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

DRAFT

High Elevation Rock Outcrops

Ecosystem Group Description:

High elevation rock outcrop communities occur on ridgetops, peaks, and upper slopes where soils are thin and discontinuous and rock dominates the surface. Even in the most rugged high mountains they represent only a small minority of the landscape. The vegetation is very patchy, reflecting the variability of the soil. High Elevation Granitic Domes occur on the exfoliated outcrops that form when massive granitic rock breaks off in sheets parallel to the surface. Exfoliation produces smooth dome-shaped outcrops that lack crevices. Lichens and mosses occur on the bare rock. Soil and vegetation develop together on the rock surface as moss mats gradually deepen and are invaded by a succession of herbs. Soil mats are not anchored to the rock below and eventually fall off or are pulled up by falling trees, leaving the rock bare again. The shallow soils are generally dry, but some zones of seepage are usually present on the edge of the soil of adjacent forests. A number of wetland plants can occur in these saturated areas.

High Elevation Rocky Summit communities occur on fractured rock. The bare rock is similarly vegetated by patches of lichen and moss, and shallow soil mats may develop locally. The presence of fractures, however, offers patches of deeper, more permanent soil that can support deeper rooted plants, and can provide an opportunity to anchor soil mats. The vegetation pattern is less likely to shift over time.

Ecosystem Level Effects:

Predicted Impacts of Climate Change:

Climate Change Factor:	Likelihood:	Effect:	Magnitude:	Comments:
Wind Damage	Med	Neg	Med	Given the extreme weather already present in the high mountains, it is unclear if the increase in severe winds will be as great as at lower elevations.
Mild Winters	Med	Neg	Med	May increase competition from species currently limited to lower elevations.
Hot Spells	Med	Neg	Med	May depend on the behavior of cloud cover.
Fire	Low	Neg	Med	Fire rarely occurs naturally under current conditions.
Drought	High	Neg	High	Potential for drought effects is uncertain, and depends on the effect of the climate on orogenic rainfall.

We expect the future climate to include warmer temperatures, longer growing season, more hot spells and drought, and more severe storms. The cncm-cm3 model predicts 4.5 degrees warmer annual average temperature by 2050 (Maurer et al., 2007). The mid value of the 16 models in Climate Wizard is about 4 degrees. Average annual rainfall is expected to increase, but only slightly. However, the uncertainty is high. Rainfall predictions among the models range from a loss of 12 inches to an increase of 15 inches. But

the future climate of the high mountain sites is particularly uncertain. These model results are for the general area and do not account for the elevations. Much of the current climate in the high mountains is orographically determined, and is quite different from the general regional climate. The rainfall in many high elevation rock outcrops is higher than in the lower basins, and more water may be input through fog drip. Much of the distinctive environment here depends on fog and orographic cloud cover. If these phenomena persist, they may ameliorate the effects of warming, drought, and fire. If they are disrupted, climate change effects will be much more drastic. These areas already experience more high wind than other areas, and it is unclear if an increase in storms will mean more wind damage than already occurs.

Plants occurring at rock outcrops can be dramatically affected by droughts because of the limited water available around the crevices of rocks. These are often the first to die and show stress during seasonal droughts. If drought increases the potential for wild fire, it would be a severe threat. Bare rocks and sparse vegetation do not carry fire well, and the natural vegetation virtually never burns under the current climate, so the biota are not thought to be adapted to fire.

Mild winters may allow species currently limited to lower elevations to invade high elevation rock outcrops, but wind damage from increased storms may mitigate this effect for woody species.

Predicted Ecosystem Reponses:

Ecosystem Response:	Likelihood:	Effect:	Magnitude:	Comments:
Elevation Change	Med	Neg	Med	Tussilago farfara may increase with surrounding canopy disruption and warming
Structural Change	Med	Neg	High	In surviving patches, structural change may result from increased wind or drought damage.
Increased Fragmentation	High	Neg	Med	High Elevation Rock Outcrops are naturally fragmentary, but upward migration may create additional gaps between patches.
Compositional Change	Med	Neg	Med	Species adapted to lower elevations may invade high elevation sites if climate becomes more moderate. This may convert the Theme to Low Elevation Rock Outcrop communities, so it is incertain how much change will occur in the higher elevation patches that survive.
Acreage Change	High	Neg	High	Sites at low elevations may convert to Low Elevation Rock Outcrop communities.
Elevation Change	High	Neg	Med	Sites at low elevation may become unsuitable, further limiting the elevational range of this theme.

Many species are currently excluded from these communities because of the extreme climate. Winter cold is the most likely cause, along with dry, exposed conditions. Frost heave slows the rate of succession and reduce vegetation on the outcrops. Mild winters presumably will lead to invasion by species from lower elevations. This may eventually lead to competitive exclusion of distinctive high elevation species from the lower parts of their elevational range. There is much uncertainty about how far this will go – particularly whether it will “push communities off the top of the mountains”. Changes might be either gradual, resulting from shifts in reproductive success, or may be abrupt, tied to severe weather or fire. Increased severe wind storm frequency may expand the areas around outcrops.

Heat or drought stress may possibly lead to mortality in some species, including dominant plants. However, this depends on whether orographic clouds and fog persist. If fog is diminished, loss of moist microclimate may threaten many species.

Drought and warmer temperatures may accelerate organic matter decomposition, reducing soil organic

layer and slowing the rate of succession. Loss of soil organic matter is a particular concern in these systems because the soil sometimes consists largely of organic matter. However, increased primary productivity, which can be expected if enough nutrients and water are available, may increase input of organic matter and offset this effect.

Fire would likely be negative. Plants around outcrops that burned would likely lose most species and take a long time to recover.

The area of this Ecosystem Group may actually increase if drought and wind damage reduce tree and shrub cover around margins and in crevices. Because the current area is limited and many patches have been reduced further in size, some species are likely already close to minimum viable population size. This concern can be expected to vary.

Most, if not all, of the expected effects of climate change were presumably experienced by High Elevation Rock Outcrops during the warmer and drier Hypsithermal period about 6000 years ago. High elevation species are believed to have been "pushed off the top" over several lower mountain ranges where they now are absent. The magnitude of temperature changes then is not clear, and they were accompanied by a reduction of rainfall that is not expected in the near future climate. However, the Hypsithermal represents a "grace period" for future climate changes, in that all existing patches of it and all of its existing species pool survived that level of warming. However, their ability to survive similar levels of climate change now may be compromised by reduction of area by 20th century logging and slash fires, and by new stresses such as air pollution.

There is no potential for latitudinal migration of these systems. No high elevation areas exist for a considerable distance north of their current range. All patches are isolated by low elevation areas that are already unsuitable in today's climate.

Habitat Level Effects:

Natural Communities:

Third Approximation Name:	Comments:
High Elevation Granitic Dome	
High Elevation Rocky Summit	

LHI Guilds:

Guilds with Significant Concentration in Ecosystem Group:	Comments:
(Dry Montane Rocky Barrens and Cliffs)	
(General Montane Rocky Barrens and Cliffs)	

Two guilds associated with exposed rock outcrops are included in this Ecosystem Group; another provisional guild that is restricted to shaded, cool, moist montane cliffs is treated under Low Elevation Cliffs and Rock Outcrops. The insect fauna of high elevation rock outcrops has not yet been well-studied and a number of additional species may yet be added. The landscape requirements of these guilds also need more study.

While certain species may exist as relict populations with little need for dispersal, others may require a metapopulation structure and depend on at least occasional dispersal.

Species Level Effects:

Plants

Species:	Element Rank:	Endemic	Major Disjunct	Extinction/ Extirpation Prone	Status: US/NC	Comments:
Calamagrostis cainii	G1/S1	Yes		Yes	FSC/E	Total global distribution: 3 sites in NC and TN.
Solidago spithamaea	G1/S1	Yes		Yes	T/E	Total global distribution: 3 sites in NC and 1 in TN.
Physcia pseudospeciosa	G1G2/S1			Yes	/SR-T	Vulnerable to extirpation in NC due to extreme rarity.
Geum radiatum	G2/S2	Yes		Yes	E/E-SC	Limited to NC and TN, isolated mountain tops over 4300' elevation.
Gymnoderma lineare	G2/S2	Yes			E/T	Limited to NC and adjacent states; could be threatened by decline of Spruce.
Houstonia montana	G2/S2	Yes		Yes	E/E	
Liatris helleri	G2/S2	Yes		Yes	T/T-SC	
Solidago simulans	G2/S2				FSC/SR-L	
Robinia hartwigii	G2/S2				/SR-L	
Xanthoparmelia monticola	G2?/S2?				/SR-L	
Diplophyllum obtusatum	G2?/S1				/SR-D	
Ephebe americana	G2G3/S1				/SR-T	
Plagiochila sharpii	G2G4/S2				FSC/SR-L	
Sphagnum flavicomans	G3/SH				/SR-T	
Gymnocarpium appalachianum	G3/S1				FSC/E	
Cardamine clematitis	G3/S2				FSC/SR-T	
Micranthes caroliniana	G3/S3				FSC/SR-T	
Pycnanthemum curvipes	G3/S1				/SR-T	
Allium allegheniense	G3?/S1				/SR-T	
Anastrophyllum saxicola	G3G4/S1				/SR-D	
Anaptychia crinalis	G3G4/S1				/SR-D	
Cephaloziella spinicaulis	G3G4/S1				/SR-P	
Usnea angulata	G3G5/S1				/SR-P	
Cetraria arenaria	G4/S2				/SR-P	
Adlumia fungosa	G4/S2				/SR-P	
Crocanthemum propinquum	G4/S1				/SR-P	
Barbilophozia barbata	G4?/S1				/SR-D	
Cystopteris tenuis	G4G5/S1				/SR-P	
Melanelia stygia	G4G5/S1S2				/SR-D	
Stenanthium leimanthoides	G4Q/S1				/SR-O	
Robinia hispida var. fertilis	G4T1Q/S1				/SR-O	

Cystopteris fragilis	G5/S1	/SR-P	
Campylopus paradoxus	G5/S1	/SR-D	
Campanula rotundifolia	G5/S1	/SR-P	
Barbilophozia hatcheri	G5/S1	/SR-D	
Agrostis mertensii	G5/S1	/E	
Crocanthemum bicknellii	G5/S1	/SR-P	
Phlox subulata	G5/S1	/SR-P	
Woodsia ilvensis	G5/S1	/SR-P	
Trisetum spicatum	G5/SH	/E	
Trichophorum cespitosum	G5/S2S3	/SR-D	
Sphagnum tenellum	G5/S1	/SR-D	
Scapania mucronata	G5/S1	/SR-D	
Rhytidium rugosum	G5/S2	/SR-P	
Rhodiola rosea	G5/SH	/E	
Minuartia groenlandica	G5/S2	/SR-D	
Lophozia heterocolpos	G5/S1	/SR-D	
Lophozia excisa	G5/S1	/SR-D	
Cystopteris tennesseensis	G5/S1	/E-SC	This species occurs on calcareous rock outcrops of the Coastal Plain and high mountains.
Leptodontium flexifolium	G5/S1	/SR-D	
Juncus trifidus	G5/S1	/E	
Diplophyllum taxifolium var. mucronatum	G5T1/S1	/SR-L	
Nardia scalaris ssp. scalaris	G5T5/S1	/SR-D	
Juniperus communis var. depressa	G5T5/S1	/SR-D	
Tritomaria exsectiformis ssp. exsectiformis	G5T5/SH	/SR-D	
Calamagrostis canadensis var. canadensis	G5T5/S1	/SR-P	

The effect of climate change on the species of High Elevation Rock Outcrops is expected to be high. This theme supports many plant species endemic to the Southern Appalachian highlands. Additionally, some species are at their southern range limits and some are northern disjuncts, and these may be directly harmed by warmer temperatures. Some are dependent on seeps or wet areas around outcrops, and may be harmed by more frequent or more intense drought. However, for most, competitive relations and the status of tree and shrub invasion are probably the most important factor for survival.

Houstonia montana, Liatris helleri, Geum radiatum, Gymnoderma lineare, and Solidago spithamaea are extremely rare plants, which occur at high elevation rock outcrops. If conditions become too warm and dry for these species, they are unlikely to migrate north because of the limited habitat available for migration corridors (mountaintops are effectively isolated from one another, making migration difficult or impossible for species with limited dispersal capabilities). Endemic species should be monitored closely for declines in the near future, and intervention may be required to prevent extinction.

Terrestrial Animals

Species:	Element Rank:	Endemic	Major Disjunct	Extinction/ Extirpation Prone	Status: US/NC/ WAP	Comments:
Hypochilus sheari	G2G3/S2S3	Yes		Yes	/SR/	Restricted to rock outcrop habitats in the southern mountains of North Carolina.
Trimerotropis saxatilis	G3?/S1S2		Yes	Yes	/SR/	Known in North Carolina from just a few sites, primarily in the southern mountains. The main part of the range for this species is located west of the mountains, including areas in the Ozarks.
Hypochilus coylei	G3?/S3?	Yes		Yes	/SR/	Restricted to rock outcrop habitats in the southern mountains of North Carolina.
Neotoma magister	G3G4/S2				FSC/SC/P	
Falco peregrinus	G4/S1B,S2N				/E/P	
Corvus corax	G5/S3				/W2/	
Neotoma floridana haematoreia	G5T4Q/S3				FSC/SC/P	

The two endemic species of Hypochilus would be particularly vulnerable to extinction if they are intolerant to increases in temperature and drought, which seems likely. Their current restriction to extremely small ranges suggests that they have only a low level of vagility and may be unable to shift their ranges fast enough to keep up with environmental change. Competition with the more widespread H. pockocki may further limit their ability to shift their ranges.

Combined Threats and Synergistic Impacts:

Importance of Climate Change Factors Compared to Other Ecosystem Threats:

Threat:	Rank Order:	Comments:
Climate Change	1	
Trampling	1	
Development	2	Development may increase trampling.
Woody Succession	3	Trees and shrubs may invade if enough water is available during the growins season.
Invasive Species	4	Coltsfoot is the most common exotic species in High Elevation Rock Outcrops.

Climate change and trampling from recreational users (hikers and rock climbers) are probably the biggest threats. Most examples of this theme are protected and managed as natural areas. Logging and development are, consequently, of less importance, but are still possible on private tracts. Development may not directly impact outcrops, but may increase access and therefore trampling.

Recommendations for Action:

Interventive Measures:

Intervention:	Importance:	Feasibility:	Comments:
Reintroduce Species	Med	High	This should be undertaken in only cases of documented extirpations. Very few such cases are currently known.
Protect/Expand Remaining Examples	High	High	
Control Invasive Species	High	High	
Monitor rare species	High	High	Endemic species should be monitored closely for declines in the near future, and transplantation may be required to prevent extinction.

Although most examples occur in nature preserves, they are not always protected from trampling. Protection from trampling would allow the species pool to expand through suitable habitat, producing larger, more robust, populations that would be better able to survive climate-related changes. Reintroduction of rare species to patches or mountain ranges where they have been lost, as well as to restored areas, would improve their prospects for survival in the future climate.

Ecosystem Group Summary:

This ecosystem is among the most vulnerable to the effects of climate change of any in the state. Communities and species associated with this Ecosystem Group are likely to be affected by changes in temperature and mild winters. Changes in precipitation may not be drastic. However, it is uncertain if fog and cloud cover will change in these high elevation communities, potentially altering moisture from fog deposition. Increased drought or lightening from increased thunderstorms may cause an increase in wildfire, which could actually promote the expansion of rock outcrop community structure around the existing outcrops. As temperatures increase, native and exotic species from lower elevations may be able to invade these areas more easily. Thus, controlling invasive species and protecting or restoring areas is critical to protect these habitats against these threats.

Given the high number of endemics and disjuncts, climate-related changes greatly threaten biodiversity here. Several of the species face outright extinction and others, if lost, are unlikely to ever recover within the region. On the other hand, this ecosystem survived through the Hypsithermal, when temperatures were substantially higher than they are now. Neither these species, nor their ecosystem more generally, should be simply written off as a lost cause. Priority should, instead, be given to several measures that may secure them enough time and space to survive both short term environmental disturbances as well as adapt to longer term changes in the climate. Since virtually all examples of this theme are located on public lands and already managed to preserve their natural features, implementation of recommended interventions should be more feasible than for many of the other themes.

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.