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Prepared in cooperation with The Nature Conservancy and Sullivan County Division of Planning and Environmental Management

# Relations of Environmental Factors with Mussel-Species Richness in the Neversink River, New York

Swollen wedgemussel *(Alasmidonta varicosa)* from the Neversink River.

## Significant Findings

- A 6-year study of mussel communities and their habitat in the Neversink River basin in southeastern New York found that the principal factors apparently affecting mussel-species richness were site (reach) elevation, drainage-area size, channel width, bottom-material composition, water velocity, shear stress at bankfull discharge, and water quality (acid-neutralizing capacity (ANC) and concentrations of calcium, phosphorus, and sulfate). Together these 10 factors explained as much as 94 percent of the variability in mussel-species richness across the watershed.

- The number of species in mussel communities throughout the basin typically increases in a downstream progression from zero or one species in upstream sites to as many as six species in downstream sites.

- A recently removed dam in the lower part of the river may have confined populations of two rare mussel species to lower reaches of the Neversink River; its removal in 2004 could allow those species to populate additional reaches in the upper basin.

U.S. Department of the Interior
U.S. Geological Survey

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Open-File Report 2007–1283
March 2008

# Introduction

Declines in the distribution, abundance, and diversity of freshwater-mussel species (family **Unionidae**[1]) have been reported worldwide (Bogan, 1993; Strayer and Jirka, 1997). The principal causes of the observed declines are difficult to confirm, however, because only a few of the many factors that affect mussel-species populations have been identified (Strayer and Ralley, 1993; Strayer, 1999; Baldigo and others, 2003; Strayer and others, 2006).

The Neversink River, which drains the Catskill Mountains in southeastern New York (fig. 1), contains seven species of mussels (Strayer and Ralley, 1991; Strayer and Jirka, 1997). Populations of the **endangered** dwarf wedgemussel (*Alasmidonta heterodon*) and the **threatened** swollen wedgemussel (*Alasmidonta varicosa*) coexist with other unionid mussels in the Neversink River (Strayer and Ralley, 1991, 1993; Baldigo and others, 2003). Dwarf wedgemussel populations had previously been found only downstream from the site of an abandoned dam in the lower part of the river at Cuddebackville (fig. 1), and swollen wedgemussels were only found in the lower and middle reaches of the river. The limited distribution of these two species suggests that they may be susceptible to local extinctions.

The distribution of mussel populations can be limited by impoundments. Mussel larvae develop in species-specific host fish; thus, impoundments that restrict passage of these host fish also restrict the extent of mussels. The Neversink River is impounded by the Neversink Reservoir [241 square kilometers ($km^2$)], a major source of drinking water for the City of New York, and was also impounded 50 km downstream by the Cuddebackville Dam until 2004, when the latter was removed by The Nature Conservancy (TNC) and the U.S. Army Corps of Engineers to improve fish passage. The removal of this dam has provided previously unavailable habitat for **diadromous** and other fish species that act as hosts for rare mussel species. In addition, releases from the Neversink Reservoir that mimic the river's original flow patterns have recently been proposed by TNC and could benefit the established mussel populations and aquatic communities. The ability to protect mussel populations and the potential to increase mussel **richness** in the Neversink River is unknown, however, because the environmental factors that affect the seven mussel species are poorly defined, and the distribution of mussel beds is patchy and thus difficult to quantify.

In 1997, the U.S. Geological Survey, in cooperation with TNC, began a 6-year study along the Neversink River and its tributaries to (1) document the current distribution of each mussel species, (2) assess environmental factors in relation to mussel-species richness and distribution, and (3) identify the factors that most strongly affect mussel populations and develop an equation that relates environmental factors to mussel-species richness. This report (a) summarizes the methods used to quantify or qualify environmental factors and mussel-species distribution and abundance, (b) presents a list of environmental factors that were correlated with mussel-species richness, and (c) offers an empirical model to predict richness of mussel species in benthic communities throughout the basin.

# Methods

Surveys were conducted during the summers of 1997–2002 on the Neversink River and its tributaries to document mussel communities, water quality, habitat characteristics, and **bankfull** discharge and **geomorphology** at 28 sites ranging in length from 100 meters (m) (for habitat assessments) to 600 m (for geomorphology surveys). Habitat characteristics and bankfull discharge were measured at least once at all sites, whereas complete bankfull geomorphology surveys were done at only 21 main-stem sites. Sampling methods for each environmental factor and mussel community are summarized below and provided in greater detail by Baldigo and others (2002, 2003).

The number of each mussel species collected per hour **(relative abundance)** and the number of mussel species (richness) were quantified through 2-hour snorkeling searches at 28 sites during the summer of 1997; of these, 17 were on the main stem and 11 were on tributaries. Habitat and hydraulic features at each study site were measured using point-and-transect methods modified slightly from those presented in Meador and others (1993). Water depth, substrate types, and water velocity were measured at five to seven equally spaced points across each transect and at the thalweg, and bank and riparian characteristics were measured or visually estimated at both ends of each transect. Water samples were collected at the same time from single samples collected under **base-flow** conditions and analyzed for acid-neutralizing capacity, and concentrations of calcium, phosphorus, sulfate, and 13 other constituents.

Mussel-transect surveys were done in 2001 and 2002 at the 28 sites studied during 1997 and at 4 additional main-stem sites. These surveys counted the number of each mussel species through snorkel surveys, measured wetted-channel widths and water velocities, documented the bankfull indicators, and estimated bankfull width, depth, and cross-sectional area within three bank-to-bank transects across each study site. Channel-slope measurements from longitudinal bed-elevation surveys were used with bankfull dimensions to calculate mean water velocities and **shear stresses** for each transect at high bankfull-discharge stages for 21 of the 32 study sites.

The relations between mussel-species richness and water chemistry, habitat features, bankfull-channel geometry, and basin characteristics (such as elevation and size of drainage area) were assessed through simple, multiple, and quantile regression analyses. Ten variables (site elevation, drainage-area size, mean channel width, amount of sand as a percentage of streambed material, water velocity, shear stress, ANC, and concentrations of calcium, phosphorus, and sulfate) were identified as important to mussel-species richness. The number of data points used to assess the relations of mussel-species richness with each of the ten factors typically varied between 21 and 32 because of the different number of sites sampled for each survey and ranged as high as 41 when transect data from 21 sites were used to assess

[1] Words in **boldface** are explained in the glossary on page 6.

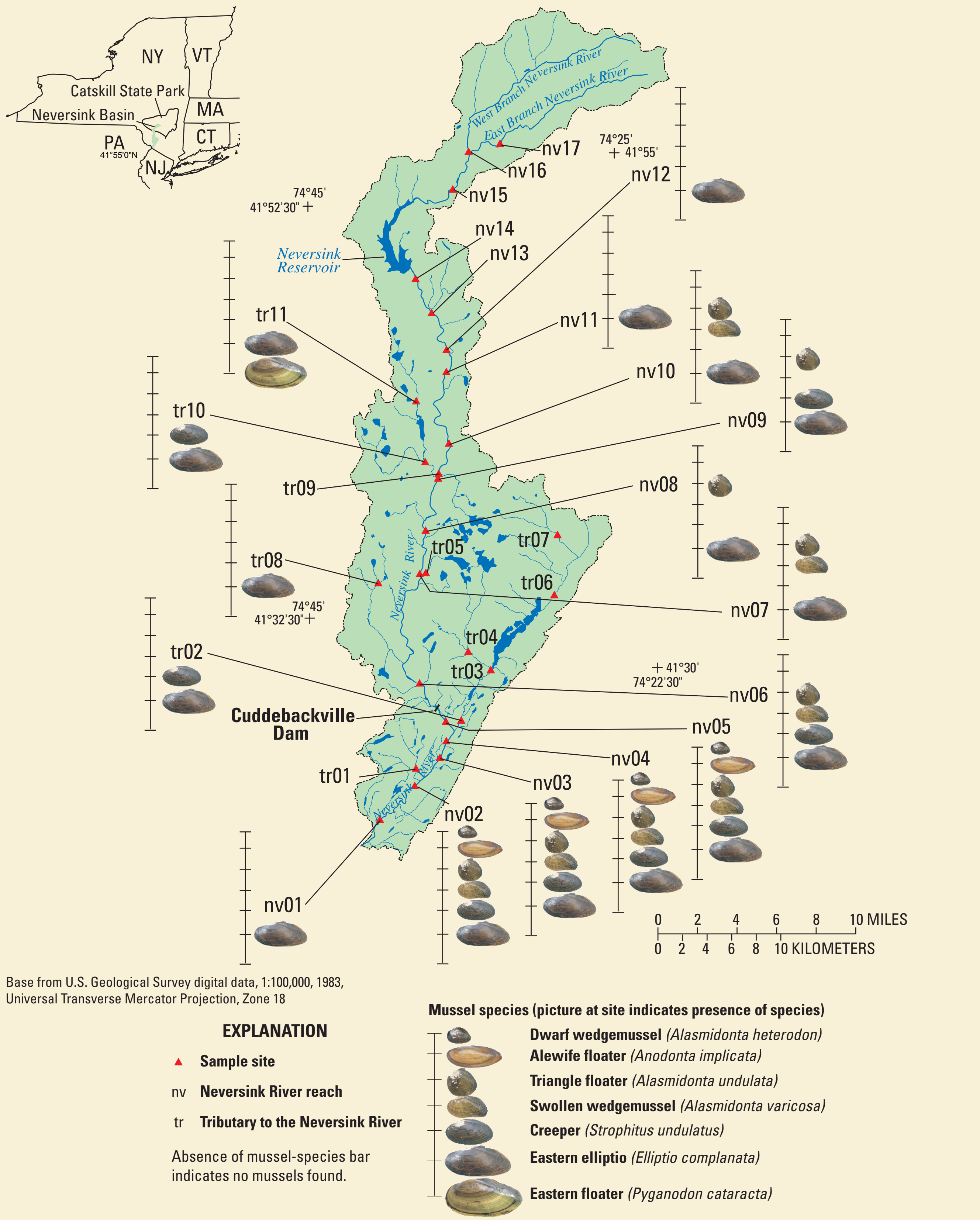


**Figure 1.** Location and number of mussel species collected during mussel surveys at 28 sites of the Neversink River basin in southeast New York, June–August 1997.

Biologists conducting timed snorkel surveys for mussels in the Neversink River.

relations with velocity and shear stress. Separate equations describing the maximum species richness, as a function of each variable, were standardized to maximum values of 1. Averaged together, these **metrics** form an unweighted index capable of predicting mussel-species richness from similar data collected at other sites throughout the Neversink River.

## Mussel-Species Distributions and Abundance

The number of mussel species varied widely at sites surveyed in the Neversink River. Species richness was greatest in main-stem reaches in the lower basin; no mussels were found in 7 of the 11 tributaries, nor in the 5 most upstream of the 17 main-stem sites (fig. 1). The most widely distributed species in the basin was the eastern elliptio (*Elliptio complanata)*, which is tolerant of a wide range of environmental conditions and habitat disturbances (Strayer and Jirka, 1997). It was the only species at several middle-basin sites and at the lowest site (nv01, fig. 1). In contrast, the dwarf wedgemussel (*Alasmidonta heterodon*) and the alewife floater (*Anodonta implicata*) were found only downstream from the Cuddebackville Dam; their sparse distribution indicates that both species either are intolerant of local environmental conditions, or are restricted by the inability of host-fish species to migrate upstream past the Cuddebackville Dam. Two to four mussel species were found at all main-stem sites located between the Cuddebackville Dam and site nv10 (fig. 1).

Relative-abundance data indicate that the eastern elliptio was the most abundant mussel species at nearly all study sites (fig. 2). Relative abundance increased downstream and was generally greatest at main-stem sites in the lower basin; the primary exception to this trend was at site nv01, where only one species (eastern elliptio) was present in low numbers. The eastern elliptio was moderately common at the other sites, but the swollen wedgemussel (*Alasmidonta varicosa*), the creeper (*Strophitus undulatus)*, and the triangle floater (*Alasmidonta undulata)* were uncommon or absent at most sites in the middle and upper basins. No dwarf wedgemussels or alewife floaters were found at study sites located upstream from the Cuddebackville Dam.

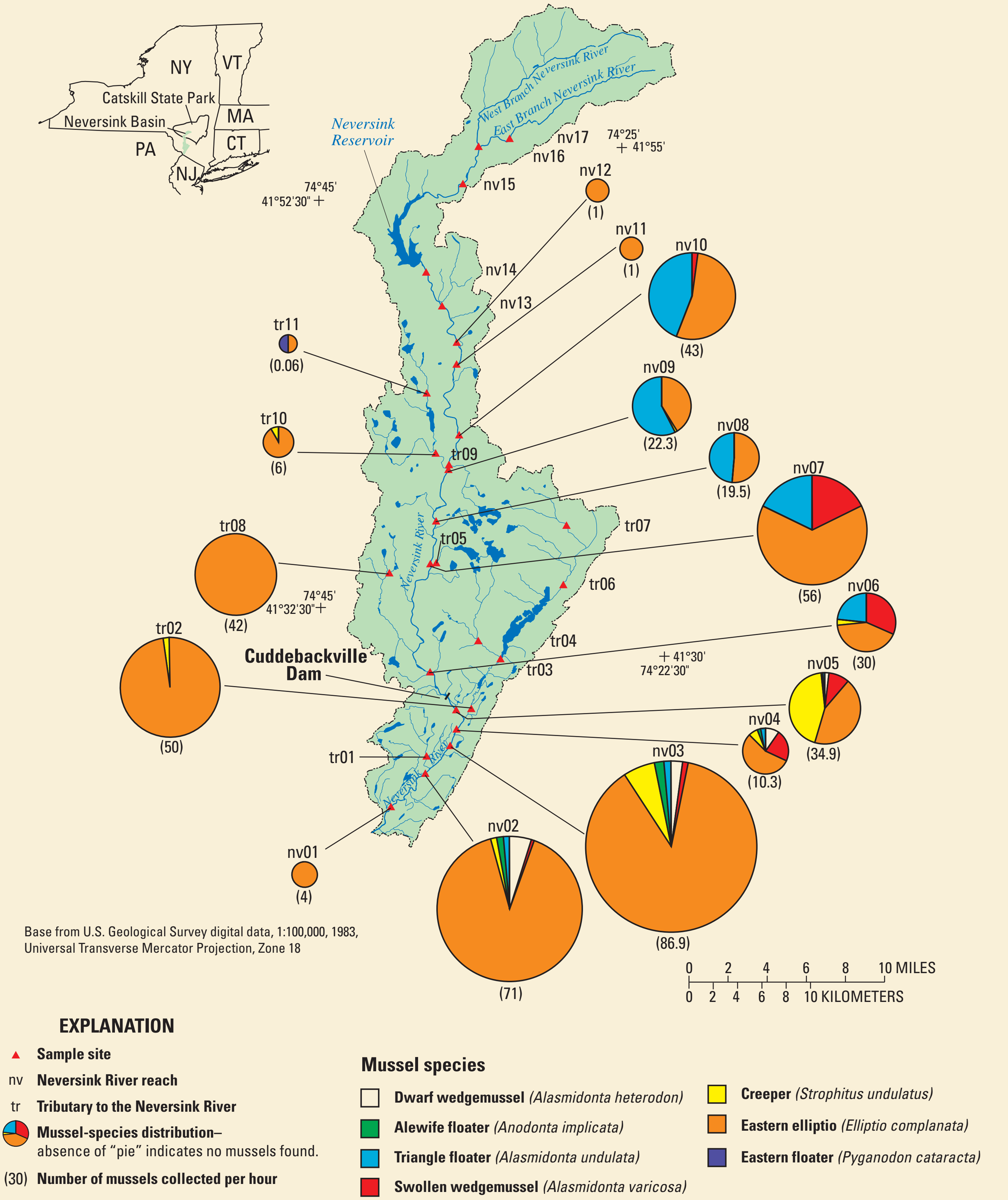


**Figure 2.** Relative abundance of each of seven mussel species and the total number of mussels collected per hour, at 28 sites of the Neversink River basin in southeast New York, June–August 1997. (Modified from Baldigo and others, 2002.)

## Effect of Environmental Factors

Mussel-species richness was found to be strongly correlated with 10 environmental and geomorphologic factors, though rarely in a linear fashion (fig. 3). In general, mussel-species richness was highest where:

- water velocities were between 0.4 and 1.0 meter per second (fig. 3A);
- shear stresses were less than 0.5 pound per square foot (fig. 3B);
- calcium concentrations were between 0.75 and 0.9 milligram per liter (fig. 3C);
- ANC was between 1.0 and 1.2 microequivalents per liter;
- drainage areas were larger than 600 square kilometers;
- mean channel widths averaged more than 35 meters ($\log_{10}$ 1.5) (fig. 3D);
- the amount of sand was between 10 and 17 percent of streambed material;
- site elevations were less than 350 meters;
- sulfate concentrations were between 5.4 and 8.0 milligrams per liter; and
- total phosphorus concentrations were between 16 and 24 milligrams per liter.

Many environmental factors, both measured and unmeasured, appear to affect mussel-species populations and community richness to different degrees in the Neversink River. Species richness and metric scores generally decreased to zero at the highest and (or) lowest values of each variable (fig. 3). The 95-percent quantiles for water velocity and bankfull shear stress produced the strongest correlations (fig. 3A and 3B) and suggest that water velocity and shear stress have an important effect on the distributions of most mussel species in the Neversink River. The spread of data points below each regression line (fig. 3) and the absence of strong individual and linear relations indicate that many factors influence species richness; this further implies that no single variable can be used to model richness of mussel species in the Neversink River basin and probably in other basins.

In an effort to measure model precision, the 10 variables were used to estimate species richness for each site and compare to the observed richness. The **richness index** explained 76 percent of the variability in mussel-species richness at all Neversink River and tributary sites and generally predicted richness to within 1 species (fig. 4A). Anomalous local conditions resulted in overprediction of richness at one small headwater tributary below a highland marsh (site tr02) and underprediction of richness at site nv01, just upstream from the mouth of the Neversink River (fig. 4A). The richness index explained 94 percent of the variability in species richness when only main-stem sites were evaluated (fig. 4B).

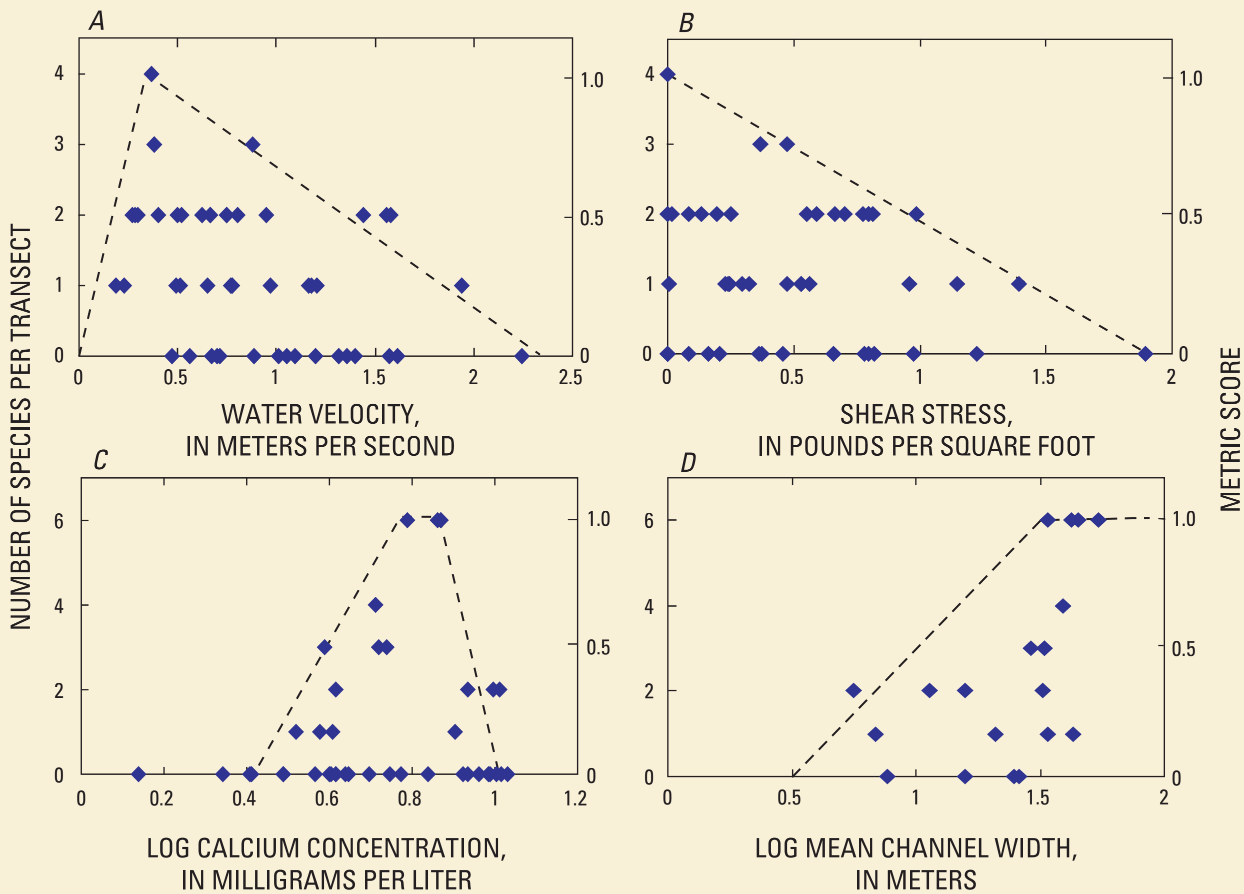


**Figure 3.** Relations between mussel-species richness at selected sites in the Neversink River basin and four predictor variables chosen to show the diversity of relations between richness and environmental condition: *(A)* bankfull water velocity, *(B)* bankfull shear stress, *(C)* alcium concentration, and *(D)* mean channel width.

These results provide empirical evidence that the 10 variables used in the richness index have an important effect on mussel-species richness and mussel distributions in the Neversink River basin. Though the index described herein is specific to the Neversink River, these same factors could have comparable relations with mussel species in other nearby systems. Such relations are critical to managing watersheds as they provide one method to model the potential effects that changing climatic and environmental conditions may have on endangered mussels and other sensitive benthic invertebrates inhabiting riverine systems.

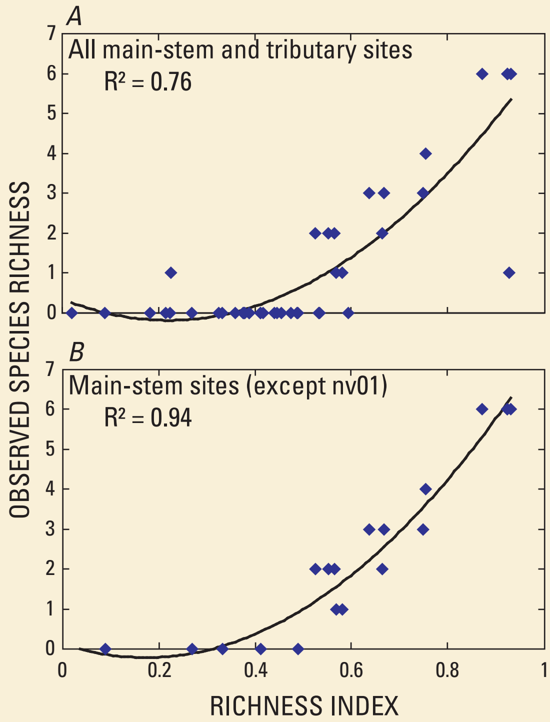


**Figure 4.** Relations between observed mussel-species richness and the richness index in the Neversink River basin, 1997–2002, at *(A)* all main-stem and tributary sites and *(B)* main-stem sites only (except nv01).

## Conclusions

The Cuddebackville Dam may have restricted dwarf wedgemussel and alewife floater populations to the lower sites of the river. The removal of the dam in 2004 potentially could increase mussel diversity upstream of the former dam site by permitting passage of host-fish species carrying larval stages of one or more mussel species.

At least 10 environmental factors appeared to affect richness of mussel communities. The factors that were most strongly correlated with maximum species richness were water velocity and shear stress at bankfull flow.

A richness index was developed that explained 76 percent of the variability in mussel-species richness at all Neversink River sites and 94 percent of the variability at main-stem sites.

Such models may be used to assess the effects that changing climatic and environmental conditions might have on mussel species and other benthic invertebrates of the Neversink and similar river systems.

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# Glossary

### B

**bankfull** The level of water in a stream channel just below the point where the water would overflow the channel onto the flood plain.

**base flow** The part of the stream discharge that does not include direct runoff from precipitation; it is usually sustained by ground water.

### D

**diadromous** Species that use both marine and freshwater habitats during their life cycles. These species are generally susceptible to impoundments on streams because of their migration patterns.

### E

**endangered** Species whose population is so small that it is at risk of becoming extinct. The federal government maintains a list of endangered species.

### G

**geomorphology** The study of the size and shape of river channels and the effect of water in controlling the channels.

### M

**metric** A measure of a community characteristic that summarizes data and facilitates comparisons among sites.

### R

**relative abundance** The number of each species of mussel collected per unit of time.

**richness** The number of species present in a given area.

**richness index** An index that combines data from several variables to predict the number of mussel species.

### S

**shear stress** The propensity of flowing waters to mobilize bed materials. Shear stress depends on depth and velocity of the water and size of the particles.

### T

**threatened** A species that is likely to become endangered in the near future unless changes are made to improve its environment. The federal government maintains a list of threatened species.

### U

**Unionidae** The family of mussels that includes freshwater mussels found in the Neversink River.