Monitoring the Swift Creek Freshwater Mussel Community

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Abstract. In terms of aquatic biodiversity, mollusk diversity and abundance, and viable populations of federally listed or candidate freshwater mussel species, Swift Creek in the Tar River Basin is North Carolina's best Atlantic Slope lotic refuge. Swift Creek is 138 km long and covers 690 km^2. A 20 km segment of Swift Creek located in the center of the subbasin was chosen as the study area. Trends in the health of the mussel species populations of Swift Creek were assessed by evaluating relative abundances, evidence of recent recruitment, and lengths of all fresh mussel shells collected from muskrat middens (nearly 10,000 shells) within the study area during the years 1989-1994. Three of the mussel species (*Lampsilis radiata, Elliptio roanokensis*, and an undescribed lanceolate *Elliptio* species) were extremely rare during the study; therefore, they are simply documented as being present. Also, because of taxonomic uncertainties, the health of populations in the *Elliptio complanata* complex and *E. icterina* complex cannot be determined. For *Alasmidonta undulata, Villosa constricta, Lampsilis cariosa, Elliptio steinstansana, Strophitus undulatus, Fusconaia masoni*, and *Elliptio lanceolata*, changes in relative abundance and evidence of recent recruitment could be determined. For the last three species, length class structure changes were documented.

Introduction

Freshwater mussels are a declining natural resource in the United States. Williams et al. (1993) summarized the opinions of malacologists throughout North America and determined that 72% of the nearly 300 species and subspecies were either extinct, endangered, threatened, or of special concern. Declines in water quality resulting from various land and water uses continue to cause population fragmentation, declines in abundance, and extirpations. As a result, the U.S. Fish and Wildlife Service's (USFWS) research branch determined that 45 species of freshwater mussels are at risk of extinction within the next 10 years under existing conditions (USFWS 1992).

Because of this loss in biodiversity and habitat, it is necessary to closely monitor our best remaining habitats and mussel communities. The focus for the Wildlife Resources Commission has been on trends in habitat changes and the health of extant populations. This allows for the improvement of best management plans and identification of areas where future research is warranted.

The objective of this study was to evaluate changes in populations of various mussel species in Swift Creek, a major tributary of North Carolina's Tar River, during a 6-year period starting in 1989. Of particular concern is the Tar spinymussel (*Elliptio steinstansana*), a Tar River basin endemic species. This mussel is a federally listed endangered species with only two populations considered viable. These populations exist in Swift Creek and Little Fishing Creek.

Study Area

Swift Creek flows southeast from Henderson in Vance County, North Carolina, then through Warren, Franklin, Nash, and Edgecombe counties to its confluence with the Tar River above Tarboro in Edgecombe County. The creek is approximately 138 km long and drains about 690 km^2 (U.S. Army Corps of Engineers 1972). The subbasin is long, narrow, and sandwiched between Fishing Creek to the northeast and the Tar River to the southwest. The subbasin above the Nash / Edgecombe county line is predominantly located in the Piedmont, while the lower subbasin in Edgecombe County is in the Coastal Plain.

The study area for this project is a 20-km segment of Swift Creek in Nash County (Figure 1). The drainage area above this segment is 430 km^2 (U.S. Geological Survey 1994). The width of the creek is usually less than 10 m, and the substrates include various combinations of silt, sand, gravel, cobble, boulders, and bedrock. Sand is the most common substrate type.

The Swift Creek subbasin is essentially rural in character, with the major land uses being a combination of agriculture and silviculture (McGrath 1992). In the study area, lands within a few hundred meters of the creek were largely forested before 1987; however, since the beginning of 1987, significant timber harvesting has occurred along Swift Creek. In some areas, sufficient buffers have been maintained to protect the creek, while in others there are virtually no forested buffers. Most of the timber

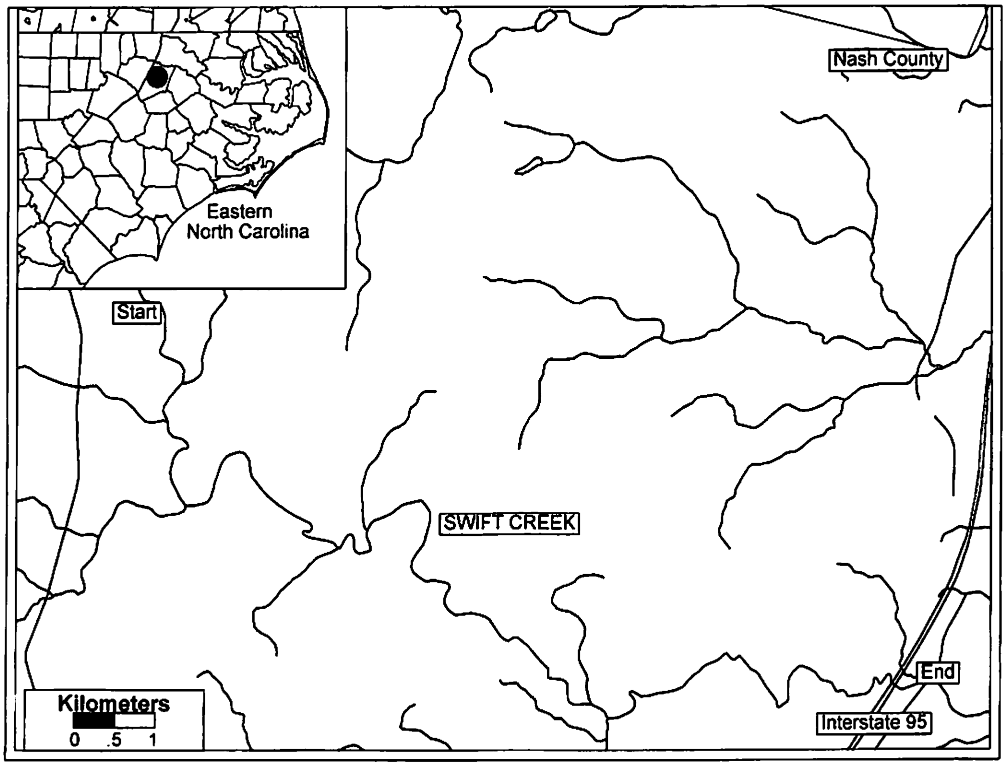

Figure 1. Map of the study area – Swift Creek in Nash County, North Carolina.

harvesting activities in the study area had been completed by 1992.

Using qualitative observations, many mussel beds composed of coarse sands and gravel were reduced in size or covered by layers of sand and silt starting in 1988 and continuing through 1992. However, during 1993 and 1994, the extent of sand/gravel substrate beds increased.

A significant change in the non-native mollusk fauna was also documented during the time of the study. During 1987 and 1988, the Asian clam (*Corbicula fluminea*) was documented in Swift Creek in Franklin, Nash, and Edgecombe counties, but in low relative abundance. At that time, usually only a shell or one live animal could be found during a full survey day in any one area. However, the *Corbicula fluminea* population expanded rapidly after 1989, and by 1992 had become the dominant mollusk throughout the main channel of Swift Creek.

Methods

Trends in the relative health of the mussel species' populations of Swift Creek were assessed by counting and measuring all fresh mussel shells collected from muskrat middens within the 20-km study area starting in 1989. Shell lengths were measured to the nearest millimeter. This method was chosen because it was noninvasive in critical endangered species habitat, and an extensive area of the creek could be surveyed in a nominal amount of time.

Based on numerous Wildlife Resources Commission field collections, North Carolina muskrats regularly consume mussels between 20 and 65 mm in length. On rare occasions, mussels outside this range are found in middens. Most of the mussel species in Swift Creek, with the exception of certain *Elliptio* species and *Lampsilis radiata*, have maximum shell lengths less than 65 mm. The relative health and trends for most mussel populations should be reflected in their size (which approximate age in freshwater mussels) and relative abundance each year. All collections of fresh shells occurred between late May and mid-August from 1989 through 1994. Because of variable muskrat predation activity and time constraints, the number of collections each year was not standard. During 1989, 1992, and 1993, only one collection within the study area was completed. During 1990 and 1994, two collections were completed, and in 1991, 2.5 collections were completed. These differences in collection efforts should not affect the shape of shell length frequency distributions in a particular year; however, the height of the distributions could change.

Shell length data were analyzed by nonparametric tests with a = .05 (Kruskal-Wallis followed by Mann-Whitney U tests compared with modified levels of significance based on the Bonferroni Inequality [Holm 1979]). SYSTAT (1992) was used in most statistical and graphical analyses. In addition, the G-test of independence with a = .05 was used to determine significant changes in each species' relative abundance within the mussel community, comparing year 1989 with 1994.

Results and Discussion

During the 6-year period, fresh shells (those with lustrous nacres or those with recently lost lustrous nacres) were collected from muskrat middens within the study area. Collections included 1,525 shells in 1989; 3,031 in 1990; 3,159 in 1991; 854 in 1992; 419 in 1993; and 855 in 1994. Most of this variation in sample size can be attributed to differences in number of collections and to differences in muskrat predation activity in a given year. However, one other influential factor on these number variations may have been the rapid expansion of *Corbicula fluminea* within Swift Creek during the early 1990s. *Corbicula fluminea* became a major part of the muskrat diet in Swift Creek, reducing their consumption of freshwater mussels.

Figure 2 is a percentage plot of the annual relative abundances of muskrat midden shells from 1989 to 1994 for the triangle floater (*Alasmidonta undulata*), notched rainbow (*Villosa constricta*), squawfoot (*Strophitus undulatus*), yellow lampmussel (*Lampsilis cariosa*), Tar spinymussel (*Elliptio steinstansana*), Atlantic pigtoe (*Fusconaia masoni*), yellow lance (*Elliptio lanceolata*), and a complex of *Elliptio* species, including *Elliptio complanata* and *E. icterina*. (Actually, there may be several species within this complex; however, based on shell morphology, it is presently impossible to identify all individuals to species level within this Swift Creek complex.) Three other species, the Roanoke slabshell (*Elliptio roanokensis*), eastern lampmussel (*Lampsilis radiata*), and a presently undescribed lanceolate *Elliptio*, are present in the study area, but their populations are largely below detection levels.

Fusconaia masoni

Fusconaia masoni, a tachytictic breeder, is a state-listed threatened and federal C2 species. *Fusconaia masoni* had the greatest increase in relative abundance in muskrat middens compared with any other species or complex (Figure 2). It increased from approximately 6% to 15% of the mussel shells found in muskrat middens between 1989 and 1994. The G-test of independence confirms this to be a significant percentage increase (P<.001). Whether this change reflects actual changes in the number of individuals in the population cannot be determined from these data. This applies to other species as well.

During the study period, there was a significant (P<.0001) change in central tendencies of shell length frequency distributions for *Fusconaia masoni*. The population as represented in the middens became increasingly dominated by younger individuals (Figure 3). Mean shell lengths were 38.3 (n=81), 33.3 (n=270), 32.8 (n=451), 29.1 (n=163), 30.7 (n=60), and 30.7 mm (n=126) during the years 1989 through 1994, respectively. Using pairwise comparisons, central tendencies of shell length frequency distributions were significantly different comparing 1989 with 1990 (P<.0001) and comparing 1991 with 1992 (P<.0001). No further significant changes occurred after 1992. These data suggest that *Fusconaia masoni* had reproduced successfully during the study period and that this species may not be jeopardized by sediments composed mostly of sands.

One other aspect of shell length data needs to be considered in this evaluation for *Fusconaia masoni*. In general, the shell length frequency distributions become increasingly skewed to the right and increasingly leptokurtic with time (Figure 4). Together, these two parameters suggest that the population is increasingly being represented by younger age classes. If this trend continues, additional significant differences in central tendencies of

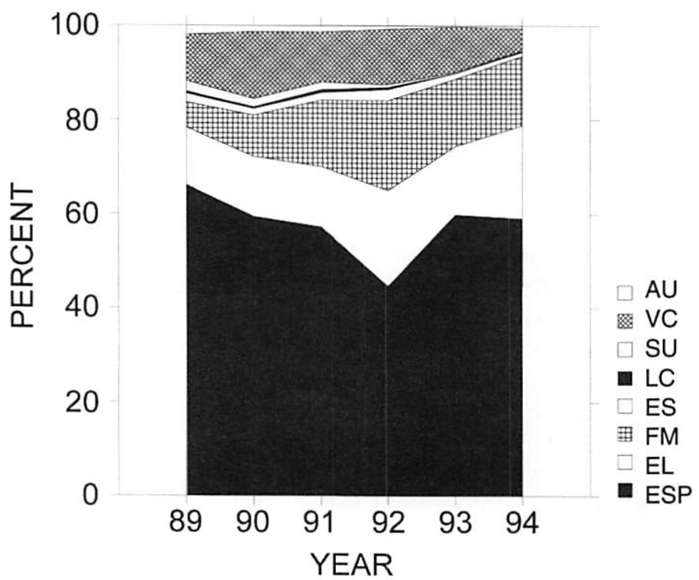

Figure 2. Percentage plot for shells collected within the study area by species (AU = *Alasmidonta undulata*, VC = *Villosa constricta*, SU = *Strophitus undulatus*, LC = *Lampsilis cariosa*, ES = *Elliptio steinstansana*, FM = *Fusconaia masoni*, EL = *Elliptio lanceolata*, ESP = *Elliptio* complex).

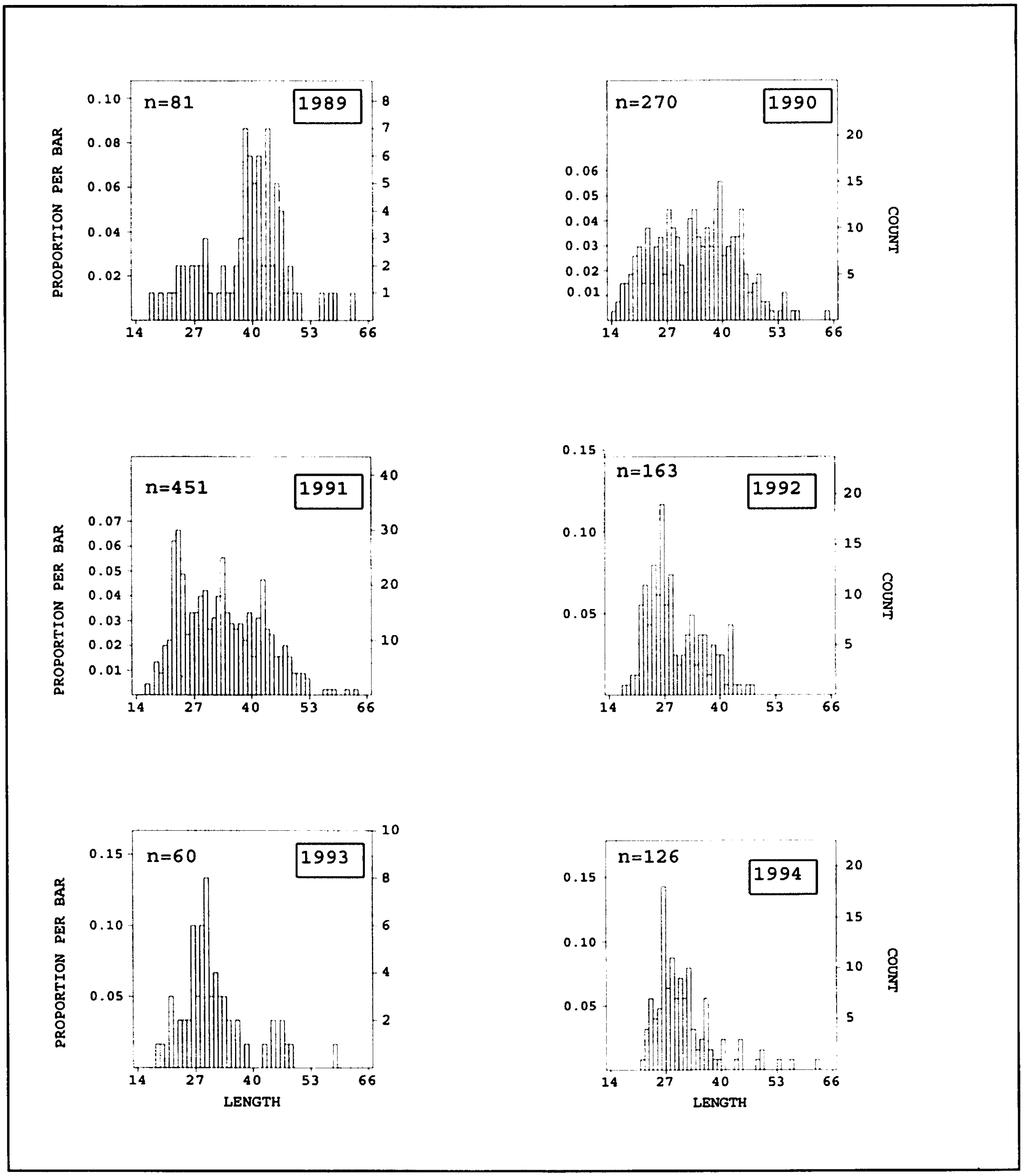

Figure 3. Length (mm) of *Fusconaia masoni* shells collected from Swift Creek muskrat middens during the years 1989-1994.

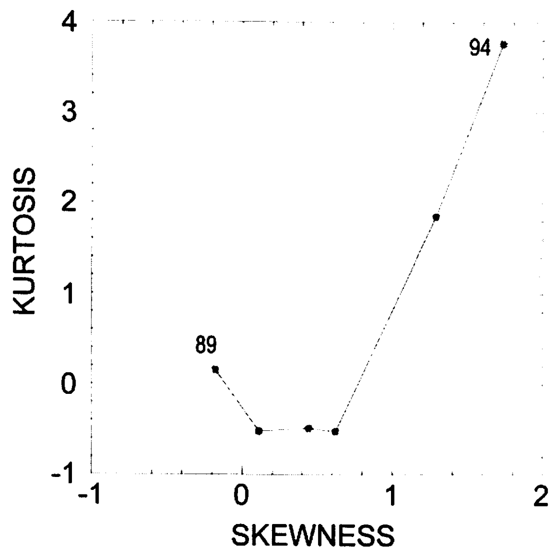

Figure 4. Skewness compared with kurtosis for frequency distributions of *Fusconaia masoni* shell lengths from Swift Creek.

shell length frequency distributions can be anticipated among samples.

Elliptio lanceolata

Elliptio lanceolata, another tachytictic breeder, is a state-listed threatened and federal C2 species. *Elliptio lanceolata* was the only other mussel species that increased in relative abundance in muskrat middens compared with other species. It increased from approximately 12% to 20% of the midden shells between 1989 and 1994 (Figure 2). Again, the G-test of independence confirms this to be a significant percentage increase ($P<.001$).

During the study period, there were significant ($P<.001$) shifts in central tendencies of shell length frequency distributions. Using pairwise comparisons, there is a significant ($P<.01$) change in the central tendencies of shell length frequency distributions comparing 1990 with 1994. Essentially, the population as represented in the middens became increasingly dominated by older (larger) individuals during the last 5 years of the study (Figure 5). Mean shell lengths were 43.3 (n=186), 42.0 (n=406), 43.1 (n=404), 42.2 (n=173), 45.9 (n=43), and 44.9 mm (n=169) during the years 1989 through 1994, respectively. Although there is no significant difference ($P=.270$) in central tendencies for frequency distributions of shell lengths for 1989 compared with 1994, testing for heterogeneity of variance indicates the variance of shell lengths for 1989 is significantly greater ($P<.0001$) than the variance of shell lengths for 1994. (Variance for 1989 is 4.052 times greater than the variance for 1994, and $F_{.025}(185,168)=1.346$.) Therefore, there has been a significant reduction in the number of size classes represented in the midden shells for the yellow lance during the study period.

As with *Fusconaia masoni*, the frequency distributions for shell lengths become increasingly skewed to the right and increasingly leptokurtic with time through 1993 (Figure 6). However, in 1994 the frequency distribution becomes skewed to the left, suggesting an aging population. If this trend continues, additional significant differences in central tendencies of shell length frequency distributions can be anticipated among samples. If significant aging of the population does occur, then concern for the continued viability of the yellow lance in Swift Creek is warranted.

Villosa constricta

Villosa constricta, a bradytictic species, is presently considered significantly rare by the North Carolina Natural Heritage Program. It is not officially listed by the state or federal governments. *Villosa constricta* decreased in relative abundance in muskrat middens compared with other species (Figure 2). This species decreased from approximately 10% to 5% of the mussel shells found in muskrat middens between 1989 and 1994. The G-test of independence confirms this to be a significant percentage decrease ($P<.01$).

No significant differences in the central tendencies of shell length frequency distributions occurred during the study period (Figure 7). Mean shell lengths were 27.8 (n=150), 26.8 (n=431), 27.5 (n=369), 26.8 (n=100), 27.7 (n=40), and 27.8 mm (n=40) during the years 1989 through 1994, respectively. However, just as with *Elliptio lanceolata*, when testing heterogeneity of variance for shell lengths, variance of shell lengths for 1989 is significantly greater ($P<.001$) than the variance of shell lengths for 1994. (Variance for 1989 is 2.468 times greater than the variance for 1994, and $F_{.025}(149,39)=1.719$.) Therefore, this suggests there has been a significant reduction in the number of size classes represented in the midden shells for the notched rainbow during the study period. This may help explain the significant 10% to 5% decline in relative abundance of *Villosa constricta* in muskrat middens during the study period.

Just as in the other previously discussed species, there is a period of time, 1990 to 1992 for *Villosa constricta*, when frequency distributions for shell lengths becom increasingly skewed to the right and increasingly leptokurtic (Figure 8). However, by 1993 and 1994 the population was rapidly returning to G1 and G2 levels similar to those for

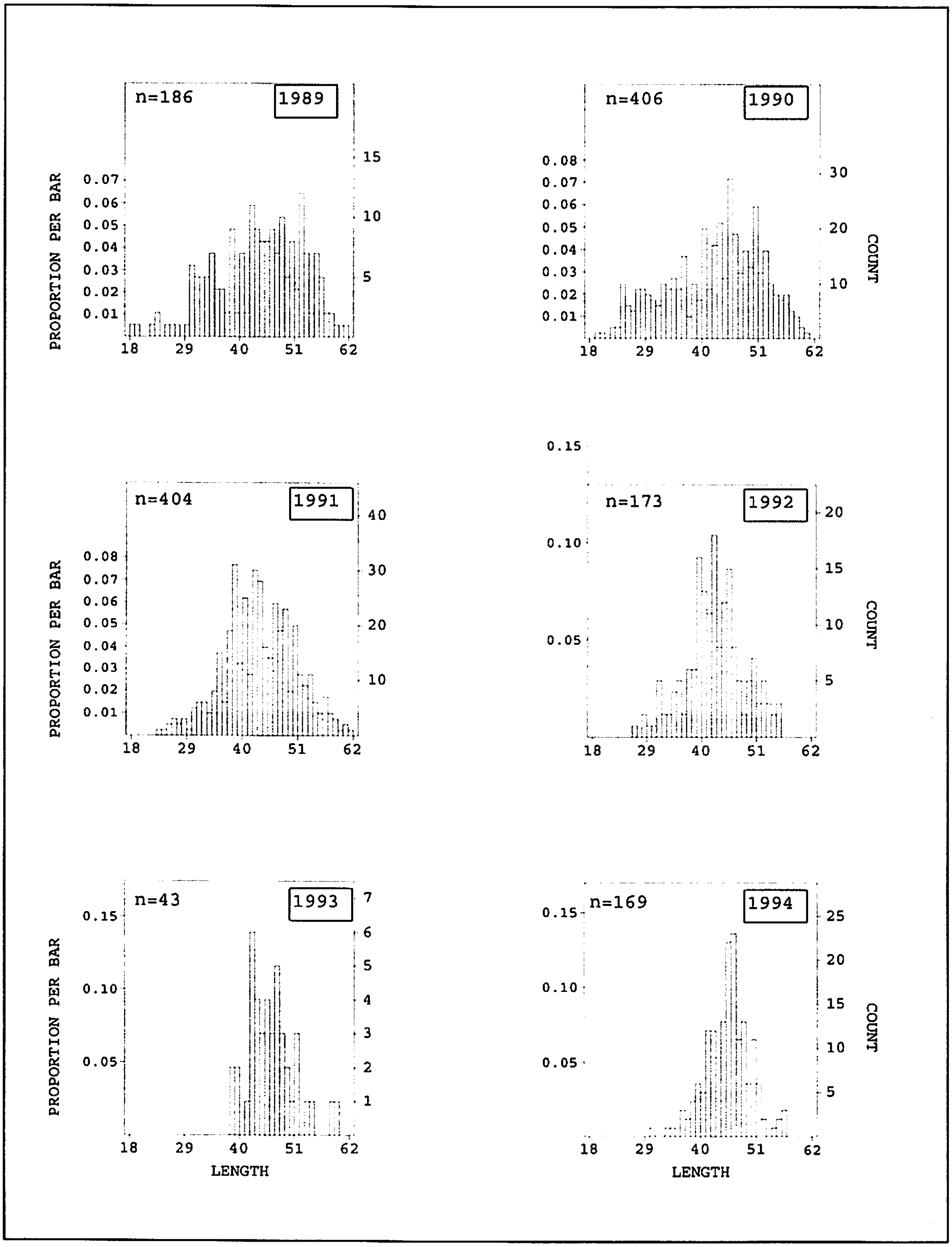

Figure 5. Length (mm) of *Elliptio lanceolata* shells collected from Swift Creek muskrat middens during the years 1989-1994.

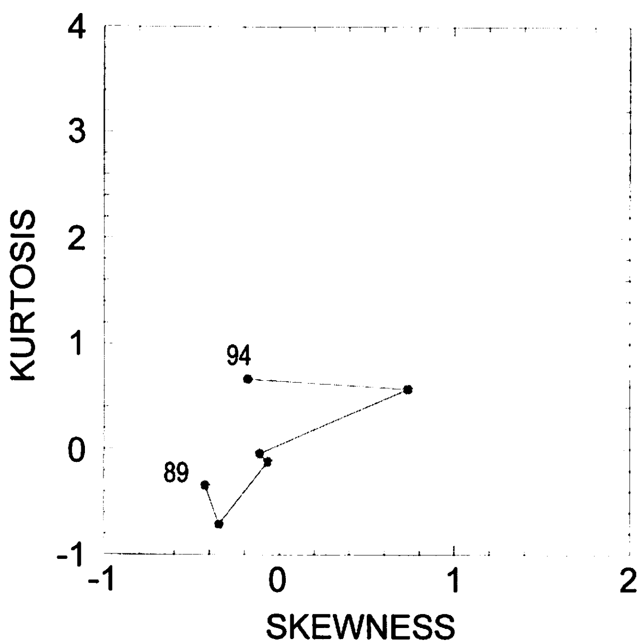

Figure 6. Skewness compared with kurtosis for frequency distributions of *Elliptio lanceolata* shell lengths from Swift Creek.

1989. This indicates that successful reproduction occurred during the early years of the study, but the levels of reproduction were not sufficient to cause significant shifts in central tendencies of the shell length frequency distributions.

Strophitus undulatus

Strophitus undulatus, a bradytictic species, is a state-listed threatened species. This species decreased in relative abundance in muskrat middens compared with other species (Figure 2). *Strophitus undulatus* decreased from approximately 2% to 0.1% of the mussel shells found in muskrat middens between 1989 and 1994. The G-test of independence confirms this to be a significant percentage decrease (P<.01).

During the first 3 years of the study for *Strophitus undulatus*, there were significant (P<.0001) changes in the central tendencies for shell length frequency distributions. Mean lengths were 44.6 (n=34), 50.4 (n=53), and 54.3 mm (n=51) during the years 1989 through 1991, respectively. Using pairwise comparisons, central tendencies of shell length frequency distributions were significantly different comparing 1989 with 1990 (P=.003) and were significantly different comparing 1990 with 1991 (P=.024). It appears that the *Strophitus undulatus* population aged rapidly during these 3 years, and this may account for the decline in relative abundance of shells seen in the muskrat middens during the study. Analysis of shell length data during the last 3 years of the study is not possible since only five squawfoot shells were found in 1992, one in 1993, and one in 1994.

Alasmidonta undulata, Lampsilis cariosa,* and *Elliptio steinstansana

Three species will be evaluated as a group: *Alasmidonta undulata* (state-listed threatened), *Lampsilis cariosa* (state-listed threatened and federal C2 species), and *Elliptio steinstansana* (state and federally listed endangered). The first two are bradytictic species, and the last is a tachytictic species. These species all showed similar trends during the study period: As reflected in muskrat midden shells (Figure 2), it appears each represented a small part of the community originally, and relative abundance declined during the 6-year period. However, using the G-test of independence, these declines were not statistically significant. Other statistical evaluations for each of the species would be largely meaningless, since sample sizes are less than 20 individuals in most of the cases.

The *Elliptio* Complex

Limited comments will be provided for trends in the *Elliptio* complex found in the study area, since separation of shells by species based on shell morphology is presently not possible. However, the G-test of independence confirms that there was a significant percentage decrease of this complex's representation within muskrat middens from 1989 to 1994 (P<.05).

Recommendations

It is appropriate to describe an important, serendipitously discovered mussel die-off event in Swift Creek and to argue the assumption that the die-off began on 2 August 1990. That day, muskrat midden shells were collected from the upper half of the Swift Creek study area. The next day, at the start of mussel shell collecting within the lower half of the study area, numerous dead mussels (meats still intact and fresh) were discovered representing most of the species found in the study area. The analysis of available mussel tissues determined that cholinesterase activity was significantly reduced in the dead mussels (Fleming et al. 1995). Therefore, one possible explanation for the die-off was that an organophosphate or carbamate pesticide had been accidentally introduced into the creek.

An alternative explanation should also be explored. The mussel die-off was determined to

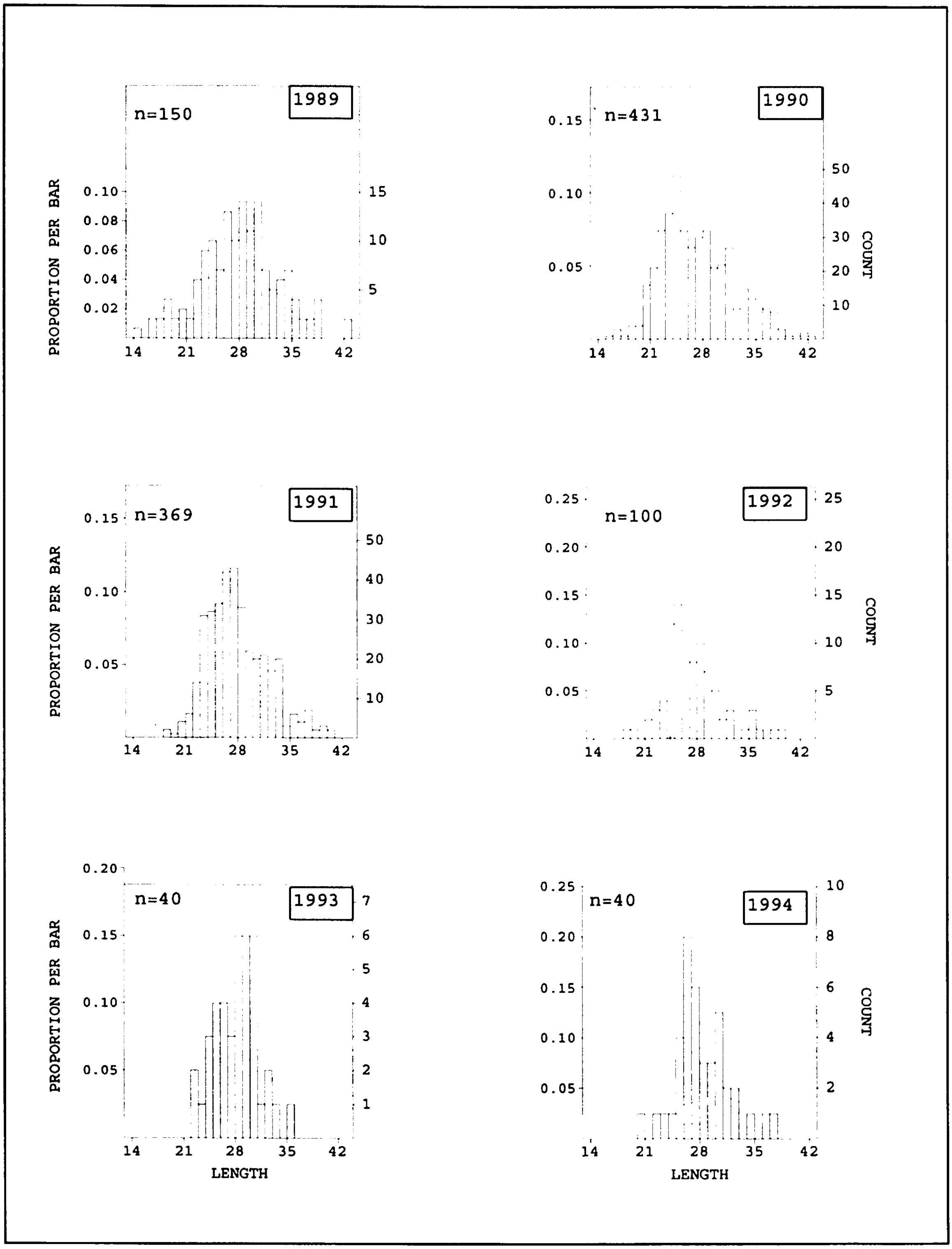

Figure 7. Length (mm) of *Villosa constricta* shells collected from Swift Creek muskrat middens during the years 1989-1994.

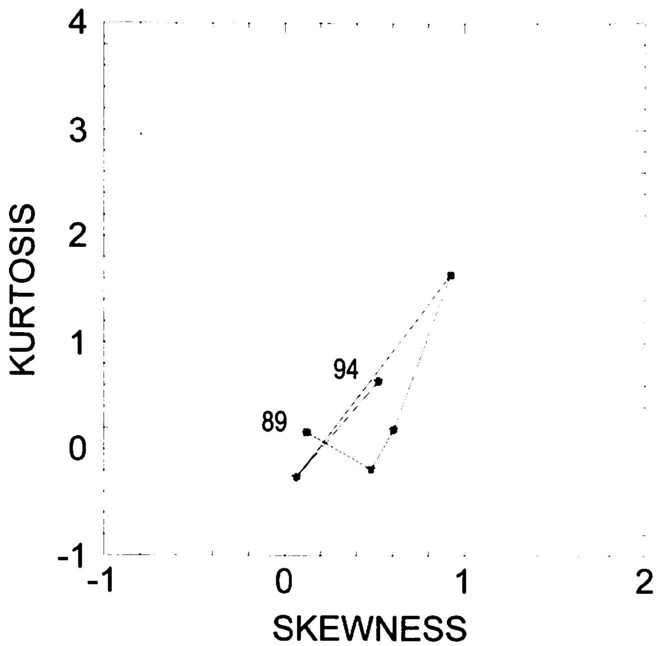

Figure 8. Skewness compared with kurtosis for frequency distributions of *Villosa constricta* shell lengths from Swift Creek.

originate within an area with a large *Corbicula fluminea* population (estimated minimum density of several hundred clams/m²). Also, the die-off started after project personnel completed their duties the day before. Therefore, the die-off probably occurred during the early evening and at night. It is important to note that the creek's extreme low flow for the year occurred on approximately August 3 (USGS 1991). Given the low-flow conditions during the summer and the presence of an exotic species in large numbers, which probably acts as an oxygen competitor or excessive waste producer, it is possible that dissolved oxygen levels dipped below the tolerance levels for some individuals of most mussel species in Swift Creek at the substrate/water column interface. This may have contributed to the significant die-off of mussels. Future research needs to be initiated to determine the effects of a large *Corbicula fluminea* population on various water quality parameters during low flow/high temperature conditions in lotic habitats. If significant water quality changes are documented, then their effects on freshwater mussel individuals, including cholinesterase levels, need to be determined. For Swift Creek, emphasis should be placed on species with declining relative abundances, such as certain bradytictic species and *Elliptio steinstansana*.

Additional research is also needed to determine the effects of increased sedimentation on reproductive success in *Corbicula fluminea* populations. If increased sedimentation (or other habitat changes, such as increased exposure of creek to sunlight) leads to enhanced reproductive success and there are negative effects on native mussel populations from large *Corbicula fluminea* populations, there should be greater emphasis on management of sedimentation when developing future best management plans for agriculture, forestry, and other intensive land-use activities.

The documented changes in the Swift Creek mussel fauna occurred at a time of environmental change within and upstream of the study area. Although there is no direct evidence that silvicultural activities caused any changes in the Swift Creek mussel fauna, field inspections by Wildlife Resources Commission personnel confirm that existing best management plans were not fully implemented along Swift Creek and its tributaries. Therefore, greater emphasis needs to be placed on fully implementing best management plans during future silvicultural activities within the subbasin.

Finally, most best management plans for agriculture and silviculture emphasize general requirements for maintaining aquatic resources. However, future research is needed to determine best management practices required to maintain our best remaining aquatic habitats, such as those found in the Swift Creek subbasin.

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