Freshwater Mussels (Mollusca: Bivalvia: Unionidae) of the Cannon River Drainage in Southeastern Minnesota

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ABSTRACT

Sampling techniques suitable for documenting the current and historical distribution of Minnesota's freshwater mussels were developed and field tested during the summer and fall of 1987 in the Cannon River drainage of southeastern Minnesota. Quantitative sampling of pool and riffle habitats was conducted using a belted transect divided into 1/2 by 1 meter frames. Qualitative sampling was conducted by walking the length of each sampling station and searching aquatic microhabitats, shorelines, muskrat middens and sand/gravel accretions for live and dead shells.

A total of 1344 live mussels, representing 15 species, were taken from 61 sampling stations.

Evidence of massive distributional disruption and mussel species extirpations were found in several areas of the drainage.

Live records of a new Minnesota mussel species, *Actinonaias ellipsiformis* - Ellipse, were found and a very large, densely populated mussel bed was discovered within the tailwaters of an old mill dam.

INTRODUCTION

Unlike other mollusks, freshwater mussels are limited in their distribution to those waters which support fish species that are suitable hosts to their larval or glochidia life-stage. Mussel distribution then, becomes a function of host-fish distributions and to barriers to the movement of fish within a drainage system. For example, St. Anthony Falls once posed a barrier to fish movement in the Mississippi River. Consequently, different mussel species are found above and below the falls (Dawley 1944, Fuller 1978). Every river drainage has a potentially unique mussel distribution and species composition. Each drainage also has the potential of posessing protected habitats which could house relict populations of now rare or endangered mussel species.

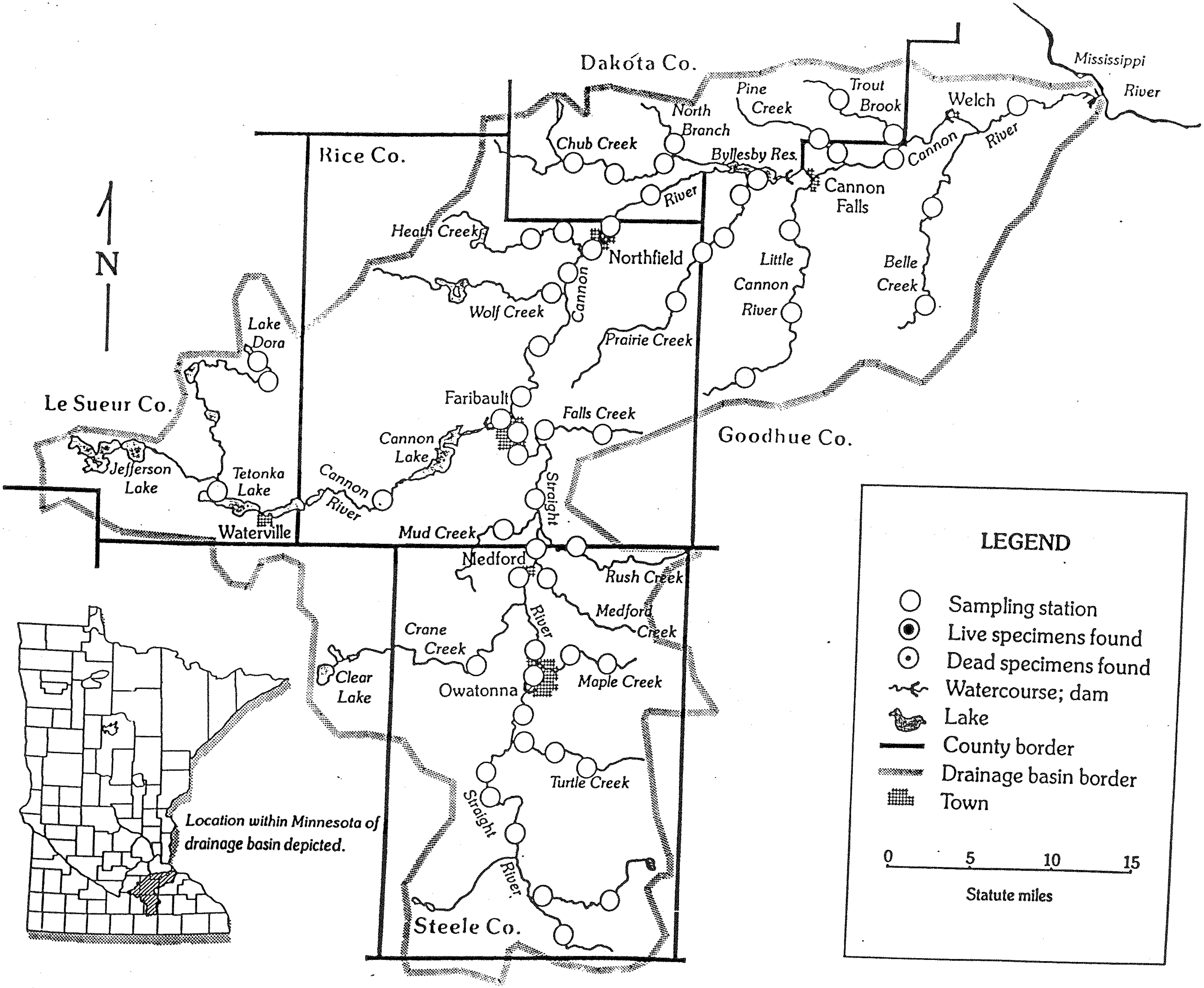
Information regarding the distribution and number of species of mussels in many of Minnesota's river drainages is lacking. It was the purpose of this survey to gather baseline data on mussel distribution and densities in Minnesota's Cannon River drainage and to develop sampling techniques for use in future surveys throughout the state. In so doing, an important tool is gained for the assessment of aquatic habitat quality, and evidence of the biological impacts of past human activity can be demonstrated in a way which will facilitate efforts to avoid harmful activities in the future.

Previous mussel surveys in Minnesota have produced mainly qualitative data. Dawley (1944) surveyed the entire state, but only investigated two sites in the Cannon River drainage. Wilson and Danglade (1914) concentrated their efforts in central and northern Minnesota and limited their interest to species useful to the pearl button industry. More recently, surveys have been conducted on the Mississippi River by Fuller (1978), Havlik (1977,1983) and Theil et al (1981), on the Minnesota River by Enblom (MNDNR 1983) and Havlik (1977), on the St Croix River by Doolittle (1987 in prep), Fuller (1978) and Havlik (1987), and on the Blue Earth River by Chelberg (unpublished).

Study Area

The Cannon River (Fig. 1) drainage occupies 1,462 square miles of southeastern Minnesota (Waters 1977). The drainage is divided at Faribault, MN into two distinct trunk streams of nearly equal size. Arising to the west in glaciated landscapes marked with numerous shallow lakes, the Cannon River flows 54 miles into an area once a part of southeastern Minnesota's "Big Woods". To the south, the Straight River originates in former wetland basins, once

FIGURE 1


Dakota Co.
Rice Co.
Le Sueur Co.
Goodhue Co.
Steele Co.
N
Mississippi
River
Welch
Trout
Brook
Pine
Creek
North
Branch
Chub Creek
Byllesby Res.
Cannon
River
Cannon
Falls
Heath Creek
Northfield
Little
Cannon
River
Belle
Creek
Wolf Creek
Cannon
Prairie Creek
Lake
Dora
Faribault
Falls Creek
Cannon
Lake
Jefferson
Lake
Tetonka
Lake
Cannon
River
Waterville
Straight
Mud Creek
Medford
Rush Creek
Medford
Creek
River
Crane
Creek
Clear
Lake
Owatonna
Maple Creek
Turtle Creek
Straight
River
Location within Minnesota of
drainage basin depicted.
LEGEND
Sampling station
Live specimens found
Dead specimens found
Watercourse; dam
Lake
County border
Drainage basin border
Town
0
5
10
15
Statute miles

surrounded by tallgrass prairie and oak barrens, which are now drained, tiled, plowed and used as cropland.

From Faribault to the 7 mile long reservoir, Lake Byllesby, a distance of 27 miles, most of the river (71%, 1985 MNDNR stream survey) flows through a narrow, wooded corridor once surrounded by the "Big Woods", but now converted primarily to cropland. In the 25 miles from Lake Byllesby to its mouth, the Cannon River passes through the unglaciated or driftless area of southeastern Minnesota. Here the valley cuts deeply into late Cambrian and Ordovician sedimentary bedrock leaving the upland plateau 300 feet or more above it (Ojakangas 1982). Just upstream of Lake Pepin the Cannon River reaches the alluvial plain of the Mississippi River to which it is a tributary. The combined lengths of all trunk streams in the drainage total approximately 170 miles.

The streams within the Cannon drainage may be characterized as hardwater types with pH's ranging from 6.7 to 8.4 and total alkalinities of 121-240 ppm as carbonate ion (MNDNR 1977, 1983, 1984). They are primarily warmwater streams with the exception of a few small trout streams in the driftless area. The latter receive cold water discharged from subterranean aquifers that have been exposed by the deeply entrenched valleys. Average annual discharge at the mouth of the Cannon is 560 cubic feet per second (cfs) with maximums of up to 40,000 (Waters 1977) during flood conditions. Normals are from 100-200 cfs (MNDNR).

Minnesota Department of Natural Resources stream surveys conducted on the Cannon River drainage in 1977, 1982, 1983, 1984, 1985, and 1986 list 65 species of fish inhabiting the watershed as well as a variety of intertebrates and aquatic plants. Barriers to the movement of fish occur at several dams in the drainage (fig.1), a condition which demonstrably affects mussel distribution (figs.4-20) and species composition (figs.21-26). A relic mill dam at Welch, Minnesota effectively blocks fish movement from the Mississippi River. In Cannon Falls a hydroelectric dam creates the Byllesby Reservoir which inundated approximately 7 miles of former river bed. Old mill dams at Northfield, Faribault and Owatonna also block upstream fish movement year round in the trunk streams. Several smaller dams in the western headwaters lake region block movement during low flow, but allow fish to pass during moderate to high flow conditions. Two tributaries, the Little Cannon River and Maple Creek, have barrier dams which block fish movement year round.

Human alterations of hydrology in the Cannon River drainage began with the signing of an 1852 treaty with the Sioux Indians in which they relinquished all rights to land in the area. In 1852 Sioux Indians were the area's only inhabitants; in 1853 settlers began arriving and in 1855 the first dam was built on the Cannon River at Northfield. In 1865 the first railroad began serving the area. Between 1875 and 1880 there were 17 operating flour mills on the Cannon River from Northfield to Faribault, a distance of 16 miles. The prairie sod and "Big Woods", which had been intact for 10-12,000 years, were cleared and plowed and replaced by wheat fields. The wooded hillsides of the driftless area were cut for lumber and fenced as pasture. By the 1870's newspaper accounts of severe flooding were appearing regularly and efforts to alter the river to facilitate navigation by steam boats were being discussed (Northfield News library files).

Prior to the invasion of European immigrants, the headwater streams of the Cannon drainage meandered slowly through tall grass prairie broken occasionally by small oak savannahs on elevated glacial till and marshy wetlands in depressions, and, nearer to Faribault, extensive areas of the "Big Woods". The wetlands and protective vegetation stored storm water runoff, and released it slowly into the creeks which supply the trunk streams. Today, only 130 years later, 99 % of the wetlands are gone and many of the creeks are now deep, straight channels designed to discharge storm water rapidly and uniformly into the trunk streams thus keeping the former wetlands dry enough to plow, plant and harvest cash crops. These drainage ditch creeks now find their source in drain tiles laid beneath former wetlands. The protective prairie and woods have been replaced by fields whose soils have been stripped of their absorbant organic matter by intense cropping and now lie exposed for much of the year. Storm water now carries a heavy load of eroded soil that leaves the uplands rapidly and enters the straightened former creeks and trunk streams as a short lived torrent possessing enormous erosive power. Now, to the detriment of the mussel fauna, the once stable river bed is alternately scoured by these hydraulic forces and buried beneath new layers of sediment. While these are natural fluvial processes, their frequency and severity has increased dramatically with modern land use practices.

The Cannon River drainage today is a highly disturbed ecosystem whose physical conditions not only restrict the diversity and abundance of its own aquatic organisms, but through the addition of suspended soil particles and sand bedload, contributes to habitat degradation in the Mississippi River as well.

Mussel Resource

The freshwater mussels of the Cannon River Drainage have a long history of human exploitation. Aboriginal peoples are known to have harvested mussels, presumably as food and for utensiles (Emerson pers. com.), many years before the European immigrants discovered a use for them . Many shells of these mussels have been excavated during the investigation of archeological sites along the Cannon River near Red Wing, MN (Dobbs 1988).

In more recent times, a 1904 article in the Northfield News complained about the mess left by pearl seeking "clam hunters". In the 1930s, clammers in the area regularly harvested and shipped clam shells to supply the button industry (McCorkle, pers. comm.) Residents of the Cannon Falls area remember the Cannon River as being paved with clams in the 1920s, but by 1940 they had become a rarity, casualties of the depression and the economic opportunity shell sales offered its victims. Today, demand for mussels in the Cannon drainage is limited to the occasional angler interested in their use as bait. Mussels are far more threatened now by impacts resulting from poor land management practices and occaisional construction projects.

The pearl button industry stimulated scientific inquiry into the distribution and biology of mussels in the early 1900's. These studies remain an important source of information to malacologists and constitute the only source of information on the life histories of many species. After the decline of the pearl button industry, scientific inquiry subsided. Recent interest in freshwater mussels as indicators of riverine health and as environmental contaminant monitors, however, has renewed scientific interest. This, and demand for mussel shell to enucleate pearl oysters in Japan for the production of cultured pearls, has compelled resource agencies to gather baseline data on mussel distribution and abundance and to protect important sites from overexploitation.

SAMPLING SITES

Most sampling locations selected for the study correspond to Minnesota Department of Natural Resources, Section of Fisheries, stream survey sampling stations. Fisheries stations had been established within most of the streams of the watershed by a systematic method of characterizing streams (Sternberg 1978). These stations were used because they are representative of the habitats found within each stream, provide descriptions of stream physical characteristics, list fish species present at each station and are periodically monitored by resource personnel. On the Cannon River, sampling stations averaged 4.6 miles apart and ranged from 0.4 mile to 11.6 miles apart. Station lengths ranged from 500 feet in headwaters areas to nearly one-half mile in stations along the lower river.

MATERIALS AND METHODS

A sampling method was sought which could be easily replicated by resource personnel seeking to document changes in aquatic habitat quality as indicated by mussel density and diversity. After reviewing available literature (Buchanan 1983, Cawley 1984, Duncan and Thiel 1983, Fuller 1978, Isom 1979, Payne and Miller 1987, Smith 1980), it was decided that methodic quantitative sampling was neeeded to insure unbiased estimates of relative abundance, density, length-frequency and mussel-substrate associations and that qualitative searching would contribute to the estimation of species richness and a description of mussel distribution.

Quantitative sampling was accomplished using a belted transect. The transect sampler consisted of two 1/4 inch diameter polypropylene ropes separated 1/2 meter by 1/2 inch diameter PVC pipes on 1 meter centers. The result was a belted transect consisting of 1/2 X 1 meter frames. Lead weights were inserted into the ropes between each pipe. A 5 meter length of this belted transect was found to be the most convenient size to work with, especially in strong currents.

Transect sampling was conducted in each of two broadly described habitats, pool and riffle. The pool and riffle selected within each station were chosen primarily for ease of access and their location subsequently described in the field notes.

In each pool the point located midway between upper and lower pool boundaries was determined, and the sampler laid out perpendicular to the longitudinal pool axis in order to provide a cross sectional sample of the pool. The sampler was moved stepwise across where stream width exceeded 5 meters. Each frame was numbered beginning with the left ascending stream bank and searched thoroughly by sight and feel to a depth of 75-100 mm. Within each frame all live mussels were identified and counted, depth recorded and substrates subjectively typed into one of the following 10 catagories: SILT, SILT/SAND, SILT/GRAVEL, SILT/RUBBLE, SAND, SAND/GRAVEL, SAND/RUBBLE, GRAVEL, GRAVEL/RUBBLE, or RUBBLE.

Length, height and width of all live mussels found in the transects were measured with a digital calipers to the nearest 0.1 mm. Length was defined as the maximum distance, anterior to posterior, parallel to the hinge ligament (Ortman 1920); height as the greatest distance, dorsal to ventral, at 90 degrees to the maximum length line (except in species with pronounced ala where the umbome was used as the most dorsal reference point. Ala refers to dorsal, wing-like extensions of the shell which are often broken or worn away in older mussels);and width as the maximum distance through both valves at 90 degrees to the maximum length line. Dead shells encountered while searching the transect frames were identified.

This entire sampling procedure was repeated at points halfway between the midpoint and the upper and lower pool boundaries thus providing 3 cross sections within each pool that could be treated as a single sample.

Riffle habitat was sampled in a manner similar to pool. In rubble substrates all stones were removed from the frames in the searching process. At a few stations riffle habitat was searched less extensively than pool habitat because of the time consuming nature of searching through coarse substrates, at these stations, one transect was searched.

Qualitative sampling consisted of walking the length of the entire station searching for additional live or dead mussel species. Attention was paid to microhabitats, such as eddies and side channels, or protected remnants of the former stream channel which provide suitable mussel habitat. Muskrat middens were searched for recent dead shell and emergent sand and gravel bars were searched for both recently dead and subfossil (very old) shells, which are often deposited by high water.

A record of all live species and of species represented only by dead shell was kept for the production of maps depicting past and present mussel distribution in the Cannon River drainage system. At most stations, only dead shell was retained as voucher specimens for deposit in the University of Minnesota's Bell Museum mollusk collection. When a species was not represented by dead shell or where identification was difficult, some live individuals were collected and preserved in ethanol.

All data collected was entered into a Lotus 123 worksheet to form a comprehensive computer database from which statistical relationships could be extracted and graphs produced.

RESULTS

SUMMARY

A total of 1344 live mussels representing 15 species were found at 61 sampling stations in the Cannon River drainage during the 1987 field survey. Of these, 888 mussels representing 12 species were found within transects at 39 stations. No mussels were found at 10 of the stations. A graph depicting the drainage wide relative abundance of these 12 species appears in fig. 3.

Of special importance was the discovery of live individuals of Actinonais ellipsiformis, a species first recorded in Minnesota during a 1983 DNR stream survey of the Straight River (Enblom 1983) only as dead shell; and the description of a large mussel bed at Faribault. A list of the mussel species inhabiting the Cannon River Drainage and the abreviations used in various graphs and tables appears in fig. 2.

DISTRIBUTION.

The location of each sampling station appears in figure 1. From live mussel and dead shell location data, distributional maps for each species were prepared (figs. 4-18). These maps illustrate the present and past distribution of each species. Evidence of distributional disruptions is very apparent for some species and usually appears related to human induced boundaries such as those created by dams or point-sources of pollution. Dead shell records indicate that 10 of the 15 mussel species found in the Cannon drainage during this survey were once distributed more widely. The present reduced distribution of the following 9 species is easily seen on these maps: Actinonaias carinata, A. ellipsiformis, Eliptio dilatata, Lampsilis ventricosa, Lasmigona compressa, L. costata, Ligumia recta, Pleurobema coccineum, Strophitus undulatus.

Less obviously, Lampsilis siliquoidea has apparently been extirpated from Chub Creek. Chelburg (1974) reported the complete extirpation of L. siliquoidea from the Blue Earth River in Minnesota while L. ventricosa continued to be distributed throughout the drainage. In the Cannon River, live L. ventricosa are now limited to that portion of the river downstream of the dam at Northfield (map fig.10). This seemingly reversed situation and the reasons for one species decline in one drainage and not the other are unknown; both drainages encompass areas of intensive agriculture and both species share common fish hosts (Fuller 1978).

No evidence of a wider past distribution was seen for five other species which include Anodontoides ferussacianus, Anodonta grandis, Lasmigona complanata, Leptodea fragilis, and Proptera alata.

Interestingly, _Leptodea fragilis_ was found only during qualitative searching below the Welch mill dam near the Cannon-Mississippi confluence where it was represented by several size classes.

Changes in the relative abundance of mussels occurs in conjunction with dam locations in the drainage (figs. 21-26) and is quite dramatic for some species.

DENSITIES.

Mussel density/M^2 was calculated using transect data at each station (tables 1-2).

Densities as high as 122 mussels/M^2 from a single transect frame were recorded from within the Faribault bed (Cannon stations 4c&d). This bed had mean densities of 30.5 mussels/M^2 in pool and 3.4/M^2 in riffle habitats (fig.25).

Straight and Cannon River trunk stations, excluding the Faribault bed, had pool habitat mussel densities ranging from 0 to 3.24/M^2 with a mean of 0.55/M^2 and riffle habitat mussel densities ranging 0-0.64/M^2 with a mean of 0.18/M^2 (table 1).

The mean mussel density in tributary stream pool habitat (table 2) was 0.47/M^2 and ranged from 0 to 5.5/M^2 in Turtle Creek where _Anodontoides ferussacianus_ accounted for 93% of the mussels. Riffle habitat was sampled at 8 of the 16 tributary stations. No mussels were found in tributary riffle habitat. Less than 5% of all mussels found in this survey were in riffle habitat.

In general, where densities were highest diversity was low and 1 or 2 species contributed to most of the density. In the Faribault bed, 65% of the mussels collected were _Proptera alata_ and 27% _Lasmigona complanata_; together they comprised 92% of all mussels present. A high diversity of 11 species occured at two widely separated trunk stations (fig.20), one in the Straight River just upsteam of Owatonna and another in the Cannon River just downstream of the Northfield dam. In contrast, 2 trunk and 6 tributary stations had only 1 species present. Chub Creek's 5 live species distinguish it as having the most diverse mussel fauna of any tributary in the Cannon drainage.

LENGTH-FRENQUENCIES.

Although mussels were measured at all stations where they occured, analysis of length-frenquency information was practical at only those where individual species were collected in large numbers. To reduce collection bias, only mussels found in transect samples were used in preparing length-frenquency graphs. Sufficient data for this analysis were collected on 5 different species at 3 locations.

At Turtle Creek (station 1B) 5 millimeter length increments were used to graph the length-frequency relationship of Anodontoides ferussacianus, a small mussel species (fig. 27); for the 4 larger species (figs. 28-32), 10 millimeter increments were used. In general, the larger the number of increment catagories occupied by mussels the more frequently juvenile recruitment is inferred to have occured. The number of individuals within each catagory is inferred to be an indication of recruitment success, perhaps in a single season. A discussion of the limitations of this analysis is offered later (page 10).

These graphs suggest that the sampling methods used are inadequate for locating mussels less than 30 millimeters in length. At Turtle Creek several juvenile Anodontoides ferussacianus under 10 millimeters in length were found out side of the transect with the aid of a sieve.

In the Faribault bed (figs. 28-31), the Proptera alata and Lasmigona complanata populations were represented by 10 and 8 size catagories respectively. However, since all were well over the 30mm size barrier mentioned earlier, it would appear that recent large-scale recruitment of these mussels has not occured in the bed. In Turtle Creek, Anodontoides ferussacianus (fig. 27) was represented by 10 size catagories beginning at 35 mm and continuing throughout its reported size range (Baker 1928). At the Waterville Area Section of Fisheries Northern Pike Spawning Station, Lampsilis siliquoidea (fig. 32) showed similar size distribution with the exception of a missing size class between the two most commonly occuring catagories. Two possible explanations are that this missing size catagory does not exist due to growth patterns or, more probably (given the rather even distribution between the next largest catagories), that no mussels were recruited in a past season, perhaps due to drought conditions which have, in the past, caused this stretch of the Cannon River to actually dry up (Gates pers com).

SUBSTRATES.

One of 10 substrate types were assigned each mussel collected from transects. The frequency of mussel occurrence in each substrate type is presented in fig. 33. Of the mussels collected during this survey, 69% were associated with substrates containing silt. This is consistent with the fact that 95% of the mussels came from pool habitats where silt is likely to accumulate. Even the riffle loving species Actinonaias elipsiformis (Van der

Schalie and Van der Schalie 1963) was found in silt substrates.

DISCUSSION

For a detailed discussion of each mussel species found in the Cannon River drainage, turn to page 11.

FARIBAULT MUSSEL BED

Four of the most common and widespread species in the Cannon and Straight River trunks (*Anodonta grandis*, *Lampsilis siliquoidea*, *Lasmigona complanata*, and *Proptera alata*) comprise the mussel fauna of this bed. It occupies a unique river segment which lies between the Straight and Cannon River's confluence at its downstream end and the Faribault Woolens Mill dam at its upstream end. This location provides a gathering point for potential host fish and a supply of well oxygenated and nutritive surface water from the reservoir while offering some protection from the river bed load during floods. While low in species diversity, the bed supports mussel densities comparable to the commercially important beds in the Mississippi River. Low diversity may be the result of poor water quality in a river which has historically recieved the pollutants of industrial and munincipal functions. High densities are probably the result of the above mentioned fish-host staging area and the protected location.

Given the high density of mussels in the bed, successful fertilization is surely enhanced. The possibility of the bed providing juveniles to other parts of the Cannon River drainage seems likely. The Woolen Mills dam effectively blocks fish movement in the Cannon River. Because of this, fish occasionally congregate over the mussel bed while attempting upstream migration. Host fish concentration over this bed at a time when glochidia are ready for discharge would result in substantial innoculations. The subsequent movement of infected fish into other areas would distribute mussels widely in the Cannon and Straight River drainages.

Length-frenquency data from the Faribault bed (figs. 28-31), however suggests that recent large-scale juvenile recruitment has not occured. Perhaps to retain or reattract the infected fish in numbers sufficient for significant in-bed recruitment to occur a prolonged high water event or a second event following host infection is necessary.

The significance of length-frenquency analysis in a population of large, old individuals may be obscured by size overlap among different age classes and a slower growth rate

(Haskins 1954). It may be that the clustered length-frenquencies in the Faribault bed reflect a much larger span of time in which small numbers of juveniles are recruited at a steady rate. A close study of age classes here could possibly reveal the actual recruitment pattern. However, physical disturbances such as the reservoir drawdown which occurred in 1987 (and nearly dewatered the bed) can produce additional growth interruption lines which would make this analysis inacurate as well (Haskins 1954, Isley 1914).

Contribution to water quality

Large mussel beds such as the one found at Faribault may play an important role in nutrient cycling and contribute to water quality by "cleansing" the water which they take in. As filter feeders, freshwater mussels remove a variety of particles from the water. Allen (1914) measured a flow of 24 ml/minute through *Lampsilis luteola* in which protozoans, green and bluegreen algae, diatoms, molds, spores, ova, spermatozoa and miscellaneous plant and animal fragments were retained as food. Coker etal (1921) found vegetable detritus to be the most important food of mussels. In the process of filter-feeding, mussels accumulate heavy metals and other contaminants in their tissues and in shell material (Bedford etal 1973,Havlik etal 1987,Rosenberg etal 1986). Deposits in the shell can be useful for determining past contamination in streams (Havlik etal 1987); each growth increment preserves a record of the animals response to its environment (Rosenberg etal 1986). The importance mussels may have to water quality in sequestering contaminants is not well known, but given Allens (1914) mussel filtering rate, a dense mussel bed could be capable of filtering large quantities of silt and detritus to which contaminants are commonly adsorbed (Rosenberg etal 1986, Cole 1983).

A population estimate of the entire Faribault bed can be made using the sample densities of pool and riffle habitats sampled during the 1987 survey. Using the MNDNR Fisheries Stream Survey Report (1983) physical data, the area occupied by each habitat within the bed can be determined. The resulting combined density of 24 mussels/M^2 multiplied by the beds approximate area (21.3 meters X 320 meters) gives an estimated 163,584 mussels. Assuming each mussel siphons 24ml/minute (Allen 1914), mussels in the Faribault bed are filtering 1.48 million gallons of water/day or 2.3 cubic feet per second.

Although these figures are highly speculative, the Faribault bed may represent the kinds of mussel desities once typical of the Cannon River. When considering that it may be filtering 10% of the water flowing over it (estimated flow of 20-25 cfs based on DNR Stream Survey Report), it is not difficult to imagine the effect on water quality of many perhaps larger beds occuring nearly continuously throughout the length of the river. Not only has modern civilization added contaminants to the river, it has reduced the river's capacity to cleanse itself.

MUSSELS OF THE CANNON RIVER DRAINAGE

Actinonaias carinata - Mucket

The mucket was an important source of material for the button industry (Coker 1919) and was apparently harvested extensively in the Cannon River drainage as recently as 1936 (McCorkle 1987, pers. comm.). In this survey, the only live individuals were found at two sampling stations between the Northfield dam and Lake Byllesby; at one of the stations they comprised 30.6% of the live mussels found. Dead shell records indicate a much wider distribution in the drainage in the past (fig. 4). Overall, muckets accounted for only 1.5% of the mussels collected in this survey (figure 3).

Charlotte Dawley (1944) reported this species from the Cannon River at Randolph, Minnesota in 1934 (the area of current distribution) and the Straight River at Medford, Minnesota (today only dead shell are found at Medford). Harvesting for the button industry may have contributed significantly to this species' decline. Perhaps ironically, the greatest abundance of this mussel occurs in a location where Bud McCorkle (1987, pers. comm.) remembers seeing a clam harvestor's camp in the 1930s. Fuller (1978) lists 12 hosts for *Actinonaias carinata*; all but one are present in the Cannon River.

Actinonaias ellipsiformis (*Venustachoncha e. elipsiformis*)

Ellipse

This species was not reported from Minnesota in Dawley's (1944) thesis on unionid distribution. Enblom (1983) reported dead shell from the Straight River during a MNDNR stream survey. During the 1987 survey, 17 live individuals were collected in the Straight River above Owatonna, 1 from Wolf Creek in Rice County, and 1 from the Cannon River below the Northfield dam. Although presently quite limited in distribution, evidence from dead shell indicates a much wider occurrence in the past (map fig. 5)

Mathiak (1979) found the ellipse only in eastern Wisconsin. VanderSchalie (1963) reports it from Iowa and Wisconsin. Seven individuals were found during the Ellis survey in Lake Pepin (VanderShalie and VanderSchalie, 1950).

Fuller (1980) reported that the Michigan DNR lists the ellipse as state "threatened". In Minnesota, the ellipse population found above Owatonna in the Straight River may be unique; it produced 84% of the individuals found in this stretch of the river during the survey; and, at one station, contributed 35.5% of the total mussels found.

The VanderSchalies (1963) report this species "to be restricted to zones with firm bottom conditions consisting of sand and coarse gravel which are subjected to moderate or strong current". In this survey, all 19 specimens were found in pool habitat, 17 from silt, and none from gravel. The cause for this discrepancy may lie in the as yet unidentified fish host (or hosts). In Michigan, where the VanderSchalies' investigations took place, the ellipse may use a riffle loving fish as its host while in the Straight River of the Cannon drainage (where most of the ellipse were found) it may use a host fish that frequents quiet pools. Perhaps the ellipse does not use a fish as its host. Ingram (1941) reported glochidial metamorphosis on tadpoles, similarly, the salamander mussel, Simpsonaias ambigua, uses the mudpuppy, Nectarus, as its host. It may also be that the Straight Rivers riffle habitats are less stable due to frequent flooding, and the elipse may be routinely displaced into pools downstream of the riffles.

Shell size was also significantly different between the two studies. In Michigan, the VanderSchalies (1963) found the largest individuals to reach about 55 mm in length compared to a mean length in the Cannon drainage of 69.5 mm with a maximum of 85.7 mm and a minimum of 57.6 mm. The agriculturally enriched waters of the Cannon drainage may be responsible for the attainment of greater size.

Anodonta grandis - Floater

The floater comprised approximately 5% of specimens collected during the survey (fig. 3). Although not present at all stations, it is probably the second most widely distributed mussel in the Cannon drainage (fig. 6). It is seldom very abundant except in Chub Creek where many individuals, including juveniles, were qualitatively collected. It was the second most commonly encountered species in Mathiak's (1979) survey of Wisconsin. Fuller (1980) lists 22 different fish hosts, many of them common to the Cannon drainage. Dawley (1944) reported this mussel from the Straight River at Medford (1934) and the Cannon at Randolph (1934). During the 1987 survey it was the only mussel species found in the westernmost extreme of the Cannon River headwaters and was one of only four species inhabiting the lowermost sampling station. The floater has been characterized as preferring soft substrates (Dawley 1944) but capable of living in a variety of substrate types

(Fuller 1978, Mathiak 1979, Dawley 1944). Most *Anodonta grandis* collected during this study were found in silt or silt/sand substrates where they often were buried to a point where only the siphonal apertures were visible.

Anodontoides ferussacianus - Cylinder

Minnesota's most common small river and creek mussel species, the cylinder (Dawley 1944) was found to inhabit all but two of the creeks which supported live mussels during this survey (fig. 7). The species is also found in the Straight River and at one site on the Cannon River; it was absent, however, from the western headwaters region. The cylinder was most abundant in Turtle Creek, Steele County, where 55% of the specimens were collected. Several young of the year were found in this creek as well as a large range of older size classes which is an indication of good reproduction and recruitment (fig. 27). Eight small-stream fish species act as host for this mussel (Fuller 1980); five are known to inhabit Turtle Creek (MNDNR 1986). The cylinder was commonly found protruding cigar-like from the stream bank in quiet pools where silt or silt/sand was the most common substrate.

Eliptio dilatata - Spike

Dead shell records for the spike indicate a once continuous presence from the Straight River upstream of Owatonna to the lower reaches of the Cannon River downstream of Cannon Falls and including two small tributary streams (fig. 8). Dawley (1944) had no record of this species from the Cannon drainage and characterized it as a large and medium size river species in Minnesota. The spike is still commonly found in Lake Pepin where it develops a much thicker shell than that found in the Cannon drainage specimans.

Shell remains were found in Maple and Prairie creeks indicating the spike's past presence there. The only live specimens collected in this survey came from the Cannon River east of Waterville, three stations on the Straight River in the Owatonna vicinity, and a single, old individual below the Northfield dam. Representing only 1% of the mussels collected during this survey (fig.3), the spike has been nearly extirpated from the drainage. Host fish are present in most areas.

Lampsilis siliquoidea - Fat mucket

The fat mucket is widely distributed in Minnesota's lakes and rivers (Dawley 1944). With the exception of the smaller tributary streams, this species is also distributed throughout the Cannon drainage (fig 9) where it ranks third in abundance (fig.3). For unknown reasons, it appears to have been extirpated from Chub Creek in Dakota County which supports an otherwise healthy mussel community. In the upper reaches of the Cannon, just north of Waterville, it is the most abundant mussel. The wide range of sizes that are present at this sampling station (fig. 32) are indicative of a healthy, reproducing population. Below the dam at Owatonna, however, it is only represented by a few very old individuals. Most of the 13 species listed as hosts to this mussel's glochidia (Fuller 1980) are found in the Cannon drainage.

Lampsilis ventricosa - Pocketbook

Recorded from the Straight River at Medford in 1934 (Dawley 1944), this species was collected during this survey from Medford downstream to the dam at Northfield only as dead shell, but often in abundance. No shell evidence was found in the Cannon above the Faribault Woolen Mills dam. From the Northfield dam downstream, however, it became a common component of the mussel fauna (figs. 10 & 26). Below the Northfield, MN dam, it contributed nearly 20% to the mussel population. Six fish species common to the Cannon drainage are host to this species (Fuller 1980). Lampsilis ventricosa was probably harvested for the pearl button industry along with Actinonaias carinata. Coker (1919) characterized this species as being of better shell quality in small rivers than in large.

Lasmigona complanata - White heelsplitter

This mussel is the most widely distributed species in the Cannon drainage (fig 11) and ranks second in total numbers (fig. 3). Dawley (1944) reports this species from two other southeast Minnesota rivers, the Root and the Zumbro, but not from the Cannon system. She discusses a variety of this mussel, katherinae, as having a smaller, thicker shell with a reduced ala or wing and inhabiting smaller rivers in the state. Her Root River specimen is labeled katherinae but not her Zumbro River specimen. The Cannon drainage appears to produce both varieties, katherinae from the Faribault area and a form quite similar to the Mississippi River white heelsplitters from Lake Byllesby. The specimens from the remainder of the system are less distinctly one variety or the other.

The apparent facultative and adaptive use of the carp (Cyprinus carpio) as a glochidial host (Fuller 1980) no doubt contributes to this mussel's wide distribution. The carp ranges widely throughout the drainage of the Cannon

River, often reaching nuisance population levels. The white heelsplitter was not sought for the button trade during the 1930s (McCorkle, pers. comm.).

Lasmigona compressa - Creek Heelsplitter

Typically a small stream species (Dawley 1944, Fuller 1980, Mathiak 1979, VanderSchalie and VanderSchalie 1950), the creek heelsplitter was found in Chub Creek, at two stations above the dam at Owatonna and a single old specimen below the Northfield dam (fig 12). A recently dead shell came from Turtle Creek and dead shell was encountered at several Cannon River trunk locations. Overall, the creek heelsplitter is rare in this drainage, only six live individuals were found during the course of the survey. There are no previous records in the Cannon drainage or from Mississippi River tributaries below the Twin Cities (Dawley 1944). Mathiak (1979) reports it from the Wisconsin River and headwater streams of the Black and Chippewa rivers in Wisconsin.

Lasmigona costata - Fluted shell

Not previously reported from the Cannon River, the fluted shell has been present historically from the Mississippi River in southeast Minnesota (Dawley 1944, 1947). Grier and Mueller (1922) found it only above Lake Pepin and considered it rare. Fuller (1980) considers it a small-stream species "probably extinct" in the Upper Mississippi River. In the Cannon drainage, shell remains indicate this species was once distributed throughout the main trunk (fig 13). During this survey, however, only three live and obviously old individuals were collected, one each from widely separated sampling stations. From the evidence collected, the extirpation of *Lasmigona costata* from the Cannon drainage seems imminent. The only recorded host for this mussel is the carp, *cyprinis carpio* (Fuller, 1980); obviously lack of a host is not to blame for the fluted shell's demise. Mathiak (1979) considered it common in Wisconsin other than in the southwest part of the state. Wilson and Danglade (1914) reported the fluted shell to be one of the principal commercial button shells in the Red River of northwestern Minnesota. It is not known if they were commercially harvested in the Cannon, but it seems reasonable to assume that they were.

Leptodea fragilis - Fragile papershell

Considered a large-river species (Dawley, 1947), the fragile papershell was found only in the lower reach of the Cannon River downstream of the Welch mill dam (fig 14). One of four species found here during qualitaitve searching, it appeared to be the most common. Recent dead shell from Belle Creek, which is tributary to this reach, suggest its presence there as well. The fragile papershell is considered common in the Mississippi River (Fuller 1980), although Thiel (1981) and Fuller (1978) reported a decline in abundance since the 1920 Grier and 1930-37 Ellis surveys. The lack of records above Welch suggests that it is a recent recruit to the Cannon River fauna from the Mississippi River via its only recorded host the freshwater drum, Applodinotus grunniens (Fuller 1978). Its recent arrival to the Cannon drainage could indicate a local increase in abundance in the Mississippi from which glochidia infected drum could migrate. Recruitment of juveniles to this river reach is ongoing, as evidenced by several size classes collected during sampling.

Ligumia recta - Black sandshell

Apparently extirpated from most of its former range in the Cannon drainage (fig 15), the black sandshell still persists above Owatonna in the Straight River and between Northfield and the Byllesby reservoir in the Cannon River trunk. The shells of this species are exceptionally thick and heavy in the Cannon River and may have been valuable to the button industry (Coker 1919). Like Actinonaias carinata, evidence of continuing reproduction in this species was found, perhaps ironically, only at the sampling station where clammers were reported to be active in the 1930s (McKorcle, pers. comm.). During this survey, Ligumia recta accounted for less than 1% of the mussels collected (fig. 3).

Pleurobema coccineum (P. sintoxia) - Round Pigtoe

From dead shell evidence it appears that the round pigtoe was once distributed over the length of the Cannon trunk downstream of Faribault and in the Straight River from well above Owatonna probably to its mouth. During this survey the round pigtoe was represented by only two widely separated, live individuals (fig 16). Representative dead shell was not difficult to find at most stations although it was not plentiful. Historically the shell was of marginal value to the button industry (Coker 1919) but was probably harvested along with the more valuable species in the hope of discovering pearls, as was customarily done with all mussels (Coker, 1919).

Based on evidence gathered during this survey, the final extirpation of this species from the Cannon drainage system would appear imminent . Fuller (1978) lists two fish hosts for Pleurobema; of these, the bluegill (Lepomis macrochirus) is the only one reported from the Cannon drainage and has not been recovered routinely there during MNDNR stream surveys (DNR 1984-83, 1983, 1977, 1974).

The taxonomy of this species is confusing (Fuller 1978, Dawley 1944, Grier and Mueller 1923, Baker 1928, Coker 1919, VanderSchalies 1950, Ortman 1920). Dr. Stansbury of Ohio State University now refers Pleurobema in this region to the species sintoxia (Stansbury 1987, pers. comm.) while Baker (1928) used the name coccineum. Ortman (1920), in his discussion of shell obesity, used Pleurobema cordatum coccineum to describe compressed shells in which the ratio of depth or diameter to length is less than 50% and Pleurobema cordatum cattilus to describe those over 50% in ratio, with coccineum occurring in the headwaters and cattilus downstream in the larger portion of rivers. The two individuals found in this survey had ratios of 37%, just above Northfield, and 35.8% upstream of Owatonna in the Straight River. Apparently these would have been considered Pleurobema cordatum coccineum in 1920, but today, perhaps, a small river variant of Pleurobema sintoxia.

Proptera alata (Potamilus alatus) - Pink heelsplitter

Comprising over 44% of all mussels collected during this survey (fig 3), Proptera alata was common in the Cannon River trunk and from the Straight River downstream of the Owatonna dam (fig 17). Because it depends on the freshwater drum (Applodinotus grunniens) as its host (Fuller 1978), its distribution is limited to those waters frequented by this fish. Its occurrence in two small streams, Chub Creek and Crane Creek, may be linked to their headwaters' connection to lakes towards which the freshwater drum migrates periodically. The absence of shell records upstream of the Owatonna dam is not understood except that this dam now presents an obstacle to the upstream movement of its host which is reported only from waters below the dam (MNDNR, 1980).

In the dense bed below the Faribault Woolen Mills dam, the pink heelsplitter represents 64.5% of the sampled mussel population. Here, in one 0.5 square meter transect frame, fifty of the sixty-one individuals found were of this species. Nearly 73% of the Pink heelsplitters found in the survey came from this bed.

Strophitus undulatus - **Strange Floater**

Today, the squawfoot is restricted to the Straight River in the vicinity of Owatonna where it occurs both above the dam and in its tailwaters. Based on dead shell evidence, this mussel apparently was once distributed along most of the length of the Straight River and in the Cannon River from Faribault downstream to Northfield. Dead shell evidence was also seen from one station on the Little Cannon River (fig 18).

Being a thin shelled species, it is probable that dead shell of Strophitus undulatus does not persist long in the environment and that information concerning the extent of its former distribution no longer exists. The reasons for this mussel's decline in the Cannon drainage are difficult to assess; it apparently inhabits a variety of substrates (Dawley 1944, Fuller 1978), and its glochidia have been reported to be capable of development independent of a fish host (Lefevre and Curtis 1911).

CONCLUSIONS

As a pilot mussel survey, an important task was to develop standardized field sampling techniques. The belted transect, with its 1/2 meter by 1 meter frames, proved to be very useful. Transect placement in the stream is done uniformly according to an easily duplicated plan. Because of the boundary it provides, every field investigator is forced to methodically search each frame of each transect in a similar way. Its use could lend the kind of consistency to mussel sampling that was envisioned in the development of standardized MNDNR stream surveys. These searching methods are easily duplicated by nearly anyone and reduce the sampling bias which individual investigators might otherwise bring with them to the field when using other, less restrictive searching methods. The results of transect searches are quantitative and can be used to estimate mussel density and to describe species relative abundance.

Transect searches are not meant to replace the need for a thorough qualitative search. An accurate description of species richness depends on the discovery of additonal mussels using qualitative searching techniques. Qualitative searching also provided most of the dead shell records for the Bell Museum collection as well as those used in preparing the distributional maps.

The continuation of this mussel survey into other river drainages will provide good baseline data which can be used by resource people to leverage the protection of aquatic environments. For example, the discovery and description of the Faribault mussel bed helped to alter a Minnesota DNR Division of Waters permit for repair of the dam immediately upstream. Restrictions designed to protect the tailwaters habitats were incorporated into the permit conditions because of Section of Fisheries concerns which included the health of the mussel bed. As a result of these permit restrictions, the dam repair contractor has decided on alternative construction methods which will leave the critical tailwaters habitat completely undisturbed.

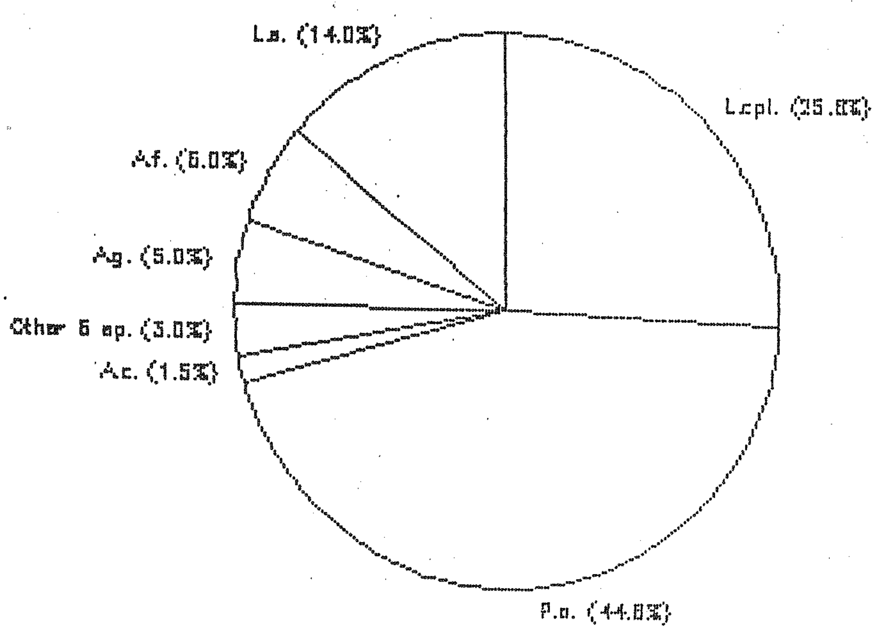
CANNON RIVER DRAINAGE
FRESHWATER MUSSELS
(fig. 2)

SPECIES	COMMON NAME	AB.
Actinonaias carinata	- Mucket	A.c.
A. ellipsiformis	- Ellipse	A.e.
Anodonta grandis	- Floater	A.g.
Anodontoides ferussacianus	- Cylinder	A.f.
Eliptio dilatata	- Spike	E.d.
Lampsilis siliquoidea	- Fat Mucket	L.s.
L. ventricosa	- Pocketbook	L.v.
Lasmigona complanata	- White Heelsplitter	L.cpl.
L. compressa	- Creek Heelsplitter	L.cmp.
L. costata	- Fluted Shell	L.cos.
Leptodea fragilis	- Fragile Papershell	L.f.
Ligumia recta	- Black Sandshell	L.r.
Pleurobema sintoxia	- Round Pigtoe	P.s.
Potamilus alatus	- Pink Heelsplitter	P.a.
Strophitus undulatus	- Strange Floater	S.u.

CANNON RIVER DRAINAGE
MUSSELS COLLECTED
BY TRANSECT

SPECIES	ABBREV.	NUMBER	% OF TOTAL
Actinonaias carinata	A.c.	13	1.46%
Actinonaias ellipsiformis	A.e.	2	0.23%
Anodonta grandis	A.g.	44	4.95%
Anodontoides ferussacianus	A.f.	53	5.97%
Eliptio dilatata	E.d.	9	1.01%
Lampsilis ovata ventricosa	L.v.	7	0.79%
Lampsilis radiata siliquoidea	L.s.	124	13.96%
Lasmigona complanata	L.cpl.	229	25.79%
Lasmigona compressa	L.cmp.	0	0
Lasmigona costata	L.cos.	0	0
Leptodea fragilis	L.f.	0	0
Ligumia recta	L.r.	7	0.79%
Pleurobema sintoxia	P.s.	1	0.11%
Proptera alata	P.a.	398	44.82%
Strophitus undulatus	S.u.	1	0.11%
TOTAL MUSSELS		888	100.00%

MUSSEL RELATIVE ABUNDANCE



ACTINONAIAS CARINATA - MUCKET

(Actinonaias ligamentina)

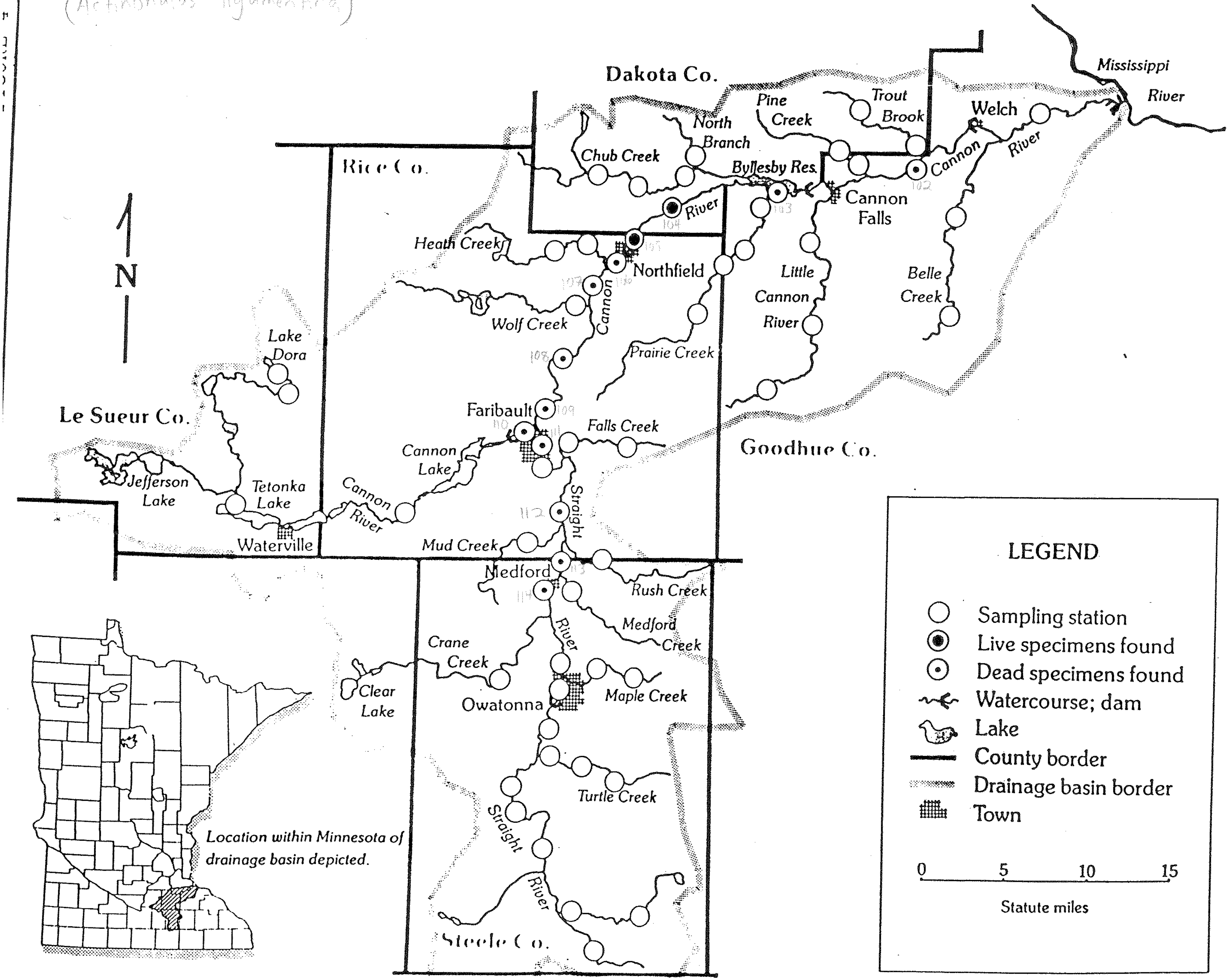
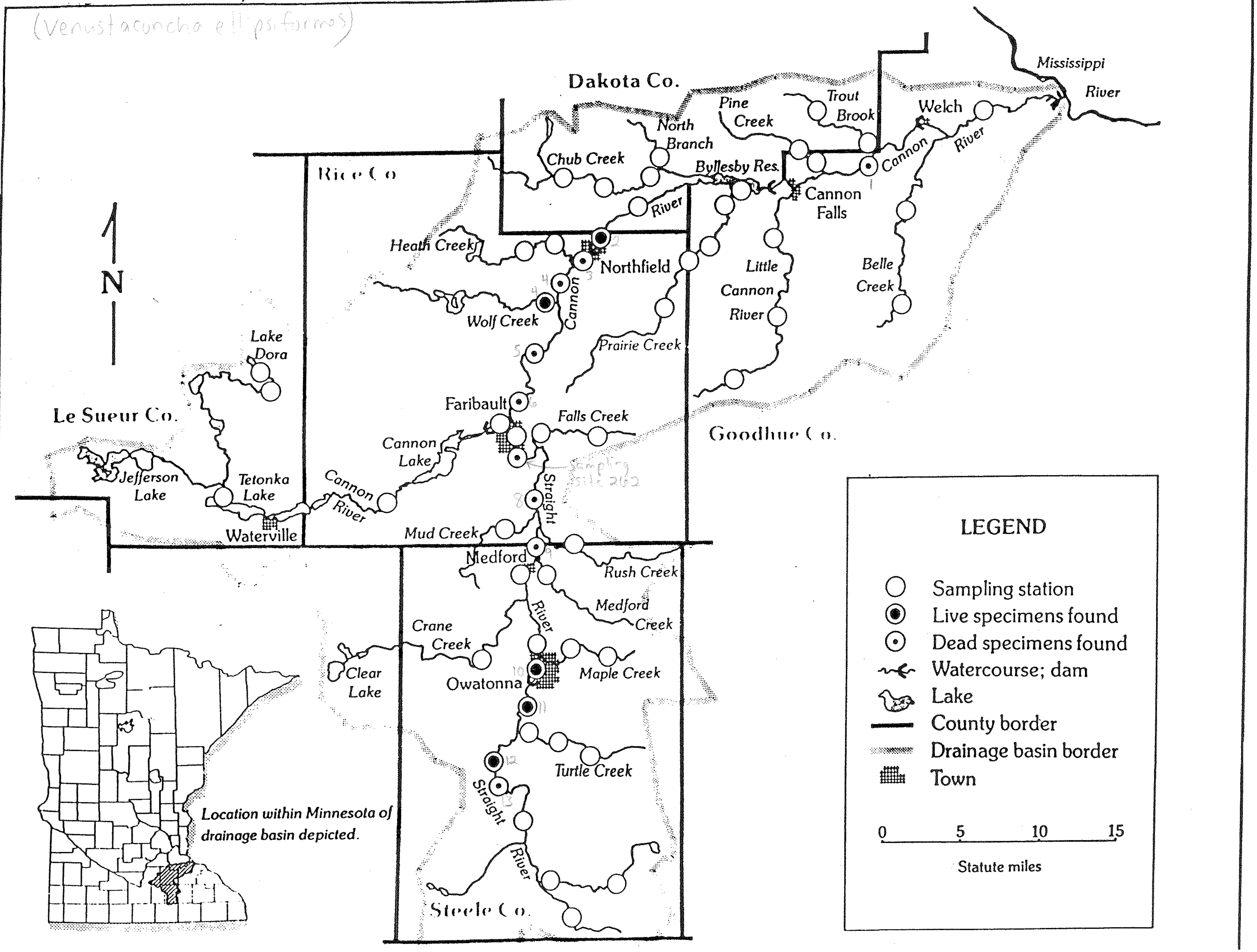


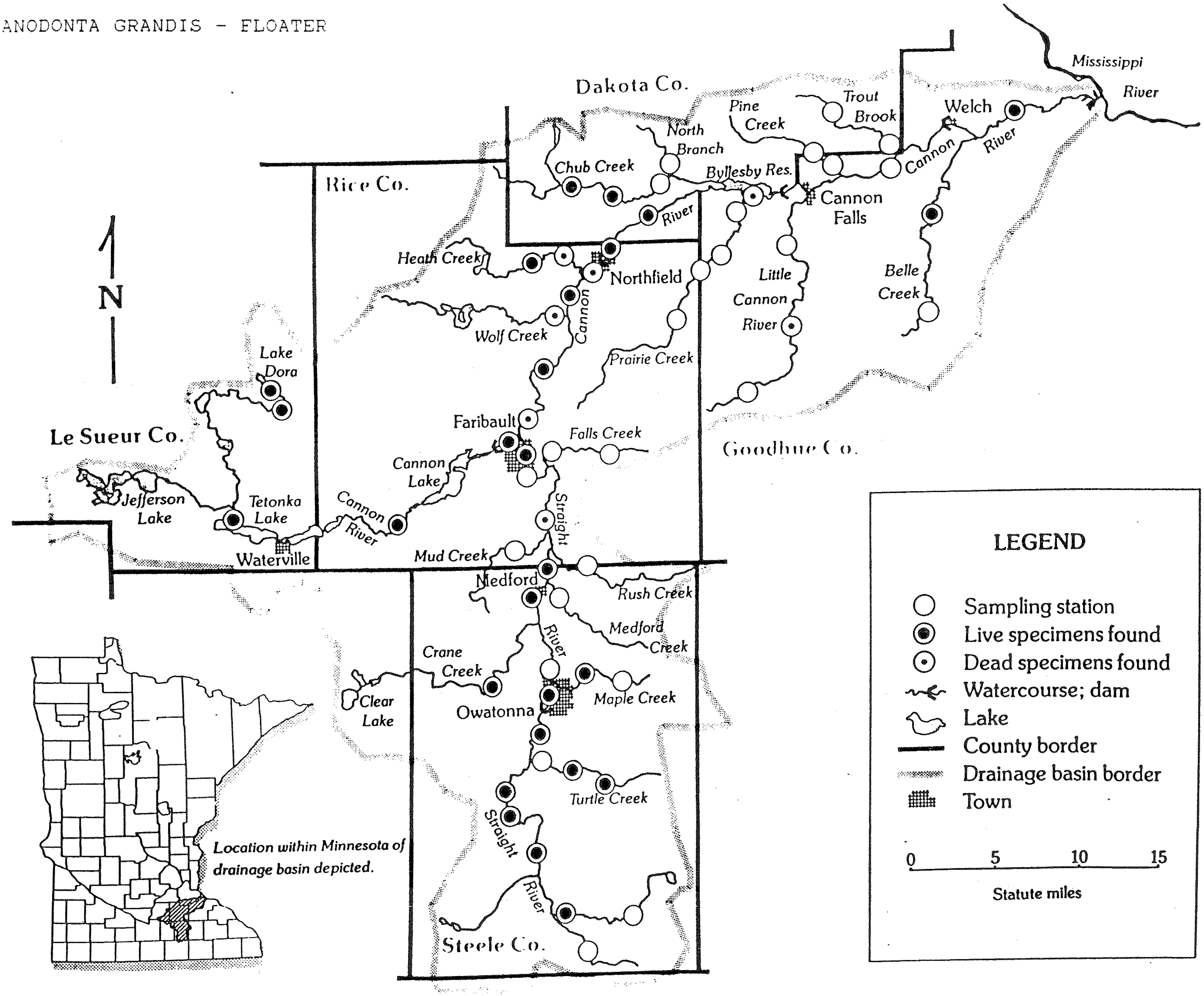
FIGURE 5

ACTINONAIAS ELLIPSIFORMIS - ELLIPSE

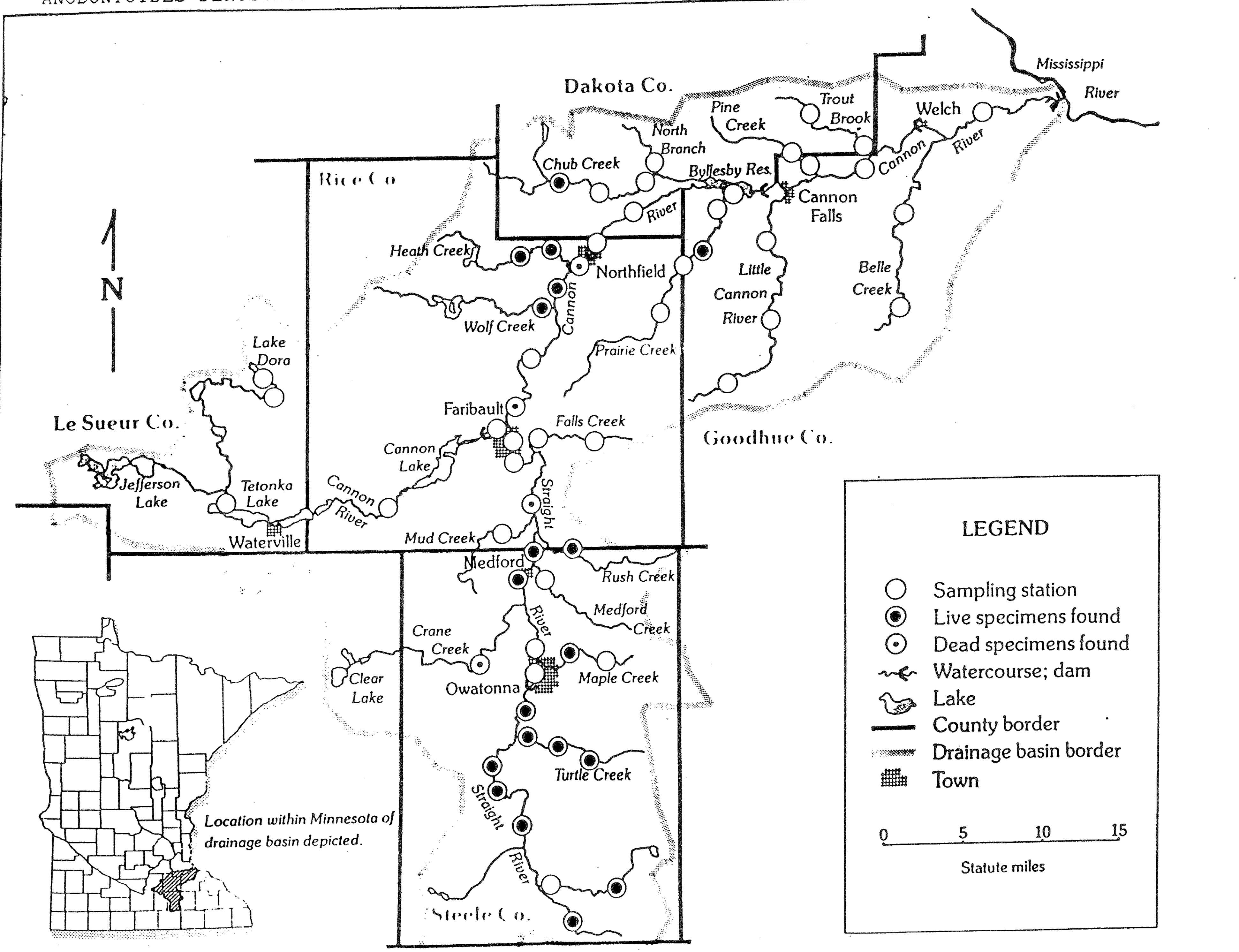
(Venustaconcha ellipsiformis)



ANODONTA GRANDIS - FLOATER



ANODONTOIDES FERUSSACIANUS - CYLINDER MUSSEL



ELIPTIO DILATATA - SPIKE

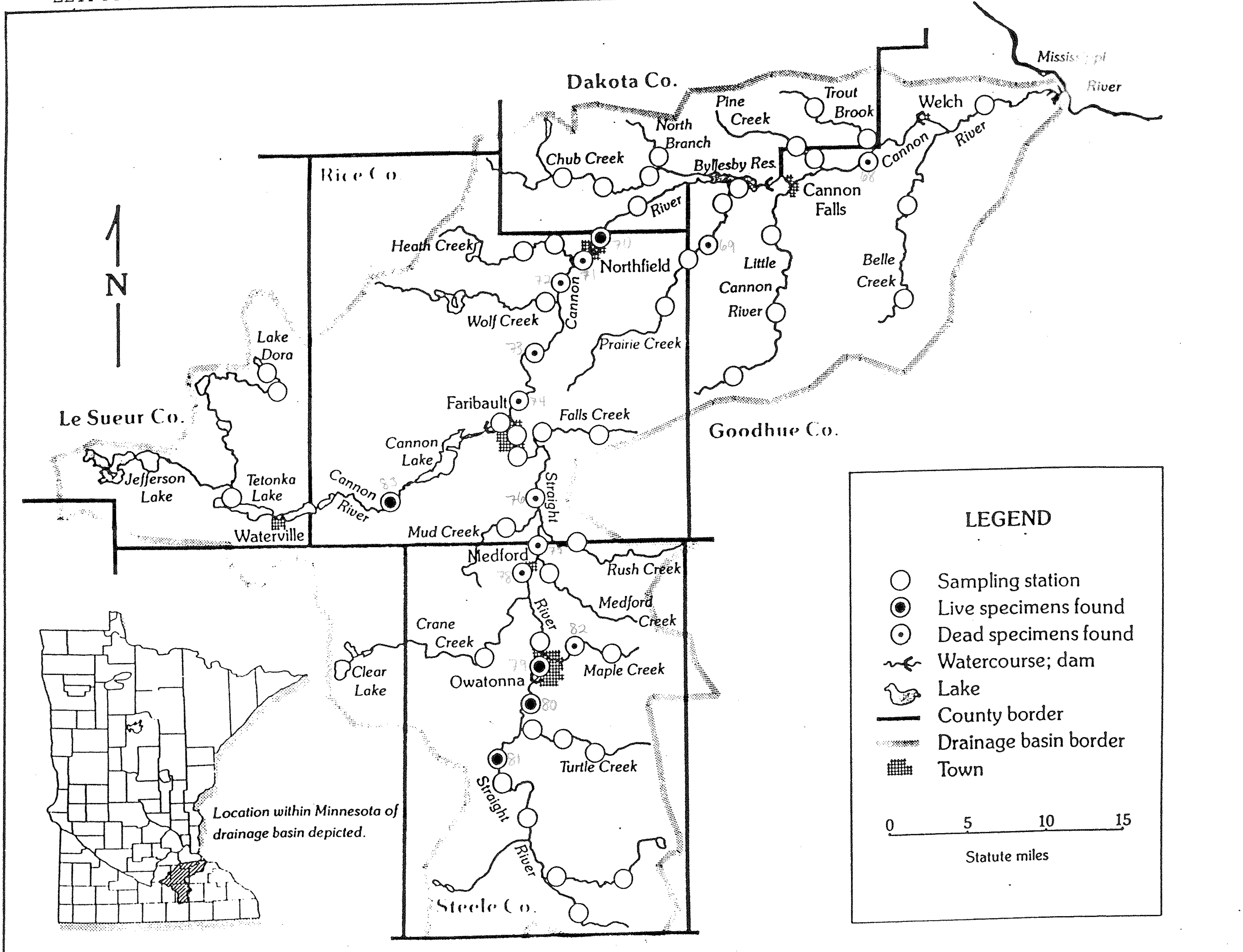


FIGURE 9

LAMPSILIS SILIQUOIDEA - FAT MUCKET

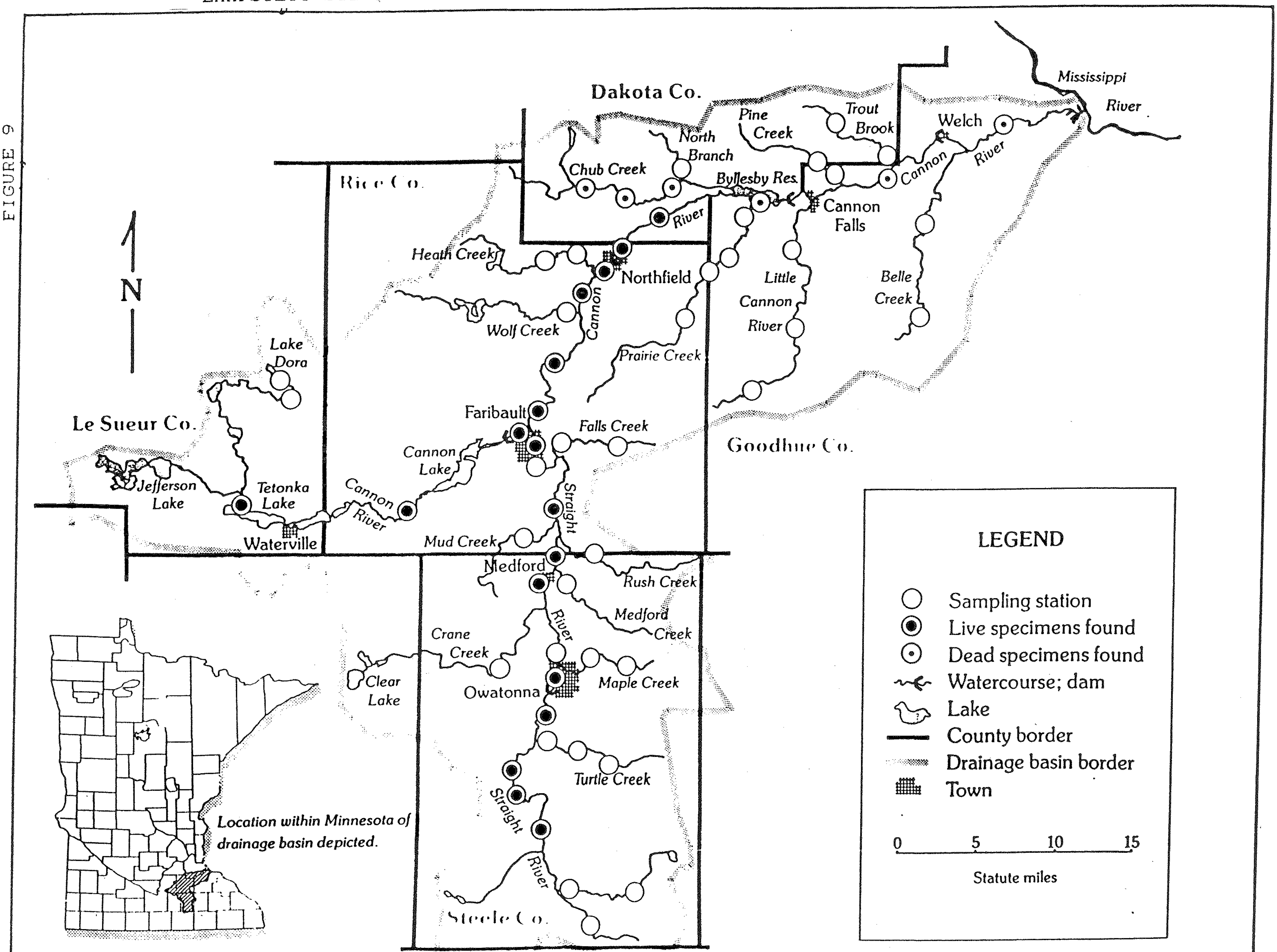
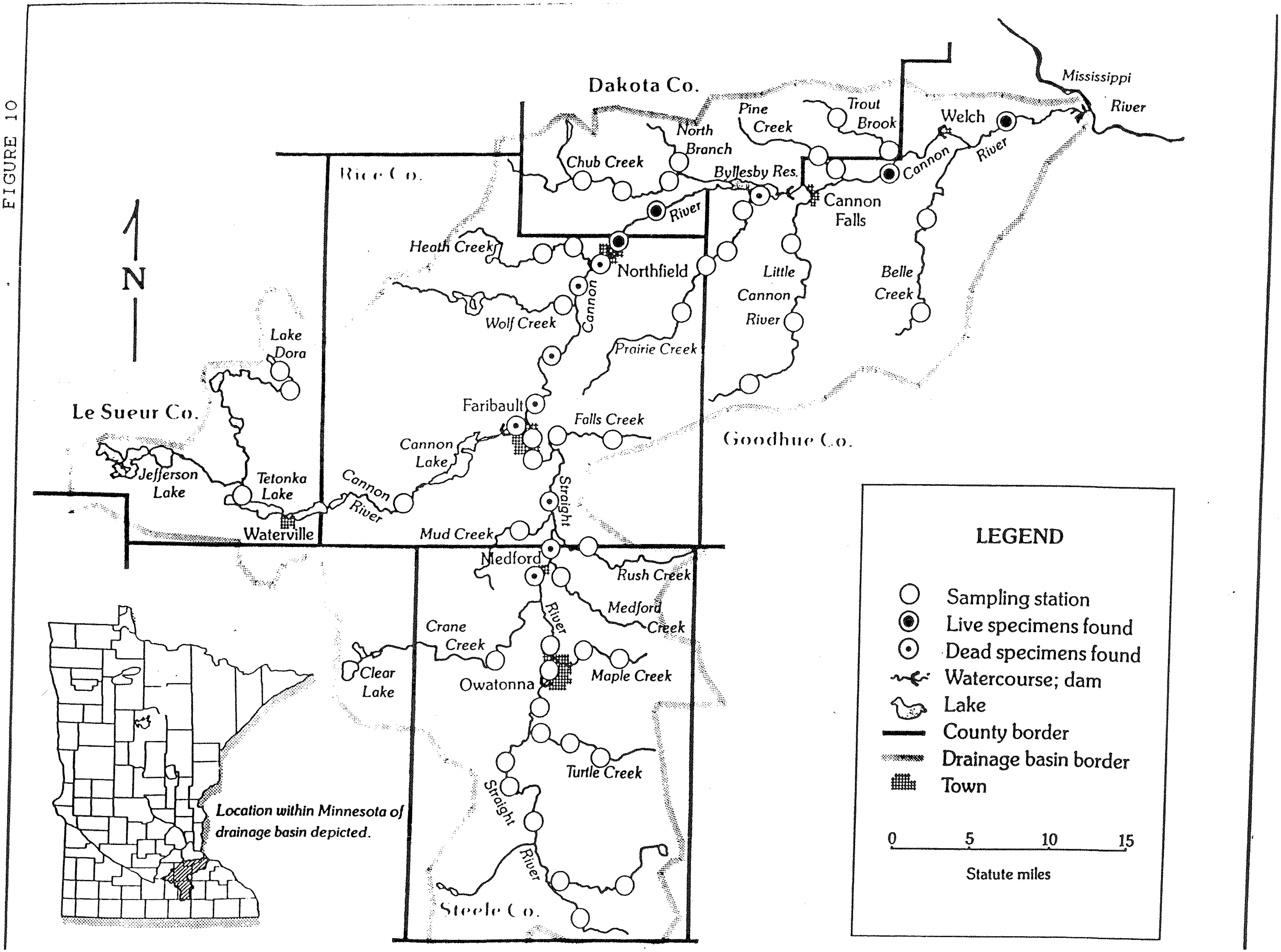
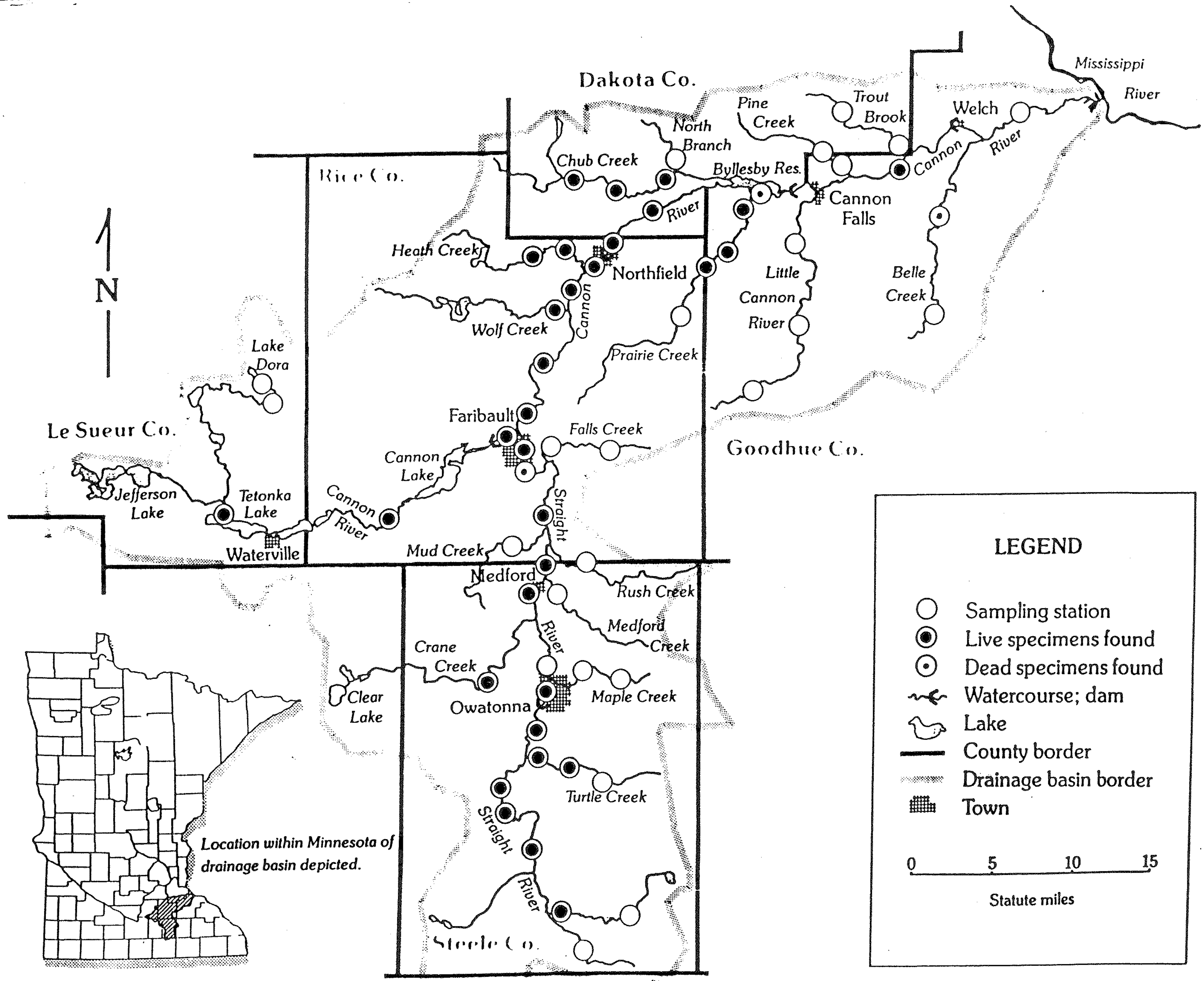


FIGURE 10

LAMPSILIS VENTRICOSA - POCKETBOOK



LASMIGONA COMPLANATA - WHITE HEELSPLITTER



LASMIGONA COMPRESSA - CREEK HEELSPLITTER

FIGURE 12

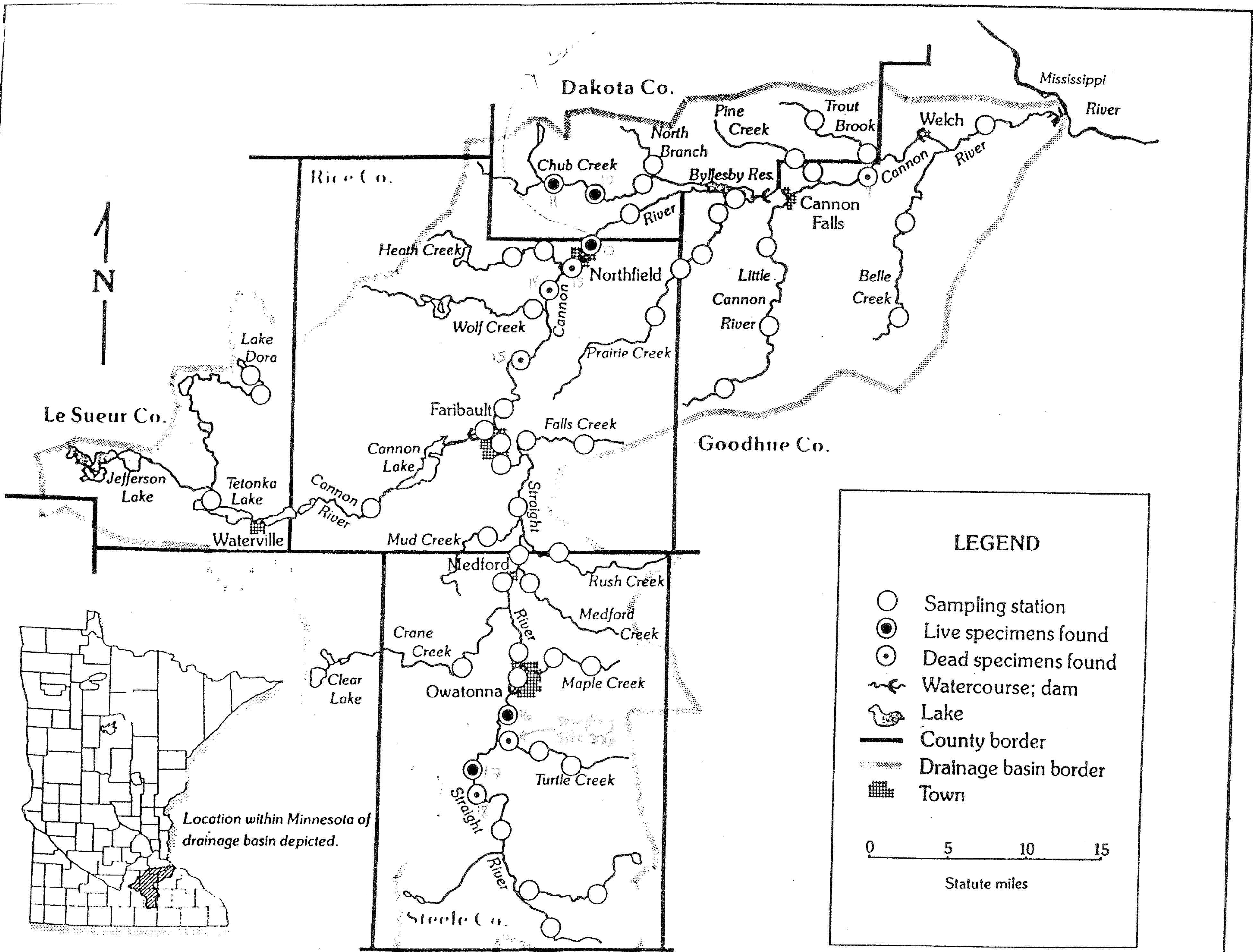


FIGURE 13

LASMIGONA COSTATA - FLUTED SHELL

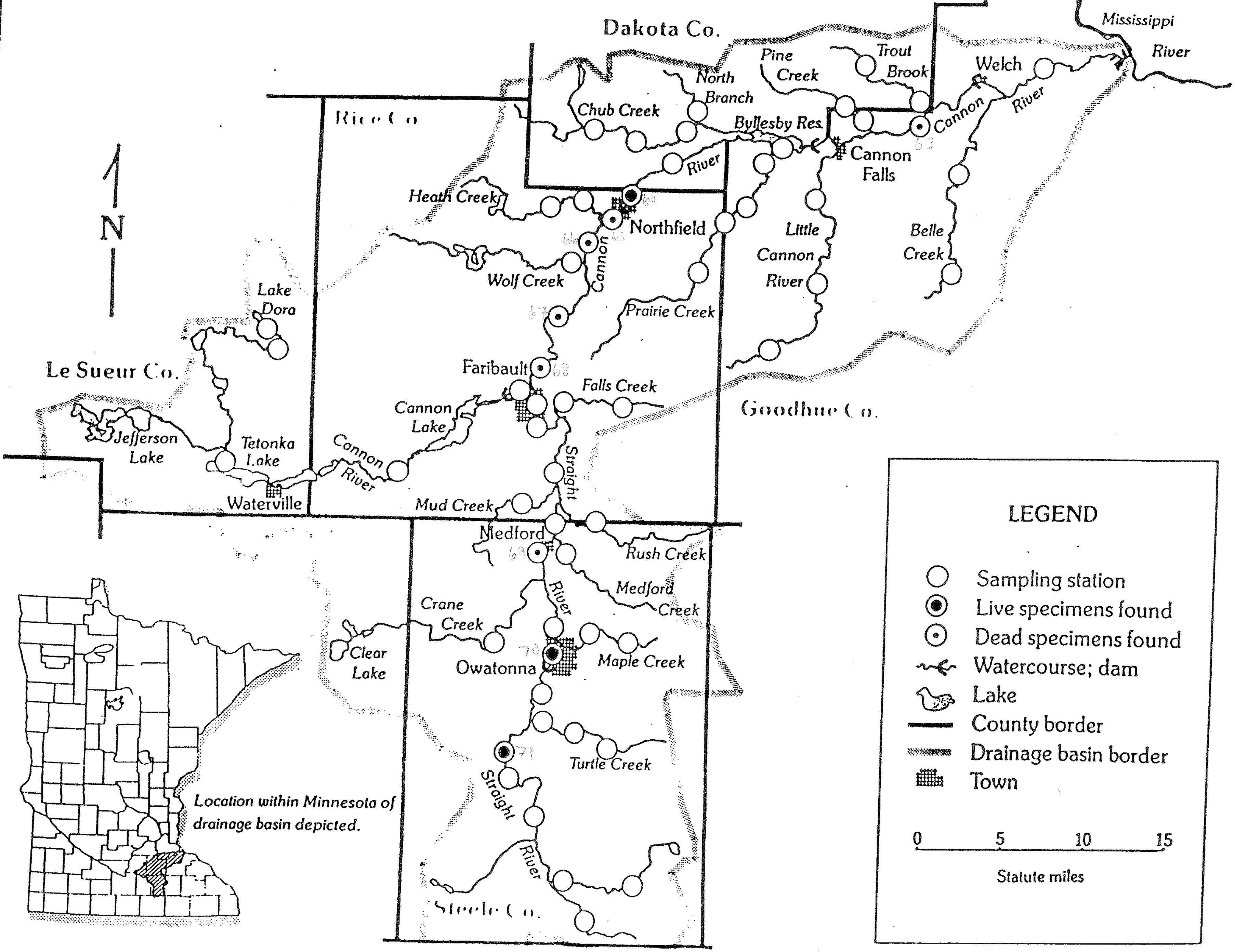
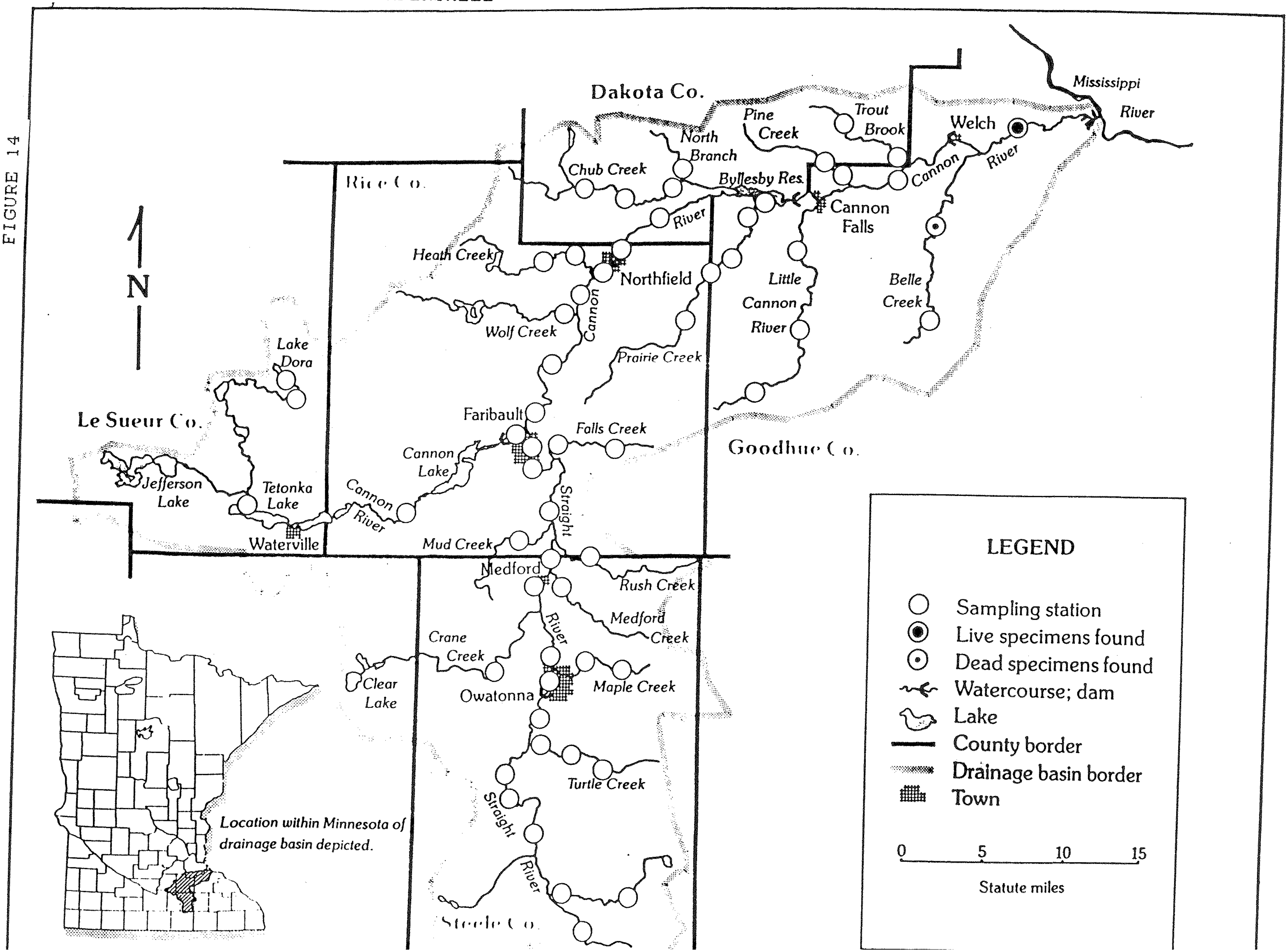


FIGURE 14

LEPTODEA FRAGILIS - FRAGILE PAPERSHELL



LIGUMIA RECTA - BLACK SANDSHELL

FIGURE 15

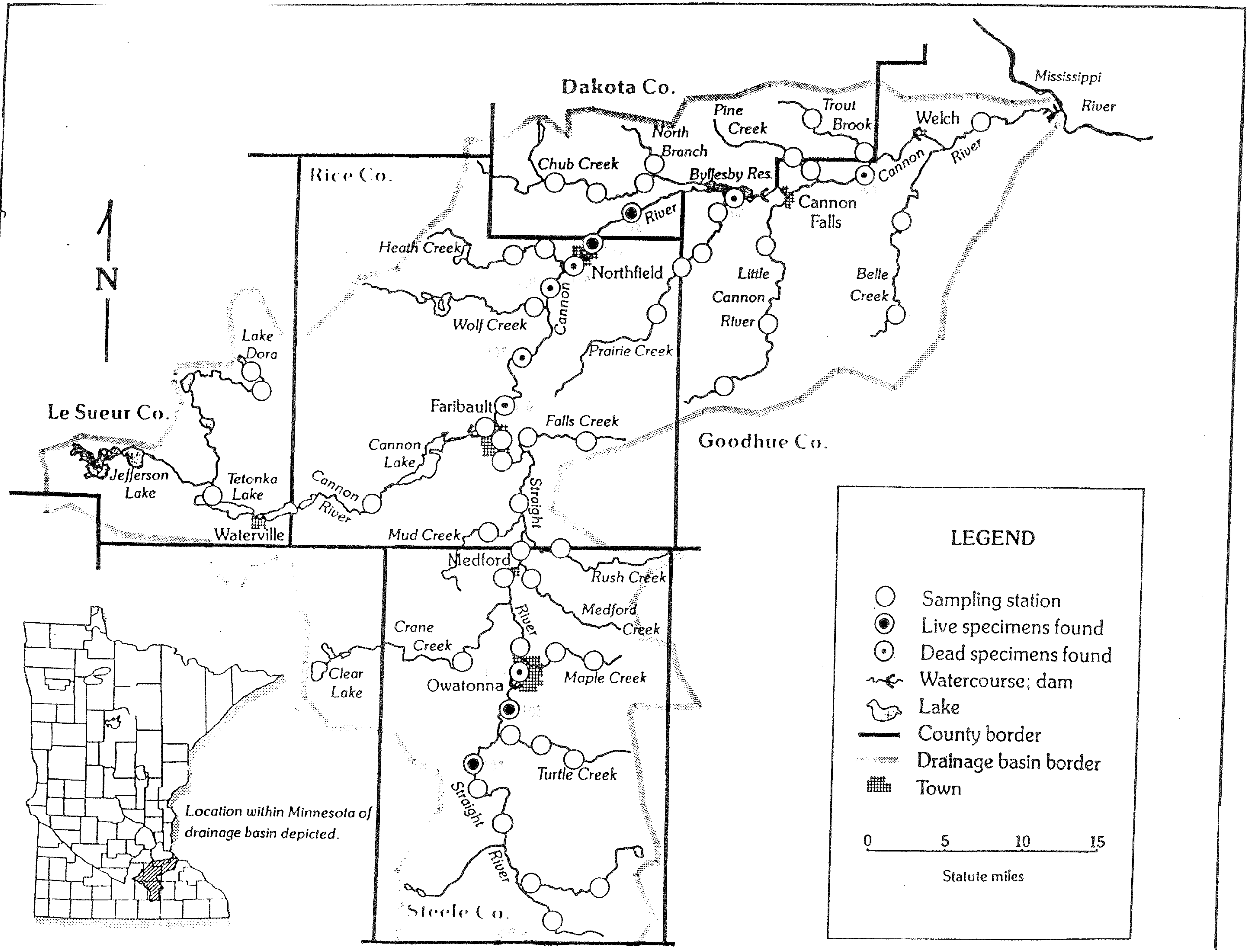


FIGURE 16

PLEUROBEMA SINTOXIA - ROUND PIGTOE

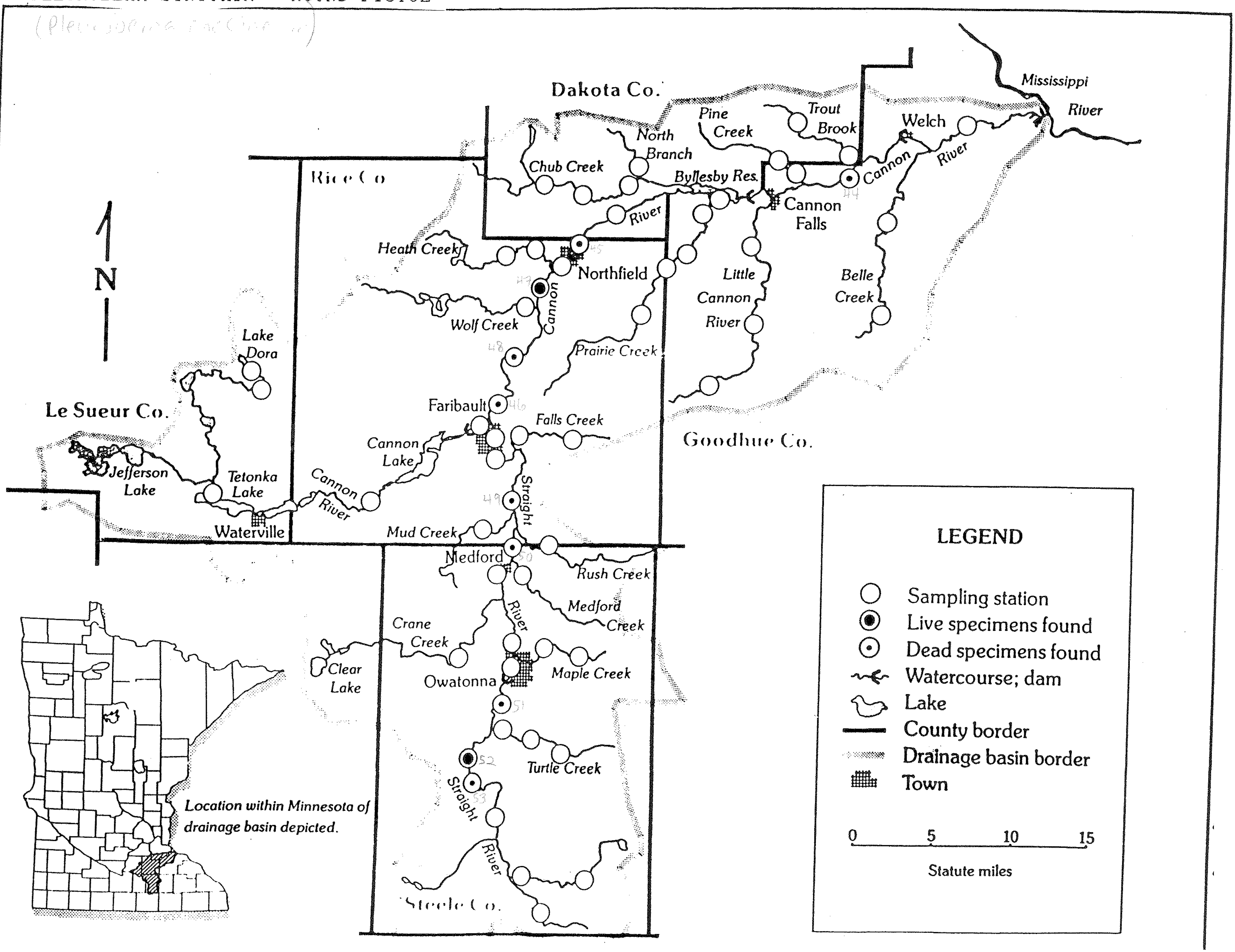
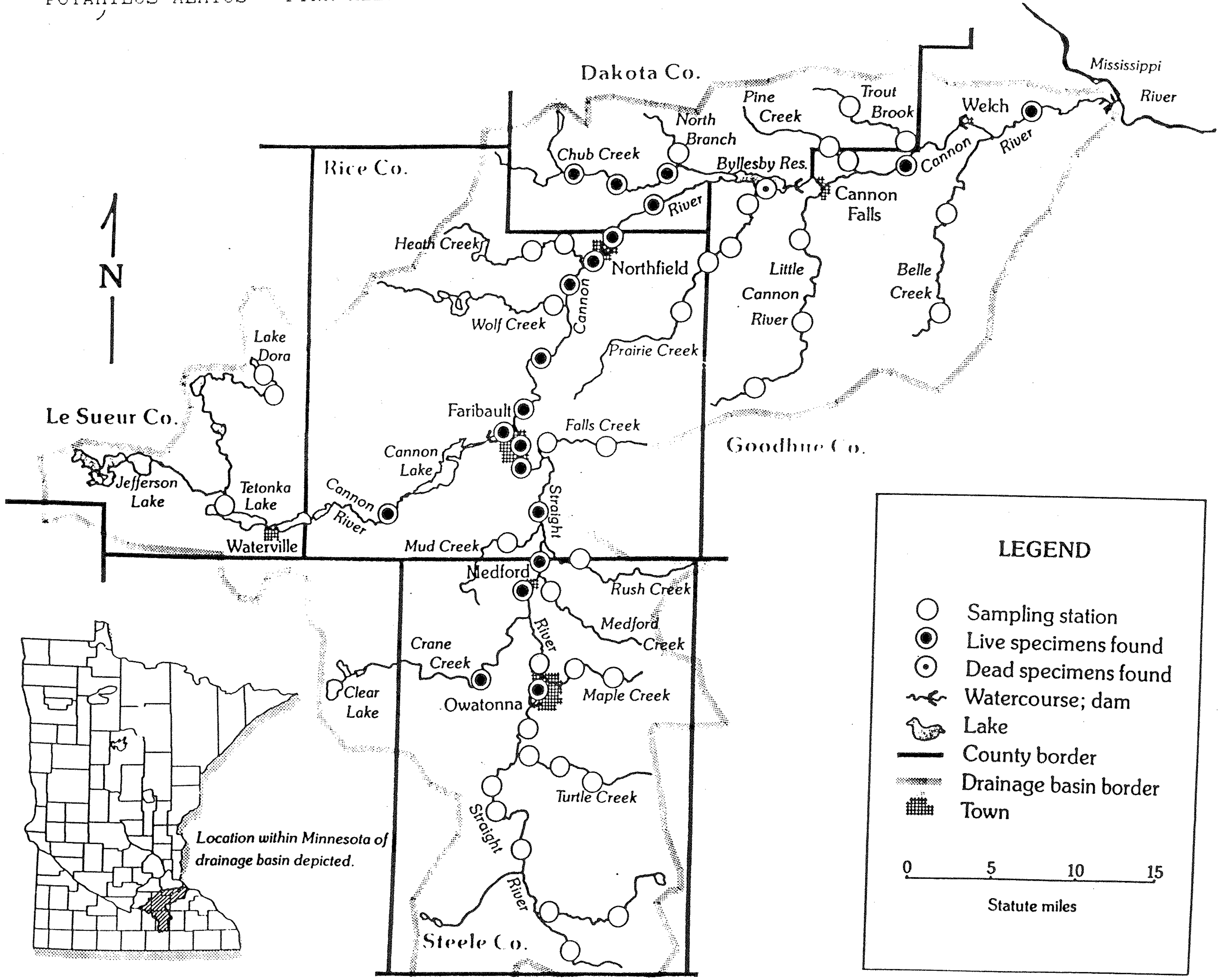
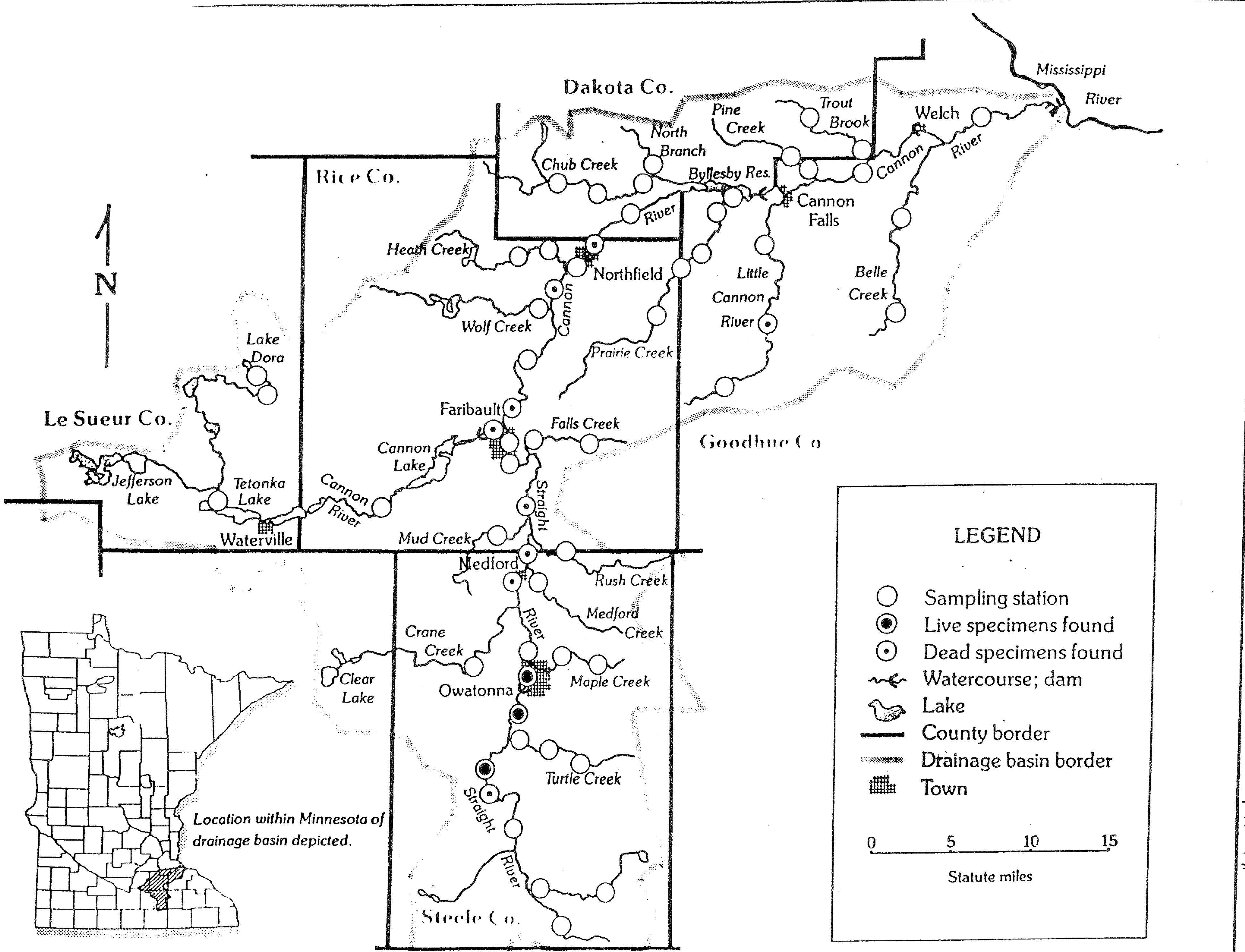


FIGURE 17

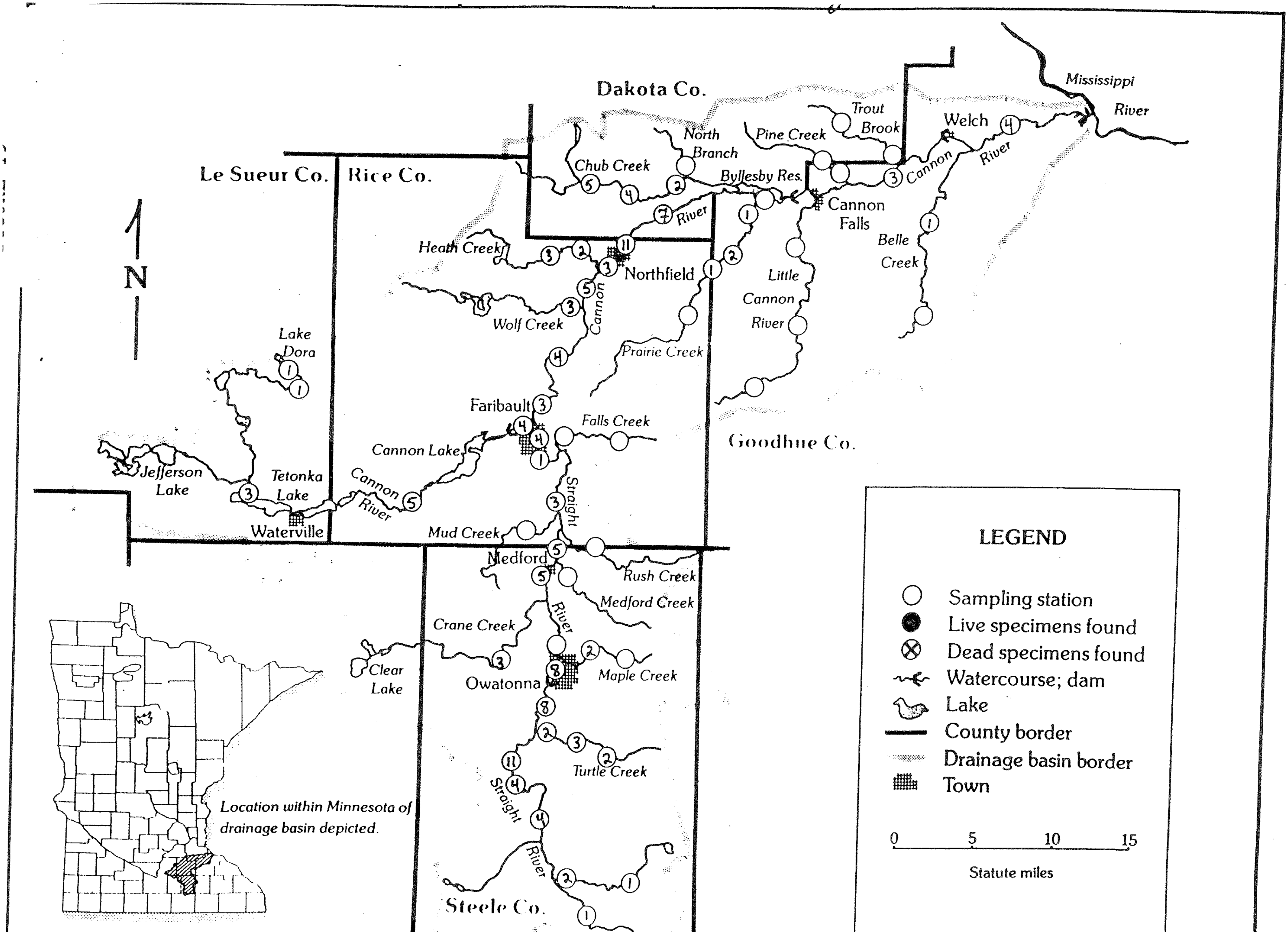
POTAMILUS ALATUS - PINK HEELSPLITTER



STROPHITUS UNDULATUS - STRANGE FLOATER



NUMBER OF SPECIES FOR WHICH LIVE SPECIMENS WERE FOUND - BY STATION



NUMBER OF SPECIES, LIVING AND DEAD, FOUND AT EACH STATION

FIGURE 20

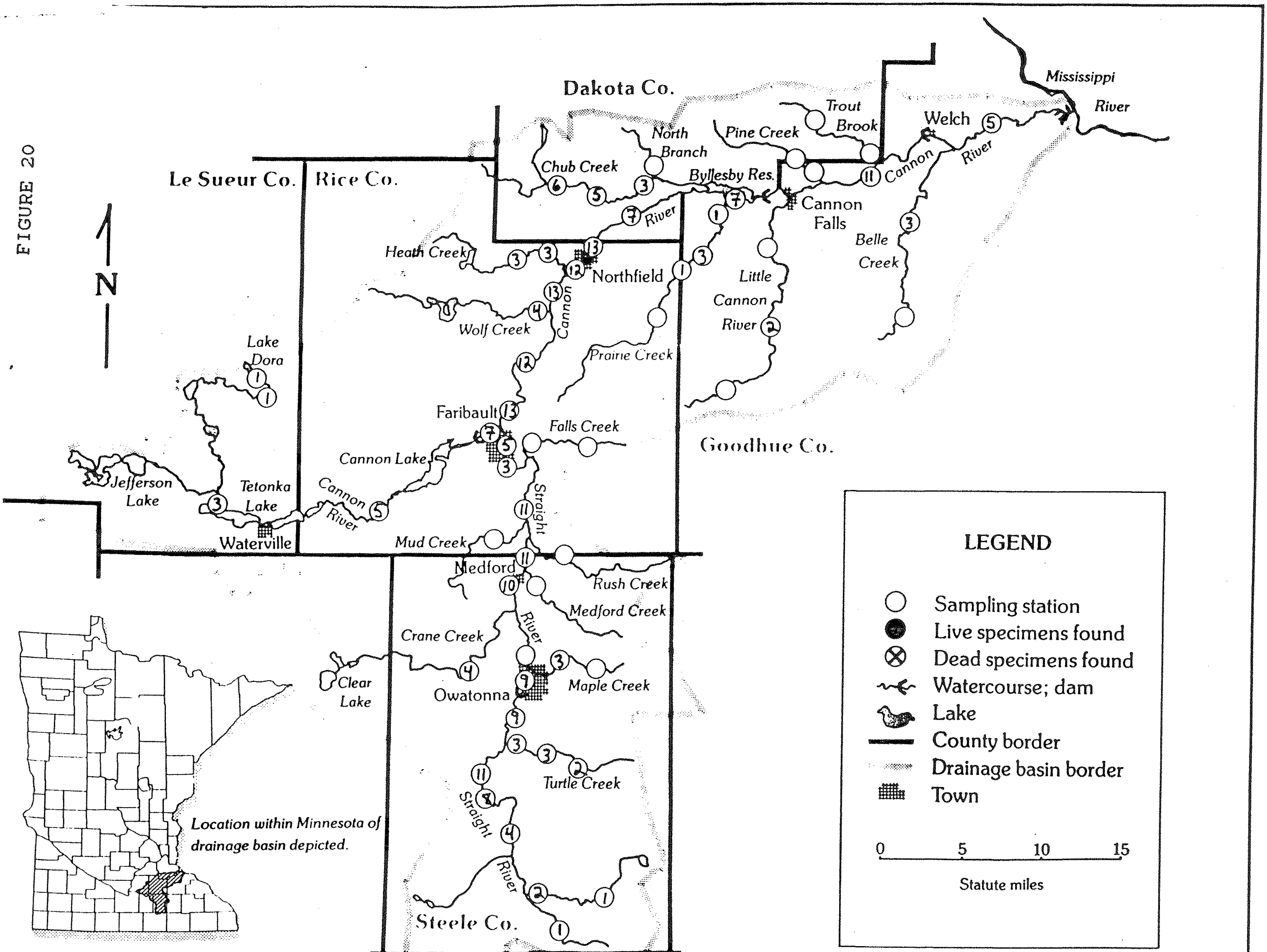


FIGURE 21

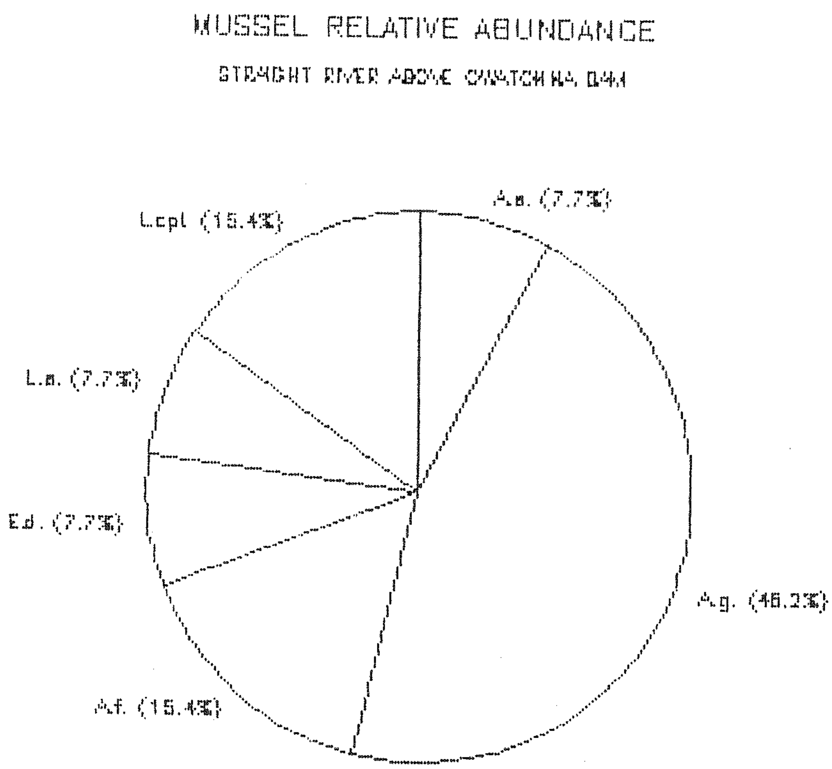
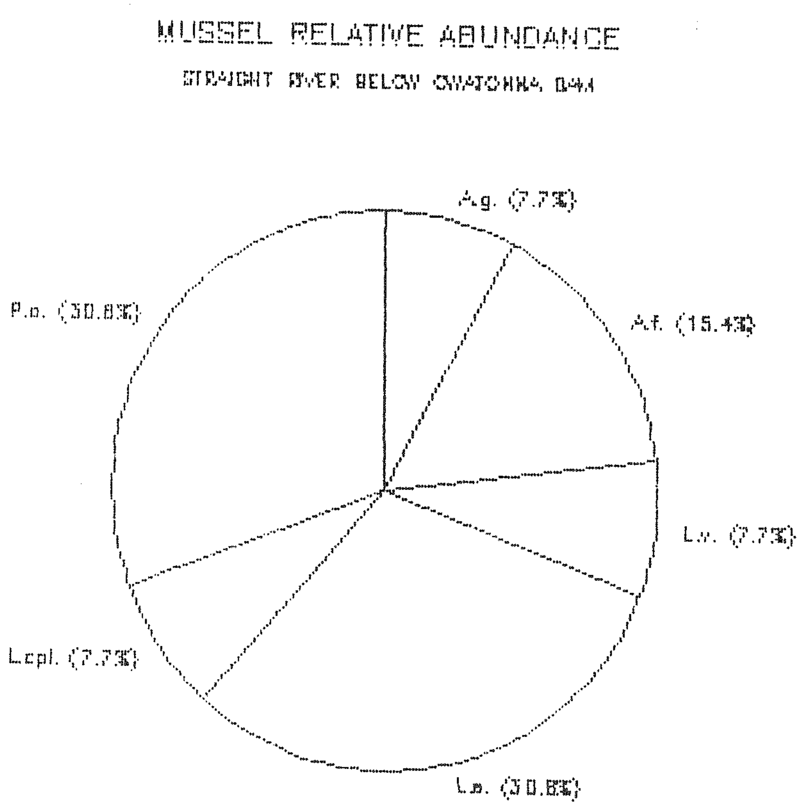


FIGURE 22



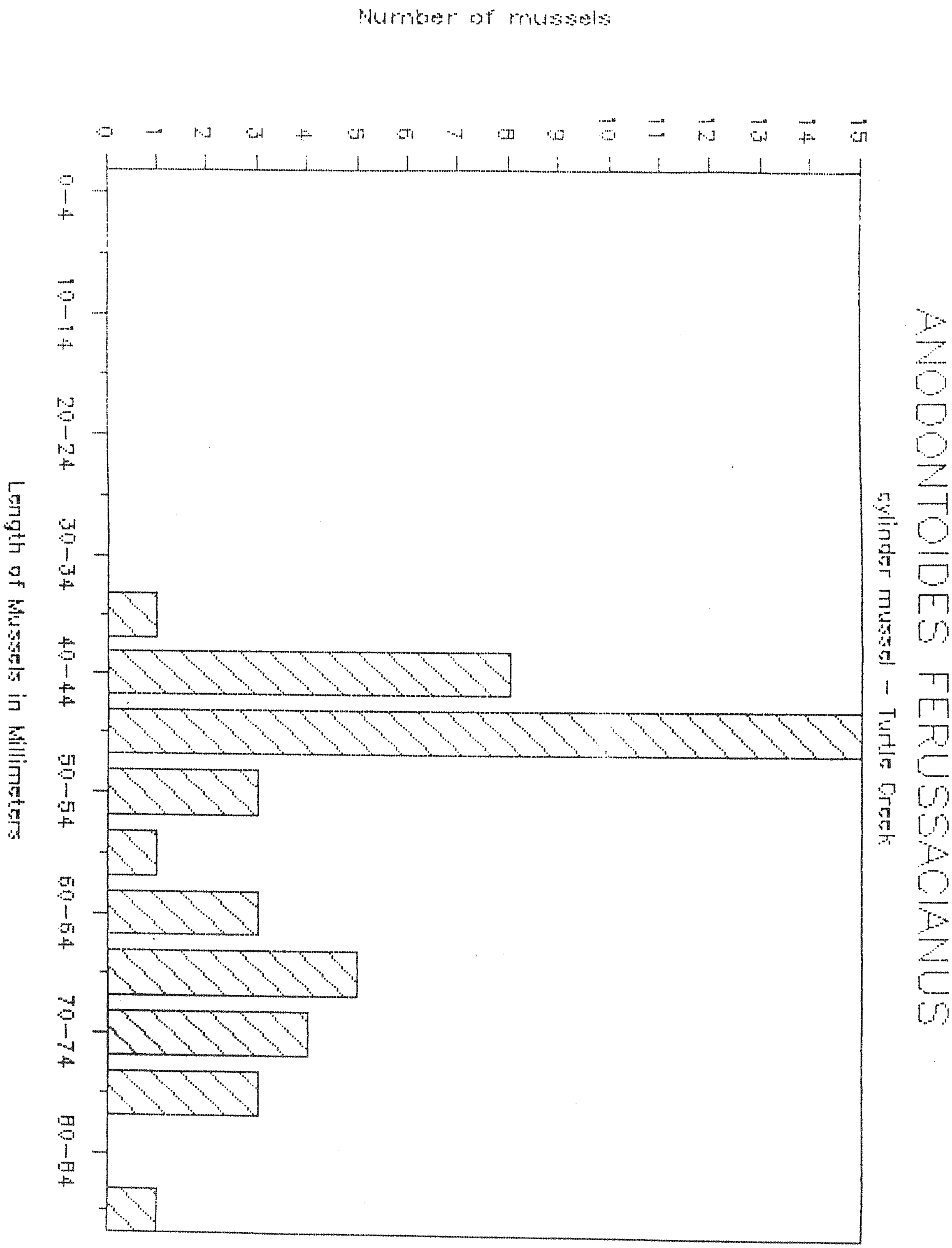
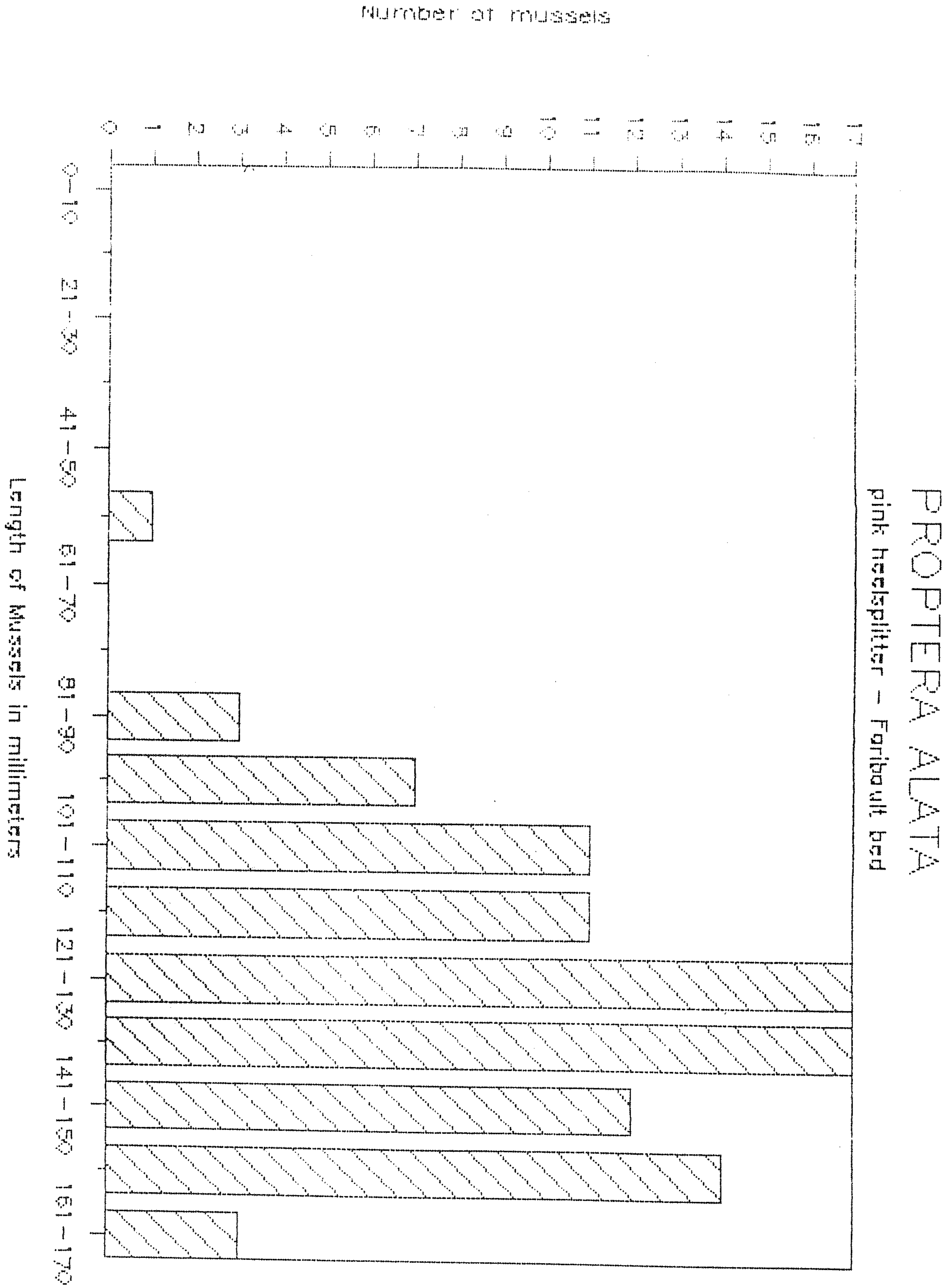

ANODONTOIDES FERUSSACIANUS
cylinder mussel - Turtle Creek
Number of mussels
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0-4
10-14
20-24
30-34
40-44
50-54
60-64
70-74
80-84
Length of Mussels in Millimeters

FIGURE 28



PROPTERA ALATA
pink heelsplitter - Faribault bed
Number of mussels
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
0-10
21-30
41-50
61-70
81-90
101-110
121-130
141-150
161-170
Length of Mussels in millimeters

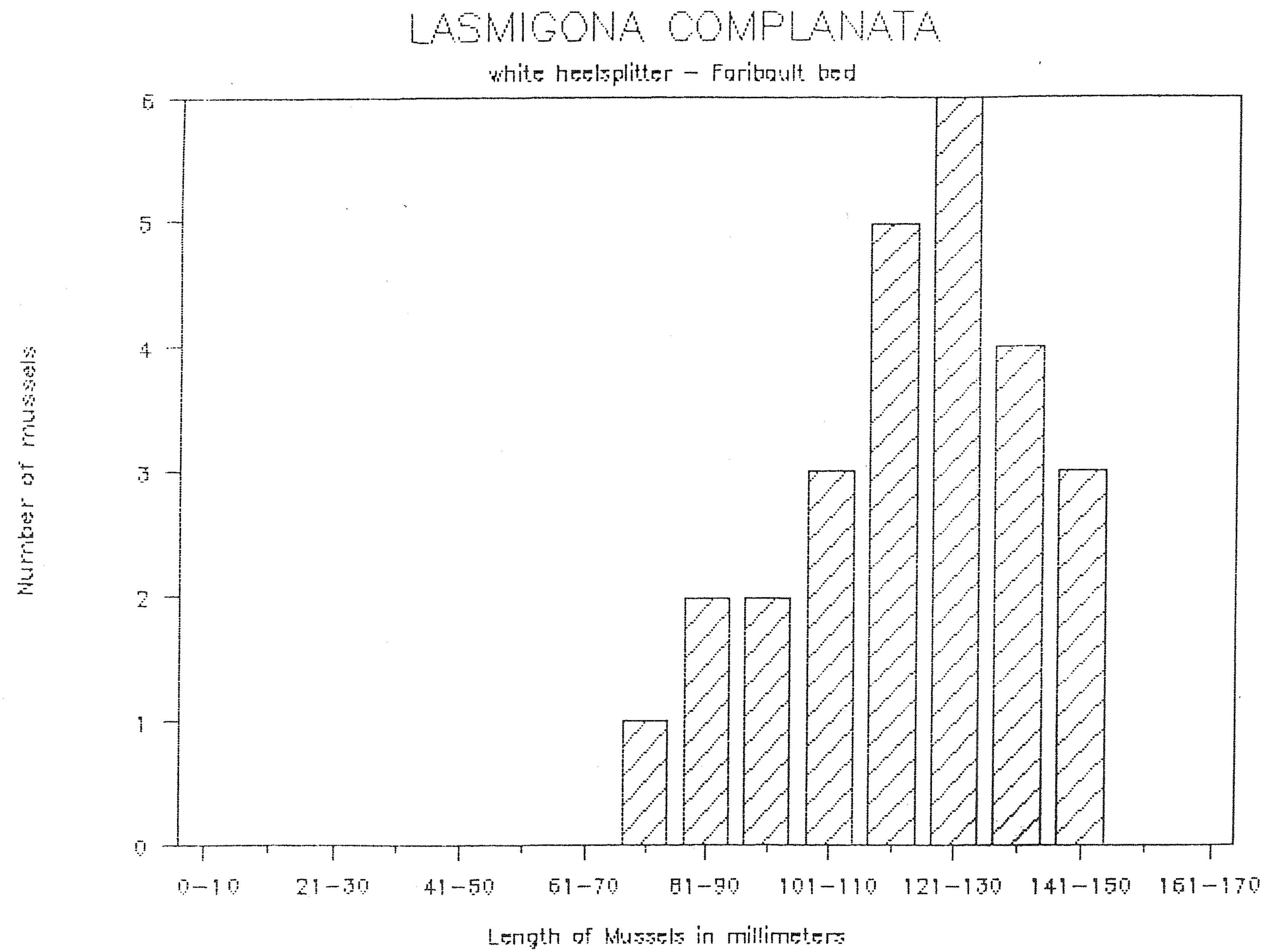

LASMIGONA COMPLANATA
white heelsplitter – Faribault bed
Number of mussels
0
1
2
3
4
5
6
0–10
21–30
41–50
61–70
81–90
101–110
121–130
141–150
161–170
Length of Mussels in millimeters

FIGURE 30

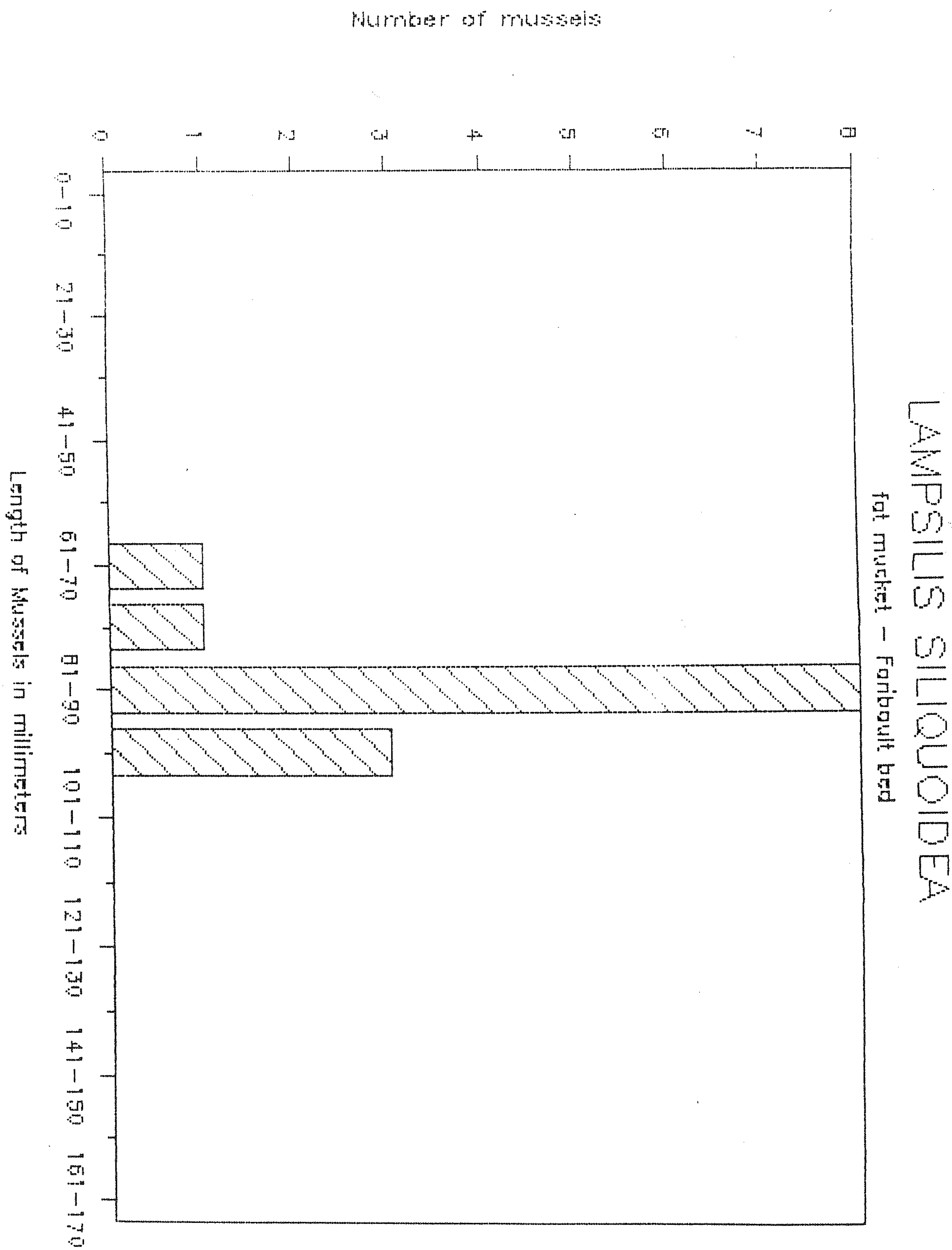
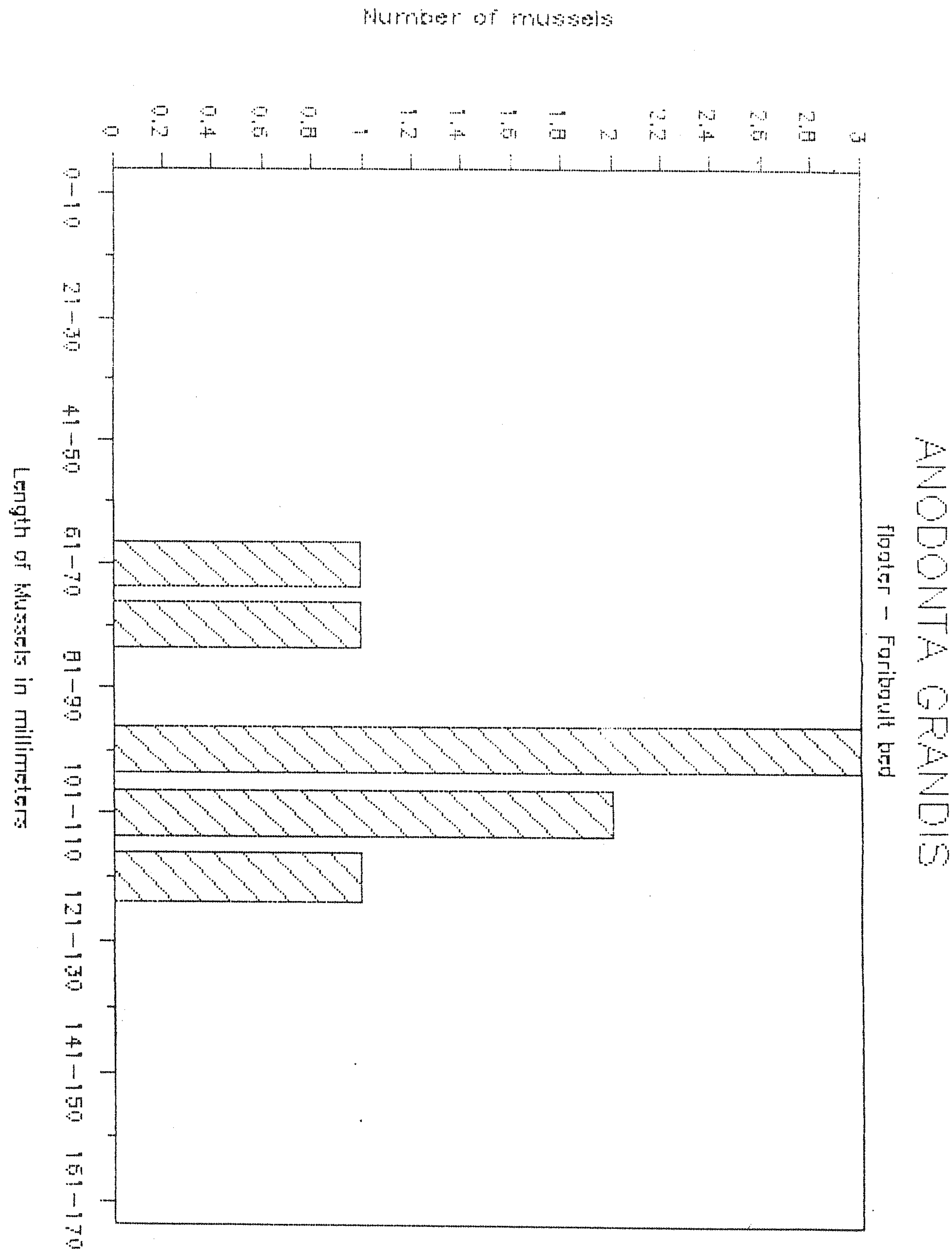
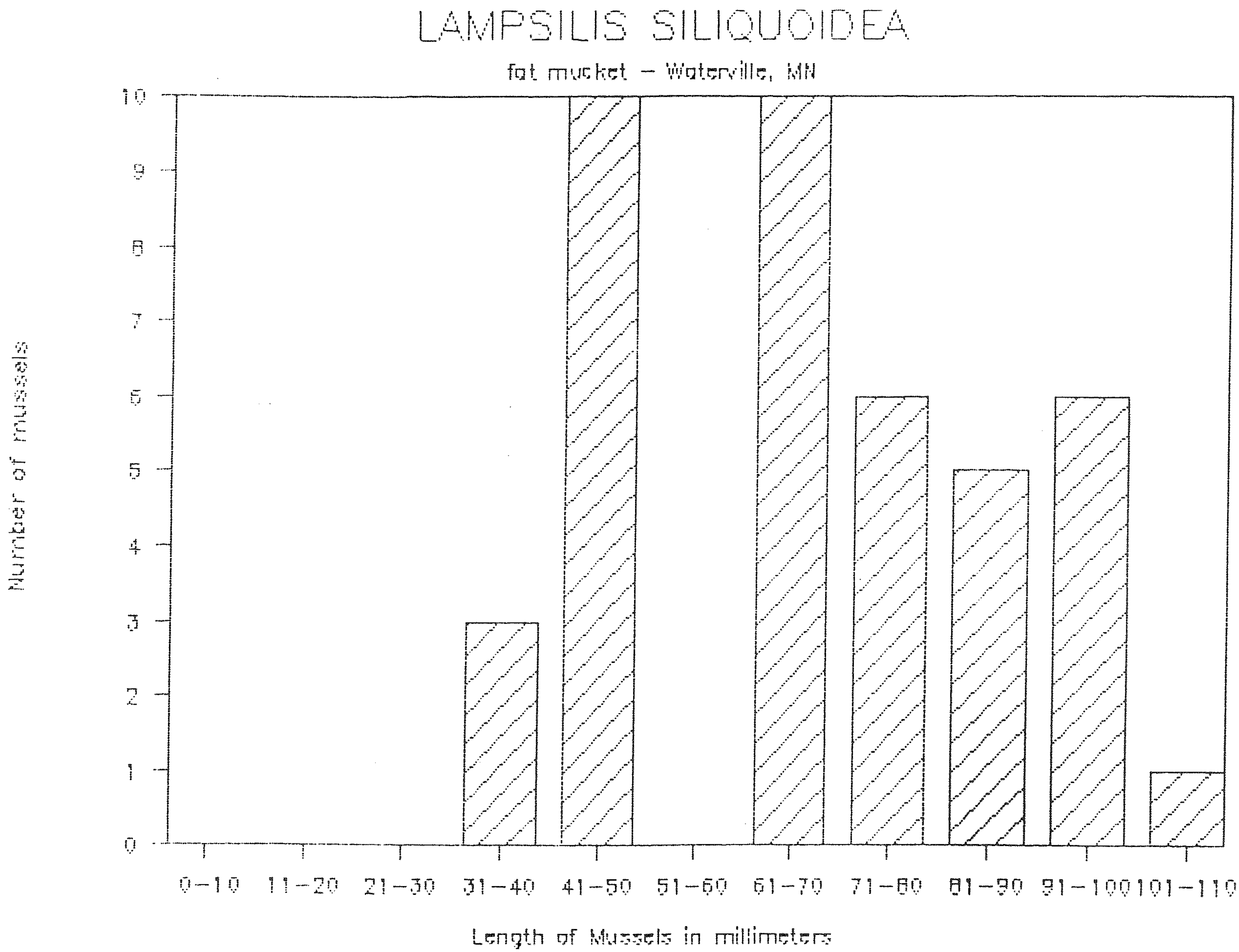

LAMPSILIS SILIQUOIDEA
fat mucket - Fairbault bed
Number of mussels
0
1
2
3
4
5
6
7
8
0-10
21-30
41-50
61-70
81-90
101-110
121-130
141-150
161-170
Length of Mussels in millimeters

FIGURE 31


ANODONTA GRANDIS
floater - Faribault bed
Number of mussels
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
0-10
21-30
41-50
61-70
81-90
101-110
121-130
141-150
161-170
Length of Mussels in millimeters


LAMPSILIS SILIQUOIDEA
fat mucket - Waterville, MN
Number of mussels
0
1
2
3
4
5
6
7
8
9
10
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
101-110
Length of Mussels in millimeters

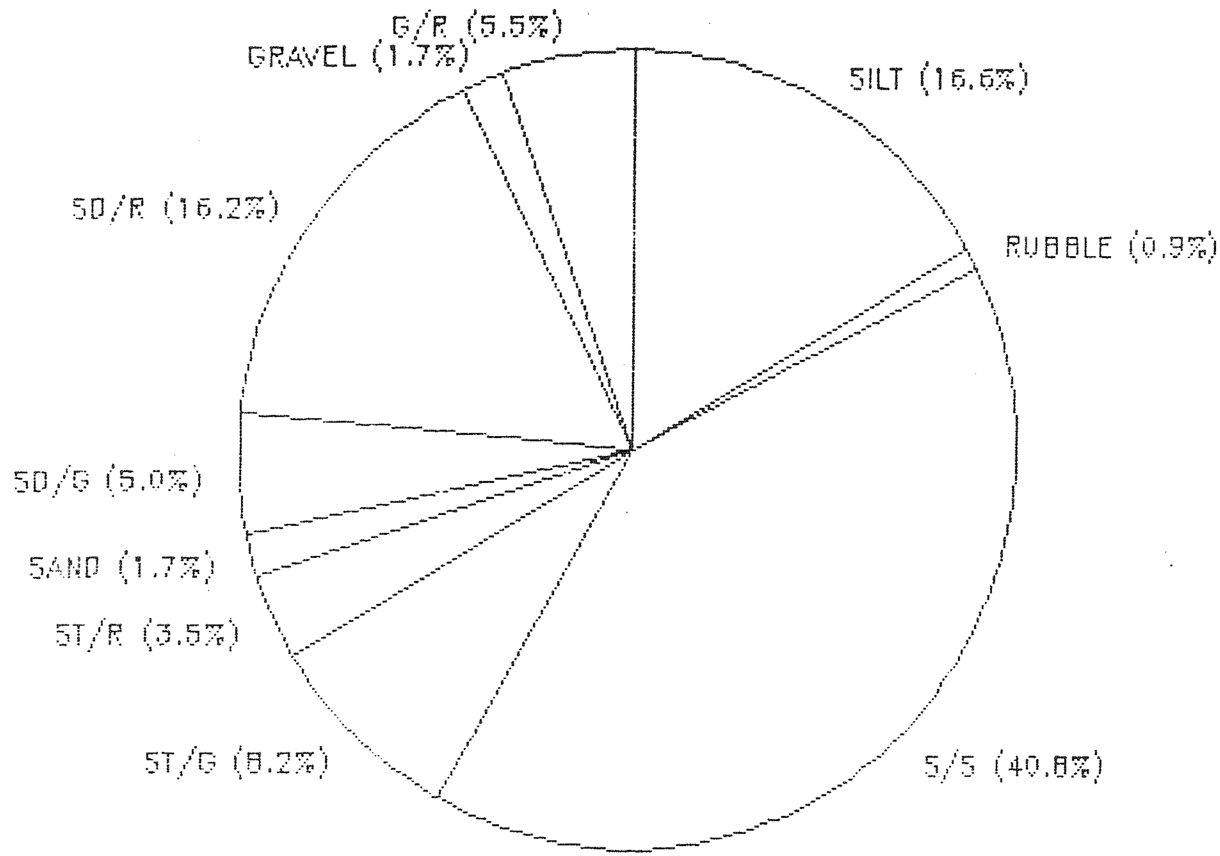
CANNON RIVER TRIBUTARY STATIONS

MAP LOC #	STATION NAME	COUNTY	SECTION	TOWN	RANGE
T-1	BELL CREEK(FORD)	GOODHUE	SW1/4 SEC 16	T112N	R16W
T-2	BELL CR.(S17T111NR16W)	GOODHUE	NW1/4 SEC 17	T111N	R16W
T-3	TROUT BROOK 1	DAKOTA	W 1/2 SEC 26	T113N	R17W
T-4	TROUT BROOK 2	DAKOTA	SEC 36	T113N	R17W
T-5	PINE CREEK 1	GOODHUE	SE1/4 SEC 5	T112N	R17W
T-6	PINE CREEK 2	GOODHUE	NE1/4 SEC 6	T112N	R17W
T-7	LITTLE CANNON 1B	GOODHUE	NE1/4 SEC 1	T111N	R18W
T-8	LITTLE CANNON 2B	GOODHUE	NW1/4 SEC 25	T111N	R18W
T-9	LITTLE CANNON 3(ALT)	GOODHUE	NE1/4 SEC 10	T110N	R18W
T-10	PRAIRIE CREEK 2	GOODHUE	NE1/4 SEC 28	T112N	R18W
T-11	PRAIRIE CREEK 3	GOODHUE	SW1/4 SEC 32	T112N	R18W
T-12	PRAIRIE CREEK 4(MI10.2)	RICE	NE1/4 SEC 12	T111N	R19W
T-13	PRAIRIE CREEK 5	RICE	NE1/4 SEC 32	T111N	R19W
T-14	CHUB CREEK 1	DAKOTA	NW1/4 SEC 11	T112N	R19W
T-15	CHUB CREEK 2	DAKOTA	NW1/4 SEC 18	T112N	R19W
T-16	CHUB CREEK 3	DAKOTA	E 1/2 SEC 10	T112N	R20W
T-17	CHUB CREEK(N.BRANCH)	DAKOTA	SEC 2	T112N	R19W
-18	HEATH CREEK 1	RICE	W 1/2 SEC 34	T112N	R20W
-19	HEATH CREEK 2	RICE	NW1/4 SEC 5	T111N	R20W
-20	WOLF CREEK	RICE	SW1/4 SEC 1	T111N	R21W
-21	CANNON 5 (WATERVILLE)	RICE	NE1/4 SEC 23	T109N	R22W
-22	CANNON 3 (WATERVILLE)	LE SUEUR	SW1/4 SEC 18	T109N	R23W
-23	CANNON 2 (WATERVILLE)	LE SUEUR	NE1/4 SEC 15	T110N	R23W
-24	LAKE DORA (LE SUEUR CO.)	LE SUEUR	SW1/4 SEC 10	T110N	R23W
-25	FALLS CREEK 1	RICE	W 1/2 SEC 33	T110N	R20W
-26	FALLS CREEK 2	RICE	N 1/2 SEC 35	T110N	R20W
-27	MUD CREEK	RICE	SEC 31	T107N	R20W
-28	RUSH CREEK	STEELE	NE1/4 SEC 3	T108N	R20W
-29	MEDFORD CREEK	STEELE	SW1/4 SEC 10	T108N	R20W
-30	CRANE CREEK	STEELE	NE1/4 SEC 11	T107N	R21W
-31	MAPLE CREEK 1B	STEELE	NW1/4 SEC 1	T107N	R20W
-32	MAPLE CREEK 2A	STEELE	SW1/4 SEC 17	T107N	R19W
-33	TURTLE CREEK 1	STEELE	NE1/4 SEC 32	T107N	R20W
-34	TURTLE CREEK 1B	STEELE	NW1/4 SEC 3	T108N	R20W
-35	TURTLE CREEK 1C	STEELE	NE1/4 SEC 1	T106N	R20W
-36	TRIB TO STRAIGHT(M482612)	STEELE	SW1/4 SEC 25	T105N	R20W

FIGURE 33

CANNON DRAINAGE

MUSSEL OCCURANCE BY SUBSTRATE TYPE

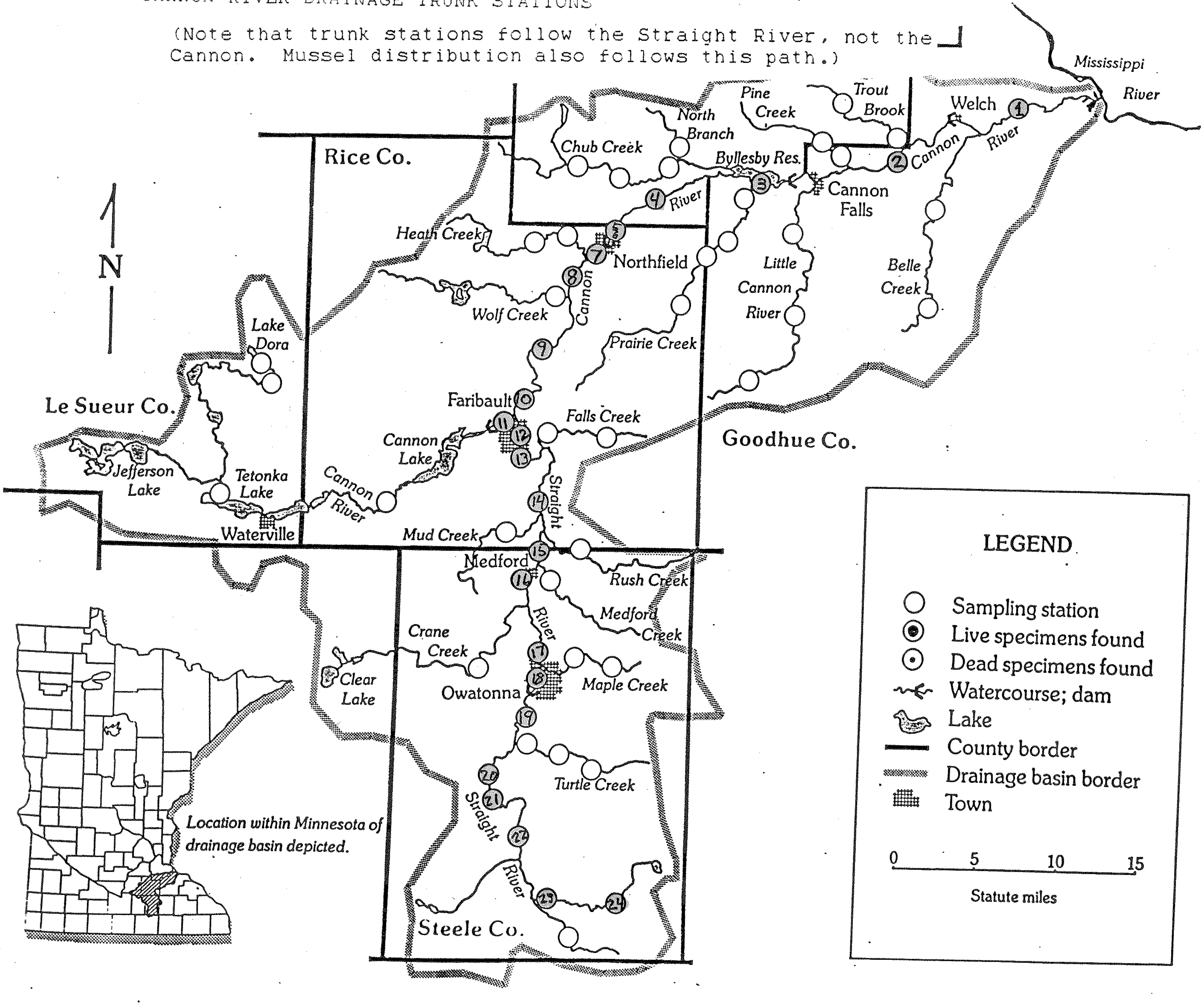


CANNON RIVER TRUNK STATION LOCATIONS

AP OC #	MILE	STATION NAME	COUNTY	SECTION	TOWN	RANGE
1	6.8	CANNON 1 (LOWER RIVER)	GOODHUE	SEC 19	T113N	R15W
2	17.4	CANNON 2 (LOWER RIVER)	GOODHUE	SEC 1	T112N	R17W
3	29.0	BYLLESBY RESERVOIR	GOODHUE	SE 1/4 SEC 16	T112N	R18W
4	35.1	CANNON 1B(LAKE CITY)	DAKOTA	SW 1/4 SEC 14	T112N	R19W
5	40.7	CANNON 1C(LAKE CITY)	RICE	N 1/2 SEC 31	T112N	R19W
6	41.6	CANNON 1D(LAKE CITY)	RICE	SW 1/4 SEC 31	T112N	R19W
7	42.0	CANNON 2(LAKE CITY)	RICE	N 1/2 SEC 1	T111N	R20W
8	45.8	CANNON 3A(LAKE CITY)	RICE	SE 1/4 SEC 15	T111N	R20W
9	50.8	CANNON 3B(LAKE CITY)	RICE	N 1/2 SEC 4	T110N	R20W
10	52.7	CANNON 4A(LAKE CITY)	RICE	N 1/2 SEC 8	T110N	R20W
11	58.1	CANNON 4C,4D(LAKE CITY)	RICE	N 1/2 SEC 30	T110N	R20W
12	1.3	STRAIGHT RIVER 1	RICE	NE 1/4 SEC 31	T110N	R20W
13	3.3	STRAIGHT RIVER 2	RICE	SW 1/4 SEC 5	T109N	R20W
14	9.2	STRAIGHT RIVER(MI.9.2)	RICE	SW 1/4 SEC16	T109N	R20W
15	13.7	STRAIGHT RIVER 3A	RICE	SW 1/4 SEC 33	T109N	R20W
16	15.5	STRAIGHT RIVER 3B	STEELE	NE 1/4 SEC 8	T108N	R20W
17	21.3	STRAIGHT RIVER(MI 21.3)	STEELE	NE 1/4 SEC 33	T108N	R20W
18	24.8	OWATONNA DAM TAILWATER	STEELE	SE 1/4 SEC 9	T107N	R20W
19	29.1	STRAIGHT RIVER 5	STEELE	SE 1/4 SEC 20	T107N	R20W
20	35.7	STRAIGHT RIVER 6A	STEELE	NE 1/4 SEC 12	T106N	R21W
21	37	STRAIGHT RIVER 6B	STEELE	NE 1/4 SEC 13	T106N	R21W
22	43.1	STRAIGHT RIVER 7A	STEELE	E 1/2 SEC 29	T106N	R20W
23	47.9	STRAIGHT RIVER 7B	STEELE	W 1/2 SEC 15	T105N	R20W
24	54.0	STRAIGHT RIVER 8B	STEELE	SE 1/4 SEC 17	T105N	R19W

CANNON RIVER DRAINAGE TRUNK STATIONS

(Note that trunk stations follow the Straight River, not the Cannon. Mussel distribution also follows this path.)



CANNON RIVER DRAINAGE TRIBUTARY STATIONS

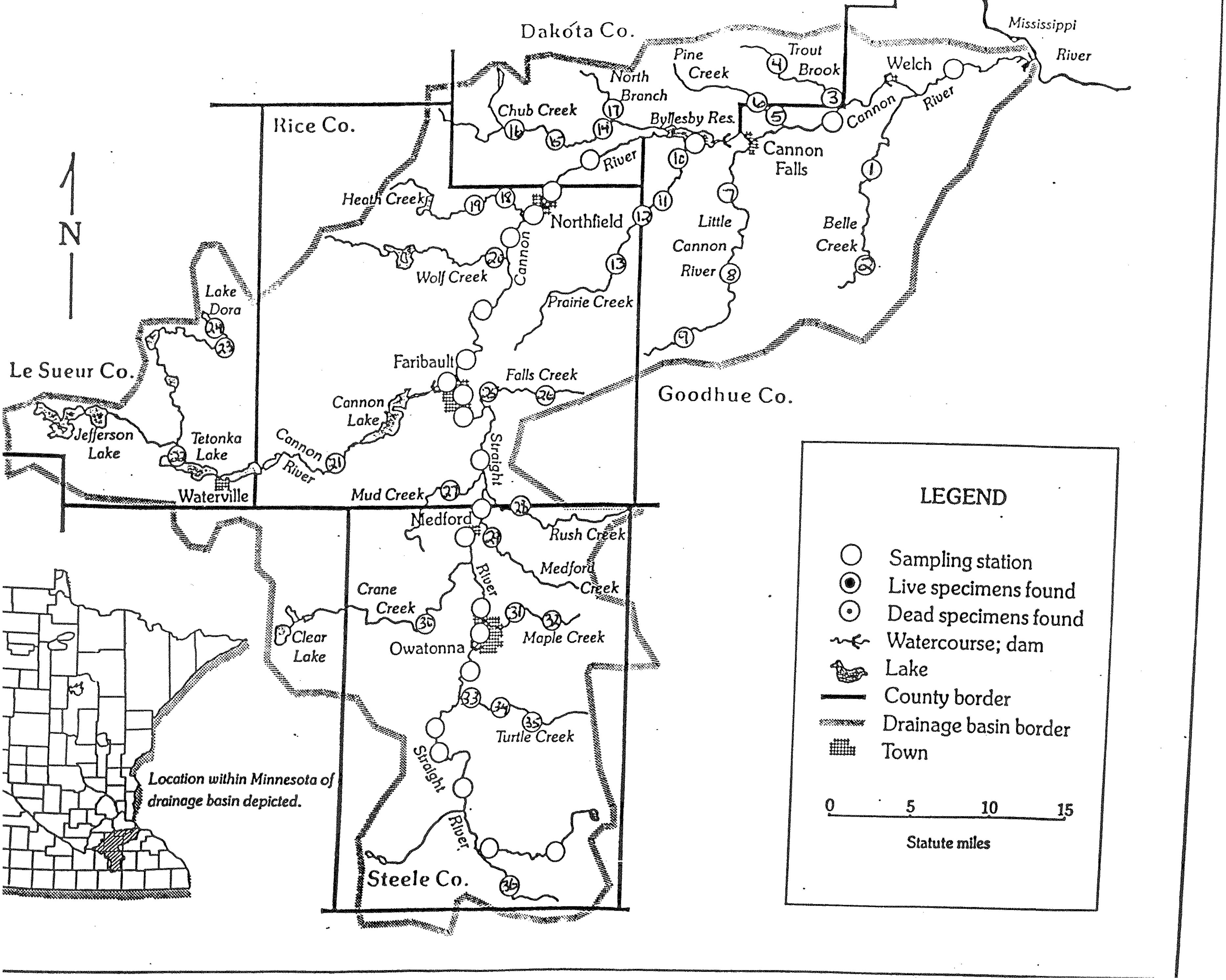
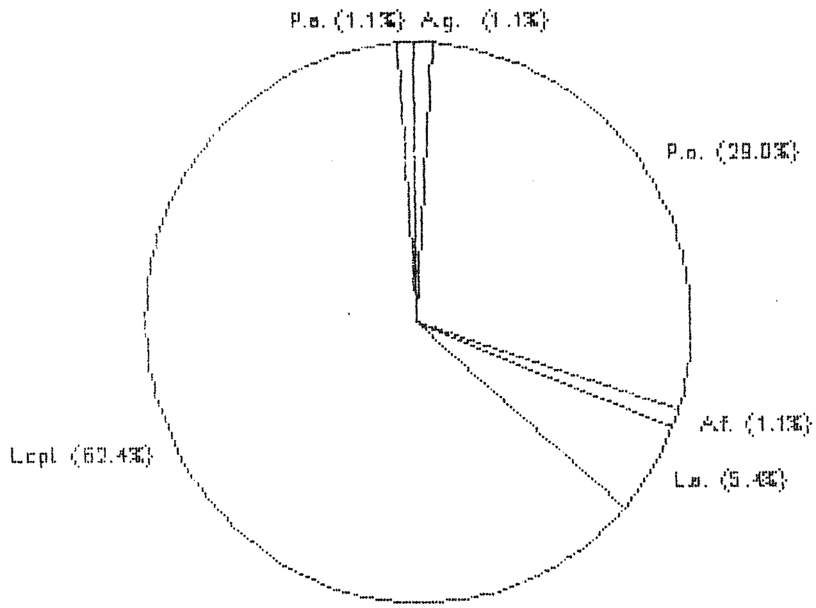


FIGURE 25

MUSSEL RELATIVE ABUNDANCE

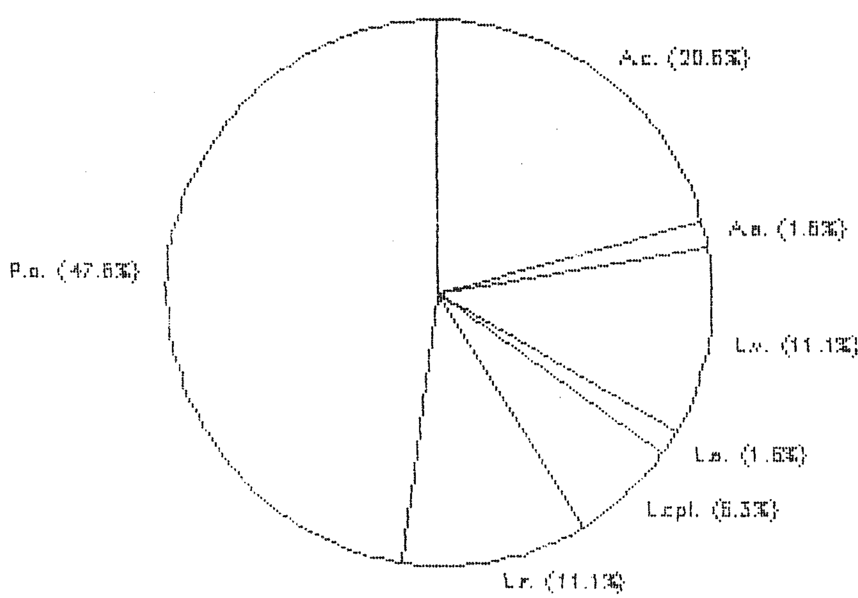
ABOVE NORTHFIELD DAM (EX FARIBAULT BED)



MUSSEL RELATIVE ABUNDANCE

BELOW NORTHFIELD DAM

FIGURE 26



STATION CONTRIBUTION TO ALL SPECIES OF MUSSELS

STATION	A.c.	A.e.	A.g.	A.f.	E.d.	L.v.	L.s.	L.cpl	L.cmp	L.cos.	L.f.	L.r.	P.s.	P.a.	S.u.	TOTAL	% OF ALL
CANNON 1B (LAKE CITY)	9					4	1	3				2		12		31	3.5%
CANNON 1C (LAKE CITY)	4	1				3		1				5		18		32	3.6%
CANNON 1D (LAKE CITY)																	
CANNON 2 (LAKE CITY)							1	13						5		19	2.1%
CANNON 2 (LOWER RIVER)								1						3		4	0.5%
CANNON 2 (WATERVILLE)			1													1	0.1%
CANNON 3 (WATERVILLE)			5				56	1								62	7.0%
CANNON 3A (LAKE CITY)			1	1			2	40					1	12		57	6.4%
CANNON 3B (LAKE CITY)							1	3						5		9	1.0%
CANNON 4A (LAKE CITY)							1	2						5		8	0.9%
CANNON 4C-1 (LAKE CITY)			3				19	105						219		346	39.0%
CANNON 4C-2 (LAKE CITY)			8				8	21						90		127	14.3%
CANNON 4D (LAKE CITY)							5	5						7		17	1.9%
CANNON 5 (WATERVILLE)			4		6		23	8						4		45	5.1%
CHUB CREEK 1														1		1	0.1%
CHUB CREEK 2																	
CHUB CREEK 3			2	1												3	0.3%
CRANE CREEK			1					1						2		4	0.5%
FALLS CREEK (CO. 2 BR)																	
HEATH CREEK 1								1								1	0.1%
LITTLE CANNON 1B																	
LITTLE CANNON 2B																	
MAPLE CREEK 1B			3	3												6	0.7%
OWATONNA DAM TAILWATER			5		2			15						6	1	29	3.3%
PRAIRIE CREEK 3																	
PRAIRIE CR. 4 (MILE 10.2)								1								1	0.1%
RUSH CREEK (#1)																	
STRAIGHT RIVER 1							1	2						3		6	0.7%
STRAIGHT RIVER 2																	
STRAIGHT RIVER 3A				1			3							1		5	0.6%
STRAIGHT RIVER 3B			2	3		2	4							4		15	1.7%
STRAIGHT RIVER 5		1	1													2	0.2%
STRAIGHT RIVER 6A			3	1	1		1	2								8	0.9%
STRAIGHT RIVER 7A				1												1	0.1%
STRAIGHT RIVER 7B			2													2	0.2%
STRAIGHT RIVER (MI.21.3)																	
TURTLE CREEK 1B TRANSECT			3	41												44	5.0%
WOLF CREEK				1												1	0.1%
TOTALS	13	2	44	53	9	9	126	225				7	1	397	1	887	100.0%
STATION	A.c.	A.e.	A.g.	A.f.	E.d.	L.v.	L.s.	L.cpl	L.cmp	L.cos.	L.f.	L.r.	P.s.	P.a.	S.u.	TOTAL	% OF ALL

STATION CONTRIBUTION TO SPECIES ABUNDANCE
(TRANSECT DATA)

STATION	SPECIES	FREQ.	COMPARED TO ALL THIS SPEC
CANNON 1B (LAKE CITY)	A.c. Actinonaias carinata	9	69.2%
CANNON 1C (LAKE CITY)	A.c. Actinonaias carinata	4	30.8%
STRAIGHT RIVER 5	A.e. Actinonaias ellipsiformis	1	50.0%
CANNON 3A (LAKE CITY)	A.e. Actinonaias ellipsiformis	1	50.0%
CHUB CREEK 3	A.f. Anodontoides ferussacianus	1	1.9%
MAPLE CREEK 1B	A.f. Anodontoides ferussacianus	1	1.9%
STRAIGHT RIVER 3A	A.f. Anodontoides ferussacianus	3	5.7%
STRAIGHT RIVER 3B	A.f. Anodontoides ferussacianus	1	1.9%
STRAIGHT RIVER 6A	A.f. Anodontoides ferussacianus	3	5.7%
STRAIGHT RIVER 7A	A.f. Anodontoides ferussacianus	1	1.9%
TURTLE CREEK 1B TRANSECT	A.f. Anodontoides ferussacianus	1	1.9%
WOLF CREEK	A.f. Anodontoides ferussacianus	41	77.4%
CANNON 2 (WATERVILLE)	A.f. Anodontoides ferussacianus	1	1.9%
CANNON 3 (WATERVILLE)	A.g. Anodonta grandis	1	2.3%
CANNON 3A (LAKE CITY)	A.g. Anodonta grandis	5	11.4%
CANNON 4C-1 (LAKE CITY)	A.g. Anodonta grandis	1	2.3%
CANNON 4C-2 (LAKE CITY)	A.g. Anodonta grandis	3	6.8%
CANNON 5 (WATERVILLE)	A.g. Anodonta grandis	8	18.2%
CHUB CREEK 3	A.g. Anodonta grandis	4	9.1%
CRANE CREEK	A.g. Anodonta grandis	2	4.5%
MAPLE CREEK 1B	A.g. Anodonta grandis	1	2.3%
OWATONNA DAM TAILWATER	A.g. Anodonta grandis	3	6.8%
STRAIGHT RIVER 3B	A.g. Anodonta grandis	5	11.4%
STRAIGHT RIVER 5	A.g. Anodonta grandis	2	4.5%
STRAIGHT RIVER 6A	A.g. Anodonta grandis	1	2.3%
STRAIGHT RIVER 7B	A.g. Anodonta grandis	3	6.8%
TURTLE CREEK 1B TRANSECT	A.g. Anodonta grandis	2	4.5%
CANNON 5 (WATERVILLE)	A.g. Anodonta grandis	3	6.8%
OWATONNA DAM TAILWATER	E.d. Eliptio dilatata	6	66.7%
STRAIGHT RIVER 6A	E.d. Eliptio dilatata	2	22.2%
CANNON 1B (LAKE CITY)	E.d. Eliptio dilatata	1	11.1%
CANNON 1C (LAKE CITY)	L.cplLasmigona complanata	3	1.3%
CANNON 2 (LAKE CITY)	L.cplLasmigona complanata	1	0.4%
CANNON 2 (LOWER RIVER)	L.cplLasmigona complanata	13	5.8%
CANNON 3 (WATERVILLE)	L.cplLasmigona complanata	1	0.4%
CANNON 3A (LAKE CITY)	L.cplLasmigona complanata	1	0.4%
CANNON 3B (LAKE CITY)	L.cplLasmigona complanata	40	17.8%
CANNON 4A (LAKE CITY)	L.cplLasmigona complanata	3	1.3%
CANNON 4C-1 (LAKE CITY)	L.cplLasmigona complanata	2	0.9%
CANNON 4C-2 (LAKE CITY)	L.cplLasmigona complanata	105	46.7%
CANNON 4D (LAKE CITY)	L.cplLasmigona complanata	21	9.3%
CANNON 5 (WATERVILLE)	L.cplLasmigona complanata	5	2.2%
CRANE CREEK	L.cplLasmigona complanata	8	3.6%
HEATH CREEK 1	L.cplLasmigona complanata	1	0.4%
OWATONNA DAM TAILWATER	L.cplLasmigona complanata	1	0.4%
PRAIRIE CR. 4 (MILE 10.2)	L.cplLasmigona complanata	15	6.7%
STRAIGHT RIVER 1	L.cplLasmigona complanata	1	0.4%
STRAIGHT RIVER 6A	L.cplLasmigona complanata	2	0.9%
CANNON 1B (LAKE CITY)	L.cplLasmigona complanata	2	0.9%
CANNON 1C (LAKE CITY)	L.r. Ligumia recta	2	28.6%
CANNON 1B (LAKE CITY)	L.r. Ligumia recta	5	71.4%
CANNON 2 (LAKE CITY)	L.s. Lampsilis radiata siliquoidea	1	0.8%
	L.s. Lampsilis radiata siliquoidea	1	0.8%

CANNON 3 (WATERVILLE)	L.s.	Lampsilis radiata siliquoidea	56	44.4%
CANNON 3A (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	2	1.6%
CANNON 3B (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	1	0.8%
CANNON 4A (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	1	0.8%
CANNON 4C-1 (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	19	15.1%
CANNON 4C-2 (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	8	6.3%
CANNON 4D (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	5	4.0%
CANNON 5 (WATERVILLE)	L.s.	Lampsilis radiata siliquoidea	23	18.3%
STRAIGHT RIVER 1	L.s.	Lampsilis radiata siliquoidea	1	0.8%
STRAIGHT RIVER 3A	L.s.	Lampsilis radiata siliquoidea	3	2.4%
STRAIGHT RIVER 3B	L.s.	Lampsilis radiata siliquoidea	4	3.2%
STRAIGHT RIVER 6A	L.s.	Lampsilis radiata siliquoidea	1	0.8%
CANNON 1B (LAKE CITY)	L.v.	Lampsilis ovata ventricosa	4	44.4%
CANNON 1C (LAKE CITY)	L.v.	Lampsilis ovata ventricosa	3	33.3%
STRAIGHT RIVER 3B	L.v.	Lampsilis ovata ventricosa	2	22.2%
CANNON 1B (LAKE CITY)	P.a.	Potamilus alatus	12	3.0%
CANNON 1C (LAKE CITY)	P.a.	Potamilus alatus	18	4.5%
CANNON 2 (LAKE CITY)	P.a.	Potamilus alatus	5	1.3%
CANNON 2 (LOWER RIVER)	P.a.	Potamilus alatus	3	0.8%
CANNON 3A (LAKE CITY)	P.a.	Potamilus alatus	12	3.0%
CANNON 3B (LAKE CITY)	P.a.	Potamilus alatus	5	1.3%
CANNON 4A (LAKE CITY)	P.a.	Potamilus alatus	5	1.3%
CANNON 4C-1 (LAKE CITY)	P.a.	Potamilus alatus	219	55.2%
CANNON 4C-2 (LAKE CITY)	P.a.	Potamilus alatus	90	22.7%
CANNON 4D (LAKE CITY)	P.a.	Potamilus alatus	7	1.8%
CANNON 5 (WATERVILLE)	P.a.	Potamilus alatus	4	1.0%
CHUB CREEK 1	P.a.	Potamilus alatus	1	0.3%
CRANE CREEK	P.a.	Potamilus alatus	2	0.5%
OWATONNA DAM TAILWATER	P.a.	Potamilus alatus	6	1.5%
STRAIGHT RIVER 1	P.a.	Potamilus alatus	3	0.8%
STRAIGHT RIVER 3A	P.a.	Potamilus alatus	1	0.3%
STRAIGHT RIVER 3B	P.a.	Potamilus alatus	4	1.0%
CANNON 3A (LAKE CITY)	P.s.	Pleurobema sintoxia	1	100.0%
OWATONNA DAM TAILWATER	S.u.	Strophitus undulatus	1	100.0%

STATION	SPECIES		FREQ.	% THIS STATIO
CANNON 1B (LAKE CITY)	A.c.	Actinonaias carinata	9	29.0%
	L.v.	Lampsilis ovata ventricosa	4	12.9%
	L.s.	Lampsilis radiata siliquoidea	1	3.2%
	L.cpl.	Lasmigona complanata	3	9.7%
	L.r.	Ligumia recta	2	6.5%
	P.a.	Potamilus alatus	12	38.7%
CANNON 1C (LAKE CITY)	A.c.	Actinonaias carinata	4	12.5%
	A.e.	Actinonaias ellipsiformis	1	3.1%
	L.v.	Lampsilis ovata ventricosa	3	9.4%
	L.cpl.	Lasmigona complanata	1	3.1%
	L.r.	Ligumia recta	5	15.6%
	P.a.	Potamilus alatus	18	56.3%
CANNON 2 (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	1	5.3%
	L.cpl.	Lasmigona complanata	13	68.4%
	P.a.	Potamilus alatus	5	26.3%
CANNON 2 (LOWER RIVER)	L.cpl.	Lasmigona complanata	1	25.0%
	P.a.	Potamilus alatus	3	75.0%
CANNON 2 (WATERVILLE)	A.g.	Anodonta grandis	1	100.0%
CANNON 3 (WATERVILLE)	A.g.	Anodonta grandis	5	8.1%
	L.s.	Lampsilis radiata siliquoidea	56	90.3%
	L.cpl.	Lasmigona complanata	1	1.6%
CANNON 3A (LAKE CITY)	A.g.	Anodonta grandis	1	1.8%
	A.f.	Anodontoides ferussacianus	1	1.8%
	L.s.	Lampsilis radiata siliquoidea	2	3.5%
	L.cpl.	Lasmigona complanata	40	70.2%
	P.s.	Pleurobema sintoxia	1	1.8%
	P.a.	Potamilus alatus	12	21.1%
CANNON 3B (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	1	11.1%
	L.cpl.	Lasmigona complanata	3	33.3%
	P.a.	Potamilus alatus	5	55.6%
CANNON 4A (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	1	12.5%
	L.cpl.	Lasmigona complanata	2	25.0%
	P.a.	Potamilus alatus	5	62.5%
CANNON 4C-1 (LAKE CITY)	A.g.	Anodonta grandis	3	0.9%
	L.s.	Lampsilis radiata siliquoidea	19	5.5%
	L.cpl.	Lasmigona complanata	105	30.3%
	P.a.	Potamilus alatus	219	63.3%
CANNON 4C-2 (LAKE CITY)	A.g.	Anodonta grandis	8	6.3%
	L.s.	Lampsilis radiata siliquoidea	8	6.3%
	L.cpl.	Lasmigona complanata	21	16.5%
	P.a.	Potamilus alatus	90	70.9%
CANNON 4D (LAKE CITY)	L.s.	Lampsilis radiata siliquoidea	5	29.4%
	L.cpl.	Lasmigona complanata	5	29.4%
	P.a.	Potamilus alatus	7	41.2%
CANNON 5 (WATERVILLE)	A.g.	Anodonta grandis	4	8.9%
	E.d.	Eliptio dilatata	6	13.3%
	L.s.	Lampsilis radiata siliquoidea	23	51.1%
	L.cpl.	Lasmigona complanata	8	17.8%
	P.a.	Potamilus alatus	4	8.9%
CHUB CREEK 1	P.a.	Potamilus alatus	1	100.0%
CHUB CREEK 3	A.g.	Anodonta grandis	2	66.7%
	A.f.	Anodontoides ferussacianus	1	33.3%
CRANE CREEK	A.g.	Anodonta grandis	1	25.0%

	L.cpl. Lasmigona complanata	1	25.0%
	P.a. Potamilus alatus	2	50.0%
HEATH CREEK 1	L.cpl. Lasmigona complanata	1	100.0%
MAPLE CREEK 1B	A.g. Anodonta grandis	3	50.0%
	A.f. Anodontoides ferussacianus	3	50.0%
OWATONNA DAM TAILWATER	A.g. Anodonta grandis	5	17.2%
	E.d. Eliptio dilatata	2	6.9%
	L.cpl. Lasmigona complanata	15	51.7%
	P.a. Potamilus alatus	6	20.7%
	S.u. Strophitus undulatus	1	3.4%
PRAIRIE CR. 4 (MILE 10.2)	L.cpl. Lasmigona complanata	1	100.0%
STRAIGHT RIVER 1	L.s. Lampsilis radiata siliquoidea	1	16.7%
	L.cpl. Lasmigona complanata	2	33.3%
	P.a. Potamilus alatus	3	50.0%
STRAIGHT RIVER 3A	A.f. Anodontoides ferussacianus	1	20.0%
	L.s. Lampsilis radiata siliquoidea	3	60.0%
	P.a. Potamilus alatus	1	20.0%
STRAIGHT RIVER 3B	A.g. Anodonta grandis	2	13.3%
	A.f. Anodontoides ferussacianus	3	20.0%
	L.v. Lampsilis ovata ventricosa	2	13.3%
	L.s. Lampsilis radiata siliquoidea	4	26.7%
	P.a. Potamilus alatus	4	26.7%
STRAIGHT RIVER 5	A.e. Actinonaias ellipsiformis	1	50.0%
	A.g. Anodonta grandis	1	50.0%
STRAIGHT RIVER 6A	A.g. Anodonta grandis	3	37.5%
	A.f. Anodontoides ferussacianus	1	12.5%
	E.d. Eliptio dilatata	1	12.5%
	L.s. Lampsilis radiata siliquoidea	1	12.5%
	L.cpl. Lasmigona complanata	2	25.0%
STRAIGHT RIVER 7A	A.f. Anodontoides ferussacianus	1	100.0%
STRAIGHT RIVER 7B	A.g. Anodonta grandis	2	100.0%
TURTLE CREEK 1B TRANSECT	A.g. Anodonta grandis	3	6.8%
	A.f. Anodontoides ferussacianus	41	93.2%
WOLF CREEK	A.f. Anodontoides ferussacianus	1	100.0%

LITERATURE CITED

Allen, W.R. 1914 The food and feeding habits of freshwater mussels. Biological Bulletin 27:127-146.

Baker, F.C. 1928. The Freshwater Mollusca of Wisconsin, Part II, Pelecypoda. Bulletin of the University of Wisconsin, General Series No. 1301.

Ball, G.H. 1922. Variations in freshwater mussels. Ecology 3:93-121.

Bedford, J.W. 1973. Bioactive compounds in the aquatic environment: uptake and loss of DDT and dieldrin by freshwater mussels. Archives of Environmental Contamination and Toxicology 1:97-111.

Buchanan, Alan C. 1983. Distribution, Abundance, Status and Habitat of the Curtis Pearly Mussel _Epioblasma florentina curtisi_ in Southern Missouri. Endangered Species Project SE-3-1, Missouri Department of Conservation.

Cawley, E.T. 1984 Report of Mussel Survey of High Quality Beds, Pools 17, 18, 19 UMR. Endangered Species Research - Higgen's Eye Pearly Mussel, Iowa Conservation Commission.

Chelburg, D.A. A Study of the Invertebrates of the Blue Earth River System. Museum Observer 7(2):2-7.

Coker, R.E. 1919. Freshwater mussels and mussel industries of the United States. Bulletin of the Bureau of Fisheries 36:15-89.

Coker, R.E., A.F. Shira, H.W. Clark and A.D. Howard. Natural History and Propagation of Freshwater Mussels. Bulletin of the Bureau of Fisheries 37:77-181.

Cole, G.A. 1983. Textbook of Limnology. St. Louis: C.V. Mosby Company.

Coon, T.G., J.W. Eckblad, and P.M. Trygstad. 1977. Relative abundance and growth of Mussels (Mollusca: Eulamellibranchia) in Pools 8, 9 and 10 of the Mississippi River. Freshwater Biology 7:279-285.

Cvancara, Alan M. 1972. Lake Mussel Distribution as Determined by SCUBA. Ecology 53:154-157.

Dawley, Charlotte. 1947. Distribution of Aquatic Mollusks in Minnesota. American Midland Naturalist 38:671-697.

Dawley, Charlotte. August 1944. Distribution and Growth Studies of the Unionidae and Aquatic Gastropoda found in Minnesota. PhD Thesis, University of Minnesota,

Dobbs, Clark. 1988. Personal communication. Minnesota State Archeologist.

Duncan, R.E., and P.A. Theil. 1983. A Survey of Mussel Densities in Pool 10 of the Upper Mississippi River. Technical Bulletin No. 139. Department of Natural Resources, Madison, Wisconsin.

Emerson, Pat. 1988. Personal communication. Minnesota State Archeologist.

Enblom, J. 1983. Minnesota Department of Natural Resources Stream Survey Report.

Fuller, S.L.H. 1978. Freshwater Mussels (Mollusca: Bivalvia: Unionidae) of the Upper Mississippi River: Observations at selected sites within the 9-foot Channel Navigation Project on behalf of the United States Army Corps of Engineers. Acad. Nat. Sci. Phila. 401 pp.

Fuller, S.L.H. 1980. Freshwater Mussels of the Upper Mississippi River: Observations at selected sites within the 9-foot Navigation Channel Project for the St. Paul District, U.S. Army Corps of Engineers, 1977-1979. Acad. Nat. Sci. Phila. 175pp. Vol. II, Appendices, 441pp.

Grier, N.M. and Mueller, J.F. 1923. Notes on the naiad fauna of the upper Mississippi. Nautilus 36:46-94; 96-103.

Haskins, H.H. 1954. Age Determination in Mollusks. Transactions of the New York Academy of Science 16(1):300-304.

Havlik, M.E. 1977. Naiad Mollusks of the Minnesota River at Savage, Minnesota, March 1977. M.E. Havlik, La Crosse, Wisconsin. Pages 1-4.

Havlik, M.E. 1983. Naiad Mollusk Populations (Bivalvia: Uniondae) in Pools 7 and 8 of the Mississippi River near LaCrosse, WIsconsin, American Malocological Bulletin 1:51-60.

Havlik, M.E., and L.L. Marking. 1987. Effects of Contaminants on Naiad Mollusks (Unionidae): A Review. U.S. Department of Interior, Fish and Wildlife Service/Resource Publication No. 164. 20pp.

Havlik, M.E., and D.H. Stansbery. 1977. The Naiad Mollusks of the Missisippi River in the Vicinity of Prairie du Chien, Wisconsin. Bulletin of the American Malacological Union, Inc. 1977:9-12.

Ingram, W.M. 1941. Tadpoles as hosts for the glochidia of the freshwater mussel. Current Science 10:535-536.

Isely, F.B. 1914. Expermimental study of growth and migration of freshwater mussels. United States Bureau of Fisheries, Report of the Commissioner of Fisheries. Appendix III. 24pp.

Isom, Billy G. 1979. Overcoming the Difficulties Encountered in Adequately Sampling Large Rivers for Mollusks. Proceedings of the UMRCC Symposium on Upper Mississippi River Bivalve Mollusks, May 3-4, 1979, Rock Island, IL.

Leferve, G., and W.C. Curtis. 1911. Metamorphosis without parasitism in the Unionidae. Science 33:863-865.

McCorkle, Bud. 1987. Personal communication. Long-time Northfield, Minnesota resident.

Mathiak, H.A. 1979. A River Survey of the Unionid Mussels of Wisconsin 1973-1977. Sand Shell Press, Horicon, Wisconsin.

Minnesota Department of Natural Resources Stream Survey. 1985. The Cannon River.

Minnesota Department of Natural Resources Stream Survey. 1984. The Cannon River Tributaries.

Minnesota Department of Natural Resources Stream Survey. 1983. The Cannon River Tributaries.

Minnesota Department of Natural Resources Stream Survey. 1977. The Cannon River Tributaries.

Northfield News. Northfield News library files, Northfield, Minnesota Public Library.

Ojakangas, R.W. 1982. Minnesota's Geology. University of Minnesota Press, Minneapolis, MN. 255pp.

Ortmann, A.E. 1920. Correlation of shape and station in freshwater mussels. Proceedings of the American Philosophical Society 59:269-312.

Payne, B.S. and A.C. Miller. 1987. Quantitative sampling to characterize freshwater mussel communities and populations. Proceedings of the Workshop on Die-offs of Freshwater Mussels in the United States. U.S. Fish and Wildlife Service. Pages 55-65.

Revling, F.H. 1919. Acquired Immunity to an Animal Parasite. Journal of Infectious Diseases 24:337-346.

Rosenberg, G.D. and Max T. Henschen. 1986. Sediment particles as a cause of nacre staining in the freshwater mussel, Amblema plicata (say) (Bivalvia: unionidae). Hydrobiologia 135:167-178.

Smith, R.L. 1980. Ecology and Field Biology. Harper and Row, New York.

Stansbery, D.H. 1987. Personal communication. The Ohio State Museum.

Sternberg, R.B. 1978. Minnesota Stream Survey Manual. Special Publication No. 120, April 1978. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries.

Van der Schalies, H. 1963. The distribution, ecology, and life history of the mussel Actinonaias ellipsiformis (conrad) in Michigan. Michigan University Museum of Zoology, Occasional papers.

Van Der Schalies, H.A. 1950. The Mussels of the Mississippi River. The American Midland Naturalist 44:448-466.

Waters, Thomas. 1977. The Streams and Rivers of Minnesota. University of Minnesota Press, Minneapolis, Minnesota.

Wilson, C.B. 1916. Copepod parisites of freshwater fishes and their economic relations to Mussel Glochidia. Bulletin of the United States Bureau of Fisheries 34:331-374.

Wilson, C.B. and E. Danglade. 1914. The mussel fauna of Central and Northern Minnesota. U.S. Bureau of Fisheries, Report of the Commissioner of Fisheries for 1913. Appendix V, 1-26.

Wisconsin Natural Heritage Inventory Rare Species Working List. 1987. Wisconsin Department of Natural Resources.