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RANGE-WIDE ASSESSMENT OF HABITAT SUITABILITY FOR ROANOKE LOGPERCH (*PERCINA REX*)

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16. Abstract

The Roanoke logperch (*Percina rex*) is a federally endangered darter endemic to Virginia. Knowledge of its distribution and habitat requirements is limited. Before this study, it was known to occur in the Smith, Pigg, Roanoke and Nottoway river watersheds. We surveyed 36 sites in the Dan, Mayo, Smith, Pigg, Blackwater, Big Otter, Falling and Meherrin river and Goose Creek watersheds for new occurrences. We found Roanoke logperch in two new watersheds, Goose Creek and Big Otter River, as well as in Smith and Pigg river watersheds.

We developed a screening model of reaches suitable for Roanoke logperch and assessed habitat suitability at fish-survey sites. We found reaches and sites suitable for logperch evenly distributed across the Roanoke drainage. Availability of suitable habitat was strongly correlated with logperch catch among sites. We estimate 30-40% of our observed logperch absence were false absences. Due to Roanoke logperch's low detectability, a combination of range modeling, habitat assessment, and fish surveys may be better indicators of logperch distribution than fish surveys alone.

This report provides a synthesis of available knowledge on the distribution of Roanoke logperch and new insights into logperch detectability. We recommend that electrofishing generally be used rather than snorkeling to establish logperch presence/absence and that logperch detectability be more rigorously evaluated under a range of sampling conditions. In preparing for road construction or maintenance projects, we recommend that our screening model be applied to potentially impacted stream segments to help determine whether sites are suitable for logperch.

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ABSTRACT

The Roanoke logperch (*Percina rex*) is a federally endangered darter endemic to Virginia. Knowledge of its distribution and habitat requirements is limited. Before this study, it was known to occur in the Smith, Pigg, Roanoke and Nottoway river watersheds. We surveyed 36 sites in the Dan, Mayo, Smith, Pigg, Blackwater, Big Otter, Falling and Meherrin river and Goose Creek watersheds for new occurrences. We found Roanoke logperch in two new watersheds, Goose Creek and Big Otter River, as well as in Smith and Pigg river watersheds.

We developed a screening model of reaches suitable for Roanoke logperch and assessed habitat suitability at fish-survey sites. We found reaches and sites suitable for logperch evenly distributed across the Roanoke drainage. Availability of suitable habitat was strongly correlated with logperch catch among sites. We estimate 30% to 40% of our observed logperch absence comprised false absences. Due to the low detectability of Roanoke logperch, a combination of range modeling, habitat assessment, and fish surveys may be a better indicator of logperch distribution than fish surveys alone.

This report provides a synthesis of available knowledge on the distribution of Roanoke logperch and new insights into logperch detectability. We recommend that electrofishing generally be used rather than snorkeling to establish logperch presence/absence and that logperch detectability be more rigorously evaluated under a range of sampling conditions. In preparing for road construction or maintenance projects, we recommend that our screening model be applied to potentially impacted stream segments to help determine whether sites are suitable for logperch.

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INTRODUCTION

Roanoke logperch (*Percina rex*) is one of three federally endangered fish species occurring in Virginia. The entire known range of the species comprises six disjunct areas in Virginia, including portions of the drainages of Smith, Pigg, upper Roanoke, Big Otter, and Nottoway rivers and Goose Creek. Logperch occur primarily in medium-size rivers with silt-free, unembedded pebble and gravel substrate. Distribution and abundance of logperch are greatest in the upper Roanoke, Smith and Nottoway drainages. Potentially suitable areas outside the known range of logperch have not been extensively surveyed for logperch.

Logperch populations in the upper Roanoke and Pigg drainages continue to be seriously threatened by siltation and contaminants stemming primarily from urbanization, agriculture, and highways. The status of Roanoke logperch has not improved since it was listed as endangered in 1989. U.S. Fish and Wildlife Service (USFWS) biologists are increasingly concerned about the continued decline of habitat quality in logperch waters. This concern is heightened by plans to construct I-73, which would intersect several river reaches that support logperch in the Roanoke and Pigg river drainages. (Herein, a “reach” is a stream segment between two confluences.) The primary tactics for improving logperch status are to (1) enhance distribution and/or abundance and (2) reduce risk of anthropogenic impacts.

Impacts of human activity on Roanoke logperch could be substantially reduced via more effective planning, mitigation, and/or restoration. For example, planning could help avoid disturbing areas crucial to logperch persistence, mitigation might involve enhancing logperch habitat in one area to compensate for unavoidable impacts in another area, and currently unsuitable habitat could be restored to allow expansion of the logperch distribution. Developing an effective strategy to conserve Roanoke logperch requires accurate knowledge of the distribution of both the species and suitable habitat. Such knowledge, especially if shared by all stakeholders and management agencies, can help avoid surprises, minimize impasses, and generate innovative solutions.

Existing information on the distribution of Roanoke logperch and habitat suitable for logperch is scarce and uneven in quality. Most previous surveys for logperch focused on areas near known occurrences, and information on habitat suitability has been scarce and inconsistently gathered. The 1992 recovery plan for Roanoke logperch recommended that additional surveys be conducted to identify sites that either supported logperch or would serve as translocation sites, but many sites in the Virginia Piedmont that might provide suitable habitat (or new logperch occurrences) remained unsurveyed.

Additional surveys that fill gaps in our knowledge of logperch and habitat distribution can help land/water managers develop more effective conservation actions as well as minimize inadvertent impacts of their other activities on logperch. More reliable knowledge about logperch distribution and abundance would be especially valuable to the Virginia Department of Transportation (VDOT) and the USFWS as they collaborate on land management plans that allow both persistence of logperch populations and maintenance of roads.

PURPOSE AND SCOPE

The purpose of this project was to provide information that can reduce costs and prevent project delays incurred by VDOT when proposed construction or maintenance projects necessitate surveys for Roanoke logperch. To accomplish this, we conducted extensive field surveys in areas with high suitability for logperch, then created a habitat model to distinguish between sites that logperch are likely or unlikely to inhabit. This model might be used by VDOT to eliminate some logperch surveys, saving the costs of surveys and project delays. If mitigation is required for future construction impacts to logperch, information from this report may also obviate needs for some mitigation studies.

This report addresses four objectives:

1. Review and summarize the published literature and agency databases on logperch distribution and habitat use.
2. Survey sites outside the known logperch range to assess habitat suitability for logperch and to determine logperch presence or absence.
3. Rank suitability of selected sites and watersheds for logperch.
4. Develop a general “screening” model of river reaches suitable for Roanoke logperch, based on known occurrences.

The subsequent report is divided into six main sections: methods, results, discussion, conclusions, recommendations, and cost/benefit analysis. All but the last are subdivided by objective: literature review, field survey, habitat assessment and screening model.

Field surveys were limited to the Roanoke and Chowan river drainages in Virginia. Projected range maps include potential Roanoke logperch habitat in North Carolina.

METHODS

Literature Review

Distribution

We summarized what is currently known about Roanoke logperch distribution. Knowledge of logperch range and habitat use has grown since the logperch was first listed as endangered in 1989. We documented new discoveries of logperch occurrences that have expanded its known range since 1980. We reviewed published and gray literature as well as VDGIF (Virginia Department of Game and Inland Fisheries) and VDCR (Virginia Department of Conservation and Recreation) databases to find known occurrences of Roanoke logperch. We contacted researchers to find unrecorded localities.

Three databases track Roanoke logperch locations. VDGIF maintains a database (VAFWIS) that allows three levels of access. The public can access general information on species occurrence in a county, city, United States Geological Survey (USGS) quadrangle or hydrologic unit. An online database generates a list of species likely to occur within 3-10 miles of any set of coordinates or administrative unit in Virginia (D. Morton, VDGIF, http://vafwis.org/wis/asp/default.asp). With a subscription, users gain a higher level of access that allows them to view 613 *Percina rex* collection records in four fields: collection ID, date collected, collector, and "view map." To avoid disclosing exact locations of endangered species, the view map depicts an 800-m buffer zone surrounding collection locations. This database also provides a list of all Threatened and Endangered Species waters in which Roanoke logperch have been found. By entering into a signed agreement with VDGIF, researchers can obtain GIS layers that display exact collection locations with date collected and collectors. This layer contains complete *P. rex* collection records from 1940 to 2006 (Miller and Morton 2000). We used this GIS layer for our study.

The VDCR Division of Natural Heritage (DNH), maintains a separate database of logperch occurrences (D. Boyd, VDCR, http://www.dcr.virginia.gov/dnh/nhrinfo.htm) that researchers can access after signing a license agreement. The database contains 35 collection locations. Fields include date of most recent observation, survey dates, site names, directions to site, notes on habitat characteristics, dates observed, dates surveyed but not observed, collectors, lengths of specimens and number collected. Three records were unique to this database (VDCR-DNH 2005).

The Gloucester, Virginia, field office of the USFWS maintains a database of Roanoke logperch occurrences, accessible only to USFWS employees, that is a composite of the DNH and VDGIF databases (K. Marbain, personal communication).

We estimated 1983 and 1986 cumulative distributions in the upper Roanoke, middle Roanoke, Pigg, Smith and Nottoway river drainages from the Burkhead (1983) and Simonson and Neves (1986) reports. To estimate 2006 distributions, we joined collection records to underlying stream reaches in ArcGIS, and used the "measure" tool in ArcGIS to find total distribution for each of the five drainages. We included unsampled intervening reaches between known occurrences. The longest unsampled intervening reach was 20 river kilometers (rkm) in Goose Creek.

Habitat Use

We summarized what is currently known about Roanoke logperch habitat use. We reviewed published literature, dissertations, and government reports to summarize how knowledge of logperch habitat use has changed over the past 25 years.

Field Survey

We surveyed sites outside the known logperch range to assess habitat suitability for logperch and to determine logperch presence or absence. We surveyed 36 sites with a relatively high probability of supporting logperch in nine watersheds: South Mayo River and Dan River in Patrick County, Pigg River and Blackwater River in Franklin County, Goose Creek and Big Otter River in Bedford County, Falling River in Campbell County, Smith River in Patrick County, and Meherrin River in Lunenburg, Brunswick, and Greensville counties (Appendix Figures A-1 and A-2, Table A-1). We chose sites similar in stream size, elevation, and gradient to reaches where logperch were known to occur. We used aerial photographs and field reconnaissance to find sites in each watershed with minimal anthropogenic disturbance, indicated by a high proportion of forest cover and low occurrence of urban and industrial land use.

Surveys were conducted from June through August of 2004 and May through September of 2005. Sample sites encompassed five riffles and the intervening areas (four runs or pools). A “riffle” is a stream segment with coarse substrate, and shallow, fast-moving water (Gordon et al. 1992). A “pool” is a segment with deep, slow-moving water and fine substrate. A “run” is intermediate in depth, velocity, and substrate features. Sites were 250-1200 m long, with site length positively related to river width and distance between riffles. Previous sampling in Virginia Piedmont streams indicated that 90% of species were detected by sampling 5-14 habitat units (i.e., riffles, runs, pools) or a stream length of 22-67 stream widths (Angermeier and Smogor 1995, Rosenberger and Angermeier 2002). Our sites contained 9 habitat units and averaged 40 stream-widths in length (Appendix Table A-1). This level of sampling effort helped ensure that observed absences could confidently be interpreted as real absences.

A crew of three researchers electrofished the sites, focusing effort on areas most likely to contain *Percina rex*. We sampled five riffles at each site, focusing on “best habitat” in each riffle, where best habitat was judged on the basis of depth, velocity, and substrate. Each netset represented a quadrat of 16 m^2 shocked downstream into a bag seine. For each netset, we identified all captured fish to species, counted them, and kept them in a live well until they could be returned to the stream. We sampled each riffle until no new species were found. Fish that we were unable to identify in the field were brought back to the lab for identification.

We supplemented electrofishing samples with underwater fish sampling (snorkeling) at 18 sites. We restricted snorkel-surveys to days when sites had underwater visibility of at least 1 m. To measure visibility, a technician held a Secchi disk horizontally in the water while another technician, wearing snorkel gear, crawled away from the disk along a tape measure. When the black edge of the disk could no longer be distinguished from the surrounding water, we measured distance from the Secchi disk ("visibility"). During sampling, three snorkelers moved abreast upstream through the site tabulating species by habitat unit (riffle, run, or pool). A fourth technician monitored safety and recorded data. This sampling encompassed runs and pools as well as the riffles sampled via electrofishing.

To estimate Roanoke logperch detection probabilities and sampling efficiency, we applied additional sampling effort to some sites, which we refer to as "intensive" or "extensive" sampling. We intensively sampled a riffle by tripling our fishing effort relative to our standard protocol. That is, we electrofished the entire riffle three times (three "passes") using 8-10 nonoverlapping netsets per pass. Intensive sampling allowed us to estimate the proportion of logperch in a riffle captured in a single pass (sampling efficiency). It also allowed us to estimate Roanoke logperch detection probability. We extensively sampled a site by tripling the site length relative to our standard protocol. That is, we extended the site to 15 riffles. Roanoke logperch are often sparse, which can lead to false observed absences. Extensive sampling allowed us to assess the likelihood of assigning a false absence to a site five riffles long and it allowed us to evaluate our confidence in observed absences. We sampled two sites intensively and one site extensively.

Habitat Suitability Assessments

Following fish sampling, we measured microhabitat at 3-m intervals across three cross-sectional transects (sampling lines perpendicular to stream flow) per riffle, for an average of 27 transects and 150 sampling points per site. At each microhabitat sampling point we recorded depth, velocity at 0.6 x depth, dominant and subdominant substrate size, percent silt cover, and embeddedness within a 1-m^2 area centered on the point. We classified substrate using a nine-category Wentworth scale (Table 1).

Table 1. Nine-category Wentworth scale used to describe stream substrate size and type.

Substrate type
1 = organic matter
2 = clay
3 = silt
4 = sand
5 = small gravel [2-16 mm]
6 = large gravel [17-64 mm]
7 = cobble [65-256 mm]
8 = boulder [>257 mm]
9 = bedrock

We developed models of suitable habitat based on previously documented logperch occurrences as well as occurrences in our field survey. We used descriptions of suitable habitat provided by Rosenberger and Angermeier (2002) as an initial template for our models, then identified the ranges of habitat parameters that accounted for the greatest variance in observed logperch densities across survey sites (Table 2). For each site in watersheds containing logperch, we calculated relative logperch density by dividing the number of logperch captured by the number of netsets. We regressed relative logperch density per site against total area of suitable habitat per site.

Roanoke logperch in the upper Piedmont and Fall Zone use habitat differently (Rosenberger 2002). Logperch in the Nottoway River (Fall Zone) use slower, deeper water than logperch in the Roanoke and Pigg rivers (upper Piedmont). We determined suitable Roanoke logperch habitat configurations for both physiographies. Model parameters for upper Piedmont sites were: depth >20 cm, dominant and subdominant substrate as small gravel to boulder, silt cover 0-25%, and embeddedness 0-25% (Table 2). Fall Zone parameters were identical except for depth > 45 cm. The model was applied across all mesohabitat types (riffle, run, and pool). Stream depth, measured at each transect point is an instantaneous, wetted-channel, low-flow measure. We do not know if there is a maximum depth above which Roanoke logperch are not found.

Table 2. Model parameters used to define suitable habitat for Roanoke logperch. Substrate was classified according to the scale in Table 1.

	Upper Piedmont	**Fall Zone**
Model parameters	Depth: > 20 cm	Depth: > 45 cm
	Dominant substrate: 5-8 (small gravel to boulder) Subdominant substrate: 5-8 (small gravel to boulder) Silt: 0-25% cover Embeddedness: 0-25% embedded	

For each site, we counted the sampled points for which all five microhabitat measurements fell within model parameters. We divided the number of these "preferred habitat" points by the total number of measured points for the site. We then multiplied this proportion by the area of the site to estimate available preferred habitat per site, which was used to rank habitat suitability for logperch of all sites. We created a GIS layer of the fourteen sites with the most logperch habitat.

To rank watershed suitability, we ranked watersheds by the proportion of sites surveyed that contained enough estimated preferred habitat (≥ 1000m^2) to support Roanoke logperch. We chose 1000 m^2 as the cutoff for minimum estimated area of preferred habitat required because most sites with < 1000 m^2 of preferred habitat did not support logperch (see Results – Habitat Suitability). We found no other distinguishing characteristics of sites with <1000 m^2 of preferred habitat.

Screening Model

The screening model produces a projection of potential Roanoke logperch range based on known occurrences. Because Roanoke logperch are known only from the Roanoke and Nottoway river drainages, we limited our screening model to these drainages. Within the Roanoke and Nottoway river drainages, we used elevation, stream size, and gradient to build the screening model. We analyzed logperch data to find the ranges of elevations, stream sizes, and gradients at which Roanoke logperch occur and used the ranges to create a model whose parameters bracket all reaches that fall within a combination of suitable stream size, gradient and elevation. We then projected these reaches as a GIS layer of potential Roanoke logperch habitat or range.

We compiled Roanoke logperch collection records from VDGIF and VDCR databases. We verified collection locations and added records from relevant scientific articles, theses, and dissertations, including reports by McIninch and Garman (2002) and Rosenberger and Angermeier (2002). We included five new reaches from the Roanoke River drainage that contained Roanoke logperch (two in Goose Creek, one in Little Otter River, and two in Smith River), which were documented during this project’s field surveys. We used the habitat parameters from these known occurrences to define potential habitat for Roanoke logperch.

We used VDGIF’s Wildlife Action Plan (VDGIF 2005) to help describe logperch habitat in the Roanoke and Nottoway river drainages. This geodatabase uses the National Hydrography Dataset (NHD; 1:100,000 scale) of the USGS to depict stream flowlines.

The hydrography used in VDGIF’s geodatabase is a network of reaches, where a “reach” is a stream segment between two confluences or “nodes.” Using GIS tools, VDGIF assigned attributes to each reach, including stream size (Strahler and Shreve order), elevation, and gradient (channel slope). In the Strahler system of stream size, reach order increases (by 1) only if the two upstream reaches are of equal order. In the Shreve system, when two reaches join, the order of the downstream reach is the sum of the orders of the joining reaches. For example, the reach downstream of the confluence of a segment of order 3 and a segment of order 64 would be Shreve order 67.

Numerical values of order for both systems depend on map resolution. Finer scale (more detailed) maps result in higher orders for a given reach. VDGIF used GIS scripts on maps of 1:100,000 scale to calculate stream sizes for all reaches. In the Roanoke basin, this resulted in streams of Strahler order 1-7 and Shreve link 1-4802. VDGIF obtained reach elevations by overlaying reaches on a standard National Elevation Dataset (NED) digital elevation model (30-m resolution). Gradient (m/km) was calculated by subtracting downstream node elevation from upstream node elevation and dividing by reach length (VDGIF 2005).

To evaluate the effect of map resolution on Strahler order we calculated a second set of stream orders at 1:24,000 scale for all reaches containing logperch. We compared stream orders at the two scales (1:24,000 and 1:100,000); (Figure 1).

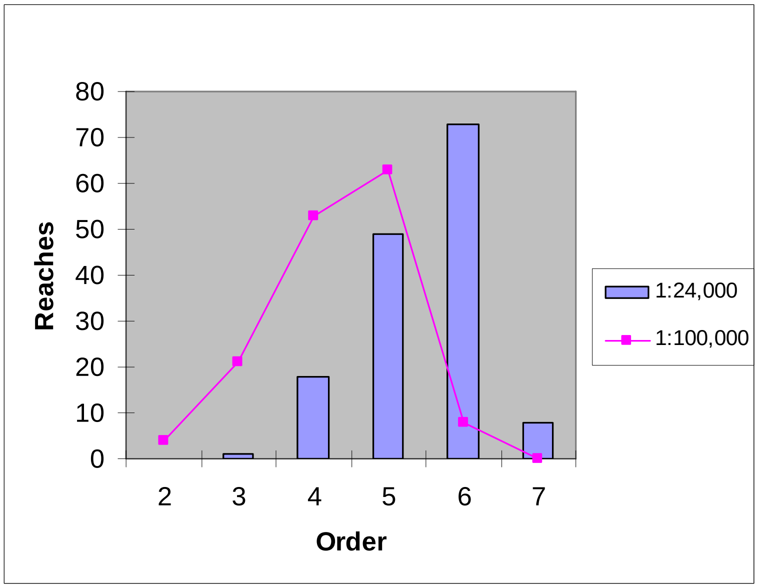


Figure 1. Distribution of Strahler stream orders for reaches known to contain Roanoke logperch. Distributions are plotted for two map scales.

At 1:24,000 scale, (the scale of 7.5' topographic maps), logperch are found primarily in 5th- and 6th-order streams. However, until recently, the NHD has been available only at 1:100,000 scale for the Roanoke and Nottoway river drainages. At this scale, Roanoke logperch are known to occur primarily in 4th- and 5th-order streams. Most reaches decrease a single unit of order between 1:24,000and 1:100,000 map coverages (Figure 1), but some 6th-order reaches shift to 4th-order. All analyses in this report are based on 1:100,000 scale.

We used ArcGIS 9.1 to spatially join fish collection records to reaches. We extracted 149 reaches that contained Roanoke logperch. We verified that mapped reaches were correct by checking each reach against locality descriptions in collection records and original reports, and against collection descriptions that had not been included in the VDCR or VDGIF databases, including collection reports by McIninch and Garman (2002), Lahey and Angermeier (2006b), and Rosenberger and Angermeier (2002).

We built reach-based models to project range-wide occurrence of Roanoke logperch. Because Rosenberger and Angermeier (2002) found that Roanoke logperch use habitat differently in the Roanoke and Nottoway drainages, we sorted reaches by drainage. We summarized the ranges of elevation, gradient, order, and link in which Roanoke logperch were known for each drainage, and used these ranges to create two models of potential habitat for Roanoke logperch (separate models for Roanoke and Nottoway drainages). For each drainage, all reaches with habitat parameters within the collective ranges of order, link, elevation, and gradient suitable to logperch were considered "potential habitat." We created an ArcGIS layer of potential logperch habitat.

Parameter choices for our range models were limited to mappable features on pre-existing coverages. To be useful, these features must remain constant over time and be available across all potential logperch habitat. Stream size, elevation, gradient (or channel slope), and underlying geology meet these criteria and can be remotely calculated using GIS tools. Several other parameters commonly used to describe fish habitat were inappropriate for this study. For example, stream discharge varies greatly through time, and discharge coverage is not widely available. Coverages of riparian vegetation are not widely available; for example, the Virginia Department of Forestry's riparian zone coverage is limited to areas where landowners have filed for state tax-relief. There is no state-wide coverage of substrate size, embeddedness, or silt cover for Virginia. Hydrologists have not yet successfully used landscape descriptors to predict reach-scale substrate composition (A. Simpson, personal communication).We explored the prospect of using features of site gradient and geology to predict substrate features based on data collected for this study. We examined simple regression models. We regressed proportion of site with acceptable substrate size, silt, or embeddedness against gradient or geology. However, the lack of predictive capability ($R^2 = 0.0$ to 0.1) indicated that gradient and geology could not be used to predict substrate features at sites where substrate data were lacking. Thus, substrate parameters were excluded from our screening models.

To detect Roanoke logperch habitat preferences at the landscape scale, we used chi-square goodness-of-fit tests to compare attributes of reaches with known logperch presences to attributes of available reaches.

We view the screening models as part of a two-step process in which the models are used to identify reaches with suitable landscape context (step 1), which may then be visited on-site to evaluate microhabitat suitability for logperch (step 2). For example, in a given road-construction area, one of the models might be used to eliminate most reaches as potential logperch habitat and to identify those reaches requiring site visits to evaluate microhabitat suitability.

RESULTS

Literature Review of Roanoke Logperch Distribution

Roanoke logperch (*Percina rex*), the largest of Virginia's darters, has a small geographic range and narrow habitat preferences. Its range is limited to several disjunct areas within Virginia's Roanoke and Chowan river drainages (Jenkins and Burkhead 1993). Due to its small range, its widely separated populations and its low densities, Jenkins (1977) recommended that Roanoke logperch be considered a federally threatened species. In 1979 the American Fisheries Society listed the Roanoke logperch as threatened (Deacon et al. 1979). In 1975 and 1980 the U.S. Fish and Wildlife Service reviewed the status of Roanoke logperch to determine if it merited listing under the Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 1980), and in 1989 determined that because of its limited distribution and its vulnerability to urban stressors, it merited federally endangered status (Moser 1992, Rosenberger and Angermeier 2003).

Prompted by a federal status review and a proposed channelization of Roanoke River, Burkhead (1983) initiated a study of the potential biological impacts of channelization on

Roanoke logperch. Burkhead's goal was to estimate population size and distribution, and gather basic life history information for *Percina rex*. His report included the then known distribution of Roanoke logperch.

According to Burkhead's 1983 report, logperch were known to occur in several localities in the Virginia portions of the Roanoke and Chowan river drainages (Table 3). In upper Roanoke River, they were in the North Fork, South Fork, and mainstem in and near the city of Roanoke. They were also known to occur in Pigg River and Smith River of the Roanoke drainage and in Nottoway River of the Chowan drainage. The Roanoke River population occupied 31.7 rkm upstream of Niagara Dam, Roanoke County, the lower 24.1 rkm of the South Fork and the lower 15.4 rkm of the North Fork, Montgomery County, for a total of 71.2 rkm, the largest contiguous range known for *P. rex*. Logperch also inhabited Mason Creek, Roanoke County, a tributary to Roanoke River.

Two localized occurrences (<1 rkm long) of logperch were known from Pigg River, one just downstream of Rocky Mount, Franklin County, at Route 220, and a second 23 rkm downstream at Route 718 (Simonson and Neves 1986). In the Smith River system, logperch were known from the lower 400 m of Town Creek, Henry County. Logperch were also known from Nottoway River, Stony Creek, Butterwood Creek and Sappony Creek, Dinwiddie/Sussex counties, for a total of 66.3 rkm (Burkhead 1983); Table 4). Burkhead (1983) estimated total range of Roanoke logperch to be 139 rkm (Table 4).

In the mid-1980s, a status survey expanded the known range of Roanoke logperch to 235.2 rkm (Simonson and Neves 1986). Most sites yielded <2 specimens, and in two summers of sampling, they found 25 logperch. They concluded that logperch populations are sparse and the species is rare. Simonson and Neves extended the known range in North Fork Roanoke River to Route 603 east of Ellett, Virginia (9.7 rkm upstream), and added Tinker Creek (Roanoke County) for a new Roanoke River drainage range of 84.1 rkm. In Pigg River, Simonson and Neves found ten logperch between Route 646 (Rocky Mount, 8 rkm downstream of 1983 finding) and Route 40. This extended the known Pigg River range to 52 rkm. They also found a single specimen in Big Chestnut Creek, Franklin County, 3 rkm above the confluence with Pigg River. In Smith River, Patrick County, they found logperch in a 4-km reach, 4 rkm upstream of Philpott Reservoir. In the Nottoway system, Simonson and Neves found no new localities, but estimated logperch range to be 94.9 rkm. They surveyed three sites in Falling River, Campbell County, but found no logperch (Simonson and Neves 1986).

Surveys in the 1990s conducted by Virginia Tech and VDGIF found Roanoke logperch in Smith River, Henry County, "from near the headwaters to the North Carolina state line" (Scott Smith, personal communication). Upstream of Philpott Reservoir, Roanoke logperch were found in 28 rkm of Smith River. Below Philpott Dam, logperch were found in Smith River from 10 rkm below the dam to the confluence with Marrowbone Creek, representing 40 rkm. In 2000-2001, a Virginia Tech crew found 21 logperch in Smith River 8.9-20.5 rkm downstream of Philpott Dam (Orth 2001). No logperch was taken closer to the dam, suggesting that the water there was too cold to be suitable. The greatest numbers of logperch occurred furthest from the dam. In 2001 and 2002, the crew also found 13 logperch in Town Creek, confirming that a population exists there (M. Anderson, personal communication). In 2005, Lahey and

Angermeier (2006a) found 28 logperch in 2 rkm of Smith River on US Army Corps of Engineers property above Philpott Reservoir, extending the range by 5 rkm. The total known range of Roanoke logperch in the Smith River watershed is now 73.4 rkm.

In his 2002 report on the Chowan drainage, McIninch (2002) noted that the VDGIF had found logperch in Waqua Creek, Brunswick County. In 1999, a logperch was found in Nottoway River in Fort Pickett, representing an upstream range extension of 20 rkm. This occurrence was confirmed in 2000 (Angermeier and Rosenberger 2000). McIninch (2002) found two logperch at the Route 613 crossing, Dinwiddie and Brunswick counties, of Nottoway River, confirming their existence between Fort Pickett and known logperch occurrences further downstream.

Rosenberger and Angermeier (2002), found *P. rex* at six sites in 45 rkm of Pigg River, Patrick County, confirming the persistence of the Pigg River population. In our 2004 survey, we found two specimens in Big Chestnut Creek, Franklin County, approximately 12 rkm upstream of its confluence with Pigg River (Lahey and Angermeier 2005). This represented an 8.8 rkm extension of range up Big Chestnut Creek. In 2005, we also found 12 *P. rex* at the Doe Run site on Pigg River (Appendix Figure A-1).

In September 2004, we found two juvenile Roanoke logperch in a new watershed: Goose Creek, Bedford County, at the Huddleston gauging station, approximately 20 rkm upstream of its confluence with Roanoke River. The confluence of Goose Creek and Roanoke River is approximately 120 rkm downstream of any logperch records documented since 1983 in the Roanoke system and approximately 70 rkm upstream of the Brookneal hatchery (Lahey and Angermeier 2005). In May 2005, the site was revisited, and logperch were again located in the same riffle (Lahey and Angermeier 2006b). At a location 20 rkm further upstream on Goose Creek, Lahey and Angermeier found seven adult Roanoke logperch. This represented 20 rkm of new range for Roanoke logperch in Goose Creek.

Table 3. Known distributions of Roanoke logperch by stream, county, and river drainage, with the timeframe in which they were observed (and data sources). Distribution is believed to be contiguous but contains unconfirmed reaches that have not been sampled for logperch. "*" indicates a collection record that consists of only 1-2 individuals.

Timeframe observed	Stream name (data source)	County	River drainage	Distribution (rkm)
1940-2005	Roanoke River (1,3,8)	Roanoke	upper Roanoke	47.2
1940-1969	Mason Creek (1)	Roanoke	upper Roanoke	1.8
1958	Elliott Creek, trib. to So. Fk. Roanoke R. (11)	Montgomery	upper Roanoke	1.6
1966-2006	North Fork Roanoke R. (1,3)	Montgomery	upper Roanoke	34.3
1967-2004	South Fork Roanoke R. (1,3)	Montgomery	upper Roanoke	26
1979-1981	Smith Mtn. Reservoir (1,11)	Bedford	upper Roanoke	*
1986-1998	Tinker Creek (9,11)	Roanoke	upper Roanoke	3.2
1989	Leesville Reservoir (6)	Bedford	upper Roanoke	*
1998	Glade Creek (11)	Roanoke	upper Roanoke	1.1*
1962-1999	Pigg River, Route 220 (1,2,3)	Franklin	Pigg	0.5*
1967-1986	Pigg River, Route 718 (1,2)	Franklin	Pigg	0.5*
1986-2005	Pigg River (2,8,9)	Franklin	Pigg	88.2
1978-2004	Big Chestnut Creek (2,9,11,12)	Franklin	Pigg	13.2*
1978-2002	Town Creek (3,9,7)	Henry	Smith	0.4
1985-2005	Smith River, upstream of Philpott Reservoir (2,9,11,12)	Patrick	Smith	33
1995-2002	Smith River, downstream of Philpott Reservoir (7,10)	Henry	Smith	40
1978	Roanoke (Staunton) River (3) (near Brookneal)	Campbell	middle Roanoke	0.2*
2004	Goose Creek (4)	Bedford	middle Roanoke	0.2*
2004-2005	Goose Creek (12)	Bedford	middle Roanoke	20
2005	Little Otter River (12)	Bedford	middle Roanoke	2.5
1949-1986	Sappony Creek (2,3)	Dinwiddie/Sussex	Nottoway	3.1
1977-2001	Stony Creek (2,3,9,11)	Dinwiddie	Nottoway	35.6
1977-2002	Nottoway River (5,8,9,11)	Dinwiddie/Sussex	Nottoway	90
2002	Waqua Creek (5,11)	Brunswick	Nottoway	2.2*

Data Sources:

1 Burkhead (1983)
2 VDCR-DNH database (2005)
3 Jenkins and Musick (1979)
4 Lahey and Angermeier (2005)
5 McIninch and Garman (2002)
6 Moser (1992)
7 Orth (2001)
8 Rosenberger and Angermeier (2002)
9 Simonson and Neves (1986)
10 Smith (1999)
11 VDGIF database (2003)
12 Lahey and Angermeier (2006)

Table 4. The cumulative known range of Roanoke logperch from 1983 to 2005. 1983 estimates are summed from Burkhead (1983). 1986 estimates are summed from Simonson and Neves (1986). 2006 estimates are summed from a GIS layer of all reaches currently known to contain logperch. Intervening unconfirmed reaches are included in range estimates.

System	Year	Cumulative range (rkm)
upper Roanoke	1983	71.2
(above Leesville Dam)	1986	84.1
	2006	107.5
middle Roanoke (Staunton)	1983	0.2
(below Leesville Dam)	1986	0.2
	2006	22.7
Pigg	1983	1
	1986	52.2
	2006	101.4
Smith	1983	0.4
	1986	4.4
	2006	73.4
Nottoway	1983	66.3
	1986	94.9
	2006	130.9

Year	Total Cumulative range (rkm)
1983	139
1986	236
2006	436

In 2005, Roanoke logperch were found in another new watershed, east of Goose Creek: Big Otter River, Bedford County. Five logperch were found in 2.5 rkm of the Little Otter River, a 4th-order tributary of Big Otter River. The Big Otter River site is 71 rkm from the Goose Creek site.

At a few sites, Roanoke logperch were observed one time only. In 1978, Roanoke logperch were observed but not captured in the middle Roanoke (Staunton) River, Campbell County, upstream of Brookneal hatchery (Jenkins and Musick 1979, Jenkins and Burkhead 1993). Single collection records exist for Beaverdam Creek Cove (1979) and Moorsman's Cove (1981) in Smith Mountain Reservoir, Bedford County. In 1989, two logperch were found in a cove near Leesville Dam, Leesville Reservoir, Campbell County (Moser 1992). Although these sites were all extensively resampled (Simonson and Neves 1986, Jenkins and Burkhead 1993), they never yielded logperch again. Biologists consider these logperch to be “waifs,” individuals that wandered outside of their normal range. We have not included these records in our range calculations.

In 1995, juvenile logperch were reported from Buckhorn (at Route 660) and Kits (at Route 662) creeks, Mecklenburg County of the Meherrin River drainage (VDCR-DNH 2005). However, no voucher was retained and three subsequent sampling efforts in 1996 and 1998 by McIninch, Maurakis and VDGIF revealed no logperch at these localities (Steve McIninch, personal communication). The collector, Billy McGuire, was a high-school teacher (Eugene Maurakis, personal communication) who had worked with Roanoke logperch in the upper Roanoke. Because these records remain unconfirmed, we excluded them from our range calculations.

Table 4 summarizes recent changes in known logperch distribution. 1983 represents the Burkhead report. 1986 represents the Simonson and Neves report. Until 1986, logperch were documented to occupy a total of 139 rkm. Surveys since 1986 have almost tripled their known range to 436 rkm.

We included intervening but unconfirmed stream reaches in our estimates of cumulative range (Table 4). Therefore, we may have overestimated total distribution of logperch. The largest intervening unconfirmed reach is 20 rkm on Goose Creek.

Literature Review of Roanoke Logperch Habitat Use

The logperch is a benthic (bottom-dwelling) invertivore (organism that eats invertebrates) that uses a feeding tactic unique to the subgenus *Percina*: it flips pebbles and gravels with its snout and eats the exposed invertebrates. Because of this specialized feeding, logperch prefer habitat with loose, unembedded, and unsilted substrates (Rosenberger and Angermeier 2003) and substrates of a size that are easily flipped. Urbanization and agricultural land use have exposed many Virginia streams within the range of logperch to heavy siltation, a process that fills substrate interstitial spaces, thereby reducing the suitability of habitat for logperch.

Burkhead (1983) was the first to study Roanoke logperch habitat preferences. Based on work in Roanoke River, he found that logperch "typically inhabit clean sections of moderate size streams having a succession of riffle-run-pool habitats, and with a mixture of predominantly gravel and rubble substrates." He discovered that habitat use varies with age, sex, and season. Adults were found over silt-free gravel and cobble in riffles and runs. Juveniles were found in slow runs and pools over clean sand bottoms. Young of the year (YOY) were found at the margins of shallow, sandy-bottomed pools. All stages were intolerant of heavily and moderately silted substrates (Burkhead 1983).

Burkhead (1983) found that logperch fed actively in April-October, when water temperatures were 8-27ºC, with an average of 17-20ºC. He reported that when water temperatures dropped below 8º C, logperch moved into pools under large cobbles and boulders for the winter. However, Ensign et al. (1999) also observed logperch under cobbles and boulders in riffle-run habitat during winter. Burkhead (1983) found that different age groups preferred different velocities. Adults preferred faster water, juveniles slower water, and YOY water with no current. The substrates logperch used also varied with age. Juveniles and YOY were found over sand, while adults were found over gravel and cobble. Depths varied with age: YOY were found in shallow pools (15-42 cm), juveniles in deeper pools (21-121 cm) and adults at intermediate depths (15-74 cm).

Burkhead (1983) also found that during the spawning season, males and females segregated by habitat. Females occupied runs (47-93 cm deep) while males occupied riffles (22-60 cm deep). Spawning and egg deposition took place in the deeper runs used by females.

Rosenberger and Angermeier (2003) compared habitat use by logperch among Pigg River, Nottoway River, and Roanoke River. They found that across systems logperch differed in mesohabitat use (riffle/run/pool) but were consistent in their use of substrate. Roanoke logperch preferred habitat that had very little silt and moderate to slightly embedded substrates. Roanoke River's riffles and runs have little silt, but its pools are silty and embedded. In Roanoke River, logperch segregate by life stage into different velocity ranges (Rosenberger and Angermeier 2003). Adults use swifter water that has substrates free of silt. Juveniles are limited by swimming ability to slower waters (pools). Rosenberger and Angermeier (2003) posited that in Roanoke River there is a habitat bottleneck for juveniles. Juveniles are restricted to lower-velocity habitats (pools) that in the Roanoke River have suboptimal embedded substrates. In contrast, the relatively silt-free Nottoway River has pools with a combination of loose unembedded substrate and large woody debris, which may provide cover from predators. In Nottoway River, logperch preferred pool habitat. Rosenberger and Angermeier (2003) concluded that logperch are “substrate specialists and mesohabitat generalists” that can occupy a range of velocities and depths to find appropriate substrate for feeding. Rosenberger also suggested that although logperch did not appear to prefer riffle-runs in Nottoway River, logperch were found near such habitat in the fall-zone because it is necessary for spawning (Rosenberger 2002).

Differences in habitat use by logperch between the Roanoke and Nottoway systems suggest that logperch may be forced to use higher velocities to find their preferred substrate of loose, silt-free pebbles in heavily silted systems (e.g., Roanoke River). This shift represents an energetic cost to the logperch. According to Rosenberger (2002), “plasticity in selection of depth and velocity characteristics may account for logperch persistence in the Roanoke River under suboptimal conditions.”

Field Survey

Roanoke logperch were captured in the Smith River, Pigg River, Goose Creek and Big Otter River watersheds. They were not found in the Dan River, Mayo River, Blackwater River, Falling River, or Meherrin River watersheds (Appendix Figures A-1 and A-2). Both Goose Creek and Big Otter River are new logperch localities and these occurrences are the first to be discovered in the middle Roanoke River system (below Leesville Dam) since the 1978 observations. In Goose Creek, we found seven adult Roanoke logperch in a 730-m reach at Twin Peaks and several 20 km downstream at Huddleston. In the Big Otter watershed, we found five logperch in 2500 m of marginal habitat in Little Otter River.

We sampled four sites in the Meherrin River watershed but found no logperch. Our sampling was limited by high flows to smaller tributaries. Only the North Meherrin contained suitable logperch habitat. We attempted to sample a Meherrin River mainstem site during low flow, but were unable to completely sample the site due to dangerously rising water. Three of the tributaries were low-gradient sand-silt streams with woody debris and with intensive logging and cattle-grazing in their catchments.

We identified 23,667 individuals of 69 species in the Roanoke and Chowan drainages. Tables A-2 through A-10 in the appendix tabulate fish species and counts of individuals by watershed and site. We captured the most species in the Pigg River, Blackwater River, Big Otter River and Meherrin River watersheds, with 38 species each. The margined madtom (*Noturus insignis*) was the most widespread species, found at all 36 sites. The most abundant species across samples were bluehead chub (*Nocomis leptocephalus*) and white shiner (*Luxilus albeolus*). The most widespread introduced species were largemouth bass and smallmouth bass (*Micropterus dolomieu* and *M. salmoides,* respectively). We found 61 largemouth bass at 13 sites and 27 smallmouth bass at 12 sites. The most abundant introduced species was bluntnose minnow (*Pimephales notatus*).

Table 5. Results of snorkel-surveys for Roanoke logperch.

Watershed	Number of sites snorkel-surveyed	Visibility (m)	*Percina rex* detected?
Smith River	3	1.0-1.6	Y (White Falls)
Pigg River	3	0.95-2.0	Y (Doe Run)
Goose Creek	3	1.0-1.3	N
Big Otter River	4	0.80-2.5	N
Falling River	4	0.90-1.6	N
Meherrin River	1	1.1	N

Some sites supported many logperch, rich native assemblages, and rare species. For example, sites on Smith River upstream of Philpott Reservoir supported bigeye jumprock (*Moxostoma ariommus*), and Pigg River upstream of Doe Run supported a rich assemblage of entirely native species including Roanoke bass (*Ambloplites cavifrons*). In the Meherrin River drainage, we found American eel (*Anguilla rostrata*) and American brook lamprey (*Lampetra appendix*).

Snorkel surveys were not universally successful at detecting logperch. Although we tried to limit our snorkel surveys to sites with visibility of at least 1m, due to the persistent turbidity of Piedmont streams, we were often unable to meet this minimal requirement (Table 5). At two sites where logperch were abundant, White Falls, Smith River (visibility 1.0 m) and Doe Run, Pigg River (visibility 1.5 m), we detected Roanoke logperch using snorkel surveys. At two sites where logperch were known to occur, but were sparse, Huddleston, Goose River (visibility 1.3 m) and Little Otter, Big Otter River (visibility 2.5 m), we were unable to detect logperch using snorkel surveys. At both Doe Run and White Falls, we found logperch in riffles and runs. We saw more logperch in slow runs than in other types of mesohabitat.

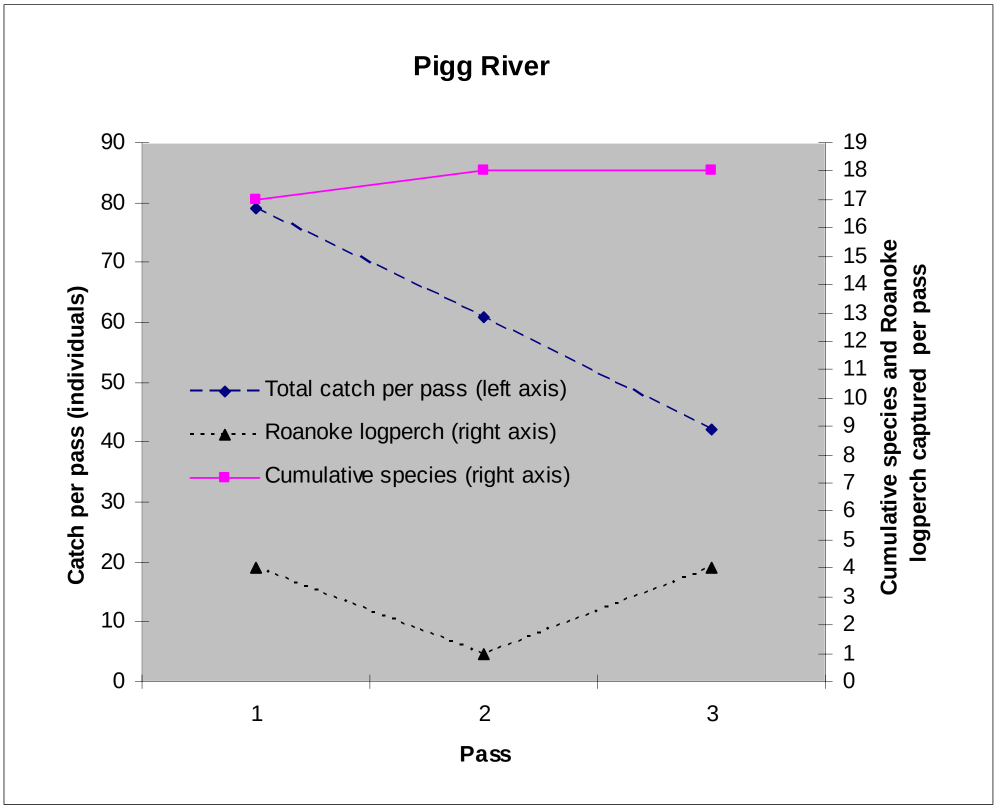


Figure 2. Cumulative species, total catch per pass of individuals, and Roanoke logperch catch per pass in Pigg River, Doe Run site. Each pass represents 10 non-overlapping netsets. As sampling effort increases, catch per effort decreases and cumulative species increases. Roanoke logperch catch rate, however, does not decline across three passes. This indicates that Roanoke logperch have low catchability.

Our extensive and intensive sampling confirmed that Roanoke logperch are difficult to detect even though our standard protocol applies considerably more sampling effort than typically is applied in general fish surveys. At the Doe Run site on Pigg River, where logperch were relatively abundant, we sampled a riffle intensively. We captured 4 logperch in the first pass, 1 in the second pass, and 4 in the third pass (Figure 2). We sampled Little Otter River intensively and extensively. In the intensive sampling (riffle 9), a Roanoke logperch was captured in the second pass but none was captured in the first or third passes (Figure 3). In the extensive sampling, logperch were detected in the 1st, 8th, 9th, and 15th riffles. Had we not intensively sampled riffle 9, we would have detected logperch in only 3 of 15 riffles (20%).

Overall, electrofishing proved a more successful method for detecting new Roanoke logperch occurrences than snorkeling. When snorkeling, we detected Roanoke logperch only at sites where they were abundant. However, snorkeling gave us a better understanding of Roanoke logperch habitat use. Electrofishing was limited to riffles and fast runs while snorkeling allowed us to sample slower runs and pools. We found logperch equally represented among riffle, runs and pools. At the Doe Run site, using electrofishing, we detected logperch in riffles 1, 2 and 5; while snorkeling, we detected them in riffles 1 and 2, as well as in intervening runs/pools 2 and 3. At the White Falls site, using electrofishing, we detected logperch in riffles 1, 2, 3, and 4; while snorkeling we detected them in riffles 1, 3, 4, and 5, as well as in intervening runs 1, 2 and 3. Roanoke logperch were most common in slow runs at least 0.5 meters deep.

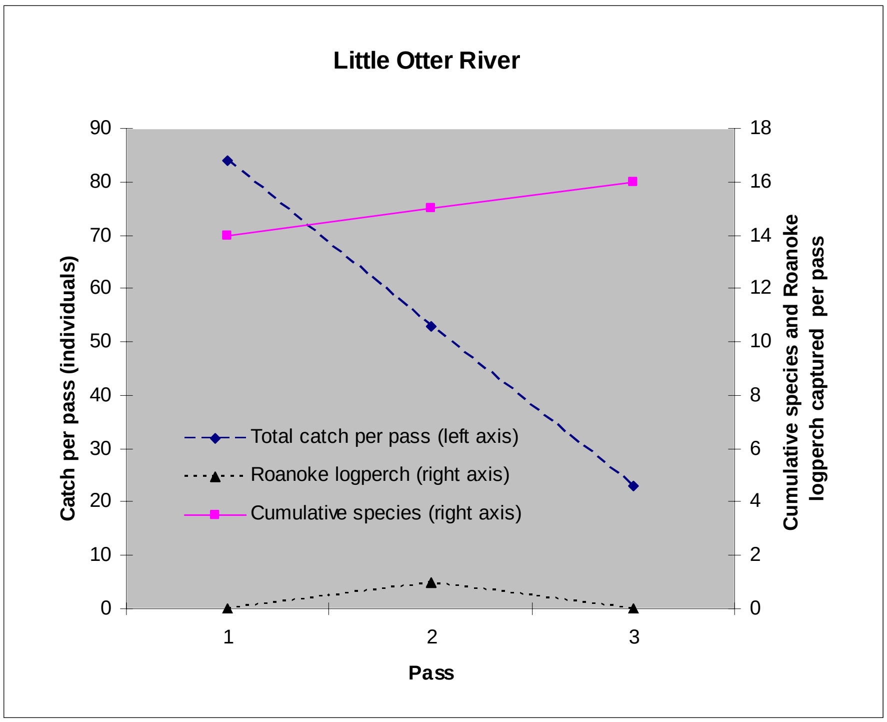


Figure 3. Cumulative species, total catch per pass of individuals, and Roanoke logperch catch per pass in Little Otter River site. Each pass represents 8 nonoverlapping netsets. As sampling effort increases, catch per effort decreases and cumulative species increases. Roanoke logperch catch rate, however, does not decline across three passes. This indicates that Roanoke logperch have low catchability.

Habitat Suitability

We ranked all surveyed sites by their estimated habitat suitability for Roanoke logperch (Table 6). We also ranked sites by habitat suitability for all sites in watersheds known to contain logperch (Table 7). We calculated logperch catch per unit effort (CPUE) for each site within watersheds containing logperch. CPUE represents relative density of logperch among sites. If our habitat model correctly reflects logperch habitat preferences and if habitat availability limits logperch abundance, then our habitat assessment should predict logperch density. That is, logperch should be denser in “better” habitat. Using data from Table 7, we regressed relative logperch density per site against total area of preferred habitat per site. This simple model explained 69% of the variance in relative logperch density (Figure 4). However, the scatter in Figure 4 shows that logperch occupy a range of habitat quality. Only 8.2% of the Twin Peaks site was preferred habitat, yet it ranked fourth in logperch density. The Mabel’s site was so heavily silted that only 4% was preferred logperch habitat, yet this site supported logperch. Thus, poor overall habitat quality at a site cannot be used to rule out logperch presence.

Rosenberger and Angermeier (2002) found that logperch use microhabitats with an average (mean ± one standard deviation) depth of 22-64 cm, dominant substrate sizes 6-9, subdominant substrate sizes 4-7 and embeddedness and silt cover of <50%. Localities where we observed logperch were generally consistent with these habitat parameters. However, we found that by narrowing the range of substrate sizes (5-8) and silt cover and embeddedness (<25%) allowed as “suitable habitat,” our models gained predictive power.

We mapped the sites with best available habitat for Roanoke logperch. We arbitrarily chose to map the best 14 sites (out of 36) (Figures 5 and 6). All watersheds surveyed had some sites with habitat suitable for logperch (Table 8). Because the ranking was weighted by site area, larger sites scored better than smaller sites. This weighting is supported by our finding that, in watersheds containing logperch, sites with logperch were significantly (t-test, $p = 0.0002$) larger (mean width = 21.1 m) than sites without logperch (mean width = 11.6 m), and is consistent with our knowledge of stream-size preferences by logperch (Strahler orders 4-6; see Results - Screening Model). The most suitable and least suitable sites were evenly scattered among and within watersheds. Collectively, sites in the Meherrin were least suitable. Only one site (North) in the Meherrin watershed looked promising for logperch. The Dan River, Mayo River and Falling River watersheds had suitable habitat for logperch, but no logperch was found there. The Big Otter River watershed, on the other hand, had some of the least suitable habitat, and yet supported a few logperch. The White Falls site on Smith River had exceptional habitat suitability and logperch density but other sites in the Smith River watershed were more typical of the upper Piedmont. Only one site with less than 1000 m^2 of preferred logperch habitat contained logperch (Figure 4).

Table 6. Sites in the Roanoke and Chowan drainages ranked by habitat suitability for Roanoke logperch. Watershed and site names are from Appendix Table A-1. Sites are ranked by estimated area of preferred habitat. "Preferred/Total" is the number of sampled microhabitat points with preferred habitat configurations divided by the total number of sampled points. "%" is the percentage of the site with preferred habitat configurations.

Percent Suitability Ranking	Watershed	Site	Measured habitat points		Estimated area of preferred habitat (m^2)	Logperch captured
			Preferred/Total	%		
1	Dan	Fish Hatchery	53/130	40.8	6106	0
2	Smith	White Falls	44/218	20.2	4461	23
3	Pigg	Doe Run	51/173	29.5	3728	12
4	Smith	Philpott	31/210	14.8	3371	5
5	Goose	Huddleston (5/28/05)	33/242	13.6	2045	1
6	Falling	Naruna (8/15/04)	31/175	17.7	2248	0
7	Mayo	Moore's	28/202	13.9	2143	0
8	Big Otter	Little Extended	8/101	7.9	2106	4
9	Falling	Naruna (5/29/05)	29/168	17.3	1896	0
10	Falling	Hevey	16/133	12.0	1790	0
11	Pigg	Big Chestnut	28/136	20.6	1760	2
12	Blackwater	Cowfarm	20/184	10.9	1693	0
13	Goose	Huddleston (8/31/04)	19/240	7.9	1438	2
14	Pigg	LaPrade	25/128	19.5	1190	0
15	Goose	Twin Peaks	13/158	8.2	1117	7
16	Dan	Kibler	13/120	10.8	1046	0
17	Blackwater	702 Ford	8/227	3.5	1035	0
18	Meherrin	North	9/149	6.0	775	0
19	Blackwater	Riddle	6/260	2.3	686	0
20	Dan	Peter's	17/101	16.8	594	0
21	Mayo	North Fork	15/63	23.8	539	0
22	Pigg	Snow	14/83	16.9	494	0
23	Pigg	Waid Park	8/108	7.4	454	0
24	Falling	Golf Course	7/91	7.7	396	0
25	Smith	Runnett Bag	7/82	8.5	378	0
26	Blackwater	Callaway	3/135	2.2	339	0
27	Big Otter	Mabel's	4/100	4.0	310	1
28	Goose	Union Church	6/83	7.2	304	0
29	Smith	Otter (Smith)	4/90	4.4	256	0
30	Falling	South Fork	4/87	4.6	193	0
31	Dan	Mitchell's	3/76	4.0	142	0
32	Big Otter	Buffalo Creek	2/81	2.5	120	0
33	Goose	Dickerson	0/105	0.0	0	0
34	Meherrin	Fontaine	0/53	0.0	0	0
35	Meherrin	Great	0/85	0.0	0	0
36	Meherrin	Flat Rock	0/91	0.0	0	0

Table 7. All sites in watersheds known to contain logperch ranked by estimated area of preferred habitat. Watershed and site names are from Appendix Table A-1 . "Available" is the number of sampled microhabitat points at a site. "Preferred" is the number of points at the site with preferred habitat configurations. "% Preferred" is the percentage of measured habitat points that are preferred habitat configurations. "Estimated Area of Preferred Habitat" is the area of the site multiplied by the proportion of habitat that is suitable to logperch. Logperch density is the number of logperch captured divided by number of netsets.

			Measured Habitat Points						
Rank	**Watershed**	**Site**	**Preferred**	**Available**	**% Preferred**	**Estimated Area of Preferred Habitat (m^2)**	**Number of Logperch Captured**	**Sampling Effort (Netsets)**	**Logperch Density**
1	Smith	White Falls	44	218	20.2	4461	23	44	0.52
2	Pigg	Doe Run	51	173	28.5	3728	12	53	0.23
3	Smith	Philpott	31	210	14.8	3371	5	33	0.15
4	Goose	Huddleston (2005)	39	242	16.1	2423	1	32	0.03
5	Big Otter	Little Extended	8	101	7.92	2106	4	132	0.03
6	Pigg	Big Chestnut	28	136	20.6	1760	2	23	0.09
7	Goose	Huddleston (2004)	19	240	7.9	1438	2	21	0.10
8	Pigg	LaPrade	25	128	19.5	1190	0	31	0.00
9	Goose	Twin Peaks	13	158	8.2	1117	7	50	0.14
10	Pigg	Snow	14	83	16.9	494	0	25	0.00
11	Pigg	Waid	8	108	7.4	454	0	18	0.00
12	Smith	Runnett Bag	7	82	8.5	378	0	27	0.00
13	Big Otter	Mabel's	4	100	4.0	310	1	36	0.03
14	Goose	Union Church	6	83	7.2	304	0	17	0.00
15	Smith	Otter (Smith)	4	90	4.4	256	0	22	0.00
16	Big Otter	Buffalo	2	81	2.5	120	0	21	0.00
17	Goose	Dickerson	0	105	0.0	0	0	18	0.00

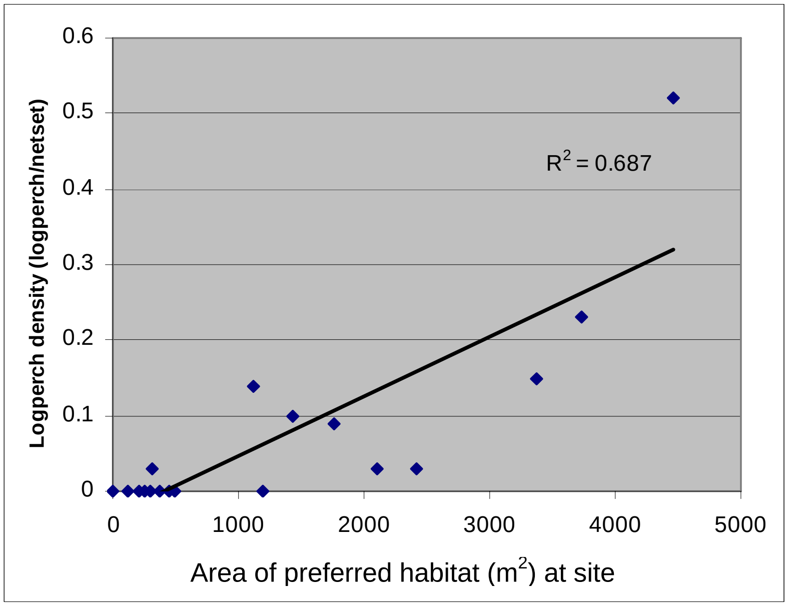


Figure 4 Regression of relative logperch density versus availability of preferred habitat. The x-axis is proportion of total habitat categorized as "preferred by Roanoke logperch" x area of site. Plotted points represent all sites in watersheds known to contain logperch.

Table 8. Watersheds ranked by % of count of sites that contained minimum area of habitat (>1000 m^2) suitable for Roanoke logperch.

Rank	Watershed	% of sites' area suitable for logperch
1	Pigg	60
2	Smith	50
3	Dan	50
4	Goose	50
5	Falling	50
6	Mayo	50
7	Blackwater	50
8	Big Otter	33
9	Meherrin	25

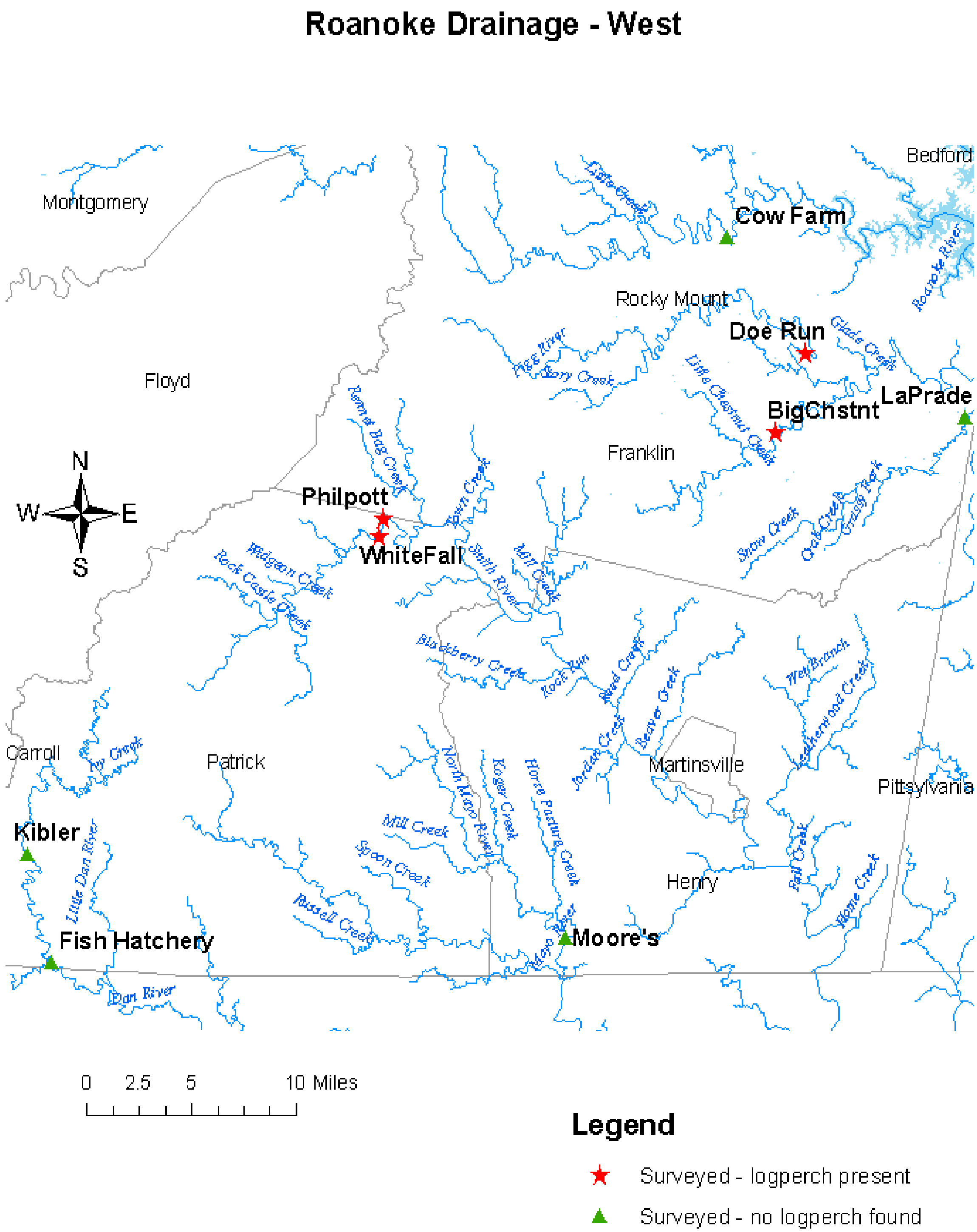


Figure 5. Map of nine sites in the western Roanoke River drainage with suitability for Roanoke logperch ranking among the top 14 sites surveyed. 1 inch = 10 miles.

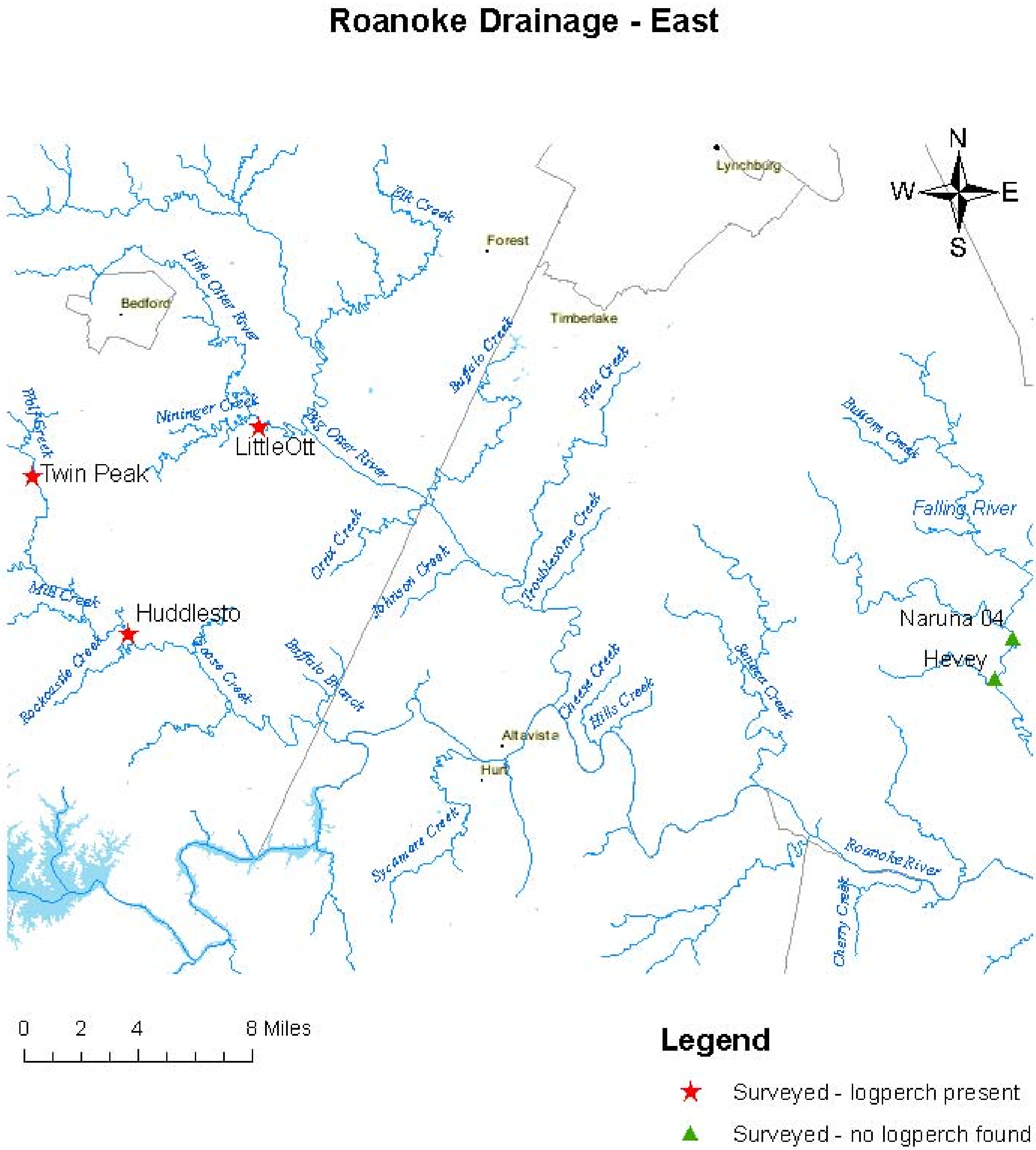


Figure 6. Map of five sites in the eastern Roanoke River drainage with suitability for Roanoke logperch ranking among the top 14 sites surveyed. 1 inch = 10 miles.

Screening Model

Roanoke logperch have been found in a wide range of stream sizes, gradients, and elevations (Table 9). Over their entire range, Roanoke logperch occur in streams of Strahler order 2-6, Shreve link 3-713, gradient 0-10.2 m/km, and elevation 4-488m.

Table 9. Ranges of habitat attributes of reaches known to contain Roanoke logperch in the Roanoke and Nottoway river drainages, including Strahler order, Shreve link, gradient, and elevation. Also included are ranges of attributes used in the VDGIF Wildlife Action Plan model and elevation adjusted for potential NED inaccuracies.

	Roanoke	**Nottoway**	**VDGIF Wildlife Action Plan**
Order	2-6	3-6	not used
Link	3-372	22-713	3-999
Gradient (m/km)	0-10.2	0-1.29	<15
Elevation (m)	181-488	4-68	175-500 (Roanoke drainage only)
Elevation (m) adjusted for potential error	156-513	0-93	

Available habitat differed in the Nottoway and Roanoke drainages (Table 10). The Nottoway is lower in elevation (0-189 m) than the Roanoke (75-950 m) and has lower-gradient streams (0-16 m/km versus 0-53 m/km). Over the past six years, as more sites in the Nottoway have been sampled, the known range of Roanoke logperch has been extended upstream.

Table 10. Available habitat in the Roanoke and Nottoway river drainages, including Strahler order, Shreve link, gradient, and elevation.

	Roanoke	**Nottoway**
Order	1-7	1-6
Link	1-4802	1-842
Gradient (m/km)	0-53	0-16
Elevation (m)	75-946	0-189

Based on known logperch occurrences, the drainage-specific models enable us to project the distribution of suitable logperch habitat. Figures 7 and 8 are GIS projections showing all reaches in the Roanoke and Nottoway drainages that may contain habitat suitable for Roanoke logperch.

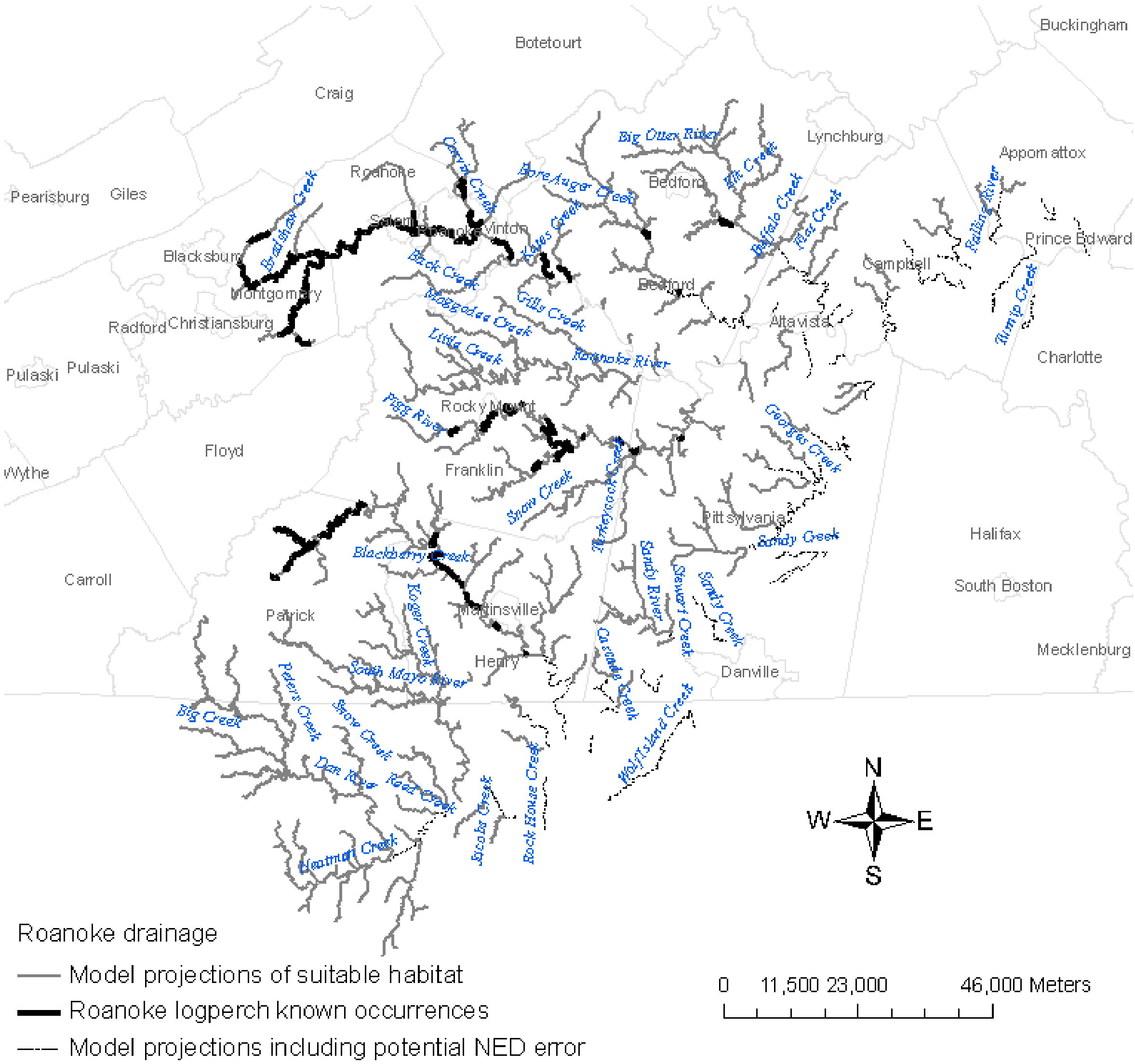


Figure 7. Potential habitat for Roanoke logperch in the Roanoke River drainage. Included are reaches with known occurrences of logperch, suitable reaches projected by our model, and suitable reaches added to our model projection when we account for potential errors in NED elevation. The added reaches extend the lower limit of suitable elevation from 181 m to 156 m.

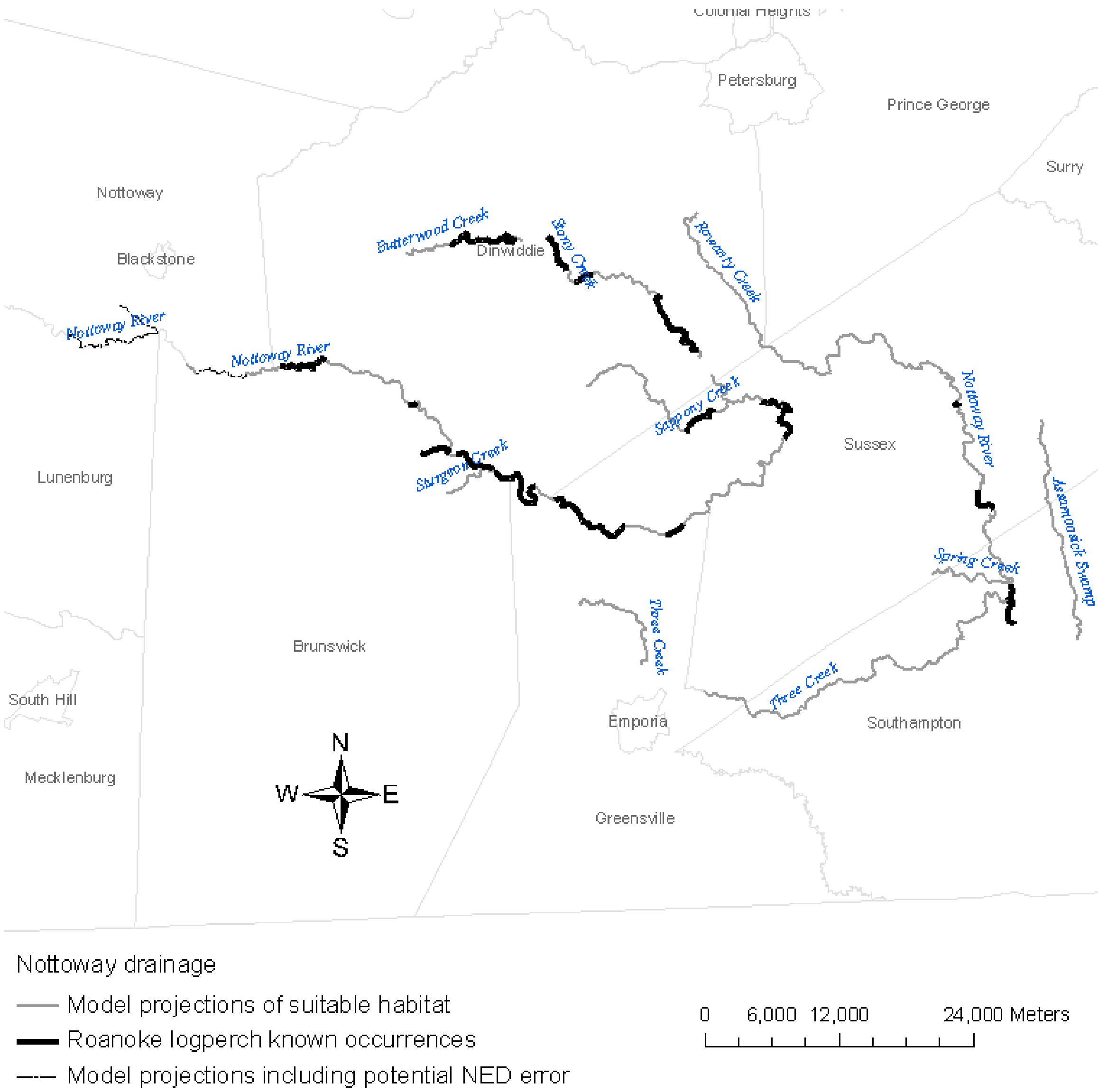


Figure 8. Potential habitat for Roanoke logperch in the Nottoway River drainage. Included are reaches with known occurrences of logperch, suitable reaches projected by our model, and suitable reaches added to our model projection when we account for potential errors in NED elevation. The added reaches extend the upper limit of suitable elevation from 68 m to 93 m.

Because we used some data from VDGIF's Wildlife Action Plan (2005) to build our models, our projections of potential logperch habitat are similar to theirs. Both projections reflect only currently known occurrences of Roanoke logperch. VDGIF created two Essential Habitat models, one for the Roanoke and one for the Nottoway drainage. VDGIF's Roanoke drainage model selected reaches of link 3-999, gradient <15m/km, and elevation 175-500m. Their Nottoway model selected reaches of link 3-999, gradient <15m/km, and elevation unlimited (Table 9). Our models were more restrictive. In the Nottoway drainage, we limited Shreve link to 22-713, elevation to 4-68m, and gradient to ≤ 1.29m/km. These new parameter ranges excluded

735 of the 1053 reaches found in VDGIF's Essential Habitat model for the Nottoway drainage (Figure 7); we identified 318 Nottoway reaches as potential Roanoke logperch habitat. In the Roanoke drainage, differences were more subtle. By limiting gradient to ≤ 10.2 m/km (versus VDGIF's <15 m/km), we excluded some upstream reaches. By excluding reaches of Shreve link >372 (versus VDGIF's >999), we removed the middle Roanoke River. By limiting the lower endpoint of elevation to 181m (the lowest known occurrence of logperch in the Roanoke drainage) rather than VDGIF's 175m, we excluded some lower elevation Roanoke River reaches (Figure 6). However, unlike VDGIF, we included about 320 potential reaches in North Carolina. For the Roanoke drainage, we identified 1739 reaches as potential habitat, while the VDGIF model identified 1623 reaches.

Accuracy of the NED potentially affected our habitat projections. At 30-m resolution (1:100,000 scale), the NED is accurate to one-half a contour interval (http://edc.usgs.gov/guides/dem.html#accuracy). Contour intervals are 6-50 m, resulting in potential elevation inaccuracy of up to 25 m. These inaccuracies also generated errors in gradient for some reaches. For example, some reaches appear to flow uphill. Most negative gradients were associated with reaches of Shreve order 1-2. Roanoke logperch have never been found in reaches of Shreve order 1-2, so we excluded this size from our analyses. Our screening models are designed so that negative gradients do not remove reaches from potential logperch habitat (gradient <= 10.2). However, negative gradients would have affected chi-square analyses of logperch habitat preference (below). For the chi-square analyses, we changed gradients for 258 out of 3593 (7.2%) of the Roanoke drainage reaches from negative to zero. Similarly, we changed gradients for 57 out of 1053 (5.4%) Nottoway reaches from negative to zero. Gradient error was uniformly scattered among reaches containing logperch and reaches with no logperch. By changing negative gradients to zero, we effectively removed them from the chi-square analyses.

Adjusting our models to account for potential NED elevation inaccuracies (up to ±25 m; Table 9) would have extended considerably the set of reaches with potentially suitable elevation (and suitable habitat). In the Roanoke drainage, this would have increased the *maximum* number of reaches with potential logperch habitat from 1739 to 2048 (+308 reaches), and in the Nottoway drainage, from 318 to 331 (+13 reaches). The exact number of suitable reaches cannot be estimated without accurate reach-specific measures of elevation. Figures 7 and 8 show projections of these extended sets of reaches. In the Roanoke drainage, elevation adjustments extend potential logperch range downstream, whereas in the Nottoway drainage, they extend potential logperch range upstream.

Roanoke logperch selectively use available habitat throughout their range. Figures 9-12 contrast habitat availability with habitat use by Roanoke logperch. All contrasts except that for Nottoway drainage gradient indicate non-random habitat use (chi-square goodness-of-fit test, $p < 0.001$). Roanoke logperch selected 5th-order streams (1:100,000) of Shreve link 150-300 in both the Roanoke and Nottoway drainages (Figures 9 and 10). In the Roanoke drainage, logperch preferred low-gradient streams (0-3 m/km), and avoided high-gradient (>3 m/km) streams (Figure 11). In the Nottoway, logperch used low-gradient streams in proportion to their availability but avoided streams with gradients >2m/km (Figure 11). In the Nottoway drainage, Roanoke logperch selected elevations between 30 and 60 m, while in the Roanoke drainage they selected elevations between 300 and 500 m (Figure 12).

Figure 9. Stream size selection by Roanoke logperch in all reaches (top), in the Roanoke River drainage (middle), and in the Nottoway River drainage (bottom). Left y-axis represents the number of available reaches. Right y-axis represents the number of reaches where logperch are known to occur.

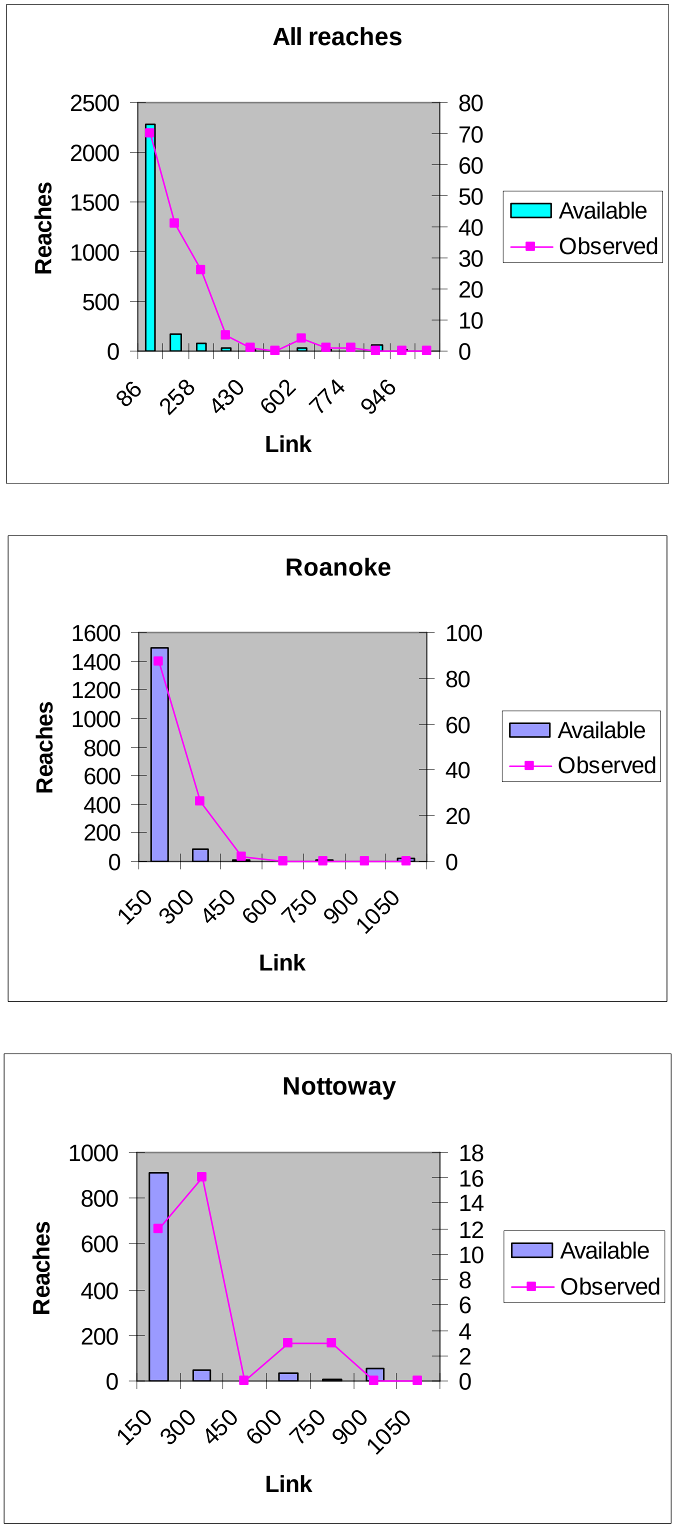


Figure 10. Stream size selection by Roanoke logperch in all reaches (top), in the Roanoke River drainage (middle), and in the Nottoway River drainage (bottom). Left y-axis represents the number of available reaches. Right y-axis represents the number of reaches where logperch are known to occur.

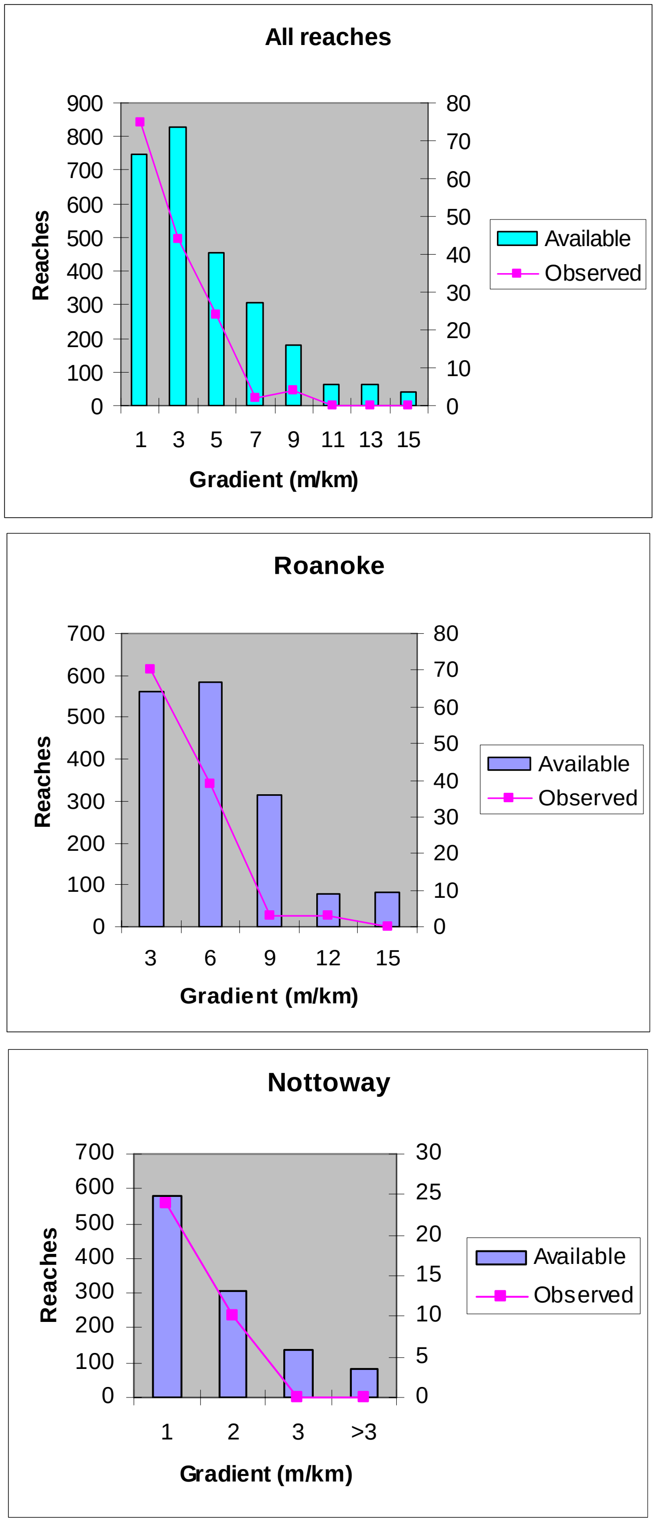
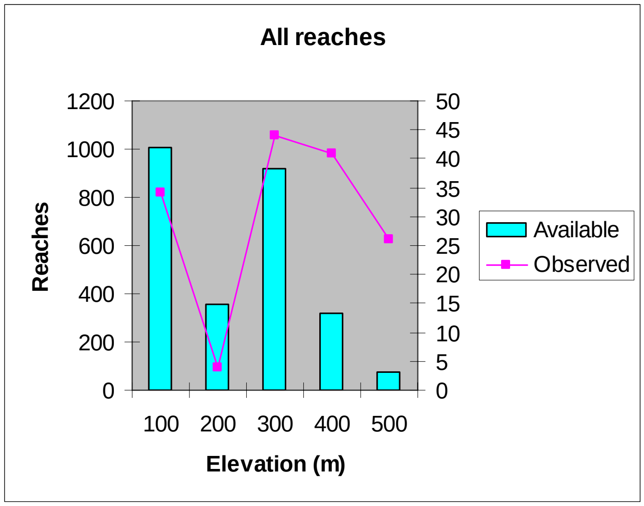
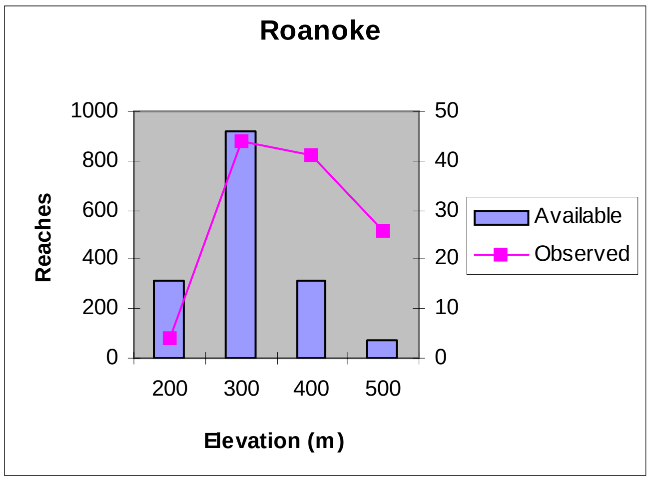


Figure 11. Stream gradient selection by Roanoke logperch in all reaches (top), in the Roanoke River drainage (middle), and in the Nottoway River drainage (bottom). Left y-axis represents the number of available reaches. Right y-axis represents the number of reaches where logperch are known to occur.





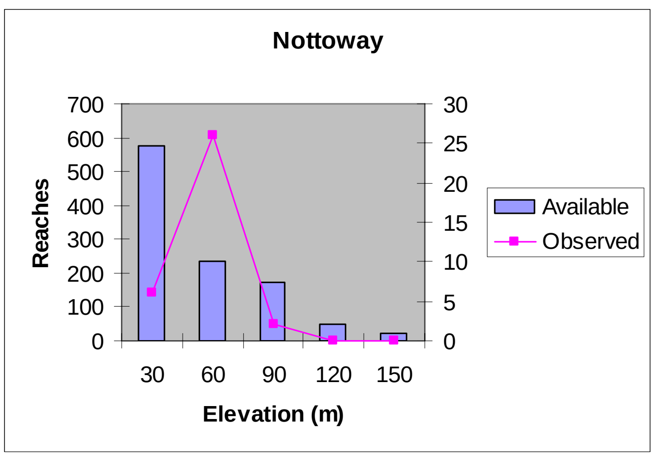


Figure 12. Stream elevation selection by Roanoke logperch in all reaches (top), in the Roanoke River drainage (middle), and in the Nottoway River drainage (bottom). Left y-axis represents the number of available reaches. Right y-axis represents the number of reaches where logperch are known to occur.

DISCUSSION

Literature Review

Three reservoir collection records for Roanoke logperch exist, but to the best of our knowledge, reservoirs are unsuitable habitat for Roanoke logperch. Thus, unless reservoirs are shown to be tenable habitat for Roanoke logperch, reservoir records shall be treated as "waifs"; that is, logperch that are dispersing through, rather than colonizing new habitats.

The probability of Roanoke logperch occurrence in the Meherrin River watershed depends on the reliability of a single DCR-DNH collection record. This record reads "collection of several individuals, summer of 1995" in Buckhorn Creek at Route 660 and in Kits Creek at Route 662 (both within 2 miles of Meherrin River mainstem). No voucher was taken. Both sites were resampled by VDGIF in fall of 1996 and in June and October of 1998, but no logperch were found (VDCR-DNH 2005). We tentatively exclude the Meherrin watershed from the range of Roanoke logperch. If logperch occur in the Meherrin River drainage, they are most likely in the mainstem where deep water and sorted substrates are available.

Field Survey

The Roanoke logperch's low catchability, patchy distribution, and low abundance make them difficult to detect. Low detectability increases the likelihood of false absences, complicating efforts to model their occurrence. In three-pass depletion sampling, CPUE is expected to decrease in consecutive passes as a riffle is depleted of fishes. In Pigg River (Figure 2), although total fish CPUE decreased over three passes, Roanoke logperch CPUE did not, demonstrating their low catchability. Roanoke logperch are patchily distributed, both among riffles within a reach and among reaches within a watershed. During Little Otter River extensive sampling, two gaps in distribution of five or more riffles showed that had we, by chance, picked the wrong five riffles to sample, we might falsely have concluded that logperch were absent from the site, and furthermore, absent from the watershed. Although we sampled six sites scattered across the Big Otter River watershed, we detected logperch in only one site, Little Otter. During our intensive sampling of Little Otter River, logperch were not captured until the second pass (Figure 3). Had we sampled the riffle using our standard single-pass protocol, we would falsely have concluded that logperch were absent. The likelihood of not detecting logperch at sites where they are present in low abundance is high, perhaps 30-40%. Precise estimates of this likelihood would require much more intensive and extensive sampling than is typically applied in fish surveys. Consequently, the problem of false absences is commonly ignored in projections of potential habitat. For example, VDGIF has not calculated presence/absence error rates for their projection of suitable logperch habitat (K. Jenkins, personal communication).

The data from intensive sampling (Figures 2 and 3) indicate that our assessments of logperch presence in riffles with many logperch are reliable (during Doe Run intensive sampling, all passes yielded logperch), but that our assessments of abundance (CPUE) must be treated cautiously. Doe Run passes 1 and 2 yielded at most 44% and 20%, respectively, of the logperch known to occur in the riffle. These data indicate that not only do most logperch evade capture on a given electrofishing pass, but also that capture efficiency varies by at least a factor of two between passes. This means that ranks of 1-pass logperch CPUE among riffles (and perhaps among sites; Table 7) should not be judged as different unless CPUE values differ by a factor of two or greater. Furthermore, for a riffle with few (e.g., < 5) logperch, our standard sampling could easily show a false absence, as would have occurred for the intensively sampled riffle in Little Otter River.

These data also show that, at sites where logperch were sparse, logperch were not detected by our standard protocol in most riffles and logperch had low detectability across several consecutive riffles. The 15 riffles in our extensive sample included 11 possible sets of five consecutive riffles (our standard site length). Our standard sampling protocol would have detected logperch in seven (64%) of those sets. Thus, if we assume that Little Otter River is representative of logperch detectability in low-abundance sites, we can estimate the frequency of false absences to be 30-40% at such sites. At low-abundance sites, greater sampling effort is required to provide more reliable estimates of logperch presence/absence, but the specifics of an appropriate sampling protocol depend on the confidence needed in observed absences (see Recommendation 2).

Habitat Suitability

Roanoke logperch relative density across sites is positively related to available habitat (Figure 4). The y-axis in Figure 4 allows a between-site comparison of logperch abundance (CPUE), not of logperch population size. We still lack the data to predict population size from habitat quality. Examining the relation between logperch population size and habitat availability would require estimates of absolute abundance (e.g., via multiple-pass depletion sampling), along with estimates of habitat availability (such as ours). Figure 4 also illustrates that suitable (or unsuitable) habitat is an imperfect predictor of actual logperch presence/absence; 30% of the variance in logperch density is unexplained by our measure of habitat suitability. Thus, some sites with little apparent logperch habitat may still support logperch and some sites with much apparent habitat may lack logperch.

Screening Model

Model projections of potential Roanoke logperch habitat are subject to change if logperch are found outside their currently known ranges of order, link, elevation, or gradient. For example, in our field survey we extended the lower endpoint of known logperch elevations in the Roanoke drainage from 191 m to 181 m. New occurrences may extend potential habitat downstream in the Roanoke drainage and upstream in the Chowan drainage. We expect that with more sampling, Roanoke logperch will be found at wider ranges of habitat parameters, and model projections will need to be expanded accordingly.

The chi-square analyses assumed that all available reaches have been sampled for logperch and that logperch are 100% detectable. In fact, most available reaches have not been sampled, and logperch are difficult to detect, so some apparent absences are not real (as illustrated in our intensive/extensive surveys [see Discussion – Field Survey]). Because a detailed analysis of how sampling effort and logperch detectability is distributed among reaches is beyond this study's scope, our assessment of habitat preferences treats these false absences as real absences. Thus, although the results of the chi-square analyses are valid, the inferences drawn from the analyses must be tempered by the data limitations.

Using our models requires balancing two kinds of errors: asserting logperch are present when they are absent and asserting logperch are absent when they are present. Our models are designed mostly to minimize the latter, especially in the context of whether a new survey has a reasonable chance of showing a new occurrence. Different users may adopt different levels of acceptable error (both kinds). If knowledge of outlying occurrences is very valuable, a user might tolerate very little error and always desire new surveys in reaches with <95% certainty of logperch absence. In this case, some reaches not designated herein as "suitable" may still be deemed suitable enough to warrant surveying. In contrast, users who do not value outlying occurrences might tolerate much more error and opt for conducting new surveys only in reaches with <50% certainty of logperch absence. All of these reaches are designated as "suitable" by our models.

Notably, high levels of absence certainty are very difficult to build because of low detectability, patchy distribution, and low abundance. Thus, even if a survey finds no logperch, certainty about absence may not increase substantially unless the survey's sampling effort is especially intensive and extensive.

CONCLUSIONS

- As Roanoke logperch have become more studied, new occurrences of Roanoke logperch have been found in new watersheds. It is not safe to assume that because a Roanoke or Chowan drainage watershed has no prior record of Roanoke logperch, that it does not contain Roanoke logperch. Roanoke logperch appear to be substrate specialists and mesohabitat generalists.

- Roanoke logperch are more widespread than previously believed. We found logperch in two new watersheds that substantively increased the known range. Our survey's downstream limits were restricted to wadeable waters. With additional focused sampling of large streams, the range of Roanoke logperch may be found to be more extensive.

- Snorkel surveys are less reliable than electrofishing for confirming Roanoke logperch absences. Given the low detectability of Roanoke logperch, it is more prudent to assume Roanoke logperch presence at sites within Roanoke logperch range containing appropriate habitat than to survey and accept a false absence.

- Suitable logperch habitat is more widespread than previously believed. All surveyed watersheds had some sites suitable to logperch. The White Falls site on Smith River had exceptional habitat suitability and logperch density. Within each watershed, larger streams generally provided more suitable habitat than smaller streams. However, even sites with little suitable habitat may contain logperch, as evidenced in the Mabel's site on Little Otter River (Table 6).

- An important implication of a high rate of false absences is that interpreting results of surveys for rare species is not straightforward. In particular, agencies charged with protecting a rare species might not be confident that a species' observed absence from a surveyed reach is real, and might insist on applying management actions that assume species presence. Thus, differences in opinions among experts and/or differences in agency mission can lead to different management recommendations.

- Our projections of suitable habitat for Roanoke logperch should be viewed as approximations, subject to errors related to false absences from surveys already conducted and to the lack of comprehensive surveys in many potentially suitable reaches. It seems very likely that additional surveys will reveal additional logperch occurrences. Some new occurrences will extend the ranges of habitat parameters used in our screening models, thereby creating the need to revise our projections. In the meantime, however, the projections represent a synthesis of the best available scientific knowledge of potential logperch distribution, and as such are useful tools in the management of Roanoke logperch.

- Our screening models can be used to determine whether a particular reach falls within Roanoke logperch range. If a reach falls within logperch range, and contains substantial preferred habitat, then it is more conservative and cautious to assume Roanoke logperch presence than absence.

RECOMMENDATIONS

1. *To detect Roanoke logperch at new sites, VDOT's environmental staff should use quadrat-based electrofishing rather than snorkeling*. Piedmont stream turbidity precluded snorkeling on most sampling days. At sites where visibility was excellent but logperch were scarce, electrofishing detected logperch when snorkeling did not.

2. *VDOT's environmental staff should use more intensive and extensive sampling efforts to estimate more rigorously logperch detectability under various sampling conditions*. Current knowledge of detectability is weak. Specifics on the sampling effort needed in a particular survey, which are beyond the scope of this study, depend on the question being asked and the confidence needed for the answer.

3. *VDOT's environmental staff should assess potential Roanoke logperch sites by using the protocol developed in this study to measure microhabitat*. Site quality (and likelihood of Roanoke logperch presence) can be assessed by multiplying the site area by the proportion of suitable habitat and then checking where the results fall on the regression in Figure 4.

4. *VDOT's environmental staff should use the screening models developed in this study to help inform VDOT management decisions.* The models can help determine whether surveys are

needed and where to prioritize restoration. Although the models cannot perfectly distinguish specific localities that do or do not support logperch, they represent the best available knowledge of logperch habitat preferences.

COSTS AND BENEFITS ASSESSMENT

More reliable knowledge of logperch distribution and abundance will help VDOT reduce costs of road projects by (1) obviating the need to pay for logperch surveys and (2) saving time during planning and construction phases. For example, VDOT recently paid approximately $7,900 for three fish surveys related to Roanoke logperch (L. Snead, personal communication). We expect our screening models to be used to exclude reaches from consideration as potential Roanoke logperch habitat in future road-construction areas. These exclusions could save VDOT substantial funds by averting unnecessary fish surveys.

Precluding project delays due to logperch surveys is also a significant benefit to VDOT. Our model projections could allow VDOT to avoid certain new-road localities, thereby avoiding logperch-related issues altogether. If logperch localities are unavoidable, prior knowledge would enable VDOT to prepare for surveys and implement appropriate construction restrictions early in the planning process, thereby avoiding unexpected delays or plan changes. Given that surveys often delay projects by two to three months, appropriate planning is highly valuable. Finally, if mitigation for damage to logperch populations becomes necessary, the habitat assessments described in this study can help inform decisions about where mitigation should occur, thereby obviating the need to pay for such a study later.

ACKNOWLEDGMENTS

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APPENDIX

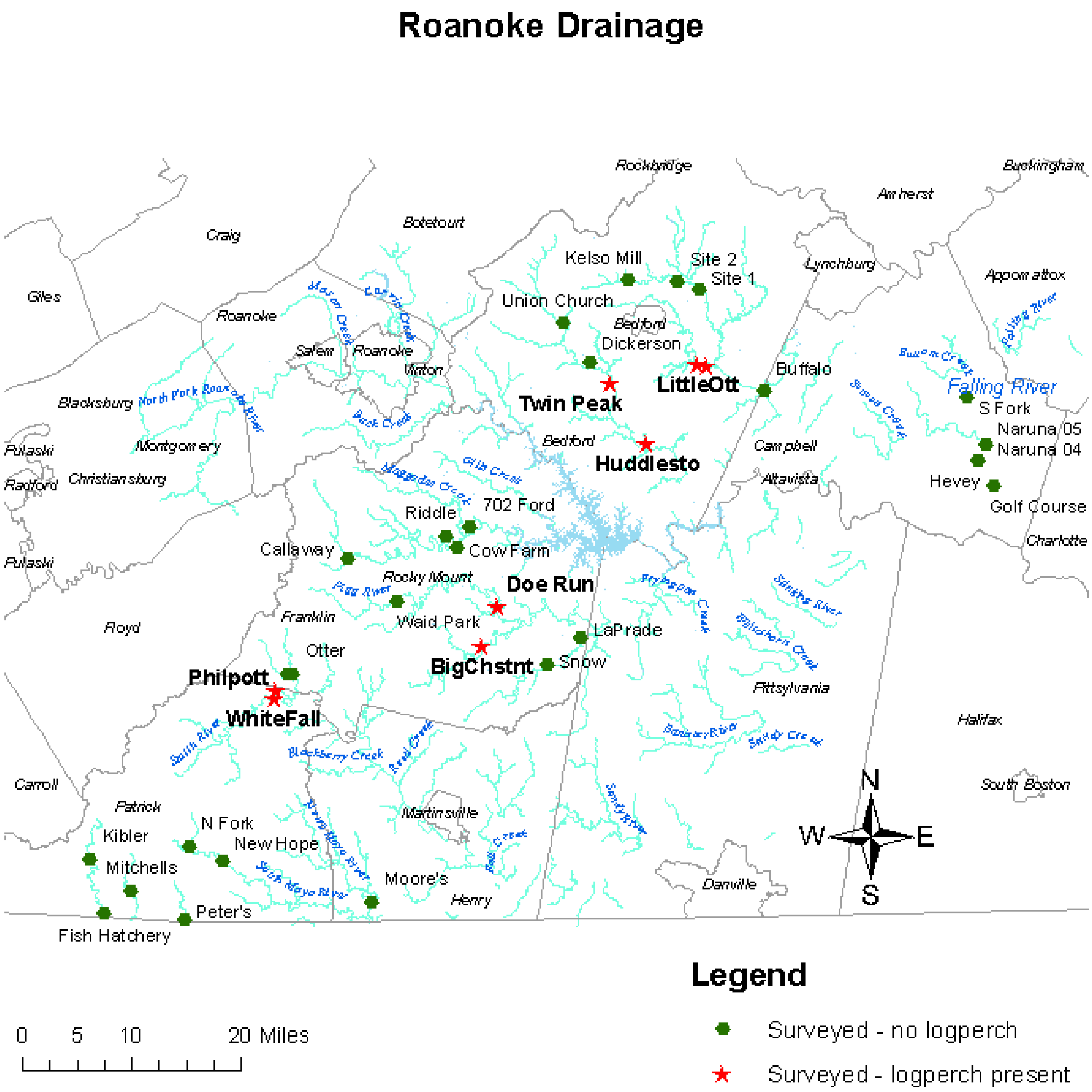

Figure A-1 Sites surveyed for Roanoke logperch in the Roanoke River drainage. Stars indicate surveyed sites where logperch were captured. Hexagons indicate surveyed sites where no logperch was found. Straight lines indicate county boundaries. The scale bar is one inch long. 1 inch = 20 miles.

Meherrin Drainage

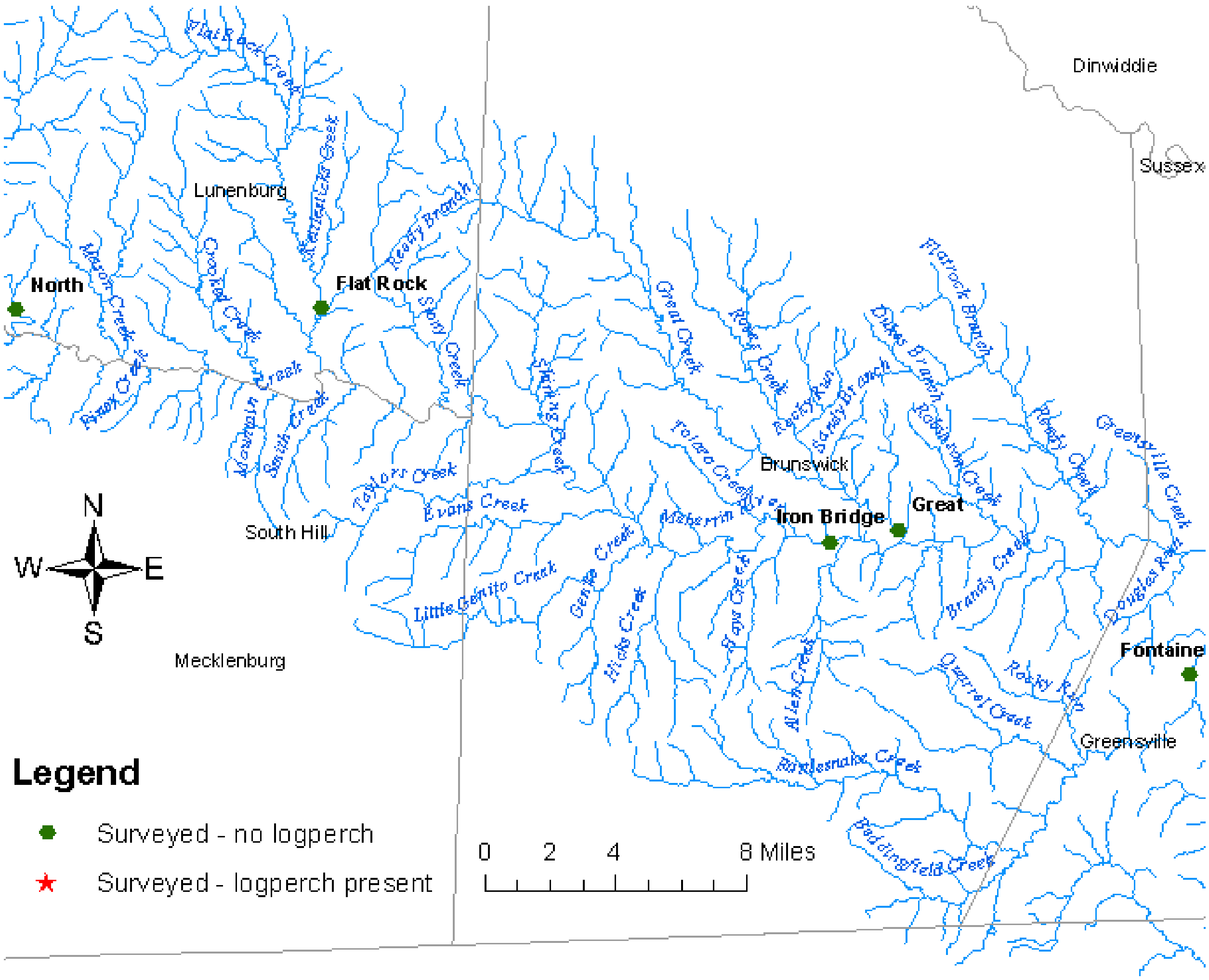

Figure A-2 Sites surveyed for Roanoke logperch in the Meherrin River drainage. No logperch was captured. Straight lines indicate county boundaries. Scale bar is one inch long. 1 inch = 8 miles.

Table A-1 Information for 36 sites sampled during July and August 2004 and May to September 2005. Grayed sites contained Roanoke logperch, *Percina rex*. Site location (decimal degrees), date sampled, elevation, length, width, and length of site divided by stream width are included.

Watershed/ Site Name	Location	Date sampled	Elevation (ft)	Length (m)	Width (m)	# Stream widths
Dan River						
Peter's	36.5457N 80.2956W	7/26/2004	1020	353	10.0	35
Mitchell's	36.5848N 80.3841W	7/27/2004	1120	349	10.3	34
Kibler	36.6272N 80.4498W	7/29/2004	1320	631	15.3	41
Fish Hatchery	36.5540N 80.4292W	6/25/2005	1120	832	18.0	46
Mayo River						
North Fork	36.6430N 80.2863W	7/27/2004	1220	246	9.2	27
Moore's	36.5675N 79.9858W	6/27/2005	720	616	25.1	25
Smith River						
Otter	36.8718N 80.1136W	9/4/2005	970	565	10.2	55
Runnett Bag	36.8713N 80.1223W	9/5/2005	970	543	8.2	66
Philpott	36.8505N 80.1408W	9/6/2005	980	976	23.4	42
White Falls	36.8397N 80.1445W	9/7/2005	990	860	25.7	33
Pigg River						
Waid Park	36.9663N 79.9398W	9/8/2004	1040	499	12.3	41
Big Chestnut	36.9062N 79.7995W	8/6/2004	820	541	15.8	34
Doe Run	36.9591N 79.7723W	6/24/2005	810	591	21.4	28
Snow	36.8794N 79.6927W	6/9/2005	740	281	10.4	27
LaPrade	36.9140N 79.6349W	6/6/2005	690	393	15.5	25
Blackwater River						
Callaway	37.0242N 80.0201W	8/9/2004	1120	942	16.2	58
702 Ford	37.0634N 79.8170W	8/10/2004	820	1068	27.5	39
Cow Farm	37.0373N 79.8394W	5/26/2005	870	749	20.8	36
Riddle	37.0523N 79.8557W	8/19/2005	890	1180	25.2	47
Goose Creek						
Union Church	37.3339N 79.6585W	8/11/2004	790	401	10.5	38
Dickerson	37.2807N 79.6143W	8/12/2004	720	385	13.3	29
Huddleston	37.1726N 79.5201W	8/31/2004	580	620	29.3	21
Huddleston	37.1726N 79.5201W	5/28/2005	580	493	30.5	16
Twin Peaks	37.2532N 79.5794W	7/17/2005	680	730	18.6	39
Big Otter River						
Buffalo	37.2387N 79.3261W	5/21/2005	570	295	7.5	39
Little Extended	37.2766N 79.4350W	7/18/2005	630	1999	13.3	150
Mabel's	37.2748N 79.4200W	6/8/2005	600	645	12.0	54
Falling River						
South Fork	37.2264N 78.9883W	8/16/2004	500	350	12.0	29
Naruna	37.1268N 78.9591W	8/15/2004	420	616	20.6	30
Naruna	37.1268N 78.9591W	5/29/2005	420	541	20.3	27
Golf Course	37.1073N 78.9460W	6/18/2005	395	483	10.4	46
Hevey	37.1411N 78.9709W	7/20/2005	415	924	16.1	57
Meherrin River						
Fontaine	36.6529N 77.6359W	6/17/2005	141	218	11.0	20
Great	36.7212N 77.7937W	6/16/2005	130	407	11.7	35

Table A-1 (cont)

Watershed/ Site Name	Location	Date sampled	Elevation (ft)	Length (m)	Width (m)	# Stream widths
North	36.8312N 78.2756W	6/13/2005	270	755	17.0	44
Flat Rock	36.8279N 78.1072W	6/15/2005	210	466	9.9	47
						Mean = 40

Table A-2 Fish species and counts of individuals tabulated by site in the Dan River watershed.

Dan River	**Peter's** 7/26/2004	**Mitchell's** 7/27/2004	**Kibler** 7/29/2004	**Fish Hatchery** 6/25/2005
Campostoma anomalum	0	19	0	2
Catostomus commersoni	0	0	0	6
Clinostomus funduloides	3	23	31	3
Cottus bairdi	0	41	451	35
Etheostoma flabellare	23	58	38	38
Etheostoma podostemone	0	0	0	15
Etheostoma vitreum	0	0	0	4
Exoglossum maxillingua	0	0	39	22
Hypentelium nigricans	17	3	7	7
Hypentelium roanokense	0	0	0	38
Lepomis macrochirus	0	1	0	0
Luxilus cerasinus	25	49	18	25
Lythrurus ardens	1	0	0	3
Micropterus dolomieu	1	0	0	2
Nocomis leptocephalus	57	75	78	88
Nocomis raneyi	7	9	4	17
Notropis chiliticus	12	43	35	42
Noturus gilberti	0	0	0	5
Noturus insignis	16	37	12	93
Oncorhynchus mykiss	0	2	0	0
Percina roanoka	0	0	3	22
Phoxinus oreas	2	5	9	0
Salmo trutta	0	3	7	0
Salvelinus fontinalis	0	1	0	0
Scartomyzon cervinus	0	11	9	45
Thoburnia hamiltoni	0	7	0	0

Table A-3 Fish species and counts of individuals tabulated by site in the Mayo River watershed.

Mayo River	**North Fork** 7/27/2004	**Moore's** 6/27/2005
Campostoma anomalum	0	0
Clinostomus funduloides	92	0
Etheostoma flabellare	82	44
Etheostoma podostemone	0	21
Etheostoma vitreum	0	2
Hypentelium nigricans	10	1
Hypentelium roanokense	0	2
Luxilus albeolus	0	18
Luxilus cerasinus	118	1
Nocomis leptocephalus	80	19
Nocomis raneyi	27	13
Notropis chiliticus	0	4
Notropis procne	0	5
Noturus gilberti	4	0
Noturus insignis	15	47
Oncorhynchus mykiss	3	0
Percina peltata nevisense	0	14
Percina roanoka	0	34
Phoxinus oreas	122	0
Salmo trutta	2	0
Scartomyzon cervinus	0	3
Thoburnia hamiltoni	68	0

Table A-4 Fish species and counts of individuals tabulated by site in the Smith River watershed.

Smith River	**Otter** 9/4/2005	**Runnett Bag** 9/5/2005	**Philpott** 9/6/2005	**White Falls** 9/7/2005
Ameiurus melas	6	1	0	0
Ameiurus natalis	8	2	0	0
Ameiurus platycephalus	1	0	0	0
Campostoma anomalum	25	130	42	30
Catostomus commersoni	31	3	4	2
Clinostomus funduloides	24	28	0	6
Cyprinella analostana	0	0	6	7
Cyprinus carpio	1	0	0	0
Etheostoma flabellare	48	129	7	3
Etheostoma podostemone	89	18	56	79
Etheostoma vitreum	27	36	3	25
Exoglossum maxillingua	0	0	9	4
Hypentelium nigricans	5	4	13	5
Hypentelium roanokense	0	19	1	0
Lepomis auritus	0	0	0	2
Lepomis macrochirus	60	4	4	4
Luxilus albeolus	17	1	109	87
Luxilus cerasinus	0	1	12	6
Lythrurus ardens	2	8	18	22
Micropterus dolomieu	0	0	2	5
Micropterus salmoides	7	3	2	1
Moxostoma ariommus	1	0	36	14
Moxostoma collapsum	0	0	3	0
Moxostoma erythrurum	1	0	0	0
Nocomis leptocephalus	64	112	63	73
Nocomis raneyi	0	0	83	76
Notropis hudsonius	92	10	16	16
Notropis procne	0	0	0	4
Noturus insignis	17	31	86	142
Percina peltata nevisense	0	0	21	23
Percina rex	**0**	**0**	**5**	**23**
Percina roanoka	11	6	214	406
Phoxinus oreas	0	32	0	1
Pimephales notatus	156	49	55	21
Scartomyzon cervinus	0	1	11	28

Table A-5 Fish species and counts of individuals tabulated by site in the Pigg River watershed.

Pigg River	**Waid** 9/8/2004	**Chestnut** 8/6/2004	**Doe Run** 6/24/2005	**Snow** 6/9/2005	**LaPrade** 6/6/2005
Ambloplites cavifrons	0	0	5	0	0
Ambloplites rupestris	2	1	0	0	0
Campostoma anomalum	0	0	16	0	1
Carpiodes cyprinus	0	0	0	0	4
Catostomus commersoni	0	0	0	0	8
Clinostomus funduloides	0	0	1	5	11
Cyprinella analostana	0	0	30	0	1
Etheostoma flabellare	55	21	45	22	13
Etheostoma nigrum	6	0	0	0	0
Etheostoma podostemone	0	11	58	0	2
Etheostoma vitreum	0	1	4	21	5
Hypentelium nigricans	3	0	4	0	7
Hypentelium roanokense	0	0	0	15	5
Lepomis auritus	3	1	9	1	1
Lepomis macrochirus	0	1	0	0	1
Luxilus albeolus	13	3	68	1	92
Luxilus cerasinus	13	8	2	3	31
Lythrurus ardens	0	1	5	9	11
Micropterus dolomieu	0	2	0	2	0
Micropterus salmoides	1	0	0	0	0
Moxostoma ariommus	0	0	3	0	8
Moxostoma collapsum	0	0	1	0	27
Moxostoma erythrurum	0	1	0	0	5
Moxostoma macrolepidotum	0	0	4	0	6
Moxostoma pappillosum	0	0	0	0	26
Nocomis leptocephalus	26	21	39	71	85
Nocomis raneyi	0	12	45	0	1
Notemigonous crysoleucas	1	0	0	0	0
Notropis hudsonius	0	0	11	0	0
Notropis procne	0	0	29	0	3
Noturus gilberti	0	5	0	0	0
Noturus insignis	4	55	14	8	30
Percina peltata nevisense	0	6	12	0	6
Percina rex	**0**	**2**	**12**	**0**	**0**
Percina roanoka	1	38	87	12	44
Phoxinus oreas	1	0	0	0	14
Rhinichthys atratulus	10	0	0	0	0
Scartomyzon cervinus	1	4	18	7	12

Table A-6 Fish species and counts of individuals tabulated by site in the Blackwater River watershed.

Blackwater River	Callaway 8/9/2004	702 Ford 8/10/2004	Cow farm 5/26/2005	Riddle 8/19/2005
Campostoma anomalum	29	0	0	2
Carpiodes cyprinus	0	0	41	0
Catostomus commersoni	6	0	0	7
Clinostomus funduloides	20	0	0	0
Cyprinella analostana	12	22	8	130
Cyprinus carpio	0	0	0	3
Etheostoma flabellare	537	7	16	33
Etheostoma nigrum	2	1	0	0
Etheostoma podostemone	62	3	8	52
Etheostoma vitreum	0	0	0	4
Hypentelium nigricans	41	0	24	24
Hypentelium roanokense	0	0	0	4
Lepomis auritus	2	3	2	4
Lepomis macrochirus	0	7	2	1
Luxilus albeolus	1	32	55	106
Luxilus cerasinus	65	1	2	14
Lythrurus ardens	2	3	26	12
Micropterus dolomieu	0	0	0	1
Micropterus salmoides	2	0	0	0
Moxostoma ariommus	0	1	0	22
Moxostoma collapsum	0	0	4	2
Moxostoma erythrurum	0	0	0	3
Moxostoma macrolepidotum	0	0	4	0
Moxostoma pappillosum	0	0	2	0
Moxostoma species	0	0	0	3
Nocomis leptocephalus	235	35	64	72
Nocomis raneyi	0	15	22	66
Notropis hudsonius	0	18	19	14
Notropis procne	1	0	14	12
Noturus insignis	13	56	41	181
Percina peltata nevisense	0	3	2	20
Percina roanoka	31	57	47	165
Phoxinus oreas	250	0	0	0
Pimephales notatus	0	0	1	0
Pimephales promelas	2	0	0	0
Rhinichthys atratulus	13	0	0	0
Scartomyzon cervinus	20	11	16	30
Thoburnia rhothoeca	0	1	19	17

Table A-7 Fish species and counts of individuals tabulated by site in the Goose Creek watershed.

Goose Creek	**Union Church** 8/11/2004	**Dickerson** 8/12/2004	**Huddleston** 8/31/2004	**Huddleston** 5/28/2005	**Twin Peaks** 7/17/2005
Ambloplites rupestris	2	0	0	2	1
Campostoma anomalum	24	68	0	3	4
Carpiodes cyprinus	0	0	0	1	0
Catostomus commersoni	7	9	1	0	17
Clinostomus funduloides	13	2	0	0	0
Cyprinella analostana	3	17	21	21	21
Cyprinus carpio	0	0	0	1	0
Etheostoma flabellare	216	48	9	0	3
Etheostoma nigrum	2	0	4	0	0
Etheostoma podostemone	54	72	21	46	63
Etheostoma vitreum	1	7	2	1	9
Hypentelium nigricans	39	28	82	16	2
Hypentelium roanokense	0	0	0	0	2
Lepomis auritus	2	2	4	9	1
Luxilus albeolus	0	0	422	376	335
Luxilus cerasinus	23	65	2	4	4
Lythrurus ardens	25	22	5	10	7
Micropterus dolomieu	0	0	8	8	11
Micropterus salmoides	3	1	0	0	0
Moxostoma ariommus	0	0	1	0	0
Moxostoma collapsum	1	17	1	2	1
Moxostoma macrolepidotum	0	0	0	1	0
Moxostoma pappillosum	0	21	1	0	0
Moxostoma species	0	2	7	0	9
Nocomis leptocephalus	149	174	41	138	135
Nocomis raneyi	0	6	18	18	22
Notropis procne	0	0	3	12	6
Noturus insignis	17	8	32	15	42
Percina peltata nevisense	0	0	41	8	19
Percina rex	**0**	**0**	**2**	**1**	**7**
Percina roanoka	63	60	75	144	130
Phoxinus oreas	132	148	0	0	4
Pimephales notatus	0	1	4	1	0
Pimephales promelas	0	3	0	0	0
Scartomyzon cervinus	13	8	11	21	38
Thoburnia rhothoeca	6	2	1	5	8

Table A-8 Fish species and counts of individuals tabulated by site in the Big Otter River watershed.

Big Otter River	**Buffalo** 5/21/2005	**Mabel's** 6/8/2005	**Little Extended** 7/18/2005
Ambloplites cavifrons	0	0	2
Ambloplites rupestris	0	1	9
Campostoma anomalum	0	0	1
Carpiodes cyprinus	0	0	1
Catostomus commersoni	2	4	12
Clinostomus funduloides	2	0	0
Cyprinella analostana	1	6	30
Dorosoma cepedianum	0	0	2
Etheostoma flabellare	83	12	42
Etheostoma podostemone	15	25	153
Etheostoma vitreum	21	1	21
Hypentelium nigricans	0	28	79
Hypentelium roanokense	25	0	0
Ictalurus punctatus	0	3	6
Lepomis auritus	1	6	14
Luxilus albeolus	144	78	340
Luxilus cerasinus	8	16	65
Lythrurus ardens	5	5	4
Micropterus dolomieu	1	3	15
Moxostoma ariommus	0	1	15
Moxostoma collapsum	0	11	8
Moxostoma erythrurum	10	0	1
Moxostoma pappillosum	0	1	0
Moxostoma species	0	2	2
Nocomis leptocephalus	104	119	237
Nocomis raneyi	1	22	48
Notropis procne	17	6	13
Noturus insignis	7	11	48
Percina peltata nevisense	4	10	111
Percina rex	0	1	4
Percina roanoka	156	51	204
Phoxinus oreas	0	0	0
Pimephales notatus	2	0	0
Scartomyzon cervinus	0	36	120
Thoburnia rhothoeca	0	11	47

Table A-9 Fish species and counts of individuals tabulated by site in the Falling River watershed.

Falling River	**South Fork** 8/16/2004	**Naruna** 8/15/2004	**Naruna** 5/29/2005	**Golf Course** 6/18/2005	**Hevey** 7/20/2005
Ambloplites cavifrons	0	0	3	3	0
Ambloplites rupestris	3	1	0	0	2
Campostoma anomalum	3	0	2	2	2
Catostomus commersoni	1	0	0	0	0
Cyprinella analostana	0	0	1	0	7
Etheostoma flabellare	173	126	139	77	123
Etheostoma nigrum	4	8	0	0	3
Etheostoma podostemone	22	36	10	10	10
Etheostoma vitreum	0	0	4	90	9
Gambusia affinis	0	0	0	0	1
Hypentelium nigricans	1	4	4	8	2
Hypentelium roanokense	0	0	0	27	19
Lepomis auritus	0	4	3	1	6
Lepomis macrochirus	0	1	0	0	0
Luxilus albeolus	92	35	49	55	45
Luxilus cerasinus	70	3	0	30	5
Lythrurus ardens	32	14	19	0	3
Micropterus salmoides	2	0	0	2	2
Moxostoma ariommus	3	0	0	2	1
Moxostoma collapsum	0	0	1	1	0
Nocomis leptocephalus	97	53	11	35	29
Nocomis raneyi	18	5	15	13	21
Notropis procne	1	3	0	9	1
Notropis volucellus	0	2	0	0	0
Noturus insignis	35	25	26	20	26
Percina peltata nevisense	0	16	1	4	9
Percina roanoka	97	79	170	54	112
Scartomyzon cervinus	9	5	8	5	12
Semotilus corporalis	6	2	5	5	5
Thoburnia rhothoeca	17	3	11	21	50

Table A-10 Fish species and counts of individuals tabulated by site in the Meherrin River watershed.

Meherrin River	Fontaine 6/17/2005	Great 6/16/2005	North 6/13/2005	Flat Rock 6/15/2005
Ameiurus natalis	1	0	0	1
Anguilla rostrata	15	0	1	4
Aphredoderus sayanus	0	0	0	1
Campostoma anomalum	0	0	0	1
Catostomus commersoni	0	0	0	0
Clinostomus funduloides	0	0	0	13
Cyprinella analostana	0	12	12	5
Esox niger	1	0	0	0
Etheostoma flabellare	0	0	12	6
Etheostoma olmstedi	5	0	0	0
Etheostoma podostemone	0	0	0	0
Etheostoma vitreum	0	120	5	47
Hybognathus regius	0	0	2	1
Hypentelium nigricans	0	7	17	5
Hypentelium roanokense	0	0	0	5
Lampetra appendix	1	4	1	7
Lepomis auritus	4	8	1	4
Lepomis gibbosus	0	0	0	2
Lepomis macrochirus	0	0	1	8
Luxilus albeolus	0	55	66	86
Luxilus cerasinus	0	3	59	26
Lythrurus ardens	0	45	61	0
Micropterus salmoides	1	0	0	0
Moxostoma collapsum	0	8	0	1
Moxostoma species	0	0	0	0
Nocomis leptocephalus	0	1	37	122
Nocomis raneyi	0	4	13	0
Notemigonous crysoleucas	0	0	0	1
Notropis altipinnis	30	0	3	0
Notropis procne	0	7	13	8
Notropis volucellus	0	2	3	0
Noturus insignis	20	14	42	24
Perca flavescens	2	0	0	0
Percina peltata nevisense	1	12	4	26
Percina roanoka	11	4	81	13
Scartomyzon cervinus	0	3	21	0
Semotilus atromaculatus	0	1	0	10