

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

*DRAFT*

## **Upland Seepages and Spray Cliffs**

### **Ecosystem Group Description:**

The communities included in Upland Seepages and Spray Cliffs are wetlands that occur on sloping uplands in the Piedmont and Mountain regions. The soils are generally saturated permanently or for long periods. They are generally fairly small and contrast sharply with adjacent communities, though boundaries may be gradational.

Spray Cliffs are areas kept wet by spray from waterfalls. Most of their area is generally vertical cliffs, but gentle slopes, talus, and soil at the base of cliffs is also included. Vegetation is very patchy, reflecting the patchiness of soil accumulations. The microclimate is generally moderated by the flowing water and sheltered position of the cliffs. Though water flow may vary with rainfall, these are probably among the most stable environments in North Carolina. Trees rooted in crevices and between rocks often grow to large size and may shade the entire area. The bare wet rocks generally have a great diversity of mosses and liverworts. Herbs in small soil pockets include a wide variety of forbs, ferns and sedges.

The other three community types are fed by seepage. Their soils are saturated for much or all of the year, but they are seldom if ever flooded. The rarest type is the Hillside Seepage Bog. These communities, in a few Piedmont locations, are wet enough to have boggy vegetation. The vegetation is generally a patchy mix of shrubs and herbs with an open tree canopy. Many species characteristic of the Coastal Plain occur in these communities. Fire may have played a role in keeping Hillside Seepage Bogs open enough to allow persistence of light-requiring bog species.

Low Elevation Seeps, occurring in uplands or edges of floodplain throughout much of the state, are also very wet but differ in vegetation; the factors which cause these differences are poorly known. Trees such as red maple may be present, or the seep may be shaded by canopy species from adjacent forests. High Elevation Seeps occur in the higher mountains, where they are surrounded by spruce-fir forests, Northern hardwood forests, or grass and heath bald communities. High Elevation Seeps are quite variable in vegetation and setting. Some are open and somewhat boggy, with peat moss, sundews, and even cranberries present. Others are shaded by canopy and more resemble a rich Northern hardwood forest.

## Ecosystem Level Effects:

### Predicted Impacts of Climate Change:

Climate Change Factor:	Likelihood:	Effect:	Magnitude:	Comments:
Increased Temperature	High	Mix	Med	
Wind Damage	Med	Neg	Low	Only forested examples are likely to be affected.
Flooding	Med	Neg	Low	Susceptibility varies widely, but only a minority of examples are likely to be significantly affected.
Drought	High	Neg	Med	Susceptibility of examples to drought varies widely.

This group of communities covers a wide geographic range in the Mountains and Piedmont, and expected climate changes are slightly different within it. At Linville Falls, the Climate Wizard mid value for average annual temperature increase by 2050 is 4.2 degrees (Maurer et al., 2007). The range of models is 2.6 to 6.2 degrees. At Whitewater Falls, in the southern escarpment, the average annual temperature increase is 3.8 degrees, with a model range of 2.6 to 6.0 degrees. In the middle of the Piedmont, at Asheboro, the expected average temperature increase is 4 degrees, with a range of 2.5 to 6 degrees. The mid value rainfall change is slight, with an increase of 1 inch projected in all three places. The range in the models for rainfall is wide: -14 inches to + 16 inches at Linville Falls, -15 inches to +15 inches at Whitewater Falls, and - 14 inches to + 19 inches at Asheboro. The general expectations of increased rain event intensity and increased drought presumably apply to all of this range. However, their effect in the Mountain Region is particularly unsure. Rainfall in the mountains is extremely variable, ranging from about 40 inches per year to more than 80 inches. The variation is produced by the interaction of topography with regional weather patterns, and it is unclear how climate change will affect it.

Temperatures in Spray Cliffs are often moderated by shading cliffs and running water. Moisture is provided by spray and seepage as well as rainfall. Spray Cliffs are also very heterogeneous in moisture availability, ranging from dry sunny rock to constantly wet areas. Seepages are more subject to regional temperature variations, but are have more constant moisture levels than most communities.

The effect of a changed climate is likely to vary widely among examples of these communities, depending on topographic sheltering, configuration of rocks, soil depth, size of groundwater pools, and amount of overland runoff. Parts of Spray Cliffs may be subject to scouring by flooded streams, while seepages on the edges of floodplains may be flooded in extreme rains. Droughts may cause seeps supplied by shallow ground water to dry up. Other examples, or portions of examples, may remain stable despite the changed climate.

Some of these communities serve as refugia for species for which the current climate is not suitable. They are likely to continue to do so, but warming temperature and changed moisture regimes may make some of them less hospitable to some of these species. At the same time, these communities may become refugia for additional species that are currently common, if the regional climate becomes unsuitable for them. They may be crucial for the survival of some species in the state. While moisture levels are probably the most important factor in these communities, some species may be directly affected by increased average or extreme temperatures.

Wind storm damage is a concern only in the seeps that are forested. Most seeps have some tree cover, often leaning in from adjacent forests.

**Predicted Ecosystem Responses:**

Ecosystem Response:	Likelihood:	Effect:	Magnitude:	Comments:
Structural Change	Med	Mix	Low	Only examples with trees as a major component are likely to be affected. Some seeps have increased in tree cover due to fire suppression or other alterations, and loss of tree cover may be positive in some examples.
Compositional Change	Med	Neg	Med	Changing temperatures, moisture fluctuations, and disturbance may affect composition in some examples.
Acreage Change	Med	Neg	Low	A few examples are likely to substantially shrink or disappear, but most likely will not.

These systems are tied to specialized small environments and will be unable to migrate as the climate changes. Ecosystem responses are likely to be extremely variable among examples, because of the extreme variability in sheltering or exposure to changes in the regional climate. Many may change very little, while a few will shrink, will be disturbed by wind or flood, or will change substantially because of temperature changes or drought. A small net loss of acreage may occur, but more seeps may be temporarily affected by drought. Warmer temperatures may cause some species to be lost from some examples, and this may include some of the most unusual and rarest species in these communities. Warmer temperatures may also allow some more southern species to enter these communities, but the small and isolated nature of these distinctive environments will limit movement of species.

**Habitat Level Effects:**

**Natural Communities:**

Third Approximation Name:	Comments:
Spray Cliff	Spray Cliffs are very variable in their configuration. Many are buffered from the regional climate by sheltering cliffs and flowing water. Increased temperatures may or may not affect any given example. Those that are affected may lose species that have used these communities as refugia from a regional climate that is already unfavorable to them. Some examples may be subject to scouring if intensity of floods increases.
Hillside Seepage Bog	Many Hillside Seepage Bogs are suffering from effects of stream downcutting, with corresponding drying and invasion of woody vegetation. Others suffer from lack of natural fire, with corresponding increase in woody vegetation. More extreme rainfall events may exacerbate the problem of stream downcutting. If drought increased wild fire, it might be of benefit to some examples, but fires are generally easy to control in the uplands around these communities.
Low Elevation Seep	These communities vary substantially in constancy and volume of seepage, and effects of drought and heat will vary. More southern species may be able to enter them. Many are subject to invasion by exotic plants in the current climate, and it is unclear if climate change will make this worse. Some Low Elevation Seeps are on the edge of floodplains, and increased intensity of rainfall events might increase flooding of them. Some seeps are only marginally wet, and more prolonged droughts may allow upland species to invade them.
High Elevation Seep	These communities of the cool high elevations are the most likely to be affected by increased temperatures. Some distinctive high elevation species may be lost, while some lower elevation species may be able to migrate into them. Most High Elevation Seeps are not subject to significant exotic species invasion at present, but warmer temperatures may allow some of the exotic species that threaten Low Elevation Seeps to threaten them as well.

## LHI Guilds:

Seepage habitats in the Piedmont and Mountains are treated as subunits within wet or mesic forest guilds rather than as stand-alone units.

## Species Level Effects:

### Plants

Species:	Element Rank:	Endemic	Major Disjunct	Extinction/Extirpation Prone	Status: US/NC	Comments:
<i>Aneura sharpii</i>	G1G2/S1		Yes		/SR-T	Little is known about this liverwort, which is endemic to the Appalachians.
<i>Bryocrumia vivicolor</i>	G1G2/SH		Yes		FSC/E	In US, this species occurs only in NC and SC; also occurs in China and India.
<i>Geum geniculatum</i>	G1G2/S1S2	Yes		Yes	FSC/T	Intrinsically at risk due to rarity; occurs only at 3 mountains in NC and 1 in TN.
<i>Lejeunea blomquistii</i>	G1G2/S1				/SR-L	
<i>Chiloscyphus appalachianus</i>	G1G2Q/S1	Yes			/SR-T	Endemic to NC, SC, and TN.
<i>Hymenophyllum tayloriae</i>	G2/S1S2		Yes		FSC/E	NC is at the northern limit of this species' range.
<i>Plagiochila caduciloba</i>	G2/S2				/SR-T	
<i>Sarracenia oreophila</i>	G2/S1			Yes	E/E-SC	NC is at the northern limit of this species' range, but it is unlikely to move north with warmer temperatures associated with climate change (due to patchy, fragmented habitat).
<i>Juncus caesariensis</i>	G2/S1		Yes		FSC/E	NC is at the southern limit of this species, and it could be extirpated here due to changing climate.
<i>Glyceria nubigena</i>	G2/S2				FSC/T	
<i>Oxyrrhynchium pringlei</i>	G2G3/S1				/SR-D	
<i>Taxiphyllum cuspidifolium</i>	G2G4/S1				/SR-T	
<i>Bryum riparium</i>	G2G4/SH				/SR-D	
<i>Plagiochila echinata</i>	G2Q/S1				/SR-L	
<i>Plagiochila sullivantii</i> var. <i>spinigera</i>	G2T1/S1				FSC/SR-L	
<i>Plagiochila sullivantii</i> var. <i>sullivantii</i>	G2T2/S2				FSC/SR-T	
<i>Lilium grayi</i>	G3/S3	Yes			FSC/T-SC	
<i>Cardamine clematitis</i>	G3/S2				FSC/SR-T	Endemic to NC, TN, and VA.
<i>Parnassia grandifolia</i>	G3/S2				FSC/T	
<i>Aconitum reclinatum</i>	G3/S3				/SR-T	
<i>Radula sullivantii</i>	G3/S2				/SR-L	

<i>Radula voluta</i>	G3/S1	/SR-D	
<i>Sphagnum flavicomans</i>	G3/SH	/SR-T	
<i>Acrobolbus ciliatus</i>	G3?/S1	/SR-D	
<i>Taxiphyllum alternans</i>	G3?/S1	/SR-O	
<i>Ephebe solida</i>	G3G4/S1	/SR-P	
<i>Danthonia epilis</i>	G3G4/S3	FSC/SR-T	
<i>Plagiochila virginica</i> var. <i>caroliniana</i>	G3T2/S1	FSC/SR-T	
<i>Asplenium monanthes</i>	G4/S1	/E	This species on moist sheltered cliffs. It probably is well protected from fire and drought, but likely has little ability to tolerate drought.
<i>Helenium brevifolium</i>	G4/S2	/E	
<i>Huperzia porophila</i>	G4/S2	/SR-P	
<i>Sphagnum pylaesii</i>	G4/S1	/SR-D	
<i>Carex leptonevia</i>	G4/S3	/W1	
<i>Vaccinium macrocarpon</i>	G4/S2	/SR-P	This species reaches its southern range limit in NC, where it has been shown to house important genetic variation.
<i>Carex baileyi</i>	G4/S2	/SR-P	
<i>Cardamine rotundifolia</i>	G4/S2	/SR-P	
<i>Trichomanes boschianum</i>	G4/S1	/T	
<i>Carex barrattii</i>	G4/SH	/E	
<i>Micropolypodium nimbatum</i>	G4?/S1	FSC/E	
<i>Philonotis cernua</i>	G4?/S1	/SR-D	
<i>Dichodontium pellucidum</i>	G4G5/S2	/SR-P	
<i>Solidago uliginosa</i>	G4G5/S1S2	/SR-P	
<i>Grimmia longirostris</i>	G4G5/S1?	/SR-D	
<i>Triantha glutinosa</i>	G4G5/S1	/SR-P	
<i>Veronica americana</i>	G5/S2	/SR-P	
<i>Conioselinum chinense</i>	G5/S1	/E	
<i>Warnstorfia fluitans</i>	G5/S1	/SR-D	
<i>Dicranum undulatum</i>	G5/S1	/SR-D	
<i>Cirriphyllum piliferum</i>	G5/S1	/SR-P	
<i>Spartina pectinata</i>	G5/S1	/SR-P	
<i>Scutellaria galericulata</i>	G5/SH	/SR-P	
<i>Mylia taylorii</i>	G5/S1	/SR-D	
<i>Micranthes pensylvanica</i>	G5/S1	/SR-P	
<i>Epilobium ciliatum</i>	G5/S2	/SR-P	
<i>Phegopteris connectilis</i>	G5/S2	/SR-P	
<i>Didymodon tophaceus</i>	G5/S1?	/SR-O	
<i>Lycopodiella inundata</i>	G5/S1	/SR-P	
<i>Homalia trichomanoides</i>	G5/S1	/SR-P	
<i>Sphagnum squarrosum</i>	G5/S1	/SR-P	

<i>Platanthera grandiflora</i>	G5/S2	/SR-P
<i>Glyceria laxa</i>	G5/S1	/SR-P
<i>Liparis loeselii</i>	G5/S1	/SR-P
<i>Ephebe lanata</i>	G5/S1	/SR-D
<i>Bryoxiphium norvegicum</i>	G5?/S1	/SR-O
<i>Carex oligosperma</i>	G5?/S1	/E
<i>Marsupella emarginata</i> var. <i>latiloba</i>	G5T1T2/S1	/SR-L
<i>Coeloglossum viride</i> var. <i>virescens</i>	G5T5/S1	/SR-P
<i>Carex lasiocarpa</i> var. <i>americana</i>	G5T5/S1	/SR-P
<i>Rhytidiadelphus subpinnatus</i>	GU/S1?	/SR-T

Spray Cliffs support a variety of rare liverworts and mosses, including *Aneura sharpii*, *Lejeune blomquistii*, *Bryocrumia vivicolor*, *Chiloscyphus appalachianus*, *Hymenophyllum tayloriae* and many others. Seeps support additional globally rare species that are restricted to high elevations in the southern Appalachian Mountains, such as *Geum geniculatum* and *Lilium grayi*, as well as many species that reach their southern range limits in NC, such as *Vaccinium macrocarpon* and *Juncus caesariensis*. The species that depend on cool, moist conditions are more likely to be extirpated if warmer temperatures (especially combined with drought) reduce the suitable habitat and/or allow other species to invade the habitat.

Of the changes associated with climate change, rare species in Upland Seepages and Spray Cliffs are probably most threatened by drought. These species occupy cool, moist sites, and while many of the species that range farther south can presumably tolerate warmer temperatures, they need regular moisture and/or moisture at the right time during the phenological cycle.

## Combined Threats and Synergistic Impacts:

### Importance of Climate Change Factors Compared to Other Ecosystem Threats:

Threat:	Rank Order:	Comments:
Groundwater Depletion	1	
Flood Regime Alteration	1	
Development	1	
Climate Change	1	
Invasive Species	1	

Threats to individual seepages and spray cliffs, as well as to the different community types, are extremely variable. They include: invasive plants; death of Canada hemlock trees due to the hemlock woolly adelgid; development on or adjacent to the community; recreational trampling; stream flooding, scouring, or downcutting; depletion of ground water pools that supply seepage; ditching or drainage; increased temperatures in sheltered refugia all represent the greatest threats to particular examples; and vegetational succession in the absence of fire or other natural disturbance. This theme is highly threatened overall, with or without climate change.

## Recommendations for Action:

### Interventive Measures:

Intervention:	Importance:	Feasibility:	Comments:
Restore/Maintain Hydrology Species Reintroduction/Augmentation Reintroduce Species	High	Medium	
Reduce groundwater extraction Preservation of Riparian Buffers/Floodplains Control Erosion	Med	Low	
Protect/Expand Remaining Examples Conduct Prescribed Burns Limit Impervious Surfaces	High	Med	
Control Invasive Species	Mediu		

The importance of all of the intervention measures varies with the importance of the threats. The needs of different examples may be quite different. In general, protection and restoration of natural composition and function, and protection of surrounding natural areas, under current conditions are the best way to improve the ability of these communities to adapt to climate change. Protection of a large and diverse pool of examples is the best way to ensure that many survive the future stresses.

### **Ecosystem Group Summary:**

Climate Change effects and responses will likely be varied among different types of Upland Seepages and Spray Cliffs. However, drought and increased temperature associated with climate change are the most severe threats to Upland Seepages and Spray Cliffs. These habitats support many rare plant species, particularly liverworts and mosses, which are not likely to be able to migrate given their close association with these specialized environments. These communities are also susceptible to invasive species, which may be exacerbated in climate change. Upland Seepages and Spray Cliffs are highly threatened overall by threats such as altered flood regime, groundwater depletion, development, and invasive species. Climate change may pose a significant threat, but no more than these other problems. Conservation needs vary due to inherent variation among sites. Permanently protecting a diversity of Upland Seepages and Spray Cliff sites, including the surrounding natural areas is the best way to ensure resiliency and the ability to adapt.

### **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.