

Soltis, P.S. and D. E. Soltis. 1988. Genetic variation and population structure in the fern *Blechnum Spicant* (Blechnaceae) from western North America. Amer. J. Bot. 75(1):37-44.

Steele, R. 1971. Red alder habitats in Clearwater County, Idaho. Unpublished M.S. Thesis, University of Idaho, Moscow. 88 p.

ter Braak, C.J.F. 1988. CANOCO–a FORTRAN program for canonical community ordination by correspondence analysis, principal components analysis and redundancy analysis (Version 2.1). Agricultural and Mathematics Group, Wageningen, The Netherlands.

The Nature Conservancy, Idaho Natural Heritage Program, and Oregon Natural Heritage Database. 1987. Final Report. Phase I, 1987 National Natural Landmark Project, Pacific Northwest Region, National Park Service. Unpublished report on file at Idaho Department of Fish and Game, Conservation Data Center, Boise. 47 pp.

Urban, DL, RV O'Neill, and HH Shugart Jr. 1987. Landscape ecology: a hierarchical perspective can help scientists understand spatial patterns. Bioscience 37: 119-127.

USDA Forest Service. 1992. Ecosystem Classification Handbook FSH 7/92 R-1. Regional Office, Northern Region, Missoula, MT.

USDA Forest Service, North Fork Ranger District. 1994. Five-year plan.

US Weather Bureau. 1989. Climatological Data, Idaho. US Dept. of Commerce.

Warofka, John. Sensitive plant coordinator for the Selway Ranger District, Nez Perce National Forest. Personal Communication, 24 January 1994.

Wilson, D.J., J. Coyner and T. Dechert. 1983. Land system inventory, Clearwater National Forest, first review draft. Clearwater National Forest, Orofino, ID.