

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

DRAFT

Piedmont Small River Communities

Ecosystem Group Description:

These river communities typically consist of 3rd and 4th order streams and rivers. These small rivers may have fragmented habitats due to mill dams and other similar structures, but are generally too small to have major hydroelectric dams operating on them. Faunal diversity increases significantly in these systems and is typically where a larger and more diverse fish and mussel assemblage is found, as compared to Piedmont Headwater Stream Communities. Examples include: Little River, Eno River, Swift Creek, Uwharrie River, Deep River, Upper Tar River, and Dan River.

Ecosystem Level Effects:

Predicted Impacts of Climate Change:

Climate Change Factor:	Likelihood:	Effect:	Magnitude:	Comments:
Increased Temperature	High	Neg	High	Chronically warmer temperatures and lower dissolved oxygen levels may increase stress on organisms
Hot Spells	High	Neg	High	Low dissolved oxygen associated with hot spells may increase fish kills.
Flooding	High	Neg	High	Increased severity and frequency of storm events, similar to hurricanes, will have impacts.
Drought	High	Neg	High	Lower water levels during dry times will increase stress to the system.

Increased air temperatures may lead to increased water temperatures and potentially lower dissolved oxygen levels. This theme consists of large streams and small rivers, which could experience water quality problems related to increased water temperatures and low dissolved oxygen. Higher air and water temperatures can also lead to increased evaporation, which results in less flowing water available for aquatic species use. Hot spells can have the same effect as overall increased air temperatures but on a much more acute scale. Algal blooms are possible in these systems and can exacerbate dissolved oxygen problems, particularly when flows are low (DeWan et al., 2010; Karl et al., 2009; Band and Salvensen, 2009, U.S. EPA, 2010).

Potential changes in precipitation have numerous and varied effects. Severe and prolonged droughts may decrease streamflow, decrease groundwater recharge, and increase evaporation, resulting in impacts to streams of this theme. Decreases in overall summer precipitation will likely cause reduced water flows,

which will further contribute to warmer water temperatures and further stress water quality. This is particularly important in the context of seasonal droughts because during low-flow periods, nutrients may become concentrated and flush out of systems more slowly (DeWan et al., 2010; Karl et al., 2009; Band and Salvensen, 2009; U.S. EPA, 2010).

Increased storm intensity can lead to flooding and therefore increased stormwater runoff and increased erosion. With increased stormwater runoff there is an increase in loading of sediments, nutrients and contaminants into streams and potential negative effects on biota. With a change in intensity and variability of rainfall, there are potential changes to streamflow patterns, channel hydrodynamics, lake or pond levels, and the volume of groundwater from aquifers (Band and Salvensen, 2009; U.S. EPA, 2010; Bakke 2009). An increase in the number of tropical events can lead to flash flooding, which causes many of the above-mentioned responses. Effects such as increased sediments and contaminants into aquatic systems, in addition to major disruption to channel design and hydrodynamics, potentially upset the physical, chemical, and biological structure of streams (Band and Salvensen, 2009).

Predicted Ecosystem Responses:

Ecosystem Response:	Likelihood:	Effect:	Magnitude:	Comments:
Phenological Disruption	Low	Neg	High	Uncertain if disruptions in organismal interactions (mussel-fish host relationship) will be affected.
Compositional Change	Med	Neg	High	Changes in species composition a possibility.
Channel Hydrodynamics	High	Neg	High	Changes in flow regime will likely result in changes in the overall stream morphology and transport of sediment.
Flow Regime	High	Neg	High	Flashiness of the system may increase with more storm events, thus changing overall habitat composition.
Sediment Transport	High	Neg	High	Changes in streamflow could change overall sediment transport dynamics, leading to altered habitat composition.
Exotic species invasion	Low	Neg	Low	Uncertain how exotic species will affect these systems.

Potential increased air temperatures and therefore increased water temperatures can lead to algal blooms in aquatic systems, which diminishes stream oxygen availability. The increased water temperature alone can cause a decline in dissolved oxygen (DO) and any decline in DO can lead to fish kills, whether as a direct result of increased water temperature or as a secondary effect of algal blooms (DeWan et al., 2010, Band and Salvensen, 2010).

Because of potential changes in storm frequency and intensity, it is likely that channel hydrodynamics will be altered. Associated with channel hydrodynamics are changes in flow regime, sediment transport, and overall channel design. The current pattern of riffles, runs, and pools, may be altered, therefore creating changes in aquatic species' habitats. Increased storm intensity may cause increased erosion and large amounts of sediment moving downstream, which can deposit into pools or bury riffles. Additionally, storms may cause the felling of riparian trees, particularly in areas with narrow riparian areas. Increased woody debris in these streams will also change channel hydrodynamics as well as available habitat. How, or if, species adapt to changing habitats will require close monitoring to observe trends and help inform future management decisions (Bakke 2008).

There are few contiguous blocks of protected habitats in Piedmont small river systems, and therefore they are threatened by land use practices that may increase stormwater runoff of nutrients, sediment, and contaminants. The increased loads could affect water quality and habitat for aquatic species, as well as drinking water for municipalities (Band and Salvensen, 2010).

Aquatic species could experience shifts in their range or distribution and sensitive species may experience decline or extirpation due to changes in water quality and habitat. Aquatic species are particularly sensitive to temperature cues and recent research has shown that many species of freshwater mussels may already be living at the upper thermal tolerances of their early life stages (glochidia and juveniles) (Pandolfo et al., 2010). Extreme temperature events could be especially harmful. These systems may experience a change in species composition due to various changes in habitat and water quality.

Because of the link between freshwater mussels and fish, phenological disruptions are a possibility, but exact mechanisms or effects are unknown at this time. Freshwater mussel larvae, called glochidia, are dependent on a host fish for transformation into juveniles. Host fish species are known for some mussels species, yet unknown for others. Temperature cues play a large role in the release of glochidia from female mussels and also in the movement and migrations of fish. Therefore, with changing temperatures predicted with climate change, there could be phenological disruptions affecting the reproductive capacity of freshwater mussels.

Exotic species invasion is a concern, yet effects on this theme are largely unknown. Asian clam (*Corbicula fluminea*) if found in aquatic systems throughout the state. However, its effects on native mussels are largely unknown. Flathead catfish (*Pylodictis olivaris*) are a concern because of direct predation on native species. The introduction of any invasive species is cause for concern and the prevalence of warmer water temperatures may increase the likelihood of additional exotic species that were previously thought to be non-threatening because the winters were too cold for survival.

Habitat Level Effects:

LHI Guilds:

Species Level Effects:

Aquatic Animals

Species:	NHP Rank:	Endemic	Major Disjunct	Extinction/Extirpation Prone	Status: US/NC/WAP	Comments:
<i>Elliptio steinstansana</i>	G1/S1	Yes		Yes	E/E/P	
<i>Notropis mekistocholas</i>	G1/S1	Yes			E/E/P	

Lampsilis sp. 2	G1/S1	Yes		/SR/
Lasmigona decorata	G1/S1		Yes	E/E/P
Pleurobema collina	G1/S1		Yes	E/E/P
Percina rex	G1G2/S1		Yes	E/E/
Alasmidonta heterodon	G1G2/S1		Yes	E/E/P
Moxostoma sp. 3	G1G2Q/S1		Yes	FSC/T/P
Alasmidonta robusta	G1Q/SX	Yes	Yes	/EX/P
Noturus furiosus	G2/S2		Yes	FSC/T/P
Noturus gilberti	G2/S1			FSC/E/P
Gomphus septima	G2/S1S2		Yes	FSC/SR/
Fusconaia masoni	G2/S1		Yes	FSC/E/P
Toxolasma pullus	G2/S1			FSC/E/P
Villosa vaughaniana	G2/S2			FSC/E/P
Homoeoneuria cahabensis	G2G3/S2			/SR/
Elliptio lanceolata	G2G3/S1		Yes	FSC/E/P
Somatogyrus virginicus	G2G3/S1?			FSC/SR/P
Alasmidonta varicosa	G3/S1			FSC/E/P
Necturus lewisi	G3/S3	Yes		/SC/P
Elliptio roanokensis	G3/S1			/T/P
Orconectes carolinensis	G3/S3	Yes		/SC/P
Elliptio congaraea	G3/S3			/W2,W5/P
Villosa constricta	G3/S3			/SC/P
Etheostoma collis	G3/S3	Yes		FSC/SC/P
Lythrurus matutinus	G3/S3			FSC/W2/P
Leptoxis dilatata	G3/S1			/T/P
Lasmigona subviridis	G3/S1			FSC/E/P
Ambloplites cavifrons	G3/S2			FSC/SR/P

Macdunnoa brunnea	G3G4/S2		/SR/
Lampsilis cariosa	G3G4/S1		FSC/E/P
Etheostoma collis pop. 1	G3T3Q/S3	Yes	FSC/SC/
Etheostoma collis pop. 2	G3T3Q/S2	Yes	FSC/SC/
Tortopus puella	G4/S1		/SR/
Ephemerella berneri	G4/S3		/SR/
Etheostoma podostemone	G4/S3		/SC/P
Alasmidonta undulata	G4/S2		/T/P
Matrioptila jeanae	G4/S3		/SR/
Ceraclea slossonae	G4/S1		/SR/
Moxostoma ariommum	G4/S1		/T/P
Hypentelium roanokense	G4/S3		/SR/P
Cottus caeruleomentum	G4/S1		/SC/P
Moxostoma pappillosum	G4/S4		//P
Ameiurus brunneus	G4/S4		//P
Elliptio cistellaeformis	G4/SU		/W3,W5/P
Etheostoma thalassinum	G4/S3		/W5/
Cyprinella labrosa	G4/S3		/W5/
Notropis chalybaeus	G4/S3		/W5/P
Elliptio fisheriana	G4/S3		/SR/
Nocomis raneyi	G4/S3		/W1/
Villosa delumbis	G4/S3		/SR/P
Cyprinella zanema	G4/S3		/SR/P
Etheostoma vitreum	G4G5/S3		/W5/P
Etheostoma nigrum	G5/S4		//P
Nocomis micropogon	G5/S3?		/W5/
Valvata sincera	G5/S1		/SR/

Strophitus undulatus	G5/S2		/T/P
Moxostoma macrolepidotum	G5/S4		//P
Clinostomus funduloides	G5/S5		//
Lampsilis radiata	G5/S1S2		/T/
Choroterpes basalis	G5/S2		/SR/
Dibusa angata	G5/S2		/SR/
Notropis amoenus	G5/S4		//P
Ceraclea mentiea	G5/S2		/SR/
Carpiodes cyprinus	G5/S1		/SR/P
Moxostoma collapsum	G5/S5		//P
Exoglossum maxillingua	G5/S1		/SC/P
Petromyzon marinus	G5/S3		//P
Elliptio icterina	G5Q/S4		//P
Lampsilis radiata conspicua	G5T2Q/S1?		/T/P
Lampsilis radiata radiata	G5T5/S1S2		/T/P
Alasmidonta sp. 2	GNR/S1?	Yes	/SR/

Combined Threats and Synergistic Impacts:

Importance of Climate Change Factors Compared to Other Ecosystem Threats:

Threat:	Rank Order:	Comments:
Development	1	Direct, secondary and cumulative effects from development.
Pollution	2	Point and nonpoint sources - runoff, endocrine disrupting chemicals - are threats.
Water Withdrawals	2	Irrigation and water supply withdrawals pose a threat to flow regime.
Flood Regime Alteration	2	High and low flow extremes pose a threat.
Cattle in Streams	3	Nutrient and sediment input; bank destabilization.
Logging/Exploitation	3	Clearing of riparian areas is problematic.
Lack of riparian vegetation	3	Loss of riparian vegetation causes numerous problems.
Climate Change	4	Climate change effects will likely compound with other threats to increase the severity of several threats to aquatic systems.

Conversion to agriculture/sylvicu	4	Loss of forest cover can cause increased erosion and sedimentation and negatively impact aquatic systems.
Invasive Species	5	Invasive plants and animals are potential problems, although specific interactions are unknown.
Impoundments	6	Water supply needs could increase number of impoundments; disruptions to flow regime and aquatic habitat.

Aquatic systems have been under threat from a variety of perturbations in the past and many of those continue today. Conversion of land, both from forest to agriculture or silviculture, as well as from development projects, continues to threaten stream integrity resulting in increased sediment, bank erosion, and stormwater runoff containing sediment and other potentially toxic materials.

Erosion and the resultant sedimentation are the largest sources of nonpoint source pollution in most all aquatic systems. Sources of erosion include disturbance from development activities and agriculture. Residential development can increase erosion during the construction process, but also as a secondary result of increased impervious surfaces in the watershed. This area of the Piedmont is highly developed and development continues. Most watersheds have high percentages of impervious surfaces, leading to increased runoff, stream and bank erosion, pollution inputs, and increased flashiness of streams and rivers. Livestock access to streams contributes heavily to bank erosion, sedimentation, and nutrient input. Another source of erosion includes timber harvest if proper erosion controls are not used and maintained, in addition to poorly constructed and maintained timber roads.

Many of the water quality and water quantity impacts resulting from climate change are analogous to impacts from economic development and population growth in North Carolina. Climate change is predicted to decrease rainfall and therefore limit water supply; however, growth and development have been and continue to increase water supply demands. Historical streamflow patterns are projected to be altered due to climate change impacts; however, these are already being altered due to rapid urbanization. An increase in impervious surfaces due to roads, parking lots, homes, and businesses increases the amount and speed of runoff being delivered into aquatic systems. Additionally, decreased groundwater recharge between storms due to impervious surfaces leads to a decrease in stream baseflow. Runoff from urban areas often contain higher concentrations of nutrients, such as nitrogen and phosphorus, sediment, metals, hydrocarbons, and microbes. An increase in frequency and intensity of storms due to climate change will have a similar impact on stream systems by increasing pollutant loading. Therefore, challenges to water quality and water quantity as related to climate change are similar to those being confronted to accommodate growth and development. Adaptation strategies for water resource management could limit negative effects of both climate change and continuing development (Band and Salvensen, 2009).

Riparian vegetation is critical to the overall stream and streambank stability. Lack of riparian vegetation or inadequate width of forested buffer can cause streambank erosion and sedimentation. In addition to stabilizing streambanks, riparian vegetation serves as a food/nutrient input to the stream community and helps regulate stream temperature by providing shade.

Invasive plants in the riparian area can have negative impacts on stream systems by often times creating a monoculture with poor nutrient inputs, reducing bank stability, and allowing too much sunlight and therefore warmer stream temperatures. Invasive aquatic species, like Asian clam, may have negative effects on native species, such as competition for space and resources. However, specific interactions are largely unknown at this time.

Recent studies have shown that endocrine disrupting chemicals (EDC) in treated wastewater can inhibit

reproduction and cause feminization of mussels and fish. Although little is known about the effects of EDCs, additional studies are being conducted to document the levels of EDC's in discharges, and measures are being identified to reduce or eliminate EDC's from wastewater prior to discharge, should those discharge studies show increases in EDC levels (Conn et al., 2006; Kim et al., 2007; Kasprzyk-Hordern et al., 2008; Joss et al., 2006; Kolpin et al., 2002; Nowotny et al., 2007).

As humans seek to adapt to climate change by manipulating water resources, streamflow and biological diversity are likely to be reduced. During droughts, recharge of groundwater will decline as the temperature and spacing between rainfall events increase. Responding by increasing groundwater pumping will further stress or deplete aquifers and place increasing strain on surface water resources. Additionally, water withdrawals related to agriculture may increase, which could further stress surface water resources. Water withdrawals can be problematic, particularly in streams with already low 7Q10 flows, because they may reduce available habitat for aquatic species.

Impoundments have direct and indirect impacts on aquatic systems. Many rivers that were once free-flowing are now flooded by reservoirs, severely fragmenting habitat and often isolating populations of species above and below the impoundment. For the unimpounded reaches there are several indirect effects, such as disruption of natural thermal and hydrologic regimes. Drought conditions over the past several years have required many municipalities to evaluate their water supply and demand. An increase in the number of proposed reservoirs is a potential consequence of reduced water supply and streams within this theme will likely be the most impacted in the state. Downstream flows could be reduced, having a negative impact on aquatic habitat as well as drinking water for downstream municipalities.

Recommendations for Action:

Interventive Measures:

Intervention:	Importance:	Feasibility:	Comments:
Water Resources Management	Mediu	Medium	
Control Erosion	High	High	
Bridge/Culvert Design	Mediu	Medium	
Increased Open Space	High	Medium	
Stormwater Management	High	High	
Limit Impervious Surfaces	High	Medium	
Preservation of Riparian Buffers/Floodplains	High	Medium	
Research and Monitoring	Mediu	High	
Species Reintroduction/Augmentation	Mediu	High	
Restore/Maintain Hydrology	High	Medium	
Restore/Maintain Landscape Connections	High	Low	
Eliminate/Prevent Pollution	High	High	

Erosion Control

Erosion control is critical to protecting waterways from excessive sedimentation. Slowing storm runoff before it enters a stream dissipates energy and allows more time for sediment deposition outside the stream channel (Shuford et al., 2010). There are numerous actions that can be taken to aid in erosion control.

Streambank erosion is much more likely in areas where riparian vegetation is scarce or lacking altogether. The preservation or restoration of riparian vegetation is crucial to the maintenance of stable streambanks, in addition to the role that riparian vegetation serves to dissipate water runoff energy and allow for sediment deposition. The implementation of various types of agriculture and forestry best management practices (BMPs) can aid in erosion control. For example, fencing livestock to prevent direct access to streams prevents accelerated erosion with higher stream flows. Typically areas used for livestock access have exposed banks and are devoid of vegetation, therefore precipitation events can lead to increased scour, and hence erosion and sedimentation. In addition to helping with erosion control, the fencing of livestock can reduce nutrient inputs to the aquatic system (NC Wildlife Resources Commission, 2005).

Bridge and Culvert Design

The effects of climate change impacts, particularly increases in precipitation, should be taken into consideration when designing bridges and culverts to allow for stream movement and aquatic organism passage. Design standards may need alteration to accommodate environmental changes due to climate change (Transportation Research Board, 2008).

Protect Floodplains and Wetlands

Floodplains and wetlands are natural features designed for flood control and dissipating flood waters. Floodplain development interferes with this natural capacity and worsens downstream flooding, scour, and erosion. Floodplain and wetland protection and preservation provide a natural and economical means for flood water attenuation, which can save human lives and property, in addition to sustaining aquatic ecosystems. Changes in flood patterns (frequency and duration) and flooded lands may periodically require updating flood maps to ensure protection of life and property (Band and Salvensen, 2009).

Support Land Conservation

Land conservation or preservation can serve numerous purposes in the face of anticipated climate change but overall it promotes ecosystem resilience, such as: protecting watersheds for clean water, flood attenuation, and decreased erosion and sedimentation; providing ecological corridors for species movement throughout the landscape in response to changing habitats; preserving existing habitats to help prevent forced migration (Band and Salvensen, 2009). With potential changes in habitats, connectivity that allows for species and ecosystem migration is crucial and can be accomplished through protection of potential migration corridors. Another important benefit of land conservation is the role that natural areas can play in carbon sequestration. Land conservation tools to be used include easements, use-value taxation, and fee simple purchase (Shuford et al., 2010).

Land Use Planning

Land use planning and land conservation go hand in hand. Green infrastructure is a tool to be used in planning to set aside such things as natural areas, habitat corridors, and recreational areas for a community. Carbon sequestration by natural landscapes can slow or inhibit its atmospheric concentration. Therefore, conservation activities such as preserving forests and open space, farm land and rural landscapes, park lands, managing open lands, and planting trees and vegetation in urban areas can aid in carbon sequestration (Shuford et al., 2010).

Aquatic Species Research

Monitoring of aquatic taxa is critical to assessing species and ecosystem health and in gauging resiliency of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. In addition to monitoring, there are several research questions that need to be answered about certain species or taxa of aquatic organisms. Many have unresolved taxonomic issues that should be

studied before proper management can occur. Also, there are numerous aquatic species that lack life history information, which can be critical in determining future management and needs of a species (Band and Salvensen, 2009; NC Wildlife Resources Commission, 2005).

Translocation/Propagation Techniques

Aquatic species propagation is an area of current and ongoing research. Developing techniques for propagation of species, particularly those that are rare, at high risk of extinction or extirpation, and are difficult to propagate in a laboratory setting, are critical for preserving those species and their genetic stock. Propagation facilities can serve as gene banks for aquatic species. Translocation, or moving aquatic species to different habitats, is another related area of needed research. Translocation can involve augmentation or reintroduction of species. Augmentation refers to adding a species to an area in which it already occurs, to aid in recruitment within the existing population. This technique can be useful for rare species populations that are too sparse for successful reproduction in the wild. Reintroduction refers to moving species to an area that currently does not support the particular species, but is within the historical range of the species. Augmentation and reintroduction are techniques that have been and are currently being used, for example, in areas where there have been significant improvements in water quality or available habitat for various reasons and species are either slow to or unable to recolonize the area on their own. Refinement of these techniques and careful monitoring of habitats that may worsen or improve over time will allow for successful intervention and the hopeful continuation of a full suite of aquatic species. Introduction of species to streams or river basins outside of historical ranges is generally a poor practice and should be avoided unless there is sufficient justification for such management activities. Guidance for mollusk population restoration and conservation has recently been finalized for the Cumberlandian region (NC Wildlife Resources Commission, 2005; Cumberlandian Region Mollusk Restoration Committee, 2010).

Stormwater Management

Stormwater management serves the purpose of reducing the amount of sediment, nutrient, and volume of runoff that enters streams. It can be managed by human-made structures, natural means, or by taking actions within the watershed to reduce the amount of runoff. Stormwater management techniques should strive to restore or maintain the pre-development hydrograph. Riparian vegetation acts as a natural control for stormwater management by filtering sediment and pollutants from runoff and by dissipating the velocity of runoff before it enters a stream (Shuford et al., 2010). Structures such as bioretention cells (i.e., rain gardens), cisterns, permeable pavement, runnels, vegetated swales, and filter strips can be used in various ways as stormwater best management practices (BMPs). These types of structures promote infiltration and natural recharge of groundwater and also surface waters (Shuford et al., 2010). Because impervious surfaces are the cause of increased volume and velocity of runoff, imposing impervious surface limits is a way to combat the problem at its source. Research has shown that at levels of 8-12% imperviousness, major negative changes in stream condition occur (Wang et al., 2001). Impervious surface impacts on stream systems can be mitigated by the maintenance or establishment of natural forested areas in riparian zones (Miltner et al., 2004, Moore and Palmer 2005; Low Impact Development (LID) Practices, 2010)

Water Resources Management

Water resources management could be an area heavily impacted by varying conditions related to climate change. Many towns and municipalities receive their drinking water from surface water – either free-flowing or impounded rivers. If precipitation and flow patterns change, it could affect intake structures and the amount of water that can be removed from the system, while still maintaining adequate flow for aquatic life. Water treatment and wastewater treatment systems may require modifications to handle varying flows and conditions that may result due to climate change. Discharge permits may need revisions since they are based on flow conditions at the time of issuance; if flows decrease and the 7Q10 is lowered, discharge

amounts may require modification to allow for sufficient dilution and mixing. Drought management may become increasingly important and water use efficiency will be imperative. Additionally, many reservoirs are used for hydropower and/or flood control. Changes in precipitation patterns may affect dam operations and require appropriate modifications to protect health, safety, and aquatic life. In addition to the above management options, other water resources management approaches (most of which have been discussed in previous sections) may include: green infrastructure, open space, native species plantings and/or xeriscaping, water conservation, and alternative water sources (Shuford et al., 2010).

Riparian Habitat

The riparian area, or area of land adjacent to water bodies, serves numerous functions including many already mentioned above. Riparian areas with forested vegetation have a greater capacity to serve these numerous functions, compared with riparian areas of grass, little mature vegetation, or no vegetation. Functions of riparian areas include: stabilize streambanks and therefore provide erosion control, allow for sediment and pollutant deposition (by dissipating energy from runoff and allowing for filtration), infiltration of water runoff to allow for groundwater recharge, stream temperature regulation by providing shade, flood control by attenuating storm flows, carbon sequestration by mature woody vegetation, increase stream habitat complexity by contributing woody debris, provide habitat for terrestrial wildlife species, and serve as corridors for movement of terrestrial wildlife species (Seavy et al. 2009; NC Wildlife Resources Commission, 2002; Wenger 1999).

Riparian areas are important for aquatic ecosystem health, in general, but they can also help mitigate for and provide resilience against climate change effects. Riparian vegetation is more resilient to flooding and drought than more upland vegetation and should be restored in areas where it is lacking to establish native vegetation and manage for genetic diversity. Habitat connectivity is a function of riparian areas already mentioned, but it becomes increasingly important in the face of climate change. Riparian areas can serve as movement corridors and because they occur along streams, can increase connectivity between habitats and across elevational zones. There is a linkage between aquatic and terrestrial systems through the riparian area. Riparian vegetation traps pollutants and sediments and helps protect water quality, while the nutrient rich aquatic systems support vegetation and habitat for wildlife species. By maintaining or restoring these riparian areas, it increases the resiliency of both aquatic and terrestrial systems and makes them more resistant to climate change. Riparian areas serve as a thermal refugia because they provide stream shading but also because they have a higher water content than upland areas. Therefore, animals with thermoregulatory limitations have refugia which will become increasingly important with anticipated increases in air temperatures. Riparian areas serve hydrological benefits because they promote water infiltration and help mitigate against flooding events. By maintaining the floodplain and restoring vegetation in these areas, flooding impacts can be lessened without using structural controls. In areas where riparian vegetation is lacking or does not consist of forested vegetation, riparian restoration or establishment is necessary. Because future conditions are unknown, it is suggested to plant riparian areas with vegetation with a broad elevational range within a particular watershed and also to plant vegetation with broad hydrologic tolerance to promote resiliency from climate change. Riparian areas can enhance ecosystem resilience and therefore mitigate against negative impacts from climate change (Seavy et al. 2009)

Ecosystem Group Summary:

Climate change is likely to have a synergistic effect with other, more impending threats to these systems, such as development and lack of/removal of riparian vegetation. Piedmont small river systems will probably persist. Very few specific climate change-related impacts have been identified, and the rare species and their habitats are expected to persist.

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