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FRESHWATER MUSSELS OF THE POWELL RIVER, VIRGINIA AND TENNESSEE: ABUNDANCE AND DISTRIBUTION IN A BIODIVERSITY HOTSPOT

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ABSTRACT

The Powell River, located in southwestern Virginia and northeastern Tennessee, is a tributary of the Clinch River in the headwaters of the Tennessee River system. Historically, the Powell River had a diverse freshwater mussel fauna of 46 species. Various surveys conducted over the past century have recorded a decline in mussel densities and diversity throughout much of the river, due to historical and on-going anthropogenic impacts. In 2008 and 2009, random timed-search, systematic search, and quadrat sampling of 21 sites were completed to document species richness, relative abundance, density, and size-class structure of resident mussel populations. During the random timed search (10 sites) and systematic search (10 additional sites) portions of the survey (n=1,399 person-h), surveyors collected 15,084 mussels of 29 species. Catch-per-unit-effort ranged from 0.33 to 22.12 mussels/person-h. We observed living individuals (n = 412) of 9 of the 17 federally endangered species previously reported in the river (*Dromus dromas*, *Epioblasma brevidens*, *E. triquetra*, *Fusconaia cor*, *Lemiox rimosus*, *Plethobasus cyphyus*, *Quadrula cylindrica strigillata*, *Q. intermedia*, and *Q. sparsa*) and two candidate species for federal protection (*Pleuronaia dolabelloides* and *Ptychobranchus subtentum*). We recorded 19 species from 18 sites, including 5 endangered species during quadrat sampling efforts. Mean densities ranged from 0.00 to 2.25 mussels/m^2 among sites sampled. Relatively recent recruitment was also evident for 16 of 29 species; including 4 endangered species (*D. dromas*, *E. brevidens*, *Q. intermedia*, and *Q. sparsa*). The mussel fauna of the lower Powell River continues to represent one of the most diverse in the United States. Outside of the Powell River, only 2 or 3 populations remain for most of the listed species extant in the river. Given these qualities, the Powell River deserves recognition as a location for focused conservation efforts to protect its diverse mussel assemblage.

KEY WORDS Freshwater mussels, Powell River, Survey, Endangered Species, Biodiversity

INTRODUCTION

The freshwater mussel fauna of the Powell River is one of the most diverse in the United States. Historically, the river was inhabited by 46 species of mussels (Table 1). Various factors account for this diversity, such as the river valley not being glaciated during the Pleistocene epoch, a carbonate-rich lithology draining the Valley and Ridge Physiographic Province, diverse and favorable habitat types, and low level of development.

Several researchers over the past century, beginning with Ortmann (1918), have sampled mussels in much of the river (Ahlstedt, 1986, 1991a; Ahlstedt & Brown, 1979; Dennis, 1981; Ahlstedt & Jenkinson, 1987; Jenkinson & Ahlstedt, 1988; Hubbs et al., 1991; Wolcott & Neves, 1994; Ahlstedt & Tuberville, 1997; Eckert et al., 2004; Ahlstedt et al., 2005). Most recently, Ahlstedt et al. (2005) documented 36 extant species in the drainage from samples taken over a 30 y period. They reported 13 of the 17 species known from the drainage that are listed under the Endangered Species Act.

The river's mussel fauna was already experiencing a noticeable decline from anthropogenic impacts reported by Ortmann (1918). Ortmann noted that a large portion of the mussel fauna in the upper river had already been decimated downstream of a wood extraction plant located in Big Stone Gap, Virginia. Between the 1960s and 1990s, mussels in other portions of the river became increasingly rare (Dennis, 1981; Ahlstedt & Jenkinson, 1987; Jenkinson & Ahlstedt, 1988; Hubbs et al., 1991; Wolcott & Neves, 1994; Ahlstedt & Tuberville, 1997; Eckert et al., 2004; Ahlstedt et al., 2005). According to Ahlstedt et al. (2005), D. H. Stansbery used sampling data collected between 1963 and 1971 to confirm his initial observations that the mussel fauna had declined substantially in the half century since Ortmann's collections. Subsequent sampling has confirmed this decline (e.g., Wolcott & Neves, 1994; Ahlstedt et al., 2005).

Mussel declines in the Powell River have largely been attributed to habitat degradation caused by agricultural practices, urban development, and coal mining (Dennis, 1981; Ahlstedt & Tuberville, 1997; Diamond et al., 2002; Ahlstedt et al. 2005). Ahlstedt et al. (2005) considered mussel distributions and abundances to be heavily influenced by the location of mined lands in the watershed. Additional studies have shown that runoff of sediments contaminated with by-products from coal mining activities is a potential factor leading to mussel declines (McCann & Neves, 1992). Black-water events (coal fines released into the river from processing activities) have occurred frequently over the last 100 y in this watershed (Ahlstedt et al., 2005). Following a period in the early 1980s, when the entire river was known to occasionally run black with coal fines (Ahlstedt, 1986), a mussel die-off was observed in 1983 between Powell River kilometer (PRKM) 230.9 and 104.8 (Ahlstedt & Jenkinson, 1987; Jenkinson & Ahlstedt, 1988). In order to understand the effects these anthropogenic events have had on the river's diverse mussel fauna, we collected current data on species presence and abundances, distribution, and size-class structure. To that end, we utilized three different sampling techniques to assess demography, distribution, and abundance of freshwater mussels at 21 sites in the Powell River. We are providing this information so that future conservation efforts can better protect the threatened mussel fauna in the Powell River.

METHODS

Study Area

The Powell River originates near Norton in Wise County, Virginia, flows in a southwesterly direction, and enters Norris Reservoir, an impoundment of the Clinch River [at CRKM 127] (Fig. 1). The watershed drains an area of approximately 2,453 km2, and is wholly contained within the Valley and Ridge Physiographic Province. Numerous parallel ridges and subterranean drainages define the Powell River watershed (Tennessee Department of Environment and Conservation 2007). Prominent land cover includes forest (58.7%), agricultural lands (29.8%), developed, mined and barren lands (9.7%), and open water and wetlands (1.8%) (2006 NASA Landsat Data Collection [U.S. Geological Survey 2011], which were extracted via ArcMap version 9.2 using USGS 8-digit HUC [Steeves & Nebert 1994]). The mainstem of the river is characterized by long pools interrupted by periodic shallow shoals where substrate consists predominantly of a heterogeneous mix of sand, gravel and cobble.

Twenty-one sites were selected for sampling (Table 2; Fig. 1). Eighteen sites were selected based on the locations of previously documented living mussel assemblages (Dennis, 1981; Ahlstedt, 1991a; Wolcott & Neves, 1994; Ahlstedt et al., 2005; Eckert et al., 2004). Three additional sites, previously un-surveyed, were also selected because they contained accessible reaches that met the following criteria: (1) suitable shoal habitat present, and (2) where results of cursory visual and tactile survey (using snorkel gear) showed that mussels were present. We conducted these surveys in suitable habitat, which we defined as riffles and runs consisting of a stable heterogeneous mix of sand, gravel, and cobble.

Survey Approach

We employed three different survey strategies to obtain species richness, relative abundance, density estimates, and evidence of recruitment. To quantify species richness and relative abundance, one of two survey strategies was used. Based on previously obtained data (Ahlstedt et al., 2005; Wolcott & Neves, 1994; J.W. Jones, USFWS, unpublished data), if federally listed species were not likely to occur at a site, a random timed search (RTS; defined below) was used to maximize search area with minimal search time. Conversely, if federally listed species were likely to occur at the site, a systematic search (SS; defined below) was used to maximize detection. Quadrat sampling was performed at all sites to quantify density estimates and

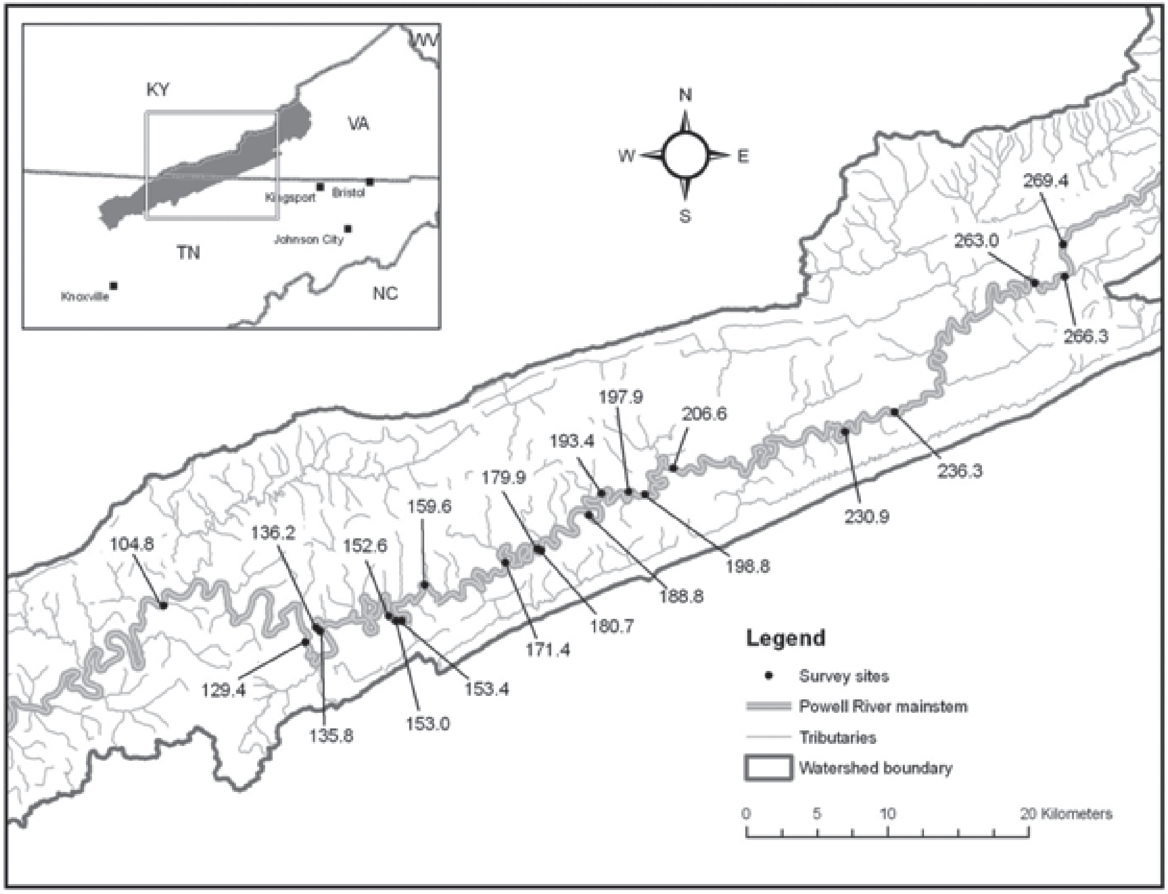

FIGURE 1

Sites surveyed using random timed search, systematic search, and quadrat sampling methods in the Powell River.

increase the probability of detecting recent recruitment.

For all survey methods, we utilized visual and tactile search methods with mask and snorkel to collect mussels. A core crew of three surveyors conducted all types of surveys; however, additional assistance was required at several sites and varied up to 20 people.

Random Timed Searches—We performed RTS at a total of 10 sites (Table 2). Surveyors initiated sampling at the downstream boundary using a series of lateral sweeps to cover as much habitat as possible within the entire delineated site, typically between 100 and 200 m. This method enabled surveyors to maximize search area while minimizing search time.

During RTS, we only collected mussels that were visible at the substrate surface and did not excavate to search for mussels. Surveyors attempted to sample the entire wetted-width of the river at each site. As mussels were found, surveyors left them undisturbed in the substrate, and marked their location with a wired florescent flag. A separate crew followed the snorkelers to remove flagged mussels and record data. Collected mussels were counted, identified to species and/or sub-species level, measured for maximum shell length (mm, anterior to posterior margin), sexed (if possible), and returned to their locations of collection. Catch-per-unit-effort (CPUE) was calculated as total number of mussels divided by the amount of time spent surveying per person, expressed hereafter as person-hours (p-h). For medium to large sized (e.g., 70 - 140 mm) mussels, we assumed mussels < 40 mm in shell length were approximately 2 to 4 y old, and that the presence of mussels below this threshold showed recent recruitment (e.g., Ahlstedt et al., 2005). For smaller species (e.g. < 70 mm), we assumed mussels < 30 mm were evidence of recent recruitment.

Systematic Searches—We conducted a SS at 10 sites (Table 2) based on likely occurrences of federally listed mussels. An eleventh site, PRKM 136.2, met the criteria for this mode of sampling; however, scheduling conflicts prevented a “SS” from being conducted at this site.

For each site, we partitioned the entire shoal into 1.5 m-wide by 50 m-long sampling lanes oriented parallel to water flow using twisted masonry nylon twine stretched between two rebar stakes (1.2 m long x 1.25 cm diameter) that were pounded into the stream bottom with a drilling hammer. The number of lanes used during sampling corresponded to the width and length of suitable habitat within the river reach. A surveyor was assigned to each lane and visually searched the substrate surface of the entire area within each lane in an upstream direction. Similar to the RTS method, surveyors minimized displacement of substrate material. Mussels were marked with flags and processed as previously described under the RTS survey technique.

Quadrat Sampling—To obtain density estimates of the mussel aggregations and to determine the occurrence of recent recruitment, we excavated multiple defined quadrat areas using a systematic sampling design that incorporated a single random start adapted from Strayer and Smith (2003). We established transects that were perpendicular to flow, and were evenly spaced across the full length of each survey site. Following the selection of a starting point from the random number table, approximately ten 0.25 m2 quadrats were placed at evenly spaced intervals (2 to 5 m) along each transect. Quadrats were placed along transects in alternating directions; i.e., placed from right ascending bank to left ascending bank on first transect, followed by left ascending bank to right ascending bank on second transect. If insufficient space existed between the final quadrat on a transect and the riverbank, the difference between the remaining distance, and distance to the riverbank would be continued on the following transect, and quadrat sampling would resume. For example, if quadrats were evenly spaced at 5 m apart, and only 3 m remained between the final quadrat and the riverbank, the first quadrat on the following transect would be placed 2 m from the riverbank.

One hundred to 200 quadrats were sampled at each site. The number of quadrats sampled at each site was primarily dictated by available resources, including time and personnel. Generally, more quadrats were taken at sites deemed to have a greater likelihood of federally endangered species and allowed us to more intensively focus our quantitative effort on areas that were most important for imperiled species within the river.

Quadrat samples were taken by placing a 0.5 m x 0.5 m square constructed of 1.25 cm diameter rebar over the area to be sampled. The area within the quadrat was then excavated by hand and visually examined to a depth of 15 cm or until hardpan (a compacted layer of substrate that could not be excavated by hand) or bedrock was reached. In each quadrat, all mussels were collected, identified, sexed, measured, and denoted as visible on the surface of the substrate or undetectable at the surface. Mussels were then returned to the substrate directly adjacent to the quadrat, and substrate that was excavated from the quadrat was returned. During the quadrat survey, mussels with any portion of their shell above the substrate were noted as "exposed", and musse $CV = \sqrt[1.82]{(nm^{.51})/2.6}$ n view during excavation were noted as "buried". Quadrat data were used to estimate mussel density for each site. The precision of each density estimate was calculated post hoc using the formula: , where, n = number of quadrats sampled, m = mean number of mussels per quadrat, and CV = precision (Strayer & Smith, 2003).

Data Analysis

All summary statistics of mussel lengths and total mussel densities were calculated using Minitab 16 (Minitab, Inc., State College, Pennsylvania). Simple linear regression of total mussel densities and PRKM also was performed using Minitab 16. P-values < 0.05 were considered significant. Tables and figures were created using Excel 2007 (Microsoft, Inc., Redmond, Washington). The site map was produced using ArcMap 9.2 (Environmental Systems Resource Institute (ESRI), Redlands, California).

RESULTS

Mussel Surveys

Based on RTS and SS, a total of 15,084 mussels representing 29 species were collected among the 21 sites surveyed (Tables 3 and 4). Species richness ranged from 1 to 23 species per site (x±SE; 13.8 ± 1.58), with the highest number at PRKM 152.6 and the fewest at PRKM 263.0 (Table 3; Fig. 2). Total live mussels ranged from 1 (PRKM 263.0) to 4,297 (PRKM 152.6) mussels (754 ± 240) per site (Table 3). Total CPUE ranged from 0.33 (PRKM 263.0) to 22.12 (PRKM 152.6) mussels/p-h (8.68 ± 1.68; Table 3). Evidence of relatively recent recruitment was observed for 16 of 29 species collected live among nine sites (Table 4). Of the 15,084 mussels collected during RTS and SS sampling, 74 (0.5%) were considered recent recruits (Table 4).

Quadrat sampling (n = 2,580) yielded 580 mussels of 19 species from 18 of 21 sites (Table 5). Mean densities ranged from 0.00 (PRKMs 269.4, 266.3, and 263.0.) to 2.25 (PRKM 135.8) mussels/m2 among sites (0.88 ± 0.144) (Table 6). A significant linear relationship was shown between mussel density and PRKM (r2 = 0.295, F = 7.94, df = 20, P = 0.011; Fig. 3). Similarly, a significant relationship occurred between PRKM and the number of species collected during quadrat sampling (r2 = 0.655, F = 36.10, df = 17, P < 0.001; Fig. 2). Pre-

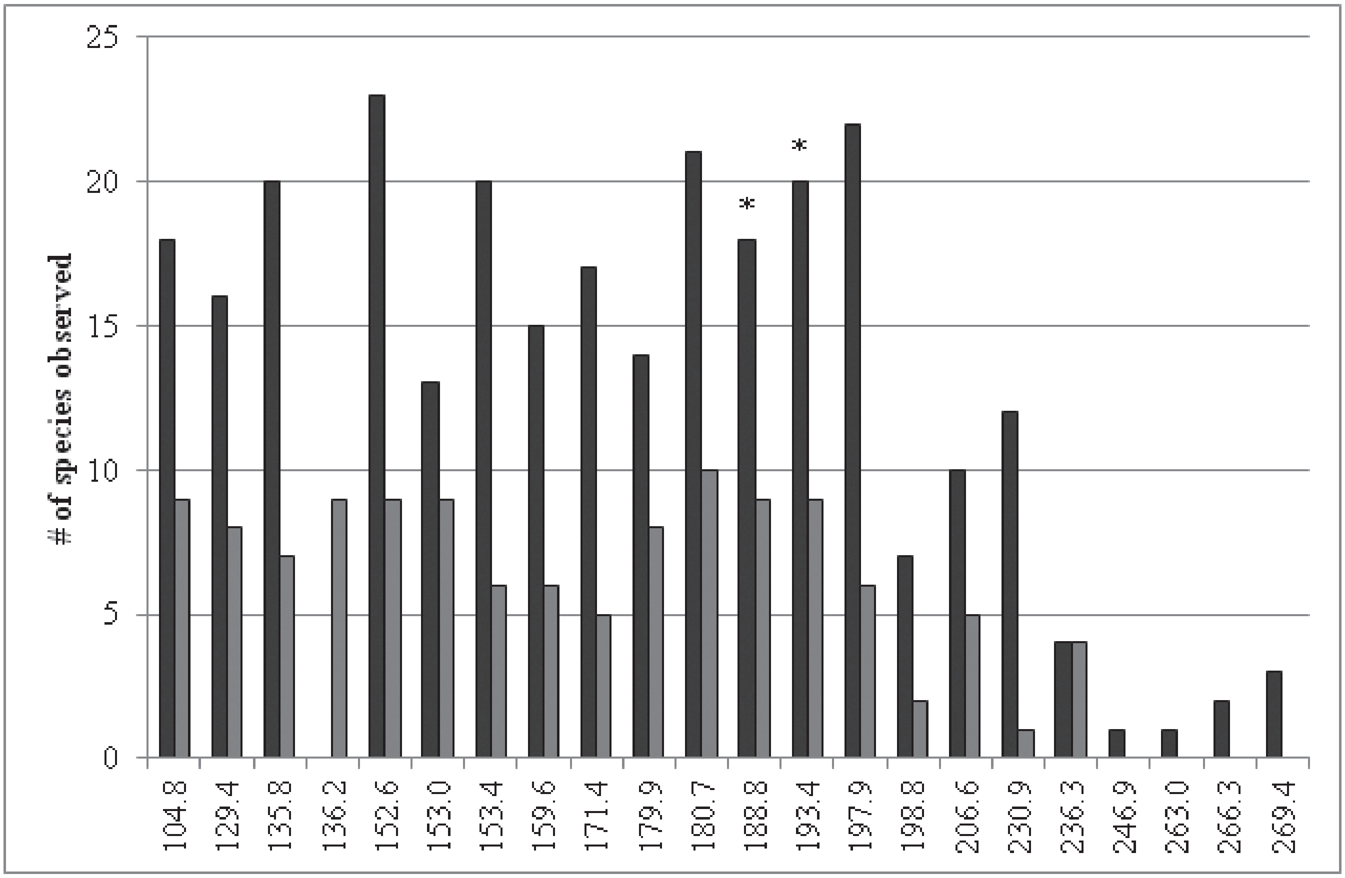

FIGURE 2

Species observed at selected sites in the Powell River during random timed search, systematic search, and 0.25 m2 quadrat sampling. Systematic sampling was not conducted at PRKM 136.2 due to resource constraints. Dark bars: Number of species collected during random timed search and systematic search; Light bars: Number of species collected during quadrat sampling. Statistically significant linear relationship between number of species collected during quadrat sampling and PRKM: r2 = 0.655, F = 36.10, df = 17, P < 0.001; * = site where propagated juveniles have been released.

cision of density estimates ranged from 0.09 to 0.22. Species richness among sites ranged from 0 (PRKMs 269.4, 266.3, and 263.0) to 10 (PRKM 180.7) species (5.81 ± 0.75).

Of 580 mussels collected from quadrats, 21 (3.6%) individuals were deemed to be relatively recent recruits among six species (*A. pectorosa, E. dilatata, E. brevidens, L. ovata, M. conradicus*, and *V. iris*) over nine sites (Table 5). For species that were sexually dimorphic, all but two species (*L. ovata* and *V. iris*) were represented by both male and female individuals.

DISCUSSION

The results of this survey show that a speciose mussel fauna still inhabits the lower Powell River, including at least 11 federally endangered and candidate species. For example, the presence of relatively recent recruits of the critically imperiled *Quadrula intermedia* and *Quadrula sparsa* illustrates the importance of continued conservation efforts in the basin. However, despite the presence of diverse, recently recruiting populations, the fauna has likely lost one-third of its species since Ortmann (1918) (from 46 species historically to 29 current species) (Table 1).

Although not collected during this survey, *Cumberlandia monodonta*, *Fusconaia cuneolus* and *Pleurobema oviforme* could still inhabit the river at undetectable levels. While live individuals of *C. monodonta* were not collected, fresh-dead specimens indicated that the species probably persist in the Powell River. Both *F. cuneolus* and *P. oviforme* may also inhabit the river in very low densities, because both having been collected in recent decades (Eckert et al., 2004). In addition, only a few older

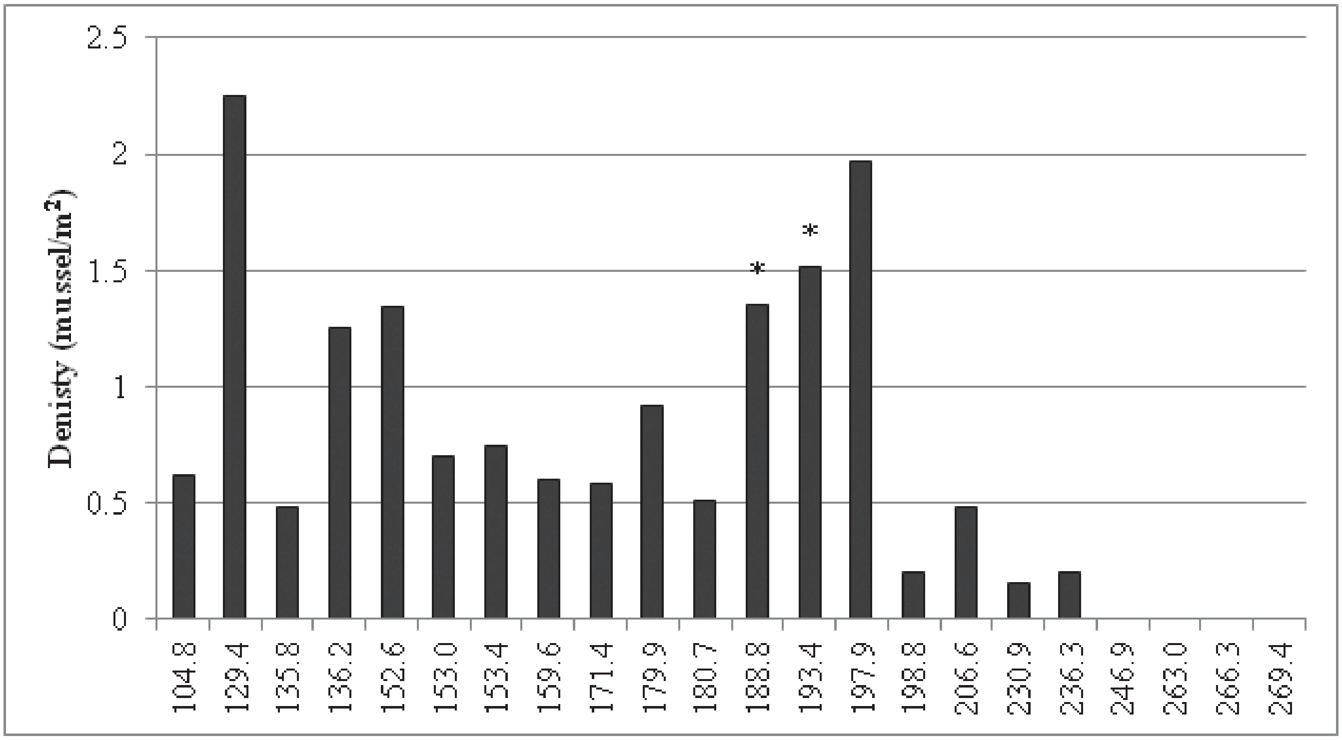

FIGURE 3

Estimated mussel densities at selected sites in the Powell River, utilizing 0.25 m2 quadrat sampling. Statistically significant linear relationship between estimated mussel density and PRKM: r2 = 0.295, F = 7.94, df = 20, P = 0.011; * = site where propagated juveniles have been released.

individuals of *Potamilus alatus* and *Q. pustulosa* were collected. However, *P. alatus* is probably more common than our sampling indicated, because slackwater, soft substrate habitat was not adequately surveyed using our site selection criteria targeting shoals.

Neither live individuals nor shell material of *Epioblasma capsaeformis* or *Hemistena lata* were collected during this survey. The last evidence of *E. capsaeformis* comes from the collection of a single individual at PRKM 193.4 in the late 1980s (Wolcott & Neves, 1994). The last evidence of *H. lata* was a single shell collected from PRKM 179.9 in the late 1990's by J. Jones (unpublished data). Given the short life spans of these species (< 15 y) (Watters et al., 2009; Jones & Neves, 2011), any remnant individuals have likely been extirpated from the river. However, *H. lata* may still reside in the river because it is difficult to detect (individuals burrow deeply (10 to 15 cm) in the substrate (Ahlstedt, 1991b), and old shell material degrades quickly. *Alasmidonta marginata, A. viridis, Pegias fabula, Strophitus undulatus, Toxolasma lividum, Truncilla truncata, Villosa fabalis*, and *Villosa perpurpurea* have not been collected in the past several decades and are very likely extirpated from the river. These species are considered headwater forms and have likely been impacted by upstream pollution (Ahlstedt & Brown, 1979; Dennis, 1981). *Epioblasma torulosa gubernaculum*, once documented as inhabiting the Powell River, is believed extinct (Williams et al., 1993). Although *Lasmigona holstonia* has been seemingly extirpated from the mainstem of the Powell River, the species is still extant in Beaverdam Creek, a tributary of the South Fork Powell River, upstream of Big Stone Gap, Virginia (The Catena Group, 2008).

As documented in previous surveys (Ahlstedt & Brown, 1979; Dennis, 1981; Wolcott & Neves, 1994), a significant decline in both species diversity and mussel abundance was observed, particularly in an upstream direction and above the island at Snodgrass Ford. This decline has been attributed primarily to coal mining, but also to agriculture, and effects from urban areas have been implicated (Ahlstedt & Tuberville, 1997; Wolcott & Neves, 1994; Ahlstedt et al., 2005). These activities will likely continue in the upper Powell River watershed over time. In addition, natural gas extraction is expanding throughout the Appalachian region and may become a factor in the future (Zoback et al., 2010; Osborn et al., 2011). During our survey, large amounts of sediment were evident in both the water column and covering the substrate surface at the most upstream sites (e.g., above PRKM 130.9). It has been suggested that sedimentation can lead to reduced reproductive success in some mussel species (Brim Box & Mossa, 1999). It is generally believed that the major decline in mussels of the Powell River headwaters is attributable to coal mining activities, and associated contaminants (e.g., McCann & Neves, 1992). The role of stressors on the mussel fauna, particularly in the upstream portions of the Powell River (upstream of PRKM 206.6), needs further study to determine their effects on all life-history stages.

Dam construction in the upper Tennessee River system will continue to have a legacy effect on Powell River mussels. Low abundance and large size indicates a long-term lack of recruitment for *Elliptio crassidens, Ligumia recta*, and *Truncilla truncata* (Table 4). This may be caused by a virtual loss of their primary host fishes, skipjack herring (*Alosa chrysochloris*) and sauger (*Sander canadense*). This loss of host fish is due to downstream dams blocking their spawning runs. As a result, extirpations of species like *Elliptio crassidens* and *Ligumia recta* can be expected due to the extinction debt caused by habitat fragmentation (Tilman et al., 1994).

Evidence of recent recruitment is an indicator of population viability. It is important to note that sub-adults of multiple species were collected during this survey, albeit in low numbers (3.1% of total abundance in quadrats), including several endangered species (*Epioblasma brevidens, Lemiox rimosus, Pleuronaia dolabelloides, Q. intermedia*, and *Q. sparsa*). Nonetheless, this is evidence that portions of the lower Powell River continue to support recruiting populations of federally endangered species and that the differences between these reaches and reaches that do not support recruitment should be studied further.

Due to the presence of several recruiting federally endangered species (e.g., *E. brevidens, Q. intermedia*, and *Q. sparsa*), the section between PRKMs 153.4 and 152.6 is perhaps the most productive reach in the river. Based on our search methods, 7 of the 8 endangered species found at PRKM 152.6 had their greatest abundance at that site (161 individuals), representing 39.1% of the total. The greatest abundance (28.5% of total abundance) and the highest CPUE (22.1 mussels/p-h) were also found at this site. This is significant because despite the presence of the *Quadrula* species in other sections of the river, young individuals were not collected outside of this reach. In addition, only one other recruiting population of *Q. intermedia* is known to exist (Duck River of central Tennessee), and no additional recruiting populations of *Q. sparsa* are known to occur elsewhere (Parmalee & Bogan, 1998). For these reasons, it is important that this reach of the river be protected.

In addition to the river section between PRKMs 153.4 and 152.6, the river section between PRKMs 197.9 and 188.8 is also of particular interest for future conservation efforts. The sites at PRKMs 193.4 and 188.8 have been release sites for propagated juveniles of both common and threatened species (Eckert et al., 2004). Densities at these sites were among the highest of sites sampled, which may be in part due to these juvenile releases. The mussel densities at PRKM 197.9 are also among the highest of the sites sampled during this study. The mussel aggregations at this site have not been frequently sampled like some adjacent sites (Eckert et al., 2004; Ahlstedt et al., 2006), so declines at this site have not been as thoroughly monitored. Additional sampling should be conducted near this site to determine why densities at this site have not declined to the extent that they have both upstream and downstream of this reach at un-augmented sites.

The mussel fauna of the Powell River continues to be threatened by numerous anthropogenic activities. Despite these impacts, the river still contains one of the most diverse mussel faunas in the United States. Among national rivers, only the Clinch River harbors more extant populations of naturally occurring federally endangered mussels. Although low, there was evidence of recruitment at a number of our sample sites, indicating that the Powell River, if managed correctly, has the potential to rebound from ongoing and historical anthropogenic impacts. It is imperative that research, habitat and population restoration, and monitoring efforts continue in this river to conserve its speciose mussel fauna.

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TABLE 1

Conservation status for mussel species known from the Powell River. American Fisheries Society (AFS) status from Williams et al. (1993). Conservation Status: CS = currently stable, E = endangered, FE = federal endangered, FC = federal candidate, PE = federal proposed endangered, T = threatened, V = vulnerable or special concern, X = possibly extinct, - = no status and √ = considered extant based on current study.

Scientific Name		Common Name	Federal Status	AFS Status
Actinonaias ligamentina (Lamarck 1819)	√	mucket	-	CS
Actinonaias pectorosa (Conrad 1834)	√	pheasantshell	-	V
Alasmidonta marginata (Say 1818)	-	elktoe	-	V
Alasmidonta viridis (Rafinesque 1820)	*	slippershell mussel	-	V
Amblema plicata (Say 1817)	√	threeridge	-	CS
Cumberlandia monodonta (Say 1829)	√	spectaclecase	FE	T
Cyclonaias tuberculata (Rafinesque 1820)	√	purple wartyback	-	V
Dromus dromas (Lea 1834)	√	dromedary pearlymussel	FE	E
Elliptio crassidens (Lamarck 1819)	√	elephantear	-	CS
Elliptio dilatata (Rafinesque 1820)	√	spike	-	CS
Epioblasma brevidens (Lea 1831)	√	Cumberlandian combshell	FE	E
Epioblasma capsaeformis (Lea 1834)	-	oystermussel	FE	E
Epioblasma haysiana (Lea 1834)	-	acornshell	-	X
Epioblasma lewisii (Walker 1910)	-	forkshell	-	X
Epioblasma torulosa gubernaculum (Reeve 1865)	-	green blossom	FE	X
Epioblasma triquetra (Rafinesque 1820)	√	snuffbox	PE	T
Fusconaia cor (Conrad 1834)	√	shiny pigtoe	FE	E
Fusconaia cuneolus (Lea 1840)	-	finerayed pigtoe	FE	E
Fusconaia subrotunda (Lea 1831)	√	longsolid	-	V
Hemistena lata (Rafinesque 1820)	-	cracking pearlymussel	FE	E
Lampsilis fasciola (Rafinesque 1820)	√	wavyrayed lampmussel	-	CS
Lampsilis ovata (Say 1817)	√	pocketbook	-	V
Lasmigona costata (Rafinesque 1820)	√	flutedshell	-	CS
Lasmigona holstonia (Lea 1838)	√	Tennessee heelsplitter	-	V
Lemiox rimosus (Rafinesque 1831)	√	birdwing pearlymussel	FE	E
Leptodea fragilis (Rafinesque 1820)	-	fragile papershell	-	CS
Ligumia recta (Lamarck 1819)	√	black sandshell	-	V
Medionidus conradicus (Lea 1834)	√	Cumberland moccasinshell	-	V
Pegias fabula (Lea 1838)	-	littlewing pearlymussel	FE	E
Plethobasus cyphyus (Rafinesque 1820)	√	sheepnose	FE	T
Pleurobema oviforme (Conrad 1834)	-	Tennessee clubshell	-	V
Pleuronaia barnesiana (Lea 1838)	√	Tennessee pigtoe	-	V
Pleuronaia dolabelloides (Lea 1840)	√	slabside pearlymussel	FC	T
Potamilus alatus (Say 1817)	√	pink heelsplitter	-	CS
Ptychobranchus fasciolaris (Rafinesque 1820)	√	kidneyshell	-	CS
Ptychobranchus subtentum (Say 1825)	√	fluted kidneyshell	FC	V
Quadrula cylindrica strigillata (Wright 1898)	√	rough rabbitsfoot	FE	E
Quadrula intermedia (Conrad 1836)	√	Cumberland monkeyface	FE	E
Quadrula pustulosa (Lea 1831)	√	pimpleback	-	CS
Quadrula sparsa (Lea 1841)	√	Appalachian monkeyface	FE	E
Strophitus undulatus (Say 1817)	-	creeper	-	CS
Toxolasma lividum (Rafinesque 1831)	-	purple lilliput	-	V
Truncilla truncata (Rafinesque 1820)	-	deertoe	-	CS
Villosa fabalis (Lea 1831)	-	rayed bean	FE	V
Villosa iris (Lea 1829)	√	rainbow mussel	-	CS
Villosa perpurpurea (Lea 1861)	-	purple bean	FE	E
Villosa vanuxemensis (Lea 1838)	√	mountain creekshell	-	V

*Known historically from a tributary of the Powell River but not from the mainstem.

TABLE 2

Site locations, site numbers, site names and survey methods used in the Powell River.

Site Number	PRKM	State	Site Name	Random Timed Search	Systematic Search	Quadrat Sampling
1	269.4	VA	Dryden	X	-	X
2	266.3	VA	State Rte. 619 Bridge	X	-	X
3	263.0	VA	Swimming Hole	X	-	X
4	236.3	VA	Cheekspring Ford	X	-	X
5	230.9	VA	Sewell Bridge	X	-	X
6	206.6	VA	Hall Ford	X	-	X
7	198.8	VA	Snodgrass Ford	X	-	X
8	197.9	VA	Island below Snodgrass	X	-	X
9	193.4	VA	State Rte. 833 Bridge	X	-	X
10	188.8	VA	Fletcher Ford	X	-	X
11	180.7	TN	Bales Ford	-	X	X
12	179.9	TN	Fugate Ford	-	X	X
13	171.4	TN	McDowell Shoal	-	X	X
14	159.6	TN	Buchanan Ford	-	X	X
15	153.4	TN	Bar above Brooks Bridge	-	X	X
16	153.0	TN	Brooks Bridge	-	X	X
17	152.6	TN	Bar below Brooks Bridge	-	X	X
18	136.2	TN	Yellow Shoals	-	-	X
19	135.8	TN	Below Yellow Shoals	-	X	X
20	129.4	TN	Double S Bend	-	X	X
21	104.8	TN	Above U.S. Rte. 25E Bridge	-	X	X

TABLE 3

Numbers and relative abundances of each species collected during random timed search and systematic search at selected sites in the Powell River. Total numbers of mussels collected, catch-per-unit-effort (CPUE), and total species collected are also provided for each site.

	Powell River Site (PRKM and Site Number)									
	269.4	**266.3**	**263.0**	**236.3**	**230.9**	**206.6**	**198.8**	**197.9**	**193.4**	**188.8**
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Actinonaias ligamentina	-	-	-	7	11	23	9	609	192	235
Actinonaias pectorosa	1	-	-	28	53	34	9	1573	1287	443
Amblema plicata	-	-	-	-	2	3	1	8	11	34
Cyclonaias tuberculata	-	-	-	-	2	4	1	9	9	24
Dromus dromas	-	-	-	-	-	-	-	2	7	6
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-
Elliptio dilatata	-	1	-	2	3	7	-	246	137	56
Epioblasma brevidens	-	-	-	-	-	-	-	-	1	6
Epioblasma triquetra	-	-	-	-	-	-	-	-	-	-
Fusconaia cor	-	-	-	-	-	-	-	12	4	-
Fusconaia subrotunda	-	-	-	1	6	2	-	7	9	3
Lampsilis fasciola	1	-	-	-	1	2	-	1	11	5
Lampsilis ovata	-	-	-	-	1	-	-	1	2	12
Lasmigona costata	-	-	-	-	-	1	-	1	-	-
Lemiox rimosus	-	-	-	-	-	-	-	3	2	4
Ligumia recta	-	-	-	-	-	-	-	-	-	-
Medionidus conradicus	-	-	-	-	-	1	1	49	33	63
Plethobasus cyphyus	-	-	-	-	-	-	1	5	1	6
Pleuronaia barnesiana	-	-	-	-	-	-	-	3	-	-
Pleuronaia dolabelloides	-	-	-	-	-	-	-	3	1	-
Potamilus alatus	-	-	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	2	1	1	-	-	2	-	8	14	23
Ptychobranchus subtentum	-	-	-	-	-	-	-	26	1	-
Quadrula c. strigillata	-	-	-	-	3	-	-	-	-	-
Quadrula intermedia	-	-	-	-	1	-	-	7	6	6
Quadrula pustulosa	-	-	-	-	-	-	-	2	-	-
Quadrula sparsa	-	-	-	-	1	-	-	-	1	2
Villosa iris	-	-	-	-	1	-	3	3	9	14
Villosa vanuxemensis	-	-	-	-	-	-	-	1	-	6
Total Number	**4**	**2**	**1**	**38**	**85**	**79**	**25**	**2579**	**1738**	**948**
CPUE (mussels/p-h)	**1.33**	**0.67**	**0.33**	**5.07**	**4.53**	**9.03**	**2.78**	**20.97**	**7.79**	**5.02**
Total Species	**3**	**2**	**1**	**4**	**12**	**10**	**7**	**22**	**20**	**18**

TABLE 3
(Continued)

	Powell River Site (PRKM and Site Number)									
	180.7	**179.9**	**171.4**	**159.6**	**153.4**	**153.0**	**152.6**	**135.8**	**129.4**	**104.8**
Species	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**19**	**20**	**21**
Actinonaias ligamentina	291	57	88	145	388	132	1717	153	80	113
Actinonaias pectorosa	64	59	74	270	485	17	1776	159	646	235
Amblema plicata	42	11	35	15	26	35	194	66	12	48
Cyclonaias tuberculata	17	7	14	7	48	53	146	53	29	45
Dromus dromas	6	7	5	8	10	2	61	2	-	1
Elliptio crassidens	-	-	2	-	-	-	2	1	-	-
Elliptio dilatata	22	17	12	10	4	-	52	17	59	24
Epioblasma brevidens	1	-	1	1	4	2	26	5	12	1
Epioblasma triquetra	-	-	-	-	2	-	4	-	1	-
Fusconaia cor	-	1	-	-	-	-	1	1	-	-
Fusconaia subrotunda	-	-	-	-	2	-	1	1	-	-
Lampsilis fasciola	5	2	1	1	6	3	9	5	34	5
Lampsilis ovata	9	-	4	4	15	-	31	5	10	1
Lasmigona costata	3	-	-	4	-	1	12	2	-	5
Lemiox rimosus	2	-	-	-	-	-	4	-	-	-
Ligumia recta	1	-	2	-	1	3	10	2	1	1
Medionidus conradicus	16	8	24	38	58	9	83	60	358	69
Plethobasus cyphyus	32	3	7	-	3	4	33	3	2	2
Pleuronaia barnesiana	-	-	-	-	-	-	-	1	-	2
Pleuronaia dolabelloides	-	-	-	-	-	-	-	-	-	-
Potamilus alatus	1	-	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	12	1	5	4	23	2	96	12	38	25
Ptychobranchus subtentum	-	-	-	-	3	-	4	-	1	-
Quadrula c. strigillata	1	-	-	-	1	-	-	1	-	2
Quadrula intermedia	3	3	8	3	3	4	23	-	1	-
Quadrula pustulosa	-	-	-	-	-	-	3	-	-	-
Quadrula sparsa	1	-	-	1	1	-	9	-	-	-
Villosa iris	7	1	3	2	-	-	-	4	-	1
Villosa vanuxemensis	4	1	1	-	1	-	-	-	2	1
Total Number	**540**	**178**	**286**	**513**	**1084**	**267**	**4297**	**553**	**1286**	**581**
CPUE (mussels/p-h)	**8.64**	**2.28**	**2.83**	**4.35**	**18.69**	**4.02**	**22.12**	**17.28**	**20.91**	**14.90**
Total Species	**21**	**14**	**17**	**15**	**20**	**13**	**23**	**20**	**16**	**18**

TABLE 4

Summary statistics of abundance, length, and recruitment for mussel species collected in the Powell River, during random timed search and systematic search. F = female, M = Male, U = Sex Undetermined.

Species	Total Number	No. Sites	Percent Relative Abundance	Length Range and Mean ± SE (mm)	No. Recent Recruits	No. Sites with Recruits	F	M	U	F:M Ratio
Actinonaias ligamentina	4250	17	28.18	16-137 (94.32 ± 0.19)	4	3	-	-	4250	-
Actinonaias pectorosa	7213	18	47.82	13-132 (95.39 ± 0.14)	10	5	-	-	7213	-
Amblema plicata	543	16	3.60	25-143 (95.62 ± 0.67)	2	2	-	-	543	-
Cyclonaias tuberculata	468	16	3.10	15-131 (85.41 ± 0.74)	2	2	-	-	468	-
Dromus dromas	117	12	0.78	46-103 (67.67 ± 0.88)	0	0	-	-	117	-
Elliptio crassidens	5	3	0.03	103-135 (117.20 ± 6.21)	0	0	-	-	5	-
Elliptio dilatata	669	16	4.44	35-110 (69.60) ± 0.40	1	1	-	-	669	-
Epioblasma brevidens	60	11	0.40	33-81 (50.65 ± 1.27)	3	1	18	28	14	0.65:1
Epioblasma triquetra	7	3	0.05	40-59 (47.00 ± 2.38)	0	0	-	-	7	-
Fusconaia cor	19	5	0.13	50-96 (98.95 ± 2.55)	0	0	-	-	19	-
Fusconaia subrotunda	32	9	0.21	56-102 (75.41 ± 2.00)	0	0	-	-	32	-
Lampsilis fasciola	92	16	0.61	22-89 (56.52 ± 1.02)	2	2	32	52	8	0.61:1
Lampsilis ovata	95	12	0.63	18-121 (80.45 ± 2.23)	7	1	4	9	82	0.44:1
Lasmigona costata	29	8	0.19	50-103 (77.31 ± 2.33)	0	0	-	-	29	-
Lemiox rimosus	15	5	0.10	35-44 (39.90 ± 0.88)	6	4	1	3	11	0.33:1
Ligumia recta	21	8	0.14	89-135 (114.81 ± 2.79)	0	0	3	8	10	0.38:1
Medionidus conradicus	870	15	5.77	21-65 (43.61 ± 0.22)	22	6	269	526	75	0.5:1
Plethobasus cyphyus	102	13	0.68	58-103 (81.97 ± 0.92)	0	0	-	-	102	-
Pleuronaia barnesiana	6	3	0.04	45-79 (63.00 ± 5.47)	0	0	-	-	63	-
Pleuronaia dolabelloides	4	2	0.03	68-76 (71.50 ± 2.06)	0	0	-	-	4	-
Potamilus alatus	1	1	0.01	119	0	0	-	-	1	-
Ptychobranchus fasciolaris	269	17	1.78	33-131 (85.61 ± 0.80)	1	1	-	-	269	-
Ptychobranchus subtentum	35	5	0.23	39-104 (79.11 ± 1.78)	1	1	-	-	35	-
Quadrula c. strigillata	8	5	0.05	58-89 (72.50 ± 4.37)	0	0	-	-	8	-
Quadrula intermedia	68	12	0.45	39-68 (57.01 ± 0.83)	2	2	-	-	68	-
Quadrula pustulosa	5	2	0.03	52-61 (56.50 ± 4.50)	0	0	-	-	2	-
Quadrula sparsa	16	7	0.11	44-80 (62.29 ± 2.94)	1	1	-	-	16	-
Villosa iris	48	11	0.32	26-72 (48.65 ± 1.53)	8	4	4	5	39	0.80:1
Villosa vanuxemensis	17	8	0.11	34-65 (47.06 ± 2.24)	2	2	4	10	3	0.40:1
Total	**15,084**	**21**			**74**	**9**				

TABLE 5

Summary statistics of abundance, length, and recruitment for mussel species collected in the Powell River, during 0.25 m2 quadrat sampling. S = # of mussels found on substrate surface, B = # of mussels found buried in substrate, F = female, M = Male, U = Sex Undetermined.

Species	Total Number	No. Sites	% Relative Abundance	Length Range and Mean ± SE (mm)	No. Recent Recruits	No. Sites with Recruits	S	B	F	M	U	F:M Ratio
Actinonaias ligamentina	104	17	17.93	36-127 (91.48 ± 1.44)	0	0	70	34	-	-	104	-
Actinonaias pectorosa	242	17	41.72	38-124 (86.56 ± 1.01)	1	1	123	119	-	-	242	-
Amblema plicata	14	7	2.41	76-107 (93.71 ± 2.38)	0	0	12	2	-	-	14	-
Cyclonaias tuberculata	16	9	2.76	46-109 (84.25 ± 4.05)	0	0	12	4	-	-	16	-
Dromus dromas	3	3	0.52	47-72 (63.67 ± 8.33)	0	0	3	0	-	-	3	-
Elliptio crassidens	1	1	0.17	105	0	0	1	0	-	-	1	-
Elliptio dilatata	47	12	8.10	28-91 (64.62 ± 2.02)	1	1	26	21	-	-	47	-
Epioblasma brevidens	6	6	1.03	22-71 (48.33 ± 6.65)	1	1	4	2	1	3	2	0.33:1
Fusconaia subrotunda	5	4	0.86	44-77 (65.40 ± 6.58)	0	0	4	1	-	-	5	-
Lampsilis fasciola	16	9	2.76	21-73 (50.00 ± 3.95)	3	1	6	10	6	7	3	0.86:1
Lampsilis ovata	2	2	0.34	95-97 (96.00 ± 1.00)	0	0	0	2	0	0	2	-
Lasmigona costata	1	1	0.17	76	0	0	1	0	-	-	1	-
Lemiox rimosus	1	1	0.17	42	0	0	1	0	-	-	1	-
Medionidus conradicus	82	12	14.14	23-55 (40.72 ± 0.77)	8	4	28	54	20	33	29	0.61:1
Plethobasus cyphyus	2	2	0.34	79	0	0	1	1	-	-	2	-
Ptychobranchus fasciolaris	15	10	2.59	62-118 (87.33 ± 4.33)	0	0	7	8	-	-	15	-
Quadrula c. strigillata	1	1	0.17	70	0	0	1	0	-	-	8	-
Villosa iris	18	7	3.10	13-51 (35.56 ± 2.87)	7	4	3	15	0	0	18	-
Villosa vanuxemensis	4	3	0.69	41-47 (44.33 ± 1.47)	0	0	2	2	3	1	0	3:1
Total	**580**	**18**			**21**	**9**	**305**	**275**				

TABLE 6

Estimated densities (mussels/m2) of each species at each site during 0.25 m2 quadrat sampling in the Powell River. Total density estimates and standard errors (SE), density estimate precision, and total species collected are also provided for each site. * = site where propagated juveniles have been released.

	Powell River Sites (PRKM and Site Number)									
	269.4	266.3	263.0	236.3	230.9	206.6	198.8	197.9	*193.4	*188.8
Species	1	2	3	4	5	6	7	8	9	10
Actinonaias ligamentina	-	-	-	0.04	-	0.12	0.12	0.27	0.06	0.31
Actinonaias pectorosa	-	-	-	0.04	0.16	0.20	-	1.14	0.94	0.50
Amblema plicata	-	-	-	-	-	0.04	-	-	-	-
Cyclonaias tuberculata	-	-	-	-	-	-	-	0.04	-	0.03
Dromus dromas	-	-	-	-	-	-	-	-	0.02	-
Elliptio crassidens	-	-	-	-	-	-	-	-	-	-
Elliptio dilatata	-	-	-	0.04	-	0.08	-	0.40	0.19	0.13
Epioblasma brevidens	-	-	-	-	-	-	-	-	-	0.03
Fusconaia subrotunda	-	-	-	-	-	-	-	0.08	0.02	-
Lampsilis fasciola	-	-	-	-	-	-	0.08	-	-	0.08
Lampsilis ovata	-	-	-	-	-	-	-	-	0.02	-
Lasmigona costata	-	-	-	-	-	0.04	-	-	-	-
Lemiox rimosus	-	-	-	-	-	-	-	-	0.02	-
Pleuronaia dolabelloides	-	-	-	-	-	-	-	-	0.17	-
Medionidus conradicus	-	-	-	-	-	-	-	-	-	0.16
Plethobasus cyphyus	-	-	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	-	-	-	0.08	-	-	-	0.04	-	0.03
Quadrula c. strigillata	-	-	-	-	-	-	-	-	-	-
Villosa iris	-	-	-	-	-	-	-	-	0.08	0.08
Villosa vanuxemensis	-	-	-	-	-	-	-	-	-	-
Total Density Estimate:	**0.00**	**0.00**	**0.00**	**0.20**	**0.16**	**0.48**	**0.20**	**1.97**	**1.52**	**1.35**
Total Density Estimate SE:	**0.00**	**0.00**	**0.00**	**0.10**	**0.08**	**.017**	**0.10**	**0.42**	**0.21**	**0.20**
Precision:	**-**	**-**	**-**	**0.31**	**0.33**	**0.24**	**0.31**	**0.16**	**0.12**	**0.15**
Total Species:	**0**	**0**	**0**	**4**	**1**	**5**	**2**	**6**	**9**	**9**

	Powell River Site (PRKM and Site Number)										
	180.7	179.9	171.4	159.6	153.4	153.0	152.6	136.2	135.8	129.4	104.8
Species	11	12	13	14	15	16	17	18	19	20	21
Actinonaias ligamentina	0.16	0.12	0.14	0.19	0.16	0.24	0.48	0.27	0.05	0.11	0.05
Actinonaias pectorosa	0.03	0.37	0.20	0.27	0.40	0.05	0.53	0.37	0.11	1.12	0.24
Amblema plicata	0.03	-	-	-	0.03	0.13	0.11	-	0.03	-	0.03
Cyclonaias tuberculata	-	0.07	-	-	-	0.11	0.05	0.05	0.03	0.05	0.03
Dromus dromas	-	0.03	-	-	-	-	0.03	-	-	-	-
Elliptio crassidens	-	-	-	-	-	-	-	-	0.03	-	-
Elliptio dilatata	0.03	0.12	0.08	0.03	-	-	-	0.11	0.05	0.11	-
Epioblasma brevidens	-	-	-	0.03	-	-	0.03	0.03	-	0.03	0.03
Fusconaia subrotunda	0.03	-	-	-	0.03	-	-	-	-	-	-
Lampsilis fasciola	0.03	0.03	-	-	0.03	-	0.03	-	0.05	0.08	0.05
Lampsilis ovata	-	-	-	0.03	-	-	-	-	-	-	-
Lasmigona costata	-	-	-	-	-	-	-	-	-	-	-
Lemiox rimosus	-	-	-	-	-	-	-	-	-	-	-
Pleuronaia dolabelloides	-	-	-	-	-	-	-	-	-	-	-
Medionidus conradicus	-	0.12	0.14	0.05	0.05	0.03	0.05	0.45	0.08	0.67	0.13
Plethobasus cyphyus	0.03	-	-	-	-	0.03	-	-	-	-	-
Ptychobranchus fasciolaris	0.03	-	-	-	0.05	0.03	0.03	-	0.05	0.08	0.03
Quadrula c. strigillata	0.03	-	-	-	-	-	-	-	-	-	-
Villosa iris	0.08	0.06	0.02	-	-	0.05	-	0.08	-	-	-
Villosa vanuxemensis	0.03	-	-	-	-	0.03	-	-	-	-	0.03
Total Density Estimate:	**0.51**	**0.92**	**0.58**	**0.60**	**0.75**	**0.70**	**1.34**	**1.36**	**0.48**	**2.25**	**0.62**
Total Density Estimate SE:	**0.13**	**0.18**	**0.11**	**0.12**	**0.17**	**0.15**	**0.18**	**0.59**	**0.13**	**0.35**	**0.15**
Precision:	**0.19**	**0.18**	**0.16**	**0.18**	**0.17**	**0.18**	**0.15**	**0.15**	**0.20**	**0.13**	**0.18**
Total Species:	**11**	**8**	**5**	**6**	**7**	**9**	**9**	**7**	**9**	**8**	**9**

WALKERANA The Journal of the Freshwater Mollusk Conservation Society

OUR PURPOSE

The Freshwater Mollusk Conservation Society (FMCS) is dedicated to the conservation of and advocacy of freshwater mollusks, North America's most imperiled animals. Membership in the society is open to anyone interested in freshwater mollusks who supports the stated purposes of the Society which are as follows:

1) Advocate conservation of freshwater molluscan resources;

2) Serve as a conduit for information about freshwater mollusks;

3) Promote science-based management of freshwater mollusks;

4) Promote and facilitate education and awareness about freshwater mollusks and their function in freshwater ecosystems;

5) Assist with the facilitation of the National Strategy for the Conservation of Native Freshwater Mussels (Journal of Shellfish Research, 1999, Volume 17, Number 5), and a similar strategy under development for freshwater gastropods.

OUR HISTORY

The FMCS traces it's origins to 1992 when a symposium sponsored by the Upper Mississippi River Conservation Committee, USFWS, Mussel Mitigation Trust, and Tennessee Shell Company brought concerned people to St. Louis, Missouri to discuss the status, conservation, and management of freshwater mussels. This meeting resulted in the formation of a working group to develop the National Strategy for the Conservation of Native Freshwater Mussels and set the ground work for another freshwater mussel symposium. In 1995, the next symposium was also held in St. Louis, and both the 1992 and 1995 symposia had published proceedings. Then in March 1996, the Mississippi Interstate Cooperative Research Association (MICRA) formed a mussel committee. It was this committee (National Native Mussel Conservation Committee) whose function it was to implement the National Strategy for the Conservation of Native Freshwater Mussels by organizing a group of state, federal, and academic biologists, along with individuals from the commercial mussel industry. In March 1998, the NNMCC and attendees of the Conservation, Captive Care and Propagation of Freshwater Mussels Symposium held in Columbus, OH, voted to form the Freshwater Mollusk Conservation Society. In November 1998, the executive board drafted a society constitution and voted to incorporate the FMCS as a not-for-profit society. In March 1999, the FMCS held it's first symposium "Musseling in on Biodiversity" in Chattanooga, Tennessee. The symposium attracted 280 attendees; proceedings from that meeting are available for purchase. The second symposium was held in March 2001 in Pittsburgh, Pennsylvania, the third in March 2003 in Raleigh, North Carolina, the fourth in St. Paul, Minnesota in May 2005, the fifth in Little Rock, Arkansas in March 2007, and the sixth in Baltimore, Maryland in April 2009. The society also holds workshops on alternating years, and produces a newsletter three times a year.

FMCS SOCIETY COMMITTEES

Participation in any of the standing committees is open to any FMCS member. Committees include:

- Awards
- Environmental Quality and Affairs
- Gastropod Distribution and Status
- Genetics
- Guidelines and Techniques
- Information Exchange - Walkerana and Ellipsaria
- Mussel Distribution and Status
- Outreach
- Propagation and Restoration

TO JOIN FMCS OR SUBMIT A PAPER

Please visit our website for more information at http://www.molluskconservation.org

Or contact any of our board members or editors of WALKERANA to talk to someone of your needs. You'll find contact information on the back cover of this publication.

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FMCS 2011-2013 Officers