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Terrestrial Riparian Arthropod Investigations In The Big Beaver Creek Research Natural Area, North Cascades National Park Service Complex, 1995-1996: Part V, Analysis of Arthropod Community Characteristics and Habitat Associations

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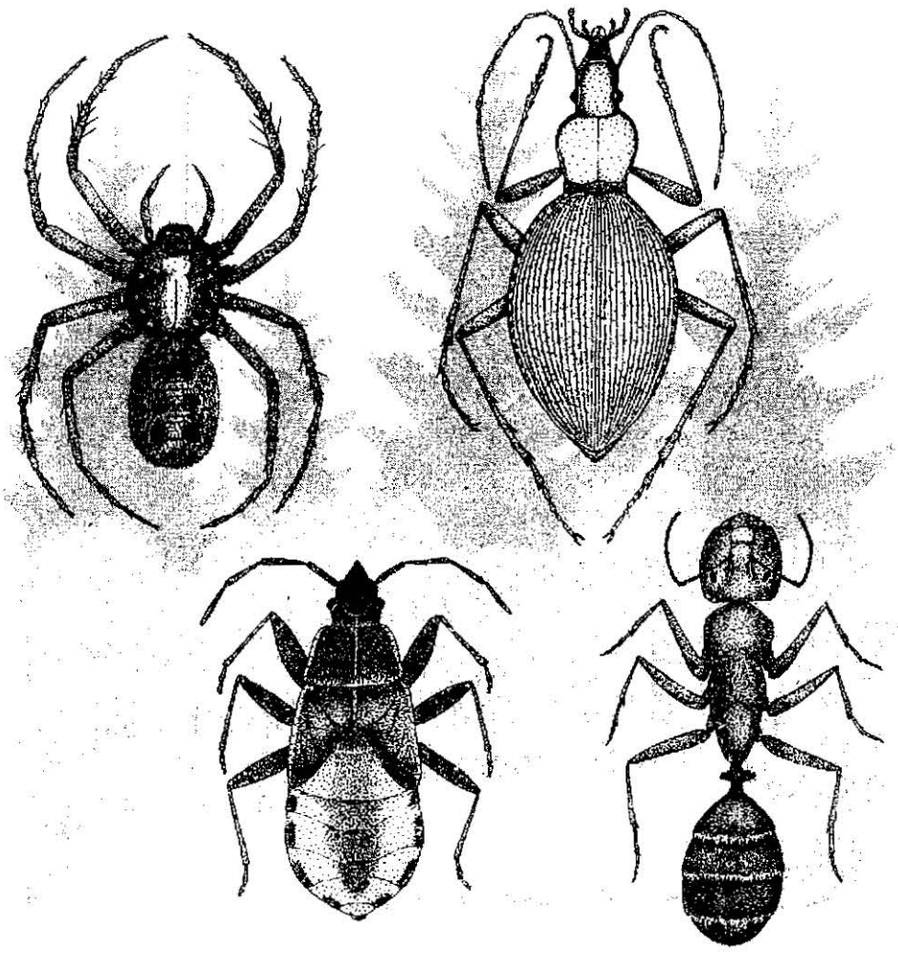

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U.S. Department of the Interior
National Park Service - Pacific West Region
North Cascades National Park Service Complex
Sedro-Woolley, WA 98284
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United States Department of the Interior - National Park Service - Pacific West Region

North Cascades National Park Service Complex, comprising North Cascades National Park, Ross Lake National Recreation Area, and Lake Chelan National Recreation Area, was established in October, 1968 and is located in northwestern Washington. North Cascades National Park was established to preserve certain majestic mountain scenery, snow fields, glaciers, alpine meadows, and other unique natural features in the North Cascade Mountains for the benefit, use, and inspiration of present and future generations. Ross Lake and Lake Chelan National Recreation Areas were established to provide for outdoor recreation use and enjoyment and to conserve scenic, scientific, historic, and other values contributing to public enjoyment of these lands and waters.

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Foreword

Primary objectives of the National Park Service Natural Resource Management Program are to manage the natural resources to maintain, restore, and perpetuate the inherent integrity of ecosystems and their component habitats and community assemblages. Arthropods represent a fundamental component of these ecosystems, comprising the majority of the biological diversity and are essential to processes of nutrient cycling, decomposition, predation, herbivory, parasitism, and pollination. Knowledge of arthropod diversity, abundance and distribution can provide extremely useful information in the evaluation of environmental perturbations and biological integrity. Arthropods are ideal study organisms because of their short generation times and rapid population growth. These characteristics make them ideal as early-warning indicators of environmental change and for monitoring recovery at disturbed sites. The vast diversity of species offers the opportunity to integrate a number of sensitive indicator species into environmental assessments.

This report represents last of a series of five technical reports on our efforts to document arthropod occurrence, abundance, and habitat associations in the Big Beaver Creek Research Natural Area of North Cascades National Park Complex (NOCA), located in northwestern Washington. The first four reports document occurrence, life history information, and information concerning taxonomy of species from four major arthropod groups including the Heteroptera (Hemiptera), Coleoptera, Arachnida (Araneae), and Hymenoptera (Formicidae). Individuals from these groups largely represent ground dwelling taxa and accounted for over 70% of the total of all specimens collected by pitfall traps in the study area.

This final report utilizes concepts from statistical and community ecology to classify habitats based on their arthropod assemblages, to describe structural and functional characteristics of these assemblages, and to identify environmental factors that influence the structure of these assemblages. This report also provides information and recommendations for development of future arthropod monitoring programs in the park.

There is much left to be learned from the samples collected during 1995 and 1996 in the study area. Specimens from several other groups of arthropods still require identification. Among these groups, the Diptera are the most numerous making up greater than 20% of all individuals collected. Working and reference collections will be maintained at the North Cascades National Park Service Research Station in Newhalem, Washington. Efforts will be made in the future to seek assistance in documenting the various species found in the remaining collection.

Funding support for this initial effort to document arthropod communities in the park was provided by the Skagit Environmental Endowment Commission. This project could also not have been done without the gracious support of John D. Lattin, Professor of Entomology, Oregon State University. Administrative support for transfer of funds to OSU from the park was provided by the Forest and Rangeland Ecosystem Science Center, Biological Resources Division, USGS, Corvallis, Oregon. This report series satisfies the conditions of Subagreement No. 31 between the Biological Resources Division and OSU.

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Abstract

Ground-dwelling arthropod communities of nine riparian habitat types were sampled within the Big Beaver Creek Research Natural Area, North Cascades National Park Service Complex, during the snow-free seasons of 1995 and 1996. This study is part of a comprehensive program to develop protocols for the assessment of biological diversity and integrity in the Park Complex. Specific objectives were to characterize arthropod community assemblages, identify environmental factors that influence community assemblage structure, and to provide basic information useful in the design and implementation of future monitoring programs. Results in this report are derived from pitfall traps, randomly placed among 9 selected habitats sampled during four monthly periods (June- October) during 1995. Five of these habitats were re-sampled during the same periods in 1996. Nearly 16,000 adult arthropods representing 448 species of beetles, spiders, ants, and true bugs were captured from 529 pitfall trap samples over the two years of the study. Species accumulation curves, combining two years of sample effort, did not reach asymptotes for most habitats. Accumulation curves using several species richness estimators also indicated that the true species richness remains unknown. Comparisons of species richness estimators at a standard level of effort revealed that the greatest richness was found in willow/carex swamp habitat. Alder swamp habitat consistently exhibited the highest diversity in a comparison of values from three diversity indices. Two-Way Indicator Species Analysis (TWINSPAN) classification of sites by species reduced the original 9 habitats, sampled in 1995, into 6 groups. Separation of habitats into the various groups was based largely upon the distributions of 10 species. TWINSPAN analysis was also completed for the 5 re-sampled habitats, using combined data from 1995 and 1996, resulted in similar groupings of habitats and similar indicator species. Non-metric Multidimensional Scaling (NMDS) ordinations of arthropod data also produced distinct habitat groupings consistent with TWINSPAN results. NMDS analysis revealed a strong gradient in percent canopy cover along Axis 1, and weaker gradients with soil moisture, coarse woody debris, and percent herbaceous plant cover along Axes 1 and 2. Gravel bars were a very distinct group separated from all the other groups along Axis 2. TWINSPAN analysis also showed strong separation of gravel bars from other habitats. Using the Indicator Value index (IV) (Dufrene and Legendre 1997), 36 potential indicator species were recognized for the 6 TWINSPAN habitat groups. TWINSPAN only identified 10 indicator species, and some site groups were only defined by the absence of a particular indicator. Recommendations for design and implementation of future structured inventory and monitoring programs using arthropods are discussed.

Acknowledgments

Our sincere appreciation is extended to Dr. John D. Lattin, Oregon State University, for his tremendous support and guidance throughout the duration of this project. In addition to his support for this study, he provided the inspiration and the technical direction that initiated our overall efforts to include terrestrial arthropods as a component of inventory and monitoring at the North Cascades National Park Complex.

Our sincere thanks are extended to Dr. Patrick Sugg, Seattle, WA, Dr. David R. Smith, Systematic Entomology Laboratory, Smithsonian Institute, Washington, D.C., and Dr. Juraj Halaj, Pacific Analytics, Albany, Oregon for their assistance with the identification of arthropod specimens. We are also very much indebted to Ron Holmes who served as the field project supervisor, assisted in writing the description of study area and methods sections, reviewed the final manuscript, and made many other contributions to this project; Brenda Cunningham who assisted with field data collection, provided oversight for all laboratory operations and management of collections, and for her cover illustration; Sherry Bottoms and Kathleen McEvoy who labored in the field and laboratory to make this report possible. Their enthusiasm, dedication, and skill is greatly appreciated.

We also extend our appreciation to members of the Skagit Environmental Endowment Commission and to Margie Allen, North Cascades National Park Service Complex, for their support and assistance in the funding of this project.

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Introduction

As sites of connectivity between aquatic and adjacent upslope forests, riparian zones have been designated among the most important habitats within forest ecosystems (Meeham *et al.* 1977, Beschta *et al.* 1987, Gregory *et al.* 1991, Swanson and Franklin 1992, Naiman *et al.* 1993, USDA 1994). Riparian habitats have unique, diverse assemblages of plants and animals, and are used by more that 400 species of wildlife (Oakley *et al.* 1985, Hancock *et al.* 1996). As a result of their importance, protection of riparian reserves has been mandated by State and Federal land-use guidelines (e.g., USDA 1994).

Riparian habitats within Pacific Northwest have a rich diversity of arthropods (Asquith *et al.* 1990, Parsons *et al.* 1991, Lattin 1993a). These organisms are an important source of energy in the food chain of adjacent aquatic systems (Patton 1977, Meeham *et al.* 1977). Changes in the structure and composition of riparian arthropod communities are likely to influence biological productivity in adjacent rivers and streams (Norton 1996). Monitoring riparian arthropod communities may provide valuable information about the overall health of the watershed ecosystem. Measuring abiotic factors tell us what is happening in the physical environment, and biological monitoring detects what is happening to the living species. Because they are part of almost all ecosystem processes, arthropods should be effective as indicators of change in forest riparian ecosystems.

Information about species can inform scientists and managers about movements, accumulations, and modifications of materials in the natural environment and identify the biological effects of these processes. Because of their size and microhabitat requirements, insects can reveal fine-scale environmental change (Samways and Steytler 1996). The functional importance of invertebrates has yet to be fully appreciated by conservation planners, in the context both of conserving species and using functional group analysis as a tool for environmental monitoring (Lattin 1993b, New 1993).

This study of Big Beaver Creek Natural Research Area was undertaken to examine the potential of riparian arthropods for use in long-term ecological monitoring and to document species occurring in the study area. The first four contributions to this five-part series (Lattin 1997, Labonte 1998, Glesne 1998, 2000) focused on the individual taxonomic groups (true bugs, spiders, ants, and beetles). Objectives of these reports were to provide basic information concerning species occurrence, relative abundance and distribution among habitats, life history and taxonomic background. This report characterizes arthropod community assemblages, identifies environmental factors that influence community assemblage structure, and to provides basic information useful in the design and implementation of future monitoring programs.

Study Area

Big Beaver Creek is located approximately 25 km south of the Canadian border and about 75 km east of Bellingham (Figure 1). Big Beaver Creek flows in a southeasterly direction into the south end of Ross Lake, a power-generating impoundment occupying the northern portion of the Skagit River Valley. The Big Beaver watershed is a pristine natural area that encompasses approximately 17,000 ha, including the tributary drainages of Luna and McMillan Creeks. The elevation ranges from 488 m in the east where Big Beaver Creek flows into Ross Lake to 2502 m at the summit of Mt. Challenger at the western boundary of the watershed. Within this watershed, there are 174 km of streams and 62 lakes/ponds represented on the USGS 7.5' topographical maps.

The climate in Big Beaver Valley is determined by general weather patterns in the North Cascades, which are modified by topographic features in and around the valley. Air masses originating as frontal systems over the Pacific Ocean release rain or snow as they rise over the Pickett Range. This results in a rain shadow effect for Big Beaver Valley. Miller and Miller (1971) reported a moisture gradient within the valley, with the west end receiving more moisture than the east end. Precipitation is estimated to range from approximately 150 cm in the lower eastern end of the valley to 250 cm in the higher, western end of the watershed (Taber and Raedeke 1976). The orientation of the valley on a northwest-southeast axis creates strong microclimatic variation. For example, the north facing slopes remain cool and moist throughout the summer months because they receive very little direct sunlight.

The bedrock of Big Beaver Valley is composed almost entirely of Skagit Gneiss with a few scattered outcrops of Cascade River Schist (Misch 1966). Several periods of glaciation have carved a typical flat-bottomed, steep-walled valley. The headwaters of all streams begin in the steep upper canyons, often flowing down into a loose talus slope and finally entering the lower gradient valley bottom. There is a soil moisture gradient from the well-drained rocky soils on the upper slopes to the saturated silty-peat soils of the valley bottom. The area surrounding Ross Lake is a transition zone between moist coastal forests west of the Cascade crest and dry interior forests (Franklin and Dyrness, 1973). This situation is evident in Big Beaver Valley, which shares plant associations and floristic affinities with both regions (Vanbianchi and Wagstaff 1988).

Only the lower 13 km of the valley were sampled during this study. Along this part of the valley, Big Beaver Creek is a fourth order, low-gradient stream with many meanders. Study site elevations were modest, ranging from 494 to 579 meters. There are substantial gravel bars along this section, while the low-gradient and relatively broad valley floors have enabled the formation of extensive swamps and marshes.

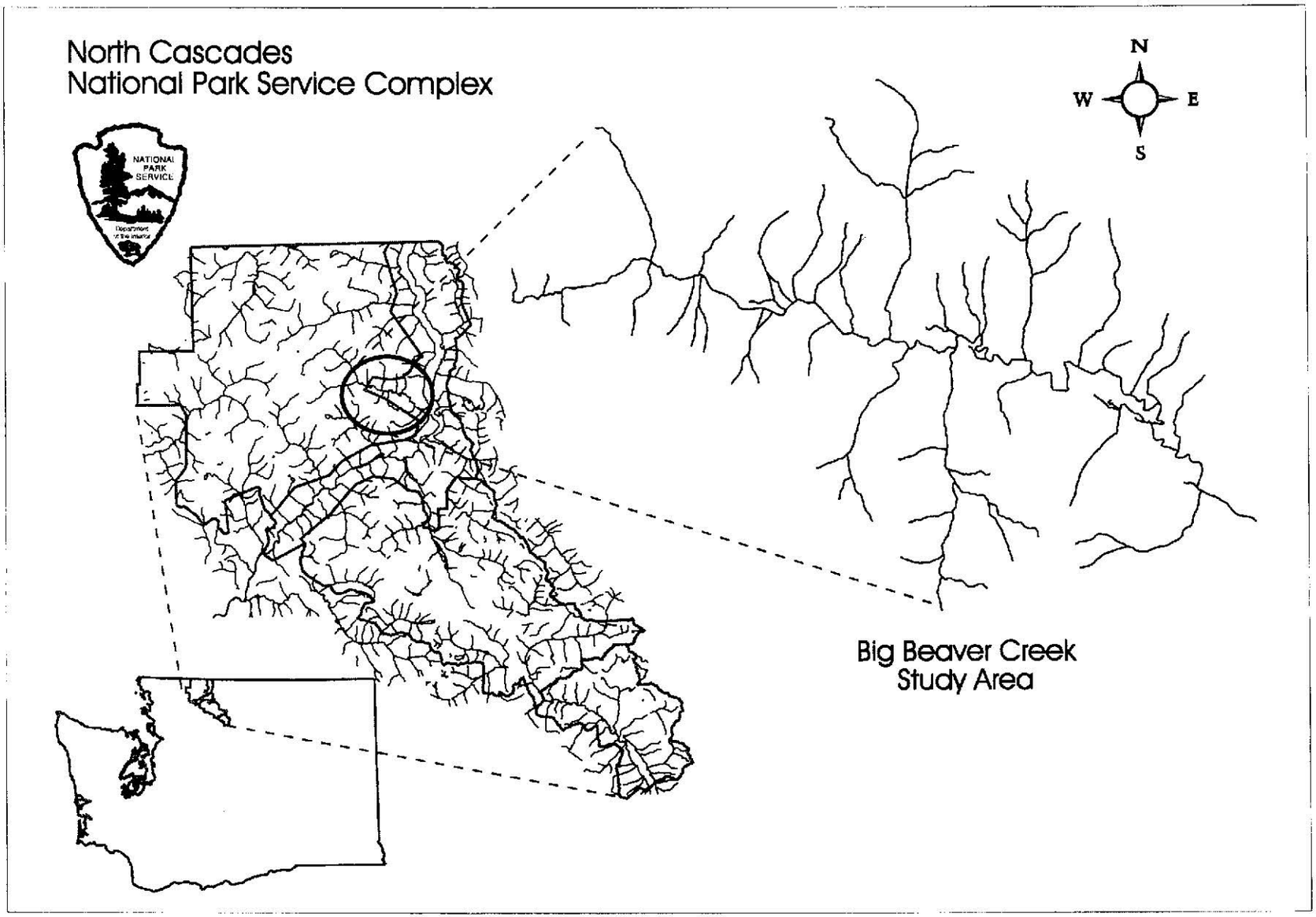

Figure 1. Location of the Big Beaver Creek study area in North Cascades National Park Service Complex, Washington.

Beavers profoundly affect the vegetation and hydrography in the lower gradient sections of the study area. They constantly reshape their channels, alter water levels, and harvest vegetation for food and construction materials. They create and maintain wetlands and kill large areas of riparian forest by inundation (Vanbianchi and Wagstaff 1988). Beavers are also responsible for the formation of most of the pond habitat in the lower valley. Thus, aquatic and riparian communities of the lower valley are largely dependent on these animals.

The vegetation of the study area can be divided roughly into wetland and montane forested communities. Finer resolution divisions can be made based on dominant species and age structure. Common wetland plant species include: aquatic species *Potamogeton natans, Nuphar polysepalum*, and *Menyanthes trifoliata;* emergent species, *Carex* spp., *Potentilla palustris, Habenaria dilatata, Glyceria elata*, and *Equisetum* spp.; bog species, *Sphagnum* spp., *Drosera rotundifolia, Tofieldia glutinosa*; shrub species, *Salix sitchensis, Salix lasiandra, Spiraea douglasii, Cornus stolonifera, Acer circinatum, Alnus sinuata*, and *Sambucus racemosa.* Common trees in forest communities include deciduous trees, *Alnus rubra, Acer macrophyllum, Populus trichocarpa*, and conifers, *Thuja plicata, Pseudotsuga menziesii, Tsuga heterophylla, Abies amabilis, Pinus contorta, Pinus monticola* and *Picea engelmanni.*

Methods

Sampling Design, Sample Collection and Processing

Sampling of the terrestrial riparian arthropod fauna of Big Beaver Creek, North Cascades National Park Service Complex (Washington) was conducted during the snow-free seasons of 1995 and 1996. Sample site locations are shown in Figure 2 and in aerial photographs in the Appendix (Figures A1 to A8). Sample site locations were based upon a high-resolution vegetation map (Vanbianchi and Wagstaff 1988) of this stretch of Big Beaver Creek. Nine habitat types representing dominant vegetation associations, or habitats of special interest, were selected for sampling in 1995 and included the following: alder swamp (AS), maple thicket (AT), sphagnum bog (B), gravel bar (G), Douglas-fir forest (PF), willow-sedge swamp (SC), willow-spiraea swamp (SS), cedar-willow-sedge swamp (TC) and cedar-hemlock forest (TT). In 1996, AS, G, PF, SC and TT habitats were re-sampled:.

Pitfall traps were used to collect all specimens. Pitfall trapping is a well-established method for sampling ground-active arthropods, with extensive literature dealing with the protocols and limitations of this technique (*e.g.*Greenslade 1964, Luff 1975, Uetz and Unzicker 1976, Adis 1979, Topping and Sunderland 1992, Spence and Niemela 1994, Mommertz *et al.* 1996). Pitfall traps selectively sample surface-active arthropods (versus litter-dwelling or arboreal species) and therefore does not provide direct unbiased measures of abundance.

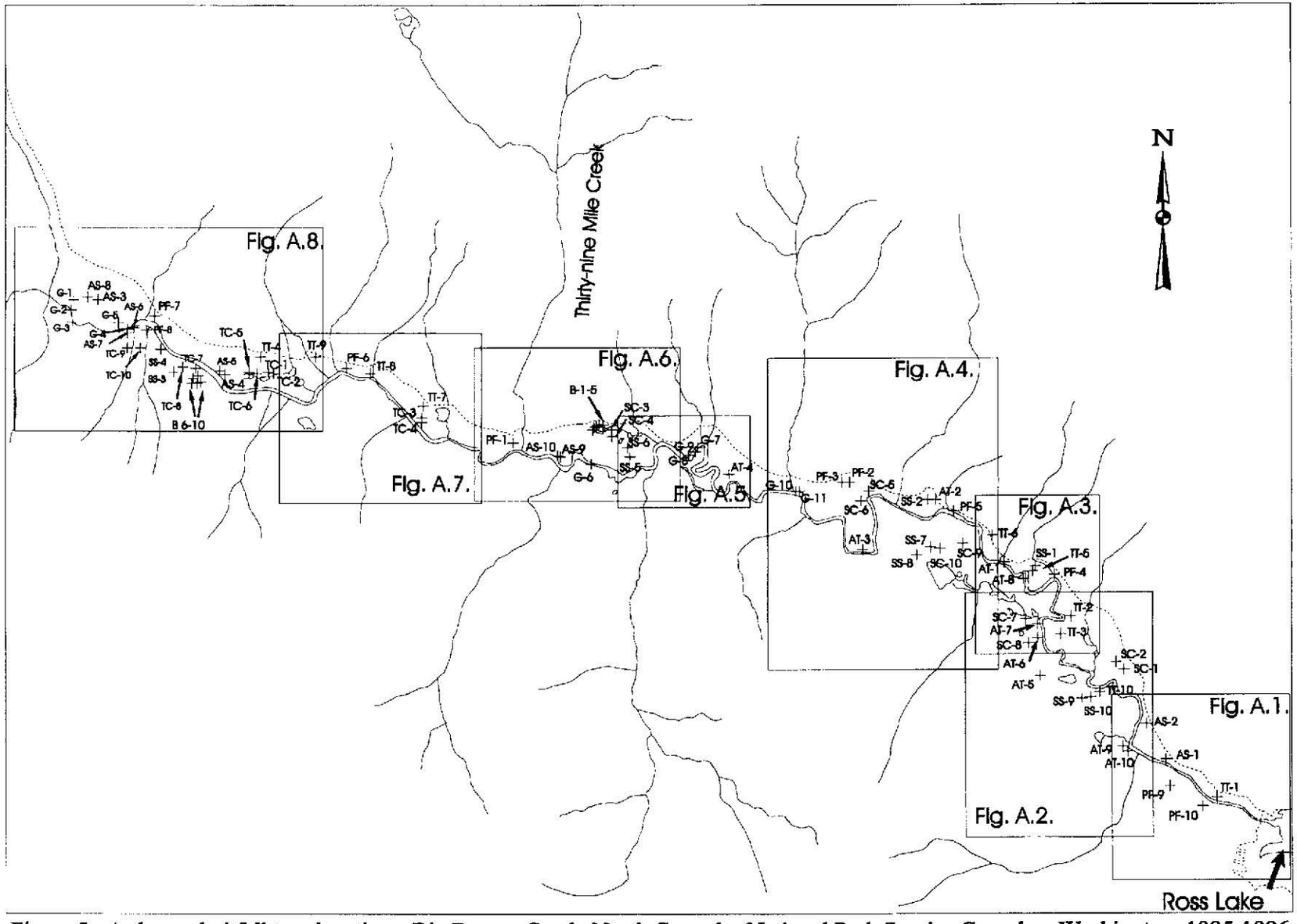

Figure 2. Arthropod pitfall trap locations, Big Beaver Creek, North Cascades National Park Service Complex, Washington, 1995-1996. (Boxes refer to aerial photos found in the Appendix, Figures A.1. - A.8.)

There has been discussion over the utility of pitfall traps for estimation of population abundance in entomological literature. However, there is general agreement that pitfall traps are useful for comparing relative abundance of invertebrate species among sites (Adis 1979, Southwood 1978, Luff and Eyre 1988). All species are not equally susceptible to this sampling method. For example, pitfall traps preferentially capture large, active species. Pitfall capture rates are also a function of climatic conditions, since these affect arthropod activity. For instance, very cold or dry conditions often result in reduced catches since many arthropods are less active under these circumstances. A further complication is that pitfalls sampling over relatively long periods may strongly attract necrophagous (carrion-feeding) insects (e.g. blowflies and burying beetles), especially traps that incidentally capture vertebrates and those with dilute preservative. There is also evidence that ethylene glycol, a standard preservative used in pitfall sampling, actively attracts some species or genders of insects (Holopainen 1990). No such evidence exists regarding the preservative used in the Big Beaver Creek study, propylene glycol, but it seems likely that it would have similar effects.

The pitfall traps consisted of a plastic bucket 18 cm tall with a diameter of 14 cm at the top and 12 cm at the bottom. An aluminum funnel was placed inside the top to prevent arthropods from escaping. This funnel extended about 8 cm down into the bucket with a bottom opening of 3 to 4 cm and the top tightly wedged inside and near the rim of the bucket. A 16 oz plastic cup, filled with approximately 100 ml of propylene glycol (non-toxic antifreeze), was placed inside the bucket. The plastic buckets were set into the ground so that the top of the bucket was even with the level of the surrounding substrate. Backfill and litter were repositioned to approximate the original condition of the trapsite. The cup, containing the antifreeze was set inside the bucket and then the funnel was installed. Finally, a 2 x 25 x 25 cm wooden board supported by 2 x 2 x 5 cm legs was set over the pitfall trap to exclude debris and rain.

Ten separate habitat patches were randomly selected for each habitat type and one pitfall trap was used per habit patch (Figure 2), with the exception of bog and gravel bar sites in 1995. There were only two patches of the bog habitat in the valley. Five pitfall traps were placed at each of these sites. For gravel bar sites, 11 separate patches were selected in 1995 and 10 in 1996. Traps operated continuously throughout the sampling period, from early June through October of 1995 and 1996. The 1995 sample effort also included May. Extensive bear damage to these early season traps, up to 70% of the traps, made it necessary to drop this sample period from analyses and exclude it from the 1996 data. Thus, 91 traps were utilized in 1995 and 50 in 1996. In order to reduce "trap-out" effects and individual trap bias, each 1996 trap position was shifted approximately 10 m from the 1995 position.

Extensive habitat information from an 8 × 8 m grid centered upon the trap was recorded for the area immediately surrounding each trap site. Information collected for each site included UTM coordinates, elevation, crude soil type (*e.g.* clay versus loam), soil moisture categories during August, litter depth, percent canopy closure (densiometer), slope, aspect, percent herb and shrub cover by species (herb and shrub cover was measured in 4x4 m plots centered upon the trap), tree species inventory (number of individuals and d.b.h.) and coarse woody debris inventory. The number and species of vertebrates collected by the pitfalls were also recorded, and all such specimens were retained.

Pitfall samples were collected once a month. Specimens collected from each trap were placed in bottles with the antifreeze preservative and returned to the lab for processing. In the laboratory, samples were washed, and sorted, and all specimens were placed in vials of 70% ethanol. All identifications were based on intact adult specimens and were identified, in most cases to the species level. Taxonomic references and expertise used in the identification of specimens from the four major groups of arthropods (true bugs, spiders, ants, and beetles) were reported in Parts I-IV of this series (see Lattin 1997, LaBonte 1998, and Glesne 1998, 2000).

Data Analysis

Species Richness and Diversity

Species richness and diversity analyses for each habitat were developed from data matrices representing the number of captures for each species by individual samples. For example, during 1995 gravel bar habitats were sampled with 11 pitfall traps during each of the four monthly sample periods, capturing 96 species, resulting in a matrix of 96 columns (species) and 44 rows (samples). These analyses were completed for each of the nine habitats sampled in 1995 and for the combined 1995 and 1996 set of samples from the 5 habitats sampled during both years.

EstimateS 5.0.1 (Colwell 1997) software was used for the analyses. Accumulation curves for all parameters were developed by computing mean values for each sample increment from 100 randomizations of sample order. This sample analysis procedure is discussed in more detail in Colwell and Coddington (1994). The following describes species richness estimators and diversity indexes used in the analyses:

Chao1 species richness estimator

The Chao1 estimator (Chao 1984, Colwell and Coddington 1994, Colwell 1997) is non-parametric, but requires relative abundance data and is calculated as follows:

$$S_{Chao1} = S_{obs} + \frac{F_1^2}{2F_2}$$

where S_{obs} is the number of species observed, F_1 is the number of singletons (species represented by only one individual), and F_2 is the number of doubletons (species represented by only two individuals). Chao1 reaches its maximum at about one-half the square of the observed richness when all species except one are singletons and considers the inventory complete when all species are represented by at least two individuals (Coddington *et al.* 1996).

Chao2 species richness estimator

The Chao2 estimator (Chao 1987, Colwell and Coddington 1994, Colwell 1997) is also non-parametric, but utilizes only presence-absence data and is calculated as follows:

$$S_{Chao2} = S_{obs} + \frac{Q_1^2}{2Q_2}$$

where Q_1 is the number of species found in only one sample ("uniques", regardless of abundance in those samples), and Q_2 is the number of species found in just two samples. Chao1 reaches its maximum at about one-half the square of the observed richness when all species except one are uniques and considers the inventory complete when all species occur in at least two samples (Coddington *et al.* 1996).

Jackknife1 species richness estimator

Jackknife1, the first-order jackknife estimator of species richness (Burnham and Overton 1978, 1979; Heltshe and Forrester 1983, Colwell 1997) is non-parametric and also uses only presence-absence data. It is calculated as follows:

$$S_{Jack1} = S_{obs} + Q_1 (m-1/m)$$

where Q_1 is the number of unique species and m is the number of samples. The Jacknife1 estimator reaches its maximum when all species are uniques at approximately twice the number of observed species (Coddington *et al.* 1996).

Shannon diversity index

The Shannon diversity index (H' - see Magurran 1988, Hayek and Buzas 1996) was calculated according to the following formula:

$$H' = -\Sigma p_i \ln p_i$$

where p_i is the proportion of individuals found in the i^{th} species. The index is sensitive to the number of species in a sample and the evenness in the distribution of abundance among the species within the sample. Values for the Shannon index usually fall between 1.5 and 3.5, and rarely surpass 4.5 (Margalef 1972).

Alpha index of diversity

The Alpha index (α - Fisher's alpha diversity index) is derived from the log series species abundance model (see Magurran 1988, Hayek and Buzas 1996). Methods for calculating the index are found in Equations 2.5 - 2.9 in Magurran (1988).

Simpson's index of diversity

Simpson's index (D) is calculated according to the following formula:

$$D = 1 / \Sigma p_i^2$$

Where p_i is the proportion of the i^{th} species in the total sample. This index goes from zero to the total number of species. A value of one indicates that all of the individuals in a sample belong to a single species. Unlike Alpha and Shannon diversity indices, Simpson's index is heavily weighted towards the most abundant species in a sample while being less sensitive to species richness (Magurran 1988).

Classification and Ordination

Data Reduction and Matrix Development

Species by site data matrices for classification and ordination analyses represented a reduced version of the original data set. First, because rare species may distort these analyses (see, Gauch 1982, Faith and Norris 1989, Jackson 1993), all species with less than 6 individuals total were dropped from the analysis. Vagrant species (those with very limited distributions among all the sample sites - species found at three or fewer sites) were also dropped. Next, matrix values for final analyses were calculated by taking monthly averages of capture data for each species from each trap.

Finally, investigation of outliers in the dataset was completed using PC-ORD ver. 3.0 software (McCune and Mefford 1997). An outlier is a sample of peculiar species composition and has low similarity to all other samples. Many multivariate methods give unsatisfactory results if outliers are present (Gauch 1982). For this study, outlier analysis of sample sites by species composition used the Sorenson distance measure. Sorensen distance measured as percent dissimilarity (*PD*) is a proportion coefficient and the formula is written as follows:

$$PD = 1-2W/(A+B)$$

where W is the sum of shared abundances and A and B are the sums of abundances in individual sample units. The Sorensen coefficient (also known as the Czekanowski or Bray-Curtis coefficient) was originally applied to presence-absence data, but it works equally well with quantitative data (McCune and Mefford 1997). A total of six outliers, with *PD* values greater than 2 standard deviations (cutoff point in the analysis) from the mean, were identified and dropped from the analysis.

Two-way Indicator Species Analysis (TWINSPAN)

TWINSPAN (Hill 1979, Gauch and Whittaker 1981) is considered a polythetic divisive classification technique, which uses information from all species, and where all samples are successively divided into smaller and smaller clusters until finally each cluster forms some specified smaller number of clusters (Gauch 1982). TWINSPAN simultaneously classifies species and samples. The resulting hierarchy of groups can be shown on a dendrogram with the species that influence division of groups of sample sites. A more detailed description of the method is found in Gauch (1982, pp. 201-203). Certain limitations of TWINSPAN have been reported by van Groenewoud (1992) and by Belbin and McDonald (1993).

TWINSPAN analysis was performed, using PC-ORD ver. 3.0 software (McCune and Mefford 1997), on the following four datasets: 1) 1995 data only for nine habitats, using all species (data matrix representing 116 species and 85 sample plots, following data reduction as previously mentioned); 2) 1995 beetle data for the nine habitat types (data matrix representing 86 species and 85 sample plots); 3) 1995 spider data for the nine habitat types (data matrix representing 14 species and 85 sample plots); and, 4) Combined 1995 and 1996 data for the five re-sampled habitats, using all species (data matrix representing 101 species and 94 sample plots). There were not enough species of ants and true bugs to apply TWINSPAN analysis to these groups.

PC-ORD parameter options used in the TWINSPAN analyses included: minimum group size for division = 5, maximum number of indicators per group = 5, and maximum levels of divisions = 3. Pseudospecies cut levels were set at 0, 2, 5, 10, and 20 individuals.

Non-Metric Multidimensional Scaling (NMDS)

The purpose of NMDS is to provide a visual representation of the patterns of similarity among individual samples as determined by the composition of their arthropod assemblages. Sites in close proximity to each other exhibit greater similarity in species composition than sites located farther apart in the ordination diagrams. This method, as with other ordination methods, simplifies large amounts of ecological information to allow a greater understanding of the structure of communities and relationships with corresponding environmental characteristics and conditions.

In NMDS, raw data is first converted into a matrix of dissimilarity values. Unlike metric forms of ordination, NMDS only uses the rank order information from the dissimilarities matrix. The intention with the non-metric method is to moderate the often violated assumption of linearity (change in value of one variable is directly proportional to the change in value of another) in the data with a weaker and less problematic assumption of monotonicity (paired variables must increase together, or as one increases the other must not decrease) (Gauch 1982). Pimentel (1995) reviews the advantages and limitations of both metric and non-metric ordination methods.

Given only the compositional dissimilarities among sites, the ordination space is derived such that the resulting distances in the ordination space match (exhibit a low 'stress' value) the corresponding dissimilarities. The stress measure is defined according to a prescribed relationship between dissimilarities and distances (see Kruskal 1964a). Stress values are used to examine the goodness of fit between the similarities and final fit. Kruskal (1964a) gives informal interpretation of stress values where; < 5% is excellent, 5-10% is good, 10-20% is fair, and >20% is poor. Kruskal (1964b) and Pimentel (1995) give detailed explanations of the NMDS method.

NMDS analysis was performed, using PC-ORD ver. 3.0 software (McCune and Mefford 1997), on the 1995 data set for nine habitats, using all species (data matrix representing 116 species and 85 sample plots), and the combined 1995 and 1996 data set for the five re-sampled habitats, using all species (data matrix representing 101 species and 94 sample plots). The coordinates graph file from a Principal Components Analysis (PCA, PC-ORD ver. 3.0 software) of the data matrices was used as the starting coordinates for the NMDS ordinations. The Sorensen distance

measure (same as for the outlier analysis) was used to construct the dissimilarity matrix. The NMDS procedure was completed requesting information for both 2 and 3 axes. Although analyses using the third axis reduced stress values, it was not a significant reduction, and it was thought that most of the information in the data set could be represented by 2 axes.

Site Attribute Correlations

Spearman rank correlations were used to measure the association between site attributes (soil moisture, soil type, vegetation composition, tree basal area, canopy cover, litter depth, and coarse woody debris), as well as with the NMDS ordination axes values. The latter indicates environmental factors that influence the grouping of sites in the NMDS ordination space. SPSS ver. 9.0 software (SPSS 1999) was used for obtaining Spearman rank correlation values.

Indicator Species Analysis

Dufrene and Legendre (1997) proposed the use of a species Indicator Value index for identifying indicator species and species assemblages characterizing groups of sites. The index is based on only within-species abundance (% relative abundance) and occurrence (% frequency of occurrence) comparisons, without any comparison among species. The index reaches its maximum (100) when all individuals of a species are found in a single habitat type and when the species occurs in all sites of that habitat type. PC-ORD ver. 3.0 software (McCune and Mefford 1997) was used to calculate Relative abundance (RA), Relative Frequency (RF), and Indicator Values (IV) for important taxa (IV value > 40) by TWINSPAN groups ordinated from data collected during 1995.

Results

Soil and Site Attributes

A summary of soil and site characteristics by habitat type is shown in Table 1. Plant species richness and common herb, shrub, and tree species found within the sample sites are shown in Tables 2-4. All plant species encountered during the survey, by habitat type, are found in the Appendix, Tables A1 - A3. Photos representing the various habitat types are shown in the Appendix, Figures A9 - A14.

Alder swamp (AS) site soils were moist to wet, predominantly sandy or loamy, with an average litter depth of 5.6 cm. The average coarse woody debris volume was 2.3 m^3 per plot (Table 1). The sites were essentially flat, with an average slope of 0.6% and canopy closure averaged 96%. Seventeen herb species were found among the AS sites, with an average of 4.3 species/plot (Table 2). *Athryium filix-femina* was the only herb species considered as common (occurring at 50% or more of the plots) to this habitat. Herb cover averaged 53%. Sixteen species of shrubs were identified within the AS habitat type. Several shrub species were commonly encountered in AS habitat sites (Table 3), of which *Rubus spectabilis* was the most abundant and widely distributed species. AS habitat sites had an average species richness of 4.6 shrub species per plot. Average shrub cover was 64%. Red alder (*Alnus rubra)* and vine maple (*Acer circinatum*) were the only common tree species of 8 species found in this habitat type.

Maple thickets (AT) had moist soils that were predominantly organic or loamy, with an average litter depth of 3.5 cm. Average coarse woody debris volume was 2.0 m^3 per plot. The average site slope was 5.4%. Canopy closure averaged 99%. Common herbaceous layer species included mosses and *Athryium filix-femina.* Herb cover averaged 45%, with average species richness of 3.6 species per plot. The most common shrubs were *Acer circinatum* and *Cornus stolenifera.* Maple thickets had the greatest average shrub cover of all sampled habitats. Shrub canopy cover consisted of multiple layers and the average shrub cover was 106%. Twelve species of shrubs were found in the AT habitat, with average species richness of 2.6 species per plot. The dominant trees were *A. circinatum* and *Pyrus fusca*, with 5 species found among the 8 plots sampled. Tree density, as measured by percent basal area in the plot, ranked 4th among the 9 habitats.

Douglas fir forest (PF) soils were dry, organic or loamy, with an average litter depth of 8.2 cm. The average coarse woody debris volume was 5.7 m^3 per plot, greatest among the habitat types. Slopes averaged 7.8%. Canopy closure averaged 100%. Mosses and *Linnaea borealis* were the most common herbaceous layer species. Herb cover averaged 55% and average species richness of 3.3 species per plot. Average shrub cover was 26%, with an average species richness of 2.7 species per plot, and a total of 11 species encountered in the habitat. Eight species of trees were found in PF habitat with an average of 2.9 species/plot. The most common trees included *Tsuga heterophylla* and *Thuja plicata.* These forests were the steepest of all sampled habitats, had the greatest average canopy closure, the greatest average woody debris volume, the greatest basal area of trees and the greatest average litter depth of all sampled habitats.

Table 1. Summary of soil and site attribute characteristics by habitat type at arthropod pitfall trap sites, Big Beaver Creek Research Natural Area, North Cascades National Park Service Complex, Washington, 1995. (AS = alder swamp, AT = maple thicket, B = Sphagnum bog, G = gravel bar, PF = Douglas fir forest, SC = willow/Carex swamp, SS = willow/Spiraea swamp, TC = cedar/willow/Carex swamp, TT = cedar/hemlock forest)

	AS (10)	AT (8)	PF (9)	TT (9)	G (10)	TC (10)	B (10)	SC (10)	SS (9)
Soil moisture and soil type class frequency (%) by habitat types (sample size)									
Soil Moisture									
Wet	60	12.5	0	0	0	70	100	100	67
Moist	20	75	0	22	0	30	0	0	33
Dry	20	12.5	100	78	100	0	0	0	0
Soil Type									
Peat	0	0	0	0	0	0	100	0	0
Organic debris/litter	20	25	56	22	0	90	0	90	89
Clay - sandy loam	80	75	44	78	20	10	0	10	11
Sand and rock	0	0	0	0	80	0	0	0	0
Mean and standard deviation of site attributes by habitat type									
	AS	**AT**	**PF**	**TT**	**G**	**TC**	**B**	**SC**	**SS**
CWD (m^3)									
Mean	2.26	2.04	5.69	3.46	1.31	0.18	0.25	0.01	0.13
Stand. Dev.	*4.17*	*2.57*	*3.65*	*2.18*	*2.23*	*0.38*	*0.76*	*0.04*	*0.23*
% Herb Cover									
Mean	52.5	45	54.9	49.2	5.5	119.8	242.5	157.3	109.4
Stand. Dev.	*40.9*	*50.5*	*40.8*	*41.1*	*5.25*	*42.8*	*34.8*	*48.1*	*62.9*
% Shrub Cover									
Mean	63.6	105.6	26.1	36.6	9.4	82.1	20.9	39.9	69.2
Stand. Dev.	*45.9*	*9.6*	*23.8*	*35.8*	*11.5*	*45*	*20.3*	*27*	*39.8*
% Tree Basal Area									
Mean	1.73	1.08	3.03	1.98	0.08	0.46	n.s	0	0
Stand. Dev.	*1.37*	*1.29*	*1.21*	*1.13*	*0.27*	*0.84*	-	*0*	*0*
% Canopy Cover									
Mean	96	99	100	99.3	12.7	62.6	7	4.5	16.6
Stand. Dev.	*5.9*	*2.1*	*0*	*1.1*	*16.1*	*26.5*	*10.6*	*6.6*	*29.4*
Litter Depth (cm)									
Mean	5.6	3.5	8.2	5.3	0	5.4	0	6.3	4.9
Stand. Dev.	*2.5*	*3.2*	*2.2*	*2.2*	*0*	*2.9*	*0*	*2.6*	*2.1*

Table 2. Herbaceous layer plant species summary by habitat type at arthropod pitfall trap sites, Big Beaver Creek Research Natural Area, North Cascades National Park Service Complex, Washington, 1995.

Habitat Type	Common Species[1]	Total No. of Species	Avg. No. of Species/Plot[2]	Range No. of Species/Plot
Alder Swamp	*Athyria filix femina*	17	4.3	2-7
Maple Thicket	Moss spp. *Athyria filix femina*	18	3.6	1-7
Sphagnum Bog	*Sphagnum sp.* *Carex spp.* *Drosera rotundifolia* *Menyanthes trifoliata* *Trientalis latifolia*	15	6.3	3-11
Gravel Bar	*Epilobium latifolium* Graminoid spp. *Anaphalis margaritacea*	13	2.8	0-9
Douglas Fir Forest	Moss spp. *Linnaea borealis*	14	3.3	1-6
Willow/Carex Swamp	*Carex spp.* *Equisetum sp.* Graminoid spp. *Angelica genuflexa* *Lysichitum americanum* *Aster modestus*	21	6.1	2-10
Willow/Spiraea Swamp	*Carex spp.* *Potentilla palustris* *Athyria filix femina* *Lysichitum americanum*	16	5.2	2-8
Cedar/Willow/Carex Swamp	*Carex spp.* *Athyria filix femina* *Lysichitum americanum* *Equisetum sp.* Graminoid spp.	20	6.3	4-9
Cedar/Hemlock Forest	*Tiarella trifoliata* *Athyria filix femina*	26	6	1-11

[1]Common species included those which occurred in 50% or more of the sites sampled within a particular habitat type.
[2]Plot size for herbaceous plant data collection was 4x4 meters, and centered on arthropod pitfall trap location.

Table 3. Shrub plant species summary by habitat type at arthropod pitfall trap sites, Big Beaver Creek Research Natural Area, North Cascades National Park Service Complex, Washington, 1995.

Habitat Type	Common Species[1]	Total No. of Species	Avg. No. of Species/Plot[2]	Range No. of Species/Plot
Alder Swamp	*Rubus spectabilis* *Cornus stolenifera* *Sambucus racemosa*	16	4.6	3-7
Maple Thicket	*Acer circinatum* *Cornus stolenifera*	12	2.6	1-5
Sphagnum Bog	*Thuja plicata* *Spiraea douglasii*	9	2.5	0-5
Gravel Bar	*Salix sitchensis* *Alnus rubra*	9	1.7	0-4
Douglas Fir Forest	*Tsuga heterophylla* *Acer circinatum*	11	2.7	1-4
Willow/Carex Swamp	*Spiraea douglasii* *Salix sitchensis*	5	2.2	1-4
Willow/Spiraea Swamp	*Spiraea douglasii* *Salix sitchensis* *Cornus stolenifera*	9	3.3	1-6
Cedar/Willow/Carex Swamp	*Salix sitchensis* *Spiraea douglasii* *Cornus stolenifera*	18	4.8	2-12
Cedar/Hemlock Forest	*Acer circinatum*	13	2.7	1-5

[1]Common species included those which occurred in 50% or more of the sites sampled within a particular habitat type.
[2]Plot size for shrub data collection was 4x4 meters, and centered on arthropod pitfall trap location.

Table 4. Tree plant species summary by habitat type at arthropod pitfall trap sites, Big Beaver Creek Research Natural Area, North Cascades National Park Service Complex, Washington, 1995.

Habitat Type	Common Species[1]	Total No. of Species	Avg. No. of Species/Plot[2]	Range No. of Species/Plot
Alder Swamp	*Alnus Rubra* *Acer cercinatum*	8	1.7	0-4
Maple Thicket	*Alnus sinuata* *Acer cercinatum* *Pyrus fusca*	5	0.8	0-2
Sphagnum Bog	(none - one tree at one plot)	1	0.1	0-1
Gravel Bar	(none - two trees at one plot)	1	0.1	0-1
Douglas Fir Forest	*Tsuga heterophylla* *Thuja plicata*	8	2.9	1-6
Willow/Carex Swamp	None	0	0	0
Willow/Spiraea Swamp	None	0	0	0
Cedar/Willow/Carex Swamp	*Thuja plicata*	3	0.6	0-2
Cedar/Hemlock Forest	*Thuja plicata*	7	2.2	1-4

[1]Common species included those that occurred in 40% or more of the sites sampled within a particular habitat type.
[2]Plot size for herbaceous plant data collection was 4x4 meters, and centered on arthropod pitfall trap location.

Cedar/hemlock forest (TT) soils were dry, with organic or loamy soils and had an average litter depth of 5.3 cm. Average coarse woody debris volume was second to Douglas fir forest habitats, 3.5 m^3 per plot. Average slope per plot was 4.8% and canopy closure averaged 99.3%. TT habitat exhibited the greatest diversity of herb species (26) and averaged 6 species/plot. *Tiarella tr.foliata* and *Atherix filix femina* were the most common species of herbs. Herb cover averaged 49%. *Acer circinatum* was the dominant shrub found among the TT sites; shrub cover averaged 37%, with average species richness of 2.7 species per plot. Thirteen species of shrubs were observed in the TT habitat. Seven species of trees were observed with an average of 2.2 species/plot. *Thuja plicata* was the most common tree found in the habitat. Tree basal area in TT habitat ranked second among the 9 habitats.

Gravel bar (G) soils were dry, lacked litter and were composed of sand, gravel and cobbles. The average coarse woody debris volume was 1.3 m^3 per plot. The average slope was 3.2% and canopy closure averaged 13%. Mean herbaceous plant cover was 5.5%, the lowest of all the habitats sampled. Thirteen herb species were found in the G sites, with an average of 2.8 species/plot. *Epilobium lat.folium* and grass species were the most common taxa. Shrub cover was also lowest at G sites (mean 9.4%). Nine shrub species were found in this habitat, with an average of 1.7 species/plot. *Salix sitchensis* and *Alnus rubra* were the most common species of shrubs. Trees were virtually absent, with only a single site that had a total of two trees.

Cedar/willow/carex swamp (TC) soils were organic, wet and had an average litter depth of 5.4 cm. Average coarse woody debris volume was negligible, <0.2 m^3 per plot. All of the sites were flat and canopy closure averaged 63%. Twenty herb species were observed in TC sites, with an average of 6.3 species/plot. Several species were widely distributed among the TC plots (Table 2), with *Carex* spp., *Athyrium filix-femina* and *Lysichitum americanum* the most common. Herb cover was of multiple layers and averaged 120%. Percent shrub cover was high in TC habitat (mean 82%). The greatest number of shrub species (18) and highest number of species/plot (4.8) were observed in TC habitat. The most common species of shrubs observed included *Salix sitchensis, Spiraea douglasii*, and *Cornus stolen.fera. Thuja plicata* was the most common tree species. Only 2 other species of trees were found in the habitat. Tree basal area was low (< 0.5 % of the plot area) compared to other forested habitats.

Sphagnum bogs (B) had wet, peaty "soils" without a litter layer. The average coarse woody debris volume was 0.3 m^3 per plot. Bog sites were flat, with no discernable slope, and canopy closure averaged 7%. Fifteen herb species were observed at B sites, with an average of 6.3 species/plot (ranking first with TC habitat, Table 2). The most common species at B sites included *Sphagnum* spp., *Carex* spp., *Drosera rotund.folia,* and *Menyanthes tr.foliata.* Herbaceous plants were the dominant plant group observed at B sites. They were in multiple layers, and percent cover was very high at 242%. Shrub cover at B sites was low (21%). Nine species of shrubs were observed, with an average of 2.5 species/plot. *Thuja plicata* and *Spiraea douglasii* were the most common shrubs. Only one tree was found in the 10 surveyed plots.

Willow/carex swamp (SC) soils were wet and organic, with an average litter depth of 6.3 cm. A small amount of coarse woody debris was found at only one of the 10 sites. These swamps were essentially flat, with an average slope of 0.3%, and canopy closure averaged 4.5%. SC sites exhibited a diverse herbaceous flora represented by 20 species and an average of 6.1 species/plot.

Many herb species were widely distributed among the plots, the most common including *Carex* spp. and *Equisetum* spp. and grass species. Herbaceous plants were in multiple layers. Herb cover was high and averaged 157%. Five species of shrubs were observed and common taxa included *Spiraea douglasii* and *Salix sitchensis*. Shrub cover averaged 40%. Trees were not found at any of the SC plots.

Willow/spiraea swamp (SS) soils were wet, organic and had an average litter depth of 4.9 cm. Average coarse woody debris volume was negligible, approximately 0.1 m^3 per plot. These sites were flat, with no discernable slope, and canopy closure averaged 19%. Sixteen species of herbaceous plants were observed with an average of 5.2 species/plot. Most common herb species included *Carex* spp., *Potentilla palustris*, *Athyria filix femina*, and *Lysichitum americanum*. Herb cover averaged 109%. Nine species of shrubs were observed and the most common species included *Spiraea douglasii, Salix sitchensis*, and *Cornus stolen.fera*. Shrub cover averaged 69%, with average species richness of 3.3 species per plot. There were no trees in any of the plots.

In summary, the various habitats can be generally characterized by gradients in soil moisture and canopy cover. These characteristics largely affect the plant community structure and consequently affect other environmental attributes such as litter and coarse woody debris. Habitat types exhibiting wet soil conditions and open canopies included bogs, willow/carex swamps and willow/spiraea swamps. Gravel bars exhibited dry soils and open canopies. Wet to moist soil conditions and closed canopies were found at maple thicket, alder swamp, and cedar/willow/carex sites. Dry soils and closed canopies were common to forested habitats of Douglas fir and cedar/hemlock sites.

Arthropod Sample Summary Statistics

General arthropod sampling statistics grouped by sample years and total number of habitats sampled are shown in Table 5. The number of species and individuals from the four major groups of arthropods investigated is also summarized in Table 5. A total of 15,916 adult arthropods representing 448 species were captured from all habitats during the 8 sampling dates over two years. Sampling of all 9 habitats during 1995 resulted in collection of 62% (9867) of all individuals and 80% (359) of all species sampled during the 2 year study.

In 1996, sampling was limited to 5 habitats (alder swamps, gravel bars, Douglas fir forest, willow/carex swamp, and cedar/hemlock forest), as previously described in the Methods section. Summary statistics for the same 5 habitats sampled during 1995 are also presented in Table 5 for purposes of comparison between years. There was little variation between years in the number of individuals (5,893 in 1995, and 6,049 in 1996) and number of species (284 in 1995, and 266 in 1966). The effects of increasing sample size can also be compared by combining both 1995 and 1996 data for the same 5 habitats, effectively doubling the sample size from 194 samples in 1995, and 182 samples in 1996, to 376 samples for the combined 1995 and 1996 5-habitat data set. The pooled sample resulted in the capture of 80 (22%) to 98 (27%) more species, for 1995 and 1996 respectively.

Table 5. Number of species and adult individuals* collected in pitfall traps, during four sampling periods, for the months of June through September, 1995 (all 9 habitats), 1995 (subset of 5 habitats), 1996 (subset of 5 habitats), and during 8 sampling periods for the months of June through September for 1995 and 1996 combined (subset of 5 habitats), and 1995-1996 (all samples combined).

	1995 (all)	1995 (5 habitats)	1996 (5 habitats)	1995&1996 (5 habitats)	1995&1996 (all)
No. of samples	**347**	**194**	**182**	**376**	**529**
No. of trap-days	**10410**	**5820**	**5640**	**11460**	**16050**
No. of individuals					
Beetles	4516	3217	3343	6560	7859
Spiders	3818	1682	1436	3118	5254
Ants	1140	861	1242	2103	2382
True bugs	393	223	28	251	421
Total	**9867**	**5983**	**6049**	**12032**	**15916**
No. of species					
Beetles	270	220	214	291	355
Spiders	38	32	24	33	38
Ants	19	16	17	21	22
True bugs	32	16	11	19	33
Total	**359**	**284**	**266**	**364**	**448**

* Number of individuals includes adult specimens only. Individuals representing Coleoptera necrophage taxa (*Catops spp.*, *Nicrophorus spp.* and unidentified Aleocharinae taxa) and the small msc. spider group (Erigonidae, Linyphiidae, Theridiidae, and Uloboridae) were not included in the analyses.

Beetles, spiders, ants, and true bugs were selected for identification to species because their taxonomy is relatively well known, and they were among the most abundant groups captured in pitfall traps. Specimens from the 4 groups were identified to the lowest possible taxonomic level. The largest proportion of specimens captured were beetles (49% of all individuals captured, and 79% of all species captured, Table 5). It is important to note that necrophagous beetle species were not included in any of the analyses because of potential sampling bias. Decomposing small mammals caught in traps may have attracted these species in unusual numbers. These taxa were extremely abundant and accounted for 41% of all beetles captured during the 2 years of sampling (LaBonte 1998). Complete lists of taxa for each of the four groups sampled can be found in the Appendix, Tables A4 - A7, and in Parts I-IV of this series (Lattin 1997, Glesne 1998, LaBonte 1998, Glesne 2000).

A summary of the sampling statistics for all 9 habitats sampled during 1995 is provided in Table 6. A summary of the sampling statistics for 5 habitats sampled in 1995 and re-sampled during 1996 is provided in Table 7. The number of samples from each habitat type varies because

Table 6. Sampling Summary Statistics. Data from all taxa collected during 4 sampling periods, June through September, 1995, by habitat type. (AS- alder swamp, AT- maple thicket, B- sphagnum bog, G- gravel bar, PF- Douglas fir forest, SC- willow/carex swamp, SS- willow/spiraea swamp, TC- cedar/willow/carex swamp, TT- cedar/hemlock forest).

Habitats	AS	AT	B	G	PF	SC	SS	TC	TT
No. of Samples	40	33	40	44	33	40	40	40	37
Total Trap-days Effort	1200	990	1200	1320	990	1200	1200	1200	1110
No. of Adults	1072	537	791	1736	783	1693	1567	976	712
No. of Species Observed	112	83	67	96	69	98	84	90	92
No. of Singletons	40	40	33	38	35	36	32	30	35
% Singletons	35.7	48.2	49.3	39.6	50.7	36.7	38.1	33.3	38
Sampling Intensity # adults per species	9.6	6.5	11.8	18.1	11.3	17.3	18.7	10.8	7.7
Capture Rate # adults per 100 trap-days	89	54	66	132	79	141	131	81	64

Table 7. Sampling Summary Statistics. Data from all taxa collected during 8 sampling periods, June through September, 1995 and 1996, by habitat type. (AS- alder swamp, G- gravel bar, PF- Douglas fir forest, SC- willow/carex swamp, TT- cedar/hemlock forest).

Habitats	AS	G	PF	SC	TT
No. of Samples	76	81	72	75	72
Total Trap-days Effort	2340	2490	2100	2340	2190
No. of Adults	2105	2968	1619	3324	2016
Observed Richness	145	113	108	143	129
No. of Singletons	43	45	40	53	47
% Singletons	29.7	39.8	37	37.1	36.4
Sampling Intensity # adults per species	14.5	26.3	15	23.2	15.6
Capture Rate # adults per 100 trap-days	90	119	77	142	92

several traps were disturbed or destroyed during the sampling periods by bears, raccoons, deer, and other wildlife.

During 1995, adult capture rates per 100 trap-days (Table 6) ranged from 54 for maple thicket habitat to 141 for willow/carex swamp habitat. High capture rates were also found at gravel bars and willow/spiraea swamp habitats, 132 and 131 adults/100 trap-days, respectively. The combined 1995 and 1996 samples for the 5 habitats sampled during both years (Table 7) resulted in very similar capture rates to those found for the same habitats with only a single year effort. One exception was cedar/hemlock forest habitat, which showed an increase from 64 adults/100 trap-nights in 1995 (1110 trap-days, Table 6) to 92 adults/100 trap-nights for combined 1995 and 1996 samples (2190 trap-days, Table 7).

The number of species observed in each habitat during 1995 ranged from 67 (bog) to 112 (alder swamp), with most habitats being represented by 80 to 100 species (Table 6). In comparison to 1995 data, the combined 1995 and 1996 sample for the 5 re-sampled habitats (Table 7) resulted in an increase in species observed, ranging from 17 in gravel bar habitat to 45 in willow/carex habitat.

Sampling intensity was described by Coddington *et al.* (1996) as the ratio of adults to species captured. They suggested that this index might provide a rough guide to the number of individuals required (sample effort) to estimate species richness, and compared sampling intensity values with species richness estimators. Sampling intensity for 1995 data from all 9 habitats ranged from 6.5 to 18.7 (Table 5). Sampling intensity, for the 5 habitats sampled during both years (Table 7) ranged from 14.5 to 26.3. In a comparison of the 5 habitats sampled in Tables 6 and 7, the combined sample resulted in a disproportionate increase in sampling intensity (30 to 50%) at all of the habitats except cedar/hemlock forest, where sampling intensity doubled with the combined set of 1995 and 1996 samples.

The percent singletons index, percentage of species represented by one adult, has been used to evaluate species inventory completeness (Coddington *et al.* 1996). This value is expected to be low for well-sampled faunas, and high values are expected from sparse samples of species rich communities. Results of 2 years of sampling showed that most species captured were represented by few individuals, and only a few species were represented by many individuals (Lattin 1997, Glesne 1998, LaBonte 1998, Glesne 2000). Percent singleton values were relatively consistent among 6 of the 9 habitats sampled during 1995, ranging from 33 to 39%. Approximately 50% of the species found at the other three habitats (maple thicket, bog, Douglas fir forest) were represented by singletons (Table 6). Comparisons between the 5 habitats sampled in both years showed that percent singleton values were little affected by combining the 2 years of data.

Species Richness

Species accumulation curves for 9 habitats sampled during 1995 are presented in Figure 3. The alder swamp habitat had the greatest number of species (112). Bog habitat had the fewest species (67). Species-area curves increased for each habitat after every sampling period and did

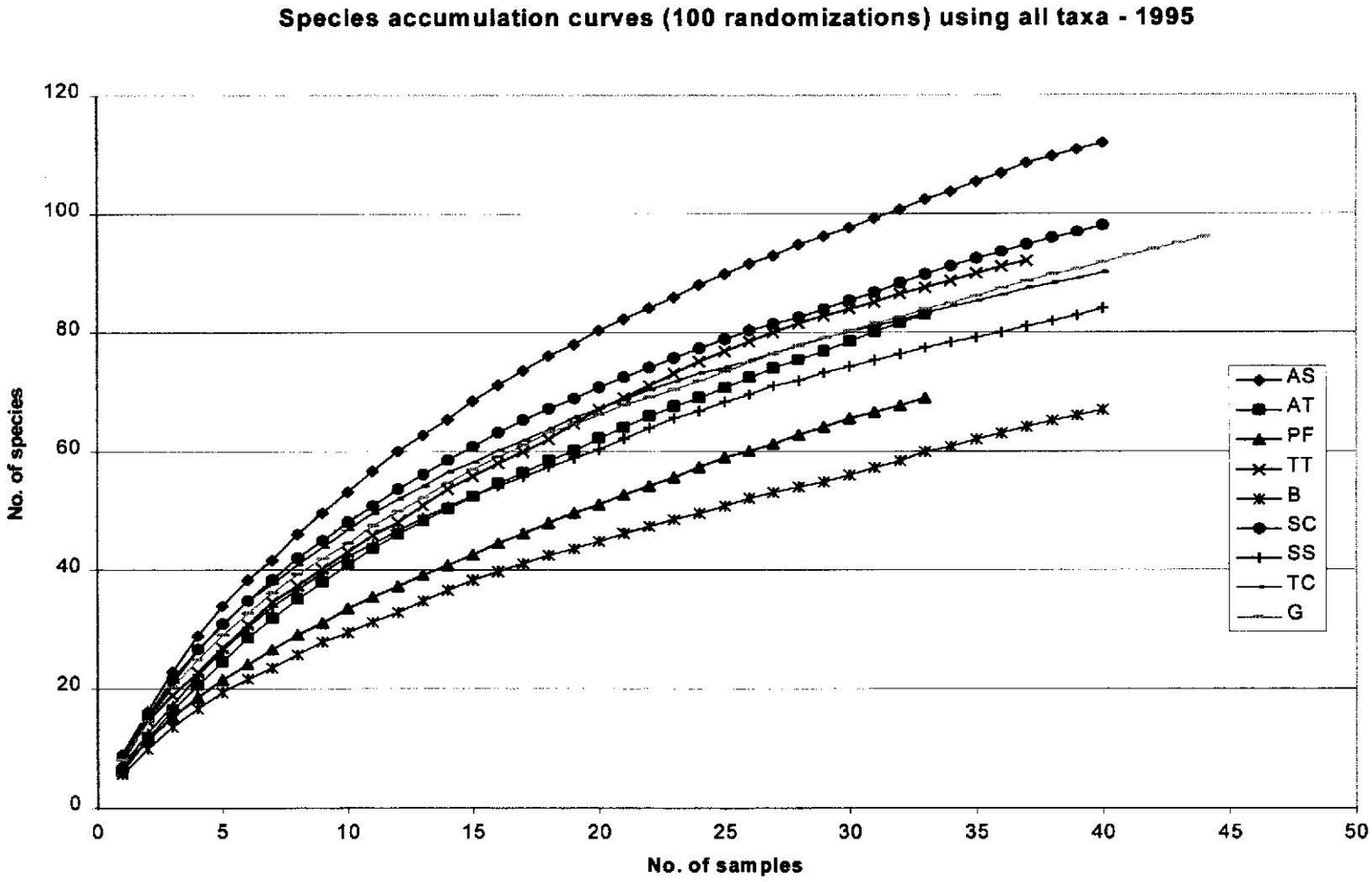

Figure 3. Species accumulation curves. Mean values of observed species richness at each sample increment for 100 randomizations of sample order. Results are represented for 9 habitats sampled over 4 monthly periods during June through September, 1995. (AS-alder swamp, AT-maple thicket, PF-Douglas fir forest, TT-cedar/hemlock forest, B-sphagnum bog, SC-willow/carex swamp, SS-willow/spiraea swamp, TC-cedar/willow/carex swamp, G-gravel bar).

not reach an asymptotic level after 4 sampling periods (representing 33 to 44 samples for each of the habitats).

Figure 4 presents species accumulation curves using combined data from 1995 and 1996 for the 5 selected habitats. Alder swamp habitat had the highest species count, 145 species captured after 8 sampling dates (76 samples). Douglas fir forest sites had the lowest species count, 108 species captured after 8 sampling dates (72 samples). Species accumulation curves increased for each habitat after every sampling period. They did not reach an asymptotic level during the study, even after combining both years of samples (33-44 samples per habitat in 1995, and 72-81 samples for combined 1995 and 1996).

Curves representing Chao1 estimates of species richness of re-sampled habitats for 100 randomizations of each sample increment are shown in Figure 5. Forested habitats appeared to be approaching asymptotes. The cedar/hemlock forest Chao1 curve leveled off at nearly 174 species after 60 samples. The Chao1 curve for Douglas fir forest habitat appeared to be slightly increasing and still not quite at its asymptote, approaching 152 species after 72 samples. The other three habitats did not reach asymptotes. Chao1 estimates were highest for willow/carex swamp habitat , reaching 207 species after 75 samples. Douglas fir forest habitat had the lowest Chao1 estimated species richness.

Curves representing Chao2 estimates of species richness of re-sampled habitats for 100 randomizations of each sample increment showed similar patterns (Figure 6) to those of Chao1 (Figure 5). Forested habitats again appeared to be approaching asymptotes as in Figure 5, for Chao1. Chao2 estimates were higher than Chao1 species estimates for all of the habitats. Willow/carex swamp habitat had the highest estimate, reaching 251 species after 8 sampling dates (75 samples). Douglas fir forest habitat had the lowest Chao2 estimated species richness, 154 species after 8 sampling dates (72 samples).

Curves representing Jackknife1 estimates of species richness of re-sampled habitats for 100 randomizations of each sample increment are shown in Figure 7. Jackknife1 estimates were similar to Chao estimates with the exception of gravel bar habitat, which had fewer species (152 , 191, and 202 species per 81 samples for Jackknife1, Chao1, and Chao2, respectively). None of the 5 habitats approached asymptotic levels.

A summary comparing mean values for observed richness, Chao1, Chao2, and Jackknife1 estimators, for the 5 re-sampled habitats, is shown in Table 8. To compare species richness among habitats, a standard sample size of 72 was selected which represents the largest sample size that all of the habitats had in common. Derived species richness values from the estimators were generally 20 to 40% greater than the observed richness values. There was reasonable agreement between the calculated estimators for all of the habitats except for gravel bar habitat, where Chao1 and Chao2 estimates appeared much higher (181 and 187 species, respectively) than the Jackknife1 estimate (154 species). Willow/carex swamp habitat consistently had the highest species estimates, ranging between 205 and 245 species. Douglas fir forest habitat consistently had the lowest species estimates, ranging between 152 and 154 species.

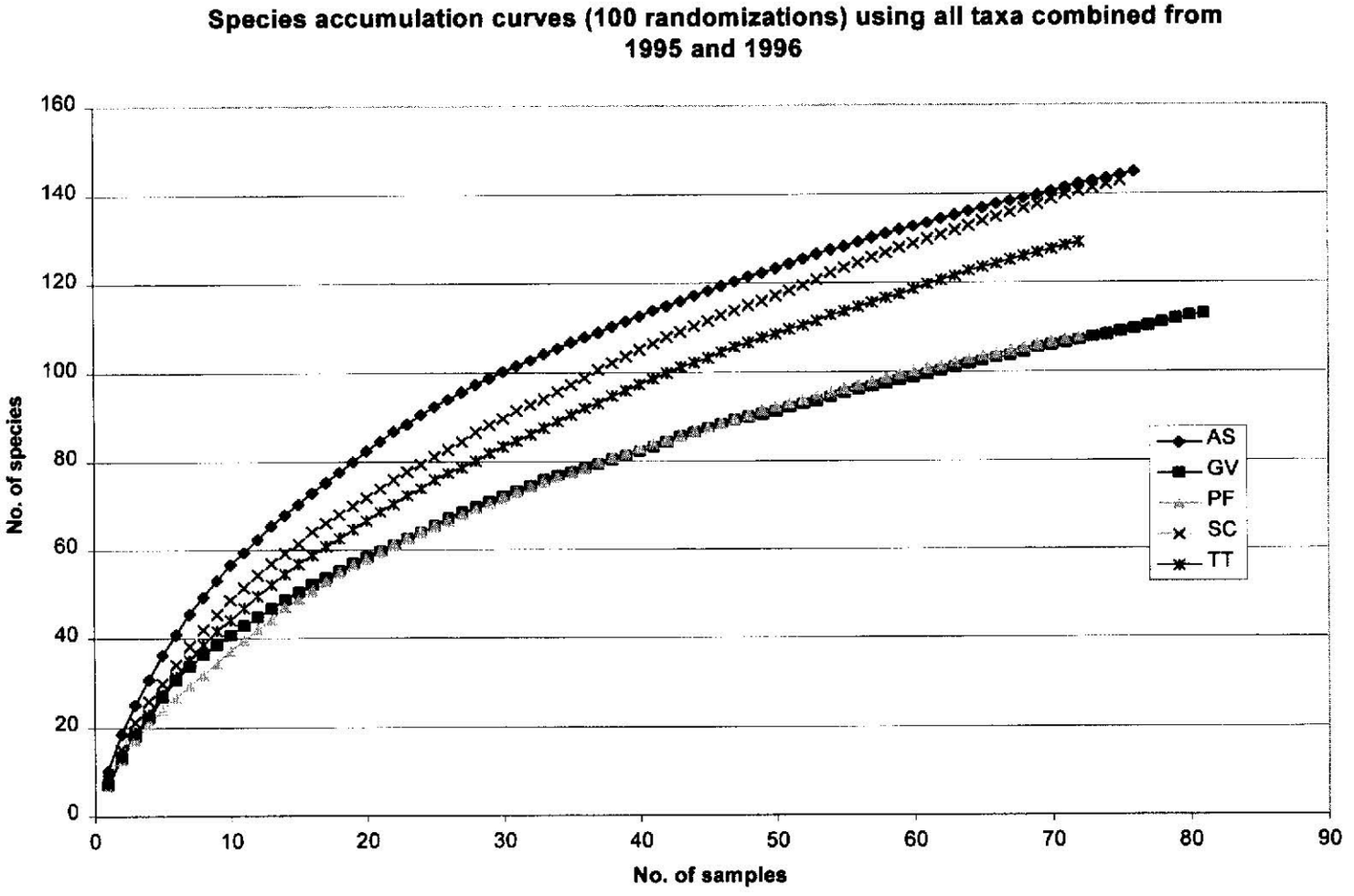

Figure 4. Species accumulation curves. Mean values of observed species richness at each sample increment for 100 randomizations of sample order. Results are represented for 5 habitats over 8 sample periods, 4 monthly sampling dates during June through September, 1995 and over the same period during 1996 (AS-alder swamp, PF-Douglas fir forest, TT-cedar/hemlock forest, SC-willow/carex swamp, G-gravel bar).

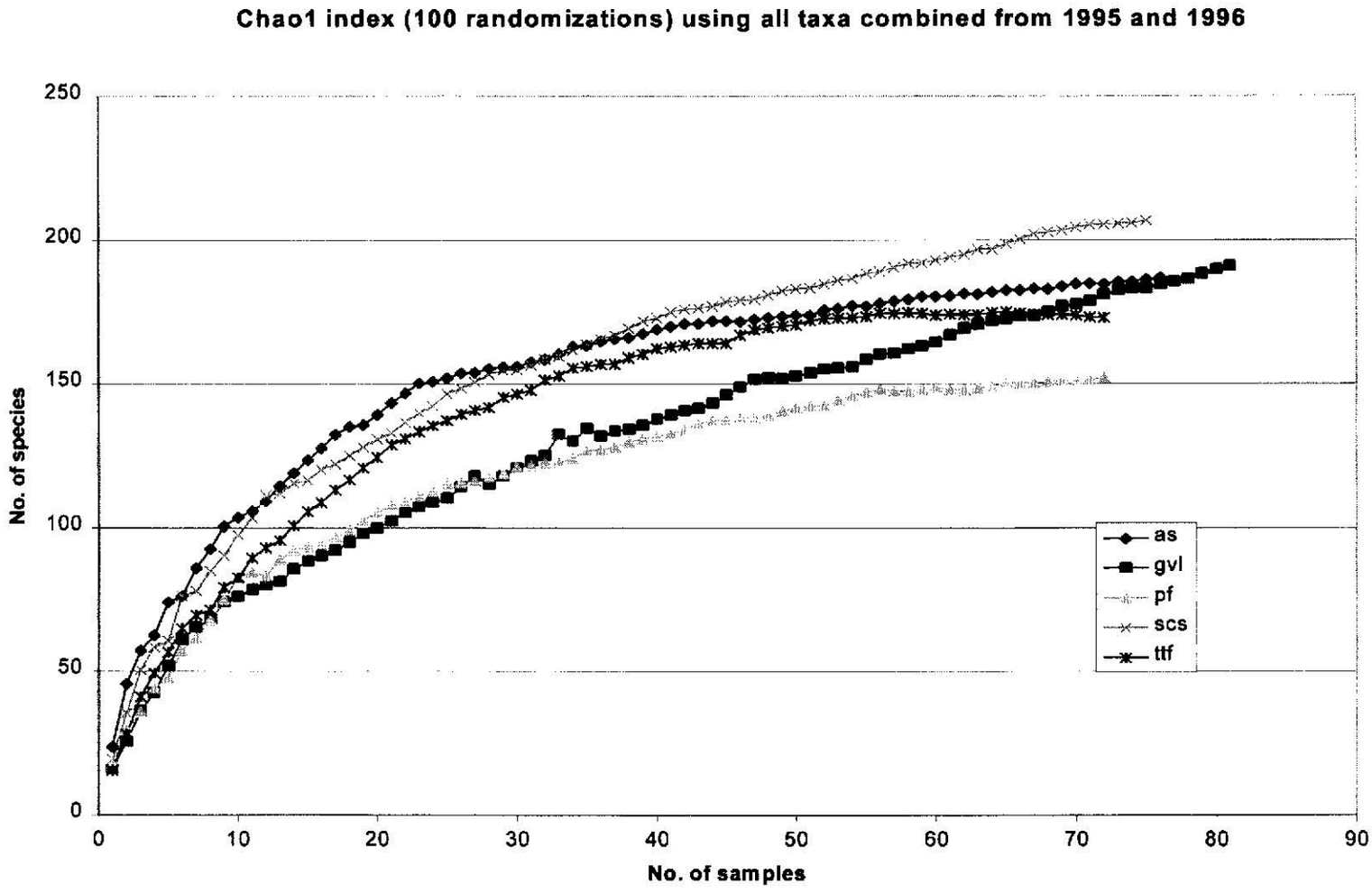

Figure 5. Mean values of the Chao 1 species richness estimator at each sample increment for 100 randomizations of sample order. Results are represented for 5 habitats over 8 sample periods, 4 monthly sampling dates during June through September, 1995 and over the same period during 1996 (AS-alder swamp, PF-Douglas fir forest, TT-cedar/hemlock forest, SC-willow/carex swamp, G-gravel bar).

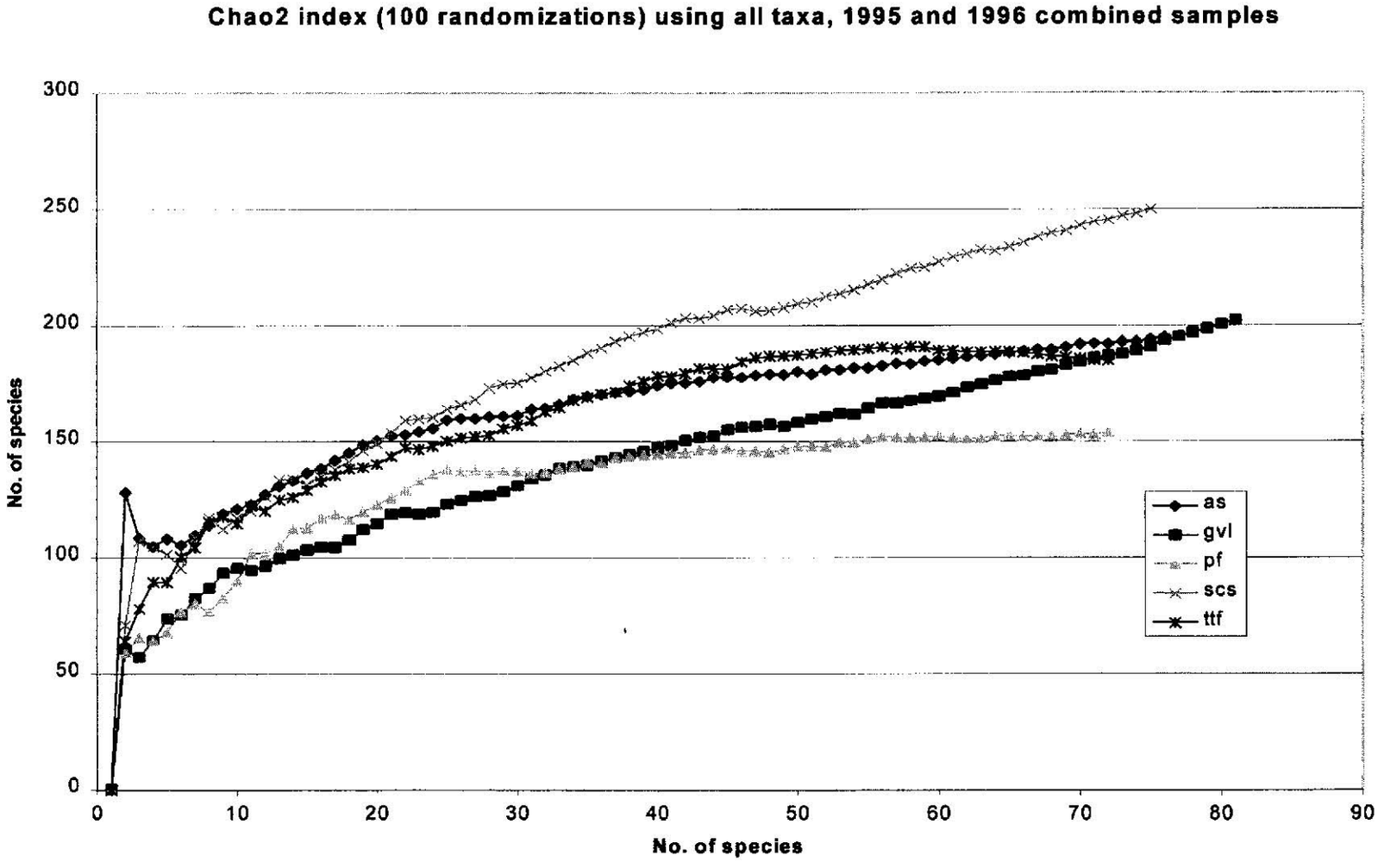

Figure 6. Mean values of the Chao 2 species richness estimator at each sample increment for 100 randomizations of sample order. Results are represented for 5 habitats over 8 sample periods, 4 monthly sampling dates during June through September, 1995 and over the same period during 1996 (AS-alder swamp, PF-Douglas fir forest, TT-cedar/hemlock forest, SC-willow/carex swamp, G-gravel bar).

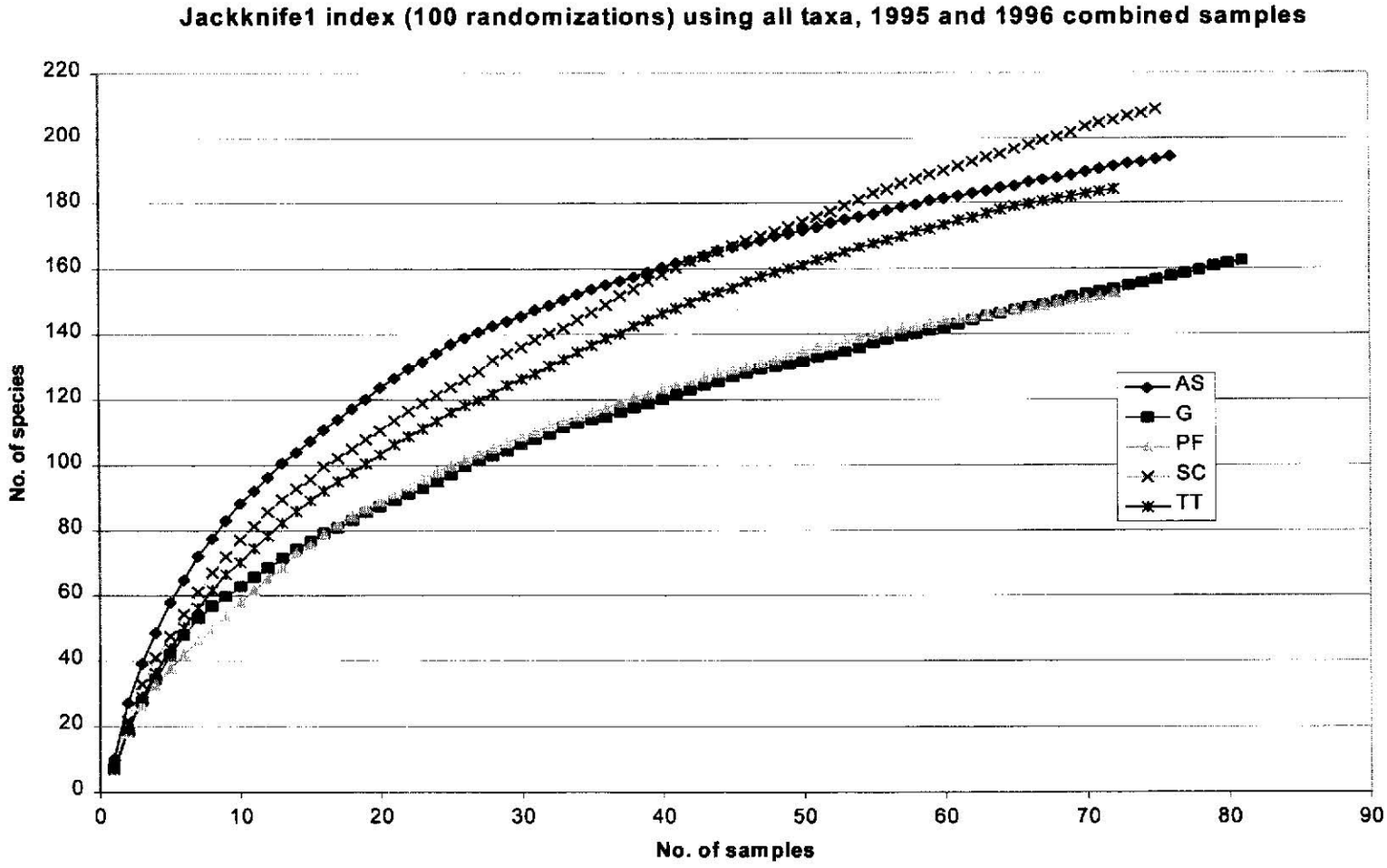

Figure 7. Mean values of the Jackknife1 species richness estimator at each sample increment for 100 randomizations of sample order. Results are represented for 5 habitats over 8 sample periods, 4 monthly sampling dates during June through September, 1995 and over the same period during 1996 (AS-alder swamp, PF-Douglas fir forest, TT-cedar/hemlock forest, SC-willow/carex swamp, G-gravel bar).

Table 8. Comparison of species richness estimators with observed richness for 5 habitats sampled over 8 periods during 1995 and 1996. All values represent means from 100 randomizations of sample order, where sample size was fixed at 72 samples for each habitat. (AS-alder swamp, G-gravel bar, PF-Douglas fir forest, SC-willow/carex swamp, TT-cedar/hemlock forest)

Habitat	AS	G	PF	SC	TT
Observed Richness	142	107	108	141	129
Chao1 Estimator	185	181	152	205	173
Chao2 Estimator	192	187	154	245	185
Jackknife1 Estimator	191	154	152	206	184

For all the habitats except gravel bars, the average percentage of singletons declined with each sample increment but did not reach asymptotic levels after 8 sampling dates (72-81 samples) over 1995 and 1996 (Figure 8). The alder swamp habitat had the lowest average percentage singletons (highest inventory completeness), declining to 29.7% after 8 sampling dates. Percentage of singletons was highest at gravel bar habitat (39.8%) and appeared to be at asymptotic levels after 30 to 40 samples had been collected.

Diversity

Average Shannon's index of diversity calculated from 100 randomizations of all taxa captured in re-sampled habitats during 1995 and 1996 was highest in alder swamp habitat, reaching 3.84 after 8 sampling dates, including 76 samples (Figure 9). Willow/carex swamp habitat had the lowest average Shannon's index, 2.76 after 8 sampling dates (75 samples) and was relatively similar to values for gravel bars, Douglas fir forest sites, and cedar/hemlock forest sites. Shannon's index continued to increase with increasing sample size for all of the habitats.

Average Alpha diversity calculated from 100 randomizations of all taxa captured in re-sampled habitats during 1995 and 1996 was also highest in alder swamp habitat, reaching 35.33 after 8 sampling dates (Figure 10). Gravel bar habitat had the lowest average Alpha diversity, 23.27 after 8 sampling dates, including 81 samples (Figure 10). Willow/carex swamp habitat, which had the lowest Shannon diversity value (Figure 9), had an intermediate Alpha diversity index value of 30.4 (75 samples). Alpha diversity values continued to increase with increasing sample size.

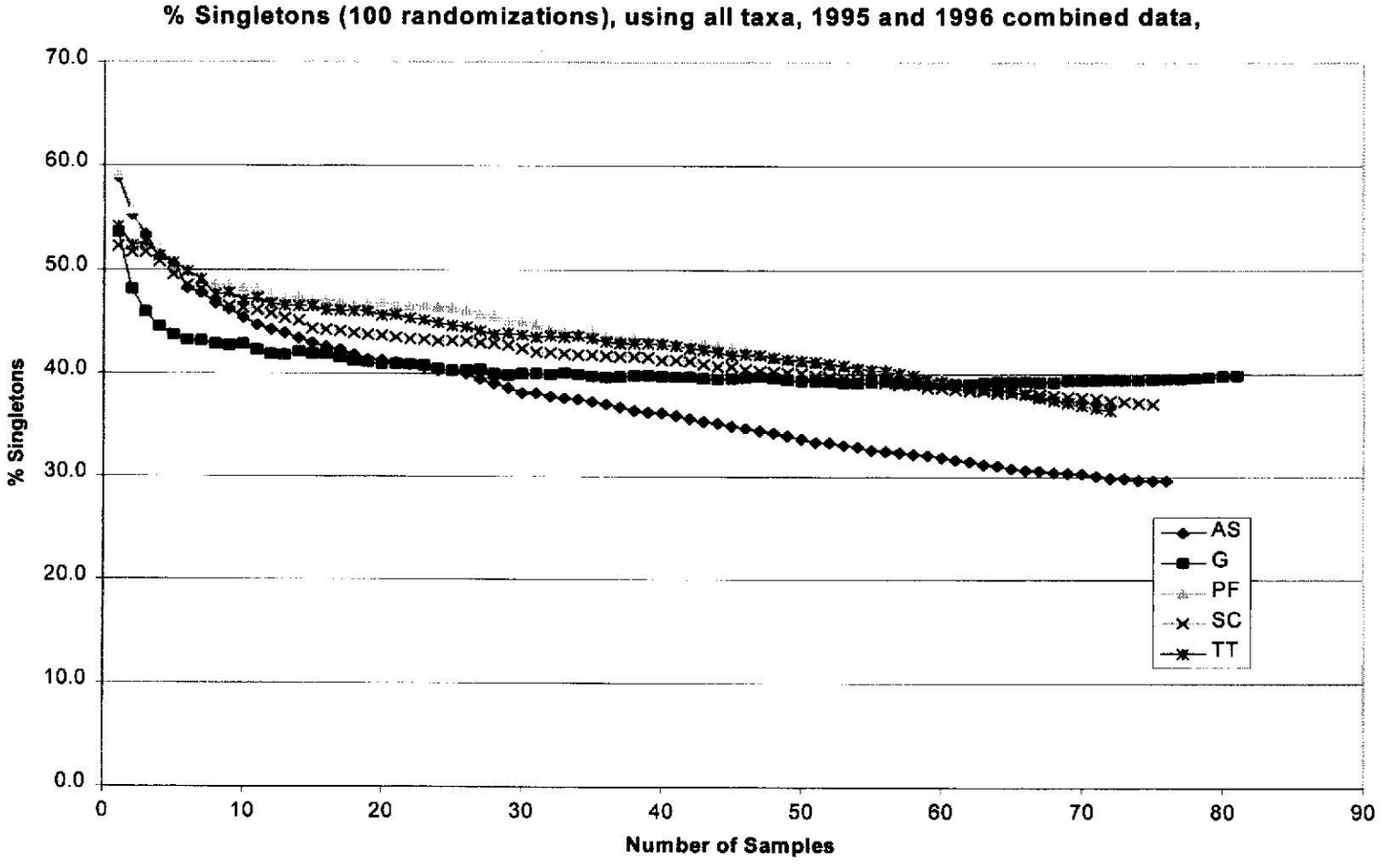

Figure 8. Mean % singleton values at each sample increment for 100 randomizations of sample order. Results are represented for 5 habitats over 8 sample periods, 4 monthly sampling dates during June through September, 1995 and over the same period during 1996 (AS-alder swamp, PF-Douglas fir forest, TT-cedar/hemlock forest, SC-willow/carex swamp, G-gravel bar).

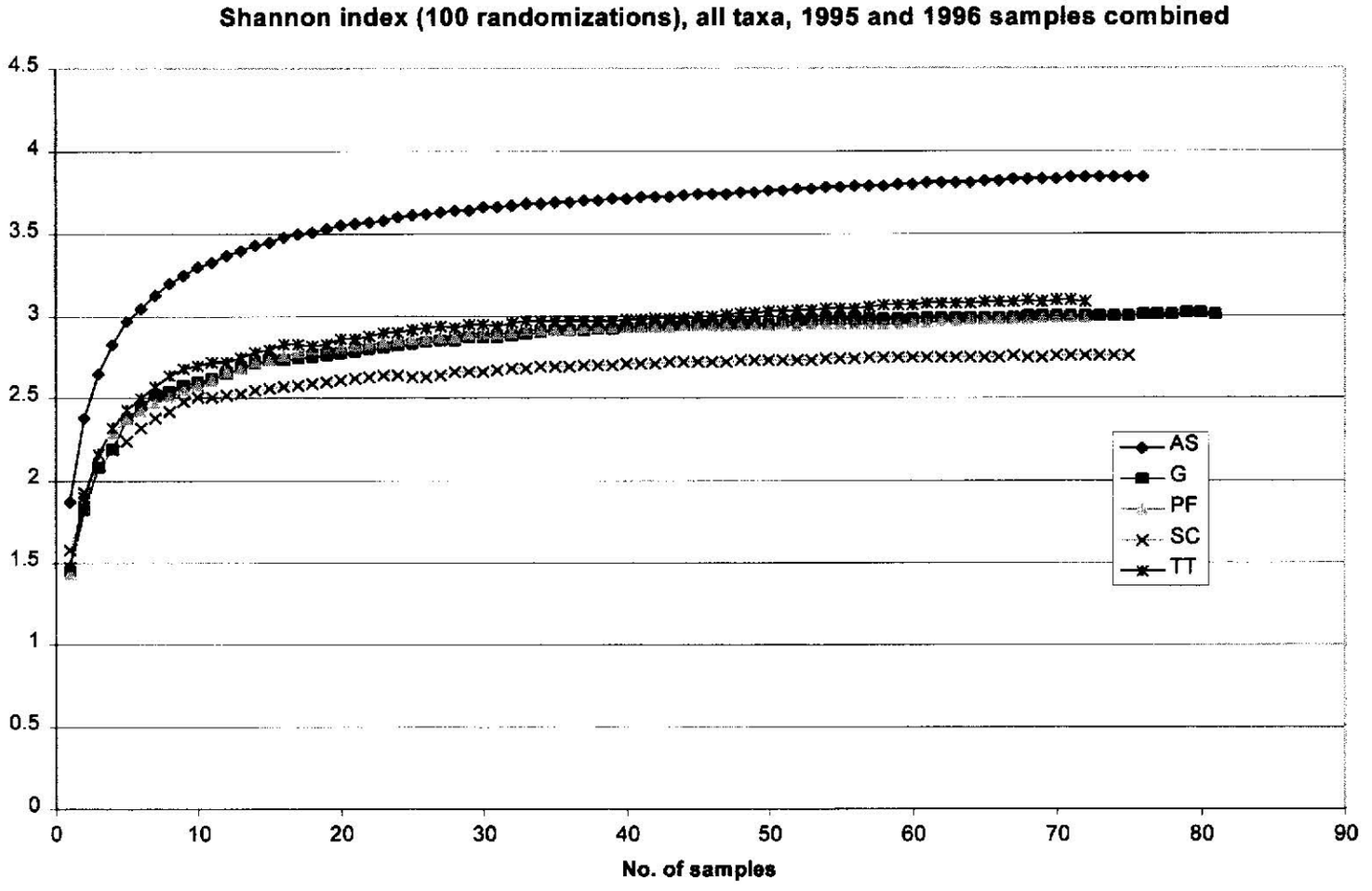

Figure 9. Average Shannon Index of diversity values calculated from 100 randomizations of sample order at each sample increment. Results are represented for 5 habitats over 8 sample periods, 4 monthly sampling dates during June through September 1995 and over the same period during 1996 (AS-alder swamp, PF-Douglas fir forest, TT-cedar/hemlock forest, SC-willow/carex swamp, G-gravel bar).

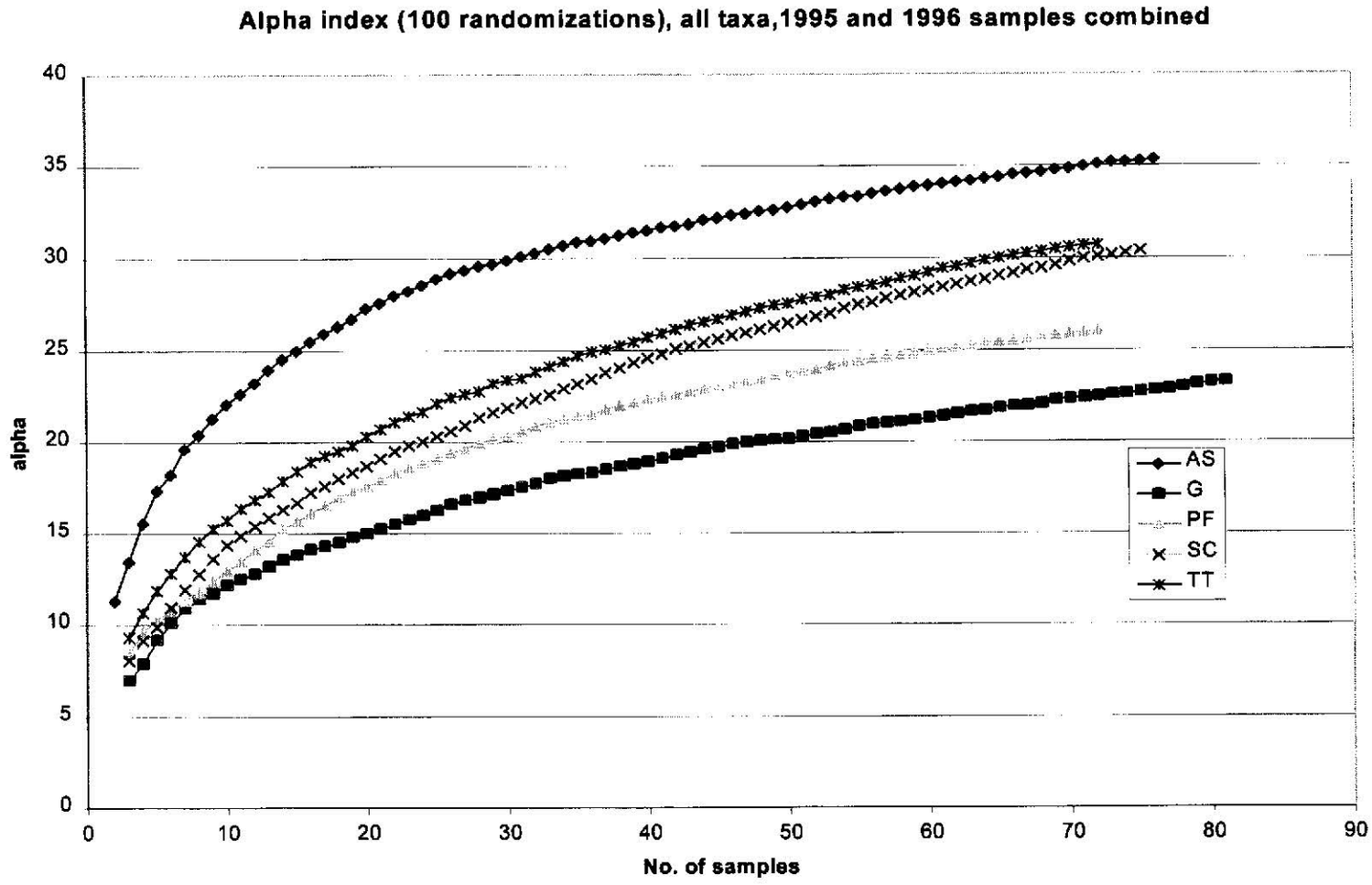

Figure 10. Average Alpha diversity values calculated from 100 randomizations of sample order at each sample increment. Results are represented for 5 habitats over 8 sample periods, 4 monthly sampling dates during June through September 1995 and over the same period during 1996 (AS-alder swamp, PF-Douglas fir forest, TT-cedar/hemlock forest, SC-willow/carex swamp, G-gravel bar).

Average Simpson's index of diversity calculated from 100 randomizations of all taxa captured in re-sampled habitats during 1995 and 1996 was again highest in alder swamp habitat, reaching 26.01 after 8 sampling dates (76 samples) (Figure 11). Simpson's index was much lower at all of the other habitats, ranging from 6.73 at willow/carex swamp habitat to 10.8 at gravel bar habitat after 8 sampling dates, including 72 to 81 samples (Figure 11).

Classification and Ordination

TwoWayIndicatorSpeciesAnalysis TWINSPAN

All Taxa, 1995

Habitats were classified into groups based on their species assemblages using TWINSPAN. The dendrogram representing TWINSPAN (75% or greater site fidelity) classifications of the 9 habitats by arthropod assemblages, collected during 1995, formed 6 groups after 3 divisions (Figure 12). At the first level of division, the abundance of the spider species *Pirata piraticus* (Clerck) at bog, willow/carex swamp, willow/spiraea swamp, and cedar/willow/carex swamp resulted in the separation of these habitats from the rest, where this species was not found.

In the upper part of the dendrogram in Figure 12, the second level of TWINSPAN division separated the bog, willow/carex swamp, and willow/spiraea swamp group of habitats from Group III (cedar/willow/carex swamp) habitat. Spider species again had the most influence on this division. The relatively wet and open canopy habitats of bogs, willow/carex swamps, and willow/spiraea swamps were represented by indicator species including *Pirata piraticus, Pardosa moesta* Banks, and the beetle species, *Agonum brevicolle* Dejean . Group III (cedar/willow/carex swamp) habitat separated from the others at this level based on the abundance of 2 spider species, *Pardosa dorsuncata* Lowrie & Dondale and *Cybaeus eutypus* Chamberlin & Ivie. At the third division level, bogs (Group I) separated from swamp habitats (willow/carex and willow/spiraea, Group II) by the presence of the heteropteran species, *Micracanthia quadrimaculata* (Champion), at bog sites.

In the lower half of the dendrogram in Figure 12, gravel bars (Group VI) were separated in the second division from the other habitats based on the presence of the large lycosid spider, *Pardosa lowriei* Kronestedt, which was unique to and common in gravel bar habitat. In the third division, alder swamp and maple thicket habitats (Group IV) were separated from the two forested habitats (Douglas fir and cedar/hemlock - Group V). Two beetle species, *Proteinus collaris* Hatch and *Tachinus crotchii* Horn (both staphylinids) were indicators for Group IV habitats. The abundance of the large carabid beetle, *Scaphinotus angusticollis* Mannerheim, at Group V forested sites separated this group from Group IV.

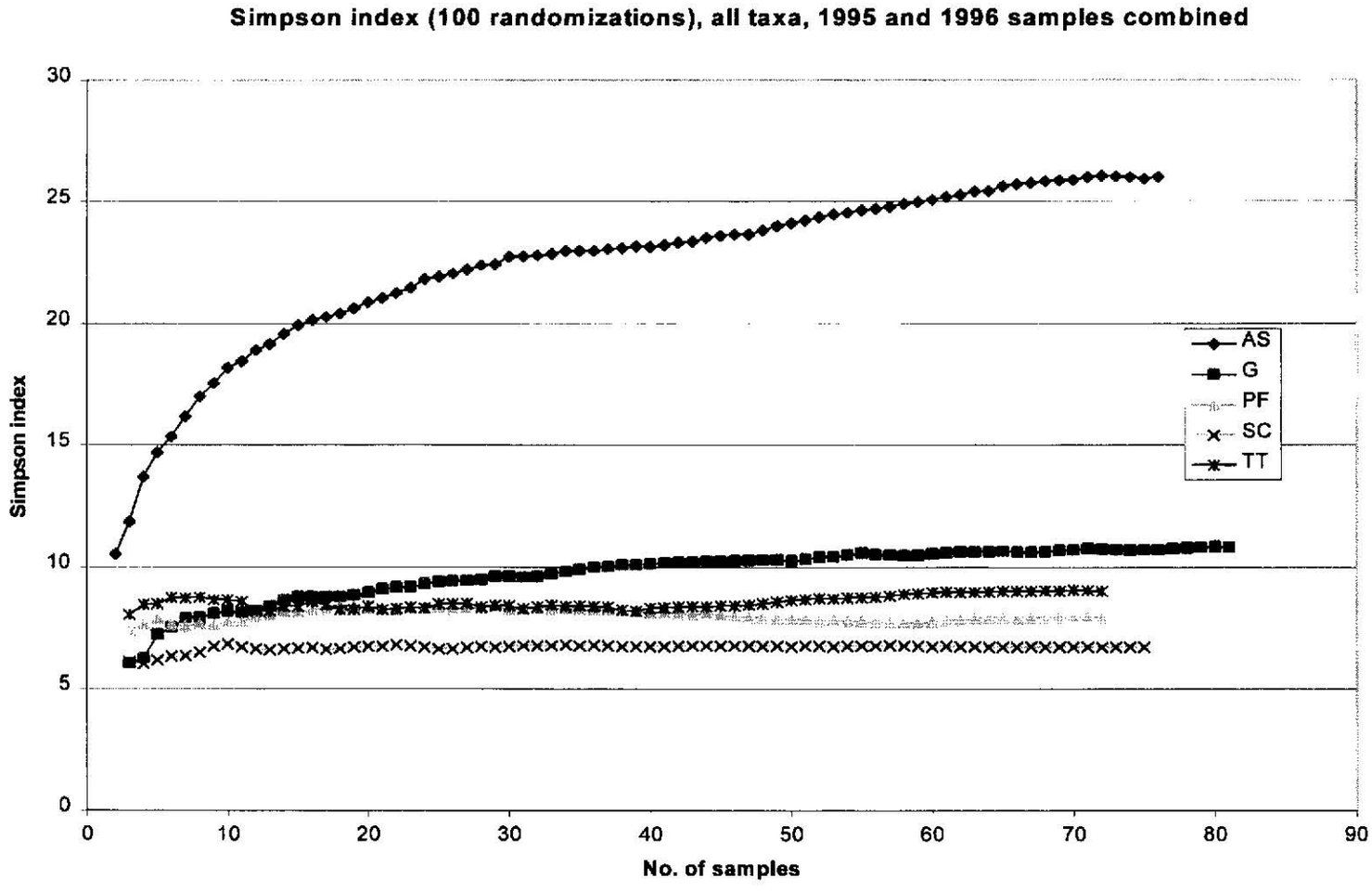

Figure 11. Average Simpson diversity values calculated from 100 randomizations of sample order at each sample increment. Results are represented for 5 habitats over 8 sample periods, 4 monthly sampling dates during June through September 1995 and over the same period during 1996 (AS-alder swamp, PF-Douglas fir forest, TT-cedar/hemlock forest, SC-willow/carex swamp, G-gravel bar).

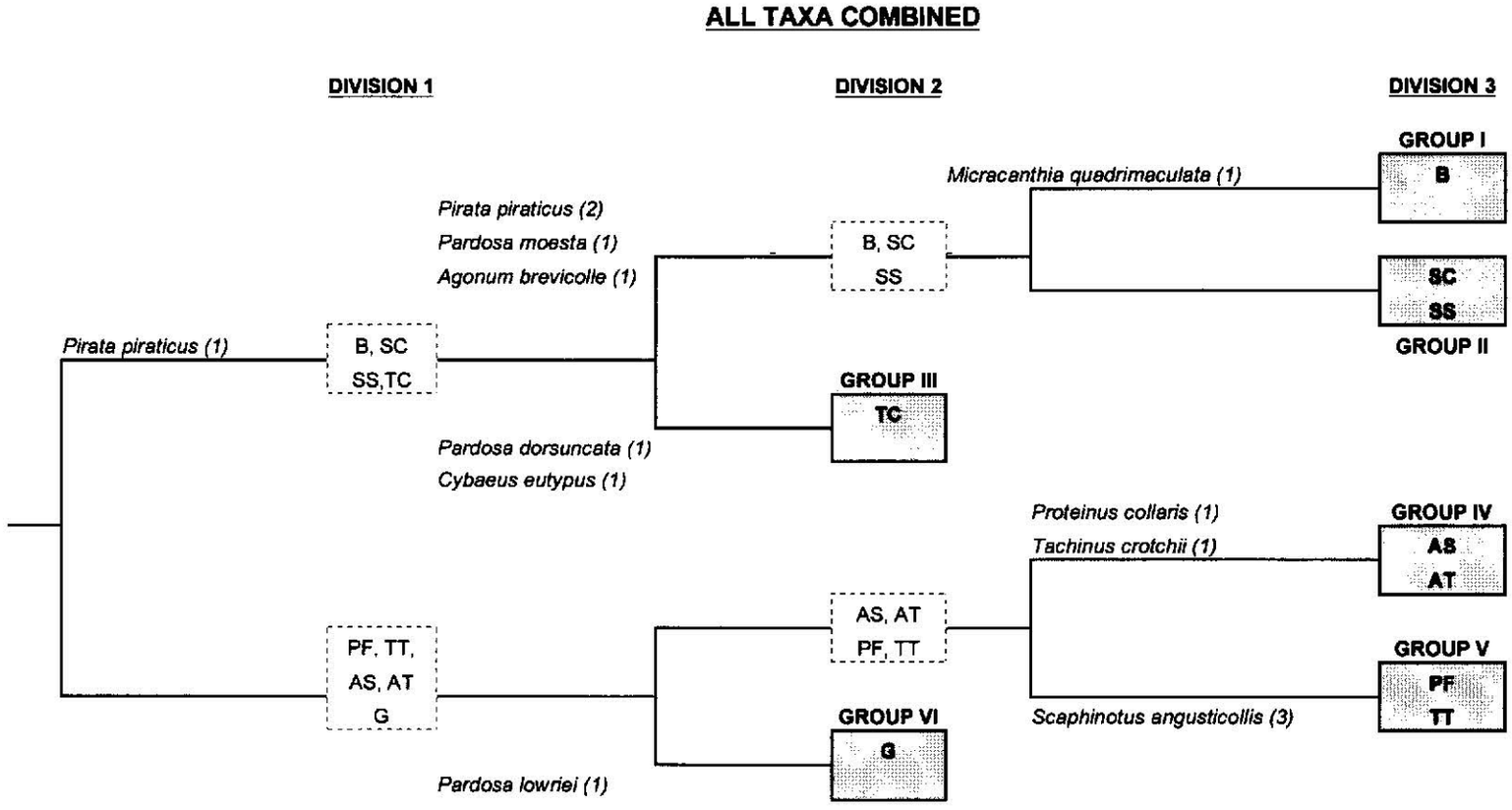

Figure 12. All 1995 Taxa TWINSPAN Dendrogram. Dendrogram representing TWINSPAN classifications of Big Beaver Creek riparian habitats (AS-alder swamp, AT-maple thicket, B-sphagnum bog, G-gravel bar, PF-Douglas fir forest, SC-willow/carex swamp, SS-willow/spiraea swamp, TC-cedar/willow/carex swamp, TT-cedar/hemlock forest) by arthropod assemblages collected in pitfall traps during 1995. Group classification by habitat types is indicated in boxes at various TWINSPAN division levels. Final classification is indicated by shaded boxes. Habitat types selected for each group are based on site fidelity of > 75%. Indicator species and pseudospecies cutlevels (represented in parenthesis with increasing numbers corresponding to increasing abundance) are also shown.

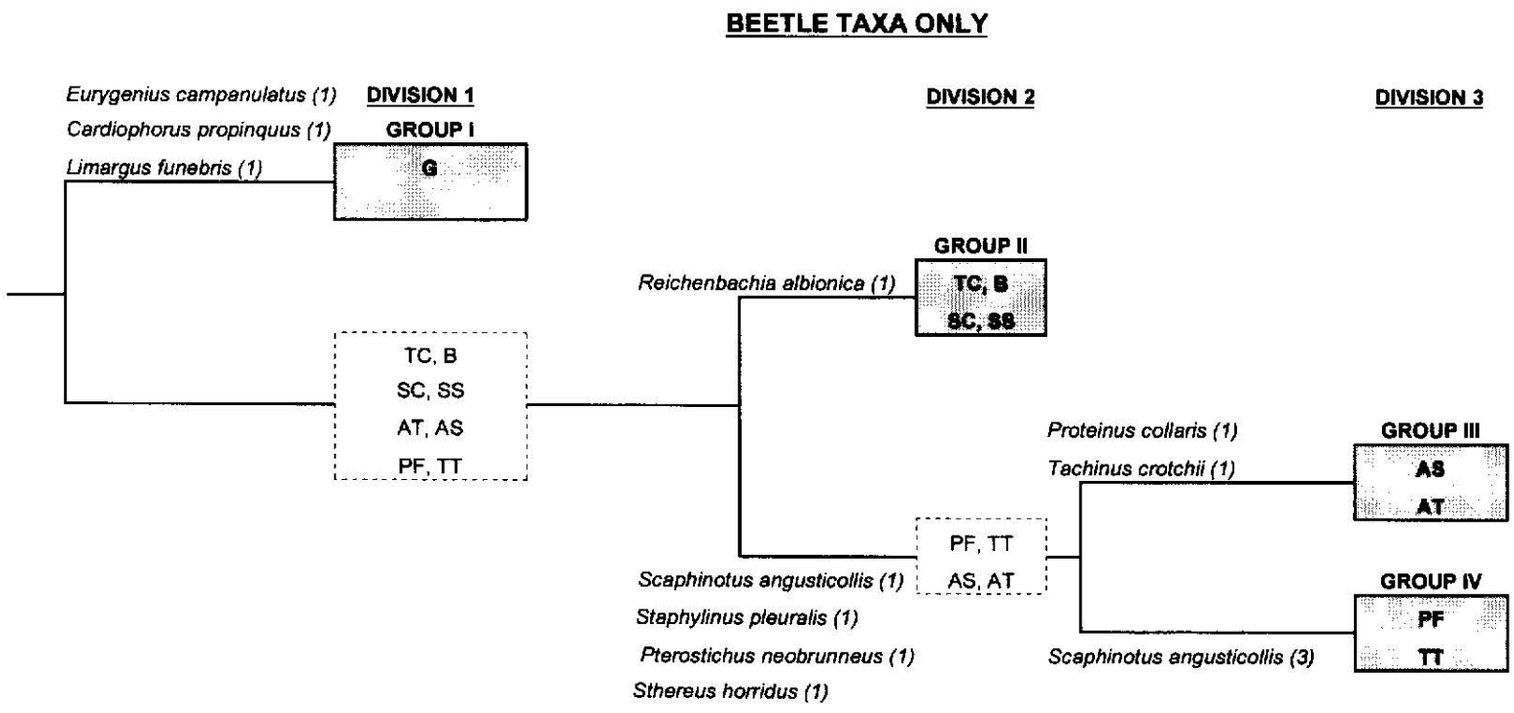

Figure 13. All 1995 beetle taxa TWINSPAN Dendrogram. Dendrogram representing TWINSPAN classifications of Big Beaver Creek riparian habitats (AS-alder swamp, AT-maple thicket, B-sphagnum bog, G-gravel bar, PF-Douglas fir forest, SC-willow/carex swamp, SS-willow/spiraea swamp, TC-cedar/willow/carex swamp, TT-cedar/hemlock forest) by beetle assemblages collected in pitfall traps during 1995. Group classification by habitat types is indicated in boxes at various TWINSPAN division levels. Final classification is indicated by shaded boxes. Habitat types selected for each group are based on site fidelity of > 75%. Indicator species and pseudospecies cutlevels (represented in parenthesis with increasing numbers corresponding to increasing abundance) are also shown.

Beetle Taxa, 1995

The dendrogram representing TWINSPAN (75% or greater site fidelity classifications) of the 9 habitats by beetle assemblages, collected during 1995, formed 4 groups after 3 divisions (Figure 13). Gravel bars (Group I) were immediately separated in the first division by the presence of abundant species including one anthicid (*Eurygenius campanulatus* LeConte) and two elaterids (*Cardiophorous propinquus* Hatch and *Limargus funebris* Candeze). These indicator species were only found in gravel bar habitat (LaBonte 1998). The eight remaining habitats were separated into two groups of which the generally wet habitats, with more open canopies, formed Group II (cedar/willow/carex, bog, willow/carex, willow/spiraea). The abundance of the beetle *Reichenbachia albionica* Motschulsky (Staphylinidae) separated this group from the other four habitats which were represented by indicator beetle species including two carabids, one staphylinid, and one curculionid (Figure 13).

Groups III and IV were separated at the third division level (Figure 13). Group III included habitats with high canopy cover and moist to wet soils (maple thicket and alder swamp) and Group IV included Douglas fir and cedar/hemlock forest habitats that also had high canopy cover, but exhibited drier soil condition. Indicator species for separation of these two groups was the same as in Figure 12, using all taxa from 1995.

In summary, classification using beetles only resulted in 4 groups where site fidelity was greater than 75%. Three groups were in common with the TWINSPAN dendrogram produced by using all taxa (Figure 12). The group formed by wetter and more open habitats (cedar/willow/carex, bog, willow/carex, willow/spiraea habitats) was split into 3 separate groups when all taxa were used in analysis (Figure 12).

Spiders, True Bugs, and Ants, 1995

Use of only spider taxa in the TWINSPAN analysis produced just 3 groups, with only 2 indicator species (Figure 14). The first division separated the wet, open canopy habitats (cedar/willow/carex, bog, willow/carex, willow/spiraea) from the others by the abundance of *Pirata piraticus* in these habitats. The other two groups were separated by *Pardosa lowriei*, which was abundant and common at gravel bar sites, but not in any other habitat. All groups met the 75 % site fidelity objective by the end of the second division.

TWINSPAN analysis was also attempted using taxa representing only true bugs and ant taxa only. Results were unsuccessful because of the low number of species and individuals in these data sets.

All Taxa, 1995 and 1996 Combined

A TWINSPAN dendrogram representing all taxa from combined 1995 and 1996 samples of the 5 re-sampled habitats is shown in Figure 15. Although this analysis only represents 5 of the 9 habitats, it is a more robust approach, being derived from nearly twice the sample size and

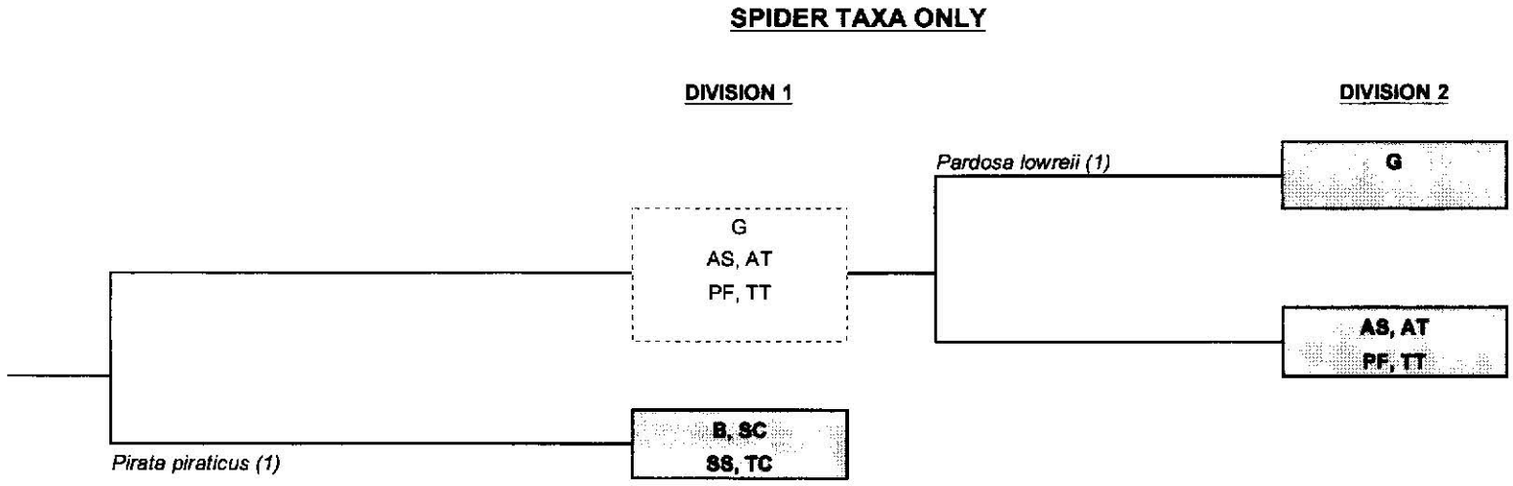

Figure 14. All 1995 spider taxa TWINSPAN Dendrogram. Dendrogram representing TWINSPAN classifications of Big Beaver Creek riparian habitats (AS-alder swamp, AT-maple thicket, B-sphagnum bog, G-gravel bar, PF-Douglas fir forest, SC-willow/ carex swamp SS-willow/spiraea swamp, TC-cedar/willow/carex swamp, TT-cedar/hemlock forest) by spider assemblages collected in pitfall traps during 1995. Group classification by habitat types is indicated in boxes at various TWINSPAN division levels. Final classification is indicated by shaded boxes. Habitat types selected for each group are based on site fidelity of > 75%. Indicator species and pseudospecies cutlevels (represented in parenthesis with increasing numbers corresponding to increasing abundance) are also shown.

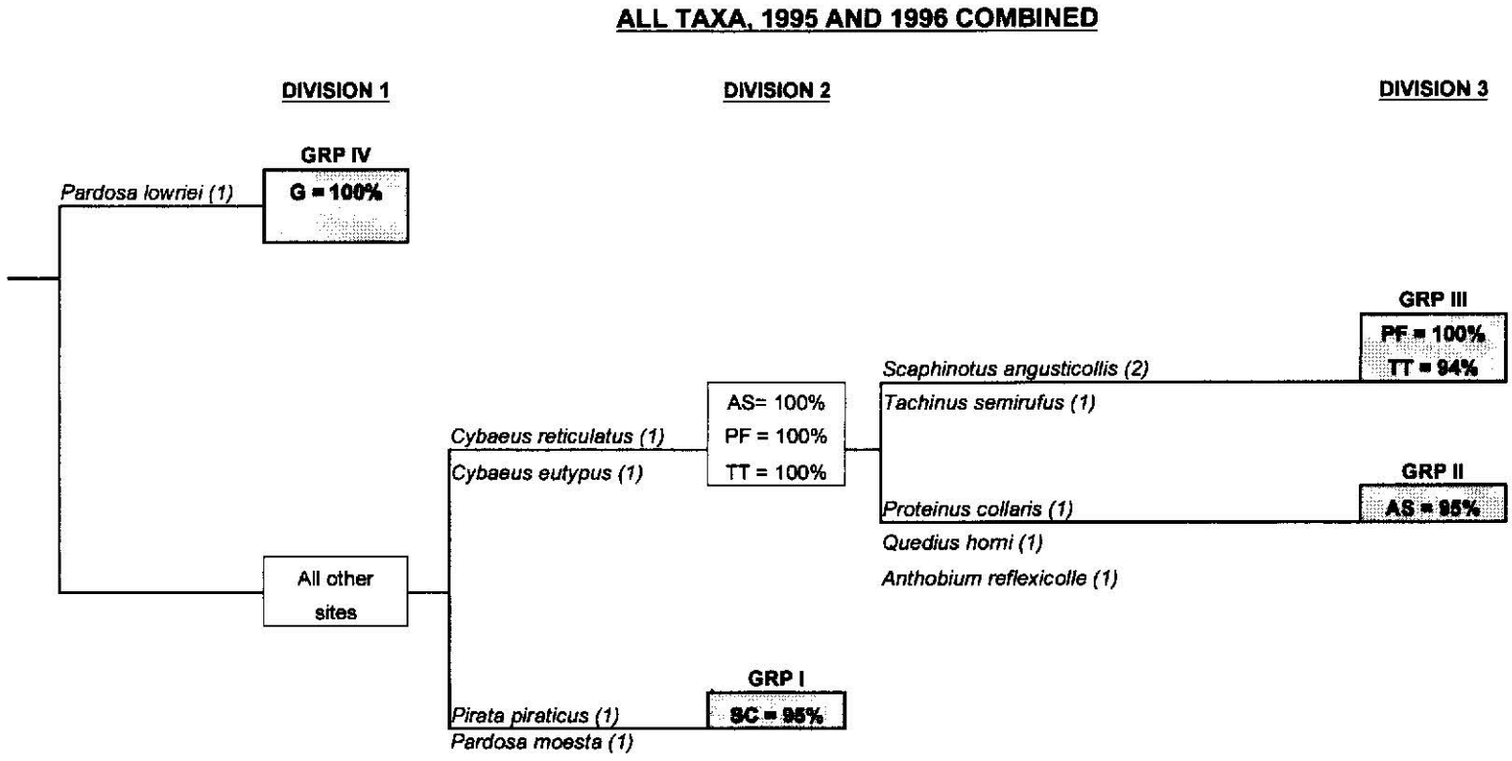

Figure 15. All 1995 and 1996 taxa TWINSPAN Dendrogram. Dendrogram representing TWINSPAN classifications of Big Beaver Creek riparian habitats (AS-alder swamp, G-gravel bar, PF-Douglas fir forest, SC-willow/carex swamp, TC-cedar/willow/carex swamp, TT-cedar/hemlock forest) by combined 1995 and 1996 arthropod assemblages (ants, spiders, beetles, and true bugs) collected in pitfall traps during 1995. Group classification by habitat types is indicated in boxes at various TWINSPAN division levels. Final classification is indicated by shaded boxes. Fidelity of habitats in final groups are shown in Group boxes. Indicator species cutlevels (represented in parenthesis with increasing numbers corresponding to increasing abundance) are also shown.

incorporating the interannual variation occurring between the two years of the study. Four groups were formed, all with site fidelity greater than 92% (Figure 15). The groups formed in this analysis, with the exception of the absence of unsampled habitats, were similar to groups formed by the TWINSPAN analysis of just 1995 data alone using all taxa (Figure 12).

The distribution and abundance of spider species among the habitats was the major factor separating groups in the first two divisions. *Pardosa lowriei* separated gravel bar habitat from all of the other sites in the first division (Figure 15). Sites without *P. lowriei* were then separated in the second division based on the abundance of agelenid spiders (*Cybaeus* spp. in sites with higher canopy cover - alder swamps, Douglas fir and cedar/hemlock forest sites) and lycosid spiders (*Pirata piraticus and Pardosa moesta* in willow/carex swamp). In the third level of division, differences in the abundance and distribution of several beetle species were important in separating forested habitats (Group III) from the alder swamp habitat (Group II).

Non-Metric Multidimensional Scaling

All Taxa, 1995

Two dimensions were adequate to describe the 1995 data of all taxa (ants, spiders, beetles, and true bugs) in Non-Metric Multidimensional Scaling (NMDS) shown in Figure 16. The final stress value of the analysis was 18.35%. The TWINSPAN Groups separated well when plotted (Figure 16). Groups I (bog habitat) and II (willow/carex and willow/spiraea habitats) were similar in ordination space. There was no separation along the first axis, and only poor separation along the second axis for Groups I and II. Group III (cedar/willow/carex habitat) was distinct, and separated from Groups I and II, and Groups IV (alder swamp and maple thicket) and V (Douglas fir and cedar/hemlock forest) along the first axis, and from Group VI (gravel bars) along the second axis. Group VI was the most distinct group, separating from the other groups strongly along the second axis.

All Taxa, 1995 and 1996 Combined

A NMDS ordination was also used to evaluate the relationships between the 5 habitats sampled in both 1995 and 1996. Using all taxa (ants, spiders, beetles, and true bugs) a two-dimensional NMDS ordination adequately described the data (stress 18.04%). The TWINSPAN Groups separated along both axes (Figure 17). Gravel bar habitat (Group IV), as in the ordination for all 9 habitats from 1995 (Figure 16), separated distinctly from the other groups.

Soil Attributes of TWINSPAN Groups

Table 9 summarizes the soil attributes of the six TWINSPAN Groups derived from 1995 data including all taxa, from all 9 habitats. Groups I, II, and III had the highest frequency of sampling sites classified as wet. The driest sites were found in Groups V and VI. The groups followed a moisture gradient of I, III, II, IV, V, VI, arranged in order of decreasing moisture.

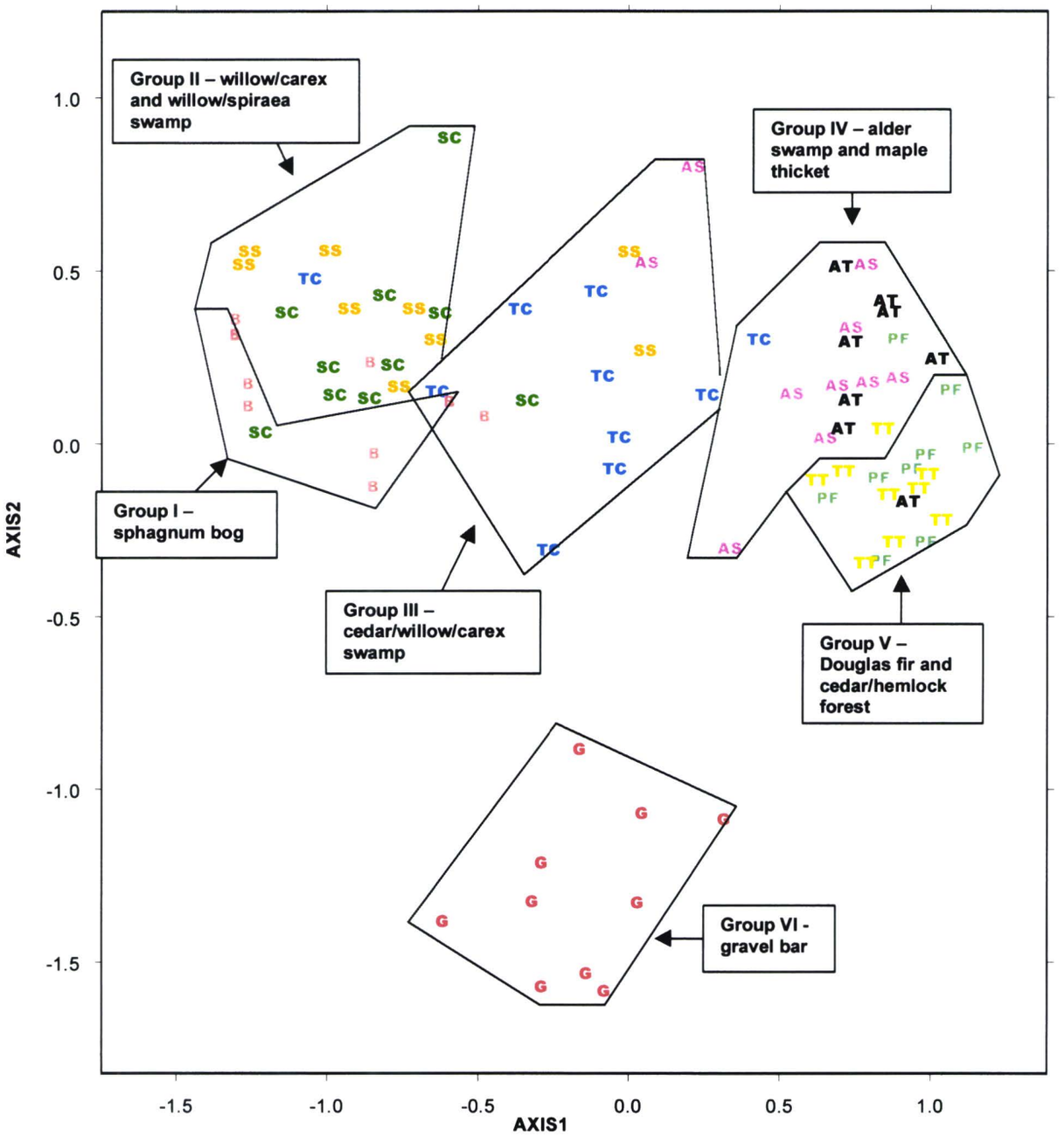

Figure 16. NMDS ordination of Big Beaver Creek riparian habitats (AS-alder swamp, AT-maple thicket, B-sphagnum bog, G-gravel bar, PF-Douglas fir forest, SC-willow/carex swamp, SS-willow/spiraea swamp, TC-cedar/willow/carex swamp, TT- cedar/hemlock forest) by arthropod assemblages (ants, beetles, spiders, and true bugs) collected in pitfall traps during 1995. TWINSPAN groups I-VI are outlined.

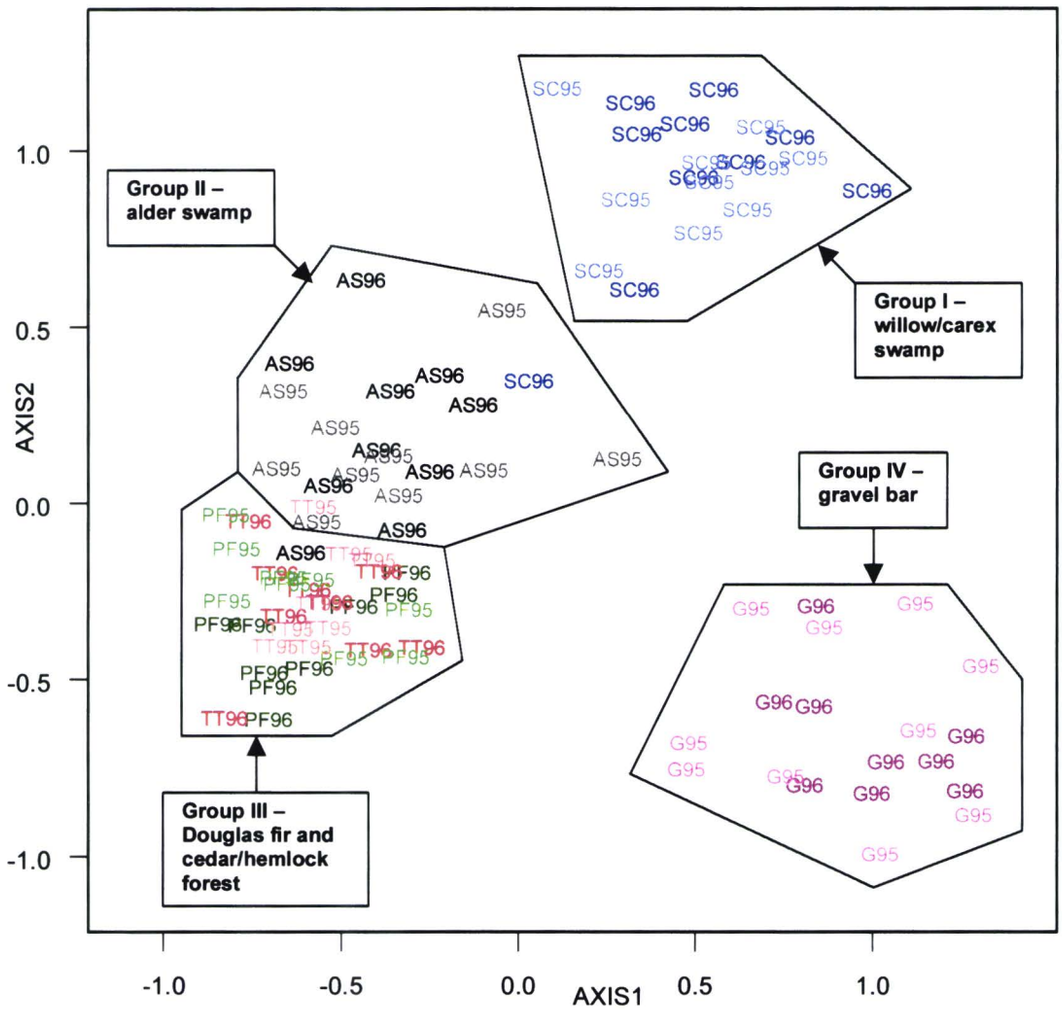

Figure 17. NMDS ordination of Big Beaver Creek riparian habitats (AS-alder swamp, G- gravel bar, PF-Douglas fir forest, SC-willow/carex swamp, TT-cedar/hemlock forest) by 1995 and 1996 arthropod communities (July-October pitfall trap collections of ants, beetles, spiders, and true bugs). TWINSPAN groups I-IV are outlined.

Table 9. TWINSPAN Group Soil Attributes. The percentage of group sampling sites, by 1995 TWINSPAN ordination groups, classified into soil moisture and soil type attribute classes.

	TWINSPAN Groups (Sample Size)					
Soil Attributes	**I (9)**	**II (17)**	**III (14)**	**IV (16)**	**V (19)**	**VI (10)**
Soil Moisture						
Wet	100	83	86	25	5	0
Moist	0	17	14	63	5	0
Dry	0	0	0	12	90	100
Soil Type						
Peat	89	6	7	0	0	0
Organic debris/litter	11	94	71	19	37	0
Clay - sandy loam	0	0	22	81	63	20
Sand and rock	0	0	0	0	0	80

Four soil types were identified at the sampling sites. There was a general trend of increasing inorganic soils and decreasing organic soils going from Group I to Group VI. Peat was found at a high frequency of sites in Group I (primarily bog sites), and low frequency in Groups II, and III Organic debris and litter was found in a high frequency of sites in Groups II, III, and V, in a few sites in Group IV, and in none of the sites in Group VI (Table 9). Clay and sandy loam soils were found in all but Groups I and II. Sand and rock were found only at sites in Group VI.

Site Attributes of TWINSPAN Groups

Site attributes for TWINSPAN Groups are summarized in Table 10. In general, similarities in site attributes among groups corresponded to their position in species-ordination space. For example, Groups I (bog) and II (willow/carex and willow/spiraea swamps) were closely related in ordination space (upper left corner of Figure 16) and had very similar values for site attributes. These 2 groups had low values for coarse woody debris (CWD), tree basal area, and canopy cover; high values for percent herbaceous plant cover; and low to moderate values for % shrub cover (Table 10). In contrast, Groups IV (alder swamp and maple thicket) and V (Douglas fir and cedar/hemlock forests) were located at the other end of the gradient, along Axis 1 of the ordination plot (Figure 16). High to moderate values for site attributes of Groups IV and V replaced the low values found for Groups I and II. Site attributes of Group III (cedar/willow/spiraea swamps), located in between Groups I-II and Groups IV-V along Axis 1 of the ordination plot, had values intermediate between those for the groups on either end of the ordination plot.

Site Attribute Correlations and Ordination Biplots

Table 11 presents the Spearman rank correlation coefficients between site attributes, and with NMDS ordination axes scores. Coarse woody debris (CWD), % herbaceous plant cover, % canopy cover, and soil moisture had the most strong correlations (>.5 or <-.5) with other site attributes. Soil moisture correlated with % herbaceous cover (-.63), CWD and soil type (.61), and % canopy cover (-.51). In addition to soil moisture, % canopy cover also correlated with tree basal area (.77), CWD (.69), and % herbaceous plant cover (-0.52). Strong correlations were also observed between % herbaceous plant cover and soil type (-.74), and between CWD and tree basal area (.68).

Correlations between site attributes and NMDS ordination axes scores (1995 data for all 9 habitats - Figure16) are also shown in Table 11. Axis 1 had a positive correlation with CWD (.71), tree basal area (.72), % canopy (.91), and negative correlation with % herbaceous plant cover (-.61). Soil moisture and soil type were also correlated with axis 1 (.59 and .52, respectively). Axis 2 had a negative correlation with soil moisture (-.62).

Figure 18 presents NMDS ordination biplots of site attributes color-coded for habitats. The biplots illustrate graphically, gradients along the ordination axes. For example, NMDS ordination axis 1 shows a strong canopy cover gradient, supported by the strong Spearman rank coefficient between axis 1 ordination scores and percent canopy cover (Table 11). Other correlations between site attributes and NMDS axes, from Table 11, are graphically illustrated in Figure 18.

Table 10. TWINSPAN Average Site Attributes. Group means and standard deviations of site attributes measured on group sampling sites, by 1995 TWINSPAN ordination group.

	TWINSPAN Groups (Sample Size)					
Site Attributes	**I (9)**	**II (17)**	**III (14)**	**IV (16)**	**V (19)**	**VI (10)**
CWD (m^3)						
Mean	0.27	0.08	0.13	2.27	4.46	1.31
Stand. Dev.	*0.8*	*0.17*	*0.32*	*3.46*	*3.25*	*2.23*
% Herb Cover						
Mean	244*	149.2*	117.4*	41.3	50.9	5.5
Stand. Dev.	*36.9*	*46.6*	*55.9*	*38.1*	*39.1*	*5.3*
% Shrub Cover						
Mean	16.4	49.5	75.6	86.8	34.7	9.4
Stand. Dev.	*15*	*26.7*	*48.2*	*40*	*32.5*	*11.5*
Tree Basal Area**						
Mean	0	0	0.41	1.36	2.53	0.09
Stand. Dev.	*0*	*0*	*0.73*	*1.31*	*1.29*	*0.27*
% Canopy Cover						
Mean	5.2	3.2	62.7	97.7	99.7	12.7
Stand. Dev.	*9.5*	*5.5*	*25.4*	*3.6*	*0.8*	*16.1*
Litter Depth (cm)						
Mean	0.89	5.62	5.36	3.5	6.97	0
Stand. Dev.	*2.67*	*2.77*	*3.27*	*1.75*	*2.56*	*0*

* Herb cover with multiple layers

** Tree Basal Area measured as % of 8x 8 m plot

Table 11. Spearman Rank Correlations between site attributes, and between site attributes and NMDS axes scores from ordination of Big Beaver Creek RNA, NOCA, 1995. [1]Soil moisture at each site was assigned a value of 1 to 3, with 1 representing wet sites and 3 representing dry sites. [2]Soil type at each site was assigned a value of 1 to 4 (1= peat, 2=organic debris, 3=clay and sandy loam, 4= sand, gravel, cobble, boulder).

	CWD (m^3)	% Herb Cov.	% Shrub Cover	Tree Basal Area	% Canopy Cover	Litter Dpth.(cm)	Soil Moist.[1]	Soil Type[2]
Site Attributes								
Coarse Woody Debris (m^3)		-0.49		0.68	0.69		0.61	0.42
% Herb Cover				-0.36	-0.52		-0.63	-0.74
% Shrub Cover					0.24	0.23		
Tree Basal Area (% of plot)	0.68	-0.36			0.77	0.43	0.49	
% Canopy Cover	0.69	-0.52	0.24	0.77		0.37	-0.51	0.39
Litter Depth (cm)			0.23	0.43	0.37			
Soil Moisture	0.61	-0.63		0.49	-0.51			0.61
Soil Type	0.42	-0.74			0.39		0.61	
NMDS Axis Scores								
Axis 1	0.71	-0.61		0.72	0.91	0.31	0.59	0.52
Axis 2	-0.46	0.41	0.43	-0.28		0.23	-0.62	-0.44

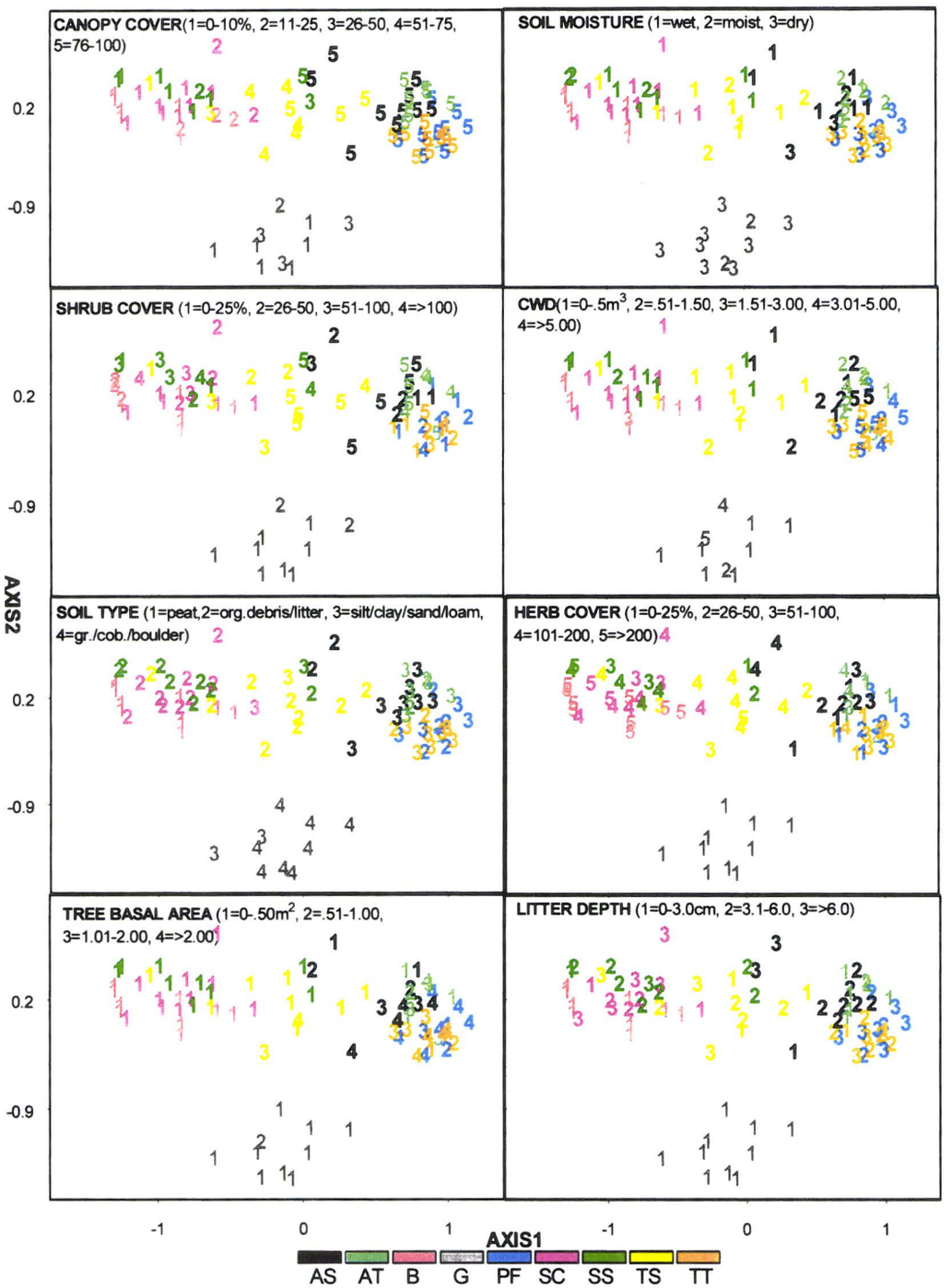

Figure 18. NMDS ordination biplots of site environmental attributes and habitat types (AS- alder swamp, AT-maple thicket, B-sphagnum bog, G-gravel bar, PF-Douglas fir forest, SC-willow/carex swamp, SS-willow/spiraea swamp, TC-cedar/willow/carex swamp, TT-cedar/hemlock forest). Ordinations derived from arthropod communities collected in pitfall traps during 1995, Big Beaver Creek, North Cascades National Park Complex.

Arthropod Sampling Summary Statistics by TWINSPAN Groups

A summary of sampling statistics for the 6 TWINSPAN Groups ordinated from the 1995 data including all taxa (ants, spiders, beetles, and true bugs) is contained in Table 12. The highest adult individual capture rates occurred at sites in Groups II and VI and lowest at Group V. The highest species richness was found in Groups III and IV, however Group VI had the highest species capture rate when standardized on sampling effort. Species capture rates were lowest for Groups II and V. Percent singleton values for all groups ranged between 33 and 49%, and were similar to the range of values found for individual habitats (Table 6) comprising the TWINSPAN Groups.

Table 12. Sampling Summary Statistics for TWINSPAN Groups. Sampling summary statistics of all taxa by 1995 TWINSPAN Groups (without outlier samples).

Groups (Habitats)	GRP I (B)	GRP II (SC/SS)	GRP III (TS)	GRP IV (AS/AT)	GRP V (PF/TT)	GRP VI (G)
No. of Samples	36	68	56	60	69	40
No. of Adults	841	2896	1379	1420	1360	1681
Observed Richness	65	104	121	132	103	93
No. of Singletons	32	39	40	48	43	38
% Singletons	49.2	37.5	33.1	36.4	41.7	40.9
Sampling Intensity # adults per species	12.9	27.8	11.4	10.8	13.2	18.1
Capture Rate - Species # species/100 trap-days	6.0	5.1	7.2	7.3	5.0	7.8
Capture Rate - Individuals # adults/100 trap-days	78	142	82	79	66	140

Indicator Species Analysis

Dufrene and Legendre (1997) proposed the use of a species Indicator Value index for identifying indicator species and species assemblages characterizing groups of sites. The index is based on only within-species abundance (% relative abundance) and occurrence (% frequency of occurrence) comparisons, without any comparison among species. The index reaches its maximum (100) when all individuals of a species are found in a single habitat type and when the species occurs in all sites of that habitat type. Relative abundance (RA), Relative Frequency (RF), and Indicator Values (IV) for important taxa (IV value > 40) by TWINSPAN groups ordinated from data collected during 1995, are shown in Table 13.

Table 13. Indicator values (IV), %relative abundance (RA), and %relative frequency (RF) of Big Beaver Creek riparian arthropods collected from pitfall traps during 1995 by TWINSPAN habitat groups. Taxa with indicator values greater than or equal to 40 are shown. Methods for calculating indicator values are from Dufrene and Legendre (1997).

	Group I Bog			Group II Willow/Carex & Willow/Spiraea Swamp			Group III Cedar/Willow/ Carex Swamp			Group IV Alder Swamp & Maple Thicket			Group V Douglas Fir & Cedar/Hemlock Forest			Group VI Gravel Bar		
	IV	RA	RF	IV	RA	RF	IV	RA	RF	IV	RA	RF	IV	RA	RF	IV	RA	RF
Araneae-Agelenidae																		
Cybaeus eutypus Chamberlin & Ivie													41	55	74			
Cybaeus reticulatus Simon										52	52	100						
Araneae-Lycosidae																		
Pardosa dorsuncata Lowrie & Dondale							65	65	100									
Pardosa lowriei Kronestedt																100	100	100
Pardosa moesta Banks				86	92	94												
Pirata piraticus (Clerck)				59	59	100												
Coleoptera-Anthicidae																		
Eurygenius campanulatus LeConte																90	100	90
Coleoptera-Carabidae																		
Agonum brevicolle Dejean				54	92	59												
Chlaenius interruptus Horn				42	89	47												
Leistus ferruginosus Mannerheim										45	80	56						
Loricera decempunctata Eschscholtz							48	68	71									
Nebria mannerheimi Fischer																40	100	40
Nebria sahlbergi Fischer																70	100	70
Pterostichus neobrunneus Lindroth													65	96	68			
Scaphinotus angusticollis Mannerheim													71	90	79			
Trechus chalybeus Dejean							42	83	50									
Coleoptera-Curculionidae																		
Rhyncolus brunneus Mannerheim																		
Steremnius carinatus Boheman													50	94	53			
Sthereus horridus (Mannerheim)										46	82	56						

Table 13. Continued

	Group I Bog			Group II Willow/Carex & Willow/Spiraea Swamp			Group III Cedar/Willow/ Carex Swamp			Group IV Alder Swamp & Maple Thicket			Group V Douglas Fir & Cedar/Hemlock Forest			Group VI Gravel Bar		
	IV	RA	RF	IV	RA	RF	IV	RA	RF	IV	RA	RF	IV	RA	RF	IV	RA	RF
Coleoptera-Elateridae																		
Cardiophorus propinquus Hatch																80	100	80
Hypolithus dispersus Horn																70	100	70
Hypolithus musculus Eschscholtz																40	100	40
Ligmargus funebris Candeze																80	100	80
Coleoptera-Staphylinidae																		
Bledius suturalis LeConte																40	100	40
Gabrius picipennis Maklin							40	63	64									
Gabrius seattlensis Hatch																		
Philonthus crotchi Horn	43	64	67															
Proteinus collaris Hatch										73	97	75						
Reichenbachia albionica Motschulsky							62	72	86									
Staphylinus pleuralis LeConte													54	79	68			
Tachinus crotchii Horn										54	57	94						
Tachinus semirufus Horn													42	100	42			
Heteroptera-Saldidae																		
Micracanthia quadrimaculata (Champion)	90	90	100															
Hymenoptera-Formicidae																		
Formica pacifica																80	100	80
Myrmica NEAR *brevispinosa*																58	97	60
Myrmica incompleta Provancher	42	62	67															

Gravel bars (Group VI) had the greatest number of indicator species with 11 species having indicator values of 40 or greater (Figure 13). All of these species could be considered as gravel bar habitat specialists, as they were almost exclusively found in gravel bar habitat (RA values of 97 to 100, Figure 13). Indicator species at gravel bars were represented by a range of taxa including 4 species of elaterid beetles, 1 species of anthicid beetles, 2 species of carabid beetles, 1 species of staphylinid beetles, 2 ant species, and 1 species of lycosid spiders.

Only 3 indicator species were found at Group I sites (primarily bog habitat). The heteropteran, *Micracanthia quadrimaculata*, was found at all of the Group I sites and had the highest Indicator Value score (IV=90, Figure 13).

The number of indicator species found in Groups II-V ranged from 4 to 6 (Figure 13). Species with strong preferences (IV value > 70) for particular habitat groups included *Pardosa moesta* in Group II, *Proteinus collaris* in Group IV, and *Scaphinotus angusticollis* in Group V (Figure 13).

Discussion

Abundance, Species Richness, and Diversity

Arthropods are sufficiently abundant in riparian habitats along Big Beaver Creek for effective monitoring, as demonstrated by pitfall trap data. The average trap capture rate (99 adult arthropods per 100 trap-days) illustrates the magnitude of arthropod abundance in the sampled habitats, and effectiveness of pitfall traps for sampling natural communities. The traps were especially effective at capturing beetles, the most abundant arthropods in our traps. The average number of adult beetles captured per 100 trap-days (49) is compares to capture rates from other studies. Brenner (2000) reported an average trap capture rate of only 31 beetles/100 trap-days in riparian habitat in the western Cascades of Oregon, and Spence *et al.* (1996) captured an average of 49 beetles/100 trap-days in boreal forests in Eastern Canada.

Species richness is an important indicator of the overall biological diversity in an ecosystem. Four hundred forty-eight species of beetles, spiders, ants, and true bugs were collected. This is a relatively low number of species compared to other sites that have been more completely sampled. For example, more than 3,400 species of arthropods have been collected from the H.J. Andrews Experimental Forest in the western Cascades of Oregon (Parsons *et al.* 1991). However, this is the first study in the Big Beaver Creek Research Natural Area, which was focused on primarily ground-dwelling arthropod assemblages in riparian habitats, and used only one method of capture. The Andrews Forest study has been conducted over many years utilizing a wide variety of arthropod sampling methods. The complete diversity of the Big Beaver Creek Research Natural Area remains to be determined.

Exhaustive sampling and accurate measurement of species richness is a goal of community ecology studies. Sampling is exhaustive when all species are represented by many individuals, or when species accumulation curves reach asymptotes (Coddington *et al.* 1996). Species richness estimates of Big Beaver Creek riparian habitats were almost certainly underestimated because singletons were a large proportion of the communities and richness accumulation curves failed to reach asymptotic levels (Tables 6, 7 and Figure 3). Furthermore, only a single sampling method was utilized, which generally excluded non-pitfall susceptible species (*i.e.*, aquatic and canopy inhabitants).

It is difficult to know the true species richness of a habitat without long-term monitoring (Coddington *et al.* 1996). There are often large variations in arthropod populations from year to year and many species commonly appear as singletons (Wolda 1978). Tourist or waif species also sometimes appear in low abundance, but are not permanent members of the community (Coddington *et al.* 1996). Algorithms have been developed for estimating species richness from community samples that take these factors into consideration (Ibid.). These estimates are often used for land-use decisions at local levels.

While actual species accumulation curves did not reach asymptotes (Figure 4), Chao1 and Chao2 calculated estimates did (Figure 5 and 6) for one of the 5 habitat types sampled during both years. According to this algorithm, the species richness is estimated to be over 200 in the

willow/carex swamp habitat group, where only 143 species were actually observed. However, the Jackknife1 species richness estimate for this habitat did not reach an asymptote (Figures 7). The lack of similar results obtained from several species richness estimating methodologies provides little confidence that species richness estimates are accurate (Coddington *et al.* 1996). Accumulation of information through a long-term inventory and monitoring program, using various methods of capture, will provide better inferences about the actual species richness of the sampled habitats.

Indices of diversity have also been used to monitor biotic communities. The diversity of plant, bird, insect, and many other communities has been studied in habitats around the world (e.g., MacArthur and MacArthur 1961, Murdoch *et al.* 1972, Coulson *et al.* 1971). Hairston (1959) was one of the first to apply diversity analysis to soil micro-arthropod communities. Since then, soil biologists have often included arthropod diversity descriptions in their studies.

Diversity accumulation curves for most habitats approached asymptotes with moderate amounts of sampling effort. Shannon and Simpson diversity value curves leveled off halfway through the study (Figure 9 and 11). The general agreement of three diversity indices indicates that diversity may have been accurately estimated. Monitoring long-term changes in community diversity via diversity indices has been recommended as a useful method for large-scale environmental change (*e.g.*, Cooperrider *et al.* 1986, Peters and Lovejoy 1992, Marshall *et al.* 1994). Fine-scale habitat differences are more difficult to detect and require important information about species composition not included in diversity index calculations. This information is best analyzed using multivariate techniques (Brenner 2000).

Classification and Ordination

Multivariate classification of community data is frequently applied in ecological work. The goal is to classify groups of habitats using species that occur in those habitats. The inferences are used to make land use and management decisions, and to assess the impacts of pollution, fire, and other natural and man-made disturbances. An additional use in this study was to investigate the application of classification methods for delineating sampling strata to assist in design of future monitoring programs. This was accomplished by subjecting the *a priori* classification of site groups (by habitat types) to multivariate classification allowing the biological data to separate groups of sites for future analyses. Classification of habitats into categories requires sophisticated mathematical techniques, and multivariate methods have become more popular since the availability of desktop computing. A multivariate approach is useful because individual parameters considered in isolation are rarely adequate to address questions of interest (Gauch 1982).

TwoWayIndicatorSpeciesAnalysis TWINSPAN

Hill (1979) developed TWINSPAN, and standard techniques for application were adopted as the method became popular in ecological studies (Pielou 1977). The method has been applied to the analysis of community data using several major taxonomic groups, including plants, small mammals, amphibians, as well as arthropods (Moss *et al.* 1987, Wright 1995, Dufrene and

Legendre 1997, Rykken *et al.* 1997). It has been particularly useful in the analysis of arthropod data because of the great diversity of species found in arthropod communities.

All Taxa and All Habitats Sampled in 1995

The 9 sampled habitats formed six TWINSPAN groups after three levels of division (Figure 12). The divisions were based largely on the distributions of ten arthropod species. The distributions of these species were clearly related to measured site attributes, and "indicator" species were identified at each division. Several of the divisions had high associated eigenvalues that indicated strong group differences.

Group I sites were almost exclusively limited to sphagnum bog habitat, with the exception of one willow/carex habitat site. Species in Group I were associated with wet peaty soils and a dense herbaceous cover. The habitat was located close to the water, on flat ground with no discernable slope, and with very low canopy cover giving it a high exposure to sunlight. Group II primarily included sites representing willow/carex and willow/spiraea swamp habitat types, with one bog site and one cedar/willow/carex site also represented. Species in Group II showed were associated with wet soils and deep litter covered by a dense herbaceous layer. Sites within Group II are also essentially level and have very low canopy cover. The eigenvalue for the TWINSPAN division that distinguished between Groups I and II was small ($\lambda = 0.3247$). The low eigenvalue for this division indicates some similarity in species composition between Groups I and II, and that most species found in these habitats were associated with wet sites.

Group III, primarily represented by cedar/willow/carex habitat, formed a transition between wetter, open canopy habitats of Groups I and II, and the moist to dry, closed canopy habitats representing Groups IV and V. Consequently, a few sites from other habitats at both ends of this gradient (bog, willow/carex, and alder swamp) were classified by TWINSPAN with this group. Species in Group III showed were associated with moist soils and deep litter covered by an herbaceous layer. Moderate canopy cover of cedar trees partially shaded sites within this group. The group's moderate eigenvalue ($\lambda = 0.4163$) indicates the habitat has many species in common with Groups I and II.

The first TWINSPAN division separating Groups I, II, and III from Groups IV, V, and VI had a high eigenvalue ($\lambda = 0.6736$). Species that occurred in Groups I, II, and III were very different from those occurring in Groups IV, V, and VI.

The wolf spider, *Pirata piraticus*, was the major indicator for Groups I-III, and was found almost exclusively in bog and swamp habitats. Our findings are consistent with published reports of the biology of this species. *Pirata piraticus* has a preference for marshes, swamps, bogs, and moist margins of lakes and streams throughout North America (Dondale and Redner 1990).

The TWINSPAN division separating Group IV from Group V had a relatively small eigenvalue ($\lambda = 0.3461$), and indicated some similarity in species between these 2 groups. Group IV included primarily sites representing alder swamp and maple thicket habitats. Single sites from 3 other habitats (Douglas fir forest, cedar/hemlock forest, and cedar/willow/carex swamp) were also represented in Group IV. Soils here were moderately moist, containing no peat or gravel,

and little organic debris. The clay-sandy loam soils were covered with a moderate herbaceous layer (45 – 53% cover), and not exposed to direct sunlight. The shrub cover in this group was higher than in all other groups. Group V sites were represented by exclusively Douglas fir and cedar/hemlock forests. The sites in this group were composed of tall trees and had deep litter layers. Dominant herbs included mosses that covered about 50% of the ground. Soils were dry, and composed of clay and sandy-loam. Canopy cover was almost 100% at both Group IV and V sites.

Two rove beetles, *Proteinus collaris* and *Tachinus crotchii*, were identified as indicators for Group IV. *Tachinus crotchii* was the fifth most abundant beetle captured. Larvae and adults are predaceous, and are associated with decaying plant material. The species may be useful as an indicator of the general abundance of its prey. *Proteinus collaris* is also associated with decaying organic matter.

Many of the same species that occurred in habitats in Group IV also occurred in habitats of Group V. *Scaphinotus angusticollis* was the indicator species for Group V, as identified by TWINSPAN. Adults of this species may make good indicators for future monitoring efforts. They are long-lived, abundant in forested habitats, and feed on slugs and snails (LaBonte 1998). The presence of *S. angusticollis* is a good indicator of their prey. Several species of slugs have recently been identified as components of the Pacific Northwest biota that should be monitored and protected (USDA 1994).

Group VI (gravel bars) were a very unique habitat, as indicated by the high eigenvalue associated with its division from Groups IV and V ($\lambda = 0.7509$). Species in this group were associated with exposed sites with dry, sandy soil and no litter. The TWINSPAN indicator species for this group, *Pardosa lowriei*, commonly occurred throughout the gravel bar study sites, and was not found in any of the other habitats in the study. It joins a host of other predatory arthropods that forage in this habitat.

Beetle Data from All Habitats Sampled in 1995

TWINSPAN analysis of only beetle data, collected in 1995, classified the 9 habitats into four groups (Figure 13). The uniqueness of the gravel bar community was again recognized, and indicated by a strong separation in the first division of this analysis ($\lambda = 0.8057$). Three TWINSPAN indicator species were associated with this group. The anthicid beetle, *Eurygenius campanulatus* was the second most abundant beetle collected in the study, all from gravel bars. Adults are hypothesized to be detritivorous and/or omnivorous (Stehr 1991). The two other indicator species for gravel bar habitat were both Elateridae, *Cardiophorous propinquus* and *Ligmargus funebris*. These two species were only found in gravel bar sites and among the most abundant arthropods in this study. Adults of both species are herbivores and larvae are predators (P.J. Johnson, pers. comm.), and are commonly found in gravely and sandy soils along streams (Hatch 1971).

The TWINSPAN analysis of the beetle data showed a strong separation ($\lambda = 0.7249$) of wet and open canopy sites (bogs, willow/carex swamps, willow/spiraea swamps, and cedar/willow/carex

swamps) from the moist and dense canopy sites (alder swamps and maple thickets) to dry, closed canopy, forested sites (Douglas fir forest and cedar/hemlock forest). There was no further separation of the bog and swamp sites in the analysis. This indicates that beetles associated with moist to wet habitats with primarily open canopy do not show a preference for vegetative site characteristic differences between these habitats.

One indicator beetle species (*Reichenbachia albionica*) was identified by TWINSPAN for the group formed by the bog and swamp sites. This species was found in all habitats with the exceptions of maple thicket and Douglas fir forest habitats, but the majority of the specimens collected (86%, LaBonte 1998) were associated with the more or less open canopy-swamp habitats of this group.

The group including alder swamps, maple thickets, Douglas fir and cedar/hemlock forest habitats were represented by four indicator species. Two carabid species (*Pterostichus neobrunneus* and *Scaphinotus augusticollis*) and one staphylinid beetle, (*Staphylinus pleuralis)*, were found in all closed canopy habitats, but were most abundant in Douglas fir and cedar/hemlock forest habitats (LaBonte 1998). One curculionid species (*Sthereus horridus*) was also selected as an indicator species, with a few specimens collected in Douglas fir and cedar/hemlock forest habitats, but with most found in alder swamp and maple thicket habitats (LaBonte 1998).

Alder swamp and maple thicket habitats separated in the TWINSPAN analysis of the beetle data from Douglas fir and cedar/hemlock forest habitats at the third level of division, but with weaker separation ($\lambda = 0.4677$). These groups corresponded to Groups IV and V from the TWINSPAN analysis of all taxa (see above and Figure 12). Indicator species were also identical.

Spider Data from All Habitats Sampled in 1995

TWINSPAN analysis of 1995 spider data created only 3 groups of habitats (Figure 14). Gravel bars again formed a unique group with strong separation from the other groups ($\lambda = 0.6621$). *Pardosa lowriei* was found to be an indicator for this group. Wet to moist, open canopy sites formed another group with *Pirata piraticus* as an indicator species. A third group classified alder swamps, maple thickets, Douglas fir forest, and cedar/hemlock forest habitats together. No indicator spider species were identified for this group of habitats, as only the absence of *Pardosa lowriei* separated this group from gravel bar sites.

The analysis of different taxonomic groups is sometimes useful because it identifies taxa that can be used as surrogates for the entire community, or that reveal different patterns than other taxa. In this case, separate analysis of beetle data and of spider data did not detect fine-scale differences anong habitats. The habitats formed fewer groups than were formed when using all taxa in the TWINSPAN analysis. However these analyses did reinforce some of the relationships observed in the grouping of habitats when all species were used in TWINSPAN (Figure 12).

Habitats Sampled in 1995 and 1996

TWINSPAN analysis was also completed for the 5 habitats sampled during both years (combined data for 1995 and 1996, Figure 15) to examine the effects of increased sample size and interannual variation on the classification outcome.

In this analysis, all gravel bar sites were separated from all other sites at the first level of division, with strong separation indicated by an eigenvalue of 0.7385. Willow/carex swamp sites were strongly separated ($\lambda = 0.7066$) at the second level of division from the other three habitats (alder swamp, Douglas fir forest, and cedar/hemlock forest). A third level of division ($\lambda = 0.4225$) separated Douglas fir forest and cedar/hemlock forest sites from alder swamp sites.

TWINSPAN analysis of all 1995 habitats (Figure 12) generally agreed with the analysis of 1996 sampled habitats. Comparisons of indicator species from the single year effort of 1995 (Figure 12) and combined 1995 and 1996 effort (Figure 15) resulted in many of the same species being selected as indicators. Consistency over 2 years provided added confidence about the relationships among the habitats and group homogeneity. Relationships among groups are not clear from TWINSPAN dendrograms. These dendrograms are one-dimensional and further analysis is needed to provide more information. Analysis with Non-metric Multi-Dimensional Scaling (NMDS) uncovered gradients, and ordinated the TWINSPAN groups in two dimensions.

Non-Metric Multidimensional Scaling (NMDS)

Habitats Sampled in 1995

Non-Metric Multidimensional Scaling ordination of the invertebrate data produced distinct groupings of habitats along Big Beaver Creek. The ordination results of NMDS were consistent with those from TWINSPAN. Relationships between groups of habitat types were much easier to discern from NMDS plots than from TWINSPAN dendrograms.

Several gradients were evident from the NMDS analysis. A strong gradient in percent canopy cover was associated with Axis 1 (Table 11). Axis 1 was also associated with weaker gradients of coarse woody debris, tree basal area, herbaceous plant cover, and soil moisture. Differentiation of the groups along this axis was due to species associations with shade and woody debris.

Axis 2 was associated with soil moisture, soil type, percent herbaceous cover, and coarse woody debris. It is difficult to make inferences about species preferences from these weak associations. Some groups formed clusters with other groups. These clusters are the result of similarities of species between groups in the clusters. The clusters are discussed below.

Group VI, containing gravel bar habitats, was the most unique, and was separated from other groups along axis 2 (Figure 16). Axis 2 appeared to be closely related to gradients of soil type, herbaceous cover, and litter depth (Figure 18). Groups I and II were ordinated close together. Some separation was evident along axis 2 and appeared to be largely caused by percent shrub

cover differences. Groups IV and V also were ordinated close together. Their separation also followed axis 2 and was apparently due to soil moisture and shrub cover (Figure 18). The habitats in these two groups had closed canopies dominated by tall trees. Group III was well defined and was intermediate between Groups I and II and Groups IV and V. The separation was primarily due to percent canopy cover.

Habitats Sampled in 1995 and 1996

NMDS analysis of the combined 1995 – 1996 data, for the 5 re-sampled habitats, was also consistent with TWINSPAN. Group IV containing gravel bar habitats was the most unique, separating along both axes. Group I, containing willow/carex swamp habitats separated along both axes but were ordinated closer to Groups II and III. Very few habitat sites were ordinated into the wrong group (Figure 17). The groups formed were apparently valid and showed little or no differences in the species collected from habitats within groups.

Between year differences were also examined in the ordination graph in Figure 17. There was no pattern in the ordination of any of the habitat groups that showed separation of 1995 sampled sites from those sampled in 1996. This indicates that there was little variation in the outcome of the ordination attributed to inter-annual sampling effects.

Indicator Species Analysis

Measuring abiotic factors may tell us what is happening in the physical environment but biological monitoring is the only method that can detect what is happening to the biota. Because they are part of almost all ecosystem processes, arthropods should be effective as indicators of change in forest ecosystems. Information about indicator species can enlighten scientists and managers about movements, accumulations, and modifications of materials in the natural environment and identify the biological effects of these processes. Because of their size and microhabitat requirements, and other attributes, arthropods can reveal fine-scale environmental change (Samways and Steytler 1996). The functional importance of invertebrates has yet to be fully appreciated by conservation planners, both in the context of conserving species and using functional group analysis as a tool for environmental monitoring (Lattin 1993b, New 1993).

TWINSPAN identified "indicator species" for many of the groups. These species are candidates for monitoring, and measurement of their abundance and distribution may provide useful information to park personnel making management decisions. The indicator species selected by TWINSPAN are based on their presence (or relative abundance at various cut-levels) or absence in a habitat and the fidelity of species to groups of sites. Species exhibiting widespread and even distributions among several habitats are not recognized as indicators by TWINSPAN.

A useful method to identify indicator species was developed by Dufrene and Legendre (1997). Their method appeared to be more sensitive at identifying indicators than TWINSPAN. For the 6 TWINSPAN groups derived from the 9 habitats sampled in 1995, 36 indicator species were found with indicator values over 40 (Table 13). The number of indicator species for individual TWINSPAN groups ranged from 3 species to 11. The TWINSPAN method identified only 10

species. Some site groups did not have designated indicator species (Figure 12). For these groups, only the absence of a species from another group was meaningful in the classification of sites within the group (Figure 12), therefore providing only the minimum information necessary for classification.

Although a number of potential indicator species have been identified in this study, the usefulness of this information for monitoring biological integrity is yet to be realized. Progress will require more specific life history information and evaluations of how these species respond to human disturbances.

Inventory and Monitoring Considerations

Inventory and monitoring programs are essential components of natural resource management. The data obtained through properly designed inventory and monitoring programs provides inferences about the impacts or changes in natural areas due to natural and human disturbances, and provides information for evaluating management strategies. During this study, much has been learned about technical and logistical problems and limitations, required sampling effort, and costs associated with arthropod sampling. The information presented above adds to the understanding of the natural history of the arthropods collected and contributes valuable input to the design of inventory and monitoring systems for future management and protection of park natural resources.

A primary question concerning development of future biomonitoring programs is: how can large and diverse landscapes such as the Big Beaver Creek Research Natural area, the entire watershed or the entire park, be broken down into ecological meaningful units that will allow for an operationally efficient and effective monitoring program? Examination of ordination results indicates that gradients in certain environmental attributes (*i.e.* canopy cover, coarse woody debris, soil moisture, percent herbaceous plant cover, etc.) may be more important classification parameters than vegetation-based habitat classes. The suitability of any classification scheme is related to the scale of the study. Rykken *et al.* (1997) sampled carabid beetles in several habitats located in the northern hardwood forest landtype association. Their study sites were relatively homogenous with some differences in composition of vegetation and soil moisture. They found that the breakdown of habitats within this zone was not useful for partitioning carabid assemblages. Studies conducted at broader scales, incorporating greater heterogeneity, have been more successful in characterizing invertebrate assemblages (Luff *et al.* 1989, and Dufrene and Legendre 1997).

In this study, ordination revealed wide gradients in environmental attributes related to broader scale factors which spanned habitat boundaries. Species assemblages did show significant separation where habitats or groups of habitats varied along these gradients. The heterogeneity between groups of habitats can be observed in the ordination graphs (Figures 16-18).

Knowledge of abiotic factors structuring biological communities will help optimize future sampling efforts. Canopy cover, coarse woody debris, soil moisture, and percent herbaceous cover were useful in reducing sampling strata in the Big Beaver Creek Research Natural Area

(for 1995 data, ordination of the species data produced six groups representing the 9 *a priori* habitats). Future expanded efforts should include these variables as well as those that integrate environmental conditions operating at even larger scales (*i.e.* climate, geology, elevation, etc.).

Investigations at the habitat scale or even finer scales (meso and microhabitat levels) should also be continued. Studies at this level are important at identifying unique habitats, monitoring biological diversity, and for prioritizing areas of conservation concern. Gravel bar habitats represent an example from this study where numerous habitat specialist species, common only in gravel bars, were found.

The use of pitfall traps for this study limited the scope to primarily ground-dwelling arthropods (beetles, spiders, ants, and true bugs) that were susceptible to this method of capture. There is a much larger diversity of arthropods yet to be discovered in the study area. Progress towards documenting this diversity will rely on different collection methods (see Finnamore *et al.* 1998) and greater sampling effort, both spatially and temporally. In the future, structured inventories would greatly compliment any ongoing monitoring program using invertebrates. A structured inventory is one that follows systematic sampling protocols and incorporates environmental data with species distribution information. Results of these inventories may help in identifying new and important indicator species and unique habitats, and update species richness estimates for existing sampling strata.

Successful inventory and monitoring programs using invertebrates rely on accurate identification of the specimens being collected. Because of the vast diversity of taxonomic groups encountered and their morphological complexity, it is difficult to find the necessary expertise for many groups. In addition, taxonomic keys for many groups are not available. Responsive monitoring programs, needing rapid turnover of results, will require personnel with extensive training in the identification of local taxa, established quality control procedures with the support of outside systematists, and well developed and documented specimen reference collections. Other, more cursory, options include using methods that are less affected by taxonomic accuracy such as working at the family level rather than the genus/species level (Bowman and Bailey 1997), or by using non-specialists for grouping species into morphologically similar groups (morphospecies - Oliver and Beattie 1996). However, more inclusive taxonomic categories may not provide sufficient resolution to address inventory and monitoring objectives.

In addition to problems and costs associated with taxonomic accuracy and sample stratification, the amount of sampling effort is also extremely important in balancing costs with effectiveness in a monitoring program. Results of increasing sampling effort were investigated by sampling 5 of the habitats, for four monthly periods, during each of the two years of the study. Addition of the second year's data in the analyses did not appreciably affect the classification of habitats based on the species assemblages. Also, for all but one of the habitats, capture rates did not significantly change with nearly doubled sample sizes. However, more species were collected with the addition of the second year's data, although the number of species observed accrued at a lower rate. Few of the species richness and diversity index curves (Figures 3-7 and 9-11) reached asymptotes (with asymptotes indicating exhaustive surveys), and percent singletons (with lower values indicating inventory completeness, Figure 8) remained relatively high. Additional effort may be feasible for longer term localized inventories (*e.g.* species richness

studies in particular habitats or other classification strata), but would not be cost effective in a long term monitoring program where frequent evaluations of status and trends are required. For this purpose, values of metrics such as Simpson and Shannon diversity indices or species richness estimators compared at standard levels of effort may be useful.

Oliver and Beattie (1996) discuss other cost effective sampling strategies including: 1) identification of taxa whose distribution is correlated with many other taxa, and 2) identification of times and methods of sampling that are representative of more intensive sampling. For example in this study, the question " is any one month's sample representative of the entire sample period?" still remains to be analyzed. If the answer is yes, then future sampling costs could be significantly reduced.

Although terrestrial arthropods are being used in ecological monitoring programs (Refseth 1980, Majer 1983, Greenslade and Greenslade 1984, Andersen 1990, Andersen 1997, Rykken *et al.* 1997), the emphasis on use of aquatic invertebrates for ecological monitoring is much more advanced (see Karr 1991, Cairns and Pratt 1993). Aquatic macroinvertebrate communities are widely accepted and used for monitoring pollution and biotic integrity in aquatic systems. Many water quality programs have incorporated benthic macroinvertebrates (BMI) into their protocols for assessing water quality and biological integrity, including the U.S. Geological Survey, U.S.E.PA, and over 40 state resource agencies. Kremen *et al.* (1993) suggested that this experience be translated to terrestrial systems for the development of similar monitoring applications using terrestrial arthropods.

Two different aquatic biomonitoring approaches have been proven to be effective in detecting impairment attributed to various perturbations. 'Multimetric' and 'Multivariate' approaches both rely on collection of aquatic BMI community data from a range of reference sites. The 'Multimetric' approach relies on *a priori* classification of site groups throughout a disturbance gradient. Physical and chemical characteristics of the site, reach, or catchment are used to classify sites. Prior biological knowledge for each site is generally not considered in the classification of sites. BMI metrics (representing functional, compositional, and pollution tolerance characteristics of the communities) are determined for each site and measured for their performance in detecting change along the disturbance gradient. Metrics that are sensitive to changes are included in the final protocol. Karr and Chu (1997) provides an exhaustive discussion of the use of multimetric indices. Protocols for the 'Multimetric' approach are described by Plafkin *et al.* (1989), Hayslip (1993), Barbour *et al.* (1996), Barbour *et al.* (1997), and Karr and Chu (1997).

The 'Multivariate' approach is being widely applied in national water quality monitoring programs of Great Britain (RIVPACS - Wright *et al.* 1993) and Australia (AUSRIVAS - Simpson *et al.* 1996). The method uses BMI data from a set of unimpaired sites that represent a wide range of environmental variation (stratified initially by watershed, elevation, and stream order). Sites are classified into groups based on similarity in their species composition, using ordination or clustering methods. A method is then required to match a test site to the appropriate reference group. A discriminant function based on environmental attribute parameters (independent of change related to human disturbance) of the reference site data is used to predict group membership of test sites. If a test site can be associated with a group of

reference sites representing unimpaired conditions, then the reference site data can be used to predict the fauna expected at the test site. Deviation in the expected vs. observed frequencies of occurrence of taxa between the reference data set and the test site data set are used to evaluate impairment. The sensitivity of this method can be determined by comparing the reference data sets with matching test sites of known impairment. Methods for the 'Multivariate' approach are given in Moss *et al.* (1987), Simpson *et al.* (1996), and Barbour *et al.* (1997). A comparison of 'Multimetric' and 'Multivariate' methods is presented in Reynoldson *et al.* (1997).

Park staff are currently working on development of both 'Multimetric' and 'Multivariate' BMI protocols for monitoring streams. A logical next step would be to integrate additional components of the aquatic-terrestrial interface for inclusion into a more comprehensive and more robust biomonitoring program. Numerous relationships between riparian arthropods and stream fish and aquatic macroinvertebrate communities have been documented (Edwards and Huryn 1996, Herring and Plachter 1997, Herring 1998). Incorporating gravel bar habitats would add a significant number of potential indicator species and possible metrics representing the integrity of this terrestrial habitat as well as the aquatic habitat it borders. Gravel bar habitats are structurally uncomplicated and easily delineated, therefore facilitating sampling. They are primarily represented by commonly occurring carnivorous and detritivorous species that are largely unique to this habitat.

Monitoring of ecosystems and natural resources in Pacific Northwest forests should be comprehensive, cost-effective, statistically designed, executed with analytical integrity, presented to decision makers by way of meaningful reports, charts, and maps, and updated regularly over many decades. Consideration and application of the use of arthropod assemblages and indicator species in future monitoring programs will provide a much greater foundation of ecological information to draw from in future assessments of biological integrity.

Summary and Conclusions

The North Cascades Park is an ideal site to study boreal arthropods. It is situated at the crossroads of an east-west boreal transect and a north-south montane transect that includes the Cascade and Sierra Nevada mountain ranges. The Park is positioned to become a significant contributor in riparian arthropod research. Support for monitoring and management research will go a long ways towards facilitating our understanding of natural systems and protecting our natural heritage. Significant new data concerning arthropod assemblages in the Big Beaver Creek Research Natural Area of North Cascades National Park Service Complex was obtained from this study and will be used to develop future monitoring and inventory programs focusing on this most diverse assemblage of organisms.

The habitats along Big Beaver Creek are the home of very diverse and abundant arthropod assemblages. More than 448 species and 15,000 adult arthropods were collected in pitfall traps during this study. Beetles made up the largest proportion, in number and species, of arthropods collected. Beetles have been extensively studied, are relatively well known taxonomically, and occupy a wide array of functional niches. These attributes make them especially promising as indicators of environmental changes.

Most species accumulation curves and species richness estimates did not reach asymptotes, and all of the diversity of the habitats probably was not collected. More work needs to be conducted to complete exhaustive sampling. New diversity information can be gathered through future structured inventory and long-term monitoring programs. The information will add to our knowledge about the riparian ecosystem along Big Beaver Creek and elsewhere in the North Cascades National Park. More extensive studies will sufficiently document species richness, and identify those taxa that are abundant and those that are rare, identify habitats that are important to biodiversity, and provide more information for improving biomonitoring programs.

TWINSPAN associated the 9 habitats sampled in 1995 into 6 groups. Non-metric Multidimensional Scaling confirmed the habitat associations based on the distributions of species, and further reduced the number of groups to four larger clusters. Knowledge about the relationships between habitat types can be used to design statistically efficient sampling systems. Efficiencies can be designed in sampling systems that will reduce the sampling effort but lead to detection of small changes in arthropod assemblages of interest.

Multivariate statistics are often applied as investigative tools. The data about relationships obtained from ordinations lead to new hypotheses, and provide information for the design of experimental studies and monitoring plans. Correlations of ordination axes scores with environmental site attributes will lead to new hypotheses about the causes of arthropod community change, and further our understanding about the effects of disturbance to the Big Beaver Creek riparian ecosystem, and elsewhere in the Park Complex. In this study, correlation of axis scores and site attributes revealed patterns of association between arthropod assemblages and canopy cover, soil moisture, coarse woody debris and herbaceous plant cover. These findings will improve the design of future arthropod sampling strategies.

Indicator species were identified for each of the habitat groups. Ecological responses are often complex and difficult to measure accurately. Indicators are often used because they are easier to measure, and because not all species in a habitat can be directly observed and counted. Practical evaluation sometimes must depend on surrogate information (Faith and Walker 1996). Monitoring planning must include definition of the indicators that will be measured. Indicators may be specific species, groups of species (taxonomic and functional), or diversity indices. Indicator species as representatives of biological diversity has been proposed as a more satisfactory conservation criterion (Webb 1989, Cousins 1991). Indicator species identified in this study may be used in monitoring programs to track ecological change, however additional information concerning the response of these indicators to human disturbances must first be evaluated.

With this study we have made considerable progress towards documenting the diversity present in the study area, and understanding their distributions, habitat associations, and problems and limitations involved in development of monitoring programs using arthropods. Yet, there is much left to be done prior to implementation of effective monitoring programs, and the following are recommended:

- Expand knowledge of arthropod species distributions and habitat associations across broader spatial scales within the Park Complex.

- Initiate structured inventories incorporating environmental attribute data along with species distributions. Utilize several capture methods to expand taxonomic focus to more arthropod groups and document diversity at multiple spatial scales.

- Continue to maintain and protect reference specimen collections and accumulate important taxonomic identification references. Make collections available to outside researchers.

- Develop and maintain contacts with additional taxonomic experts and encourage research opportunities related to park inventory and monitoring objectives.

- Develop cost effective monitoring programs that are sensitive to changes in biological and ecological integrity. Explore the application of methods widely used in aquatic biomonitoring studies for development of similar methods using terrestrial invertebrates.

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Appendix

Figure A.1. Arthropod pitfall trap locations, Big Beaver Creek, North Cascades National Park Service Complex, 1995-1996.

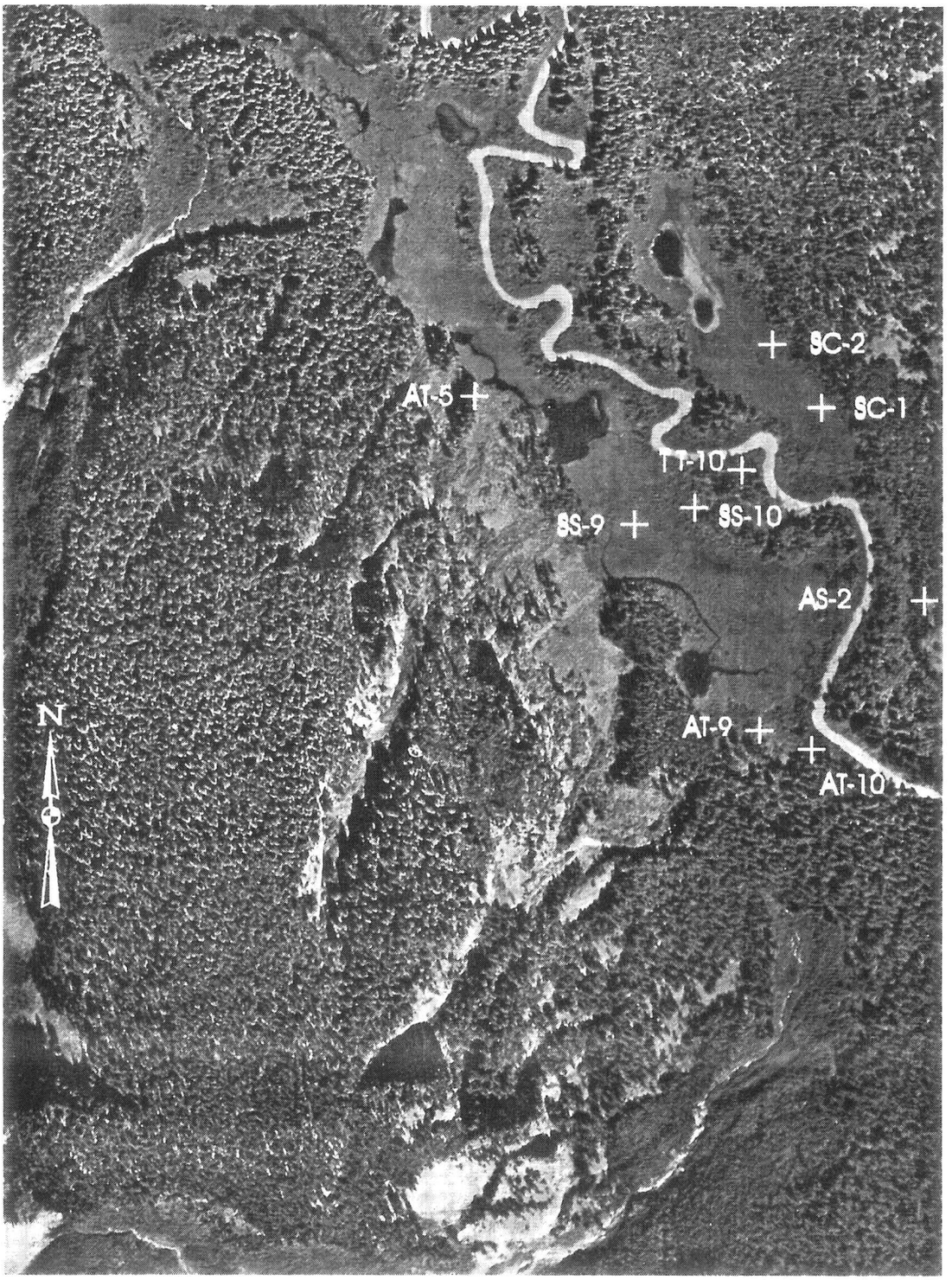

Figure A.2. Arthropod pitfall trap locations, Big Beaver Creek, North Cascades National Park Service Complex, Washington, 1995-1996.

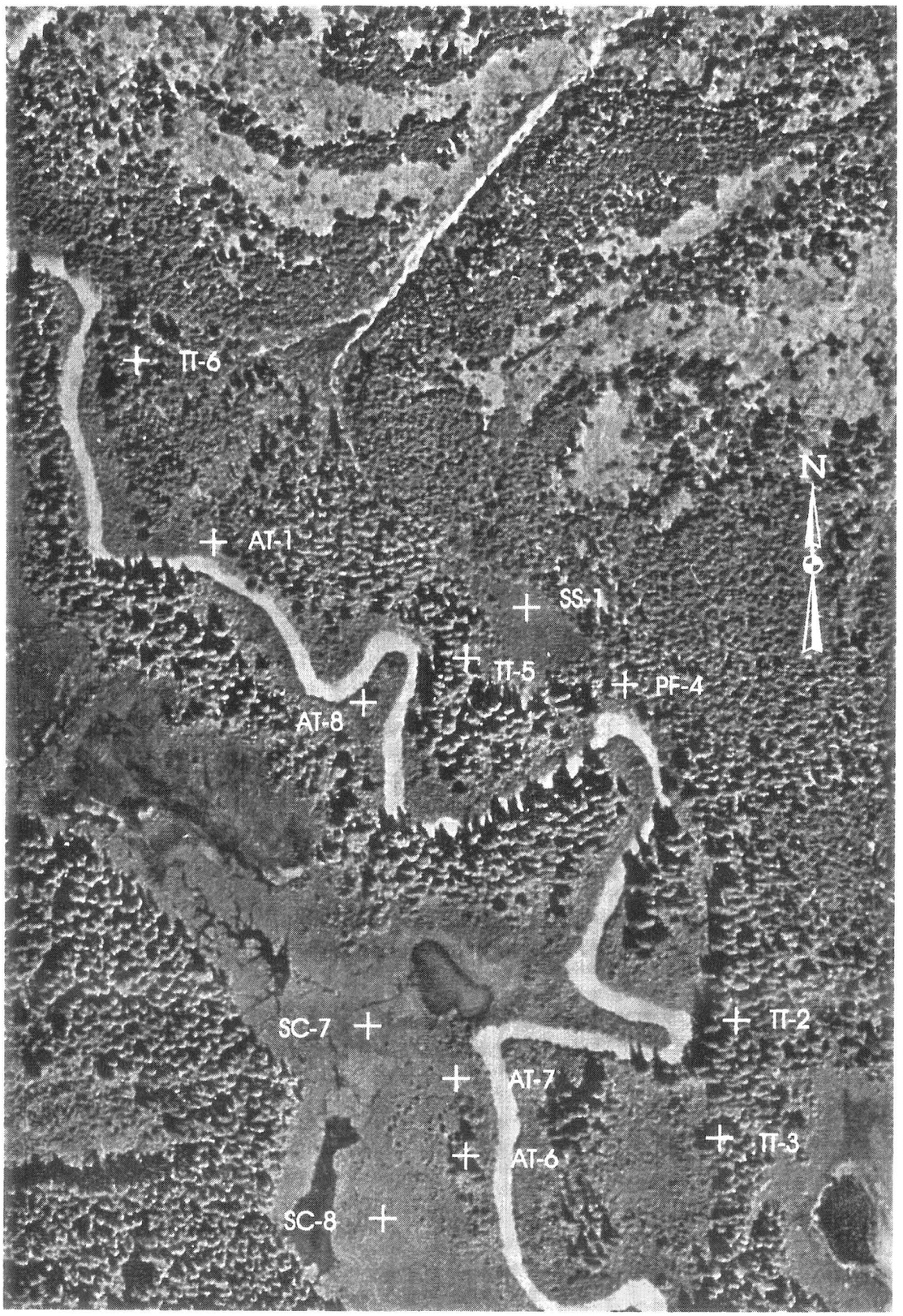

Figure A.3. Arthropod pitfall trap locations, Big Beaver Creek, North Cascades National Park Service Complex, 1995-1996.

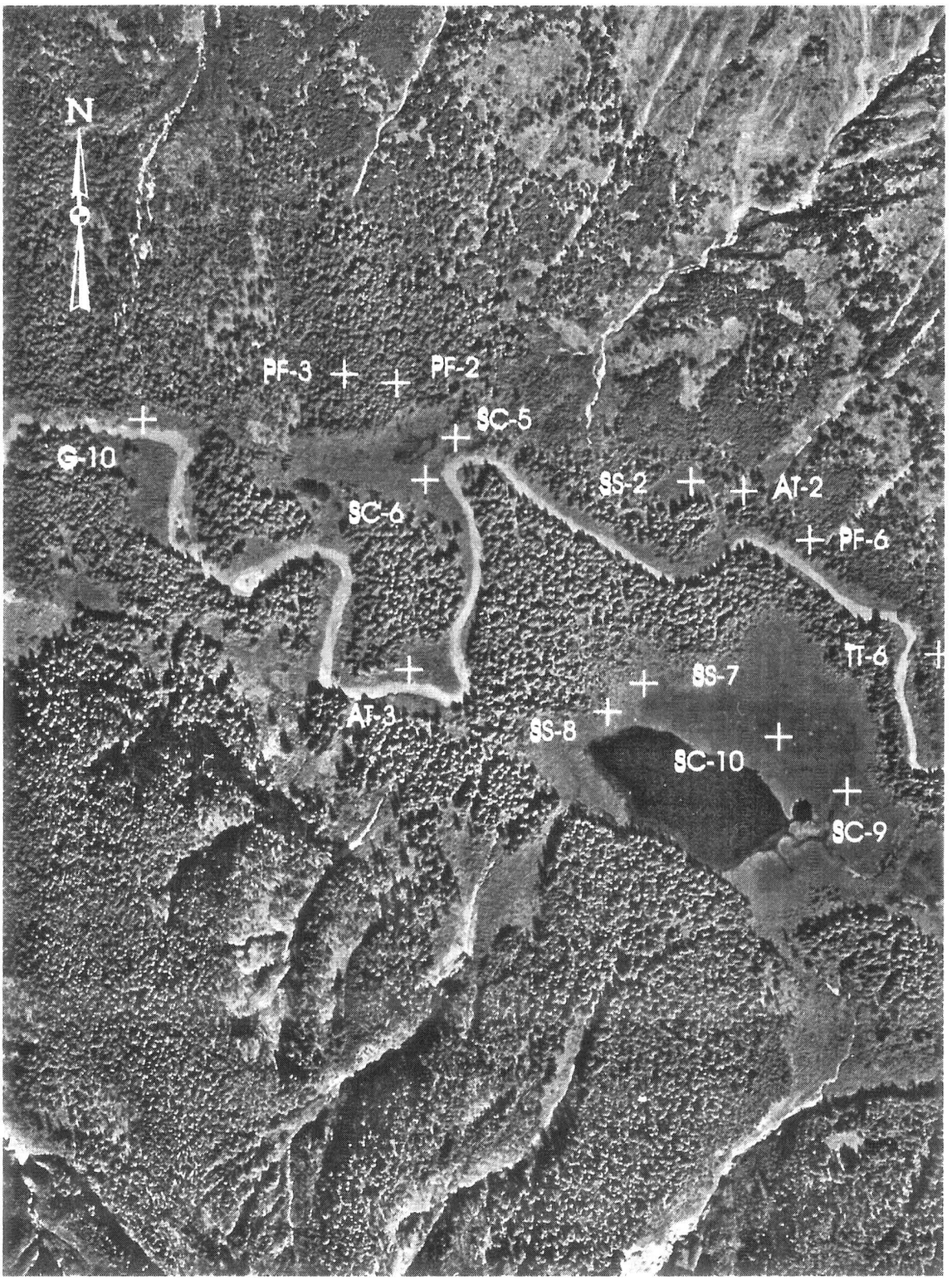

Figure A. 4. Arthropod pitfall locations, Big Beaver Creek, North Cascades National Park Service Complex, 1995-1996.

Figure A.5. Arthropod pitfall trap locations, Big Beaver Creek, North Cascades National Park Service Complex,1995-1996.

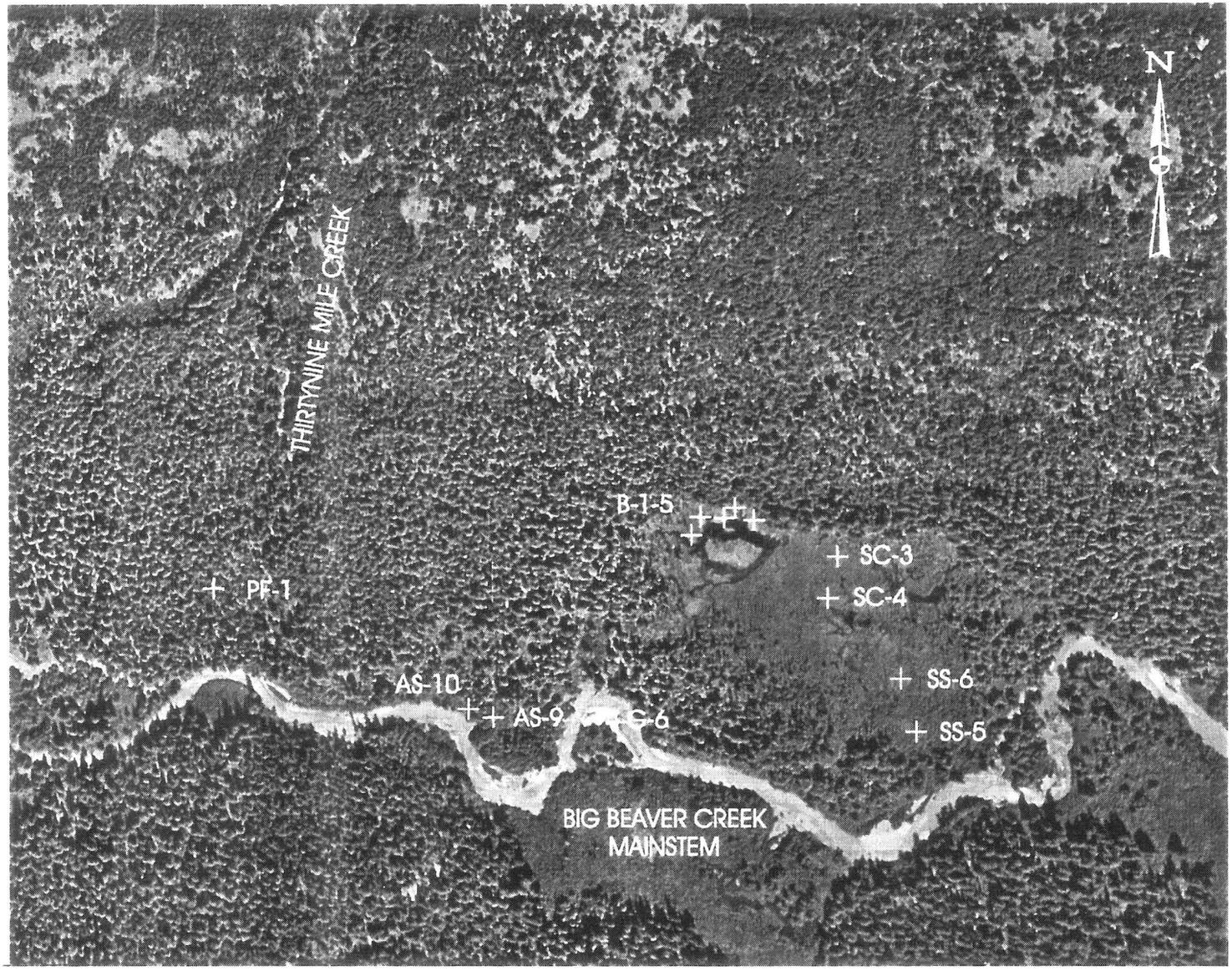

Figure A.6. Arthropod pitfall trap locations, Big Beaver Creek, North Cascades National Park Service Complex, 1995-1996.

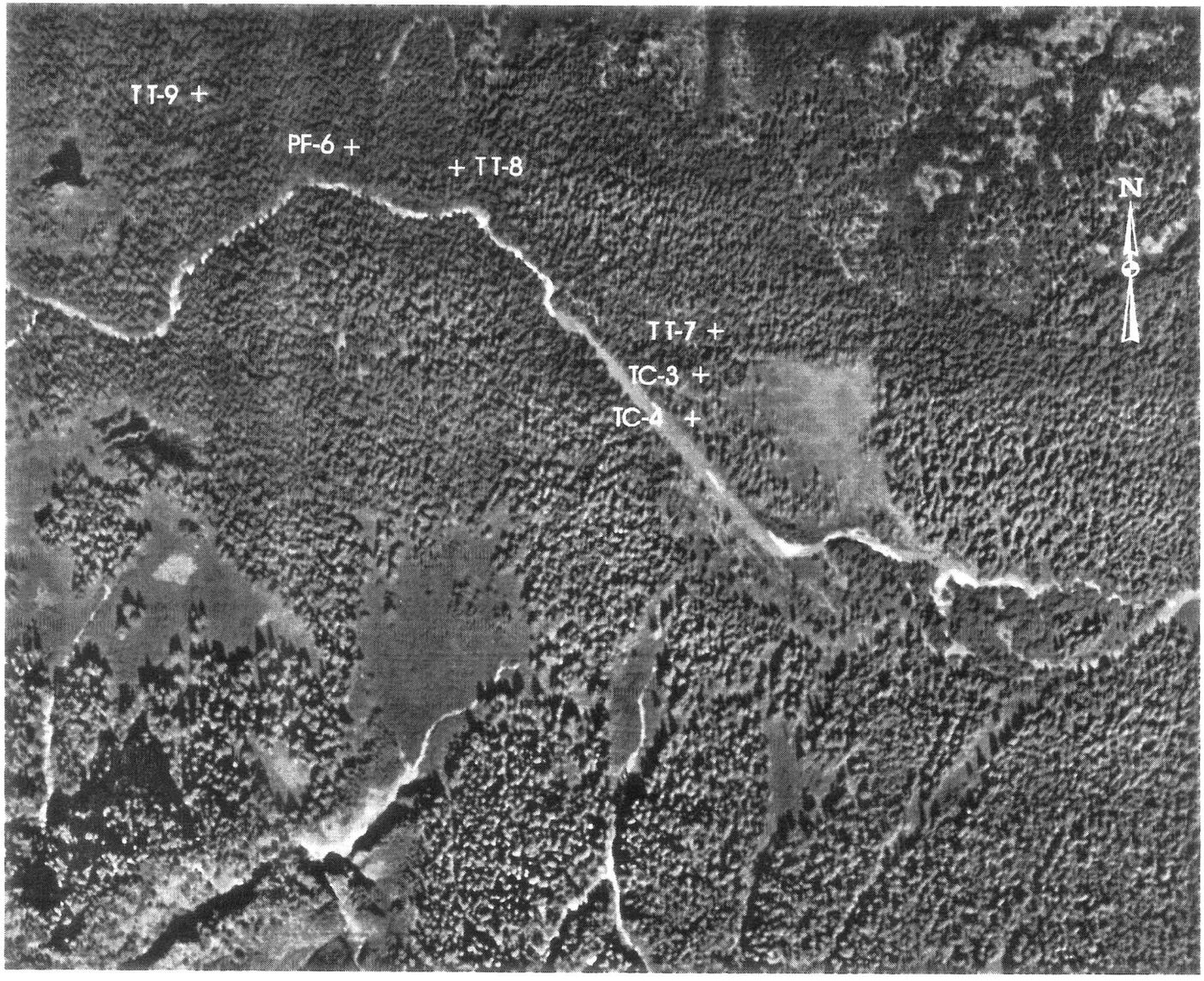

Figure A. 7. Arthropod pitfall trap locations, Big Beaver Creek, North Cascades National Park Service Complex, 1995-1996.

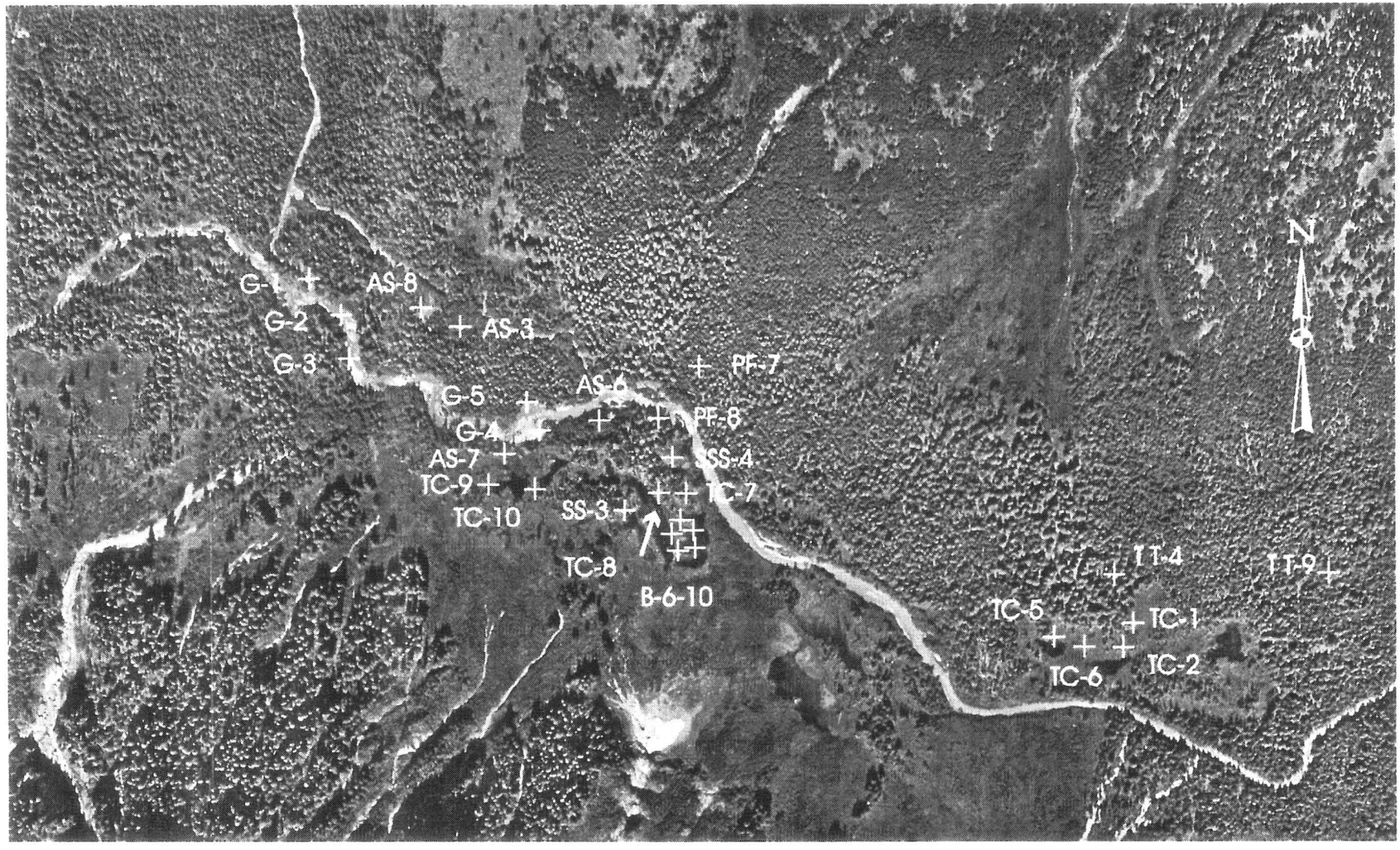

Figure A. 8. Arthropod pitfall trap locations, Big Beaver Creek, North Cascades National Park Service Complex, 1995-1996.

Table A1. Average percent cover and relative frequency of occurrence (RF) of herbaceous plant species by habitat type at arthropod pitfall trap sites, Big Beaver Creek Research Natural Area, North Cascades National Park Complex, Washington, 1995.

Herb Species	Habitat																			
	AS		AT		BOG		GVL		PF		SCS		SSS		TSCS		TTF	
	%	RF	%	RF	%	RF	%	RF	%	RF	%	RF	%	RF	%	RF	%	RF
Achillea millefolium	0	0	0	0	0	0	0.2	18.2	0	0	0	0	0	0	0	0	0	0
Adiantum pedatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10
Angelica arguta	0	0	0	0	0	0	0	0	0	0	3	10	0.1	10	0	0	0	0
Angelica genuflexa	0	0	0	0	3.1	20	0	0	0	0	13	50	5.8	40	1.5	30	0	0
Anaphalis margaritacea	0	0	0	0	0	0	0.9	45.5	0	0	0.2	10	0.5	10	0.5	10	0	0
Apocynum androsaemifolium	0	0	0	0	0	0	0.1	9.1	0	0	0	0	0	0	0	0	0.1	10
Aquilegia formosa	0	0	0	0	0	0	0.5	9.1	0	0	0	0	0	0	0	0	0	0
Asarum caudatum	0	0	0.1	10	0	0	0	0	0.8	20	0	0	0	0	0	0	4.2	30
Aster modestus	0	0	0	0	0	0	0	0	0	0	3	60	0.6	50	2.4	40	0	0
Athyrie filix-femina	17	90	5.6	50.0	0.5	30	0	0	0	0	0.6	20	7.1	80	20	80	4.7	60
Blechnum spicant	0	0	0	0	0	0	0	0	0	0	0	0	0.1	10	0	0	0	0
Carex spp.	0	0	0	0	75	100	0	0	0	0	65	90	34	60	35	70	0	0
Cerastium viscosum	0	0	0	0	0	0	0	0	0	0	2	10	0	0	0	0	0	0
Chimaphila umbellata	0	0	0	0	0	0	0	0	2	10	0	0	0	0	0	0	0	0
Circaea alpina	7.5	40	4.5	20	0	0	0	0	0	0	0	0	0	0	0	0	1.1	30
Clintonia uniflora	0	0	0	0	0	0	0	0	0.7	30	0	0	0	0	0	0	0.5	50
Cornus canadensis	0	0	0	0	0	0	0	0	0.6	20	0	0	0	0	5	10	0.6	20
Dicentra formosa	2.3	40	0	0	0	0	0.1	9.1	0	0	0	0	0	0	0	0	0.1	10.0
Disporum hookeri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	10
Disporum smithii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	10
Dryopteris austriaca	0	0	0	0	0	0	0	0	0.1	10	0	0	0	0	0	0	0.1	10
Drosera rotundifolia	0	0	0	0	25	80	0	0	0	0	0	0	0	0	0	0	0	0
Dulichium arundinaceum	0	0	0	0	2.2	30	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium angustifolium	0	0	0	0	0.2	10	0	0	0	0	0	0	0.2	10	1	10	0	0
Epilobium latifolium	0	0	0	0	0	0	2.3	63.6	0	0	1.5	10	0	0	0.1	10	0	0
Equisetum spp.	0	0	0.1	10	2.5	10	0	0	0	0	25	70	1.7	30	9.1	80.0	0	0
Galium triflorum	1.5	20	0.2	20	0	0	0.1	9.1	0	0	0	0	0	0	0.6	20	0.2	20
Geum macrophyllum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	10	0	0
Goodyera oblongifolia	0	0	0	0	0	0	0	0	0.4	40	0	0	0	0	0	0	0.4	40
Graminoid spp.	0.6	20	2.7	30.0	0	0	0.4	45.5	0	0	17	60	13	30	7.8	50	0.5	10
Gymnocarpium dryopteris	1.1	20	0.1	10	0	0	0	0	0	0	0	0	0	0	0.5	10	1.6	40
Habenaria dilatata	0	0	0	0	0	0	0	0	0	0	0.7	20	0.7	20	0	0	0	0
Heracleum lanatum	0.2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophyllum fendleri	0	0	0	0	0	0	0.7	18.2	0	0	0	0	0	0	0	0	0	0
Kalmia microphylla	0	0	0	0	5.7	30	0	0	0	0	0	0	0	0	0	0	0	0
Lactuca muralis	0.5	10	0.1	10	0	0	0.1	9.1	0	0	0	0	0	0	0	0	0.5	10
Lactuca serriola	0	0	0	0	0	0	0.1	9.1	0	0	0	0	0	0	0	0	0	0
Linnaea borealis	0	0	0	0	0	0	0	0	1.6	50	0	0	0	0	0	0	0.4	30
Lichen spp.	0	0	0	0	0	0	0	0	0.5	10	0	0	0	0	0	0	0	0
Lysichitum americanum	12	40	0	0	0.3	20	0	0	0	0	3.2	60	4.4	60	13	70	4	10
Lycopodium clavatum	0	0	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maianthimum dilatatum	0.1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mentha arvensis	0	0	0	0	0	0	0	0	0	0	0.5	10	0	0	0	0	0	0
Menyanthes trifoliata	0	0	0	0	15	80	0	0	0	0	4	20	6	40	1.5	20	0	0
Montia sibirica	0	0	0	0	0	0	0.1	9.1	0	0	0	0	0	0	0	0	0	0
Moss spp.	1.5	20	26	50	0	0	0.2	18.2	54	90	8	10	0	0	10	20	17	40
Pachistima myrsinites	0	0	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petasites frigidus	0	0	0	0	0	0	0	0	0	0	0	0	0.1	10	0	0	0	0
Polystichum munitum	0.1	10	0	0	0	0	0	0	0.1	10	0	0	0	0	0	0	2	10
Potentilla palustris	0	0	0	0	3.6	30	0	0	0	0	0.9	30	17	60	0.5	10	0	0
Pteridium aquilinum	0	0	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus pedatus	0	0	0	0	0	0	0	0	0.1	10	0	0	0	0	0	0	0	0
Scirpus microcarpus	3.5	20	0	0	0.1	10	0	0	0	0	6.2	30	8.3	20	11	40	0	0
Senecio triangularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	10	0	0
Smilacina racemosa	0.2	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	20
Smilacina stellata	0	0	0.1	10	0	0	0	0	0	0	0	0	0	0	0	0	0.1	10
Sphagnum moss	0	0	0	0	92	100	0	0	0	0	0	0	0	0	0	0	0	0
Streptopus amplexifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	20
Stachys pavistris	0	0	0	0	0	0	0	0	0	0	3	20	0	0	0	0	0	0
Streptopus roseus	0	0	0.4	30	0	0	0	0	0.1	10	0	0	0	0	0	0	3	10
Tiarella trifoliata	5.1	30	0.8	40.0	0	0	0	0	0.1	10.0	0	0	0	0	0	0	5.3	50
Tolmeia menziesii	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0	1.5	20
Trientalis latifolia	0	0	0	0	8.9	50	0	0	0.1	10	0	0	0	0	0	0	0	0
Trillium ovatum	0	0	0.1	10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urtica dioica	0.1	10	3.1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veronica americana	0	0	0	0	0	0	0	0	0	0	0.5	10	0	0	0	0	0	0
Viola palustris	0.2	20	0	0	9	20	0	0	0	0	1	10	0	0	1.1	30	0	0

Table A2. Average percent cover and relative frequency of occurrence (RF) of shrub species by habitat type at arthropod pitfall trap sites, Big Beaver Creek Research Natural Area, North Cascades National Park Complex, Washington, 1995.

	Habitat																	
	AS		AT		BOG		GVL		PF		SCS		SSS		TSCS		TTF	
	%	RF	%	RF	%	RF	%	RF	%	RF	%	RF	%	RF	%	RF	%	RF
Abies amabilis	0.3	10	0	0	0	0	0	0	5	10	0	0	0	0	0	0	0.5	10
Abies grandis	0	0	0	0	0	0	0	0	0.5	10	0	0	0	0	0	0	0	0
Acer circinatum	3	30	70	80	0	0	0	0	6.2	50	0	0	0.2	10	5.1	30	10	60
Alnus rubra	1.9	20	0	0	0.1	10	6.1	36	0	0	0	0	0	0	4	10	0	0
Alnus sinuata	0.9	20	5	10	1.5	10	2.4	18	0	0	0	0	0	0	6.2	40	0	0
Amelanchier alnifolia	0	0	1.5	10	0	0	0	0	0	0	0	0	0	0	0.1	10	0	0
Berberis repens	0	0	0	0	0	0	0	0	0.7	30	0	0	0	0	0	0	7.3	30
Cornus stolenifera	18	60	22	40	0	0	0.1	9	0	0	1.6	30	4.1	50	5.6	70	8	10
Corylus cornuta	0	0	0.5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaultheria humifusa	0	0	0	0	0.1	10	0	0	0	0	0	0	0	0	0	0	0	0
Lonicera involucrata	0.5	10	0	0	0	0	0.1	9	0	0	0	0	0.2	10	4	40	0	0
Menziesia ferruginea	0	0	2	10	5.2	30	0	0	0	0	0	0	0	0	2	10	0	0
Oplopanax horridum	17	40	0.1	10	0	0	0	0	0	0	0	0	0	0	0	0	4.5	20
Pachystima myrsinites	0	0	0	0	0	0	0	0	1.2	20	0	0	0	0	0	0	0.5	10
Populus trichocarpa	0	0	0	0	0	0	0.2	9	0	0	0	0	0	0	0	0	0	0
Pyrus fusca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	10	0	0
Rhamnus purshiana	0	0	0	0	0.5	10	0	0	0	0	0.1	10	0.8	30	0.6	20	0	0
Ribes bracteosum	1.5	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes sanguineum	0.1	10	0.2	20	0	0	0	0	0.1	10	0	0	0	0	0.5	10	0	0
Rosa gymnocarpa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	10
Rosa nutkana	0	0	0.2	10	0	0	0	0	0.1	10	0	0	0.1	10	0	0	0	0
Rubus leucodermis	0	0	0	0	0	0	0.2	18	0	0	0	0	0	0	0	0	0	0
Rubus parviflorus	2.3	40	0.15	20	0	0	0.5	9	0	0	0	0	0.5	10	0.8	20	0.1	10
Rubus spectabilis	10.4	90	0.1	10	0	0	0	0	0	0	0	0	0	0	0.6	20	1	10
Salix lasiandra	0	0	0	0	0	0	0	0	0	0	3.2	30	0	0	2.5	10	0	0
Salix sitchensis	1	10	0	0	3.3	20	1.5	55	0	0	25.2	90	21	70	34.5	80	0	0
Sambucus racemosa	2.8	60	5.5	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiraea douglasii	3	10	0	0	5.9	60	0	0	0	0	9.8	60	40.7	100	12.5	60	0	0
Taxus brevifolius	0	0	0	0	0	0	0	0	5	10	0	0	0	0	0	0	3	20
Thuja plicata	0.5	10	0	0	3.8	90	0.3	9	2.7	40	0	0	0	0	0	0	2.5	20
Tsuga heterophylla	0.4	10	0	0	0	0	0	0	3.2	50	0	0	0	0	0.5	10	1.5	20
Vaccinium ovalifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	20	1.5	10
Vaccinium parvifolium	0	0	0	0	0	0	0	0	1.2	30	0	0	0	0	0	0	0.3	30
Viburnum edule	0	0	0	0	0.5	10	0	0	0	0	0	0	3.8	40	0.5	10	0	0

Table A3. Relative frequency of occurrence (RF) of tree species by habitat type at arthropod pitfall trap sites, Big Beaver Creek Research Natural Area, North Cascades National Park Complex, Washington, 1995.

	Habitat								
Tree Species	**AS**	**AT**	**BOG**	**GVL**	**PF**	**SCS**	**SSS**	**TSCS**	**TTF**
Abies amabilis	0	0	0	0	40	0	0	10	40
Abies grandis	0	0	0	0	10	0	0	0	0
Acer circinatum	20	30	0	0	40	0	0	0	30
Acer macrophyllum	0	10	0	0	10	0	0	0	0
Alnus rubra	90	0	0	0	0	0	0	0	20
Alnus sinuata	10	10	0	0	0	0	0	0	0
Picea engelmannii	10	0	0	0	0	0	0	0	0
Pseudotsuga menziesii	0	0	0	0	30	0	0	0	10
Pyrus fusca	0	20	0	0	0	0	0	0	0
Taxus brevifolia	0	0	0	0	20	0	0	0	10
Thuja plicata	10	10	10	0	70	0	0	40	70
Tsuga heterophylla	10	0	0	0	70	0	0	10	40

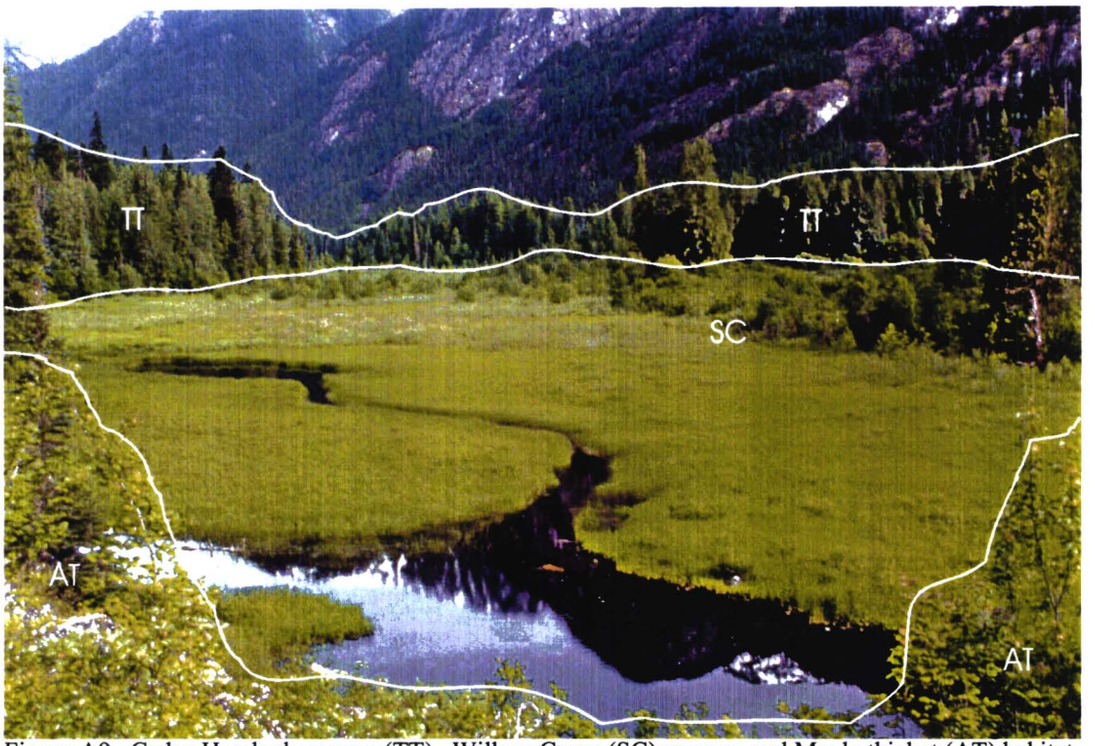

Figure A9. Cedar-Hemlock swamp (TT), Willow-Carex (SC) swamp, and Maple thicket (AT) habitat types in the lower Big Beaver Valley, North Cascades National Park Service Complex.

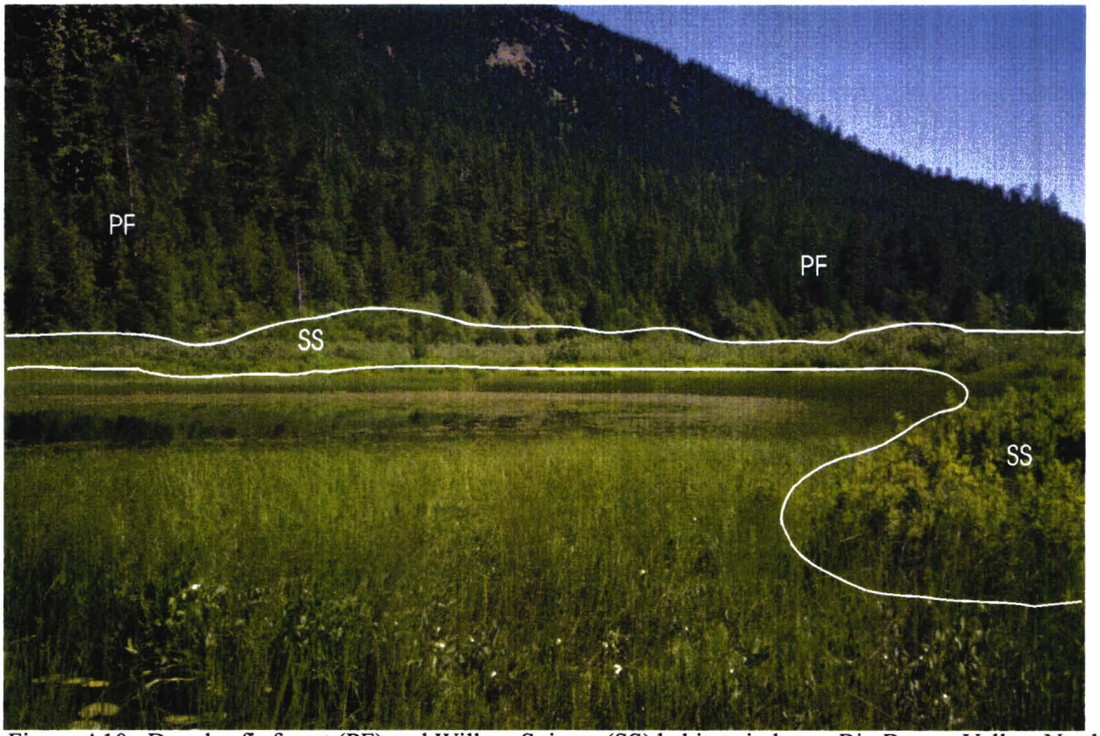

Figure A10. Douglas fir forest (PF) and Willow-Spiraea (SS) habitats in lower Big Beaver Valley, North Cascades National Park Complex.

Figure A11. Gravel bar (G) habitat in lower Big Beaver Valley, North Cascades National Park Service Complex.

Figure A12. Alder swamp (AS) habitat in lower Big Beaver Valley, North Cascades National Park Service Complex.

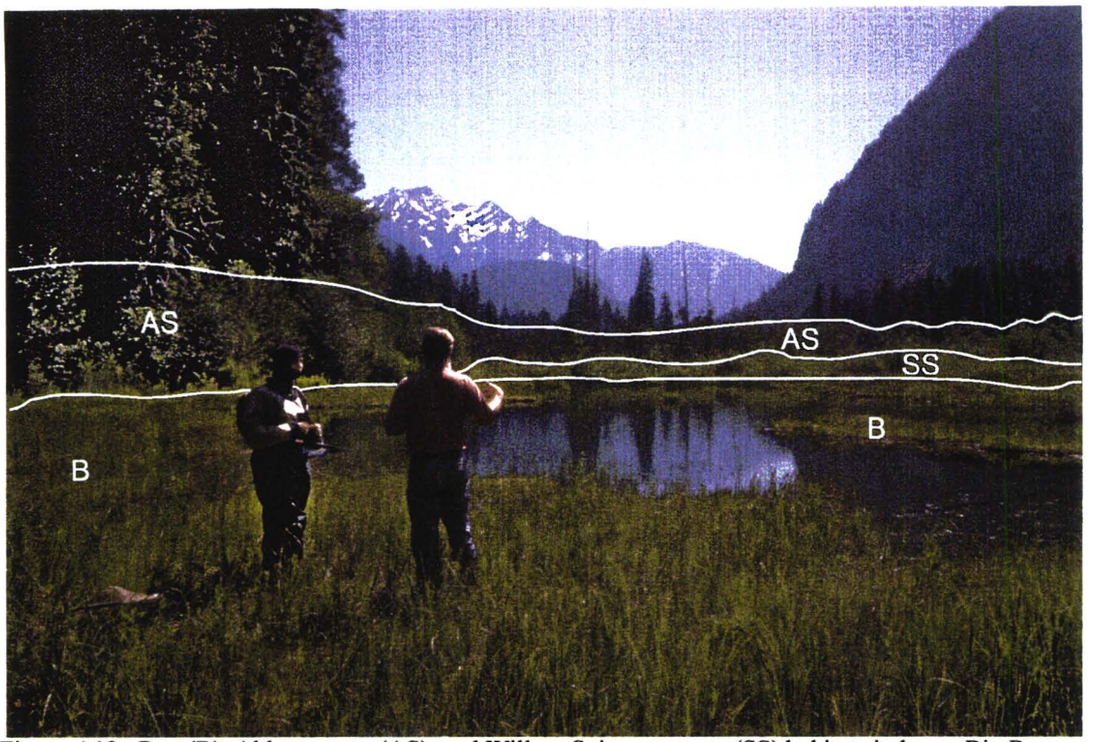

Figure A13. Bog (B), Alder swamp (AS), and Willow-Spiraea swamp (SS) habitats in lower Big Beaver Valley, North Cascades National Park Service Complex.


Figure A14. Cedar-Willow-Carex swamp (TC) habitat type in lower Big Beaver Valley, North Cascades National Park Service Complex.

Table A.4. Heteroptera species collected during, 1995 and 1996, in the Big Beaver Creek study area, North Cascades National Park Complex, Washington.

Heteroptera Taxa
Anthocoridae
Anthocoris antevolens White
Aradidae
Aradus orbiculus Van Duzee
Belostomatidae
Lethocerus americanus (Leidy)
Ceratocombidae
Ceratocombus vagans McAtee and Malloch
Gerridae
Gerris buenoi Kirkaldy
Gerris incurvatus Drake and Hottes
Lygaeidae
Cordillonotus stellatus Scudder
Cymus luridus Stal
Eremocoris borealis (Dallas)
Eremocoris obscurus Van Duzee
Geocoris pallens Stal
Kleidocerys franciscanus (Stal)
Kleidocerys resedae (Panzer)
Peritrechus saskatchewanenis Barber
Scolopostethus pacificus Barber
Scolopostethus thomsoni Reuter
Stygnocoris sabulosus (Schilling)
Nabidae
Nabis alternatus uniformis Harris
Nabis roseipennis Reuter
Nabis rufusculus Reuter
Pagasa fusca (Stein)
Pentatomidae
Banasa dimidiata (Say)
Cosmopepla bimaculata (Thomas)
Holcostethus tristis (Van Duzee)
Neottiglossa trilineata (Kirby)
Perillus exaptus (Say)
Reduviidae
Barce fraterna banksii Baker
Saldidae
Micracanthia quadrimaculata (Champion)
Saldula laticollis (Reuter)
Saldula saltatoria (Linnaeus)
Tingidae
Acalypta lillianis Torre-Bueno
Acalypta mera Drake

Table A.5. Coleopteran species collected during, 1995 and 1996, in the Big Beaver Creek study area, North Cascades National Park Complex, Washington.

Coleoptera Taxa
Amphizoidae (1 species)
Amphizoa insolens LeConte
Anthicidae (3 species)
Anthicus nanus LeConte
Eurygenius campanulatus LeConte
Ischalia vancouverensis Harrington
Buprestidae (1 species)
Agrilus politus (Say)
Byrrhidae (7 species)
Byrrhus kirbyi LeConte
Curimopsis albonotata LeConte
Cytilus alternatus Say
Exomella pleuralis (Casey)
Listemus acuminatus (Mannerheim)
Morychus aeneolus LeConte
Morychus oblongus LeConte
Cantharidae (4 species)
Cantharis oregonus LeConte
Malthodes alexanderi Fender
Malthodes sp.
Podabrus conspiratus Fall
Podabrus piniphilus Dejean
Carabidae (54 species)
Agonum affine Kirby
Agonum brevicolle Dejean
Agonum consimile Gyllenhal
Agonum ferruginosum Dejean
Agonum piceolum LeConte
Agonum thoreyi Dejean
Amara littoralis Mannerheim
Amara sanjuanensis Hatch
Anchomenus quadratus (LeConte)
Anisodactylus binotatus Fabricius
Apristus constrictus Casey
Bembidion breve (Motschulsky)
Bembidion concretum Casey
Bembidion convexulum Hayward
Bembidion erasum LeConte
Bembidion fortestriatum Motschulsky
Bembidion hesperum Casey
Bembidion inaequale Say
Bembidion incrematum LeConte
Bembidion iridescens LeConte
Bembidion kuprianovi Mannerheim
Bembidion planatum LeConte
Bembidion planiusculum Mannerheim
Bembidion quadrifoveolatum Mann.
Bembidion quadrulum LeConte
Bembidion quadrimaculatum dubitans LeC.
Bembidion semipunctatum Kirby

Coleoptera Taxa
Bembidion stillaguamish Hatch
Blethisa oregonensis LeConte
Bradycellus conformis Fall
Bradycellus lecontei Csiki
Bradycellus nigrinus Dejean
Calathus fuscipes Goeze
Chlaenius interruptus Horn
Cicindela depressula Casey
Cicindela oregona LeConte
Diplous atterrimus Dejean
Elaphrus clairvillei Kirby
Elaphrus purpurans Hausen
Harpalus cordifer Notman
Harpalus somnulentus Dejean
Leistus ferruginosus Mannerheim
Loricera decempunctata Eschscholtz
Nebria gebleri cascadensis Kavanaugh
Nebria mannerheimi Fischer
Nebria sahlbergi Fischer
Notiophilus sylvaticus Eschscholtz
Opisthius richardsoni Kirby
Patrobus fossifrons dimorphicus Darl.
Pterostichus adstrictus Eschscholtz
Pterostichus castaneus Dejean
Pterostichus herculaneus Mannerheim
Pterostichus neobrunneus Lindroth
Pterostichus riparius Dejean
Scaphinotus angulatus Harris
Scaphinotus angusticollis Mannerheim
Scaphinotus marginatus Fischer
Stenocorus flavolineatus LeConte
Synuchus impunctatus Say
Trechus chalybeus Dejean
Trechus oregonensis Hatch
Trichocellus cognatus Gyllenhal
Cerambycidae (5 species)
Brachyleptura dehiscens (LeConte)
Leptura obliterata Haldeman
Plectura spinicauda Mannerheim
Xestoleptura crassipes (LeConte)
Xestoleptura tibialis LeConte
Chrysomelidae (10 species)
Altica corni Woods
Altica tombacina Mannerheim
Chaetocnema irregularis LeConte
Chrysomela mainensis Bechyne
Crepidodera nana (Say)
Hippuriphila mancula LeConte
Macrohaltica ambiens LeConte
Macrohaltica caurina Blake

Table A.5. (Continued)

Coleoptera Taxa
Plateumaris nitida Germar
Pyrrhalta punctipennis Mannerheim, aberration *pallida* Beller & Hatch
Pyrrhalta spiraeophila Hatch & Beller
Ciidae (1 species)
Cis americanus Mannerheim
Cis maritimus (Hatch)
Octotemnus laevis Casey
Coccinellidae (3 species)
Hippodamia washingtoni Timberlake
Scymnus caurinus Horn
Stethorus punctum picipes Casey
Colydiidae (1 species)
Lasconotus vegrandis Horn
Corylophidae (1 species)
Orthoperus scutellaris LeConte
Cryptophagidae (11 species)
Anchicera ephippiata Zimmerman
Anchicera kamtschatica Motschulsky
Anchicera ochracea Zimmerman
Anchicera postpallens Casey
Antherophagus ochraceus Melsh.
Atomaria constricta Casey
Atomaria quadricollis Casey
Caenoscelis ferruginea Sahlberg
Cryptophagus cellaris Scopoli
Cryptophagus confertus Casey
Cryptophagus lapponicus Gyllenhal
Cryptophagus tuberculosus Maklin
Henotiderus lorna Hatch
Curculionidae (8 species)
Baris sparsa LeConte
Cryptorhynchus lapathi Linnaeus
Geoderces horni Van Dyke
Lepesoma lecontei Casey
Lepesoma verrucifera Casey
Rhyncolus brunneus Mannerheim
Steremnius carinatus Boheman
Sthereus horridus (Mannerheim)
Dytiscidae (7 species)
Agabus anthracinus Mannerheim
Agabus austinii Sharp
Agabus strigulosus (Crotch)
Agabus tristis Aube
Agabus sp. (female)
Dytiscus sp.
Graphoderus perplexus Sharp
Hydroporus pacificus Fall
Hydroporus sp.
Rhantus suturellus Harris
Elateridae (24 species)

Coleoptera Taxa
Agriotes ferrugineipennis LeConte
Ampedus carbonicolor Eschscholtz
Ampedus rhodopus LeConte
Athous rufiventris Eschscholtz
Athous vittiger LeConte
Cardiophorus amplicollis Motschulsky
Cardiophorus propinquus Hatch
Ctenicera aeripennis (Kirby)
Ctenicera angusticollis Mannerheim
Ctenicera opacula (LeConte)
Ctenicera propola columbiana Brown
Ctenicera resplendens (Eschscholtz)
Ctenicera suckleyi (LeConte)
Ctenicera umbripennis (LeConte)
Ctenicera volitans Eschscholtz
Dalopius maritimus Brown
Eanus striatipennis Brown
Hemicrepidius pallidipennis Mann.
Hypnoidus bicolor Eschscholtz
Hypolithus dispersus Horn
Hypolithus musculus Eschscholtz
Hypolithus nocturnus Eschscholtz
Hypolithus squalidus LeConte
Hypolithus sp.
Ligmargus funebris Candeze
Megapenthes caprella (LeConte)
Migiwa striatulus (LeConte)
Negastrius ornatus (LeConte)
Zorochrus caurinus Horn
Endomychidae (1 species)
Xenomycetes laversi Hatch
Erotylidae (1 species)
Triplax antica LeConte
Gyrinidae (1 species)
*Gyrinis picipes*Aube
Histeridae (1 species)
Hypocaccus bigemmeus LeConte
Hydraenidae (2 species)
Hydraena vandykei vandykei d'Orch.
Ochthebius cribricollis LeConte
Hydrophilidae (4 species)
Cercyon adumbratum Mannerheim
Crenitis paradigma d'Orchymont
Cymbiodyta acuminata Fall
Helophorus auricollis Eschscholtz
Megasternum posticatum (Mannerheim)
Laemophloeidae (1 species)
Rhinomalus cygnaei Mannerheim
Lampyridae (1 species)
Phausis skelleyi Fender
Latridiidae (5 species)

Table A.5. (Continued)

Coleoptera Taxa
Latridiidae (5 species)
Enicmus cordatus Belon
Melanopthalma americana Mannerheim
Melanopthalma distinguenda Com.
Melanopthalma gibbosa Herbst
Stepostheihus liratus LeConte
Leiodidae (20 species)
Agathidium californicum Horn
Agathidium concinnum Mannerheim
Agathidium contiguum Fall
Agathidium jasperinum Fall
Agathidium sp. (Near *contiguum* Fall)
Anisotoma confusa Horn
Anisotoma errans Brown
Catops basilaris Say
Catops egenus Horn
Catops simplex Say
Catops spp.
Catoptrichus frankenhaeuseri (Mann.)
Colon complicatum Hatch
Colon inerme Mannerheim
Colon magnicolle Mannerheim
Colon nevadense Horn
Colon schuhi Hatch
Colon serripoides Hatch
Colon sp.
Hydnobius simulator Brown
Leiodes alesi Baronowski
Leiodes cascadensis Baranowski
Leiodes lateritia (Mannerheim)
Leiodes puncticollis (Thomson)
Leptinus occidentamericanus Peck
Platycholeus opacellus Fall
Nemadus decipiens Horn
Lucanidae (1 species)
Ceruchus striatus LeConte
Lycidae (1 species)
Dictyopterus simplicipes Mannerheim
Melandryidae (1 species)
Xylita laevigata Hellenius
Melyridae (1 species)
Hypebaeus bicolor (LeConte)
Mordellidae (1 species)
Mordella atrata Melsheimer
Nitidulidae (1 species)
Epuraea avara Randall
Oedemeridae (4 species)
Calopus angustus LeConte
Ditylus gracilis LeConte
Ditylus quadricollis LeConte
Xanthochroa testacea Horn

Coleoptera Taxa
Phalacridae (2 species)
Phalacrus pencillatus Say
Stilbus apicalis Melsheimer
Ptiliidae (4 species)
Acrotrichis cognata Matthews
Acrotrichis henrici Matthews
Acrotrichis vicina Matthews
Ptenidium pusillum Gyllenhal
Ptilodactylidae (1 species)
Araeopidius monachus LeConte
Pyrochroidae (2 species)
Dendroides ephemeroides Mannerheim
Pedilus jonae Young
Pythidae (1 species)
Priognathus monilicornis Randall
Scarabaeidae (4 species)
Aegialia lacustris LeConte
Aegialia opaca Brown
Aphodius opacus LeConte
Onthophagus nuchicornis Linnaeus
Scirtidae (3 species)
Cyphon brevicollis LeConte
Cyphon padi Linnaeus
Cyphon variabilis Thunberg
Scolytidae (1 species)
Gnathotrichus retusus (LeConte)
Scydmaenidae (3 species)
Scydmaenus californicus Motschulsky
Scydmaenus fuchsi Bndl.
Veraphis mirabilis Marsh
Silphidae (3 species)
Nicrophorus defodiens Mannerheim
Nicrophorus investigator Zetterstedt
Nicrophorus spp. (in alcohol)
Thanatophilus lapponicus (Herbst)
Sphaeritidae (1 species)
Sphaerites politus Mannerheim
Staphylinidae (97 species)
Acidota crenata Fabricius
Actium barri Park & Wagner
Actium hatchi Park&Wagner
Aleochara bilineata Gyllenhal
Aleochara bimaculata Gravenhorst
Aleocharinae
Amphicroum maculatum Horn
Anthobium clarkae Hatch
Anthobium reflexicolle Casey
Anthobium sinuosum Hatch
Atrecus macrocephalus Nordmann
Atrecus punctiventris Fall
Baeocera humeralis Fall

Table A.5. (Continued)

Coleoptera Taxa
Batrisodes albionicus (Aube)
Bisnius hesperidum Smetana
Bisnius siegwaldi (Mannerheim)
Bledius cedarensis Hatch
Bledius suturalis LeConte
Bolitobius kremeri Maklin
Bryophacis discalis (Hatch)
Bryophacis punctatissimus Hatch
Bryophacis punctulatus Hatch
Cupila excavata Park & Wagner
Cypha crotchi Horn
Dianous nitidulus LeConte
Elonium NEAR *barri* (Hatch)
Elonium rugosa (Hatch)
Empelus brunnipennis Mannerheim
Erichsonius cinerascens Gravenhorst
Eusphalerum fenyesi Bernh.
Eusphalerum pothos Mannerheim
Gabrius cushmani Hatch
Gabrius picipennis Maklin
Gabrius seattlensis Hatch
Gabrius shulli Hatch
Hemiquedius fusculus (LeConte)
Ischnosoma fimbriatum Campbell
Ischnosoma pictum (Horn)
Ischnosoma splendidus (Gravenhorst)
Lathrobium punctulatum? LeConte
Lathrobium vancouveri Casey
Lithocaris capitula Casey
Lobrathium sp.
Lordithon fungicola Campbell
Lordithon poecilus Mannerheim
Lordithon thoracicus Fabricus
Lucifotychus cognatus LeConte
Lucifotychus impellus Park & Wagner
Mathrilaeum pictum Fauvel
Mathrilaeum subcostatum Maklin
Megarthrus arcuatus Hatch
Megarthrus pictus Motschulsky
Megarthrus sinuaticollis Boisd. & Lac.
Microedus austinianus LeConte
Microedus laticollis Mannerheim
Micropeplus minor Campbell
Micropeplus nelsoni Campbell
Mycetoporus americanus Erichson
Mycetoporus bipunctatus Campbell
Mycetoporus maculicollis LeConte
Mycetoporus pacificus Campbell
Olophrum consimile Gyllenhal
Omalium foraminosum Maklin
Ontholestes cingulatus Gravenhorst
Oropodes dybasi Grigarick & Schuster
Oropus striatus (LeConte)
Orus punctatus Casey
Oxyporus occipitalis Fauvel

Coleoptera Taxa
Oxytelus laqueatus Marsham
Pelecomalium testaceum Mannerheim
Philonthus crotchi Horn
Philonthus cruentatus (Gmelin)
Philonthus duplicatus Bernh. & Schub.
Philonthus furvus Nordmann
Philonthus spiniformis Hatch
Philonthus varians Paykull
Phlaeopterus frosti Hatch
Proteinus basalis Maklin
Proteinus collaris Hatch
Proteinus limbatus Maklin
Pseudopsis sulcata Newman
Quedius aenescens Maklin
Quedius breviceps? Casey
Quedius crescenti Hatch
Quedius fulvicollis (Stephens)
Quedius griffinae Hatch
Quedius horni Hatch
Quedius nevadensis Casey
Quedius oculeus Casey
Reichenbachia albionica Motschulsky
Sonoma hespera Park & Wagner
Staphylinus pleuralis LeConte
Staphylinus rutilicauda Horn
Stenus juno Fabricius
Stenus laccophilus Casey
Stenus maritimus Motschulsky
Stenus occidentalis Casey
Stenus plicipennis Casey
Stenus subgriseus Casey
Subhaida ingrata (Hatch)
Tachinus basalis Erichson
Tachinus crotchii Horn
Tachinus maculicollis Maklin
Tachinus nigricornis Mannerheim
Tachinus semirufus Horn
Tachinus tachyporoides Horn
Tachyporus canadensis Campbell
Tachyporus chrysomelinus Linnaeus
Tachyporus maculicollis Campbell
Tachyporus mexicanus Sharp
Trichophya pilicornis Gyllenhal
Unamis fulvipes Fall
Tenebrionidae (2 species)
Helops pernitens LeConte
Scaphidema pictum Horn
Throscidae (2 species)
Aulonthroscus validus LeConte
Pactopus hornii LeConte
Trogositidae (1 species)
Temnochila chlorodia Mannerheim
Zopheridae (1 species)
Phellopsis porcata LeConte

Table A.6. Hymenoptera (Formicidae) species collected during, 1995 and 1996, in the Big Beaver Creek study area, North Cascades National Park Complex, Washington.

Formicidae Taxa
Aphaenogaster occidentalis (Emery)
Camponotus modoc W.M. Wheeler
Camponotus novaeboracensis (Fitch)
Camponotus herculeanus (Linnaeus)
Camponotus vicinus Mayr
Formica densiventris Viereck
Formica pacifica Francoeur
Formica obscuripes Forel
Formica neorufibarbis Emery
Formica propinqua W.M. Wheeler
Lasius pallitarsis (Provancher)
Lasius alienus (Foerster)
Lasius vestitus W.M. Wheeler
Leptothorax sp01
Leptothorax muscorum (Nylander)
Leptothorax rugatulus W.M. Wheeler
Manica hunteri (W.M. Wheeler)
Myrmica nr. brevispinosa
Myrmica incompleta Provancher
Myrmica nr. fracticornis
Myrmicine unident.
Stenamma diecki Emery

Table A. 7. Arachnida:Araneae species collected during, 1995 and 1996, in the Big Beaver Creek study area, North Cascades National Park Complex, Washington.

Araneae Taxa
Agelenidae
Agelenopsis oregonensis Chamberlin & Ivie
Cryphoeca exlinae Roth
Cybaeus eutypus Chamberlin & Ivie
Cybaeus exlinae Chamberlin & Ivie
Cybaeus reticulatus Simon
Cybaeus signifer Simon
Cybaeus sp. 1
Cybaeus sp. 2
Calymmaria sp.
Novalena intermedia (Chamberlin & Gertsch)
Amaurobidae
Callobius nomeus (Chamberlin)
Callobius pictus (Simon)
Callobius severus (Simon)
Callioplus wabritaskus new sp.
Callioplus spenceri new sp.
Corrinidae
Castianeira longipalpa (Hentz)
Clubionidae
Clubiona pacifica Banks
Gnaphosidae
Micaria pulicaria (Sundevall)
Zelotes fratris Chamberlin
Lycosidae
Pardosa dorsalis Banks
Pardosa dorsuncata Lowrie & Dondale
Pardosa lowriei Kronestedt
Pardosa metlakatla Emerton
Pardosa moesta Banks
Pardosa vancouveri Emerton
Pardosa xerampelina (Keyserling)
Pirata piraticus (Clerck)
Trochosa terricola Thorell
Philodromidae
Tibellus oblongus (Walckenaer)
Pisauridae
Dolomedes triton (Walckenaer)
Salticidae
Metaphidippus aeneolus Curtis
Undetermined sp. 1
Undetermined sp. 2
Undetermined sp. 3
Thomisidae
Coriarachne utahensis (Gertsch)
Ozyptila pacifica Banks
Xysticus luctuosus (Blackwall)
Xysticus pretiosus Gertsch

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interest of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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