

A VEGETATIONAL CHARACTERIZATION OF CLIFF FACES
IN THE LINVILLE GORGE WILDERNESS AREA

INSTRUCTIONAL MATERIALS CENTER
APPALACHIAN STATE UNIVERSITY
Boone, North Carolina 28608

A Thesis

by

Peter Smith

INSTRUCTIONAL MATERIALS CENTER
APPALACHIAN STATE UNIVERSITY
BOONE, NC 28608

Submitted to the Graduate School

Appalachian State University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

December 1998

Major Department: Biology

Archives
Closed
LD
175
A40K
Th
414

A VEGETATIONAL CHARACTERIZATION OF CLIFF FACES
IN THE LINVILLE GORGE WILDERNESS AREA

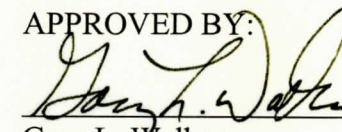
A Thesis

by

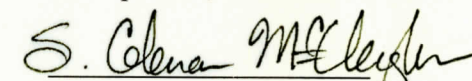
Peter Smith

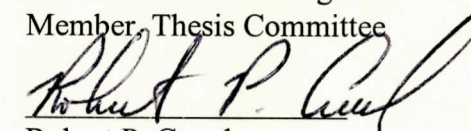
December 1998

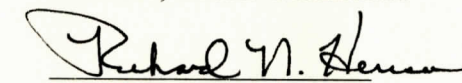
APPROVED BY:

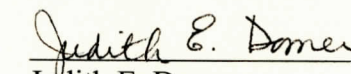

Gary L. Walker

Chairperson, Thesis Committee


S. Coleman McCleneghan
Member, Thesis Committee


Robert P. Creed
Member, Thesis Committee


Richard N. Henson
Chairperson, Department of Biology


Judith E. Domer
Dean of Graduate Studies and Research

Copyright by P. Smith 1998
All Rights Reserved

ABSTRACT

A VEGETATIONAL CHARACTERIZATION OF CLIFF FACES IN THE LINVILLE GORGE WILDERNESS AREA (December 1998)

Peter Smith

B.S., Appalachian State University

M.S., Appalachian State University

Thesis Chairperson: Gary L. Walker

Throughout North America few ecosystems have escaped disturbance associated with the rapid expansion of humans. Cliff-face ecosystems are largely undisturbed and some represent ancient pre-settlement forests. However, even these habitats are now being disturbed by rock climbing and rappelling.

There were three objectives to this study. First, to characterize cliff-face plant and lichen vegetation on Linville Gorge cliff faces. Second, to compare plant and lichen communities on cliff-edge rock outcrops to those on cliff faces. The third objective of this study was to compare vegetation type and percent cover of climbed and unclimbed cliff faces in the Linville Gorge Wilderness Area.

Twenty-three lichen genera (one newly described species) and thirty-one plant taxa were identified in association with rock outcrops and cliff faces.

Principal Components Analysis based on percent coverage of eleven dominant

taxa with regard to transect position showed significant differences in community structure between cliff-edge rock outcrop, cliff-face top, and cliff-face bottom. Lichen taxa on cliff faces were found to be non-randomly distributed along the length of cliff faces. This may represent distribution along a moisture and/or light gradient but the effect of environmental factors should be further quantified.

Percent coverage of five vegetational morphotypes (crustose, foliose, and fruticose lichens, seed-bearing vascular plants, seedless vascular plants) were used to compare climbed and unclimbed cliff faces. Principal Components Analysis found significant differences in percent coverage of the five morphotypes between climbed and unclimbed cliff faces. Foliose lichens, fruticose lichens, seed-bearing vascular plants and seedless vascular plants decreased in mean percent cover on heavily climbed cliff faces. Crustose lichens increased in percent cover on heavily climbed cliff faces, possibly responding to a competitive release.

The fragile nature of cliff environs and increasing public use of the Linville Gorge Wilderness Area warrants the need for further quantitative studies regarding the impact of disturbance on these habitats. This would provide a more complete understanding of cliff-face and associated cliff-edge rock outcrop communities so that sustainable management plans can be employed to insure the preservation of our wilderness areas for future generations.

ACKNOWLEDGEMENTS

I would first like to thank Dr. Gary Walker for agreeing to chair this project and his enthusiasm in designing this project. I thank my other committee members, Drs. Robert Creed and Coleman McCleneghan for their invaluable advice, comments, suggestions, and discussions. I extend great appreciation to Jim Soberiaj, Tom Bahleda, Coleman McCleneghan, Gary Walker, and Trent Peterson for their help in the field, lab, and for their moral support. I also thank Drs. William and Chicita Culberson for the use of the Duke Lichen Herbarium and Dr. Richard Harris for his efforts regarding lichen identification. I am also indebted to Drs. Ken McFarland, D.K. Smith, and Teresa Lange at the University of Tennessee, Knoxville for their assistance in identifying bryophytes collected in this study. Dr. Ruth Dewell was very helpful in processing film of a previously undescribed species of lichen found during this study. I would like to thank Dr. Doug Larson for the hours of stimulating conversation and getting me psyched to learn all I could about cliff habitats. Last, but certainly not least, I would like to thank my future wife, Julia Rowland, for all of her help in the field and invaluable support through this project.

This thesis was supported by the Cratis D. Williams Graduate School, the Appalachian State University Graduate Student Association, the Appalachian State University Biology Department, and the U. S. D. A. Forest Service.

DEDICATION

I dedicate this thesis to my family, who believed in me. Words certainly do no justice in conveying how much I appreciate all of their love and support in all I have done. You would have been proud Dugan.

TABLE OF CONTENTS

	<u>PAGE</u>
List of Tables	IX
List of Figures	X
Introduction	1
Study Site	13
Materials and Methods	18
Floristic Identification	19
Statistical Analysis	23
Results	24
Discussion	46
Vascular Flora and Cliff Systems	46
Distribution of Lichen Taxa on Cliff Systems	52
Climbed vs. Unclimbed Cliff Faces	54
Literature Cited	58
Appendix A	64
Appendix B	73
Appendix C	79
Vita	81

LIST OF TABLES

	<u>PAGE</u>
1. Results of the ANOVA's with orthogonal contrasts on the first three principal components. Data analyzed are from the 1997 vegetational surveys.	24
2. Numbers of times dominant taxa were present in the twelve transects and number of times they were present with regard to position on transect across all transects.	26
3. Mean percent coverage of five vegetational morphotypes on disturbed and undisturbed cliff faces.	45
4. Results of the ANOVA on the first principal component for the comparison of climbed (disturbed) and unclimbed (undisturbed) cliff faces.	45

LIST OF FIGURES

	<u>PAGE</u>
1. Location of the Linville Gorge Wilderness Area: Burke Co., North Carolina.	14
2. Generalized geologic map of the southern Appalachian region showing the location of the Grandfather Mountain window (modified from Bryant 1970).	15
3. Geologic map of the Grandfather Mountain window (modified from Bryant 1970).	16
4. Schematic diagram depicting belt transect placement among cliff microhabitats.	20
5. Principal Components analysis of mean percent cover of eleven dominant taxa with regard to transect position across all transects.	25
6. Mean percent cover of <i>Lasalia</i> sp. with regard to transect position across all transects.	28
7. Mean percent cover of <i>Lecidea</i> sp. with regard to transect position across all transects.	28
8. Mean percent cover of <i>Pertusaria</i> sp. with regard to transect position across all transects.	30
9. Mean percent cover of <i>Lepraria</i> sp. with regard to transect position across all transects.	30
10. Mean percent cover of <i>Cladonia</i> sp. with regard to transect position across all transects.	32
11. Mean percent cover of <i>Cladina</i> sp. with regard to transect position across all transects.	32
12. Mean percent cover of <i>Dimelaena</i> sp. with regard to transect position across all transects.	34

13. Mean percent cover of <i>Mycoblastus</i> sp. with regard to transect position across all transects.	34
14. Mean percent cover of <i>Umbilicaria</i> sp. with regard to transect position across all transects.	36
15. Mean percent cover of <i>Selaginella tortipila</i> with regard to transect position across all transects.	36
16. Mean percent cover of <i>Rhododendron minus</i> with regard to transect position across all transects.	37
17. Principal Components analysis of percent cover of five vegetational morphotypes on disturbed vs. undisturbed cliff faces.	39
18. Mean percent cover of crustose lichens on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).	41
19. Mean percent cover of foliose lichens on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).	41
20. Mean percent cover of fruiticose lichens on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).	43
21. Mean percent cover of seed-bearing vascular plants on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).	43
22. Mean percent cover of seedless vascular plants on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).	44

INTRODUCTION

The topographic, climatic, and geologic inconsistencies in the southern Appalachian Mountains have led to the formation of unique and very complex vegetational communities in the region. One such community type, high elevation rock outcrops, has numerous rare species and is one of the most distinctive of any habitat in the mountains (Wiser 1994). Floral communities associated with rock outcrops are often unique in structure and physiology (Baskin and Baskin 1988). It is well known that most rock outcrops represent harsh environments with generally low nutrient availability and little to no soil accumulation (Wiser 1994). Many studies of rock outcrop vegetation have been made throughout the world and similarities exist among vegetational structure on geologically similar rock outcrops (Burbanck and Platt 1964). Although the species are different, Burbanck and Platt (1964) observe that the types of plants and the stages of succession on exposed granite and accumulated gravel at Enchanted Rock, Texas are similar to those on granitic rock outcrops of the Georgia piedmont. Burbanck and Platt term these plant communities "island communities" since each occurs on soil depressions surrounded by exposed rock. They classified these communities into four types based on maximum soil depth and type of vegetation in each community. Burbanck and Platt (1964) suggested that the four types of communities represent seral stages related to the edaphic conditions. The stages begin with a lichen - annual community and may end in

a shrub - tree community, which may represent an edaphic climax subject to periodic regression to earlier stages. The deeper the soil the more advanced the seral stage (Burbanck and Phillips 1983). Studies such as these help clarify the extremely lengthy processes involved in going from bare rock to a perennial vegetational community. The soils accumulated in these rock outcrop communities can initially be attributed to the presence of lichen taxa. Lichens can affect weathering of rock surfaces by both mechanical and chemical means thus establishing a primary soil layer in which bryophytes become established, eventually leading to the colonization of these soils by vascular plant species (Syers and Iskandar 1973). Because of these lengthy processes and the harsh conditions associated with rock outcrops it follows that taxa associated with these systems are often rare or endemic taxa that have evolved characteristic traits that allow them to live under such conditions.

To better understand the high incidence of endemism in rock outcrop plant communities of the unglaciated eastern United States, Baskin and Baskin (1988) assessed the roles of edaphic factors, gene flow, and light on these taxa. They hypothesized that a high photosynthetic photon flux density is an obligate requirement common to all the rock outcrop endemics and it is likewise an important factor restricting endemics to rock outcrops (Baskin and Baskin 1988). Their hypotheses are supported by the observations that the endemics (1) are restricted to well-lit areas of rock outcrops, (2) growth and photosynthesis is optimal in full sun, and (3) they compete poorly with plants that shade them (Baskin and Baskin 1988). It is likely that narrowly restricted endemics have refuge on unglaciated rock outcrops in the eastern United States because these are

have refuge on unglaciated rock outcrops in the eastern United States because these are the only habitats within their geographical distribution that fulfill their long term physiological requirements and are not out competed by other taxa. The rarity of these habitats explains the rarity of these taxa (Wiggs and Platt 1962). Lack of genetic variation might explain rock outcrop endemism, but Baskin and Baskin (1988) noted that most of the endemics they studied exhibit intraspecific variability in one or more of the following characteristics: morphology, physiology, breeding system, flower color, and enzyme pattern.

In addition to endemic species there are numerous boreal disjuncts associated with rock outcrops in the southern Appalachian Mountains (Walker 1987, Young 1996). Species such as *Thuja occidentalis*, *Juncus trifidus*, *Scirpus cespitosus*, and *Huperzia appalachiana* are just a few taxa found in the southern Appalachians with more northerly main ranges (Wiser 1994). These isolated communities represent glacial relicts of an alpine flora that was widespread in the southern Appalachians until 12,000 years ago. It is likely that as the region warmed, these once widespread boreal relic communities retreated to smaller, isolated pockets that now exist on rock outcrops that are largely treeless and where competition for sunlight is minimal (Ramseur 1960, Baskin and Baskin 1988, Wiser 1994).

Because of their unique flora, rock outcrop communities have received a great deal of quantitative and qualitative analyses regarding their vegetational structure (Burbanck and Platt 1964, Ashton and Webb 1977, Burbanck and Phillips 1983, Baskin

and Baskin 1988). In light of ever-increasing anthropogenic disturbance (i.e. pollution, trampling etc.) it is important that these communities are more thoroughly understood. Even less understood, but often closely related to rock outcrops, are cliff faces and their associated vegetational communities.

Until recently cliff systems were completely overlooked by ecologists because they have viewed these systems as unsafe, unimportant, or seemingly impossible to sample (Larson 1989). The earliest studies were primarily efforts describing the types of vegetation found on cliffs (Oosting and Anderson 1937, Jackson and Sheldon 1949). Oosting and Anderson (1937) described the vegetation of a barefaced cliff in western North Carolina and noted in detail the stages of vegetational and soil development from bare rock pioneers, to woody species. Twelve years later, Jackson and Sheldon (1949) conducted a study of the vegetation of magnesian limestone cliffs at Markland Grips near Sheffield, England. Their detailed study identified the relative abundance of tree and shrub species at the cliff edge, cliff top, cliff-face, and in the rock below the cliffs. Interestingly, this study may have been the first of its kind to recognize a pattern of distinct shifts in vegetation types as one samples from the cliff edge, down the cliff face, to the scree below. *Taxus bacata* dominated at all sampling sites. *Ulnus* saplings were most common near top of the cliff and *Sambucus* toward the base. In this same study cliff breakdown (recession) was correlated with the establishment of *Taxus* seedlings and their ability to extend their roots in all directions along existing cracks and bedding planes. As secondary thickening of the roots occurred, compounded by the action of

drainage water in the soft rock, the first obvious stages in the process of cliff breakdown were noted. This study pioneered the understanding of cliff face communities and patterns of organization. Subsequent studies continued cliff face investigations in light of current ecological theory, which Grime (1979) notes as relating varying amounts of stress, disturbance, and competition to the productivity, form, and developmental properties of the communities.

Culberson and Culberson (1967) provided details of habitat selection in chemically differentiated races of lichens. In the field of cliff ecology, this paper was seminal in sampling design and its advance beyond mere descriptive approaches of organisms growing on cliff faces. Using six vertical line transects composed of strips of contiguous 1 foot square blocks, 980 individuals of the *Ramalina siliquosa* complex were collected and assigned to six known chemical types represented in this species. Each of the six chemical types exhibited discrete zonation regarding their position on the cliff face. The zonation represented the differential accumulation of phenolic substances in the lichens. This is analogous to the same phenomenon that produces zonation in species of strikingly different morphology, namely, physiological differences that underlie and delimit the amplitude of ecological tolerance. In the *R. siliquosa* complex salt from the sea was the limiting factor regarding the ecological tolerance of each of the chemical races, resulting in a phenotypic expression of genetically determined physiological races. Other examples of such physiological zonation are observed in the

highly stratified species of plants and animals in the littoral communities of maritime cliffs throughout the world (Culberson and Culberson 1967).

Until the mid-1980's cliff ecology regarding vascular plant organization was largely dominated by descriptive studies. However, during this same period lichenologists were busy detailing the complexities of vertical zonation of lichens on cliff-faces throughout Europe. In 1977, James *et al.* eloquently described, in a quantitative manner, lichen communities throughout the British Isles on limestone and other basic rock cliff faces. It was noted that within a single, climatically uniform region, each particular rock type tends to support a characteristic and often remarkably uniform lichen vegetation. Cliff face community ecology dealing with higher plants was still largely descriptive, with some notable exceptions. Walker's (1987) genetic analysis of disjunct populations of *Thuja occidentalis* described boreal communities at the genetic level largely restricted to limestone outcrops and cliff faces in the southeastern United States. Then in 1989 the scientific communities' view of the importance of cliff-face ecosystems relative to vascular plants underwent a major transition.

Larson *et al.* (1989) initially characterized the organization of the vegetation of the cliff-face and plateau communities of the Niagara Escarpment in Ontario, Canada. They found marked changes in soil depth, available photosynthetically active radiation, species richness, local diversity, and life form characteristics across the gradient from plateau to cliff-face. This led to the observation that while resource pool size might influence species distribution on the plateau, other factors such as competitive

displacement and disturbance seem to regulate the abundance of species on the cliff-face (Larson *et al.* 1989). Larson and his colleagues have formed a cliff ecology research group at the University of Guelph in Ontario, Canada. Recent work by the group includes studies looking at rooting characteristics of plants on cliff faces. Results of this study show that the majority of plants grow in rock without soil or in very small soil pockets and that rooting is shallow, penetrating solid rock to an average depth of 9 cm (Matthes-Sears and Larson 1995). This same study found that roots are restricted almost exclusively to rock fissures and that root competition is largely absent when plants grow in rock.

Another significant study by the group includes an investigation of the degree to which the productivity of the slow-growing *Thuja occidentalis* on limestone cliff faces is constrained by the availability of water and nutrients. Prevailing ecological theory predicts that plants adapted to stressful habitats respond relatively little to pulses of resources and that their responses tend to be physiological rather than morphological (Grime 1979). To increase the probability of detecting such responses, Matthes-Sears *et al.* (1995), assessed productivity on multiple scales, including short-term physiological responses (light-saturated photosynthetic rate) and growth responses that integrate small physiological responses over intermediate and longer time intervals (shoot elongation, leaf area growth, morphological changes, and biomass allocation). However, even with strict attention to detail and scale, they realized that additional unstudied factors were equally as important to the cliff-face habitat. Matthes-Sears *et al.* (1995) proposed that a

source of the physiological variation and the varying degree of nutrient constraint found in *Thuja* on cliff faces is in the quality of the microsite in which the plants are growing. Factors that all contribute to microsite quality and that are highly variable on a small scale include; size and shape of the ledge or crevice the plant is occupying; amount and quality of accessible soil; type and weathering of the surrounding rock; rooting density; and amount of surrounding vegetation (Matthes-Sears *et al.* 1995). This important observation demonstrated the multitude of factors that must be considered in order to understand this poorly studied community.

It should also be noted that in the course of their ground-breaking cliff-face research, Larson and Kelly (1991) proposed that cliff-face communities on the Niagara escarpment are the oldest, most extensive old-growth forest east of the Rocky Mountains. The age of certain individuals in this forest have been estimated at 1032 years making these some of the slowest growing plants on earth. Larson and Kelly (1991) speculated that this ancient forest has been overlooked and undisturbed because it is largely inaccessible and the ancient trees are grotesquely deformed and stunted on cliff faces, not representative of what most associate with old-age individuals. The implications of such a significant discovery are far-reaching. It is widely known that the large majority of old-growth forest in the northern hemisphere have been cut or have been heavily disturbed by humans. They proposed that the existence of an undisturbed, intact old-growth forest system can be used to study the processes that control the assembly and maintenance of forest ecosystems in general. They also noted the need for

more dendrochronological reconstruction of past climatic conditions for the northern hemisphere. The ancient forests they have discovered could lead to the development of a chronology that extends back 1500 years or more.

In light of these recent discoveries regarding cliff-face communities there is an apparent need for better understanding of cliff-face communities worldwide. Recently, activities such as rock climbing, rappelling, and backpacking have seen unparalleled increases in the numbers of peoples participating. Obviously this means that many areas that have historically seen little to no anthropogenic disturbance, such as cliff faces and their associated rock outcrops, may be jeopardized before the scientific community can understand better the unique assemblages of organisms that constitute these fragile communities. There has been an increased awareness regarding the impacts of trampling, rock climbing, and rappelling in the scientific community and assessments are beginning (Spear and Schiffman 1979, Pyle 1988, Larson 1989, Frost 1992, Taylor *et al.* 1993, Parikesit *et al.* 1995, Nuzzo 1995, 1996, Kelly and Larson 1997). Adding to the urgency of our increased understanding of cliff systems, Larson *et al.* (1998) observed that cliffs in the temperate zone worldwide have been overlooked as sites that support ancient woodlands and that the often rare or endemic plant and animal populations that co-occur with the trees on cliff faces are an indication that the cliffs support a complete and ancient woodland.

Historically, vegetational community studies in general have not synthesized the lichen - vascular flora association (Jackson and Sheldon 1949, Burbanck and Platt 1964,

Jarvis 1974, Baskin and Baskin 1988, Larson *et al.* 1989, Ogle 1989, Wiser 1994, Lerdolf and McDaniel 1998, Fletcher and Vankatt 1998). Looman (1964) notes that whereas it is possible to make a releve of vascular vegetation without collecting a single plant, cryptogams in general must always be collected and identified in the laboratory, often requiring microscopic examination. But, if time and effort permit, lichens are important as ecological indicators and in the classification of vascular vegetation. Lichen communities may be used to distinguish smaller units within the association and in the correlation of successional phases (Looman 1964). Rock outcrop and cliff systems have been described as cyclic systems (Burbanck and Phillips 1983). By including lichens in the vegetational analysis one may better understand the position of stochastic stages represented by vegetational communities on rock outcrops or cliff faces in light of natural disturbance and harsh conditions that are ever present in these cycles (Looman 1964, Ashton and Webb 1977, Maycock and Fahselt 1992).

The present study was designed to describe plant and lichen taxa in cliff-face communities and to compare these communities to plant and lichen communities on the rock outcrops above cliff faces in Linville Gorge. The Cherokee name for the Linville River was Eeseeoh, "a river of many cliffs" (USDA 1994). This term aptly describes the Linville Gorge Wilderness Area, as there are numerous cliffs ranging in height from 15 to 500 feet on both sides of the river. The landscape is extremely rugged, topographically complex, and generally has particularly infertile soils for the southern Appalachian region (Newell and Peet 1997). Linville Gorge is home to such rare endemics as *Liatris helleri*

and *Hudsonia montana*. Only six populations of *H. montana* are known to exist, and all but two of the populations occur at elevations ranging from 3,000 - 4,000 ft on rock outcrops of the walls of Linville Gorge facing southwest (Frost 1993). It is well known that Linville Gorge is one of the most popular climbing and hiking destinations in North Carolina (Kelley 1988). The fragile vegetation associated with rock outcrops and cliff faces is little understood in the Linville Gorge Wilderness, but with the ever-increasing use of this wild area by the public it is urgent that we understand these fragile systems so others may enjoy these wild lands as we do today. It is estimated that in 1990, 1991, and 1992, camping and trampling eliminated 70% the *H. montana* population that exists on Tablerock in the Linville Gorge Wilderness (Frost 1993).

Recently Newell and Peet (1997) characterized the vegetation of Linville Gorge Wilderness Area. They described 28 community types spanning eight vegetation classes within Linville Gorge. Their characterizations were based partly on the presence of vascular plant species, which on rock outcrops accounted for 8% of mapped vegetation (Newell and Peet 1997). They noted the close association between the rock outcrops and the steep cliffs but did not sample cliff faces citing the seemingly sparse vegetation associated with cliff faces. This may be true when considering only vascular vegetation but they did not include lichen taxa in their descriptions.

The first objective of this study was to determine if there are any significant differences between rock outcrops (which will be referred to as cliff edges from this point forward) and cliff faces with respect to plant and lichen community structure. The second

objective was to determine if plant and lichen communities were homogenous on cliff faces or if they varied along the cliff face.

The final objective of this study was to determine if heavily used climbing sites have altered vegetational structure. This question was addressed by comparing plant and lichen communities on heavily climbed cliff faces to cliff faces which receive (little or) no climbing pressure.

STUDY SITE

Linville Gorge is located in Burke County, North Carolina, within the Blue Ridge Province of northwestern North Carolina (Figure 1). The Gorge is the result of erosion by the Linville River which cuts perpendicularly across the Linville Fault forming a spectacular gorge 1,500 feet deep with vertical rock walls up to 500 feet in height (Boyer 1978).

Geologically, Linville Gorge is associated with the Grandfather Mountain Window (GMW) (Figures 2 and 3) which consists of ancient, layered, migmatic gneiss and metamorphosed diorite and gabbro that are cut by granitic rocks of Precambrian age (Boyer 1978, Bryant and Reed 1970). Overlying these rocks is the Grandfather Mountain Formation, a sequence of interlensing arkose, siltstone, shale, and volcanic rocks of late Precambrian age (Bryant and Reed 1970). Exposed formations in the GMW are Cambrian quartzite and phyllite of the Chilhowee group (Bryant and Reed 1970). It is these rocks that form the Tablerock thrust sheet that includes all of Linville Gorge. The Tablerock thrust sheet is a tectonic slice between the Blue Ridge thrust sheet and autochthonous rocks in the southwestern part of the GMW. The gorge is composed of shady dolomite and several thousand feet of quartzite, arkosic quartzite, and phyllite of the underlying Chilhowee group of early Cambrian age (Bryant 1970). Precambrian gneiss makes up the lower two thirds of Linville Gorge (Newell and Peet 1997). The

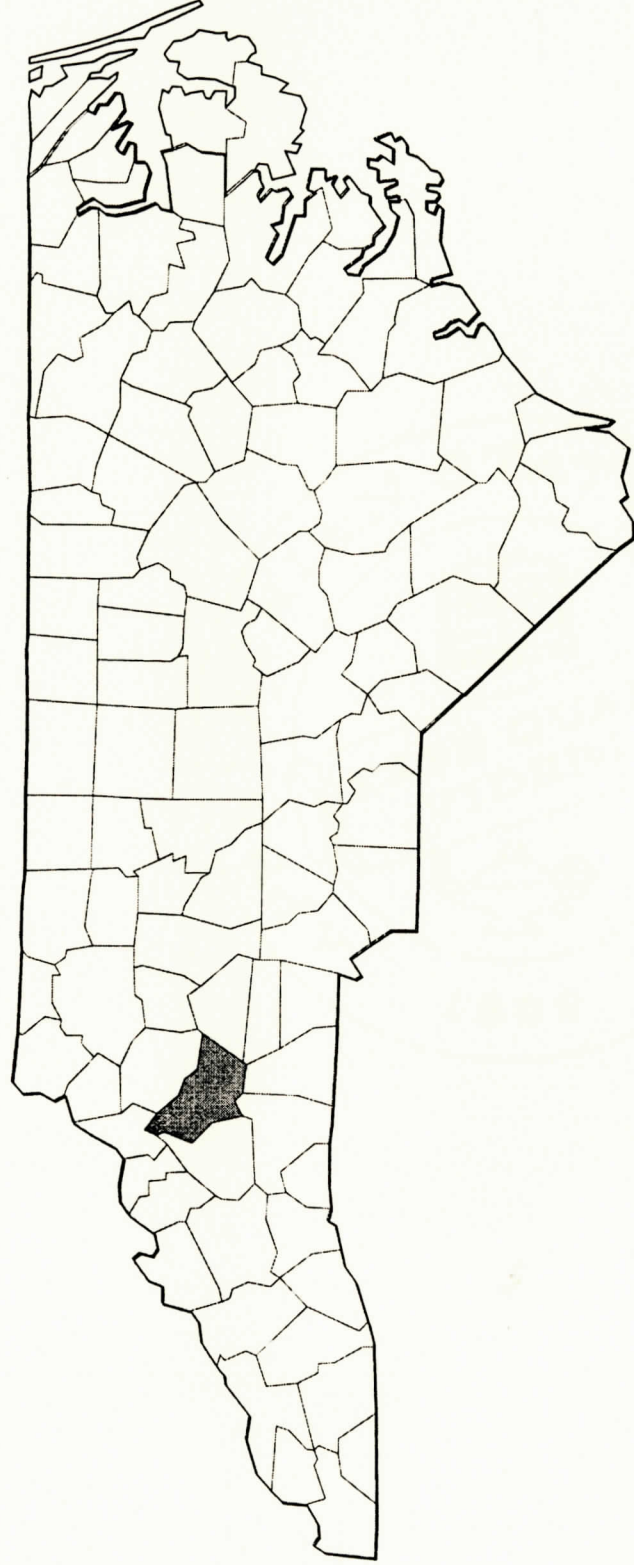


FIGURE 1. Location of Linville Gorge Wilderness Area: Burke Co., North Carolina

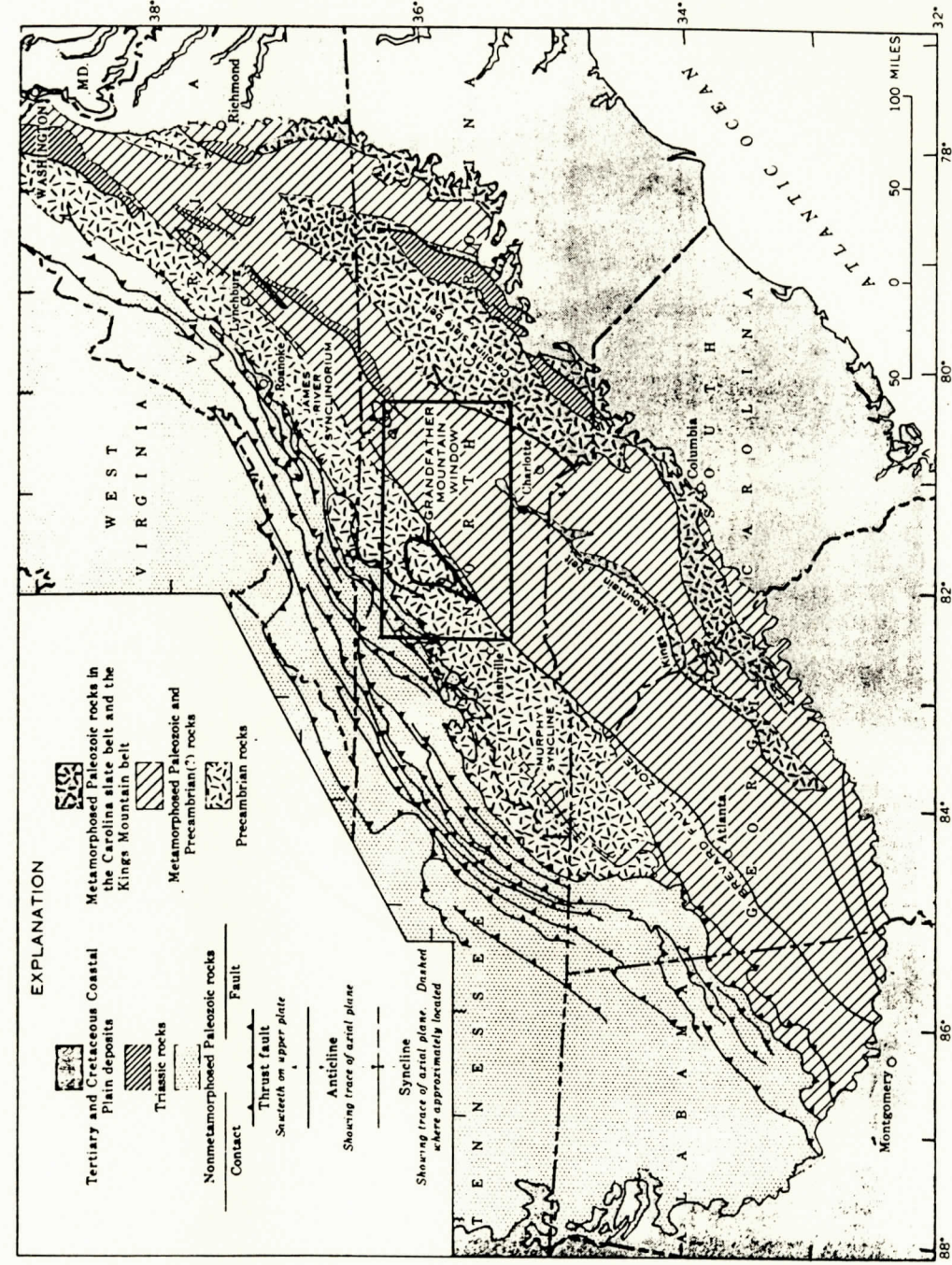


FIGURE 2. Generalized geologic map of the southern Appalachian region showing the location of the Grandfather Mountain window (modified from Bryant 1970).

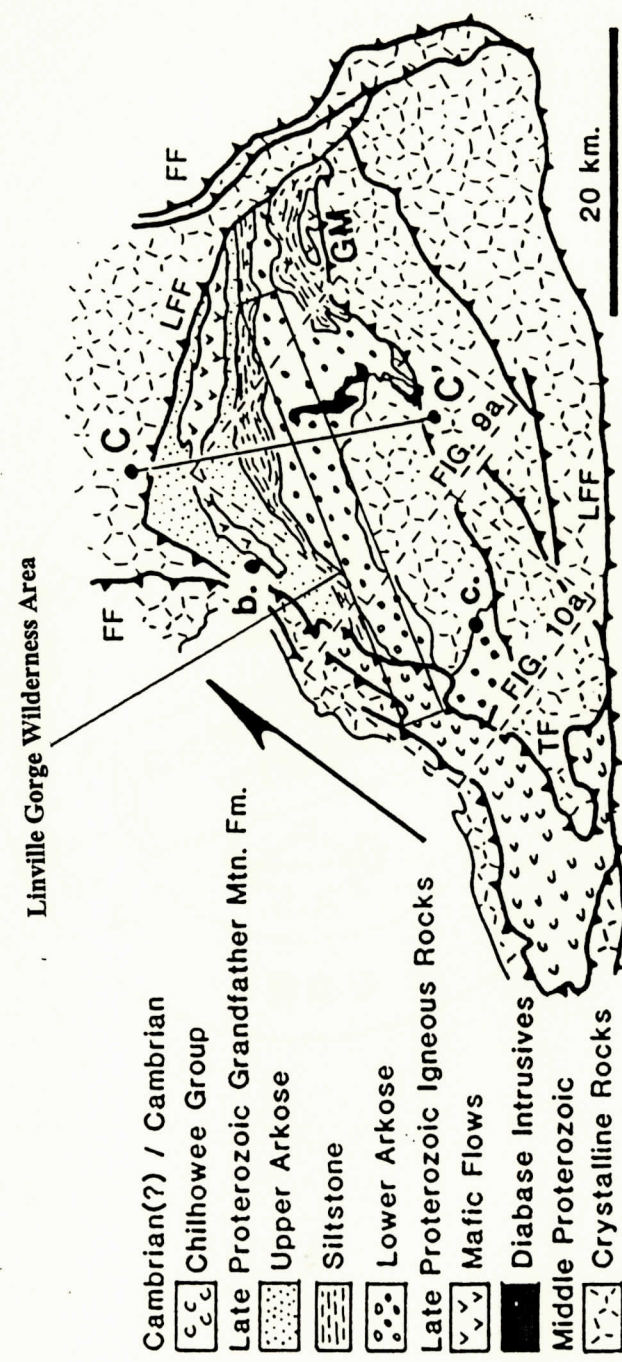


FIGURE 3. Geologic map of the Grandfather Mountain window (modified from Bryant 1970).

prominent cliffs and rock massifs that are found within the Gorge are composed of arkosic quartzite and thin bands of phyllite.

No long term climatological data are available specifically for Linville Gorge but long term data are available for surrounding weather stations. Mean annual temperatures and mean annual precipitation between the years 1931 and 1994 have been compiled using data from the following North Carolina weather stations: Boone, Blowing Rock, Grandfather Mnt., Banner Elk, to the north of Linville Gorge, Morganton and Ashford to the south of Linville Gorge. Mean annual temperature for the region is 13 °C. The hottest period is June through August, with an average temperature of 20 °C and the coolest period is February, with an average temperature of 5°C. Precipitation in the region averages 1200 to 1650 mm annually, peaking in early summer (NOAA, 1992).

MATERIALS AND METHODS

The initial sampling and data collection were conducted from April 1997 through November 1997. Sampling was conducted throughout the entire growing season to obtain the most complete floristic survey possible. Sampling and data collection on heavily climbed cliffs was conducted over a period of three days, May 21-23, 1998. Sampling methodology was modified from that of Larson and Kelly (1991).

Sampling Design

Twelve sites (transects) spread over a distance of 10 km and representing a range of aspects were selected throughout Linville Gorge based on two criteria: (1) the presence of a distinct cliff-face and (2) the presence of a mature woodland at the cliff top. All transects were randomly chosen (random numbers table applied to a grid laid on a topographic map (USDA 1994) of the study area). It should be noted that study sites were chosen without regard to surrounding forest or vegetative types and the transects ranged from disturbed to undisturbed. Once the study sites were selected a complete floristic survey was conducted. The survey was performed on cliff face (cliff face microhabitat) and rock outcrops (cliff-edge microhabitat), up to the transition into Thermic-Oak-Pine Forests as described by Newell and Peet (1997). Distinction among the two microhabitats (cliff-face and edge) was based on an abrupt change in slope, from "walkable" or requiring two points of contact (*i.e.*, both feet) on the substrate surface for

mobility (slope < *ca.* 50 degrees), to "non-walkable" or requiring three or more points of contact (*i.e.*, both feet and at least one hand) on the substrate surface (slope > *ca.* 50 degrees) (Young 1996). Each study site was established and sampled by setting up single line transects (10mm static rope) that extended from the forest edge, through the rock outcrop on top and extending down the length of the cliff face. Using the absolute cliff edge as a center point and then measuring away from this point, four 1 m² plots (A, B, C, D) were placed one meter from either direction of the center point. All plots were thereafter placed every 3 meters along the length of each transect (Figure 4).

The line used to establish each transect was also used as a rappel and/or ascent line. Aid climbing and standard rappelling gear used in conjunction with the transect line and a back-up line (10mm static rope, safety line) with a belayer at the top allowed safe access to the cliff face so that sampling could be conducted.

To determine if climbing disturbance had an impact on plant and lichen communities, disturbed and undisturbed cliff faces were compared. Three of eleven undisturbed transects sampled in 1997 were selected at random. The three disturbed transects were selected by the presence of top rope anchors at the top of cliff faces.

Floristic Identification

All vascular and non-vascular plants in each plot were identified to species level and percent cover was estimated visually for each species. The non-vascular taxa that could not be identified in our labs were sent to the University of Tennessee Bryological Herbarium and identified in the lab of Dr. Ken McFarland. All lichen taxa in each plot

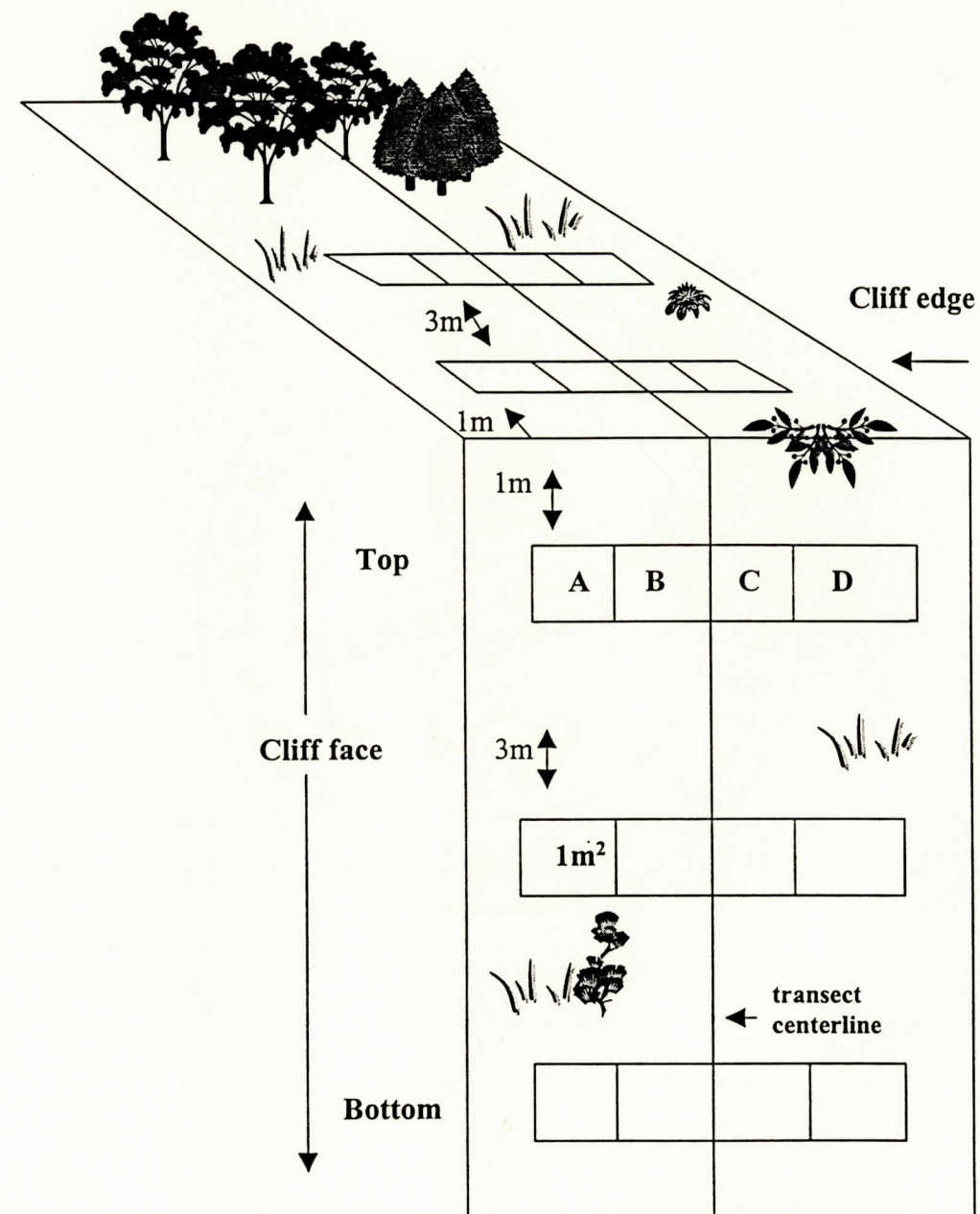


FIGURE 4. Schematic diagram depicting belt transect placement among cliff microhabitats.

were identified to genus and percent cover was visually estimated for each genus. Any collected specimens (plant and lichen taxa) were deposited in the herbarium of the Biology Department at Appalachian State University (BOON).

Lichens were collected by either gently removing them from the substrate or, if tightly appressed, a chisel was used to remove the lichen from the rock. Upon removal all lichens were placed in small zip lock bags and labeled with the location of collection.

All collected specimens of lichens were first sorted based on three common morphological types: crustose, fruticose, and foliose. To determine the genus of each specimen, apothecial characters, ascospore morphology, and ascospore numbers were determined by preparing thin sections (cut with a razor blade and mashed) of individual lichen apothecia, which were then mounted on slides. The mashed sections were mounted in H₂O or 3% Potassium Hydroxide (KOH). One percent Phloxine Red was often added to the slide mount to enhance the visible characters of the spores when viewed under a light microscope.

Color differences in lichen thalli are important for determining genus and species of lichens, as in the separation of *Parmeliopsis ambigua* (thallus yellow, containing usnic acid) and *P. hyperopta* (thallus gray, containing atranorin) (Hale 1983). Most lichen substances are colorless and more sensitive techniques must be employed for substance detection.

Lichens are unique in their chemical compositions and of the thousands of lichens tested chemically over the last one hundred years all express constant chemical

composition regardless of substrate (i.e. rock, wood, soil) (Hale 1983). In the 1860's, Nylander used the first practical method of identifying colorless compounds by simply applying a drop of potassium hydroxide (K test) or calcium hypochlorite (C test) on lichen thalli or medulla to induce color changes (Hale 1983). This same technique was applied to collected specimens in this study to aid in confirmation of identification of lichens at the genus level. Color change is often rapid and must be observed as soon as possible.

A positive reaction with the KOH test results in formation of salts with a red, yellow, or dark red to violet color, while a negative reaction results in a dingy color response (DePriest 1983). C tests are often performed with household bleach. A positive reaction is noted when there is a slow color change from translucent to a pink or red color. This test should be used with caution as excess calcium hypochlorite destroys the color change (DePriest 1983). K and C reagents are also combined in the KC test in which, immediately following the application of potassium hydroxide, calcium hypochlorite is applied and color change to a rose or red color is noted as a positive change. When performing any chemical or morphological examinations lichen identification guides were a constant point of reference in identifying all lichens to the genus level (Degelius 1941; Dobson 1979; Hale 1983; DePriest 1983; Vitt, Marsh, and Bovey 1988; Hale and Cole 1988; McCune and Goward 1995). Any crustose lichen that could not be identified in our lab was identified by Drs. Chicita and William Culberson

at Duke University or sent to Dr. Richard Harris at the New York Botanical Gardens where specimens were analyzed using standard thin layer chromatographic methods.

Statistical Analysis

A Principle Components Analysis (PCA) in conjunction with ANOVA with orthogonal contrasts (SAS Inst. 1990) was conducted to test the null hypothesis that there was no significant difference between cliff-face plant and lichen community structure and cliff-edge plant and lichen community structure. PC analysis first determined the principal components and then ANOVA with orthogonal contrasts were run on each principal component comparing cliff-edge versus cliff-face and cliff-face top versus cliff-face bottom. The analysis was run on arc-sine transformed percent coverage of eleven dominant taxa. Taxa were considered dominant if they were present in at least twelve out of forty-eight plots. One hundred forty four total plots were analyzed; 48 cliff-edge plots; 48 cliff-face top plots, and 48 cliff-face bottom plots (Figure 4).

PCA with ANOVA was used to test the null hypothesis that there was no significant difference in plant and lichen community structure on heavily-climbed cliff faces compared to unclimbed cliff faces. For this analysis, all taxa were sorted into five morphological classes: crustose lichens, foliose lichens, fruiticose lichens, seedless vascular plants, and seed-bearing vascular plants. Percent cover of the five morphological classes was recorded and arc-sine transformed for analysis. A total of 96 plots were analyzed; 48 plots on heavily-climbed cliff faces and 48 plots on unclimbed cliff faces.

RESULTS

Statistical Analysis

Significant separation of cliff-edge and cliff-face communities were observed on PC I and PC II (Figure 5, Table 1). When the Principal Components were analyzed with ANOVA with orthogonal contrasts the first principal component showed significant differences between cliff-edge and cliff-face ($P = 0.0010$, first contrast) and cliff-face top vs. cliff-face bottom ($P = 0.0003$, second contrast). The second principal component showed a significant difference between cliff-edge and cliff-face ($P = 0.0035$) but no significant difference between cliff-face top and cliff-face bottom. Neither of the contrasts were significant for the third Principal Component. Fifty-five percent of the variation was explained with the first three principal components.

Table 1. Results of the ANOVA's with orthogonal contrasts on the first three principal components. Data analyzed are from the 1997 vegetational sampling.

Principal Component 1	F	P
cliff ledge vs. cliff face	11.52	0.0010
cliff face top vs. cliff face bottom	19.04	0.003

Principal Component 2	F	P
cliff ledge vs. cliff face	13.92	0.0035
cliff face top vs. cliff face bottom	0.11	0.9345

Principal Component 3	F	P
cliff ledge vs. cliff face	0.14	0.7579
cliff face top vs. cliff face bottom	0.01	0.5331

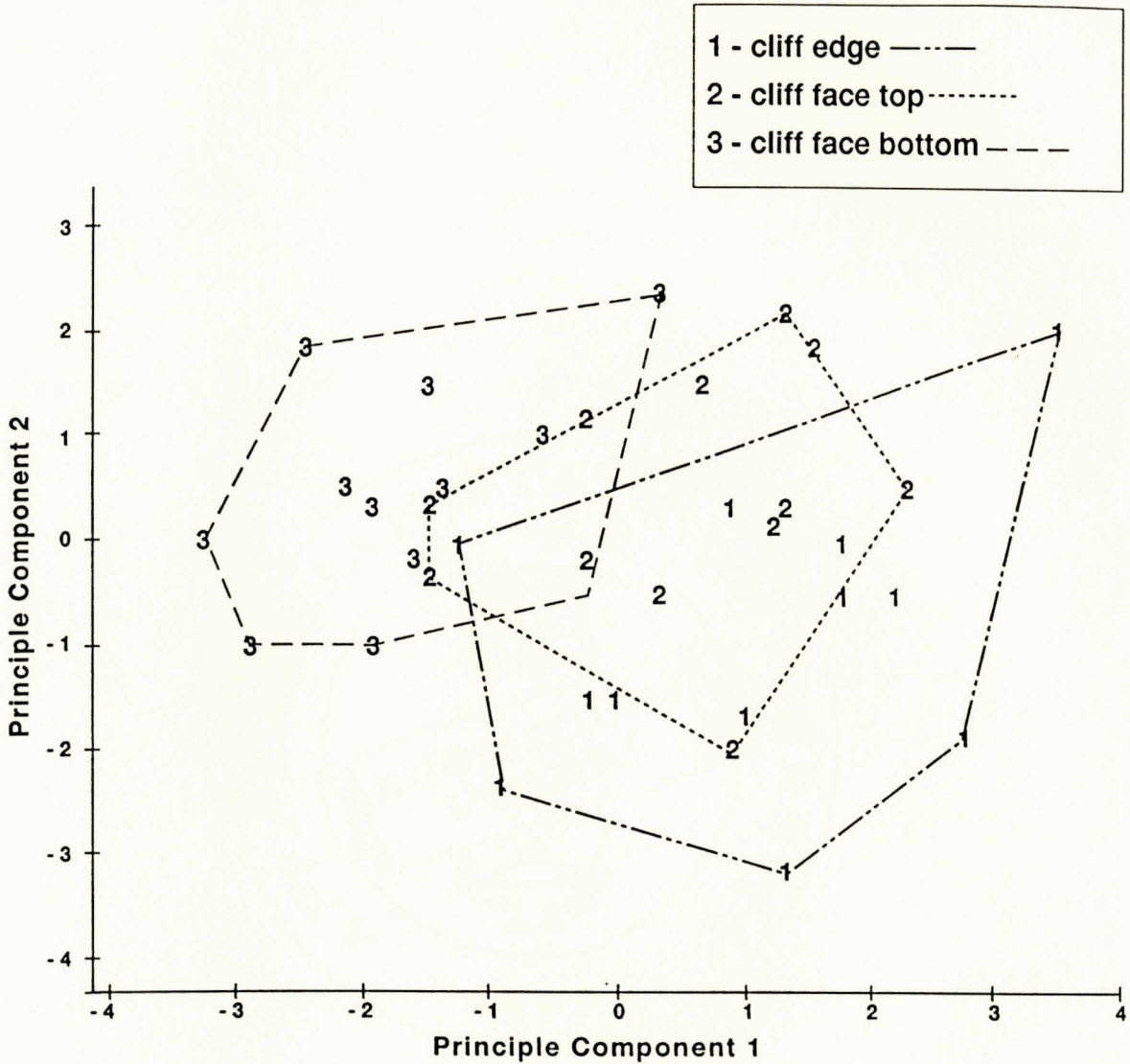


FIGURE 5. Principal Components analysis of mean percent cover of eleven dominant taxa with regard to transect position across all transects.

To see which of the eleven dominant taxa (Table 2) used in the Principal Components analysis contributed to the differences among the communities, I plotted the mean percent cover, plus or minus one standard deviation of each taxa for the cliff-edge, cliff-face top, and cliff-face bottom communities. Data are means from the twelve transects sampled in 1997. These histograms revealed that many taxa differed in their relative abundance across these habitats (Figures 6-16). Taxa such as *Lasalia* sp., *Pertusaria* sp., *Lecidea* sp., and *Lepraria* sp. had higher percent coverage at the bottom of the cliff-face. Taxa such as *Dimelaena* sp. and *Mycoblastus* sp. showed higher percent coverage on the cliff-edge. Still other taxa were most abundant at the top of the cliff-face. Certain taxa (*Cladonia* sp., *Rhododendron minus*, *Umbilicaria* sp., *Selaginella tortipila*) were equally abundant on the cliff-edge or cliff-face top, but showed higher percent coverage at these positions than at cliff-face bottom.

Table 2. Numbers of times the dominant taxa were present in the twelve transects and number of times they were present with regard to position on transect across all transects.

Dominant Taxa	Presence/12 Transects	Cliff Edge Presence/48 Plots	Cliff Face Top Presence/48 Plots	Cliff Face Bottom Presence/48 Plots
<i>Lasalia</i> sp.	9	5	13	12
<i>Lecidea</i> sp.	9	9	14	35
<i>Pertusaria</i> sp.	11	0	8	16
<i>Lepraria</i> sp.	12	0	19	32
<i>Cladonia</i> sp.	9	10	17	5
<i>Cladina</i> sp.	10	15	20	3
<i>Dimelaena</i> sp.	10	25	6	2
<i>Mycoblastus</i> sp.	11	19	12	5
<i>Umbilicaria</i> sp.	11	30	27	20
<i>S. tortipila</i>	12	20	35	5
<i>R. minus</i>	11	15	13	11

FIGURE 6. Mean percent cover of *Lasalia* sp. with regard to transect position across all transects.

FIGURE 7. Mean percent cover of *Lecidea* sp. with regard to transect position across all transects.

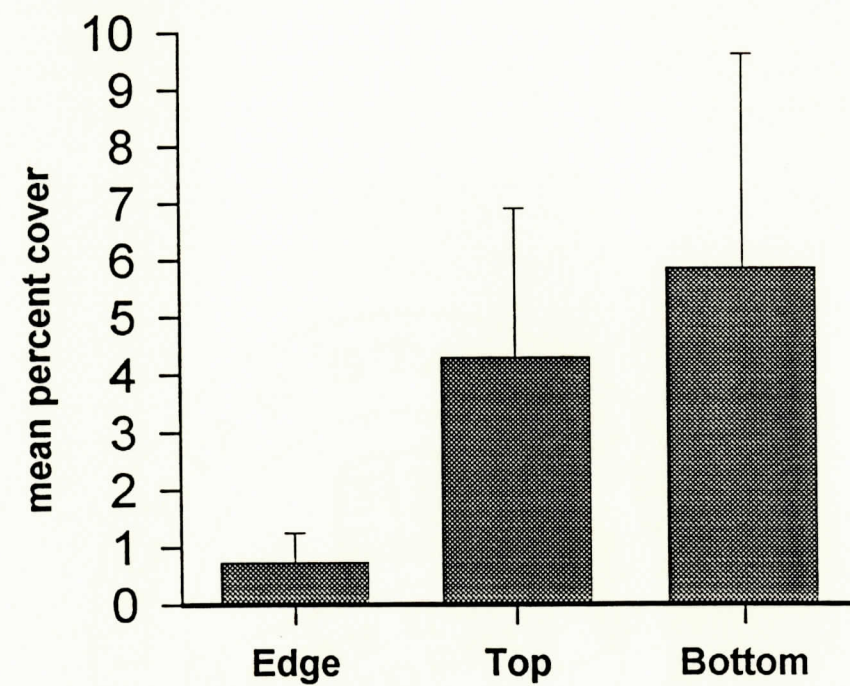
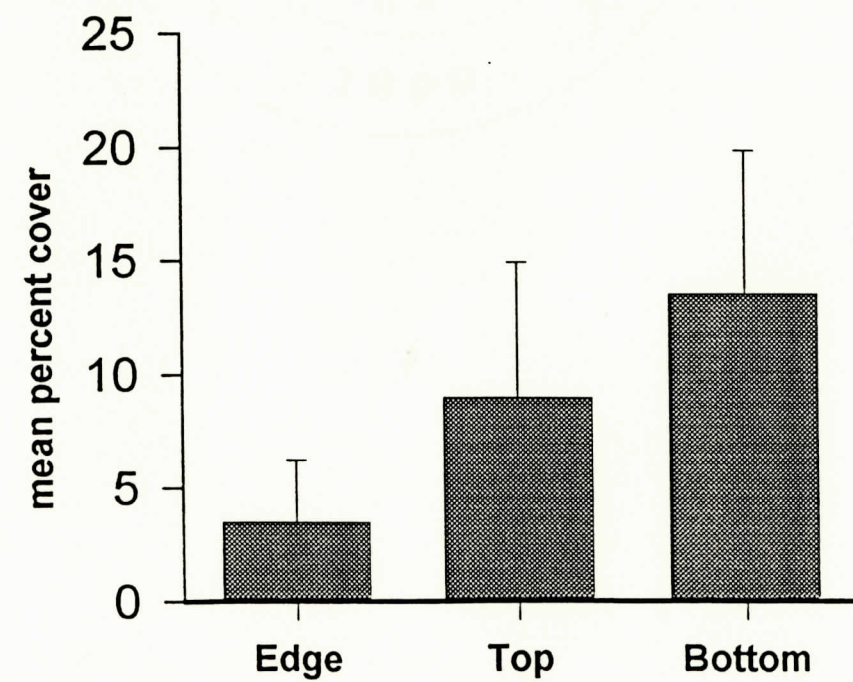
Figure 6. *Lasalia* sp.Figure 7. *Lecidia* sp.FIGURE 8. Mean percent cover of *Pertusaria* sp. with regard to transect position across all transects.FIGURE 9. Mean percent cover of *Lepraria* sp. with regard to transect position across all transects.

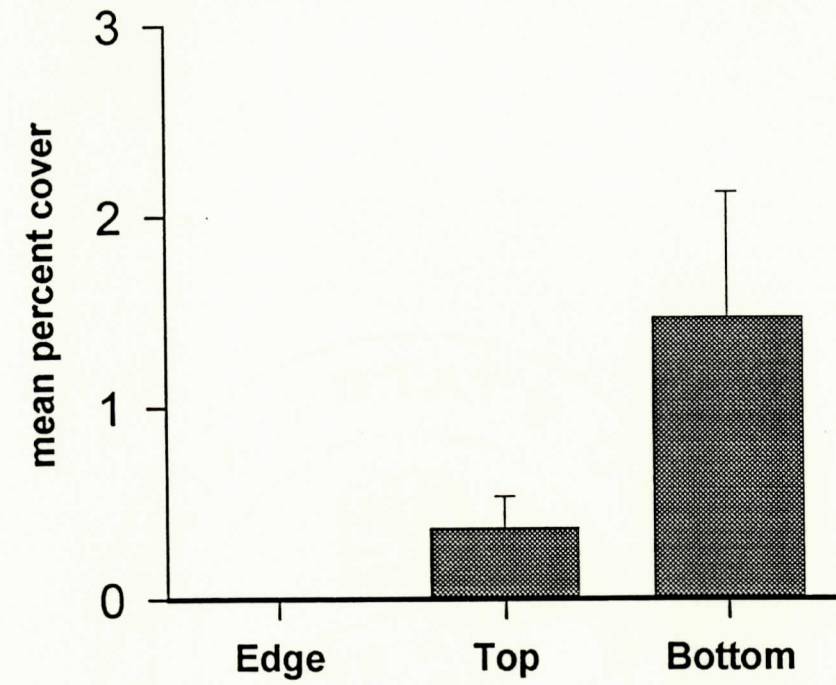
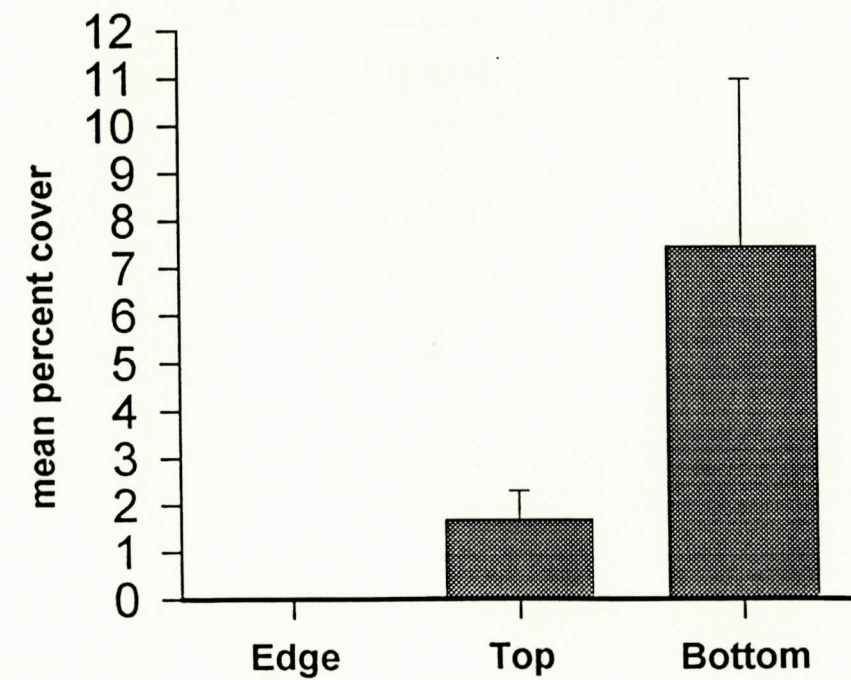
Figure 8. *Pertusaria* sp.Figure 9. *Lepraria* sp.FIGURE 10. Mean percent cover of *Cladonia* sp. with regard to transect position across all transects.FIGURE 11. Mean percent cover of *Cladina* sp. with regard to transect position across all transects.

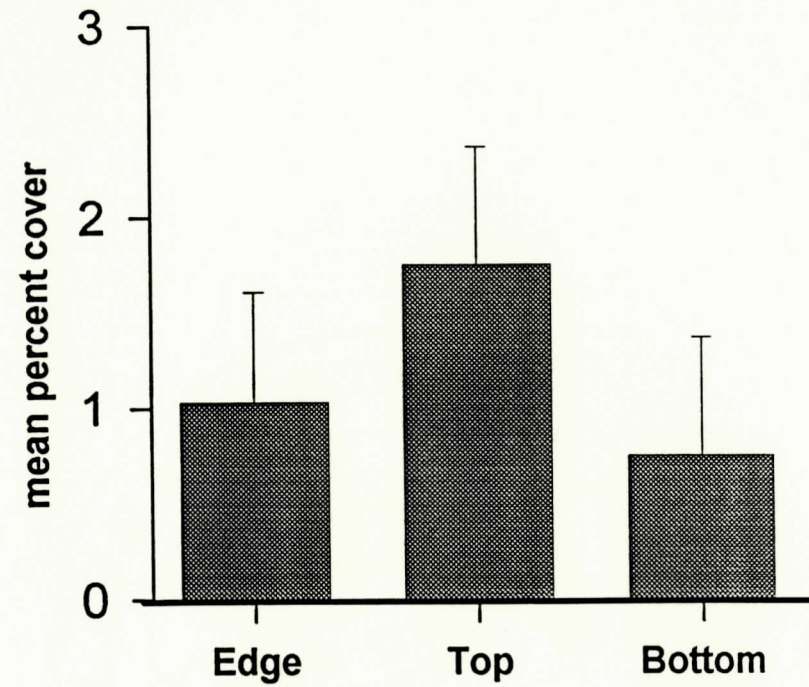
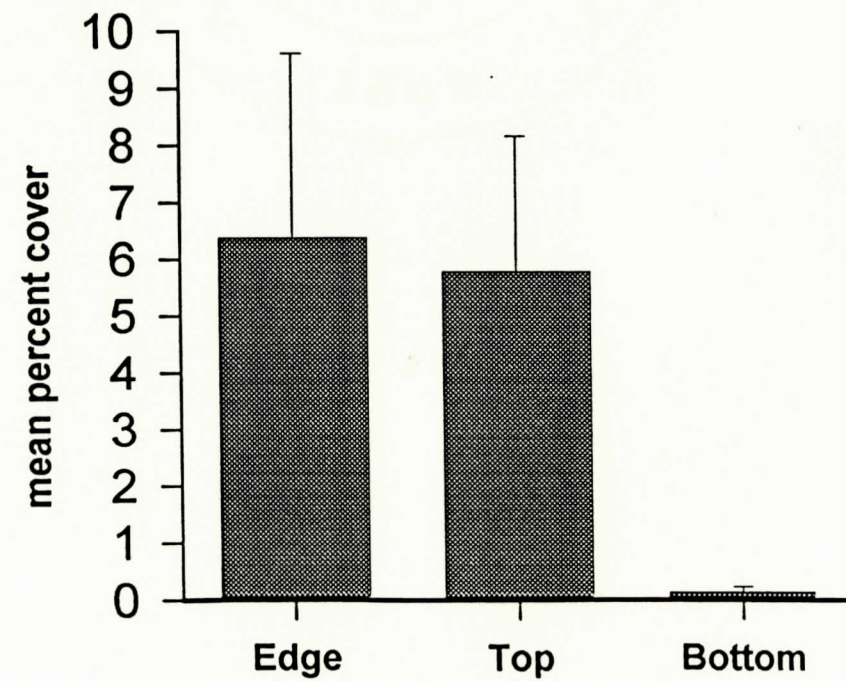
Figure 10. *Cladonia* sp.Figure 11. *Cladina* sp.FIGURE 12. Mean percent cover of *Dimelaena* sp. with regard to transect position across all transects.FIGURE 13. Mean percent cover of *Mycoblastus* sp. with regard to transect position across all transects.

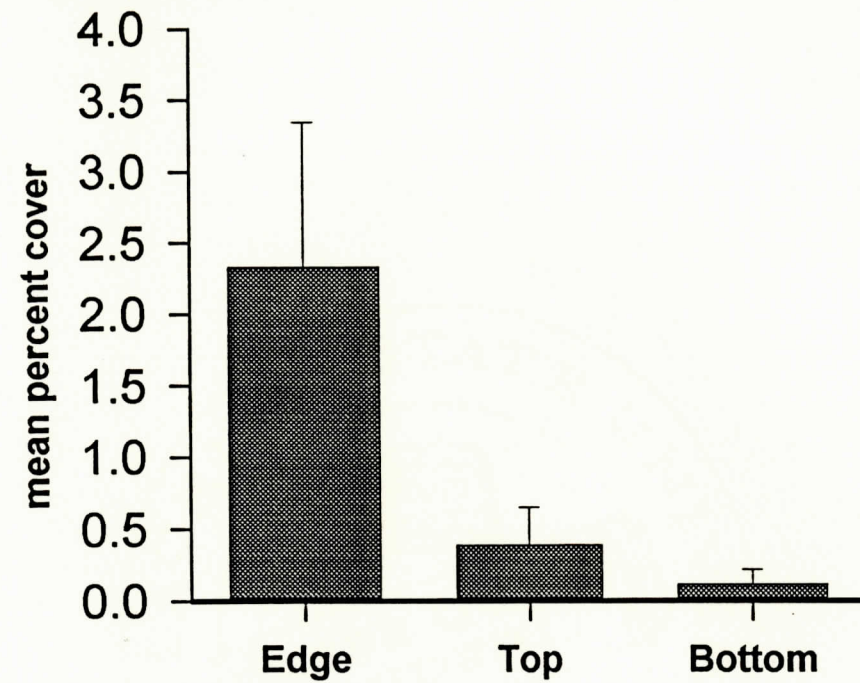
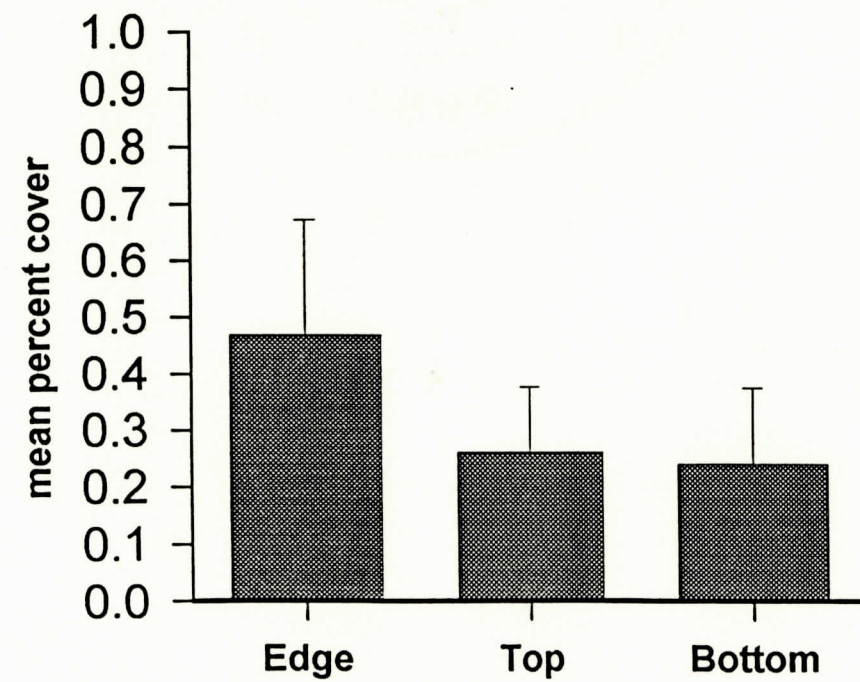
Figure 12. *Dimelaena* sp.Figure 13. *Mycoblastus* sp.FIGURE 14. Mean percent cover of *Umbilicaria* sp. with regard to transect position across all transects.FIGURE 15. Mean percent cover of *Selaginella tortipila* with regard to transect position across all transects.

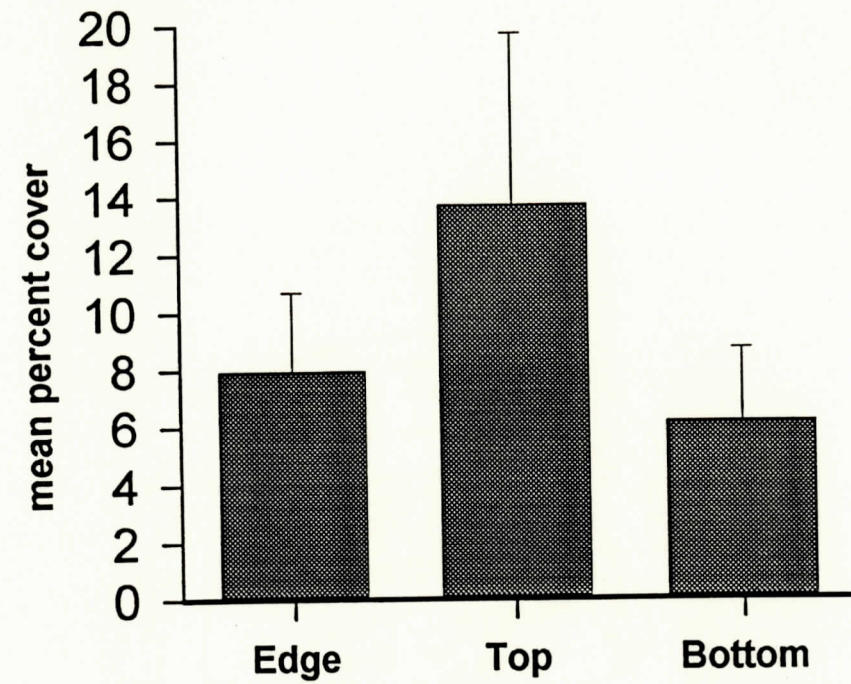
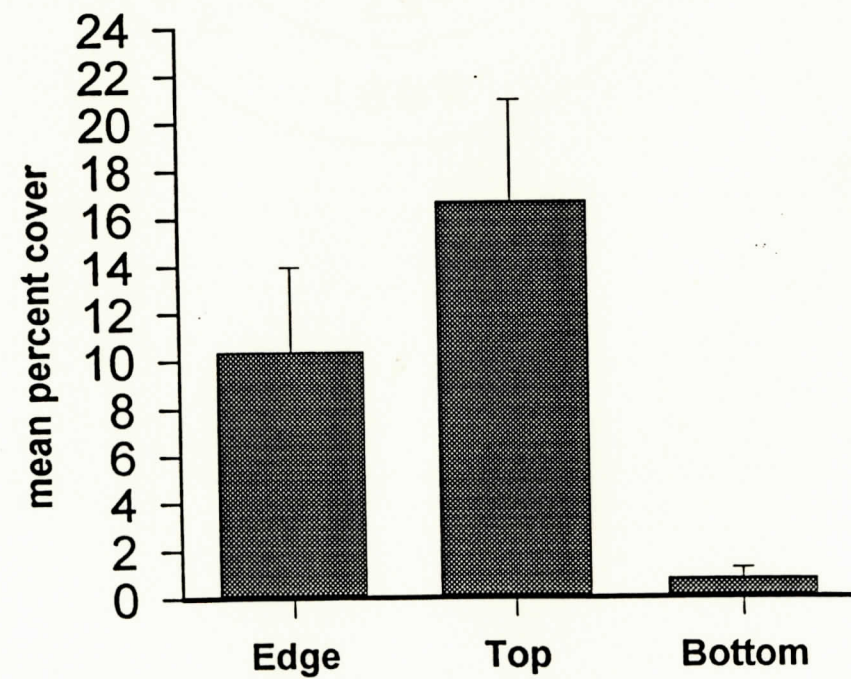
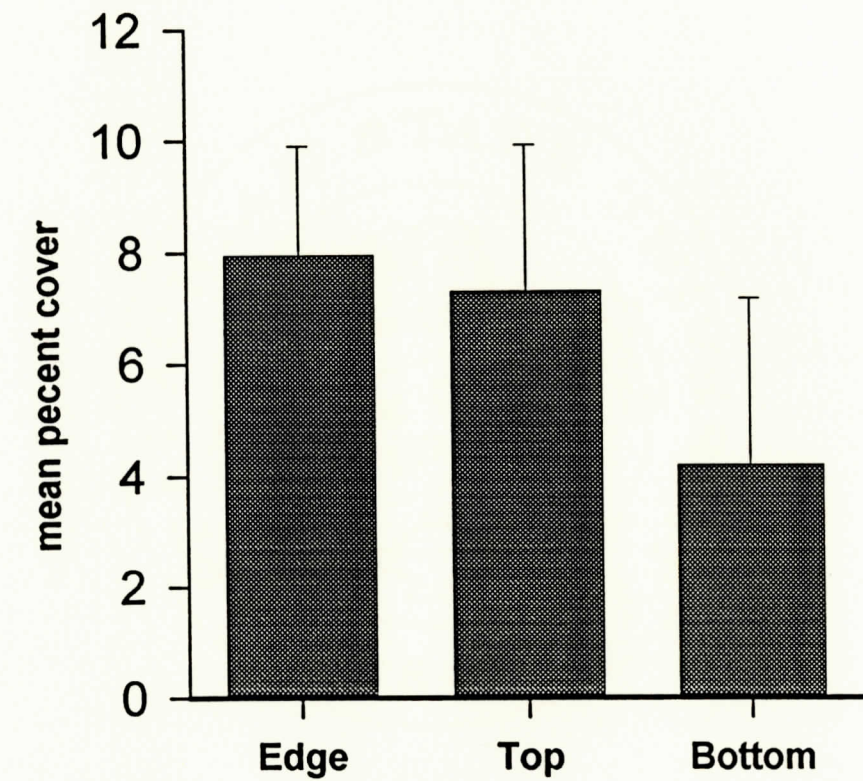
Figure 14. *Umbilicaria* sp.Figure 15. *Selaginella tortipila*Figure 16. *Rhododendron minus*FIGURE 16. Mean percent cover of *Rhododendron minus* with regard to transect position across all transects.

Table 3 shows mean percent cover of the different morphotypes in the two habitats. The Principal Component analysis revealed that climbed (disturbed) and unclimbed (undisturbed) cliff faces were significantly different from one another with respect to the percent cover of the morphological classes (Figure 17, Table 4). The first principal component explained 67% of the variation. Together, the first three principal components explained 99% of the variation. Foliose and fruiticose lichens, and seedless vascular plants were more abundant on undisturbed cliff faces (Figures 19, 20, 22). Crustose lichens were the dominant taxon on disturbed cliffs (Figure 18). There was no significant difference between cliff types for seed-bearing vascular plants (Figure 21, Table 3).

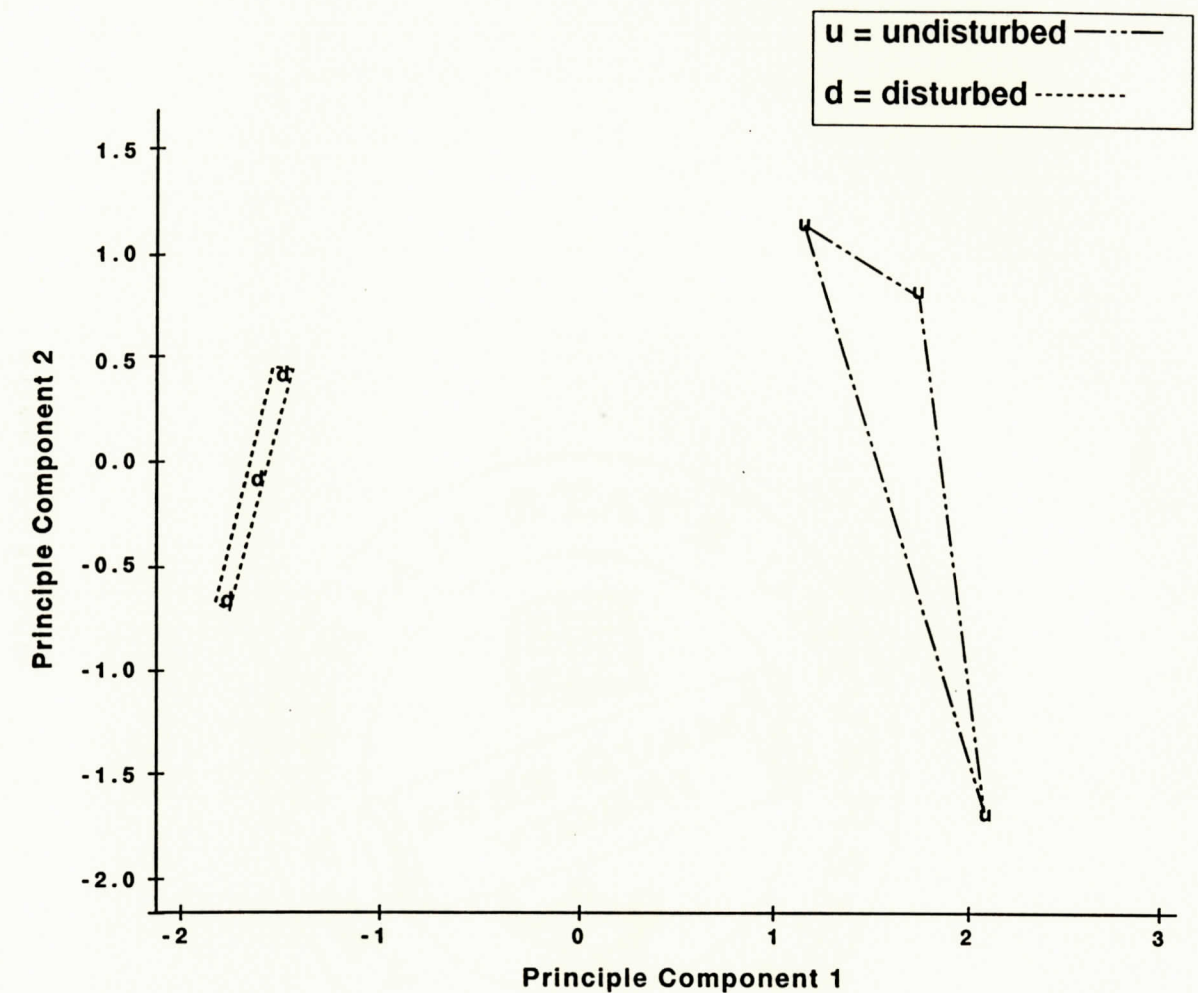


FIGURE 17. Principal Components analysis of percent cover of five vegetational morphotypes on disturbed vs. undisturbed cliff faces.

FIGURE 18. Mean percent cover of crustose lichens on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).

Figure 18. crustose lichen

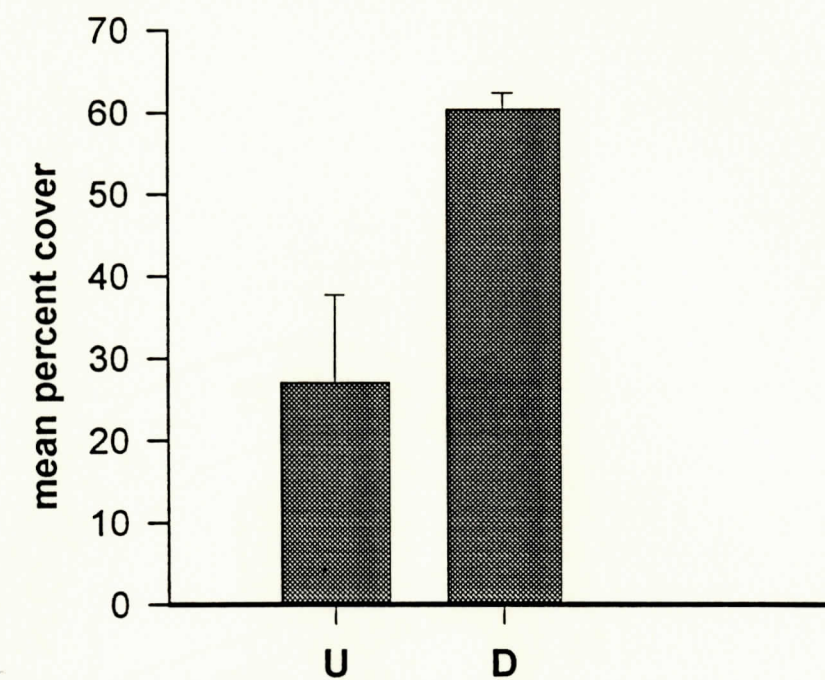


FIGURE 19. Mean percent cover of foliose lichens on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).

Figure 19. foliose lichen

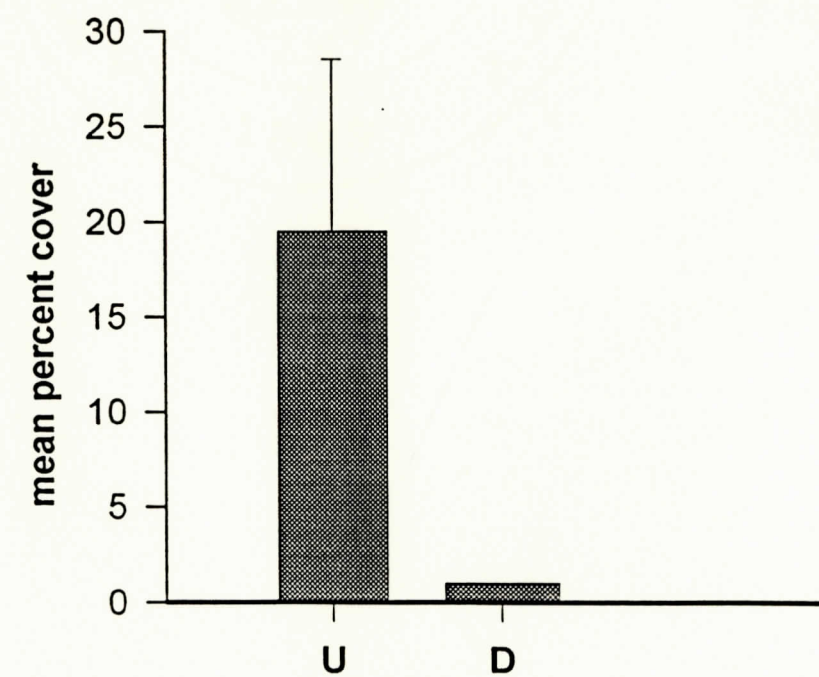


FIGURE 20. Mean percent cover of fruiticose lichens on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).

Figure 20. fruiticose lichen

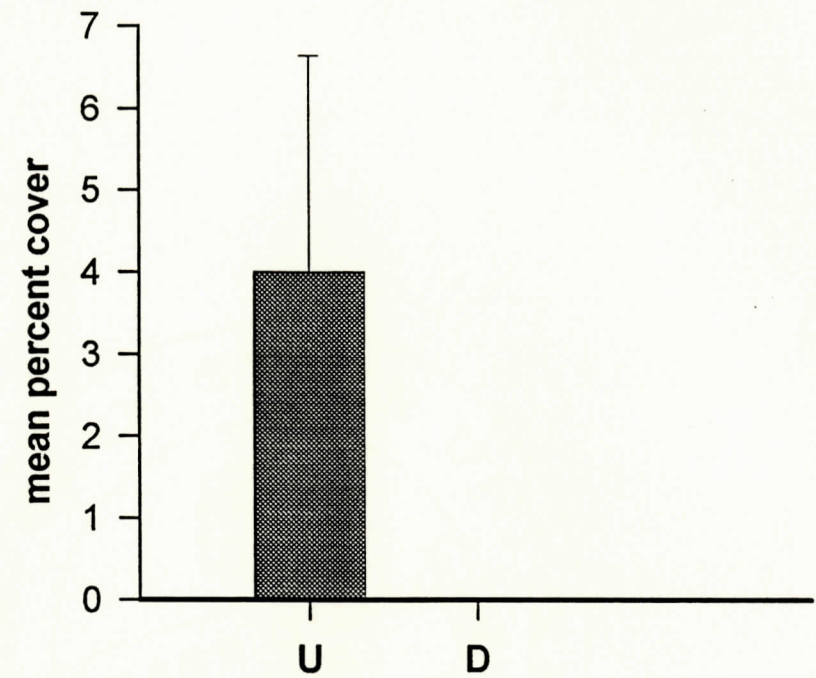


FIGURE 21. Mean percent cover of seed-bearing vascular plants on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).

Figure 21. vascular/seed

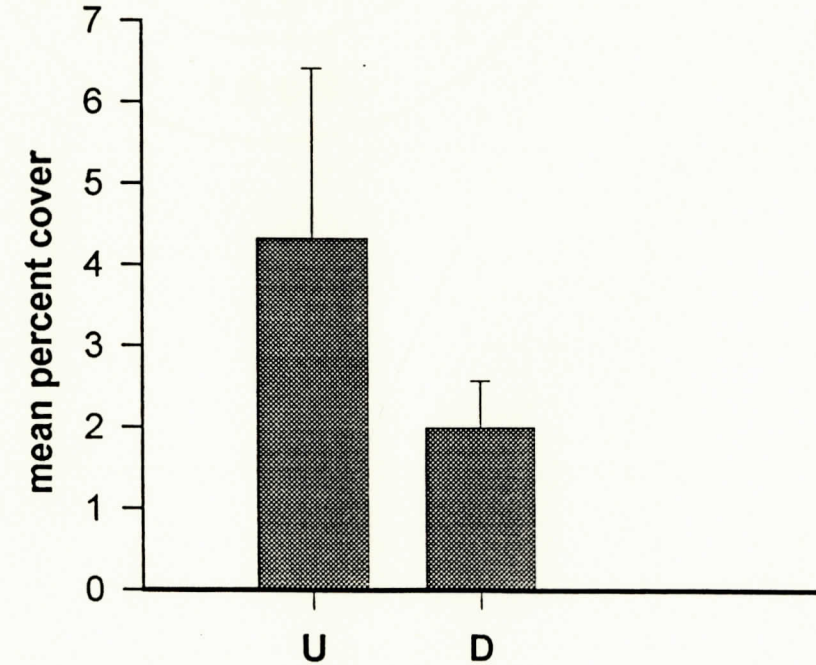


Figure 22. vascular/seedless

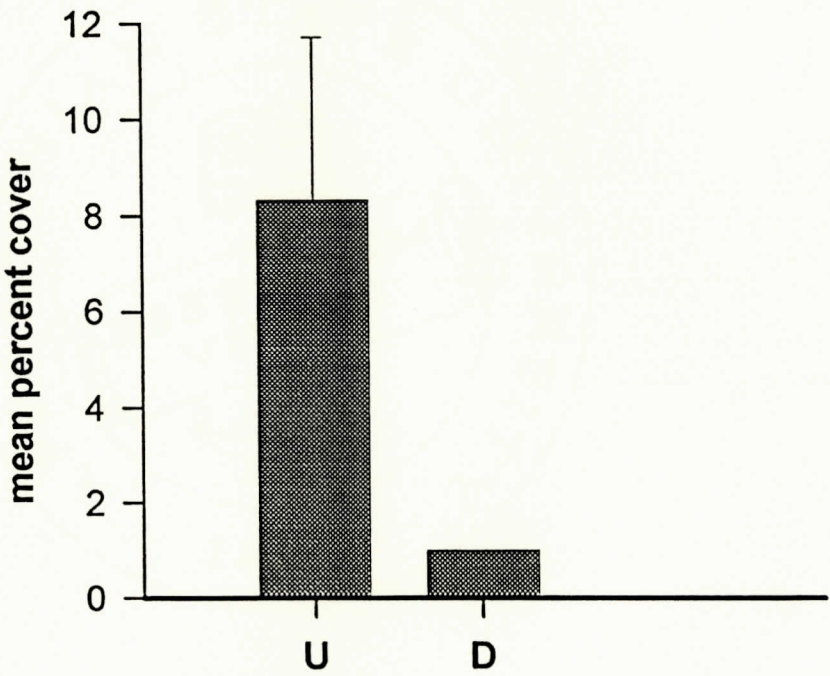


FIGURE 22. Mean percent cover of seedless vascular plants on undisturbed and disturbed cliff faces (U = undisturbed, D = disturbed).

Table 3. Mean percent coverage of five vegetational morphotypes on disturbed and undisturbed cliff faces.

Morphotype	Undisturbed Mean Percent Cover	Standard Error	Disturbed Mean Percent Cover	Standard Error	F	P
Crustose lichens	27.0	10.78	60.3	2.02	7.98	0.0476
Foliose lichens	19.5	9.04	1.0	0.0	9.23	0.0385
Fruiticose lichens	4.0	2.64	0.0	0.0	17.11	0.0144
Vascular/seed plants	4.3	2.08	2.0	.577	2.89	0.1641
Vascular/seedless plants	8.3	3.38	1.0	0.0	9.44	0.0372

Table 4. Results of the ANOVA on the first principal component for the comparison of climbed (disturbed) and unclimbed (undisturbed) cliff faces.

Principal Component 1	F	P
disturbed vs. undisturbed	143.33	0.0003

DISCUSSION

The rugged and topographically complex landscape of the Linville Gorge Wilderness Area sets it apart from most of the southern Appalachians. Newell and Peet (1997) noted a unique combination of environmental conditions such as low precipitation and particularly infertile soils for the region that contribute to the distinctive features of this dynamic wilderness area. As mentioned earlier, Linville Gorge is home to a unique floral suite that includes federally endangered species. Because of the topographic complexity, Linville Gorge largely escaped the widespread logging common to this region in the early twentieth century (Newell and Peet 1997). These factors and the observation that Linville Gorge is one of the most popular hiking and climbing destinations in North Carolina should prioritize the need for future research in understanding the ecology of this area so we may better manage this fragile wilderness area for future generations.

Vascular Flora and Cliff Systems

On cliff faces in Linville Gorge, vascular cliff vegetation forms colonies within pockets and along joint crevices (fractures). Areas of rock which are bare or colonized by lichens, and to some degree bryophytes, separate such stands. These cliff areas include dry, sheer cliff faces and well-shaded overhangs. Where well-shaded overhangs or ledges are present, vascular vegetation can be continuous on the cliff face.

Vascular vegetation is infrequent on all cliffs in the Linville Gorge Wilderness Area. This same condition has been previously reported by Larson *et al.* (1989), Maycock and Fahselt (1992), Coates and Kirkpatrick (1992), and Nuzzo (1996) for other cliff faces. *Selaginella tortipila* and *Rhododendron minus* are the dominant vascular vegetation contributing to the majority of vascular cover in Linville Gorge. Ferns (*Asplenium montanum*), grasses and other herbaceous taxa are represented with lower percent cover.

Several species of vascular taxa were found only on the cliff edge. These cliff-edge species were *Goodyera pubescens*, *Quercus montana*, *Pinus pungens*, *Xerophyllum asphodeloides*, *Vaccinium angustifolium*, and *Acer rubrum*. That these taxa were found only on the cliff edge and certain lichen taxa such as *Rhizocarpon sp.* and *Fuscidea sp.*, were found only on cliff faces further supports our observation that cliff edges differ significantly from cliff faces. This leads to two questions; why are some taxa unable to move onto cliff faces, and why are certain taxa largely restricted only to cliff faces? Nuzzo (1996) described two factors that strongly influence the abundance and distribution of vascular vegetation on cliffs of the Mississippi Palisades: position on the cliff face and fracturing of the rock surface. Her study noted positive correlations between fracture length and density and cover of vascular flora. Nuzzo (1996) noted that to a lesser degree cliff-face slope appears to influence vascular flora. Often ledges on cliff faces in Linville Gorge are completely covered in vascular vegetation. This supports Nuzzo's observation that where soil accumulates, vascular vegetation will be present. I

did not examine slope or fracturing of rock in this study. But it appears likely that the distribution patterns of the vascular flora of Linville Gorge are influenced by similar factors. Coates and Kirkpatrick (1992) analyzed vascular vegetation on sandstone cliffs in Tasmania and found that vegetational distributions are controlled by microtopography of the rock face and by light and moisture availability.

Taxa such as *P. pungens* and *X. asphodeloides* are described as fire released (Frost 1994; Newell and Peet 1997). It may be possible that these taxa rely on the nutrient regime created in soils and/or the competitive release that may result in areas exposed to periodic burns. These taxa may be unable to compete with other taxa on the cliff faces that are not subjected to fire. In controlled burn plots in Linville Gorge I observed substantial seedling recruitment of fire released taxa that were previously diminishing (e.g. *Hudsonia montana*) and the absence of fire-sensitive taxa such as *R. minus* and *Leiophyllum buxifolium*. This new recruitment may be explained by the competitive release created by removing non-fire released taxa and/or the physiology of the seed-bearing structure, especially in the case of *P. pungens*. A brief period of intense heat is required before the cones of serotonous pines will open and release the seed. Once the seed is released wind or water runoff should be able to disperse the seed to the cliff face where germination can take place. *Rhododendron minus* and *L. buxifolium* both colonize cliff faces and may restrict competitively the colonization of the fire-released taxa on cliff faces because fire does not affect these areas and thus does not remove these taxa. No seedling recruitment was observed for any fire-released taxa on cliff faces in this study.

Bartlett and Larson (1990) suggest that taxa that produce large seeds and seedlings may be vulnerable to moisture shortage or mechanical damage during the initial stages of establishment. These same reasons, Bartlett and Larson (1990) suggest, may explain the absence of *A. rubrum* from cliff faces. That cliff habitats are extremely hostile in terms of temperature, water, nutrient and light relations likely restricts *Acer* to the forested plateau adjoining the rock outcrop or cliff edge (Bartlett and Larson 1990). Observations such as these in previous studies, and those made in this study, indicate that cliff faces differ significantly from cliff edges regarding the abundance of vascular plant taxa.

Ninety percent of all known plant species have mycorrhizal associations (Raven *et al.* 1992). A study by Whiton and Lawrey (1984) was the first study showing that lichen acids can inhibit spore germination of the fungal component of other lichens. That cliff faces are largely inhabited by a great diversity of lichens may correlate with the absence of taxa (e.g. *G. pubescens*) from these environments that are known to have strong mycorrhizal associations. A literature review has revealed no such studies assessing the allelopathic nature of lichen substances on mycorrhizal associations of higher plants with regard to their ability to colonize cliff faces. However, there are a number of studies that demonstrate the allelopathic effects of secondary lichen substances on vascular vegetation. Brown (1967) and Goldner *et al.* (1986) found that secondary compounds extracted from the lichen *Cladonia cristatella* inhibited seed germination in *Pinus sylvestris*, moss spore germination, and the growth of fungi of the division Zygomycotina

known to form mycorrhizal associations with trees common to eastern deciduous forests. Fahselt (1996) notes that in spite of experimental demonstrations of the potency of several lichen products, allelopathic interactions in ecosystems are not well understood. Likely, the allelopathic products of lichens are just one of many factors that regulate what can or cannot colonize cliff environs and separate community structure on cliff edges and cliff faces as found in this study.

Other vascular taxa such as *R. minus* and *Kalmia latifolia* take full advantage of even the smallest crack in the cliff face into which they may extend roots (Peter Smith, pers. obs.). Larson *et al.* (1993) found that individual roots of *Thuja occidentalis* are separate from one another, either in their water relations or for translocation, and that stem sections are sectored into functionally independent parts. That is, the vascular tissues of this species are independent of one another with regard to the part of the plant to which they are supplying nutrients. When *T. occidentalis* suffers rockfall that exposes supporting roots, or when high winds and ice loading invert stems and break roots closest to the cliff, the productivity and reproductive output falls to zero for only the one branch and stem section to which the dying root is connected (Larson *et al.* 1993). The present study did not address the hydraulic architecture of either *R. minus* or *K. latifolia* but this may be another advantage these plants have over plants that cannot compete on cliff faces.

Selaginella tortipila primarily inhabits exposed rocky cliffs in the southern Appalachians (Wofford 1989). This species forms dense mats over exposed rock and is

often associated with the lichen taxa *Cladina* sp. and *Cladonia* sp. These large mats grow over the cliff edge and down the cliff face until the weight of the mat is too great for support and the mat then breaks loose. Where ledges are present these *S. tortipila* mat fragments may reestablish themselves down the cliff face, but are probably unable to compete in the low light situations at the cliff face bottom and persist in low percent cover (>1% across all cliff face bottoms). *Selaginella tortipila* is heterosporous and the bi-flagelated sperm require water in order to fertilize the eggs (Raven *et al.* 1990). The cliff-edge and cliff-face top provide the optimal environment for the plant to receive large amounts of sunlight and still be able to take full advantage of direct rain and water runoff.

Selaginella tortipila displayed slightly higher percent cover on the cliff-face top compared to the cliff edge across all transects (edge = 10.34 %; cliff face top = 16.67 %). This result may be best explained by anthropogenic disturbance, which was not accounted for on cliff edges but was investigated on cliff faces in this study. The rim of Linville Gorge is lined with numerous hiking trails that often pass through rock outcrops. The disturbance is evidenced by the numerous bare soil mats that now exist along the rim of the Gorge. Undisturbed cliff edges are often colonized by *S. tortipila*, *Cladina* sp., *Cladonia* sp., and *Umbilicaria* sp. to the extent that very little bare rock remains (Peter Smith, pers. obs.). Parikesit *et al.* (1995) found that soil properties of heavily used trails did not completely recover even after ten years of trail abandonment. This same study found that soil characteristics were the major factors organizing the vegetation of cliff-

edge forests and that soil properties and community organization were more strongly influenced by anthropogenic factors than by environmental gradients. The results of their study and others (Larson 1989; Frost 1993; Taylor *et al.* 1993) suggest that the current use of trails along cliff edges in Linville Gorge may be unsustainable and further quantitative studies should be done to assess this possibility.

Distribution of Lichen Taxa on Cliff Systems

Coates and Kirkpatrick (1992) and Nuzzo (1996) conclude that vegetational distribution on cliff systems is controlled by microtopography of rock, light and moisture availability. In the previous subsection, regarding vascular vegetation and cliff systems, it was mentioned that certain lichen taxa in this study were found only on cliff faces (*Rhizocarpon* sp., *Fuscidea* sp.). Microhabitat variation in the amounts of insolation may explain this distribution. The cliff-edge probably receives much more insolation than does the cliff-face because of their horizontal nature. Certain taxa may be unable to colonize horizontal cliff edges because of the conditions created by the intense insolation, and are thus largely restricted to vertical cliff faces. As one moves from cliff edge to cliff-face top and finally to cliff-face bottom, microhabitat variation becomes evident. Most cliff faces in Linville Gorge are forested at the base resulting in a high degree of shading on lower portions. Lower portions of cliff faces are more humid and tend to recruit vegetation that requires low light, high moisture conditions. This part of the cliff-face and overhangs on cliff faces are largely dominated by *Lepraria* sp. (Figure 9). In describing lichen communities on the cliffs in the British Isles, James, Hawksworth, and

Rose (1977) describe the *Leproplacetum chrysodetae* associations (in which *Lepraria* sp. are associated) as restricted to moderately shaded dry underhangs, recesses, cave entrances, and sheltered sides of mortar stone walls, where the substrate is rarely wetted directly by rain. Presumably, the component species obtain their moisture from the atmosphere which is humid in such habitats. Other taxa encountered in our present study, and noted with similar habitat associations by James, Hawksworth, and Rose (1977), include *Lasalia* sp. and *Lecidia* sp. (Figures 6 and 7).

Cliff edges and cliff-face tops in Linville Gorge are well lit and primarily dominated by crustose lichens *Umbilicaria* sp., and *Dimelaena* sp., a crustose lichen that is found almost exclusively on the cliff edge in Linville Gorge. This lichen has been described as a widespread saxicolous species that is restricted to open sunny habitats (Sheard 1974). The genus *Umbilicaria* has also been described as primarily inhabiting well-lit areas (Hale and Cole 1988). This genus was more abundant on the cliff-face top and cliff-edge but is also found at cliff-face bottoms (Figure 14). All umbilicate lichens were identified to genus but not species. It is quite possible that umbilicate lichens found at the bottom of the cliff-face are different species than those found on cliff-edge and cliff-face top. Like *S. tortipila*, *Umbilicaria* sp. were more abundant on cliff-face tops compared to cliff edges. This may be explained by anthropogenic disturbance in the form of trampling. Hale and Cole (1988) describe this genus as primarily growing on dry sunny rocks and as extremely brittle, breaking into fragments upon collection. This suggests that this species may be highly susceptible to trampling.

Mycoblastus sp., has minute apothecia (> 2mm. diameter) with no apparent thallus. The incredibly small size of this lichen easily allows it to inhabit features of the rock that would not be affected by human disturbance. Across all transects the percent coverage of this lichen is almost equal on cliff-face top and cliff-face bottom (0.26% compared to 0.24%) and almost twice as high on the cliff edge (0.47%). Trampling on the cliff edge probably does not affect directly the presence of this lichen, but the impact trampling may have on larger, more conspicuous taxa may result in a competitive release for *Mycoblastus* sp., resulting in the higher percent coverage on the cliff-edge for this organism.

Climbed vs. Unclimbed Cliff Faces

Larson *et al.* (1989) speculated that the cliff-face community is composed of a few species tolerant of environmental variation but intolerant of disturbance. This idea would lead one to expect the decline of vascular vegetation and lichens on climbed cliff faces.

Of the five morphotypes used in the analysis of climbed versus unclimbed cliff faces only crustose lichens show higher mean percent coverage (57%) on heavily climbed cliff faces than on unclimbed cliff faces (27%). All other morphotypes were less abundant on faces that were regularly climbed.

Although unknown, it is not unreasonable to speculate that prior to being climbed the heavily impacted transects resembled the unclimbed transects in plant and lichen abundance. As climbers began to climb these cliffs the brittle foliose and fruiticose

lichens were quickly eliminated and the vascular vegetation that is rooted in fissures and pits in the rock were impacted later. It is the fissures and pits in vertical rock that are used as hand- and footholds by rock climbers and these are often cleared of vegetation by climbers. The observation that percent coverage of crustose lichens increases with climbing--related disturbance may be related to their morphology (tightly appressed to the substrate). With the removal of other taxa these lichens may experience a competitive release. Crustose lichens are the primary colonizers of bare rock (Burbanck and Phillips 1983; Maycock and Fahselt 1992; Nash 1996) and initiate pedogenesis. On unclimbed cliff faces, competition in the form of allelopathic substances inhibiting spore germination of crustose lichens may be responsible for subsequent colonization by foliose and fruiticose types of lichens (Whiton and Lawrey 1984). The absence of other lichens and the morphological characteristics of crustose lichens likely give them advantage in these heavily disturbed areas without themselves being substantially negatively impacted. The results reported here may not hold true for areas of different rock type. For example, the quartzite in Linville Gorge is extremely hard and does not weather or shatter as easily as sandstone or limestone.

Vegetation types on disturbed (heavily climbed) cliff faces were found to differ significantly from vegetation types and percent coverage on undisturbed (unclimbed) cliff faces. It is important to know and understand the finer details of community change in light of anthropogenic disturbance. As previously reported, Linville Gorge is a popular destination for hikers and rock climbers. As the popularity of both rock climbing and

hiking will likely continue to increase recreational use in Linville Gorge it is imperative that we have a more detailed understanding of the ecology of this wilderness area. For example, during the course of this study a previously undescribed species of lichen was discovered on the cliff faces in Linville Gorge. Quantitative studies regarding impacts of trampling and rock climbing need to be conducted so that a working management plan can be put into practice to insure the integrity of this wilderness area and its more fragile communities. It is my opinion that present use of hiking trails through Linville Gorge rock outcrops is non-sustainable. Parikesit *et al.* (1995) found significant differences in soil mineral characteristics in heavily trampled soils compared to untrampled soils on cliff edges. They correlated changes in community structure with changes in soil mineral content. Steps are now being taken to restore the fire-released cliff-edge vegetation that once dominated the rim of Linville Gorge prior to fire suppression by the USDA Forest Service. Observations of controlled burned plots revealed an increased trampling effect as views are opened up from the fires allowing easier access to the rim of Linville Gorge. Provided the USDA Forest Service plans on more widespread controlled burns, it is important that the dynamics of trampling through these areas are better monitored and quantified.

Early in this study cross sections were made of small diameter dead stems (approximately 5cm.) from *L. buxifolium* and *R. minus* growing on cliff faces. The growth rings were so close together that they could only be distinguished with the use of a dissecting scope. Although these observations have not been quantified they suggest

consistency with the findings of Larson *et al.* (1990, 1997) that these cliff-face plants are very slow growing and the cliffs of Linville Gorge may represent ancient, stable, and largely disturbance (anthropogenic) free habitats.

Results of this study, based on my methodology, demonstrate that cliff faces in Linville Gorge differ significantly in plant and lichen community structure compared to cliff edges. I feel that this study demonstrates the existence of a previously undescribed community on cliff faces in Linville Gorge. Microhabitat variation and competition are likely the factors that regulate both cliff-edge and cliff-face community structure. This study also demonstrates that lichen taxa on cliff faces are spatially distributed in a non-random manner. This finding is consistent with those of previous studies and is probably controlled by microhabitat variation in the form of light and moisture requirements of lichen taxa on cliff faces.

The effects of rock climbing were shown to significantly alter the distribution plant and lichen taxa on cliff faces. These results and the fact that a previously undescribed lichen species was discovered while sampling a small percentage of Linville Gorge cliff faces only strengthens the need for further studies assessing anthropogenic disturbance on these fragile habitats.

Literature Cited

- Ashton, D.H., and R. N. Webb. 1977. The ecology of granite outcrops at Wilson's Promontory, Victoria. *Aust. J. Ecol.* **2**:269-296.
- Bartlett, R. M., and D. W. Larson. 1990. The physiological basis for the contrasting distribution patterns of *Acer saccharum* and *Thuja occidentalis* at cliff edges. *J. of Ecol.* **78**: 1063-1078.
- Bartlett, R. M., U. Matthes-Sears, and D. W. Larson. 1989. Organization of the Niagara escarpment cliff community II. Characterization of the physical environment. *Can. J. Bot.* **68**:1931-1941.
- Baskin, J. M. and C. C. Baskin. 1988. Endemism in rock outcrop plant communities of unglaciated eastern United States: an evaluation of the roles of the edifice, genetic and light factors. *J. of Biogeo.* **8**: 830-840.
- Boyer, S. E. 1978. Structure and origin of the grandfather mountain window and vicinity, North Carolina and Tennessee. Doctoral dissertation, Johns Hopkins University.
- Brown, T. B. 1967. Influence of naturally occurring compounds on germination and growth of Jack Pine. *Can. J. Bot.* **64**: 1586-1590.
- Bryant, B. 1970. Geology of the Grandfather mountain window and vicinity, North Carolina and Tennessee. United States Government Printing Office.
- Burbanck, M. P. and D. L. Phillips. 1983. Evidence of plant succession on granite outcrops of the Georgia piedmont. *Am. Mid. Nat.* **109**: 95-103.
- Burbanck, M. P., and R. P. Platt. 1964. Granite outcrop communities of the piedmont plateau in Georgia. *Ecology* **45**: 292-306.
- Coates, F., and J. B. Kirkpatrick. 1992. Environmental relations and ecological responses of some higher plant species on rock cliffs in northern Tasmania. *Aust. J. Ecol.* **17**: 441-449.
- Culberson, W. L., and C. F. Culberson. 1967. Habitat selection by chemically differentiated races of lichens. *Science* **158**: 1195-1197.

- Degelius, G. 1941. Contributions to the lichen flora of North America II. Lichen Flora of the Great Smoky Mnts. Almqvist and Wiksells Boktryckeris, Stockholm.
- DePriest, P. 1983. Macrolichen flora of the Unaka mnt. Masters Thesis. University of Tennessee, Knoxville.
- Dobson, F. 1979. Lichens, an illustrated guide. Richmond Publishing Co. Ltd. England.
- Fahselt, D. 1996. Individuals, populations, and population ecology. **In** *Lichen Biology. Edited by Thomas H. Nash.* Cambridge University Press, United Kingdom. pp.181-198.
- Foote, K. G. 1966. The vegetation of lichens and bryophytes on limestone outcrops in the Driftless Area of Wisconsin. *Bryologist.* **69**: 265-292.
- Frost, C. C. 1993. *Hudsonia montana* monitoring and management for 1992. USDA Forest Service and U. S. Fish and Wildlife paper.
- Fletcher, T. S., and J. L. Vankat. 1998. Understanding old-growth forests of south-central Alaska. *ASB Bulletin* **45**: 99, Abstract.
- Goldner, W. R., Hoffman, F. M., and R. J. Medve. 1985. Allelopathic effects of *Cladonia cristatella* on ectomycorrhizal fungi common to bituminous strip-mine spoils. *Ecology* **48**: 542-546.
- Grime, J.P. 1979. Plant Strategies and Vegetation Processes. John Wiley and Sons, Inc. New York.
- Hale, M. E. 1983. The Biology of Lichens. Edward Arnold Publishing Ltd. London.
- Hale, M. E., and M. Cole. 1988. Lichens of California. University of California Press, London.
- Jackson, G. and J. Sheldon. 1949. The vegetation of magnesian limestone cliffs at Markland Gripps near Sheffield. *J. Ecol.* **37**: 38-50.
- James, P. W., Hawksworth, D. L., and F. Rose. 1977. Lichen communities in the British Isles. **In** *Lichen Ecology. Edited by M. Seaward.* Academic Press, London. pp. 296-413.

- Jarvis, S. C. 1974. Soil factors affecting the distribution of plant communities on the cliffs of Craig Breidden, Montgomeryshire. *J. Ecol.* **62**: 721-733.
- Kelley, T. 1988. The climber's guide to North Carolina. Earthbound Inc., Chapel Hill, NC.
- Kelly, P. E., and D. W. Larson. 1997. Effects of rock climbing on populations of presettlement eastern white cedar (*Thuja occidentalis*) on cliffs of the Niagara Escarpment, Canada. *Conservation Biology* **11**: 1125-1132.
- Larson, D. W. 1989. Effects of disturbance on old-growth *Thuja occidentalis* at cliff edges. *Can. J. Bot.* **68**: 1147- 1155.
- Larson, D. W., and P. E. Kelly. 1991. The extent of old-growth *Thuja occidentalis* on cliffs of the Niagara Escarpment. *Can. J. Bot.* **69**: 1628-1636.
- Larson, D. W., Matthes-Sears, U., Gerrath, J. A., Gerrath, J. M., Nekola, J. C., Walker, G. L., Flinspach, H. M., Hollweck, M., Porembski, S., Charlton, A., and N. W. K. Larson. 1998. The ubiquity of ancient woodlands on cliffs.[In preparation].
- Larson, D. W., Matthes-Sears, U., and P. E. Kelly. 1993. Cambial dieback and partial shoot mortality in cliff face *Thuja occidentalis*: Evidence for sectorial radial architecture. *Int. J. of Plant Sciences* **154**: 496-505.
- Larson, D. W., Spring, S. H., Matthes-Sears, U., and R. R. Bartlett. 1989. Organization of the Niagara Escarpment cliff community. *Can. J. Bot.* **67**: 2731- 2742.
- Leidolf, A., and S. McDaniel. 1998. A floristic study of Black Prairie plant communities at sixteen section prairie, Oktibbeha County, Mississippi. *Castanea* **63**: 51-62.
- Linville Falls Quadrangle, North Carolina [topographic]. U. S. Geological Survey[ed.] Washington, DC: United States Department of the Interior Geological Survey; 1968. 1:24,000; colored. English. (7.5 minute series).
- Looman, J. 1964. Ecology of lichen and bryophyte communities in Saskatchewan. *Ecology* **45**: 481-491.
- Lubchenco J. 1994. The Sustainable Biosphere Initiative: An ecological research agenda. *Ecology* **72**: 371-412.
- Matthes-Sears, U., and D. W. Larson. 1995. Rooting characteristics of trees in rock: a study of *Thuja occidentalis* on cliff faces. *Int. J. Plant Sci.* **156**: 679-686.

- Matthes-Sears, U., Nash, C. H., and D. W. Larson. 1995. Constrained growth of trees in a hostile environment: The role of water and nutrient availability for *Thuja occidentalis* on cliff faces. *Int. J. Plant Sci.* **156**: 311-319.
- Maycock, P. F., and D. Fahselt. 1992. Vegetation of stressed calcareous scree and slopes in Sverdrup Pass, Ellesmere Island, Canada. *Can. J. Bot.* **70**: 2359-2377.
- McCune, B., and T. Goward. 1995. Macrolichens of the northern Rocky Mnts. Mad River Press Inc. Eureka, CA.
- Montgomery, D. C. 1984. Design and Analysis of Experiment, 2nd ed. John Wiley and Sons, Inc. New York.
- Murdy, W. H., Johnson, T. M., and V. K. Wright. 1970. Competitive replacement of *Talinum mengesii* by *T. teretifolium* in granite outcrop communities of Georgia. *Bot. Gaz.* **131**: 186-192.
- National Oceanic and Atmospheric Administration. 1992. Climatological Data, North Carolina February 1992. Volume 97#2.
- Newell, C. L., and R. K. Peet. 1997. Vegetation of Linville Gorge Wilderness, North Carolina. *Castanea* [in review].
- Nuzzo, V. 1995. Effects of rock climbing on cliff goldenrod (*Solidago sciaphila* Steele) in northwest Illinois. *Am. Midl. Nat.* **133**: 229-241.
- Nuzzo, V. 1996. Structure of cliff vegetation on exposed cliffs and the effect of rock climbing. *Can. J. Bot.* **74**: 607-617.
- Ogle, D. W. 1989. Rare Vascular plants of the Clinch River Gorge Area in Russell County, Virginia. *Castanea* **54**: 105-110.
- Oosting, H. J. and L. E. Anderson. 1937. The vegetation of a barefaced cliff in western North Carolina. *Ecology* **18**: 280-292.
- Parikesit, P., Larson, D. W., and U. Matthes-Sears. 1995. Impacts of trails on cliff edge forest structure. *Can. J. Bot.* **73**: 943-953.
- Pyle, C. 1988. The type and extent of anthropogenic vegetation disturbance in the Great Smoky Mountains before National Park Service acquisition. *Castanea* **53**: 183-196.

- Ramseur, G. S. 1960. The vascular flora of the high mountain communities of the southern Appalachians. *J. Elisha Mitchell Soc.* 76: 82-112.
- Raven, P. H., Evert, R. F., and S. E. Eichhorn, ed. *Biology of Plants*. New York: Worth Publishers, Inc., 1992: 208-243.
- SAS Institute Inc. 1990. *SAS Users Guide: Statistics, Version 6, 4th edition*. SAS Institute, Cary, North Carolina.
- Sheard, J. W. 1974. The genus *Dimelaena* in North America north of Mexico. *Bryologist* 77: 128-141.
- Spear, P. W., and M. J. Schiffman. 1980. Rock climbing and endangered plants: a case study. **In** Annual national conference on recreation planning and development: proceedings of the specialty conference, New York. American Society of Civil Engineers, pub. pp: 630-636.
- Syers, J.K., and I. K. Iskunder. 1973. Pedogenic significance of lichens. **In** The Lichens, ed. V. Ahmadjian and M. E. Hale pp. 225-48. London: Academic Press
- Taylor, K. C., Reader, R. J., and D. W. Larson. 1993. Scale dependent inconsistencies in the effects of trampling on a forest understory community. *Environmental Management* 17: 239-248.
- United States Department of Agriculture. 1994. Linville Gorge Wilderness: recreation guide r8-rg 4. U. S. Dept. of Agriculture, publishers.
- Vitt, D. H., Marsh, J. E., and R. B. Bovey. 1988. *Mosses, Lichens, and Ferns*. Lone Star Publishing. Edmonton, Alberta.
- Walker, G. L. 1987. Ecology and population biology of *Thuja occidentalis* L. in its southern disjunct range. Unpublished Ph.D. Dissertation, The University of Tennessee, Knoxville.
- Whiton, J. C., and J. D. Lawrey. 1984. Inhibition of crustose lichen spore germination by lichen acids. *Bryologist* 87: 42-43.
- Wiggs, D. N., and R. B. Platt. 1962. Ecology of *Diamorpha cymosa*. *Ecology* 43: 654-669.
- Wiser, S. K. 1994. High elevation cliffs and outcrops of the southern Appalachians: Vascular plants and biogeography. *Castanea* 59: 85-116.

- Wofford, B. E. 1989. *Guide to the vascular plants of the Blue Ridge*. University of Georgia Press. Athens, Ga.
- Young, J. M. 1996. The cliff ecology and genetic structure of northern white cedar (*Thuja occidentalis* L.) in its southern disjunct range. Unpublished Masters thesis, The University of Tennessee, Knoxville.

APPENDIX A

Site Descriptions

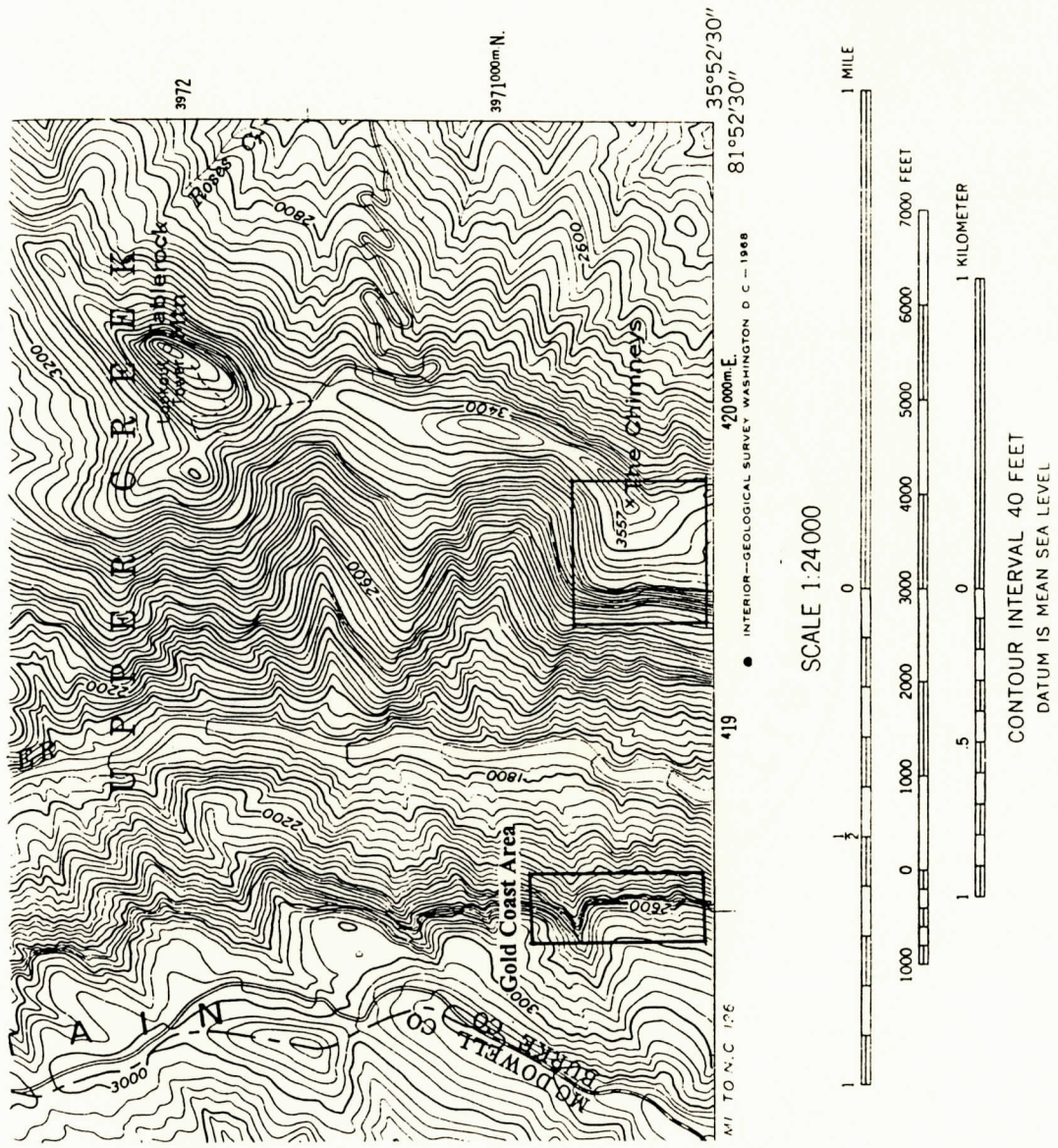
The following subsections are detailed descriptions of each transect (Figure 1).

Plant and lichen taxa noted at each transect are included in Appendix A. Twenty-three lichen genera and 31 plant species were identified in this study. Species nomenclature for vascular plants follows Wofford (1989); lichen nomenclature follows the fore mentioned authors.

Site Descriptions:

Transects 1 - 4 are located on the Gold Coast Wall of Linville Gorge Wilderness Area approximately one half mile south of the Conley Cove trailhead on the western rim of the Gorge. The Gold Coast Wall derives its name from the golden hue of the quartzite in this part of the Gorge. Transects on the Gold Coast Wall represent some of the most undisturbed (anthropogenic) transects of this study. Trails are poorly marked along the rim and access to this area is limited, often requiring the use of a four-wheel drive vehicle. The cliffs in this area range in height from 15 to 100 meters. The geologic composition of outcrops and cliffs is arkosic quartzite of the Chilhowee group. The forest type associated with the rock outcrops and cliffs is largely dominated by *Pinus pungens*, *Pinus rigida*, *Quercus montana*, and *Tsuga caroliniana*. The understory is largely comprised of *Vaccinium* spp. and *Xerophyllum asphodeloides*.

Transect one: Transect one is 27 meters long and was sampled on 6/17/97. The cliff face aspect is 344° northwest at an elevation of 848 meters. The cliff face



bottom receives shade throughout most of the day from the forest present at the cliff base. The cliff face top and cliff edge is shaded only during part of any given day because of the northerly aspect. Dominant taxa on the cliff face and cliff edge are *Rhododendron minus*, *Selaginella tortipila*, *Cladina* sp., and *Lecidea* sp.

Transect two: Transect two was 19 meters in length and was sampled on 8/17/97. The cliff face aspect was 102° east/southeast at an elevation of 848 meters. The cliff face bottom received shade throughout most of the day from the forest present at the cliff base. The cliff face top and cliff edge received direct insolation throughout the day. Cliff face and rock outcrop was dominated by the following taxa: *S. tortipila*, *Lasalia* sp., *Buellia* sp., and *Dimelaena* sp.

Transect three: Transect three was 23 meters in length and was sampled on 9/16/97. The cliff face aspect was 115° east/southeast at an elevation of 848 meters. The cliff face bottom received shade throughout most of the day from the forest present at the cliff base. The cliff face top and cliff edge received direct insolation throughout the day. Cliff face and cliff edge are dominated by the following taxa: *S. tortipila*, *Cladina* sp., *Cladonia* sp., and *Buellia* sp.

Transect four: Transect four was 27 meters in length and was sampled on 10/14/97. The cliff face aspect was 170° east/southeast at an elevation of 848 meters. The cliff face bottom received shade throughout most of the day from the forest present at the cliff base. The cliff face top and cliff edge received direct insolation throughout the

day. Cliff face and rock outcrop are dominated by the following taxa: *Lecanora* sp., *Lepraria* sp., and *S. tortipila*.

Transects 5 - 14 are located in the Chimneys area of the Linville Gorge Wilderness Area. The Chimneys area is so named because of the numerous “chimney like” rock formations. This area is located on a knife edge ridge on the eastern rim of Linville gorge. In contrast to the Gold Coast area, the Chimneys area is heavily used by the public. A paved road to the Tablerock parking area allows easy access to well marked, moderately strenuous hiking trails approximately one mile long south to the Chimneys area. Many summer camps and outdoor education programs bring large groups to practice rock climbing, rappelling, and backpacking. Almost all of the cliff edges in this area have been moderately to heavily impacted by people. There are numerous unmarked trails evidenced by trampled mats of soil on the cliff edges. This side of the gorge is home to such rare endemics as *Liatris helleri* and *Hudsonia montana*. *Hudsonia montana* has been the subject of intensive management plans implemented in hopes of increasing the sizes of the few populations that still exist (Frost 1993).

The rock type associated with this part of the Linville Gorge Wilderness Area is arkosic quartzite of the Chilhowee group. The forest type associated with cliff edges and cliffs is largely dominated by *P. pungens*, *P. rigida*, *Fothergilla major*, *Rhododendron maximum*, *Kalmia latifolia*, and *Vaccinium* spp. In well lit areas and on cliff edges the vegetation is largely dominated by *Leiophyllum buxifolium*, *R. minus*, and *S. tortipila*.

Transect five: Transect five was 27 meters in length and was sampled on 8/21/97. The cliff face aspect was 328° west/northwest at an elevation of 1060 meters. After mid-afternoon this entire transect received direct insolation and, unlike many areas of the Chimneys, this transect shows very little sign of human impact. This transect is dominated by the following taxa: *S. tortipila*, *Lecidea* sp., and *R. minus*.

Transect six: Transect six was 19 meters in length and was sampled on 8/26/97. The cliff face aspect was 305° west/northwest at an elevation of 1060 meters. The cliff face bottom was shaded throughout the day from the forest at the cliff bottom. Cliff face top and cliff edge received direct insolation in the afternoon. The cliff face in this transect showed no sign of human impact but the cliff edge showed signs of impact in the form of trampled soil mats devoid of vegetation. This transect is largely dominated by *Umbilicaria* sp., *S. tortipila*, and *Lecidia* sp.

Transect seven: Transect seven was 23 meters long and was sampled on 9/2/97. The cliff face aspect was 10° north/northeast at an elevation of 1060 meters. The cliff edge received direct insolation during the latter part of the day. The cliff face in this transect was shaded during a large portion of the day. It was noticeably cooler and more moist on this part of the transect. High moisture and low light requiring taxa such as *Asplenium montanum* and *Lecidea* sp. were abundant on the cliff face of this transect.

Transect eight: Transect eight was 27 meters long and was sampled on 9/5/97. The cliff face aspect was 12° north/northeast at an elevation of 1060 meters. Cliff face and cliff edge on this transect received partial shading early in the day. The cliff edge

showed signs of heavy human use (fire ring, trampling etc.) while the face was the most vegetationally diverse of all the transects in this area. The following taxa are represented in this transect: *S. tortipila*, *R. minus*, *Lecidea* sp. and *Cladonia* sp.

Transect nine: Transect nine was 23 meters long and was sampled on 10/22/97. The cliff face aspect was 180° south at an elevation of 1060 meters. The entire transect received direct insolation throughout the day. Unlike other transects in the area both the cliff edge and cliff face showed no observable signs of human disturbance. The vegetation of this transect is largely represented by *Umbilicaria* sp. and *S. tortipila*.

Transect ten: Transect ten was 31 meters long and was sampled on 10/23/97. The cliff face aspect was 300° northwest at an elevation of 1060 meters. The cliff face bottom was shaded by the forest below while the rest of the cliff face and cliff edge was shaded early in the day. Again, atypical to most rock in this area of Linville Gorge, this transect showed no observable signs of human disturbance. The cliff edge vegetation is largely represented by *S. tortipila* and *L. buxifolium* and on the cliff face by *S. tortipila* and *Fuscidea* sp. *Fuscidea* sp. is a previously undescribed species (Richard Harris, pers. com).

Transect eleven: Transect eleven was 23 meters long and was sampled on 10/28/97. The cliff face aspect was 150° south/ southeast at an elevation of 1060 meters. Although this transect has a southerly aspect it remained shaded throughout the day from other rock faces proximate to this transect. Both cliff face and cliff edge showed no

observable signs of human disturbance. *Selaginella tortipila* and *Umbilicaria* sp. are prevalent on this entire transect.

Transects twelve-fourteen: These transects were/are heavily used by climbers and people rappelling. All three of these transects were between 19 and 21meters long and had an aspect of 322° north/northwest at an elevation of 1060 meters. These transects were on the top of the ridge and shaded until early afternoon. These three transects were readily characterized by the almost complete absence of plant taxa (vascular and non-vascular) and the extensive presence of crustose lichens.

APPENDIX B
Taxa Lists

**SPECIES ASSOCIATED WITH ROCK OUTCROPS AND CLIFF FACES IN
THE LINVILLE GORGE WILDERNESS AREA**

Taxa lists are arranged by transect.

Gold Coast Area

Transect one:

<i>Acer rubrum</i>	<i>Melampyrum lineare</i>
<i>Buellia</i> sp. (lichen)	<i>Mycoblastus</i> sp. (lichen)
<i>Cladina</i> sp. (lichen)	<i>Parmelia</i> sp. (lichen)
<i>Cladonia</i> sp. (lichen)	<i>Pertusaria</i> sp. (lichen)
<i>Clethra acuminata</i>	<i>Rhododendron catawbiense</i>
<i>Dicranium scoparium</i>	<i>Rhododendron minus</i>
<i>Dimelaena</i> sp. (lichen)	<i>Selaginella tortipila</i>
<i>Galax urceolata</i>	<i>Tsuga caroliniana</i>
<i>Kalmia latifolia</i>	<i>Umbilicaria</i> sp. (lichen)
<i>Lasalia</i> sp. (lichen)	<i>Usnea</i> sp. (lichen)
<i>Lecidea</i> sp. (lichen)	<i>Vaccinium corymbosum</i>
<i>Leiophyllum buxifolium</i>	<i>Xanthoparmelia</i> sp. (lichen)

Transect two:

<i>Buellia</i> sp. (lichen)	<i>Mycoblastus</i> sp. (lichen)
<i>Carex austrocaroliniana</i>	<i>Parmelia</i> sp. (lichen)
<i>Cladina</i> sp. (lichen)	<i>Pertusaria</i> sp. (lichen)
<i>Dimelaena</i> sp. (lichen)	<i>Pinus rigida</i>
<i>Haematoma</i> sp. (lichen)	<i>Rhabdoweisia crispata</i>
<i>Kalmia latifolia</i>	<i>Selaginella tortipila</i>
<i>Lasalia</i> sp. (lichen)	<i>Trapelia</i> sp. (lichen)
<i>Lepraria</i> sp. (lichen)	

Transect three:

<i>Aspicilia</i> sp. (lichen)	<i>Lepraria</i> sp. (lichen)
<i>Asplenium montanum</i>	<i>Mycoblastus</i> sp. (lichen)
<i>Buellia</i> sp. (lichen)	<i>Pertusaria</i> sp. (lichen)
<i>Cetraria</i> sp. (lichen)	<i>Pycnothelia</i> sp. (lichen)
<i>Cladina</i> sp. (lichen)	<i>Rhizocarpon</i> sp. (lichen)
<i>Cladonia</i> sp. (lichen)	<i>Rhododendron minus</i>
<i>Dicranella heteromalla</i>	<i>Selaginella tortipila</i>
<i>Dimelaena</i> sp. (lichen)	<i>Umbilicaria</i> sp. (lichen)
<i>Lasalia</i> sp. (lichen)	<i>Xanthoparmelia</i> sp. (lichen)
<i>Lecidea</i> sp. (lichen)	

Transect four:

<i>Carex umbellata</i>	<i>Parmeliopsis</i> sp. (lichen)
<i>Cetraria</i> sp. (lichen)	<i>Pertusaria</i> sp. (lichen)
<i>Cladina</i> sp. (lichen)	<i>Pinus rigida</i>
<i>Cladonia</i> sp. (lichen)	<i>Quercus montana</i>
<i>Dicranium scoparium</i>	<i>Rhizocarpon</i> sp. (lichen)
<i>Dimelaena</i> sp. (lichen)	<i>Rhododendron minus</i>
<i>Lasalia</i> sp. (lichen)	<i>Saxifraga michauxii</i>
<i>Lecidea</i> sp. (lichen)	<i>Selaginella tortipila</i>
<i>Lepraria</i> sp. (lichen)	<i>Umbilicaria</i> sp. (lichen)
<i>Mycoblastus</i> sp. (lichen)	<i>Xanthoparmelia</i> sp. (lichen)

Chimneys Area

Transect five:

<i>Buellia</i> sp. (lichen)	<i>Leiophyllum buxifolium</i>
<i>Carex umbellata</i>	<i>Lepraria</i> sp. (lichen)
<i>Cladina</i> sp. (lichen)	<i>Mycoblastus</i> sp. (lichen)
<i>Dicranella heteromalla</i>	<i>Pertusaria</i> sp. (lichen)
<i>Dicranium scoparium</i>	<i>Pycnothelia</i> sp. (lichen)
<i>Fothergilla major</i>	<i>Rhabdoweisia crispata</i>
<i>Kalmia latifolia</i>	<i>Rhododendron minus</i>
<i>Lasalia</i> sp. (lichen)	<i>Selaginella tortipila</i>
<i>Lecidea</i> sp. (lichen)	<i>Umbilicaria</i> sp. (lichen)

Transect six:

Cladonia sp. (lichen)
Dicranella heteromalla
Dimelaena sp. (lichen)
Galax urceolata
Lasalia sp. (lichen)
Lecidea sp. (lichen)
Leiophyllum buxifolium

Lepraria sp. (lichen)
Mycoblastus sp. (lichen)
Pertusaria sp. (lichen)
Rhododendron minus
Selaginella tortipila
Umbilicaria sp. (lichen)
Xanthoparmelia sp. (lichen)

Transect seven:

Aspicilia sp. (lichen)
Asplenium montanum
Cladina sp. (lichen)
Cladonia sp. (lichen)
Dicranella heteromalla
Dimelaena sp. (lichen)
Haematoma sp. (lichen)
Lasalia sp. (lichen)
Lepraria sp. (lichen)

Mycoblastus sp. (lichen)
Parmelia sp. (lichen)
Paronychia argyrocoma
Pertusaria sp. (lichen)
Rhabdoweisia crispata
Rhododendron minus
Selaginella tortipila
Umbilicaria sp. (lichen)
Xanthoparmelia sp. (lichen)

Transect eight:

Asplenium montanum
Carex umbellata
Cetraria sp. (lichen)
Cladina sp. (lichen)
Cladonia sp. (lichen)
Dicranella heteromalla
Dimelaena sp. (lichen)
Lasalia sp. (lichen)
Lecidella sp. (lichen)
Lepraria sp. (lichen)

Mycoblastus sp. (lichen)
Parmelia sp. (lichen)
Parmeliopsis sp. (lichen)
Pertusaria sp. (lichen)
Rhizocarpon sp. (lichen)
Rhododendron minus
Selaginella tortipila
Umbilicaria sp. (lichen)
Usnea sp. (lichen)

Transect nine:

Cladina sp. (lichen)
Cladonia sp. (lichen)
Dimelaena sp. (lichen)
Haematoma sp. (lichen)
Lecidea sp. (lichen)
Lepraria sp. (lichen)

Mycoblastus sp. (lichen)
Parmelia sp. (lichen)
Pertusaria sp. (lichen)
Rhododendron minus
Selaginella tortipila
Umbilicaria sp. (lichen)

Transect ten:

Aspicilia sp. (lichen)
Asplenium montanum
Carex umbellata
Cladina sp. (lichen)
Cladonia sp. (lichen)
Dicranium scoparium
Dimelaena sp. (lichen)
Fuscidea sp. (lichen)
Galax urceolata
Goodyera pubescens
Haematoma sp. (lichen)
Lecanora sp. (lichen)
Lecidea sp. (lichen)
Leiophyllum buxifolium

Lepraria sp. (lichen)
Mycoblastus sp. (lichen)
Parmeliopsis sp. (lichen)
Pertusaria sp. (lichen)
Rhabdoweisia crispata
Rhizocarpon sp. (lichen)
Rhododendron minus
Scapania undulata
Selaginella tortipila
Umbilicaria sp. (lichen)
Usnea sp. (lichen)
Vaccinium angustifolium
Vaccinium corymbosum
Xanthoparmelia sp. (lichen)

Transect eleven:

Cladina sp. (lichen)
Cladonia sp. (lichen)
Dicranella heteromalla
Dimelaena sp. (lichen)
Gautheria procumbens
Haematoma sp. (lichen)
Lasalia sp. (lichen)
Lecidea sp. (lichen)

Leiophyllum buxifolium
Lepraria sp. (lichen)
Mycoblastus sp. (lichen)
Pinus pungens
Rhabdoweisia crispata
Rhododendron minus
Selaginella tortipila
Umbilicaria sp. (lichen)

Transect twelve:

Asplenium montanum

Carex umbellata

Dimelaena sp. (lichen)

Lecidea sp. (lichen)

Leiophyllum buxifolium

Mycoblastus sp. (lichen)

Pertusaria sp. (lichen)

Rhabdoweisia crispata

Rhododendron minus

Selaginella tortipila

Umbilicaria sp. (lichen)

Xanthoparmelia sp. (lichen)

APPENDIX C

Principal Components Analysis Eigenvectors

The following tables list the Eigenvectors in the Principal Components analysis used on transects sampled in 1997 and the disturbed (climbed) transects sampled in 1998.

Table 1: Eigenvectors of Principal Components analysis on transects sampled in 1997.

Dominant Taxa	Eigenvectors Principal Component 1	Eigenvectors Principal Component 2	Eigenvectors Principal Component 3
<i>Rhododendron minus</i>	0.35590	0.239093	-0.063874
<i>Lecidea</i> sp.	-0.29770	-0.072515	-0.457646
<i>Cladina</i> sp.	0.393805	0.230572	0.005910
<i>Cladonia</i> sp.	0.361520	0.401675	0.030092
<i>Umbilicaria</i> sp.	0.128084	0.105303	-0.233204
<i>Selaginella tortipila</i>	0.412630	-0.040251	0.015040
<i>Lepraria</i> sp.	0.298683	0.328514	0.399101
<i>Lasalia</i> sp.	-0.151479	0.007968	0.693168
<i>Pertusaria</i> sp.	-0.331508	0.021659	-0.196935
<i>Mycoblastus</i> sp.	0.200268	-0.545722	0.023911
<i>Dimelaena</i> sp.	0.224320	-0.551448	0.227621

Table 2. Eigenvectors of Principal Components analysis on disturbed and undisturbed transects.

Morphotype	Eigenvectors Principal Component 1	Eigenvectors Principal Component 2
Crustose lichen	-0.484856	0.395205
Foliose lichen	0.450298	0.328403
Fruiticose lichen	0.472444	-0.000761
Seed bearing vascular plants	0.310729	0.763069
Seedless vascular plants	0.492333	-0.392032

VITA

Peter Smith was born in Salisbury, North Carolina under the nonsensical leadership of Lyndon B. Johnson on December 31, 1967. He was raised by his parents, Wayne and Marilyn Smith in a variety of places early in his childhood. When he was ten years old Peter and his family had permanently located themselves in Stone Mnt., Georgia. He attended public high school in Stone Mnt., graduating in 1986. A love affair with mountains and a desire to further his education led Peter to Boone, N.C., to pursue an undergraduate education at Appalachian State University. While an undergraduate student, he spent three years volunteering his time to the Peregrine Fund, rock climbing, and working at many area restaurants. He graduated with a B. S. in Biology (Naturalist concentration) in May, 1992. Tired of school, he worked seasonal jobs traveling and climbing in the western United States and completed a through hike of the Appalachian Trail in October, 1993. With an earnest desire to further his education and still pursue his rock climbing passion, he entered a Master's degree program with a concentration in ecology at Appalachian State University in the fall of 1995.