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A Survey of Mussel Faunas in the Cannon River and Superior National Forest

from

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Abstract

We studied the distribution and abundance of mussels in the Cannon River (4 sites) and its tributaries (5 sites) and in 10 lakes in the Range River watershed in Superior National Forest. In the Cannon River we found 12 species (12 and 7 at trunk and tributary stations, respectively). The most commonly encountered species was Lasmigona complanata (11 stations) followed by *Pyganodon grandis* (8), *Lampsilis siliquoidea* (7), and *Potamilus alatus* (7). We also collected *Anodontoides ferussacianus* (6), *Lasmigona compressa* (5), *Ligumia recta* (2), *Actinonaias carinata* (2), *Pleurobema sintoxia* (2), *Elliptio dilatata* (2), *Lampsilis cardium* (1), and *Strophitus undulatus* (1). Trunk stations had higher species richness (10 and 6 species) than tributary stations (6 or fewer species). Distribution and abundance were not clearly related to physical or chemical parameters in the Cannon River watershed. In lakes in the Range River watershed we found two species (*P. grandis*, 8 lakes; *Utterbackia imbecilis*, 2 lakes). Both species were found in three lakes. Abundance varied tremendously among lakes and appeared to be related to the availability of appropriate habitat and the effects of poisoning prior to trout stocking. The distribution of *Utterbackia* may be related to historical fish stocking.

Introduction

The Cannon River undoubtedly supported a diverse mussel fauna prior to the arrival of settlers in the 1850s. Its low gradient, extensive wetlands, and connection to the Mississippi River would have enabled the fish species required for larval dispersal to move throughout the entire drainage with little restriction and provided excellent mussel habitat. Graf (1997) lists 25 species known from the lower Mississippi River in Minnesota. Even though several of these are obligate deep water species, it seems likely that the historic distribution of mussels in the Cannon River drainage exceeded the 15 species collected by Davis (1988). Since European settlement the river has been extensively dammed with a concomitant loss of fish movements. Clearing of the "Big Woods" and extensive plowing of the native prairie exposed the Cannon to tremendous amounts of sediment. More recently the river has received domestic and industrial wastes. The Cannon River mussel fauna was abundant and diverse enough to support a commercial shell industry into the 1920s (Davis 1988). The mussel fauna in the Cannon drainage has decreased since European settlement due to human impacts.

In his extensive survey, Davis (1988) found 15 species living in the Cannon River drainage, but, based on the distribution of dead shells, their distributions had been extensively reduced. A subsequent survey (Wagenbach et al. 1997) of two of Davis' sampling sites below the Northfield dam (Cannon 1C, 1D) found only five of the 11 species recorded by Davis (1988). Since Davis' (1988) survey there has been no systematic survey of mussel distribution in the Cannon drainage. Mussel relocation associated with replacement of the sewer main through Carleton College's Arboretum in 1996 provided only a snapshot of mussel distribution at one of Davis' sampling sites. Ten years have passed since Davis' (1988) extensive survey of the mussels in the Cannon River system. Based on the apparent changes at the Northfield dam sites during those 10 years (Wagenbach et al. 1997), it is important to document possible changes at other sites of high mussel diversity identified by Davis (1988) so that management decisions in the Cannon River basin can be based on the most up-to-date information. High diversity sites identified by Davis (1988) are important because they contained living individuals of species listed as Minnesota Threatened (*Actinonaias ligamentina*, mucket; *Venustaconcha ellipsiformis*, ellipse) and Special Concern (*Elliptio dilatata*, spike; *Lasmigona compressa*, creek heelsplitter; *Lasmigona costata*, fluted-shell; *Ligumia recta*, black sandshell) (MNDNR 1996).

The mussel distribution is much less well known in the lake of the Woods drainage than it is in the Mississippi River drainage. Graf (1997) lists six species in the Lake of the Woods drainage based on specimens with two more reported only from the literature. Of the six species listed by Graf (1997), four were collected in the Sturgeon River or Sturgeon Lake and only one species, *Lasmigona compressa*, was collected in Fall Lake, a site near the lakes we sampled, but in a different drainage. All the distribution records in the Lake of the Woods system listed by Graf (1997) were based on collections by Dawley (1944, 1947). Our study of the lakes in the headwaters of the Range River has expanded our knowledge of the mussel fauna in this region. The lakes we will sample are found on two branches of the headwaters of the Range River.

The Low, Bass, Dry, Little Dry, and High Lakes system has an interesting history that may have affected mussel distributions. The drainage pattern for these lakes is from High Lake into Dry Lake/Little Dry Lake, down a 10 m waterfall into Bass Lake, and then through Low Lake into the Range River. Little Dry Lake is a bay of Dry Lake. Prior to 1925, Bass Lake and Dry Lake were a single lake. They were separated when the terminal moraine separating Bass Lake from Low Lake washed out. Bass lake dropped 55 feet in elevation in 10 hours, leaving Dry Lake and Little Dry Lake stranded above it. High Lake and Dry/Little Dry Lakes were poisoned in the 1960s in preparation for the stocking of trout.

Methods

Cannon River

Mussel Sampling Protocols -- Streams

We proposed to use the same quadrat sampling protocol that Wagenbach et al. (1997) used; they randomly identified sampling locations within two sites sampled by Davis (1988) (Cannon 1C and 1D) and collected every mussel found there within four contigous 1 m^2 quadrats oriented parallel to the flow. As soon as we began to sample, it became apparent that the quadrat sampling method used by Wagenbach et al. (1997) was inadequate. Despite the obvious presence of mussels, they were seldom collected in the quadrats. All our sampling was done by hand, either kneeling or floating; mussels were identified by feel or by sight from above the surface if it was very shallow or using a face mask.

To solve the problem of sampling mussels we tried several sampling techniques. Timed searches of 5 or 10 minutes duration by several investigators moving upstream in parallel were not very satisfactory because the time required to identify and measure mussels found at a site interfered with the pace of sampling so that each search covered a different area. The technique of using several investigators moving in parallel and each sampling an area one meter wide was effective at collecting essentially all the mussels in an area as wide as the number of investigators. We standardized that sampling method by sampling the entire width of the stream. To test this sampling method, we compared it to quadrat sampling in an area of Chub Creek in which the mussel population was well characterized. The two sampling methods were tried in Chub Creek so that they could be compared with respect to their ability to collect rare taxa and their ability to provide variance estimates of population size.

We sampled Chub Creek upstream of the Dakota County Highway 23 bridge three ways: a) we sampled the first 150 m from bank to bank; b) we randomly identified 50 sample locations (linear distance and right, middle or left) within the first 300 m upstream of the bridge and sampled them using a single 1 m^2 quadrat; c) we randomly identified 15 sampling locations (linear distance) and sampled a 10 m (downstream-upstream) segment of the stream from bank to bank at each location. Using each of

these sampling protocols we collected every mussel we could find and identified and measured them (length, width, height). Based on our results, we used randomly located, bank-to-bank, 10 m stream segment samples except where mussel density was very high. In that case we sampled using 1 m^2 quadrats or 10 m stream segments that sampled only part of the total stream width.

Sampling Stations

We intended to sample five main stem sites and five tributary sites that were identified by Davis (1988) as sites with a high diversity of living mussels (Fig. 1). The main stem, or trunk, sites, named with their MNDNR stream survey station names and the numbering system used by Davis (1988) are described below.

Main Stem (Trunk) Stations:

Cannon 1C (Davis 5). This site extends approximately 1700 feet downstream from the mouth of Spring Creek on the campus of Carleton College (44° 27' 57.98" N, 93° 09' 16.07" W).
Cannon 1D (Davis 6). This site is located between the Northfield dam and the second bridge downstream in Northfield (MN Hwy 19) (44° 27' 24.32" N, 93° 09' 39.18" W). The river at these sites ranges from about 10 - 30 m in width depending on water level and is deeply incised and subject to a wide range of flows. The substrate ranges from silty sand to coarse cobble. The gravel and cobble substrates are firmly embedded in the substrate. Wagenbach et al. (1997) combined these two sites, and the intervening 930 m or so, into a single sampling area within which they identified 20 sampling locations. Of those, they sampled 18. Our intention was to sample the two quadrat sampling locations that were not sampled by Wagenbach et al. (1997), but we were prevented from sampling them because of high water. These two sampling locations require SCUBA even at low water because of the local hydrology of the river. We did sample at four of the sites sampled by Wagenbach et al. (1997) in order to compare our 10 m stream segment sampling results with their quadrat sampling results. We sampled at approximately their 312 m, 423 m, 682 m, and 898 m sampling locations as measured from the Northfield dam.

Owatonna Dam Tailwater (Davis 18). This site is the tailwater of the Owatonna Dam in downtown Owatonna (44° 05' 0.7" N, 93° 13' 54.04" W). We were not able to sample this site because of high water throughout most of the summer.

Straight River 5 (Davis 19). This site is at a campground (no longer KOA, as in Davis, 1998) located at the intersection of Steele County Route 18 and the Straight River, just west of Interstate 35 (44° 03' 5.91" N, 93° 15' 7.62" W). The river at this site is about 10 - 15 m wide and incised as much as 4 m at some points. The substrate ranged from silt to coarse gravel or cobble depending on current velocity. It is surrounded by grazing land and the campground (grassy). We randomly identified 15 sampling locations within a 400 m length of stream centered on the Rte. 18 bridge (200 m downstream and 200 m

upstream) and sampled them using bank-to-bank 10 m stream segment samples. There was no overlap of the sample locations.

Straight River 6A (Davis 20).This station is located at the junction of County Route 31 and the Straight River south of Owatonna and west of Interstate 35 (44° 00' 23.7" N, 93° 17' 26.4" W). The river at this station is contained within vertical banks ranging from 2-6 m in height. The substrate ranged from silt to cobble depending on current velocity. The cobble sized rocks were deeply embedded in the substrate. We randomly identified 9 sampling locations within a 400 m length of stream measured downstream from the Rte. 31 bridge. These sampling locations were sampled using bank-to-bank 10 m stream segment samples. There was no overlap of the sample locations.

Tributary Stations

Chub Creek 2 (Davis T-15). This station extends approximately 400 m upstream from the intersection of MN Route 3 and Chub Creek (44° 30' 42.19" N, 93° 08' 44.18" W). At this site Chub Creek is surrounded by farmland. The station reach is characterized by low gradient, sharp meanders, and large amounts of coarse woody debris formed from living and dead trees that have fallen into the creek. The substrate included silt, sand, gravel, and cobble. We randomly identified 15 sampling locations within the 400 m station. These sampling locations were sampled using bank-to-bank 10 m stream segment samples. There was no overlap of the sample locations.

Chub Creek 3 (Davis T-16). This station extends approximately 400 m upstream from the intersection of Dakota County Route 3 and Chub Creek (44° 31' 19.4" N, 93° 12' 4.5" W). This station has a low gradient and is surrounded by corn fields planted to the edge of the stream. The creek is deeply incised and ranges from about 3 m to 6 m in width. The substrate includes organic and inorganic silts, sand, gravel, cobble, clay, and occasional large boulders. We sampled this site three ways: the downstream 150 m was sampled completely; 50 randomly located 1 m2 quadrats were sampled in the first 300 m and 15 randomly located 10 m segments were sampled in the first 400 m. There was no overlap of the sample locations.

Heath Creek 2 (Davis T-19). This station extends upstream from the intersection of Rice County Road 59 and Baldwin Avenue. Heath Creek is surrounded by pasture and corn/soybean fields. The station (upstream) now passes through a pasture housing bison. We sampled within the first 400 m downstream of the intersection where the creek passes through a horse pasture (44° 27' 26.63" N, 93° 15' 3.7" W). The creek is about 2-3 m wide and incised as much as 2 m. The substrate was predominately mud and gravel. We randomly identified 14 sampling locations within the 400 m station. These sampling locations were sampled using bank-to-bank 10 m stream segment samples. There was no overlap of the sample locations.

Wolf Creek (Davis T-20). This station extends 400 m upstream from the intersection of Rice County Route 8 and Wolf Creek (44° 24' 38.07" N, 93° 13' 16.56" W). The creek at this site has a higher gradient than any other tributary site. The creek is incised about

1-2 m throughout the station. The substrate is almost entirely hard, embedded gravel, cobble and boulders; the bottom is very rough. The only silt is located at the lower end of the station. We randomly identified 15 sampling locations within the 400 m station. These sampling locations were sampled using bank-to-bank 10 m stream segment samples. There was no overlap of the sample locations.

Cannon 5 - Waterville (Davis T-21). This station is located approximately 2.3 miles below the Morristown Dam and is approximately 305 m long (44° 14' 15.3" N, 93° 25' 45.36" W). The exact location of the stream reach sampled by Davis (1988) is unclear; we sampled downstream from the western boundary of the Cannon River State Wildlife Management Area (WMA) (at a high, steep bank on the north side of the river). We randomly identified 15 sampling locations within the first 400 m downstream from the WMA boundary. We also qualitatively assessed mussel distribution and abundance along this section of the river downstream to the eastern end of the WMA at approximately river mile 67. The river is bordered by extensive wetlands, hardwoods, and agricultural land. It is incised up to a few meters and is approximately 15 m wide. The substrate ranges from silt and silty sand in depositional areas to gravel and cobble. We randomly identified and were able to sample only 9 sampling locations within the 400 m station because the water depth was seldom lower than 0.6 m and there were large numbers of mussels. These sampling locations were sampled using 5 m wide (4 or 5 people) by 10 m long (upstream-downstream) segment samples. There was no overlap of the sample locations.

Superior National Forest

Mussel Sampling Protocols -- Lakes

We used three sampling protocols in the lakes in the Range River Drainage.
1. Canoe surveys were used to search for mussels where the water was too shallow for a swimming search and the substrate was too soft to support an observer in the water. Canoe surveys consisted of slow paddling and observation of the substrate; they lasted up to several hours in extensive lily-pad beds.
2. Swimming searches were carried out by teams of up to four observers. Searches were done for 10 minutes and consisted of the observation team arranged at right angles to the shore and swimming together parallel to the shore. Observations were made from the surface when the water was shallow enough or by surface diving to near the bottom. Because of the clarity of the lakes and our use of underwater swimming, swimming searches were effective to a depth of about 5-6 m. Unless mussel density was quite high, 10 minute swimming searches covered about 200 m (mean = 197, n = 36). All mussels seen were collected into mesh bags, identified, measured, and returned to the substrate. In lakes where there were large numbers of mussels, once a large sample of mussels was measured, mussels seen in subsequent searches were just identified and counted.
3. When mussel density was high, we used a 1 m^2 quadrat to sample mussels. Quadrats were placed at randomly identified sampling locations along the shoreline and

at a depth of about 1 m. All mussels within the quadrat were collected, identified, measured, and returned to the substrate.

Sampling Sites

The sampling sites we studied in the Superior National Forest were chosen because they included the headwaters of the Range River, a tributary in the Lake of the Woods watershed known to contain mussels that had not been systematically surveyed (Fig. 2). The U. S. Forest Service was interested in mussel populations in the Superior National Forest because of increasing tourism and dam management.

Low Lake Drainage

Hobo Lake. Hobo Lake (USGS 7.5' quad -- Ely; 47° 57' 46" N, 91° 49' 38" W; elevation 430 m; max. depth 4.6 m) lies in a narrow valley on the eastern side of Low Lake. It is steep walled and has little littoral area. It drains northward through a small creek that traverses a boulder filled, steep moraine and a flat wetland meadow before it enters Low Lake on its east side. During the summer the creek exits Hobo lake largely by seepage.

High Lake. High Lake (USGS 7.5' quad -- Ely, Shagawa Lake; 47° 58' 03" N, 91° 52' 22" W; elevation 437 m; area 112.1 ha; littoral area 40.1 ha; max. depth 15.2 m, 20.1 m, 6.1 m in east, middle, and west basins) is the uppermost lake in the chain of lakes that drains into Low Lake from the southwest. It is drained by a small creek on the south side that drains into Dry Lake. High Lake was poisoned in 1966 with Toxaphene prior to stocking rainbow and brown trout. It is managed as a trout fishery by MNDNR.

Little Dry Lake. Little Dry Lake (USGS 7.5' quad -- Ely, Shagawa Lake; 47° 57' 19" N, 91° 52' 31" W; elevation 419 m; area 5.3 ha; littoral area 3.84 ha; max. depth 8.2 m) is a bay off the southwest side of Dry Lake. It is connected by a narrow (3 m wide) channel.

Dry Lake. Dry Lake (USGS 7.5' quad -- Ely, Shagawa Lake; 47° 57' 33" N, 91° 52' 19" W; elevation 419 m; area 33.2 ha; littoral area 7.0 ha; max. depth 13.4 m) is located between High lake and Bass Lake. Prior to 1926, Dry Lake was a shallow bay of Bass Lake. It was separated from the existing Bass Lake when the terminal moraine of Bass Lake washed out and the lake level dropped 55 feet. Dry Lake drains into Bass Lake through a short, steep creek that includes a waterfall/cascade that is about 8 m high. Dry Lake has relatively steep sides, but there is a lot of littoral area. The substrate ranges from rocky to sandy mud.

Bass Lake. Bass Lake (USGS 7.5' quad -- Ely; 47° 57' 39" N, 91° 51' 15" W; elevation 414 m; area 70.42 ha; littoral area 28.7 ha; max. depth 11.0 m) is located southwest of Low Lake and is separated from Low Lake by a short, low gradient stream. Bass Lake has very steep sides and very little littoral zone. Where the water is shallow there are extensive beds of aquatic macrophytes and filamentous algae. The substrate is mostly rocky except in the few shallow areas where there is silty sand and mud.

Low Lake. Low Lake (USGS 7.5' quad -- Ely; 47° 58' 27" N, 91° 49' 19" W; elevation 412 m; area 139.6 ha; littoral area 85.4 ha; max. depth 12.2 m) is the bottom lake in the headwaters of the Range River. It has steep walls along most of its shoreline, but there are extensive areas of macrophytes (*Nuphar*, *Nymphaea*) and wetlands at the northern end of the lake where the Range River exits. The substrate in the littoral areas and north arm is mostly hard packed mud and silty sand. In the macrophyte beds the substrate is flocculent layers of dead organic material.

Grassy Lake Drainage

Sletten Lake. Sletten Lake (USGS 7.5' quad -- Shagawa Lake; 47° 59' 30" N, 91° 53' 00" W; elevation 452 m; area 9.7 ha; littoral area 6.5 ha; max. depth 14.0 m) is the highest lake in the Grassy Lake side of the Range River headwaters. It drains into Tee Lake. Grassy Lake has steep sides and a wetland area where the creek exits to Tee Lake. Littoral areas are limited to the east and west ends of the lake and represent only about 20 percent of the lake surface area.

Tee Lake. Tee Lake (USGS 7.5' quad -- Angleworm Lake, Shagawa Lake; 48° 00' 00" N, 91° 52' 40" W; elevation 438 m; area 14.6 ha; max. depth 7.6 m) sits between Grassy Lake and Slettin Lake. It has steep sides and a small littoral area. It is stained with humic material.

Grassy Lake. Grassy Lake (USGS 7.5' quad -- Ely, Fourtown Lake-MN; 48° 00' 00" N, 91° 51' 46" W; elevation 416 m; area 86.2 ha; max. depth 4.6 m, east bay 1.5 m) is the lowest lake in the western branch of the headwaters of the Range River. It is separated from the Range River proper by a small creek that drains into a very extensive wetland in which the Range River begins. Grassy Lake has two main basins. The eastern basin is completely clogged with macrophytes (*Nuphar*, *Nymphaea*). The western basin has steep sides toward the southwest and Tee Lake. There are littoral areas in several places around this basin.

Burntside Lake Drainage

Little Sletten Lake. Little Sletten Lake (USGS 7.5' quad -- Shagawa Lake; 47° 59' 15" N, 91° 53' 09" W; elevation 443 m; area 6.9 ha; littoral area 2.83 ha; max. depth 9.8 m) is separated from Slettin Lake to the north by a ridge. It drains westward into Fenske Lake, and, ultimately, into Burntside Lake near Ely.

Fenske Lake. Fenske Lake (USGS 7.5' quad -- Shagawa Lake; 47° 59' 41" N. 91° 54' 27" W; elevation 41 m; area 42.5 ha; littoral area 25.5 ha; max. depth 13.1 m, south arm 3.1 m) is the second in a chain of four lakes that drain westward into a northern arm of Burntside Lake. Fenske Lake is a narrow lake with a cliff-like eastern side and a ridge on the west. At the southern end of the lake there is a long narrow bay that contains almost all the littoral area in the lake. The substrate there is silty sand and mud.

Physical/Chemical Measurements

Chlorophyll *a*. We used the trichromatic method for analysis of chlorophyll *a* (Wetzel and Likens (1991). Water samples were filtered through glass fiber filters (Gelman A/E) and the filters were extracted in 90% alkaline acetone for 24 hours at 4C. Prior to spectrophotometric analysis the acetone extract was filtered through a glass fiber filter (Gelman A/E) to remove debris. Absorbance was measured at 750, 665, 664, 663, 647, 630, and 480 nm. Chlorophyll *a* concentration was calculated using the equations in Wetzel and Likens (1991) and reported as μg/L chlorophyll *a*. The volume sampled varied depending on the amount of algae in the water and ranged from 0.5 L to 3.0 L.

Alkalinity. Alkalinity was calculated using the Gran titration method (Wetzel and Likens 1991) because it eliminates the necessity of estimating colorometric endpoints and inflection points on titration curves. In this procedure standard acid is used to titrate the sample to below the equivalence point where the addition of acid becomes linear with pH change. The linear portion of the relationship between pH and volume of acid added is used to estimate the equivalence point and the alkalinity (reported as μeq/L) is computed as the volume of acid added to reach the equivalence point normalized to sample volume.

Total Nonfiltrable Residue. We measured nonfiltrable residue by filtering (Gelman A/E) water samples and weighing the residue trapped by the filter after drying at 105 C for 24 h. We followed Standard Method 209 D (APHA 1981). Total nonfiltrable residue was partitioned into its inorganic and organic component by combusting the filters at 500 C for 24 h followed by re-weighing.

Temperature / Secchi Depth / Depth. Temperature was measured using field thermometers or a temperature / dissolved oxygen meter (VWR Scientific Model 4000 or Yellow Springs Instruments, Model 51B). Secchi depth was measured using a 20 cm diameter white Secchi disk. Depth was measured using a meter stick in streams and a sounding line in lakes.

Dissolved Oxygen. Dissolved oxygen concentration was measured using an oxygen meter (Yellow Springs Instruments, Model 51B). The dissolved oxygen meter calibration was periodically checked against the Winkler titration method (Wetzel and Likens 1991).

Sediment Characteristics. The substrate at each sampling site was characterized in the field by its size (silt, gravel, cobble, etc.) and composition (inorganic, organic).

Results

Cannon River

Chub Creek 2 (Davis T-15). We collected six mussel species at this station (Table 1). *Pyganodon grandis* was the most abundant followed by *Lasmigona complanata* and

Potamilus alatus. *Anodontoides ferussacianus*, *Lasmigona compressa*, and *Lampsilis siliquoidea* were present, but rare. Mussel density was low at this site (Table 2). The length distributions of the three abundant taxa we collected at this site were very similar to their length distributions at the Chub Creek 3 site, upstream. *P. alatus* was the largest species collected (Fig. 3). The dissolved oxygen (6.8 mg/L), temperature (19.1 C), Secchi depth (67 cm), water-column chlorophyll concentration (3.07 mg/L) and alkalinity (6,551 μeq/L) values were characteristic of the low-flow, summer conditions under which we sampled (Table 3). The high alkalinity value here and throughout the Cannon River watershed is indicative of the well buffered soils through which the river flows. The stream bottom at this station was primarily composed of fine silt, sand, and gravel with occasional larger rocks depending on the velocity at a particular point. There were many fallen trees in and across the stream at this station. We collected two species (*A. ferussacianus, L. siliquoidea*) that were not collected as live individuals by Davis in his 1987 survey (Davis 1988).

Chub Creek 3 (Davis T-16). We sampled this station using three different methods and collected seven mussel species (Table 1). *Pyganodon grandis* and *Anodontoides ferussacianus* were the most abundant. *Lasmigona complanata* and *Potamilus alatus* were the next most abundant and *Lasmigona compressa*, *Lampsilis siliquoidea*, and *Ligumia recta* were rare. A continuous 150 m stream segment and 10 m stream segments yielded six species while quadrat samples collected only three species; quadrat samples missed rare taxa. Quadrats collected many fewer mussels than the 10 m segment samples or the 150 m sample. However, mussel density based on quadrat samples was greater than density based on 10 m segments (Table 2). Mussel density at this site was greater than further downstream at Chub Creek 2. The mussels collected at this site showed the inter-species size differences expected from their scientific descriptions (Figs. 4, 5). *Pyganodon grandis* and *P. alatus* were the largest species and *A. ferussacianus* was the smallest. Only *L. complanata*, *P. grandis* and *A. ferussacianus* were collected in a wide range of sizes. The 150 m continuous stream segment and the 10 m stream segment sampling methods sampled essentially the same population of mussels; there was little difference in the length distribution of *P. grandis* collected by these two methods (Fig. 6). Water chemistry data were not collected at this site, but temperature and Secchi depth (greater than water depth) were characteristic of summer, low flow conditions. Substrate included fine organic debris, silt, sand, gravel, cobbles, and veins of clay. Occasional small boulders were scattered throughout the station. Mussels were found in all these substrate types. We collected two species (*L. recta*, *L. siliquoidea*) that were not collected by Davis (1988); we found only a single *L. recta*.

Heath Creek 2 (Davis T-19). We collected only a few individuals of three species at this station in Heath Creek . Our sampling sites were downstream of those used by Davis (1988) because bison are now pastured in the field where the original Heath Creek 2 fisheries station was located. We collected only *Pyganodon grandis*, *Anodontoides ferussacianus*, and *Lasmigona complanata* (Table 1). Mussel density was the second lowest of any station we sampled (Table 2). The P. grandis and L. complanata we collected were large, but comparable in size to those collected in Chub Creek (Fig. 7).

The *A. ferussacianus* individuals we collected at this station were smaller than those in Chub Creek (Fig. 7). The water on the day we sampled was warm, clear and well oxygenated (Table 3). The substrate at this station was uniformly silty sand and sandy gravel. We collected live individuals of the same three species found by Davis (1988).

Wolf Creek (Davis T-20). Only one species of mussel (*Lasmigona complanata*) was collected in Wolf Creek (Tables 1), and the density of mussels there was the lowest at any station that we sampled (Table 2). The physical and chemical properties of Wolf Creek were characteristic of summer, low-flow conditions. Wolf Creek has a steeper gradient than any other tributary station. Partly as a result of that gradient, the substrate was uniformly hard and composed of embedded gravel with large numbers of boulders scattered throughout the stream reach included in our sampling. Davis (1988) collected *Anodontoides ferussacianus* and *Venustaconcha ellipsiformis* (*Actinonaias ellipsiformis*) at this station as well as the *L. complanata* we collected.

Cannon 5 - Waterville (Davis T-21). We collected six mussel species at this site (Table 1). *Lampsilis siliquoidea* was the most abundant species followed by *Potamilus alatus*, *Pyganodon grandis*, *Elliptio dilatata*, and *Lasmigona complanata*. A single *Ligumia recta* was also collected. Mussel density at this station was the highest we measured in the Cannon River watershed (Table 2). At one of our 10 m stream segment samples the mussel density was 1.2/m^2. At this station *P. alatus* were the largest mussels (Figure 8). The presence of a single small individual suggests that the *P. alatus* population has reproduced successfully in the recent past. The length distribution of *L. siliquoidea* may also have a smaller cohort represented by a single mussel (Fig. 8). There was little difference in the length frequencies of male and female *L. siliquoidea* (Fig. 9); this is not surprising since the sexual dimorphism in this species is seen in a greater width in the female. The physical and chemical properties of the Cannon River at this station were characteristic of summer, low-flow conditions (Table 3). The chlorophyll *a* concentration we measured was the highest we measured in this study (25.2 □g/L) and was apparently due to washout of phytoplankton from the reservoir behind the Morristown dam just a mile or so upstream. The substrate at this station was mostly silty sand where we found mussels. There were occasional areas of gravel and cobble, but there were fewer mussels in those areas. We collected only *L. recta* that was not collected by Davis (1988).

Cannon 1C, 1D (Davis 5,6). Sampling at these stations was constrained by high water during most of the summer. We were able to conduct four 10 m searches at locations sampled by Wagenbach et al. (1997). Sampling these locations using the 10 m stream segment method enabled us to compare our results to theirs. We collected six species at this site (Table 1). *Potamilus alatus* was the most abundant species followed by *Lasmigona complanata*, *Lampsilis cardium*, and *Ligumia recta*. *Lampsilis siliquoidea* and *Elliptio dilatata* were the other species found at this site. Mussel density at these stations (0.24/m^2) was the third highest of the Cannon River tributary and trunk stations (Table 2). *Potamilus alatus* and *Ligumia recta* were the largest species at this site followed by *Lampsilis siliquoidea* (Fig. 10). The *L. complanata* we collected were smaller than most of those collected at other sites. The length distribution of *P. alatus*

was similar to that found at other sampling stations (Fig. 10). The chlorophyll *a* concentration was the second highest measured (18.93) (Table 3) and was undoubtedly due to the presence of algae from the reservoir upstream of the Northfield dam. The substrate varied from silty sand to embedded gravel and cobbles. Most of the mussels we collected were found in the rocky sections rather than the sandy sections. Davis (1988) collected 11 species of live mussels at these two stations while we collected only six. The species Davis (1988) collected that we did not include *Venustaconcha ellipsiformis*, *Actinonaias carinata*, *Lasmigona costata*, *Lasmigona compressa*, and *P. grandis*.

Owatonna Dam Tailwater (Davis 18). This station was not sampled because of high water and lack of time once the high water receded. We decided that it was more important to sample the Straight River stations upstream of Owatonna.

Straight River 5 (Davis 19). We collected seven species at this station. *Lampsilis siliquoidea*, *Elliptio dilatata*, *Lasmigona complanata*, and *Pyganodon grandis* were the most abundant species (Table 1). We also collected *Actinonaias carinata*, *Pleurobema sintoxia*, and *Lasmigona compressa*. Mean mussel density was low despite the presence of small patches of higher density within some 10 m segments (Table 2). The largest mussels at this station were *L. complanata* (Fig. 11). *Elliptio dilatata* overlapped the lower end of the distribution of *L. complanata* lengths. The *P. grandis* we collected at this site included one quite small individual. The physical and chemical properties of the Straight River at this station were typical summer values (Table 3); the water was warm, clear, and well oxygenated. The alkalinity was high, but similar to the values from other sampling stations in the Cannon River watershed. We measured no chlorophyll *a* (a negative value) at this station. This could have been the result of inaccurate readings or a turbidity blank with a high absorbance. This sampling station does not have a reservoir upstream that could have exported algae to the river. The substrate at this station ranged from silty sand to embedded gravel or cobbles. Davis (1988) collected three species that we did not find (*Strophitus undulatus*, *Ligumia recta*, and *Venustaconcha ellipsiformis*), but we collected two species (*P. sintoxia*, *A. carinata*) that he did not.

Straight River 6A (Davis 20). This sampling station was the most species rich of any we sampled. We collected nine species at this station (Table 1). The most abundant was *Lasmigona complanata* followed by *Pyganodon grandis*. Others included *Lampsilis siliquoidea*, *Elliptio dilatata*, *Pleurobema sintoxia*, *Strophitus undulatus, Actinonaias carinata*, *Lasmigona compressa*, and *Anodontoides ferussacianus*. Mussel density ($0.25/m^2$) at this site was among the highest we measured (Table 2). *Lasmigona complanata* were the largest mussels at this station (Fig. 12). The size distribution of *P. grandis* included some small individuals. The physical and chemical characteristics of the Straight River at this station were characteristic of summer, low-flow periods with clear water. The chlorophyll *a* concentration at this station was the second highest measured in this study. There is no reservoir upstream of this station, but the Straight River at this point receives runoff from a large area of farmland that might be providing a source of nutrients. The substrate in the Straight River at this sampling station was

predominantly silty sand, sandy gravel, or embedded cobbles. Most mussels were found in the rocky substrate; *Pleurobema* was only collected from sand. Davis (1988) collected three species at this station that we did not find (*Lasmigona costata*, *Ligumia recta*, *Venustaconcha ellipsiformis*), and we collected one species (*A. carinata*) that he did not find.

Superior National Forest

Low Lake Drainage

Hobo Lake. We collected two species of mussel in Hobo Lake. *Pyganodon grandis* and *Utterbackia imbecilis* were about equally common (Table 1). Mussel density was nearly 1/m^2 (Table 2). The length distribution of *P. grandis* in Hobo Lake suggests that there may be two age classes (Fig. 13). The physical and chemical properties of Hobo Lake were typical of lakes in northern Minnesota in mid-summer (Table 3). The alkalinity was among the highest in the headwater lakes of the Range River. The Secchi depth was one of the lowest we measured, suggesting more suspended material in the water column, however, the chlorophyll *a* concentration was among the lower values we measured. The substrate in the littoral zone included silty sand and sandy gravel where the gradient was low and cobbles and boulders where the sides of the lake were steeper. Mussels were often found in crevices among cobbles which made them difficult to sample.

High Lake. Only *Pyganodon grandis* was collected in High Lake. Extensive searching around the perimeter of the three basins of the lake resulted in finding only a very few mussels and most of them were in the western basin. The water quality parameters indicated that High Lake was among the least productive of the lakes we studied (Table 3). The Secchi depth was the deepest and the chlorophyll *a* concentration was the second lowest. The alkalinity value of High Lake was similar to several other lakes located on the western side of Low Lake and at the upper end of the drainage system. The littoral zone of high lake is characterized by extensive areas of silty sand with scattered rocky areas where the shoreline consisted of cliffs and steep rocky areas. There appeared to be little difference between the littoral substrate in High Lake and Dry Lake.

Dry Lake. Dry Lake contained a large population of *Pyganodon grandis* (Table 1). Length frequency data for the *P. grandis* population had a single peak (Fig. 14). Mussel density was high (3.7/m^2) (Table 2). The physical and chemical parameters were characteristic of lakes in the summer (Table 3). Alkalinity was higher than in High Lake from which Dry Lake receives runoff, but the alkalinity was lower than that of lakes lower in the drainage system. The substrate consisted of silty sand or cobbles and boulders. An unexplained crust was often present just beneath the surface of the sediment.

Little Dry Lake. Little Dry Lake contained a large population of *Pyganodon grandis* (Table 1). Mussel density (3.7/m^2) was high and the same as in Dry Lake (Table 2). The *P. grandis* population had almost the exact same length frequency distribution as

the population in Dry Lake. The physical and chemical parameters were characteristic of summer conditions (Table 3). Algal biomass was higher than in Dry Lake, and the Secchi depth was shallower than in Dry Lake. The lake bottom is largely silty sand and sandy gravel.

Bass Lake. We collected only *Pyganodon grandis* in Bass Lake (Table 1). The littoral zone in Bass Lake is not extensive; the south side of the lake consists of steep cliffs and the bottom is very rocky. We found so few mussels that it was impossible to estimate their density. The alkalinity of Bass Lake was higher than that of Dry Lake which drains into Bass Lake. That could indicate higher concentrations of nutrients and higher productivity, but algal biomass was low (Table 3).

Low Lake. We collected only *Pyganodon grandis* in Low Lake (Table 1). Mussel density was so low that we were unable to estimate it. The physical and chemical parameters were characteristic of lakes in summer (Table 3). The alkalinity in Low Lake was the highest in its drainage basin. The high alkalinity may have indicated higher nutrients; algal biomass was the highest of any lake we sampled. Low Lake has little shallow littoral area in the main lake basin. The northern arm of the lake is all less than four meters deep. The sediment is hard silty sand and mud. We found a few mussels in this arm. At the northern end of Low Lake there is an extensive bed of water lilies. The substrate there is soft dead organic matter. Despite the presence of mussels that sit on similar sediment in other lakes in northern Minnesota, we found none in that habitat in Low Lake.

Grassy Lake Drainage

Sletten Lake. We found no mussels in Sletten lake (Table 1). Extensive swimming searches were unsuccessful. The littoral area was relatively extensive and the substrate was largely silty sand. The physical and chemical parameters were characteristic of summer conditions (Table 3). The alkalinity was low, indicative of the geology to the west of Low Lake. Algal biomass was also very low.

Tee Lake. We found no mussels in Tee Lake (Table 1). This lake was highly colored by humic materials which was responsible, along with the high algal biomass, for the relatively shallow Secchi depth (Table 3). Temperature, dissolved oxygen, and alkalinity were characteristic of summer conditions. The substrate in Tee Lake was largely silty sand and sandy gravel.

Grassy Lake. We collected only *Pyganodon grandis* in Grassy Lake (Table 1). Only eight individuals were collected in our swimming surveys. The physical and chemical parameters were characteristic of lakes in summer. The Secchi depth (310 cm) was greater than in Tee Lake and algal biomass was lower. The substrate in Grassy Lake was mostly sandy gravel and cobbles.

Burntside Lake Drainage

Little Sletten Lake. No mussels were collected in Little Sletten lake (Table 1). The physical and chemical parameters were characteristic of northern lakes in mid-summer (Table 3). Alkalinity was low as was algal biomass, and the Secchi depth was quite deep. The substrate in Little Sletten Lake was silty sand and gravel.

Fenske Lake. We collected *Pyganodon grandis* and *Utterbackia imbecilis* in Fenske Lake (Table 1). We collected 21 mussels about evenly divided between the two species in our swimming searches. The *P. grandis* population had a greater size range than did the *U. imbecilis* population (Fig. 16). Surprisingly, the alkalinity in Fenske Lake (132.1 □eq/L) was lower than that of Little Sletten Lake which is included in the Fenske Lake drainage basin (Table 3). Fenske Lake was quite clear (Secchi depth, 420 cm; algal biomass 0.55 □g/L), but its physical and chemical parameters were otherwise similar to the other lakes we sampled.

Discussion

Cannon River Tributary Stations

Chub Creek. This creek was characterized by high mussel richness and abundance. Species richness was higher than any other tributary station that we sampled. The high richness in Chub Creek, especially at Station Chub Creek 3 (7 species) has been recognized since the work of Davis (1988). Davis collected six species (5 living, 1 dead) in Chub Creek. The additional species we collected in this study was represented by a single individual. There is no obvious reason for the high species richness in Chub Creek, but it is unregulated from Chub Lake to its confluence with the Cannon River just upstream of Lake Byllesby. The creek is narrower and more incised than the other tributary stations we sampled, and, based on debris deposits, it must be subject to periodic very high flows. We found debris deposited as high as 6-8 feet above the water surface. There is a high diversity of substrate types at Chub Creek 3, and we collected mussels in all of them. Chub Creek flows out of Chub Lake about 6.5 km upstream from Station Chub Creek 3. Chub Lake is eutrophic, and it is likely that the lake provides a source of phytoplankton that can be eaten by mussels. A source of abundant food may be the reason that Chub Creek supported the third highest density that we measured in this study. Davis did not sample upstream of Station Chub Creek 3; we predict that Chub Creek is large enough to support mussel populations between Chub Lake and Station Chub Creek 3. At Station Chub Creek 3 the creek is closely surrounded by agricultural fields (corn in 1998). We even found full grown corn stalks in the stream at Station Chub Creek 3 after a mid-summer thunderstorm. It was apparent that Chub Creek was actively eroding upstream.

We collected two species listed as of Special Concern in Minnesota (*Lasmigona compressa, Ligumia recta*). We collected only one *L. recta*, but several *L. compressa* at both stations. Based on its species richness and its mussel abundance, Chub Creek should be high on a list of watersheds in which agricultural and other land use practices are managed to minimize damage to mussel populations.

Heath Creek. Heath Creek supported low numbers of only three species. Davis (1988) collected the same three species in his survey. Heath Creek contained large amounts of phytoplankton, probably washed out of Union Lake, about 4 km upstream of Station Heath Creek 2. The original Station Heath Creek 2 includes pasture that now contains bison. The creek is less incised at the original station than where we sampled, but that is unlikely to have affected mussel distribution. There doesn't appear to be any water chemistry parameter that correlates with the low richness and abundance we measured at this site. There was visibly more algae in the water at this Heath Creek station than in any other tributary creek we studied. Heath Creek branches off the Cannon River above the existing Northfield dam, and perhaps the series of dams historically located at Northfield affected fish distribution in the past. Davis (1988) described abundant muskrat activity at this station; predation could be affecting mussel abundance. Interestingly, there was apparently much less algae visible in Heath Creek downstream of Station Heath Creek 2. It is not clear whether the apparent decrease in algae was the result of removal by filter-feeding mussels or of dilution.

Wolf Creek. Wolf Creek has a length of about 16 kilometers including three lakes. The nearest lake upstream of Station Wolf Creek was about 8 km away. Mussel richness and abundance was very low at this station. Davis (1988) found low numbers of three species in a walking search of 300 m of stream; the species we collected (*Lasmigona complanata*) was the most abundant species he collected. Wolf Creek at the upstream side of the Rice County Route 8 bridge has a higher gradient than any other tributary station we sampled. It would be interesting to know whether mussels inhabit Wolf Creek further upstream where the gradient is lower and whether they inhabit the stream reach between the bridge and the Cannon River (1 km) where the gradient is also very low.

Cannon River 5. The Cannon River downstream of the Morristown Dam is an exceptional mussel habitat. This was recognized by Davis (1988) when he collected five species there in beds with local densities as high as 122/m^2 and a mean density of 49.4/m^2. Davis estimated that the mussel bed where he found the high densities was 27 m x 14 m and contained 18,685 mussels. We were unable to locate the particular mussel bed described at this station by Davis (1988). We did collect six species (those collected by Davis plus *L. recta*), and this station had the highest mean mussel density (0.6/m^2) that we found in the Cannon River and its tributaries. One 10 m stream segment at this station had a density of 1.2 mussels/m^2. The food supply for mussels at this station is very high due to washout of phytoplankton from the reservoir behind the Morristown Dam. We sampled this station downstream for approximately 1200 m from the upstream boundary of the State Wildlife Management Area. Mussel abundance varied among sampling locations, but mussels were abundant throughout this section of the Cannon River. We predict that areas of equally high densities and species richness are located in the approximately 2-2.5 km between the Morristown Dam and the border of the wildlife management area. Based on the presence of species rich and abundant mussel populations below the dams at Northfield and Faribault, the area below the Morristown Dam is particularly interesting.

Cannon River Trunk Stations

Cannon River 1C, 1D. These stations, below the Northfield Dam, were difficult to sample because of high water throughout most of the summer. Consequently our sampling was restricted to a few locations chosen primarily to facilitate comparisons between the randomly located, linear, four square meter sampling units used by Wagenbach et al. (1997) and our bank-to-bank, 10 m stream-segment sampling units. We collected fewer species (6) than Davis (1988) (11). Some of this discrepancy between the two studies is certainly a function of the small number of locations we sampled. Of the five species collected by Davis (1988) but not collected in this study (*P. grandis*, *L. compressa*, L. *costata*, *A. carinata*, and *V. ellipsiformis*) *P. grandis* has been collected by one author (G.E.W.) in other studies of these stations. The mean mussel density we measured at these stations was the second highest ($0.6/m^2$) in the Cannon River and its tributaries. Even within a 10 m segment mussel distribution was not random, and local mussel densities were often higher than the mean density. This station, too, was enriched by algal washout from the reservoir above the dam.

Straight River. The Straight River was not sampled at the Owatonna Dam Tailwater Station because of high water and lack of time during periods of low flow in late summer.

Upstream of the Owatonna Dam the Straight River is one of the two most species rich areas in the Cannon River watershed. Davis (1988) found eight and 11 species at the stations he sampled and we found seven and nine at those same stations. Between both studies, 12 species of living mussels were collected in this section of the Straight River. This is a truly exceptional mussel habitat in terms of species richness and abundance. The species present at the two stations in this section of the Straight River included one species listed as Threatened in Minnesota (*V. ellipsiformis*) and three species listed as of Special Concern (*L. recta*, *L. compressa*, and *E. dilatata*) when sampled by Davis (1988). We were unable to find living individuals of *V. ellipsiformis* and *L. recta* at either of the stations where Davis (1988) found them.

Davis (1987) commented in his field notes that the mussels in the Straight River above the Owatonna Dam were in danger of suffocation from shifting sand resulting from increased flashiness and erosion in the river. Upstream of The Straight River 20 station the Straight River becomes much smaller and its headwaters consist largely of agricultural ditches. Management practices designed to minimize erosion in these agricultural areas and flashiness in the floodplain of the Straight River can help conserve the mussel diversity and abundance at Stations 19 and 20.

Superior National Forest

Range River Drainage

Low Lake Drainage. The lower lakes in the Low Lake drainage side of the headwaters of the Range River (Bass, Low) contained the fewest mussels. Only one species was

found in them (*P. grandis*), and their abundance was very low. The low mussel densities in these lakes was due in a large part to their morphology. Bass Lake is the lower of two lakes (the other is Dry/Little Dry Lake) which resulted after the terminal moraine of Bass lake washed out in 1925 and the lake level dropped by 16.8 m. The existing Bass Lake was the profundal part of the previous Bass Lake. Its basin is steep-walled and its littoral area is only 41% of the lake area. Most of the littoral area in Bass Lake contained dense stands of rooted aquatic macrophytes; no mussels were found in macrophyte beds in this study. Low Lake receives water from Bass Lake and Hobo Lake. Low Lake has a large littoral zone (61% of surface area), but most of it is not suitable mussel habitat. The entire north arm of Low Lake is less than 4 m in depth. About one quarter of the north arm has an open sandy gravel substrate that is suitable for mussels, and a few mussels were found there. Where the substrate is suitable, the depth is greater than three meters and sits below the thermocline during the entire summer. Mussels were only rarely found below the thermocline in the lakes we studied. The other two thirds of the north arm of Low Lake is covered by a dense growth of macrophytes (e.g., *Nuphar*, *Nymphaea*, *Potamogeton*). The substrate consists of the lake bottom which is covered by a flocculent organic ooze that is only a little more dense than the water in which it is suspended. While mussels have been observed sitting in this flocculent organic layer of this sort in Hula Lake (G. Wagenbach, personal observation), we did not observe this phenomenon in Low Lake.

Hobo Lake contained both *P. grandis* and *U. imbecillis*. The creek connecting Hobo Lake to Low Lake is very small during most of the year, and drains Hobo Lake largely by seepage during the summer. The stream has a steep rocky section and a marshy section on its way to Low Lake; based on the appearance of this creek in summer, it seems unlikely that it is used by fish to move between Hobo Lake and Low Lake. Fish species currently known to be hosts for larval *U. imbecillis* that are found in Hobo Lake include bluegill, largemouth bass, and yellow perch (Watters 1994). *Utterbackia* has also been reported to reproduce without a fish host for its larvae (cf. Watters 1994). Because no *Utterbackia* were found in Low Lake, where the fish fauna includes all the species known to be in Hobo Lake, it seems likely that *Utterbackia* was introduced to Hobo Lake through fish introductions.

Little Dry Lake and Dry Lake were a bay in the original Bass Lake before its water level dropped as a result of the erosion of the terminal moraine that formed one end of the lake. These two lakes are connected by a narrow channel that is no particular barrier to fishes. Dry Lake connects to the existing Bass Lake by a steep creek that drops into Bass Lake over a falls with a height of several meters. Mussels were found in the creek between Dry lake and Bass Lake in 1997 (M. Swift, personal observation). Only *P. grandis* currently lives in these lakes, but their density is quite high ($3.7/m^2$). These lakes were poisoned (probably rotenone) in the 1960s and have been managed since then as trout fisheries. These lakes contain brook trout, brown trout, white sucker, and tulibee.

High Lake, upstream from Dry Lake, is the uppermost lake in this chain of lakes. We collected only small individuals of *P. grandis* in this lake despite large areas of

apparently suitable habitat (36% littoral). High Lake was poisoned using Toxaphene during the 1960s and is now managed as a trout fishery. Currently there are bluegill, brook trout, white sucker, and splake living in High Lake. At this time, it seems most likely that the absence of large populations of *P. grandis* in High Lake is due to mortality from Toxaphene exposure followed by removal of a preferred fish host. The non-salmonid host fishes for *P. grandis* larvae include all the species collected by MNDNR in High Lake (Watters 1994). Because these lakes are in close proximity, it would be possible to stock High Lake with *P. grandis* from Dry Lake if that became a management goal.

Grassy Lake drainage. The northern branch of the headwaters of the Range River drains from Sletten Lake to Tee Lake to Grassy Lake and then into the Range River. Neither Sletten Lake nor Tee Lake contained mussels. Grassy Lake is large (82 ha) and shallow (100% littoral). We found only *P. grandis* in Grassy Lake, and they were very rare.

Burntside Lake drainage. There is a ridge between Sletten Lake, which drains north, then east, into the Range River and Little Sletten Lake which drains west into Fenske Lake, and then west and south into Burntside Lake. Little Sletten Lake contained no mussels, but Fenske Lake contained both *P. grandis* and *U. imbecillis*. Fenske lake contained the same fishes that have been reported as larval hosts for *U. imbecillis* as there were in Hobo Lake. Fenske Lake is a popular fishing lake with boat launch facilities day and overnight camping facilities, and several houses on its shore. We hypothesize that *U. imbecillis* reached Fenske Lake accidentally as a result of fish stocking.

Mussel Species

Ambleminae

Pleurobema sintoxia. Round Pigtoe. Davis collected live specimens of *Pleurobema* only at the Cannon River 3A (above the Northfield Dam) and Straight River 6A fishery stations. We found live individuals at the two Straight River stations we sampled, but did not sample the Cannon River 3A station. *Pleurobema* was relatively abundant at the randomly chosen sampling locations we sampled within the Straight River 6A fishery station. Unlike most of the other species we collected, it was routinely found in sandy areas. While present at the Straight River 5 sampling locations, it was not abundant. Most of the mussels at this station were found in a few of the 10 m segments in gravelly riffle habitat which may not have been optimal substrate for *Pleurobema*.

Pleurobema sintoxia has not been reported from the Lake of the Woods system in the Superior National Forest (Graf 1997).

Elliptio dilatata. Spike. The spike is on the list of species of Special Concern in Minnesota (MNDNR 1996). While still present at those stations where it was found by Davis (1988) that were sampled in this study (Cannon River 5, Cannon River 1C/1D,

Straight River 5, 6A), *E. dilatata* was only relatively abundant at the Straight River stations upstream of the Owatonna Dam. The low number of live individuals collected at the stations below the Northfield Dam is probably due to the low number of sampling units we sampled.

Elliptio dilatata has not been reported from the Lake of the Woods system in the Superior National Forest (Graf 1997).

Anodontinae

Utterbackia imbecillis. Paper Pondshell. Graf (1997) listed *Utterbackia imbecillis* as a member of the Upper Mississippi River Fauna, but noted that it was unreported in the Lake of the Woods system. We found *U. imbecillis* in two lakes in the headwaters of the Range River in Superior National Forest, and it was reported from two additional lakes in Superior National Forest in 1998 (T. Wagner, personal communication). These lakes are within the Lake of the Woods drainage system and appear to be the first records of *U. imbecillis* in that system.

Pyganodon grandis. Floater. This species was abundant in Chub Creek and in the Straight River above the Owatonna Dam. The morphology of *P. grandis* was quite variable, including large, thick-shelled individuals in the main stem of the Cannon and Straight Rivers and thin-shelled individuals in the tributaries. Either our sampling methods were not appropriate to collect them, or there were just very few small individuals present at our sampling locations.

In the lakes we sampled in the headwaters of the Range River, *P. grandis* was the most abundant species we collected, and it was found in the most lakes. The size distribution of *P. grandis* was smaller (maximum size 119 mm) in these small northern lakes than in the Cannon River drainage system (maximum length 149 mm). Individuals as small as 30 mm were collected using our swimming search technique in the Superior National Forest lakes. The growing season is shorter in northern Minnesota and the productivity of the lakes is far lower than in the reservoirs and slow moving water in the Cannon River drainage. Our samples expand the known distribution of *P. grandis* in the Superior National Forest and Lake of the Woods watershed, but *P. grandis* is widespread in the lakes and rivers of the Superior National Forest and was found in 27 lakes and 4 rivers during summer, 1998 (T. Wagner personal communication).

Anodontoides ferussacianus. Cylinder. Davis (1988) describes this as Minnesota's most common small river and creek species. We found it in Chub Creek, Heath Creek, and the Straight River above Owatonna. Unlike Davis (1988), we were unable to find it in Wolf Creek. The substrate in Wolf Creek was exceptionally hard. This may have had some effect on its distribution.

Anodontoides ferussacianus has been reported from the Lake of the Woods system (Graf 1997), but Graf reports that no unambiguously identified shells from that system are archived in the James Ford Bell Museum. Since Graf's (1997) paper, individuals of

A. ferussacianus have been identified in three lakes and three rivers in the Superior National Forest (T. Wagner, personal communication). We did not find any living or dead shells of *A. ferussacianus* in the lakes we studied in the Superior National Forest.

Strophitus undulatus. Strange Floater. To the extent that our samples were representative of the species present at a station, the distribution of *S. undulatus* has become more restricted since Davis (1988) surveyed the mussel fauna of the Cannon River Drainage. We found it only at Station Straight River 6A, while Davis (1988) found it in the Straight River 5 and Owatonna Dam Tailwater stations.

Strophitus undulatus has been reported in the Lake of the Woods drainage system in a single reference according to Graf (1997), but its status there is not clear. We did not find *S. undulatus* in our sampling in the Lake of the Woods system.

Lasmigona complanata. White Heelsplitter. *Lasmigona complanata* was the most widely distributed species we collected in the Canon River drainage system (8 stations). Davis (1988) found live individuals at the stations we sampled as well. This species was abundant at four of the stations, including the two stations we sampled upstream of the Owatonna Dam.

Lasmigona complanata has been found in the Lake of the Woods system (Graf 1997). We did not find it in our sampling in the Range River system in this study, nor was it collected in the U. S. Forest Service sampling during summer 1998 (T. Wagner, personal communication).

Lasmigona costata. Fluted Shell. Lasmigona costata was not collected in our study. Davis (1988) found this species only at three widely separated sites although two were in the Straight River. He suggested that its extirpation was imminent Our results support his conclusion.

Lasmigona costata has not been reported from the Lake of the Woods system (Graf 1997). Recent sampling in the Superior National Forest (this study; T. Wagner, personal communication) did not collect it.

Lasmigona compressa. Creek Heelsplitter. *Lasmigona compressa* was found at low densities in Chub Creek, the Cannon River at Northfield, and in the Straight River upstream of the Owatonna Dam by Davis (1988). We also found it in Chub Creek and in the Straight River upstream of the Owatonna Dam. *Lasmigona compressa* was not abundant at any station in our study.

Lasmigona compressa has been reported in the Lake of the Woods system (Graf 1997). Live specimens were collected in sampling by U. S. Forest Service personnel in 1998 (T. Wagner, personal communication). We did not collect this species in the Superior National Forest.

Lampsilinae

Actinonaias ligamentina. Mucket. Davis (1988) reported finding living *A. ligamentina* (carinata) at only two stations between Northfield and Lake Byllesby. We collected live specimens at both Straight River stations above the Owatonna Dam. The difference in distribution in these two studies may have been the result of the larger area we sampled. Mussel density was not very high at either station. Graf (1997) lists *A. ligamentina* as a member of the Lower Mississippi River Fauna; we did not find it in northern Minnesota.

Potamilus alatus. Pink Heelsplitter. *Potamilus alatus* was abundant in our samples from Chub Creek, the Cannon River below the Morristown Dam, and below the Northfield Dam. Davis (1988) found a similar distribution of live individuals. Graf (1997) includes *P. alatus* in the Red River of the North Fauna, and notes that it is also found in the Lower Mississippi River, Minnesota River, and St. Croix River subsystems of the Mississippi River Fauna. This species accounted for 44% of the live mussels Davis (1988) found in his study. In our study, *P. alatus* was very abundant at some sampling stations. Like Davis(1988), we did not collect P. alatus above the Owatonna Dam. It appears that the distribution of this species is limited by the distribution of its obligate host, the freshwater drum (*Aplodinotus grunniens*).

Ligumia recta. Black Sandshell. Davis (1988) found low numbers of *Ligumia recta* in the Cannon River at Northfield and in the Straight River above the Owatonna Dam. We found none in the Straight River, but numerous individuals in the Cannon River at Northfield. We also found single individuals in Chub Creek (Chub Creek 3) and the Cannon River downstream of the Morristown Dam Cannon River 5). Finding *L. recta* in Chub Creek and the Cannon River near Morristown where Davis (1988) did not find them is probably due to our sampling technique, which sampled a larger area than that used by Davis.

Graf (1997) included *L. recta* in the Upper Mississippi River Fauna and cited records of it in the Lake of the Woods system. We found no *L. recta* in our study of lakes in the Range River system and Burntside Lake drainage, and it was not collected in the U. S. Forest Service survey in 1998 (T. Wagner, personnel communication).

Venustaconcha ellipsiformis. Ellipse. Davis (1988) collected 17 live individuals of this Minnesota Threatened species in the Straight River above the Owatonna Dam and in the dam tailwaters and single live specimens in Wolf Creek and below the Northfield Dam. We were unable to locate a single live specimen of *V. ellipsiformis*. Our data suggest that *V. ellipsiformis* is less widespread than it was in 1988.

Lampsilis siliquoidea. Fat Mucket. *Lampsilis siliquoidea* was found in Chub Creek, the Cannon River near Morristown and in the Straight River in our study. It was particularly abundant at the Cannon River 5 station and the Straight River stations above the Owatonna Dam. Davis (1988) found *L. siliquoidea* in abundance at the Cannon River 5 station and the Straight River, but not in Chub Creek. If it was extirpated from Chub Creek when Davis (1988) sampled there in 1987, it has returned.

Graf (1997) listed *L. siliquoidea* as one of the species in the Upper Mississippi river Fauna, and it has been reported from the Lake of the Woods system. We did not find it in the lakes we studied, but it was found in 24 lakes and six rivers in Superior national Forest in 1998 (T. Wagner, personal communication).

Lampsilis cardium. Pocketbook. *Lampsilis cardium* was abundant in the limited survey we made at the Cannon River 1C/1D stations below the Northfield Dam. Davis (1988) found *L. cardium* in abundance at stations below Northfield.

Graf (1997) included *L. cardium* in the Upper Mississippi River Fauna, and recorded it from the Lake of the Woods system. We did not find any live *L. cardium* or dead shells in our survey of lakes in the headwaters of the Range River. The 1998 U. S. Forest Service mussel survey did nor collect it either.

Sampling Methods

One of the goals of mussel survey programs is to provide estimates of abundance (density) and its variability that can be used to compare populations among areas (streams, lakes) and among times (past, present, future). Because the distribution of mussels within a sampling site or station is usually not known, estimating abundance and its variance requires large numbers of sampling units to provide abundance estimates with acceptable levels of percent error (Elliott 1977, Downing 1979, Downing and Downing 1992). Surveys often use preliminary sampling programs to provide estimates of the population mean and variance which are then used to calculate the number of sampling units required for a particular level of percent error (Elliott 1977). Problems arise in designing sampling programs using this methodology because the number of sampling units required often varies dramatically between abundant and rare taxa at a particular site. In practice, then, surveys usually sample too few sampling units to provide reasonable estimates of abundance for any but the most abundant taxa.

Another complication in designing sampling programs is that the number of sampling units appropriate to provide reasonable estimates of abundance are often different from the number of sampling units required for estimating species richness. This problem is exacerbated when there are a few abundant taxa and several rare taxa present at a sampling site. One way to avoid the different requirements for sampling species richness and abundance is to combine quantitative samples for estimating abundance and qualitative samples for assessing species richness. This design allows precise estimates of abundance of common taxa as well as good estimates of richness.

Davis (1988) used a combination of quantitative samples (belted transects 1/2 m x stream width) located in pools and riffles to estimate abundance and qualitative samples (walking surveys) within all available habitats to estimate abundance. Our results from extensive sampling at the Chub Creek 3 station provided some insights about sampling for species richness and abundance. We found that multiple 10 m stream segment samples provided better estimates of abundance than quadrat samples for an equal

investment in time and that these 10 m bank to bank sampling units also provided a much better estimate of species richness than quadrat samples. Using the bank-to-bank sampling units we did not need to use additional qualitative sampling to find rare taxa after completing quantitative sampling. We chose a 10 m long (upstream-downstream) bank-to-bank sample size. These sampling units were large enough to sample all the taxa present, yet were possible to complete in a timely fashion. We do not know how short the sampling unit could be and still adequately sample both abundance and richness. The 1/2 m length used by Davis(1988) was too short, according to his observations. Perhaps shortening the sampling unit length to 5 m and increasing the number of sampling units would be closer to optimizing sampling both abundance and richness.

Lakes present the same sampling problems as streams. Since mussels are distributed in a relatively narrow range of depths, in deep lakes they are distributed in a ring of varying width around the lake perimeter. In lakes with this type of distribution the band of inhabited depths can be considered as a "stream". Because of the difficulties of working in water deeper than about one meter, we surveyed lake populations using timed swimming searches. Swimming searches were successful at surveying large areas for the presence of mussels. Where high densities were encountered, we used quadrat samples to provide estimates of abundance. This sampling protocol provided good estimates of richness and abundance.

Acknowledgments

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Table 1

Site	Search Type	# Searches	*Pyganodon grandis*	*Utterbackia imbecillis*	*Anodontoides ferussacianus*	*Lasmigona complanata*	*Lasmigona compressa*	*Lampsilis cardium*	*Lampsilis siliquoidea*	*Potamilus alatus*	*Ligumia recta*	*Actinonaias ligamentina*	*Strophitus undulatus*	*Pleurobema sintoxia*	*Elliptio dilatata*
Cannon River															
Tributary Stations															
Chub Creek 2 (T-15)	10m	15	34		1	17	7		2	18					
Chub Creek 3 (T-16)	150m	1	39		24	6	4		6	5					
	Quadrat	50	3		1	3									
	10m	15	29		12	5	1			4	1				
Heath Creek 2 (Near T-19)	10m	14	2		11	1									
Wolf Creek (T-20)	10m	15				2									
Cannon River 5 (T-21)	10m	5	7			7			90	37	1				7
	timed	3				2			8	7					
Trunk Stations															
Cannon River1C (5)	10m	2													
						26		17	3	75	21				1
Cannon River 1D (6)	10m	2													
Owatonna Dam Tailwater (18)	not sampled														
Straight River 5 (19)	10m	15	10			22	1		31			6		2	25
Straight River 6A (20)	10m	8	57		2	82	2		29			5	8	19	22
Superior National Forest															
Low Lake Drainage															
Hobo Lake	Swimming	7	+	+											
	Quadrat	28	23												
High Lake	Swimming	10	+												
Dry Lake	Swimming	1	+												
	Quadrat	15	55												
Little Dry Lake	Swimming	1	+												
	Quadrat	16	59												
Bass Lake	Swimming	4	+												
Low Lake	Swimming	7	+												
	Canoe	2													
Grassy Lake Drainage															
Sletten Lake	Swimming	3													
Tee Lake	Swimming	2													
Grassy Lake	Swimming	4	+												
Burntside Lake Drainage															
Little Sletten Lake	Swimming	2													
Fenske Lake	Swimming	6	+	+											

Table 2. Mean (SD) mussel density at selected sampling stations in the Cannon River watershed and Superior National Forest. No density estimates were possible for swimming searches.

Site	Search Type	Number of Searches	Density (# / m^2)
Cannon River			
Tributary Stations			
Chub Creek 2 (T-15)	10m	15	0.076 (0.035)
Chub Creek 3 (T-16)	150m	1	0.10[1]
	Quadrat	50	0.14 (0.4)
	10m	15	
Heath Creek 2 (Near T-19)	10m	14	0.033 (0.073)
Wolf Creek (T-20)	10m	15	0.0044 (0.037)
Cannon River 5 (T-21)	10m	5	0.60 (0.46)
Trunk Stations			
Cannon 1C (5)	10m	2	0.24 (0.23)
Cannon River 1D (6)	10m	2	
Owatonna Dam Tailwater (18)	not sampled		
Straight River 5 (19)	10m	15	0.042 (0.07)
Straight River 6A (20)	10m	8	0.25 (0.25)
Superior National Forest			
Low Lake Drainage			
Hobo Lake	Quadrat	28	0.82 (1.09)
High Lake	Swimming		
Dry Lake	Quadrat	15	3.70 (3.09)
Little Dry Lake	Quadrat	16	3.69 (4.06)
Bass Lake	Swimming		
Low Lake	Swimming		
Grassy Lake Drainage			
Sletten Lake	Swimming		
Tee Lake	Swimming		
Grassy Lake	Swimming		
Burntside lake Drainage			
Little Slettin Lake	Swimming		
Fenske Lake	Swimming		

[1] Single value

Table 3. Water quality characteristics of sampling stations in the Cannon River watershed and the Superior National Forest. Station labels in parentheses are those used by Davis (1988). Values are single measurements; if multiple measurements were made the values are means (number of measurements). Data from Cannon River stations 1C and 1D are combined. For Secchi depth values >x the Secchi disk was visible on the bottom at a depth of "x" cm.

Site	Alkalinity (□eq/L)	Chlorophyll a (□g/L)	Dissolved Oxygen (mg/L)	Temperature (°C)	Secchi Depth (cm)
Cannon River					
Tributary Stations					
Chub Creek 2 (T-15)	6,551	3.07	6.8	19.1	67
Chub Creek 3 (T-16)	-----	-----	-----	26.0	>50
Heath Creek 2 (Near T-19)	-----	-----	7.9	25.0	>100
Wolf Creek (T-20)	5,003 (2)	-----	7.4	19.0	75
Cannon River 5 (T-21)	3,670 (2)	25.2 (2)	4.6	25.8	41
Trunk Stations					
Cannon 1C (5)	-----	18.93	-----	-----	-----
Cannon River 1D (6)					
Owatonna Dam Tailwater (18)	-----	3.35	4.5	24.1	40
Straight River 5 (19)	5,997 (2)	0.0	7.5	22.0	80
Straight River 6A (20)	5,762 (3)	13.27	6.0 (2)	18.9 (2)	110
Superior National Forest					
Low Lake Drainage					
Hobo Lake	509.5	0.90	6.4	25.5	240
High Lake	176.2	0.62	8.0	23.5	630
Dry Lake	317.2	0.57	6.5	24.0	560
Little Dry Lake	420.9	1.12	-----	26.0	340
Bass Lake	690.5	0.77	7.6	23.5	550
Low Lake	686.0	8.91	7.6	24.2	420
Grassy Lake Drainage					
Sletten Lake	140.7	0.97	7.4	25.0	420
Tee Lake	101.4	2.60	7.3	25.0	210
Grassy Lake	174.7	1.68	7.8	24.5	310
Burntside Lake Drainage					
Little Slettin Lake	154.6	0.23	7.6	25.0	320
Fenske Lake	132.1	0.55	6.8	25.0	420

Table 4. Filterable residue measurements at sampling stations in the Cannon River watershed. Station labels in parentheses are those used by Davis (1988). Values are means of three water samples. Some stations were sampled twice. Data from Cannon River stations 1C and 1D are combined.

Site	Filterable Residue (mg/L)	Inorganic Residue (mg/L)	Organic Residue (mg/L)
Cannon River Tributary Stations			
Chub Creek 2 (T-15)	25.3	15.3	10.0
Chub Creek 3 (T-16)	7.1	1.2	5.9
Heath Creek 2 (Near T-19)	-----		
Wolf Creek (T-20)	19.5	6.9	12.6
Cannon River 5 (T-21)	31.5 64.8	13.9 32.3	17.5 32.5
Trunk Stations			
Cannon 1C (5) Cannon River 1D (6)	28.1	14.8	13.3
Owatonna Dam Tailwater (18)	39.3	27.9	11.4
Straight River 5 (19)	15.9	7.3	8.6
Straight River 6A (20)	93.1 3.5	74.1 0.0	19.0 3.5

Table 5. Mussels collected in this study (S) and by Davis (1988) (D). The sampling station codes are as follows (with Davis' (1988) notation in parentheses): CC2 – Chub Creek 2 (T-15); CC3 – Chub Creek 3 (T16); HC2 – Heath Creek; WC – Wolf Creek; CR5 – Cannon River 5 (T-21); CR1C/D -- Cannon River 1C and 1D; ODT -- Owatonna Dam Tailwater (not sampled in this study); SR5 – Straight River 5 (19); SR6A – Straight River 6A (20).

Species	Sampling Stations																							
	CC2 (T-15)		CC3 (T-16)		HC2 (T-19)		WC (T-20)		CR5 (T-21)		CR1C/D (5, 6)		ODT (18)		SR5 (19)		SR6A (20)							
	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Ambleminae																								
Pleurobema sintoxia																	S				S	D		
Elliptio dilatata									S	D	S	D		D			S	D			S	D		
Anodontinae																								
Utterbackia imbecillis																								
Pyganodon grandis	S	D	S	D	S	D			S	D		D		D		S	D		S	D				
Anodontoides ferussacianus		S		S	D		S	D			D										S	D		
Strophitus undulatus														D				D			S	D		
Lasmigona complanata	S	D	S	D		S	D		S	D	S	D	S	D		D			S	D		S	D		
Lasmigona compressa		S	D		S	D									D				S	D		S	D	
Lasmigona costata													D											D
Lampsilinae																								
Actinonaias ligamentina												D				S				S				
Potamilus alatus		S	D		S	D					S	D	S	D				D						
Ligumia recta				S							S		S	D						D				D
Venustaconcha ellipsiformis								D				D			D				D			D		
Lampsilis siliquoidea		S		S							S	D	S	D				D		S	D		S	D
Lampsilis cardium												S	D											

Figure Captions

Figure 1. Map of the Cannon River drainage system. Sampling stations are labeled as Tributary Stations (e.g., T-15) or as Trunk Stations (e.g., 1C) using the MNDNR fisheries sampling station notation).

Figure 2. Map of the Range River headwaters in Superior National Forest. Lakes chosen for sampling are labeled.

Figure 3. Length frequency of mussels collected at Chub Creek 2.

Figure 4. Length frequency of mussels collected at Station Chub Creek 3. Mussels were collected from a 150 m stream section.

Figure 5. Length frequency of mussels collected at Station Chub Creek 3. Mussels were collected from 15 10 m stream segments.

Figure 6. Length frequency of *P. grandis* collected at station Chub Creek 3. Mussels were collected in a 150 m stream section and 15 10 m stream sections.

Figure 7. Length frequency of mussels collected at Station Heath Creek 2. Mussels were collected in 14 10 m stream segments.

Figure 8. Length frequency of mussels collected at Station Cannon 5. Mussels were collected in 7 10 m stream segments.

Figure 9. Length frequency of male and female *Lampsilis siliquoidea* collected at Station Cannon 5. Mussels were collected in 7 10 m stream segments.

Figure 10. Length frequency of mussels collected at Station Cannon River 1D. Mussels were collected in 4 10 m stream segments.

Figure 11. Length frequency of mussels collected at Station Straight River 5. Mussels were collected in 15 10 m stream segments.

Figure 12. Length frequency of mussels collected at Station Straight River 6A. Mussels were collected in 8 10 m stream segments.

Figure 13. Length frequency of *Pyganodon grandis* in Hobo Lake. Mussels were collected in 28 1 m^2 quadrats.

Figure 14. Length frequency of *Pyganodon grandis* in Dry lake. Mussels were collected in 15 1 m^2 quadrats.

Figure 15. Length frequency of *Pyganodon grandis* in Little Dry Lake. Mussels were collected in 16 1 m^2 quadrats.

Figure 16. Length frequency of *Pyganodon grandis* and *Utterbackia imbecilis* in Fenske Lake. Mussels were collected in 28 1 m^2 quadrats.

Appendix 1. Presentations at Meetings Supported by this Grant.

A. The Freshwater Mollusk Conservation Society, First Symposium. Chattanooga, TN. 17-19 March, 1999. Abstract submitted.

Anthropogenic Mussel Distributions -- Cannon River and Superior National Forest, MN. G. E. Wagenbach[1], M. C. Swift[2], S. DeRuiter[2], T. Dickson[2], C. Harbison[1], and G. Jesperson[1]. [1]Biology Department, Carleton College, Northfield, MN, 55057, [2]Biology Department, St. Olaf College, Northfield, MN 55057.

We studied the distribution and abundance of mussels in the Cannon River (4 sites) and its tributaries (5 sites) and in 10 lakes in the Range River drainage in the Superior National Forest. In the Cannon River *Potamilus alatus* is found below the Owatonna dam, but not above the dam; this distribution is matched by the distribution of its sole known larval host , the freshwater drum (*Aplodinotus grunniens*). In Superior National Forest, *Pyganodon grandis* is abundant in Dry Lake but almost non-existent in High Lake, which is a short distance upstream of Dry Lake. Old, decayed shells in High Lake suggest that *P. grandis* was once more abundant there, and host fish for *P. grandis* larvae currently inhabit both lakes. Both lakes were poisoned prior to trout stocking in the 1960s -- High Lake with toxaphene and Dry Lake apparently with rotenone. The High Lake population has apparently not recovered from the toxaphene application. *Utterbackia imbecillis* is found in Hobo Lake and Fenske Lake, but not in the other lakes to which they are connected. We hypothesize that its distribution is due to fish stocking activities.

B. North American Benthological Society. 47th Annual Meeting. Duluth, MN. 25-28 May, 1999. Abstracts submitted.

1. Mussel Distribution and Abundance in the Cannon River Watershed and Superior National Forest, MN. M. C. Swift[1], G. E. Wagenbach[2], S. DeRuiter[1], T. Dickson[1], C. Harbison[2], and G. Jesperson[2]. [1]Biology Department, St. Olaf College, Northfield, MN 55057; [2]Biology Department, Carleton College, Northfield, MN, 55057.

We studied the distribution and abundance of mussels in the Cannon River (4 sites) and its tributaries (5 sites) and in 10 lakes in the Range River watershed in Superior National Forest. In the Cannon River we found 12 species (12 and 7 at trunk and tributary stations, respectively). The most commonly encountered species was Lasmigona complanata (11 stations) followed by Pyganodon grandis (8), Lampsilis siliquoidea (7), and Potamilus alatus (7). We also collected Anodontoides ferussacianus (6), Lasmigona compressa (5), Ligumia recta (2), Actinonaias carinata (2), Pleurobema sintoxia (2), Elliptio dilatata (2), Lampsilis cardium (1), and Strophitus undulatus (1). Trunk stations had higher species richness (10 and 6 species) than tributary stations (6 or fewer species). Distribution and abundance were not clearly related to physical or chemical parameters in the Cannon River watershed. In lakes in the Range River watershed we found two species (P. grandis, 8 lakes; Utterbackia imbecilis, 3 lakes). Both species were found in three lakes. Abundance varied

tremendously among lakes and appeared to be related to the availability of appropriate habitat and the effects of poisoning prior to trout stocking. The distribution of Utterbackia may be related to historical fish stocking.

2. A Comparison of Stream Segment and Quadrat Mussel Sampling Techniques. T. L. Dickson. Biology Department, St. Olaf College, Northfield, MN 55057.

The importance of freshwater mussels in river ecosystem dynamics and as environmental indicators and endangered species is well recognized. Well designed, rapid methods of sampling mussels are needed. We tested the more traditional method of $1m^2$ quadrat searches against 10m long bank-to-bank searches. Using data collected during the summer from local streams we calculated how well the two sampling techniques measured mussel density, mussel richness (total number of species present), and mussel aggregation. We found that quadrats required more samples for a particular level of precision in density estimates than did 10m searches, however 10m searches may still be more time-consuming. A better estimate of species richness is provided by 10m searches, and 10m searches also tended to detect uniform distributions, while quadrats tended to detect clumped distributions within the same population. Ten meter long bank-to-bank searches appear to be a viable alternative to quadrat sampling.

3. Freshwater Mussel - Fish Interactions in the Superior National Forest and the Cannon River Watershed, MN. S. DeRuiter. Biology Department, St. Olaf College, 1520 St. Olaf Ave., Northfield, MN 55057.

Freshwater mussels (Unionoidea) are an important group of aquatic environmental indicator species. Their value as indicators has generated significant interest in the factors affecting mussel distribution and abundance. I investigated the effect of one such factor, fish distribution, on the mussel faunas of ten lakes in the Superior National Forest (near Ely, MN) and the Cannon River watershed (south-central MN). Mussel larvae, or glochidia, are obligate parasites on specific host fishes, and mussels can not reproduce unless their fish hosts are present. I compared mussel distribution data from summer 1998 and summer 1987 with DNR records of fish distributions for the same sites. My analysis showed that host fish distributions did not influence mussel distributions in the SNF lakes. In the Cannon River watershed, however, my results suggest that distribution of the pink heelsplitter (*Potamilus alatus*) was limited by distribution of its host fish, the freshwater drum (*Aplodinotus grunniens*).

C. Mississippi River Research Consortium. 31st Annual Meeting. La Crosse, WI. 22-23 April, 1999. Abstracts submitted.

1. Mussel Distribution and Abundance in the Cannon River Watershed and Superior National Forest, MN. G. E. Wagenbach[1], M. C. Swift[2], S. DeRuiter[2], T. Dickson[2], C. Harbison[1], and G. Jesperson[1]. ; [1]Biology Department, Carleton College, Northfield, MN, 55057; [2]Biology Department, St. Olaf College, Northfield, MN 55057.

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Freshwater mussels (Unionoidea) are an important group of aquatic environmental indicator species. Their value as indicators has generated significant interest in the factors affecting mussel distribution and abundance. I investigated the effect of one such factor, fish distribution, on the mussel faunas of ten lakes in the Superior National Forest (near Ely, MN) and the Cannon River watershed (south-central MN). Mussel larvae, or glochidia, are obligate parasites on specific host fishes, and mussels can not reproduce unless their fish hosts are present. I compared mussel distribution data from summer 1998 and summer 1987 with DNR records of fish distributions for the same sites. My analysis showed that host fish distributions did not influence mussel distributions in the SNF lakes. In the Cannon River watershed, however, my results suggest that distribution of the pink heelsplitter (*Potamilus alatus*) was limited by distribution of its host fish, the freshwater drum (*Aplodinotus grunniens*).

3. A Comparison of Stream Segment and Quadrat Mussel Sampling Techniques. T. L. Dickson. Biology Department, St. Olaf College, Northfield, MN 55057.

The importance of freshwater mussels in river ecosystem dynamics and as environmental indicators and endangered species is well recognized. Well designed, rapid methods of sampling mussels are needed. We tested the more traditional method of $1m^2$ quadrat searches against 10m long bank-to-bank searches. Using data collected during the summer from local streams we calculated how well the two sampling techniques measured mussel density, mussel richness (total number of species present), and mussel aggregation. We found that quadrats required more

samples for a particular level of precision in density estimates than did 10m searches, however 10m searches may still be more time-consuming. A better estimate of species richness is provided by 10m searches, and 10m searches also tended to detect uniform distributions, while quadrats tended to detect clumped distributions within the same population. Ten meter long bank-to-bank searches appear to be a viable alternative to quadrat sampling.

D. Minnesota Academy of Science. 68th Annual Meeting. 1999. Macalester College. Abstracts to be submitted.

1. Freshwater Mussel - Fish Interactions in the Superior National Forest and the Cannon River Watershed, MN. S. DeRuiter. Biology Department, St. Olaf College, 1520 St. Olaf Ave., Northfield, MN 55057.

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Appendix 2. Independent Research Supported by this Grant

Dickson, T. L. Mussel sampling. Fall 1998. Supervisors: M. C. Swift, H. Shierholz