

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

DRAFT

Piedmont Headwater Stream Communities

Ecosystem Group Description:

This Ecosystem Group includes first order and second order streams of the Piedmont, in addition to intermittent streams. Headwater streams are very important elements in the stream and river networks in terms of influencing water quality and quantity. In fact, the majority of land (approximately 80-85%) area drains to headwater streams (Gregory 2009) and headwater streams constitute at least 80% of the nation's stream network (Meyer et al., 2003). Species diversity tends to be a bit lower in these systems, with benthic macroinvertebrates being a very important component of the community. Fish assemblage is typically lower than in small river systems and mussels are often absent from these headwater streams. Examples include: Morgan Creek, Parkers Creek, Little Creek, and White Oak Creek, although many streams in this theme are unnamed tributaries.

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 Ecosystem Group consists of headwater streams, those that are first or second order, or intermittent streams, and because of their small size makes them extremely susceptible to water quality problems related to increased water temperatures and low dissolved oxygen. Higher air and water temperatures can 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. These stream systems are vitally important to the overall health of the downstream watershed, yet are likely to experience potentially severe physical, chemical, and biological changes with temperature and dissolved oxygen alteration (DeWan et al., 2010; Karl et al., 2009; Band and Salvensen, 2009).

Potential changes in precipitation have numerous and varied effects. Severe and prolonged droughts may decrease streamflow, decrease groundwater recharge, and increase evaporation, resulting in major impacts to streams within this Ecosystem Group. Decreases in overall summer precipitation will likely cause

reduced water flows, which will further contribute to warmer water temperatures and further stress water quality. Additionally, these headwater streams could dry up, potentially leading to aquatic species extirpation (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 and channel hydrodynamics (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:
Compositional Change	Med	Neg	High	Changes in species composition a possibility.
Channel Hydrodynamics	High	Neg	High	Changes in channel morphology and streamflow could change overall habitat composition.
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.

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. These effects are highly likely in Piedmont headwater streams, in addition to complete drying of streams during drought conditions (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. Changes may occur in aquatic species' habitats and how, or if, these species adapt to changing habitats will require close monitoring to observe trends and help inform future management decisions (Bakke 2008).

The majority of these headwater streams are in private ownership and therefore 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 (Band and Salvensen, 2009).

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. Piedmont headwater streams are already vulnerable to drought conditions with low dissolved oxygen or partial or complete drying of streams; climate change-induced drought will only increase this vulnerability. Aquatic species could become extirpated or may move further downstream into higher order streams. Therefore, these systems may experience a change in species composition.

Habitat Level Effects:

LHI Guilds:

Species Level Effects:

Plants

Species:	Element Rank:	Endemic	Major Disjunct	Extinction/Extirpation Prone	Status: US/NC	Comments:
Cardamine micranthera	G2/S1	Yes		Yes	E/E	Very vulnerable to changes in hydrology that would cause drying of the habitat.
Plantago cordata	G4/S1		Yes	Yes	/E	In NC, this species occurs in only two populations.

Few rare aquatic plant species are found in Piedmont Headwater Communities, but the two rare plants species associated with these systems are extremely rare in North Carolina. Small-anthered bittercress (*Cardamine micranthera*) is globally restricted to just one watershed on the NC/VA line (the upper Dan River), and usually occurs in the first-order streams, where it is very susceptible to changes in hydrology that would alter the habitat. Currently, no sites are protected. Heartleaf plantain (*Plantago cordata*) is known from several states in the eastern United States, but it is scattered and rare in every state in which it occurs except Missouri. The two NC populations have been found to "represent sites of primary [conservation] concern with unique genetic composition" (Mymudes & Les 1993 in Weakley 2010). Changes in hydrology (especially drying of these small streams) could cause habitat to become unsuitable.

Aquatic Animals

Species:	NHP Rank:	Endemic	Major Disjunct	Extinction/Extirpation Prone	Status: US/NC/WAP	Comments:
<i>Cambarus lenati</i>	G2/S2				/SR/P	
<i>Barbaetis benfieldi</i>	G2G4/S1				/SR/	
<i>Macromia margarita</i>	G3/S2S3				FSC/SR/	
<i>Cambarus davidi</i>	G3/S2S3				/SR/P	
<i>Cambarus catagius</i>	G3/S2				/SC/P	

Thoburnia hamiltoni	G3/S1	FSC/E/P
Notropis chlorocephalus	G4/S3	/W5/
Diplectrona metaqui	G4G5/S3	/SR/
Triaenodes marginatus	G5/S3	/SR/
Lampetra aepyptera	G5/S2	/T/P

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.
Climate Change	2	Piedmont headwater streams may shrink in habitat or extent.
Lack of riparian vegetation	2	Loss of riparian vegetation causes numerous problems.
Logging/Exploitation	2	Clearing of riparian areas is problematic.
Flood Regime Alteration	3	High and low flow extremes pose a threat.
Invasive Species	4	Invasive plants and animals are potential problems, although specific interactions are unknown.
Cattle in Streams	4	Nutrient and sediment inputs; bank destabilization.
Pollution	5	Point and nonpoint sources - runoff, endocrine disrupting chemicals - are threats.

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. 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 and available aquatic habitat.

Recommendations for Action:

Interventive Measures:

Intervention:	Importance:	Feasibility:	Comments:
Control Erosion	High	High	
Eliminate/Prevent Pollution	High	High	
Increase Open Space	High	Medium	
Stormwater Management	High	High	
Limit Impervious Surfaces	High	Medium	
Restore/Maintain Hydrology	High	Medium	

Preservation of Riparian Buffers/Floodplains	High	Medium
Restore/Maintain Landscape Connections	High	Low

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).

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).

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).

Riparian Habitat

The riparian area, or area of land adjacent to waterbodies, 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 effects, especially drought and higher temperatures, will likely have a significant impact on headwater stream communities, possibly creating a shift where several perennial streams will become intermittent or ephemeral systems. This potential shift will result in the loss of aquatic species diversity in the piedmont areas of North Carolina.

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