North Carolina's RIPARIAN BUFFERS:

A Scientific Review

Excess nitrogen and phosphorus contribute to fish kills downstream, such as this kill of over 100,000 fish along Flanner's Beach on the Neuse estuary in 2014.

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Executive summary

In response to extensive fish kills in the Neuse estuary in the late 1990s, the North Carolina legislature directed state regulators to develop cleanup plans for a series of waters – estuaries and reservoirs – burdened by excessive nitrogen and phosphorus pollution. Those cleanup plans include rules that limit clearing of riparian buffers, forested strips of land adjacent to streams, rivers, lakes, and estuaries. Because the rules limit activities on private property, development interests have periodically questioned whether riparian buffers are genuinely needed to protect water quality.

In the nearly two decades since the NC General Assembly mandated protection of riparian buffers, scientists have honed our understanding of how buffers work, and by extension, what state rules must do to keep riparian buffers functioning, and keep North Carolina's waters compliant with state and federal water quality standards. This report revisits the topic, offering an up-to-date overview of riparian buffer science.

The scientific literature shows that riparian buffers deliver multiple benefits: removal of pollutants, including excess nitrogen, phosphorus, and sediment; drinking water protection; wildlife habitat; bank stabilization; flood control; and shade that moderates water temperature for fish.

Our survey of research offers these key findings:

- Buffer width is crucial: riparian buffers with widths of 100 ft to 165 ft have been found to reduce total nitrogen loadings to streams by as much as 85% or more.
- Pollutant removal efficiencies decrease sharply as buffer width decreases. North Carolina research in the Neuse basin coastal plain found that 49 ft buffers reduced nitrogen by 48%, while 26 ft buffers only reduced nitrogen by 28%.
- For 50 ft buffers such as those currently required by state rules, North Carolina research indicates that the factors most directly shaping their effectiveness are whether they have a high water table and extensive woody vegetation.
- Beyond sufficient width, effective riparian buffers need:

  Hydrology. Groundwater table height and movement strongly influences nitrogen removal. Because groundwater flows can shift seasonally and over time, buffer protections should extend along the length of waterways and not just apply at selective spots.

  Natural vegetation. The soil microbes that permanently remove organic nitrogen need leaf litter provided by trees and shrubs. Natural vegetation also slows surface runoff, allowing removal of phosphorus and sediment before waters reach protected waterbodies.

  Trees, especially in the 15 feet of buffer closest to the water. Trees are important for bank stabilization, erosion prevention,

Excess nitrogen and phosphorus trigger algal blooms that can harm fisheries, damage quality of life for nearby residents, and place drinking water at risk. PHOTO © HEATHER DECK and flood control that protects downstream landowners. In the zones closest to streams and rivers, trees provide shade and keep buffered waters cooler, reducing algal blooms and preventing fish kills.

The scientific review supports these policy recommendations:

- Fifty foot, naturally vegetated buffers should remain in place along perennial and intermittent streams, rivers, lakes, and estuaries in watersheds that are impaired by or sensitive to nutrient or sediment pollution.
- Crossings of and surface flows into these buffers should be managed to prevent the creation of channels that circumvent the buffer. As much as allowed by existing uses, buffers should be protected along the length of tributaries, without new exemptions that punch holes through the protection provided by the buffer.
- On-site stormwater management should continue to be required for development that impacts buffers. Time-tested measures such as level spreaders, constructed wetlands, bioretention areas, and wet ponds followed by level spreaders for more intensive development are critical measures to ensure that the buffers function properly and remove pollutants.
- Much of the research on riparian buffers has been carried out in North Carolina's coastal plain and lower Piedmont. Other forms of buffers may be needed in watersheds elsewhere, given different slopes, soils, and patterns of groundwater flow.
- To the extent that local governments conclude that wider buffers are needed to better control nitrogen and to protect the biological, physical, or chemical integrity of waterways, the available science supports those local ordinances.
- When impacts to buffers are allowed with mitigation requirements, the mitigation must offset the loss in treatment of both surface and groundwater flows.
- When federal or state funds are being spent to restore riparian buffers, funding should, where possible, prioritize restoration of buffers on wet soils that will intercept nutrient-laden surface and groundwater flows.
- Protection of existing riparian buffers upstream from impaired waters provides a cost-effective hedge against further increases in pollution. To clean up those waters, buffer protections must be paired with other measures – wastewater treatment plant upgrades, stormwater control standards for developed area, reductions in runoff from farmland – that reduce pollution at the source.

After nearly two decades of implementation in parts of North Carolina, riparian buffers remain the most effective and cost-effective tool to keep nitrogen and phosphorus pollution out of our waterways. North Carolina is not alone in facing the problem of nutrient pollution in major waterbodies. Just to our north, the states bordering the Chesapeake Bay have embarked on an extraordinarily complex cleanup of that estuary. Last year the agency overseeing that cleanup concluded:

> Riparian forest buffers provide critical barriers between polluting landscapes and receiving waterways using relatively little land…Per acre, they likely provide more benefits and are more cost-effective than any other BMP [best management practice], especially when considering the added value of habitat at the critical juncture of land and water.

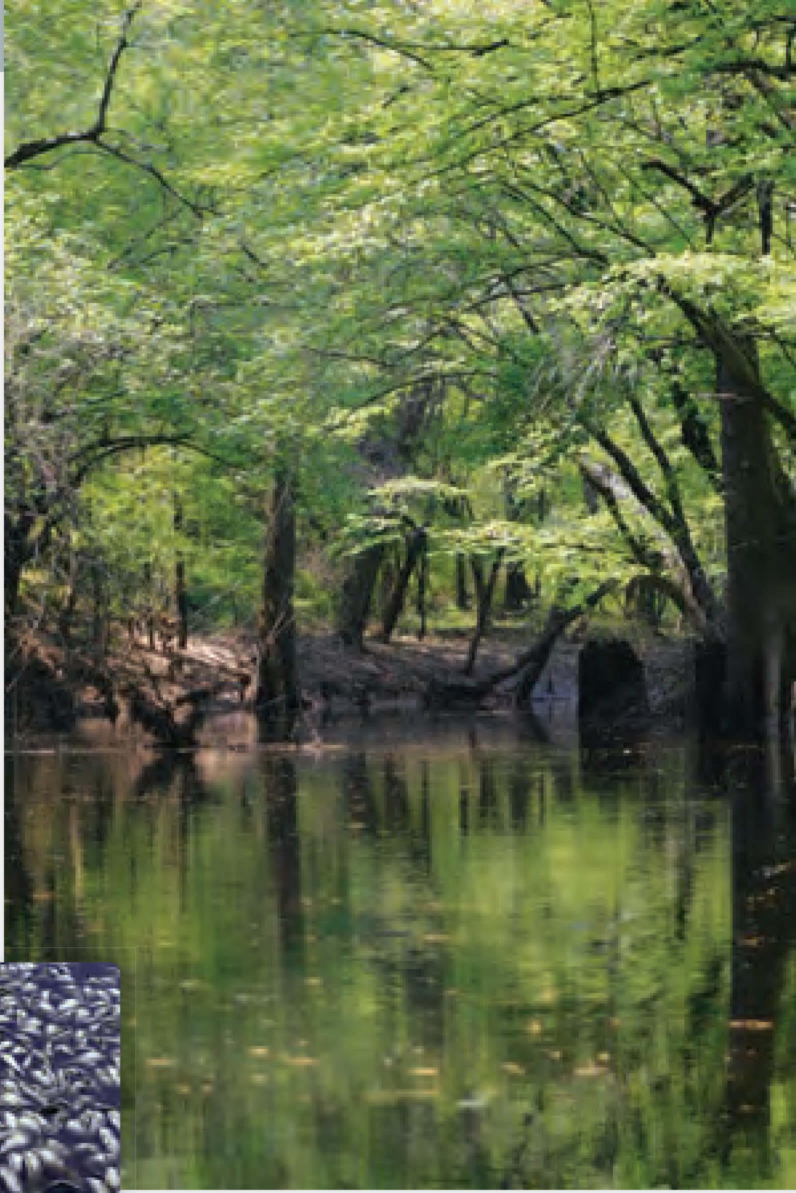
To protect the Bay, the six states are seeking to restore 100 ft buffers along 70% of the Bay's tributaries at a rate of 900 stream miles each year. In contrast, North Carolina's existing buffer rules offer the opportunity to keep existing buffers in place. That, in turn, will protect water quality (and downstream property values) from further declines, and will avert much larger costs to fix North Carolina's impaired lakes and estuaries in the future. North Carolina's buffer protections are worth retaining.

Water quality in our estuaries and coastal rivers, such as the Pungo River shown here, depends on protection of buffers throughout the watersheds upstream. PHOTO © HEATHER DECK

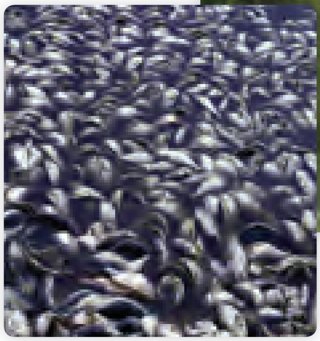
On August 12, 1995, the Raleigh News & Observer ran this front page headline: "Dramatic Fish Kills Trouble Scientists", describing one of several massive fish kills on the Neuse River that summer and fall.[1] The article quoted a local resident from a crabbing family who went out on the water with his daughter: "It looked like the end of the world… the whole creek was just sheeted with dead fish."

Appalled by conditions in the Neuse estuary, the NC Environmental Management Commission framed a broad-based plan to reduce the nitrogen pollution feeding algal blooms and causing fish kills in the estuary. After further negotiations, the NC General Assembly approved the plan and established a statutory framework for similar plans for other waters in 1997. In the nearly two decades since, packages of rules have been adopted under that authority to address nutrient-driven impairment of water quality in the Tar-Pamlico river and estuary, in Jordan Lake, and in Falls Lake; to prevent impairment of water quality in Randleman Reservoir; and in portions of two other watersheds (see the sidebar, *Riparian buffer rules: content and recent history*).

Each of these packages of rules has relied on protection of 'riparian buffers' – forested strips of land adjacent to state waters – to keep water quality from getting worse. These riparian buffers account for less than 1% to 2.5% of the land area in the affected watersheds, but play an outsized role in keeping nitrogen and phosphorus pollution out of North Carolina's waterways.
Over the past 30 years, substantial scientific research has shown that riparian buffers are an effective method for reducing nutrient pollution in runoff and groundwater that enter streams and rivers.[2]



Above: River and protected buffer along Otter Creek in the upper Coastal Plain, Tar river basin PHOTO © HEATHER DECK



Left: Excess nitrogen and phosphorus contribute to fish kills downstream, such as this kill of over 10,000 fish at Crystal Beach on the Pamlico in October 2012. PHOTO © HEATHER DECK

This report reviews the science that informs North Carolina's riparian buffer protection rules. We start with a discussion of why control of nitrogen matters, then examine the factors that make a riparian buffer effective at removing nitrogen. The report considers the role of riparian buffers in controlling phosphorus, and examines some of the other benefits of riparian buffers, including sediment and flood control and provision of habitat for fish and wildlife.

Why nitrogen matters: the nitrogen cycle

To understand how buffers remove nitrogen, it is helpful to understand how riparian buffers fit into the nitrogen cycle, the path nitrogen follows from the atmosphere into living organisms and back again. Most nitrogen is in the form of nitrogen gas (N_2), which is colorless and odorless, and forms roughly 78% of Earth's atmosphere by volume. Atmospheric nitrogen is naturally converted to ammonia (NH_4), and from that into various other forms that plants can use, including nitrites (NO_2) and nitrates (NO_3). As animals eat the plants, or eat other animals, that organic nitrogen moves through the food chain. When the plants or animals die, or excrete wastes, some is recycled by other plants and animals; some is decomposed by microbes that release it back into the air as nitrogen gas.

Over the last century, humans have significantly altered this

natural cycle, pulling nitrogen out of the air for use in fertilizers and explosives. On the one hand, this has allowed for massively expanded crop yields, feeding a growing global population. On the other, it means we have added a great deal of momentum to the nitrogen cycle. Combustion of fossil fuels has also added to the natural nitrogen cycle through the emission of nitrogen oxides (NO, NO_2, NO_3) that drift or rain from the sky and are carried into waterbodies in stormwater runoff. In America today, human activities pump roughly *four times* more nitrogen into the environment than natural nitrogen-fixing processes.[3]

Both on land and in water, nitrates boost plant growth. In flowing streams, that growth takes the form of periphyton, algae and microbes growing on rocks underwater. In slower rivers, lakes, or estuaries, algae blooms in the water column. Some algae release toxins that can injure fish and wildlife and render water unsafe for people to drink or swim in.[4] When algae die, the microbes that decompose them use up oxygen in the water, creating de-oxygenated 'dead zones' where fish and shellfish cannot breathe.[5] This can lead to massive fish kills, of the kind that prompted enactment of the Neuse buffer rules.

Buffers fit into the nitrogen cycle by absorbing and processing biologically active nitrogen before it reaches the water and causes algal blooms or fish kills. Even without human additions to the nitrogen cycle, riparian buffers would play a key role in keeping our waterways healthy. But buffers' filtering function has become all the more vital as human activities have massively increased the nitrogen carried by runoff from fertilized farm fields and lawns, and by stormwater from developed areas. When buffers are paved over, or simply cleared of trees and shrubs, that extra nitrogen flows into rivers and estuaries, with serious consequences downstream.

Saturated soils remove nitrogen most efficiently, as in this floodplain forest along the Neuse River. PHOTO © GRADY MCCALLIE

How riparian buffers control nitrogen

Riparian buffers receive surface and groundwater flows. If the buffer is wide enough, surface flows have time to sink into the soil. Under the surface, natural processes remove nitrogen pollution from groundwater, as documented by substantial research in North Carolina and elsewhere.[6] Riparian buffers remove nitrate and ammonium through two chemical processes: denitrification, where the nitrogen is permanently released back into the atmosphere;[7] and uptake by growing microbes and plants, where the nitrogen is held for a time and then released when the microbe dies or the plant loses its leaves.[8] Much riparian buffer research has sought to identify conditions that maximize these two process, particularly denitrification.[9]

Repeatedly, research has shown that the key factors needed to sustain denitrification are naturally-occurring denitrifying bacteria; low-oxygen groundwater; a quality source of carbon (leaf litter); suitable temperatures; and suitable soil pH (roughly neutral, not too acidic or basic).[10]

Most denitrifying bacteria can live with or without oxygen. However, they do their best work – converting organic nitrogen back into nitrogen gas – when the water table is high and oxygen is not readily available.[11] Thus, fluctuations in the water table under the buffer can significantly affect the amount of nitrogen the buffer can remove.[12] When submerged, the bacteria need ready supplies of organic carbon,[13] which means it is important to have plenty of litter

NORTH CAROLINA'S BUFFER RULES: CONTENT AND RECENT HISTORY

Today North Carolina has rules protecting riparian buffers in six watersheds: the Neuse River basin (effective 1997), Randleman Lake watershed (1999), Tar-Pamlico River basin (2000), Catawba River basin (2001), Goose Creek watershed (2009), and Jordan Lake watershed (2009).

Under the federal Clean Water Act, states must set water quality standards that, if met, will sustain uses of various waters for fishing, swimming, or drinking. When waterbodies fail to meet those standards – as have the Neuse and Pamlico estuaries, along with the Jordan and Falls reservoirs – the state must develop a plan to control pollution and restore water quality in the impaired waters. The buffer rules in the Neuse, the Tar-Pamlico, and Jordan Lake watersheds are part of nutrient management strategies designed to bring the estuaries and reservoir back into compliance with state water quality standards and the federal Clean Water Act. Falls Lake reservoir also has a nutrient management strategy, but as it lies entirely within the Neuse basin, the Neuse buffer rule already provides for protection of buffers in the Falls watershed.

The buffer rule for Randleman is designed proactively to protect water quality in Lake Randleman, a drinking water reservoir that serves Greensboro. The Catawba buffer rule is unusual, applying only to lakeshores and the main stem of the river from Lake James to the South Carolina border; because it does not include tributaries, it misses much of the pollution that enters the system through those, and provides only limited water quality benefits. The Goose Creek buffer rule was designed to protect endangered mussels from the impacts of development, and differs significantly from the other rules.

The US Department of Agriculture recommends an 95 foot, three zone buffer to protect water quality: 15 feet of undisturbed forest closest to the water, 60 feet of forest with limited disturbance (timber management and mowing, for example), and 20 feet of grass filter strips, where mowing and grazing are allowed.[1]

North Carolina's approach has been weaker: a 50 foot, two zone buffer: 30 feet of 'natural vegetation' adjacent to the protected water, and an outer 20 feet where a greater range of impacts are are allowed. The Goose Creek buffers are an exception, requiring 100 foot to 200 foot undisturbed buffers. While North Carolina's riparian buffer rules vary slightly from basin to basin, all have a similar three-part structure: a buffer rule proper; a rule outlining procedures for delegation of implementation to local governments; and a mitigation rule. Each buffer rule includes a 'table of uses' that explains what activities are exempt, allowed, allowed with mitigation, or prohibited in each zone of the buffers in that watershed.

All of the buffer rules, with the exception of the Catawba rule, apply to intermittent and perennial tributaries as well as lakes and estuaries. Several rules under other North Carolina laws require 'vegetated setbacks'; unlike the riparian buffer rules, these are not intended to filter nutrient pollution, and so they are usually narrower – 30 feet instead of 50 feet – and do not require natural vegetation.

Over the last five years, the NC General Assembly has made a number of changes to the buffer rules:

- **SL 2011-394 (H119)**, Amend Environmental Laws 2011, §17, allowed new single family residences in the coastal zone to encroach on the outer zone of the Neuse and Tar-Pamlico buffers with various conditions for the development.
- **SL 2012-200 (S229)**, Amend Environmental Laws 2012, §8, expanded the 2011 exemption to the entire Neuse and Tar-Pamlico watersheds, and clarified that the inner zone was to be measured from the top of the streambank or normal high water level.
- **SL 2013-413 (H74)**, Regulatory Reform Act of 2013, §52, exempted farm ponds from all six buffer rules.
- **SL 2014-95 (S883)**, Mitigation Buffer Rule/Wastewater Treatment, overturned an Environmental Management Commission (EMC) rule merging the mitigation rules for each basin into a single 'consolidated mitigation buffer rule.' Instead, the act directed the EMC to adopt a weaker proposal. The final version of those weaker rules took effect in November 2015.
- **SL 2014-103 (H366)**, NC Farm Act of 2014, exempted drainage districts from riparian buffer rules.
- **SL2015-246 (H44)**, Local Government Regulatory Reform Act of 2015, §13, required local governments to obtain approval from the EMC for all buffer ordinances adopted pursuant to state buffer rules that exceed the minimum state protections. Local ordinances not approved by the EMC by January 2017 will become invalid. The section also mandated that, in the coastal zone, the inner zone of the buffer be measured from the high water mark. It also mandated that the EMC allow case by case departures from requirements to maintain woody vegetation in a buffer where a landowner proposes alternative measures that provide 'equal or greater' water quality protection.

All of the buffer rules are part of the readoption of state water rules slated to begin in late 2016.

1 D. Welsch, 1991. Riparian Forest Buffers. *USDA Forest Service. Forest Resources Management*; R. Lowrance et al., 1995, Denitrification in a Restored Riparian Forest Wetland, *J. Environ. Qual.* 24:808-815.

on the ground in the form of roots, leaves, and branches from plants in the buffer or nearby.[14]

What makes riparian buffers effective: width, hydrology, natural vegetation.

Over the past 30 years, many studies have focused on nitrate (NO_3) removal. Factors such as buffer width, the length of time water stays in the buffer, and nitrogen and carbon availability all contribute to the effectiveness of nitrate removal in buffers and the waters they protect.[15]

Wide buffers control nitrogen pollution better than narrow buffers

Wider buffers remove more nitrogen pollution than narrow buffers.[16] Retaining protections for 50 foot buffers along North Carolina's nutrient-sensitive waters is the most cost effective, practical way to protect rivers, lakes, and estuaries downstream.

A series of experiments performed by scientists from NC State University, studying buffers in the North Carolina coastal plain, found that riparian buffers with widths between (roughly) 150 ft and 200 ft, removed as much as 94% of nitrogen in 5 ft deep wells and 86% in 10 ft deep wells, when the buffers were well positioned in relation to groundwater flows.[17] Another study at the site found a 150 ft buffer reduced nitrates entering the stream by 76% to 92%.[18] A study of a much wider buffer – greater than 400 ft. – found that significant reductions were concentrated in the 200 ft of buffer closest to the stream edge, where groundwater and leaf litter were most available.[19]

Those North Carolina findings are echoed in the broader scientific literature. A 2007 meta-analysis assessed 89 buffers from 45 studies to estimate nitrate removal rates as buffer widths increased from zero (that is, no buffer) up to 164 ft. The researchers found that nitrate removal increased with width up to about 82 ft; after that, wider buffers showed no consistent increase in nitrate removal, likely because of poor hydrology and limited vegetation.[20] A 2014 meta-analysis of 30 different studies estimated a median nitrate removal of 55% for buffers less than 131 ft wide, and a median removal of 89% for buffers wider than that.[21]

North Carolina's 50 ft buffers are much narrower than the 130 ft or 150 ft buffers that appear to yield the greatest nitrate removal. One 2002 study in the Neuse basin coastal plain compared nitrogen removal rates across a 26 ft versus a 49 ft buffer. The researchers found that the narrow buffer reduced nitrogen in mid-depth wells by 28%, while the wider buffer reduced nitrogen in similar wells by 48%.[22] A 12-year longitudinal study on the same site, published this year, found that the wider buffer – essentially the width required under state rules – removed 2.5 times more nitrogen than the narrower buffer.[23] North Carolina's 50 ft buffers could remove more nitrogen if they were significantly wider; they will remove dramatically less if they are narrowed.

Nitrogen removal varies with groundwater levels and flows

Beyond buffer width, hydrology – the direction of groundwater flow, the depth of the water table, and the chemical composition of the soils – strongly affects nitrate removal.[24] The bacteria that, in saturated soils, convert nitrates to nitrogen gas tend to live near the surface – so denitrification happens most when the water table is high.[25] Also, the densest mats of plant roots are within a foot of the surface, so uptake of nitrates from groundwater is most efficient at that depth. Studies have found most denitrification happens within two feet of the surface.[26]

A U.S. Geological Survey study of buffers in the Neuse and Tar-Pamlico basins found that nitrate removal rates across a buffer could vary substantially depending on how groundwater moves through, under, or around the buffer.[27] Where groundwater moves close to the surface through denitrification 'hotspots,' pollutant

Leaves fallen from trees in the buffer support the natural food web of the stream – microbes, insects, fish, birds, and larger wildlife.

PHOTO © GRADY MCCALLIE

removal rates are higher. Moreover, the seasonal rise and fall of groundwater levels means that riparian buffers remove nitrogen at variable rates around the year.[28]

The key role of hydrology has implications for science-based policy:

What to restore, what to protect. Because buffers can have denitrification hotspots, it may make sense to prioritize public investments in buffer restoration projects, such as agricultural cost-share programs or mitigation banks, to sites where nitrate-rich groundwater is known to be flowing into a waterbody.[29] On the other hand, it can be very hard to tell where groundwater is entering or leaving a buffer. Moreover, these locations can move upstream and downstream in different seasons.[30] For that reason, for riparian buffer protections to be effective, they must apply along the length of streams and rivers, not just on isolated properties.

Natural vegetation temporarily stores nitrogen, and also sustains microbes in the soil that remove nitrogen permanently. PHOTO © GRADY MCCALLIE

HOW TO MEASURE THE EFFECT OF BUFFER PROTECTIONS

Buffer rules have been in place in the Neuse watershed since 1997 and in the Tar-Pamlico watershed since 2000. Yet, despite action taken to reduce pollution over that time, nitrogen concentrations in the main stems of the rivers and the upper estuaries remain high. Why is that?

Existing riparian buffers are important and effective filters for pollution, but they cannot remove all pollution from water and can be overwhelmed by significant increases in pollution occurring behind them. Other rules have to reduce pollution at its sources by addressing wastewater treatment plants and runoff from farmland and developed landscapes. That is why, in each of North Carolina's nutrient management strategies, buffer rules are complemented with rules to control pollution from those sources.

Of course, many historic buffers were cleared or developed years or decades before the current rules came into effect. On those properties, existing development and agriculture directly release nutrients into North Carolina's waterways. Restoring mature buffers on these properties can be a very effective practice to reduce current pollution, but is not required by the buffer rules.

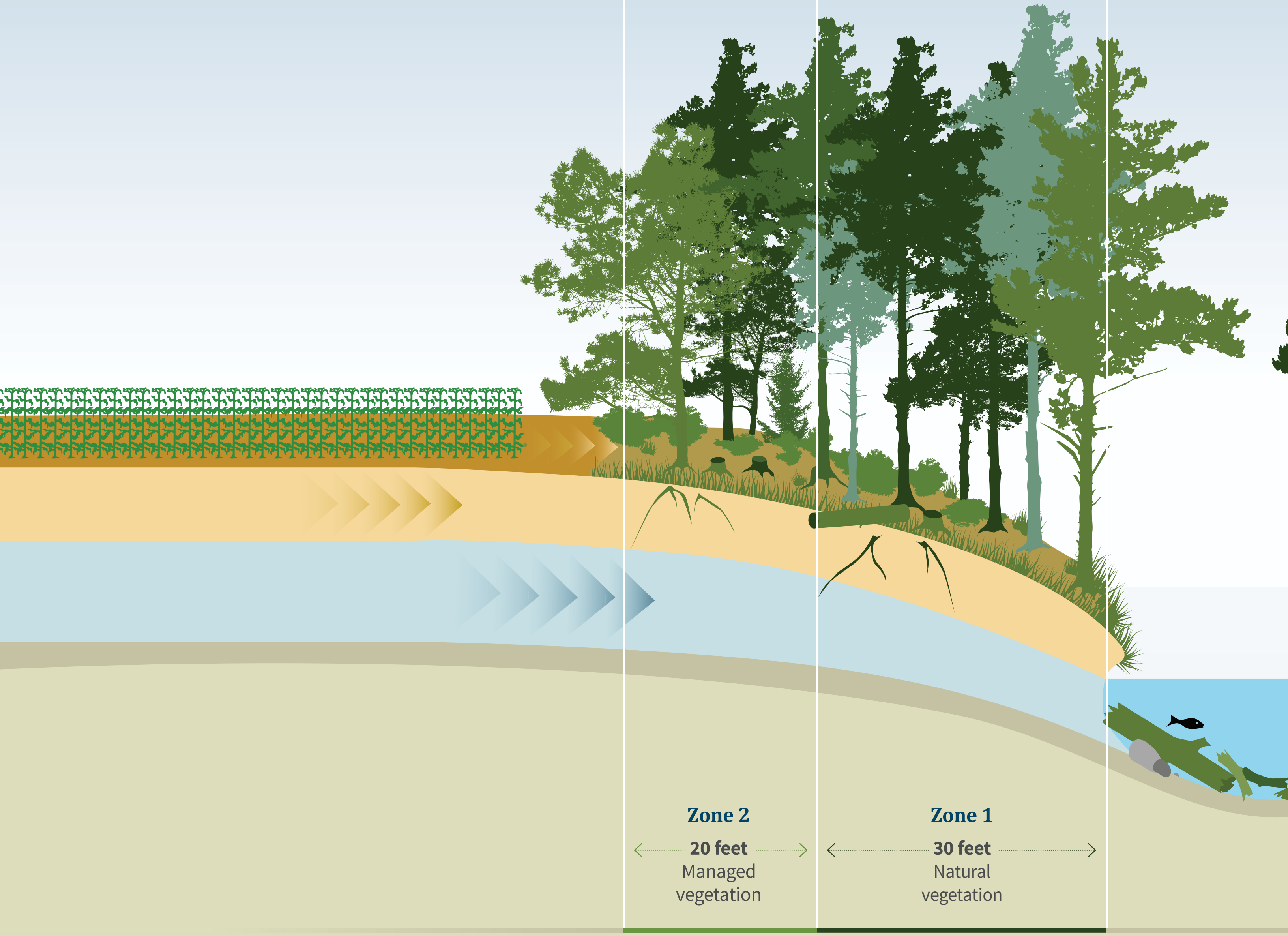
So why hasn't water quality in the Neuse and Tar-Pamlico estuaries fully recovered yet? There are at least three factors that may be delaying success:

- A number of observers have worried that some key sources of nitrogen and phosphorus pollution remain unaddressed by the strategies, including swine and poultry confined animal feeding operations (CAFOs), and leaking residential septic systems. On paper, none of these are supposed to discharge to surface waters, but on the ground studies have found examples of discharges from all three.
- In each of the watersheds, farmers have collectively implemented practices to lower runoff from farm fields. That is important progress, but groundwater takes a long time to percolate from fields to streams – three decades or more.[1] That means that successful efforts to reduce application of nitrogen may take years to translate into improved river conditions, because the groundwater has to clear a several-decade backlog of pollution first.
- Finally, over the years, North Carolina's lakes and estuaries have built up a reservoir of pollution that cycles back and forth between the water column and bottom sediments. It will take some time for that legacy pollution to clear.

So if concentrations of nitrogen and phosphorus in the lower rivers and estuaries are not a marker of the buffer rules alone – and if pollution reductions will take years to show – how do we know buffers are working? Two ways: we can look at stream health and water quality downstream from where buffers have been removed – nearly always poor – and look at changes in stream quality when missing buffers are restored – nearly always better, if the stream hasn't already been too damaged. Protected and restored buffers work, and add up to cleaner waters downstream.

1 T. Gilmore, 2015, *Groundwater Transit Times and the Fate of Aquifer Nitrate: Observations from Sampling in Stream Channels and Well Nests in an Agricultural Watershed*, North Carolina, USA, PhD dissertation, NC State University.

Riparian Buffers: State Rules and Federal Recommendations

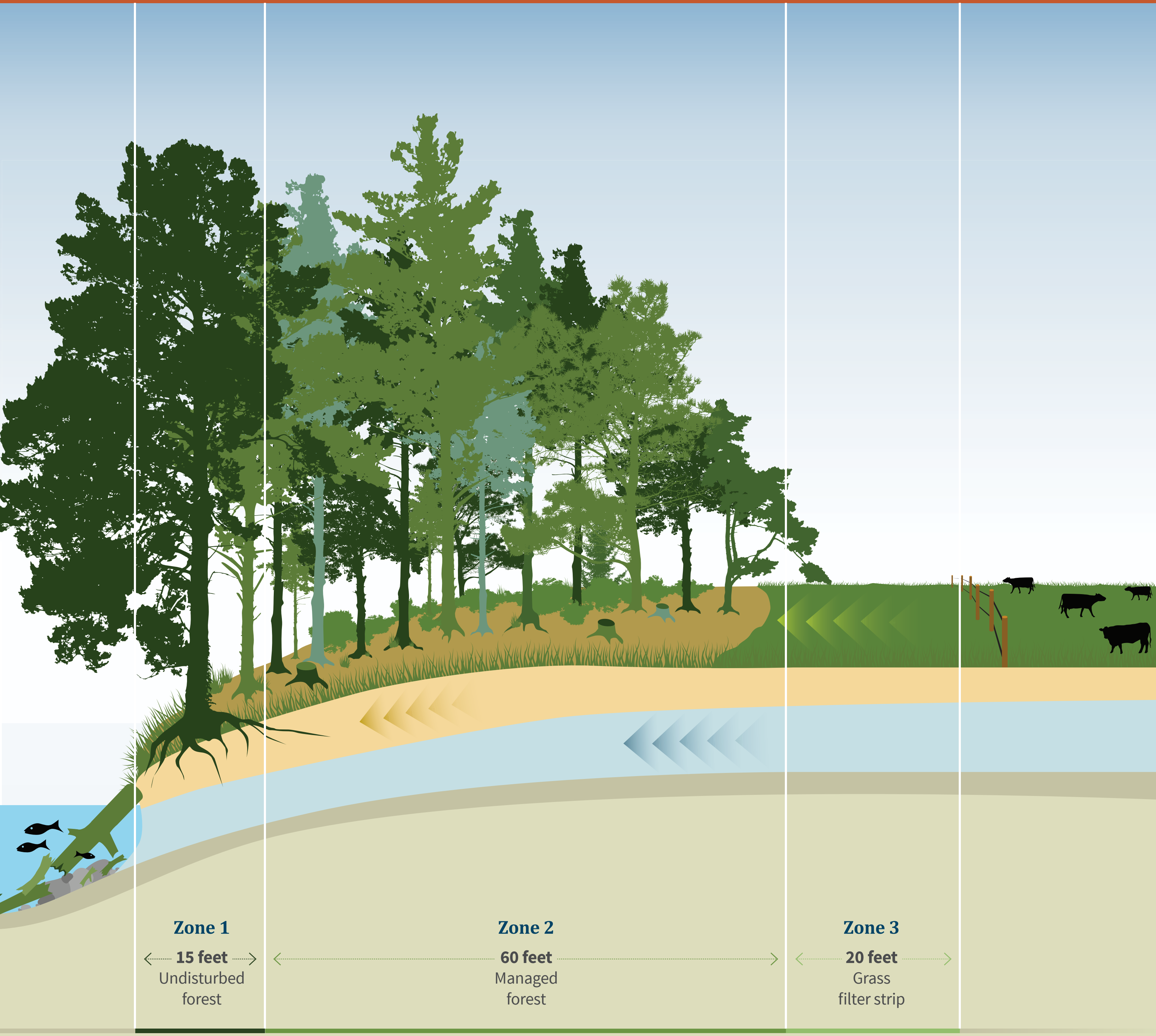


North Carolina riparian buffers

The North Carolina Environmental Management Commission explains: "The Neuse, Tar Pamlico, Catawba, Randleman and Jordan rules require a 50 foot riparian buffer that is divided into two zones. The 30 feet closest to the water (Zone 1) must remain undisturbed. The outer 20 feet (Zone 2) can be managed vegetation, such as lawns or shrubbery."

The Goose Creek rules, designed to protect the endangered Carolina Heelsplitter mussel, require a much wider 100 foot undisturbed buffer outside of the floodplain and a 200 foot undisturbed buffer inside the floodplain.

NC Environmental Management Commission, 2016, Study of the State's Riparian Buffer Protection Program Pursuant to SL2015-246.



US Department of Agriculture, National Forest buffer system

In 1991, the USDA National Forest Service published recommended 'technical specifications' for a riparian buffer, 95 feet divided into three zones. The inner 15 feet closest to the water (Zone 1), consists of undisturbed forest that stabilizes the bank, shades the water, and contributes detritus and large woody debris to the stream ecosystem. The next 60 feet (Zone 2), is also forested but can be managed and harvested. It provides space for denitrification and sequestering of nutrients in forest trees as runoff moves through groundwater or across the surface in sheet flows. Finally, the outer 20 feet of grass strips (Zone 3) filters sediment and helps ensure that surface runoff enters Zones 2 and 1 as a shallow sheet flow, not as a channel that punches through the buffer.

D. Welsch, 1991, Riparian Forest Buffer: Function and Design for Protection and Enhancement of Water Resources, USDA National Forest Service.

Excess nitrogen and phosphorus can trigger massive algal blooms such as this one on the Chowan River in 2015. PHOTO © HEATHER DECK

Managing flows into buffers. Researchers have pointed out that when surface runoff is allowed to erode channels through the buffer, water moves across too quickly to sink in and virtually no nitrogen is removed.[31] Channels circumvent the buffer. That is why current buffer rules require the use of level spreaders to disperse upland flows entering the buffer, and why variances that allow impacts in the buffer routinely require that stormwater be dispersed, treated, and then directed away from the waterbody. It is also why it is critical to maintain buffers on intermittent streams. When intermittent streams are not buffered, pollution washing into them reaches larger rivers without any nitrogen removal.

How impacts are mitigated. All of the existing buffer rules define certain impacts as 'allowable with mitigation,' and some observers have recommended that mitigation options be expanded. When a buffer is developed or paved, its ability to remove nitrogen is lost. Mitigation – through buffer restoration nearby – can offset this impact, particularly if a mitigation ratio is used to create a margin of safety. Even then, though, it is key that stormwater on the developed site be captured and directed away from the receiving water, so the allowed use does not in effect create a new channel bypassing the buffer.

Forested buffers control nitrogen better than cleared buffers

North Carolina's buffer rules attempt to limit impacts to trees and shrubs in the zone closest to protected waters. As noted above, that's in part because denitrifying bacteria are dependent on the carbon produced by the plants – especially leaves falling from deciduous trees and needles falling from pines – and in part because the trees and shrubs themselves take up nitrogen and groundwater.[32] "In small first or second order Coastal Plain streams near the Fall Line … vegetative water use and nutrient uptake may be as important as denitrification in limiting nitrate movement."[33] Thanks to the plants, in these settings, nitrogen-laden groundwater may simply not reach the stream for much of the year.

Where groundwater largely bypasses the riparian buffer zone (for example, by flowing deep below it and then back up into a stream or river), forested riparian buffers may still play an unexpectedly important role. The leaf litter and other organic matter they produce falls into the stream and feeds denitrifying bacteria that live on the bottom of the stream, where the groundwater emerges. A series of studies of coastal plain streams has found that those streambed bacteria, feeding on litter from the forested buffer, can remove as much as 60% of the nitrates from that emerging groundwater.[34] That makes protection of forest vegetation in the buffer a high priority for effective nutrient management.

Buffers trap excess phosphorus

Several of the state's nutrient management strategies call for reductions in phosphorus as well as nitrogen. Phosphorus, like nitrogen, is a vital nutrient for plant and algal growth. However, it is much less soluble in water than nitrogen, and instead adheres readily to soil particles. Human activities – especially widespread land application of fertilizers and animal and human wastes containing phosphorus, and discharges from wastewater treatment plants – have increased levels of phosphorus flowing into North Carolina's rivers, lakes, and estuaries. As with nitrogen, algal growth spurred by excessive phosphorus can cause fish kills and degrade water quality. In fact, some species of toxic algae are able to draw nitrogen out of the air and grow to the limit of the available phosphorus. Excess phosphorus has been identified as a driver of massive algal blooms in the Great Lakes in recent summers.[35]

Buffers are important for phosphorus removal.[36] The primary way riparian buffers control phosphorus is by catching the particles of sediment carrying the pollutant.[37] Grass filter strips and woody debris both catch sediment by slowing and dispersing runoff.[38] To the extent that dissolved phosphorus is carried in water, riparian buffers may also remove phosphorus that binds to clay particles[39] or is taken up by vegetation and soil microbes.[40]

Maryland researchers have observed 80% retention of phosphorus in a deciduous hardwood riparian buffer.[41] A Virginia study observed 89% phosphorus removal in 30 ft wide grass buffer strips but only 61% phosphorus removal in 15 ft wide buffers.[42] This suggests that, while the width of the buffer matters for phosphorus as well as nitrogen, buffers that are too narrow to substantially reduce nitrogen can still deliver meaningful phosphorus control.

Natural vegetation matters less for phosphorus control than it does for nitrogen. A North Carolina study of filter strips found that grass buffers could reduce phosphorus loads by as much as 50 to 70%.[43] A similar study in Iowa found that a 23 ft buffer of switchgrass captured 78% of the phosphorus and 95% of the sediment washing across it, and a 53 ft. buffer of switchgrass and trees captured 91% of the phosphorus and 97% of the sediment.[44]

What makes a larger difference for phosphorus is the rate at which it is applied to the land – farmland, land application sites, or developed areas – beyond the buffer. Studies have reported that riparian forests can significantly reduce total phosphorus

RIPARIAN BUFFERS AND AGRICULTURE

North Carolina's existing buffer rules exempt agricultural operations that were ongoing on the date each rule came into effect. In fact, the rules apply only when land in the riparian buffer experiences a 'change in use,' defined as the addition of new impervious surface, conversation of agricultural uses to non-agricultural uses, or an end of maintenance of lawn areas.

In parts of eastern North Carolina, drainage ditches are an integral part of the agricultural landscape. The buffer rules exempt existing drainage ditches, and allow construction of new drainage ditches so long as their effluent is treated to remove nitrogen before it is discharged into waters of the state. The rules prohibit construction of a new drainage ditch without such a control, and prohibit excavation of natural streambeds to encourage greater drainage.

Fencing and small road crossings are exempt. Where land is not actively being cropped, periodic mowing and harvesting of hay is allowed in the outer zone of the buffer.

Forestry activities in the buffer are limited close to protected waters. Trees are supposed to be undisturbed in the 10 feet closest to the water; some may be harvested in the next 20 feet; and all of the trees may be harvested in the outer 20 feet, so long as the ground is replanted with groundcover to help trap and treat runoff. A host of practices that are a part of forest management are allowed, including pruning, treating trees, removing trees that threaten property, and replanting vegetation.

In the Neuse and Tar-Pamlico basins, loss of existing riparian buffers would increase the pollution challenges facing the estuaries, despite the investments farmers have made to reduce runoff from farm fields. If the experience of the Chesapeake Bay is any guide, further heavy pollution reductions and mandates could eventually land on farmers as well as cities in these basins. Maintenance of strong buffer protections now is a highly efficient way to avert more burdensome regulations in the future.

North Carolina's buffer rules allow timber harvesting that leaves a narrow strip of trees in the zone closest to the water, as seen in this clearcut along the Tar River. PHOTO © SOUND RIVERS in the Coastal Plain region.[45] However, even if buffers capture a significant share of phosphorus-bearing sediment, high levels of soil phosphorus and erosion may eventually overwhelm the capacity of neighboring buffers to absorb it.

Unfortunately, field surveys and soil sampling suggest that some landowners apply phosphorus fertilizers without much attention to pre-application soil concentrations, and in some river basins, average soil concentrations are already high or very high.[46] In these circumstances, the state's riparian buffers serve as the last line of defense for North Carolina's river systems against phosphorus pollution.

Riparian buffers provide other significant benefits

Beyond controlling nitrogen and phosphorus pollution, riparian buffers also help control downstream flooding and bank erosion, and sustain healthy fish and wildlife populations.[47] These benefits have direct economic impacts: the U.S. Army Corps of Engineers estimates that North Carolina incurred over $47 million in direct flood damages between October 2010 and October 2014 (not including agricultural crop losses).[48] North Carolina's commercial and recreational fishing industries – which depend on clean estuaries as nurseries and adult habitat for fish and shellfish – contribute more than $1 billion to the state economy annually.[49]

Riparian buffers abate floods and keep streambanks stable.

Riparian buffers help limit downstream flooding by reducing runoff, as trees and shrubs in the buffer slow surface flows and take up water from the ground.[50] Dense tree cover catches significant amounts of rainfall on leaves, from which the water then evaporates without running off.[51] Natural vegetation slows water that falls on or runs into the buffer, reducing the amount of water moving quickly into rivers and recharging groundwater that provides flows during dry months.[52]

Because buffers slow surface runoff, they also help keep streambanks stable, reducing bank erosion and downstream sedimentation. A meta-analysis of 30 buffer studies found that forested buffers reduce channel meandering and bank

RIPARIAN BUFFERS AND PRIVATE PROPERTY

Most objections raised to North Carolina's riparian buffer protections have focused on implications for private property rights.

On the most basic level, riparian buffers protect private and public resources downstream, by limiting uses of property adjacent to streams, rivers, lakes, and estuaries. A 2009 study of the Neuse buffer rules found minimal impact to property values overall[1], and growth rates in the buffered watersheds indicate conclusively that the rules have not suppressed development in any broad sense. Nonetheless, buffer rules clearly do limit some activities in riparian zones.

In an effort to minimize constraints, North Carolina's buffer rules sort activities into four categories: exempt; allowed with prior permission from the regulatory agency; allowed with prior permission and mitigation of impacts; and prohibited. Some activities are allowed or allowed with mitigation in the outer 20 feet of the buffer, but not in the most sensitive 30 feet adjacent to the stream.

Rules drafters recognized that projects on most tracts of land could be designed simply to avoid impacts to the buffer. However, a minority of properties would be rendered unbuildable, usually because they were small tracts located almost wholly within the buffer. To ease the burden on these landowners, the rules include a variance process that allows buffer impacts that would ordinarily be forbidden. Minor variances, covering impacts to the outer zone of the buffer, are approved by state staff or local delegated program staff. Major variances, covering impacts to the inner zone of the buffer, must be approved by the NC Environmental Management Commission (EMC).

Under the buffer rules as currently written, a landowner is only eligible to obtain a variance if, among other conditions, they owned the property at the time the buffer rule came into effect. For the last five years or so, however, the EMC has routinely granted variances that do not meet this requirement, and simply required management of flows and mitigation of the impacts.

In 2015, the NC General Assembly debated whether to flatly exempt some or all properties that were platted at the time a rule was adopted. That is significantly different from the mitigation approach taken by the EMC, since exempt impacts would require no mitigation. The flood and pollution control benefits of the exempt buffers would simply be lost. Such a change might leave the form of a buffer rule on the books, but would destroy its benefits.

2 O. Bin *et al.*, 2009, Riparian buffers and hedonic prices: a quasi-experimental analysis of residential property values in the Neuse River basin, Amer. J. Agr. Econ. 91:4, 1067–1079.

erosion.[53] Studies have found that both tree roots and grass roots increase the resistance of soil to erosion.[54] However, research in southwestern Virginia has provided hard evidence that trees are better at preventing bank erosion than grasses, thanks to trees' longer, thicker roots.[55] This offers another indication of the need to protect forest vegetation in the riparian buffer, especially in the zone closest to water.

Riparian buffers protect water temperatures and provide habitat for fish and wildlife

Beyond helping protect water quality, riparian buffers help sustain and protect fish and wildlife populations:

- Scientists in North Carolina evaluated the relative benefits for birds of three different buffer structures: 82 ft wide planted woodland buffer, 98 ft wide grass, shrub, and woodland 3-zone buffer, and 30 ft wide shrub buffer. Both the diversity of species and the total number of birds were highest in the 98 ft, 3-zone buffer, likely thanks to the presence of multiple habitat types.[56]
- In western North Carolina – where forested buffers are present on many streams but are not currently protected by state rules – scientists have observed many species of aquatic and terrestrial salamanders breeding within 118 ft of adjacent streams. Researchers recommended that these terrestrial habitats be taken into consideration for buffer width regulations due to the significance salamanders have for the food web in headwater streams.[57]
- When riparian buffer forests were cut along 12 stream segments in North Carolina and Georgia, scientists found that fish habitat in the streams decreased as riffles became filled with fine sediments, and water temperature increased. Not surprisingly, fish populations dropped; loss of habitat and increased water temperature significantly affects the reproduction and survival of aquatic species.[58]
- A meta-analysis of 30 buffer studies reported that macroinvertebrate and fish communities, and their instream habitat, remained healthy when buffered by at least 98 ft of forest.[59]
- That same meta-analysis found that a forested buffer of at least 65 ft kept stream water temperatures within approximately 4° F of natural levels; a 98 ft forested buffer prevented temperature changes in the stream.[60]

All of these recommended widths are larger than the 50 ft protected under North Carolina rules, signaling that the existing rules already reflect significant compromise from the perspective of keeping the state's fish and wildlife populations healthy. Collectively, these studies argue against further unmitigated exemptions from buffer protections, and against narrowing the protected zone to less than the current 50 ft.

Buffers along intermittent streams, such as this one in in the upper Neuse river basin, are essential to protect water quality downstream.
PHOTO © GRADY MCCALLIE

Riparian buffers work in both rural and urban landscapes

Riparian buffers are the most cost-efficient tool we have to protect streams, rivers, and estuaries from nutrient pollution and other negative impacts of runoff in both agricultural and urban landscapes. Much of the scientific research has been conducted in agricultural landscapes.[61] However, recent studies have shown that forested riparian buffers in urban landscapes provide nutrient removal, temperature control, and sediment retention at levels comparable to those observed in agricultural landscapes.[62] In other words, buffers work across entire watersheds.

Conclusion: riparian buffers protect North Carolina's water resources

Riparian buffers protect North Carolina's water resources. Substantial scientific evidence suggests that buffers of 50 ft and wider provide important nutrient removal in runoff and groundwater.[63] Forested riparian buffers also provide other benefits (e.g., drinking water protection, flood abatement and stream/river bank stability, habitat, water temperature control) in both urban and agricultural landscapes.[64]

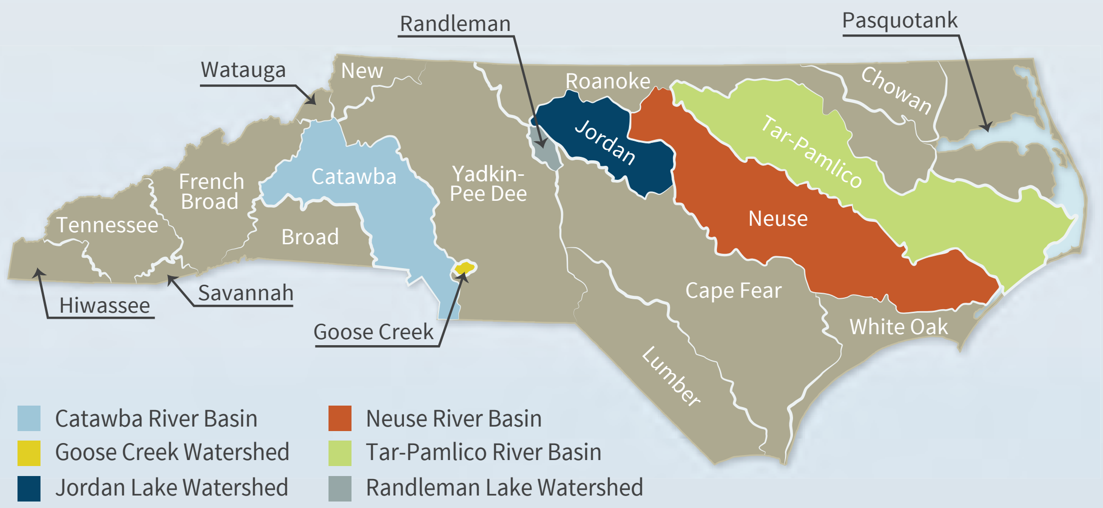
Far from burdening the economy, buffer protections protect and enhance increasingly valuable water resources in our communities, region, and state, for everyone. After nearly 20 years of buffer protections in the Neuse, a weakening of those protections would mean a windfall profit for some owners who, during that time, acquired partially unbuildable lots at discounted prices. On a broader scale, though, the Neuse buffer rule has not had a significant impact of the value of riparian properties in the basin.[65] Beyond that, research from the Chesapeake Bay has shown that improved water quality adds to the value of properties around protected waters.[66] Even more, all North Carolinians enjoy the benefits of clean water for drinking, swimming, boating, and fishing.

If buffer protections in current law are weakened, nutrient levels will increase downstream, along with predictable impacts: a return of massive fish kills, increased drinking water treatment costs, loss of valuable recreational and commercial fish stocks. Also, because the federal Clean Water Act requires states to keep waters fishable and swimmable, multiple stakeholders – especially cities, counties, and developers building new projects – will find themselves required to provide much more aggressive pollution control at much higher levels of cost.

Based on the scientific evidence provided by expert ecologists, soil scientists, and engineers, our scientific review supports these policy recommendations:

- Fifty foot, naturally vegetated buffers should remain in place along perennial and intermittent streams, rivers, lakes, and estuaries in watersheds that are impaired by and sensitive to nutrient pollution.
- Crossings and surface flows into these buffers should be managed to prevent the creation of channels that circumvent the buffer. As much as allowed by existing uses, buffers should be protected along the length of tributaries, without new exemptions that that punch holes through the protection provided by the buffer.
- On-site stormwater management should continue to be required for developments that impact buffers. Time tested measures such as level spreaders, constructed wetlands, bioretention areas, and wet ponds followed by level spreaders for more intensive development are critical measures to ensure that the buffers function properly and remove pollutants.

Riparian Buffer Protection Programs



Protected buffer along Tar River in the Coastal Plain. PHOTO © HEATHER DECK

- Much of the research on riparian buffers has been carried out in North Carolina's coastal plain and lower Piedmont. Other forms of buffers may be needed in watersheds elsewhere, given different slopes, soils, and patterns of groundwater flow. Additional research would be valuable in these landscapes.
- To the extent that local governments conclude that wider buffers are needed to better control nitrogen and to protect the biological, physical, or chemical integrity of waterways, the available science supports those local ordinances.
- When impacts to buffers are allowed with mitigation requirements, the mitigation must offset the loss in treatment of both surface and groundwater flows.
- When federal or state funds are being spent to restore riparian buffers, funding should, where possible, prioritize restoration of buffers on wet soils that will intercept nutrient-laden surface and groundwater flows.
- Protection of existing riparian buffers upstream from impaired waters provides a cost-effective hedge against further increases in pollution. To clean up those waters, buffer protections must be paired with other measures – wastewater treatment plant upgrades, stormwater control standards for developed area, reductions in runoff from farmland – that reduce pollution at the source.

After nearly two decades of implementation in parts of North Carolina, riparian buffers remain the most cost-effective tool to keep nitrogen and phosphorus pollution out of our waterways. North Carolina is not alone in facing the problem of nutrient pollution in major waterbodies. Just to our north, the states bordering the Chesapeake Bay have embarked on an extraordinarily complex cleanup of that estuary. Last year the agency overseeing that cleanup concluded:

> Riparian forest buffers provide critical barriers between polluting landscapes and receiving waterways using relatively little land…Per acre, they likely provide more benefits and are more cost-effective than any other BMP, especially when considering the added value of habitat at the critical juncture of land and water.[67]

To protect the Bay, the six states are seeking to restore 100 ft buffers along 70% of the Bay's tributaries at a rate of 900 stream miles each year. In contrast, North Carolina's existing buffer rules offer the opportunity to keep existing buffers in place. That, in turn, will protect water quality (and downstream property values) from further declines, and will avert much larger costs to fix North Carolina's impaired lakes and estuaries in the future. North Carolina's buffer protections are worth retaining.

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Cover: A small river and protected buffers in the Falls watershed of the Neuse river basin; This page: Buffer along lake in Catawba basin.

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