

North Carolina Ecosystem Response to Climate Change: DENR Assessment of Effects and Adaptation Measures

DRAFT

Low Elevation Cliffs and Rock Outcrops

Ecosystem Group Description:

This broad Ecosystem Group contains a wide variety, though not all, of the community types that are too steep or rocky to support a closed tree canopy. The vegetation of these communities is generally very patchy, reflecting extreme variability in the depth and composition of soil and of available moisture. Plants include forest species with broad site tolerances, species characteristic of a wide range of open habitats, and species specialized for rock outcrops. Rock outcrops typically are very dry, but seepage zones are often present and may support wetland vegetation. The nine natural community types are separated based on rock chemistry, topographic location, and geographic region, and the latter is an important factor in determining flora.

Like their high elevation counterparts, Low Elevation Rocky Summit and Low Elevation Granitic Dome communities occur in exposed positions on peaks, ridgetops, and upper slopes. Most are in the Mountain Region, but a few examples occur in the upper Piedmont. Low Elevation Granitic Domes occur on exfoliated outcrops of granitic rock, where peeling of sheets of rock parallel to the surface produces a dome-shaped outcrop of solid rock. Soil mats that begin as moss clumps gradually thicken over time and follow a characteristic vegetational succession from herbs to shrubs and stunted trees. The unanchored mats are periodically destroyed by falling off or by being pulled up by falling trees, leaving the rock bare and beginning the succession anew. Low Elevation Rocky Summits, in contrast, have fractured rock which allows growth of deep-rooted woody plants in places. Soil accumulates in pockets of varying depth and produces heterogeneous vegetation. Many variants potentially occur, but are not well known.

Cliff communities occur on lower, more sheltered topographic sites. They generally are created by streams undercutting a bluff, but may occur somewhat above a stream. Like Rocky Summits, the rock is usually fractured and supports very patchy vegetation that includes woody plants rooted in crevices as well as herbs in soil pockets and mosses and lichens on bare rock. The Montane and Piedmont/Coastal Plain types have flora typical of their regions, often combining plants from adjacent communities with typical outcrop plants. North-facing cliffs have a cooler microclimate than the surrounding areas and sometimes harbor disjunct or regionally rare species characteristic of cooler, moister regions. In some cases these species are believed to be remnants from more widespread populations that existed in the Ice Ages. In the Mountain Region, south-facing cliffs may support species more typical of the warmer Piedmont or even Coastal Plain.

The Acidic, Mafic, and Calcareous types support different flora that reflect the rock chemistry. Mafic and Calcareous cliffs contain calcium-loving species that do not occur on the more common Acidic cliffs. The floristic differences between Calcareous and Mafic cliffs is more subtle, and reflects differences in balance of basic elements.

Piedmont/Coastal Plain Heath Bluffs differ somewhat from the other community types in that they have little bare rock. They do, however, lack a closed tree canopy, apparently because of steepness. They are characterized by a dense shrub layer of mountain laurel or Catawba rhododendron, which are otherwise essentially absent in the Piedmont and Coastal Plain. These communities occur on north-facing bluffs, and the cool microclimate is believed to be important to these species.

Ecosystem Level Effects:

Predicted Impacts of Climate Change:

Climate Change Factor:	Likelihood:	Effect:	Magnitude:	Comments:
Wind Damage	Med	Pos	Med	Wind damage could create and maintain openings around outcrops.
Drought	Med	Mix	Med	Droughts could favor herbaceous species and grasses in open, dry outcrops, which tend to be more rare than the woody species associated with outcrops.
Fire	Med	Mixed	High	Low intensity fires could reduce woody succession, but high intensity fires could be catastrophic in some examples.
Increased Temperature	High	Neg	Med	Increased temperatures could increase demand for water, a limited resource in these sites.

This group includes communities in both the Piedmont and Mountain regions. The Climate Wizard mid model temperature increase is about 4 degrees by 2050, in the Asheboro area (Maurer et al., 2007). The cmd model predicts an increase of 4.5 degrees. The mid value rainfall forecast is for a slight increase, but there is substantial variation among the models: anywhere from a decrease of 13 inches to an increase of 18 inches per year. Some models predict that rainfall will be concentrated during the fall, and there will be increased droughts in the spring and summer. This may reflect an expectation of increased hurricane activity rather than well-distributed rainfall in the fall. An increase in hurricanes or other severe storms may increase wind damage around outcrops. Plants occurring at rock outcrops can be dramatically affected by droughts because of the limited water available in shallow soils and in small crevices. They are often the first to die and show stress during seasonal droughts. If drought increases the potential for wild fire, it could have mixed effects. Bare rocks and sparse vegetation do not carry fire well, but burning the vegetation around the edges of rock outcrops could expand the open area and benefit some of the rare plants of outcrops. More mesic outcrops such as heath bluff communities are more likely to be harmed by fire. Landscape fragmentation and fire suppression practices likely will continue to prevent most fires from spreading very far.

Predicted Ecosystem Responses:

Ecosystem Response:	Likelihood:	Effect:	Magnitude:	Comments:
Exotic species invasion	Med	Neg	Med	Exotic plants readily invade favorable microsites on many outcrops. Increased disruption of adjacent forests may bring seed sources closer to many outcrops.
Structural Change	Med	Mix	Low	Dense woody vegetation around edges may become more open.
Compositional Change	Low	Mix	Med	Some outcrops have been altered by fire suppression and these changes may help return to more natural composition. Others will lose characteristic mesophytic species. The effect may be severe in a small number of outcrops.
Acreege Change	Low	Mix	Med	Some dry outcrops may expand into adjacent forests, while heath bluffs may shrink.

These communities are tied to specialized sites, and are unable to migrate. Species characteristic of most low elevation outcrops and cliffs are tolerant of drought and heat. These communities have had limited damage from the most severe droughts of recent times, and may weather them better than most. Drought appears to be an important factor keeping these communities from becoming more shaded. If trees die, it will create more open conditions on the edges and in deeper soil pockets, and this would favor the characteristic herbaceous species. Because lack of fire has caused increased canopy density, climate change may help offset recent alterations. Drought may also allow them to expand into adjacent forests, though this expansion is likely to be limited by soil conditions. However, these are among the driest sites in the Piedmont and Mountains. If droughts become much more extreme, they may be beyond the tolerance of plants in the more extreme microsites on the outcrops. Seasonal distribution of rainfall may be important, and may affect different species differently. Drought in spring would be detrimental, while drought in other seasons might not be.

Some communities in this group, including all the Piedmont/Coastal Plain Heath Bluffs and some of the cliffs, depend on cool, moist micro-environments. Drought may be harmful to these communities. Heath Bluffs contain Pleistocene relict species, in disjunct and isolated populations, while mesic cliffs may contain drought-intolerant bryophytes. These communities weathered the Hypsithermal period, but if temperatures rise beyond that level, rapid deterioration may occur.

While fire has little effect in open rock outcrops communities, it was an important natural influence on edges of many, and likely determined their boundary with adjacent forests. If increased drought and hot weather increase wild fires, this may benefit dry rock outcrops, allowing them to expand. It might also create more open canopy and lower shrub cover around their edges, increasing habitat for herbaceous plants. Some of these communities likely have substantially altered by fire suppression, so some of the changes associated with climate change may shift them more toward more natural composition, and may even allow these communities to expand. However, fires during severe drought may be too intense and may cause damage to the characteristic plants and the shallow soils as well. Heath Bluff and mesic cliff communities are naturally sheltered from fire by topography and by streams, so they may not be harmed. But if drought-driven fire were able to penetrate them, it would be harmful. It is unclear how much climate change will change fire frequency in the fragmented landscapes of the Piedmont and lower Mountains. If increased drought inhibits prescribed burning, it will be more harmful than beneficial to fire-dependent communities.

Cliffs and rock outcrops have some problems with invasive plants, which can invade edge zones and more favorable soil pockets. Some examples have had severe damage by them. One invasive plant not already present and likely to increase with climate change, that would be harmful to these communities, is cogon grass (*Imperata cylindrica*). However, if climate change increases disturbance of adjacent forests, it may allow invasive plant seed sources to develop closer to rock outcrops that are now remote from them. It is possible that some of the invasive species, such as *Lonicera japonica* and *Rubus phoenicolasius*, will be harmed by drought more than the native species of rock outcrops.

Habitat Level Effects:

Natural Communities:

Third Approximation Name:

Comments:

Piedmont/Coastal Plain Heath Bluff

Piedmont Mafic Cliff	
Piedmont Calcareous Cliff	Most of the few Piedmont Calcareous Cliffs are dry sites with unstable, shale-like rock. They are unlikely to be affected by fire and probably are unlikely to expand much. They may be susceptible to drought or to extreme rainfall.
Piedmont/Coastal Plain Acidic Cliff	Cliffs are often a mixture of dry and moist microsites. Some microsites depend on seepage, which may be affected by drought. Most cliffs are sheltered by topography, which will ameliorate heat and drought, as well as fire.
Montane Mafic Cliff	Cliffs are often a mixture of dry and moist microsites. Some microsites depend on seepage, which may be affected by drought. Most cliffs are sheltered by topography, which will ameliorate heat and drought, as well as fire.
Montane Calcareous Cliff	Cliffs are often a mixture of dry and moist microsites. Some microsites depend on seepage, which may be affected by drought. Most cliffs are sheltered by topography, which will ameliorate heat and drought, as well as fire.
Montane Acidic Cliff	Cliffs are often a mixture of dry and moist microsites. Some microsites depend on seepage, which may be affected by drought. Most cliffs are sheltered by topography, which will ameliorate heat and drought, as well as fire.
Low Elevation Granitic Dome	Extreme drought might affect the dynamics of shallow vegetation mats. Drought or fire might push back edge zones.
Low Elevation Rocky Summit	Most of these communities are dry and many may have shrunk because of lack of fire and invasion of woody vegetation on edges. Increased drought or fire might allow them to expand, or might produce beneficial structural changes.

LHI Guilds:

Guilds with Significant Concentration in Ecosystem Group: Comments:

(Mesic Montane Rocky Cliffs)	Provisional guild currently based on just two indicator species.
Piedmont Heath Bluffs	Guild composed primarily of montane or northern species having a relict distribution in the Piedmont. Likely to be particularly affected by climate change with few options for adaptation.

The two guilds with significant concentrations of habitat within this Ecosystem Group are both associated with cool, moist habitats on steep slopes or rock cliffs, often with a northern exposure or where the cliffs are shaded by trees. Their dependence on cool, moist conditions makes the members of these guilds highly vulnerable to the effects of increased temperature and more frequent droughts and fires. The Piedmont Heath Bluff Guild is especially vulnerable, since it is highly restricted to areas where steep, north-facing bluffs are extensive. Guilds of drier rock outcrops, which might benefit from drier conditions, have not been as well studied.

Species Level Effects:

Plants

Species:	Element Rank:	Endemic	Major Disjunct	Extinction/Extirpation Prone	Status: US/NC	Comments:
Tortula ammonsiana	G1/S1		Yes		/E	Known from eight extant occurrences in West Virginia and in the Smoky Mountains of North Carolina and Tennessee, and it is also known from two collections from South Africa.

<i>Packera millefolium</i>	G2/S2		FSC/T	Restricted to granite and limestone outcrops endemic to the Blue Ridge and inner Piedmont from Virginia south to northeastern Georgia. Fewer than 50 populations are known but many are protected and thought to be stable. However, this species is known to hybridize with a weedy native species (<i>S. anonymous</i>). If disturbance of adjacent forests increases the abundance of this species, hybridization problems may increase.
<i>Orthotrichum keeverae</i>	G2/S2	Yes	/E	Known from thirteen extant occurrences in the upper Piedmont region of North Carolina and Virginia. This species is epiphytic on red cedar trees. Increased drought or fire mortality in cedars may be harmful to it.
<i>Thaspium pinnatifidum</i>	G2G3/S1		FSC/SR-T	Restricted to a few states in the southern Appalachians where it occurs in forests and woodlands with calcareous bedrock ; rare throughout its range.
<i>Arabis patens</i>	G3/S1		/SR-T	Although this species ranges widely, the populations are scattered and the population numbers very low; approximately 60 known occurrences rangewide.
<i>Marshallia trinervia</i>	G3/SH		/SR-P	
<i>Weissia sharpii</i>	G3/S1?		/SR-O	
<i>Mannia californica</i>	G3?/S1		/SR-T	
<i>Plagiochasma wrightii</i>	G3?/S1		/SR-D	
<i>Homaliadelphus sharpii</i>	G3?/S1		/SR-P	
<i>Coscinodon cribrosus</i>	G3G4/S1		/SR-T	
<i>Liatris microcephala</i>	G3G4/S1		/SR-P	
<i>Palamocladium leskeoides</i>	G3G5/S1		/SR-D	
<i>Archidium donnellii</i>	G3G5/S1		/SR-O	
<i>Allium cuthbertii</i>	G4/S2		/SR-T	
<i>Dicentra eximia</i>	G4/S3		/SR-P	
<i>Draba ramosissima</i>	G4/S2		/SR-P	
<i>Eucladium verticillatum</i>	G4/S1		/SR-O	
<i>Orthotrichum strangulatum</i>	G4/SH		/SR-P	
<i>Entodon compressus</i>	G4/S1		/SR-P	
<i>Woodsia appalachiana</i>	G4/S2		/SR-P	
<i>Sedum glaucophyllum</i>	G4/S2		/SR-P	
<i>Asplenium bradleyi</i>	G4/S2		/SR-P	
<i>Asplenium pinnatifidum</i>	G4/S2		/SR-P	
<i>Carex oligocarpa</i>	G4/S1		/SR-P	
<i>Pohlia lescuriana</i>	G4?/S1?		/SR-T	
<i>Anemone berlandieri</i>	G4?/S2		/SR-P	

<i>Heuchera pubescens</i>	G4?/S1	/SR-P
<i>Entodon concinnus</i>	G4G5/S1	/SR-P
<i>Encalypta procera</i>	G4G5/S1	/SR-D
<i>Anticlea glauca</i>	G4G5/S1	/SR-P
<i>Polygala senega</i>	G4G5/S2	/SR-D
<i>Dichodontium pellucidum</i>	G4G5/S2	/SR-P
<i>Platydictya confervoides</i>	G4G5/S1	/SR-P
<i>Cheilanthes alabamensis</i>	G4G5/S1	/SR-P
<i>Tortula plinthobia</i>	G4G5/S1?	/SR-O
<i>Campylopus atrovirens</i> var. <i>atrovirens</i>	G4G5TNR/S1?	/SR-D
<i>Carex hitchcockiana</i>	G5/S1	/SR-P
<i>Asplenium ruta-muraria</i>	G5/S1	/SR-P
<i>Croton monanthogynus</i>	G5/S1	/SR-P
<i>Didymodon fallax</i>	G5/SH	/SR-O
<i>Chenopodium simplex</i>	G5/S1	/SR-P
<i>Amelanchier sanguinea</i>	G5/S3	/SR-P
<i>Carex eburnea</i>	G5/S1	/SR-P
<i>Leptodontium flexifolium</i>	G5/S1	/SR-D
<i>Dicranella varia</i>	G5/S1?	/SR-O
<i>Panicum flexile</i>	G5/S1	/SR-P
<i>Trichostema brachiatum</i>	G5/S1	/SR-P
<i>Tortula fragilis</i>	G5/S1	/SR-D
<i>Symphyotrichum oblongifolium</i>	G5/S1	/SR-P
<i>Primula meadia</i>	G5/S2S3	/SR-P
<i>Pellaea wrightiana</i>	G5/S1	/E-SC
<i>Euphorbia commutata</i>	G5/S1	/SR-P
<i>Orthodontium pellucens</i>	G5/S1	/SR-O
<i>Neckera complanata</i>	G5/S1	/SR-O
<i>Melica nitens</i>	G5/S1	/SR-P
<i>Fleischmannia incarnata</i>	G5/S2	/SR-P
<i>Lejeunea cavifolia</i>	G5/S1	/SR-P
<i>Matelea decipiens</i>	G5/S3	/SR-P
<i>Muhlenbergia glomerata</i>	G5/S1	/SR-P
<i>Minuartia groenlandica</i>	G5/S2	/SR-D
<i>Stachys cordata</i>	G5?/S1	/SR-P
<i>Pleurochaete luteola</i>	G5?/S1?	/SR-O
<i>Buchnera americana</i>	G5?/S1	/SR-P
<i>Boechera missouriensis</i>	G5?Q/S1	/SR-P
<i>Nardia scalaris</i> ssp. <i>botryoidea</i>	G5T1/S1	/SR-O
<i>Rudbeckia triloba</i> var. <i>pinnatiloba</i>	G5T3/S1	/SR-T

This species occurs on Mafic Cliffs and Granitic Domes.

Corydalis micrantha ssp. micrantha	G5T4/S1	/SR-P
Arabis pycnocarpa var. adpressipilis	G5T4Q/S1	/SR-P
Coreopsis grandiflora var. grandiflora	G5T4T5/S1	/SR-O
Solidago rigida var. rigida	G5T5/S1	/SR-P
Juniperus communis var. depressa	G5T5/S1	/SR-D
Packera paupercula var. appalachiana	G5TNR/S1	/SR-P
Orbexilum macrophyllum	GX/SX	FSC/E

Many rare species associated with this habitat are tied to basic soils and are unlikely to migrate far. Extreme weather might be a threat to some species on some sites.

The rare plants associated with dry outcrops are tolerant of drought and are likely to benefit from more canopy openings and more fire. However, it is not known how close the characteristic species are to their tolerance limits in the most extreme sites. Climate change is not expected to be a significant threat, and may even improve or create more habitat for these species.

Some rare plants in this group are bryophytes on moist, sheltered cliffs. These would be harmed by droughts or fire.

Terrestrial Animals

Species:	Element Rank:	Endemic	Major Disjunct	Extinction/Extirpation Prone	Status: US/NC/WAP	Comments:
Aneides aeneus	G3G4/S2		Yes		FSC/E/P	Populations located in the Southern Blue Ridge Escarpment of North and South Carolina are isolated from populations in the major portion of this species' range, located farther to the west and north.
Plethodon yonahlossee pop. 1	G4T1Q/S1	Yes		Yes	/SC/P	The taxonomic status of the crevice salamander needs further clarification. Whether a separate subspecies or just a distinctive form of the Yohnallossee Salamander, however, the disjunct population located in the vicinity of Hickory Nut Gorge is highly associated with cool rock outcrops and is especially vulnerable to extinction/extirpation.

No species belonging to these guilds appear to be vulnerable to complete extinction due to the effects of climate change. However, both the Hickory Nut Gorge population of *P. yonahlossee* and the Piedmont populations of *P. cinereus* exist as isolated disjuncts and are likely to be highly vulnerable to the effects of climate change. In both cases, extirpation of these populations would constitute loss of significant ecological as well as genotypic variants of their species.

Combined Threats and Synergistic Impacts:

Importance of Climate Change Factors Compared to Other Ecosystem Threats:

Threat:	Rank Order:	Comments:
Development	1	Development can have both direct and indirect impacts that severely threaten many unprotected examples.
Invasive Species	2	
Climate Change	2	Some particular outcrops in this theme are more likely to suffer from the effects of climate change than others.
Fire	3	Fire suppression has been a major factor degrading some of these communities.
Logging/Exploitation	4	

For the plants associated with this theme, climate change is not expected to be a major threat. Development and changes caused by fire suppression are the most severe threats. In some areas, excessive deer browse is also a major threat.

For animals associated with cool, moist slopes or cliffs, particularly in relict situations, climate change represents the most significant threat, particularly in the Piedmont where their populations are typically small and highly isolated.

Recommendations for Action:

Interventive Measures:

Intervention:	Importance:	Feasibility:	Comments:
Conduct Prescribed Burns	Med	High	Burning around open, dry outcrops will restore more natural structure around the margins, and will favor species that will tolerate drought and wild fire better.
Protect/Expand Remaining Examples	High	Med	Protect remaining examples and surrounding forests.

For outcrops that naturally burned, fire will restore more natural structure around the margins, and will favor species -- particularly plants -- that tolerate drought and wild fire. Fire suppression has shifted these communities toward denser vegetation, making them more likely to carry a fire. Burning would increase their resilience to warmer climate and drought, as well as make them less prone to destruction by wild fire.

For animal species associated with cool, sheltered cliffs and steep slopes, on the other hand, any openings in the canopy created by increased droughts and/or fire are likely to have major adverse effects. Areas that have such populations should receive special protection from fire.

Ecosystem Group Summary:

Low Elevation Cliffs and Rock Outcrops are a diverse group that are expected to have a variety of responses to climate change. While some are dependent on moisture and may be harmed, others may actually benefit from increased drought and fire. This benefit will only be realized if sites are protected from other forms of destruction, and for most, if fire is restored to them through prescribed burning. These communities are naturally rare in North Carolina, due to limited availability of suitable habitat. Examples need to be protected and managed appropriately.

References:

Maurer, E.P, L.Brekke, T.Pruitt, and P.B. Duffy. 2007. Fine-resolution climate projections enhance regional climate change impact studies. *Eos Trans. AGU*, 88(47), 504.
