AQUATIC MOLLUSKS OF NORTH DAKOTA

by

Alan M. Cvancara

COVER: The white heel splitter mussel (Lasmigona complanata) with a cyprinid fish, symbolic of the [illegible] mussels on fish hosts during their larval stage. This mussel is from the Turtle River, 35 kilomet[illegible] Forks. Original photograph taken from an aquarium by A. M. Cvancara.

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INTRODUCTION

Purpose

This study primarily: (1) provides diagnostic characters and illustrations for identifying the 44 species of aquatic mollusks known to inhabit North Dakota; (2) provides state distribution maps for all the species; (3) identifies species associations and their relationship to general habitat; (4) evaluates ecological factors limiting aquatic mollusk occurrence; and (5) speculates on the origin of the aquatic molluscan fauna. An attempt has been made to minimize technical jargon so the non-specialist, as well as the specialist in mollusks, can use this report.

Acknowledgments

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Previous Studies

Prior to the 1960s, only species lists and notations were published on the aquatic mollusks of North Dakota. Say (1825, p. 11) noted a snail ("Planorbis armigerus") from the "Red River." Owen (1852, p. 177) noted five mussels from the Red River below the mouth of the Red Lake River. Lea (1858) noted two mussels from the Missouri River at Fort Clark. Hayden (1862, p. 180) listed one mussel from the White Earth River, one from the Missouri at Fort Clark, two from the James (in North Dakota?), and two snails from Fort Berthold. Froebel (1870, p. 72) mentioned a mussel, a pill clam, and four snails from small streams and ponds in the state. Dawson (1875, p. 350) listed seven mussels from the Red River. Call (1885) reported (cited by Ortmann, 1919, p. 281) a mussel from presumably the same river at Pembina; and Grant (1885, p. 115-119) recorded eight mussels from the Red in Wilkin County, Minnesota. Dall (1905, p. 125-136) listed 14 mussels and two pill clams for the Red River drainage; many of the occurrences, however, were for Manitoba. Coker and Southall (1915, p. 15) reported six mussels from the Red River at Fargo and four from the Sheyenne River at Lisbon. Ortmann (1919, p. 17, 31, 203, 292) noted four mussels from the Sheyenne River near Argusville. Winslow (1921) listed 49 aquatic mollusks from the Devils Lake region, Turtle Mountains, and westernmost North Dakota, and incorporated notes on general molluscan habitats. Clench (1935) proposed the name "Physa gouldi" (presumably a synonym of P. gyrina) for a snail whose type specimens were collected from the Mouse River north of Towner, North Dakota. Dawley (1947, p. 679) listed 11 species of mussels from the Red River.

Tuthill (1962, 1963) compiled a list of the state's aquatic mollusks based largely on the literature; in 1963, he and Laird published the first ecologic paper on aquatic mollusks in North Dakota. Since 1966, my associates and I have reported on the distribution and ecology of the aquatic mollusks, with greatest emphasis on the mussels: Cvancara (1966, 1967, 1970a, 1970b, 1975, and 1977); Cvancara, Bluemle, and Bluemle (1978); Cvancara and

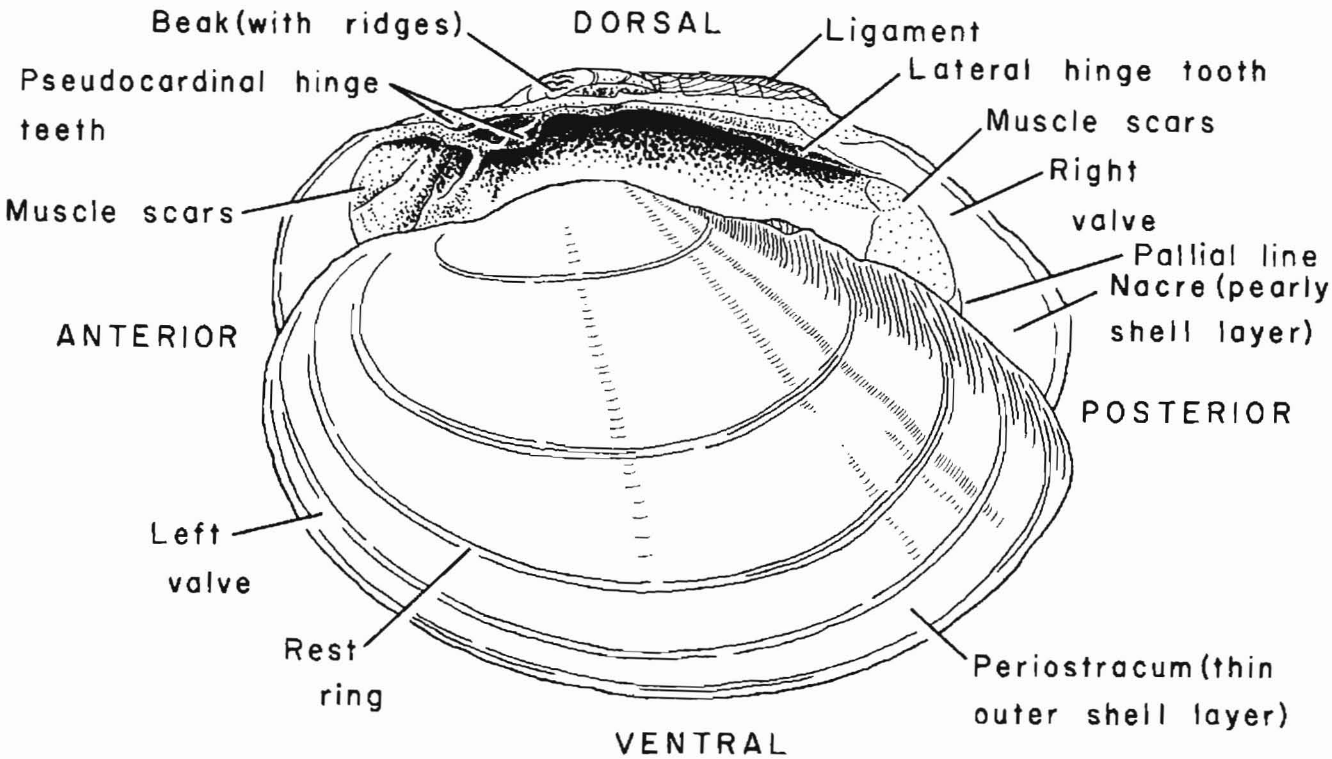

Figure 1. Mussel shell morphology, as depicted for Lampsilis ovata (Say).

Erickson (1968); Cvancara, Erickson, and Delimata (1972); Cvancara and Freeman (1978); Cvancara and Harrison (1966); Cvancara, Heetderks, and Iljana (1967); Cvancara, Norby, and Van Alstine (1976); Cvancara and Van Alstine (1977); and Groenewold (1971). Peterka (1972) discussed two genera of pill clams and four genera of snails from Lake Ashtabula, a man-made reservoir on the Sheyenne River. Clarke (1973) reported 12 species of mussels, 8 species of pill clams, and 25 species and subspecies of snails from the Hudson Bay drainage in North Dakota; these occurrences were based on 18 of his collecting stations and the literature. I (Cvancara, 1976; Ashworth and Cvancara, 1983) have summarized the Quaternary fossil aquatic mollusks in the state.

Morphology, Reproduction, Growth, and Biotic Associations

Mussels.--To non-marine malacologists, mussels are the larger freshwater clams, not to be confused with certain marine clams--as the "blue mussels." Mussels are known also as unionacean clams, referring to the superfamily to which they belong. A complete classification of North Dakota mussels is given in the Systematic Account of Species.

The shell (fig. 1) is of two valves, right and left, giving rise to the term "bivalve," applied also to clams in general. The valves are held together and opened by the dorsal, elastic, proteinaceous ligament. The area of the beak, pointed initial part of each valve, is set with characteristic ridges useful in identification. Externally, the shell may be smooth, set with undulations or folds, knobs or pustules, and even spines. Internally, in most mussels, interlocking pseudocardinal (or cardinal) and lateral hinge teeth hold the valves in position. Impressions or scars mark the positions of several muscles: adductors (the largest) for closing the valves, retractors for withdrawing the locomotory foot, a protractor for extending the foot, and dorsal muscles that attach the animal to the roof of the shell. Connecting the adductor scars is the pallial line, marking where the shell-secreting mantle, a fleshy flap, attaches to the shell. The shell consists of three main layers: the outer, thin, proteinaceous periostracum; the middle, relatively thin, prismatic layer of prisms of calcium carbonate about normal to the shell surface; and the

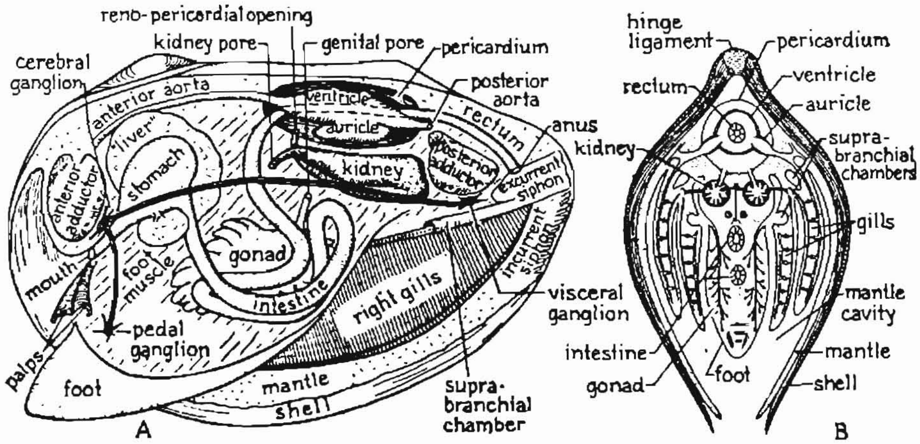

Figure 2. Diagrammatic soft-part morphology of the mussel Anodonta. A. The left valve, mantle, and gills of the left side have been removed. B. Cross section at the position of the heart. (From General Zoology by T. I. Storer, 1951, fig. 20-9; used with permission of McGraw-Hill Book Company.)

inner, thickest lamellar layer--also called the nacre or mother-of-pearl layer--of laminae of calcium carbonate parallel to the shell surface. A fourth layer, the myostracum, may also be present; it resembles the nacre and is secreted by the muscles.

Appressed to the inner shell surface and enveloping the remainder of the animal is the mantle (fig. 2). Besides shell secretion, it is sensory, and also aids in respiration and feeding. Posteriorly, the mantle is formed into the tubelike incurrent (inhalant) and excurrent (exhalant) siphons for the intake and the removal of water. Anteroventrally is the foot; protractor muscles extend it, and pumped-in blood anchors it into the substrate. Contraction of the retractor muscles enable the animal to pull itself forward. On either side of the foot is a pair of gills for respiration that also aid in feeding and reproduction.

The digestive system is readily understood by tracing the passage of food--organic detritus and animal plankton. Water-borne food enters the incurrent siphon, is trapped in mucous on the gills, and transferred by gill cilia toward the mouth. A pair of elongate structures on either side of the mouth, labial palps, pass the food into the mouth. The food continues to the stomach, through the sinuous intestine (above the foot), and waste discharges from the anus into the excurrent siphon. A kidney is just below the heart, which surrounds the lower intestine and pumps colorless blood into forward and rear aortas. Gonads occur above the foot. Connected by long nerve cords are three pairs of nerve centers or ganglia: cerebral (near the mouth), pedal (in the foot), and visceral (near the siphons). Detailed accounts of mussel shell morphology have been given by Coker and others (1921, p. 168-170) and Murray and Leonard (1962, p. 14-19), and of the soft part morphology by Baker (1928b, p. 3-6) and Simpson (1884).

Sexes are usually separate in fresh-water mussels, but hermaphroditism is common (van der Schalie, 1970a). Eggs pass from the ovaries to vertical water tubes in the gills; here, they are fertilized by sperm entering via the incurrent siphon. Parts of the gills serve as brood sacs (fig. 3) or marsupia as the eggs develop into microscopic larvae or glochidia that are bivalved but incompletely developed. These glochidia are discharged, in most mussels, through the excurrent siphon, and become attached and encysted in the fins, tail, or gills of a fish host. (A salamander host is also known, and the glochidia of a few species of mussels may develop without a parasitic stage.) During this stage, mussels can be widely dispersed through a drainage system. Fish hosts of North Dakota mussels are given in the Systematics. As the cyst on the fish host ruptures, a juvenile mussel emerges and drops to the bottom. If a suitable substrate exists, the juvenile develops into a reproductive adult mussel. Detailed accounts of mussel reproduction have been provided by

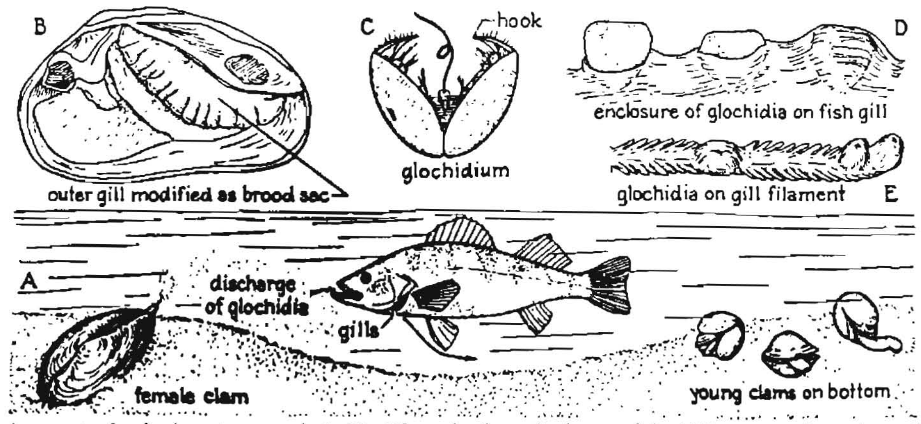

Figure 3. Development of a fresh-water mussel. A. The life cycle, from discharge of glochidia, to attachment to a fish host, to settlement of young mussels on the bottom. B. Outer gill of a female mussel modified as a brood sac. C. A single glochidium. D, E. Glochidia on fish gills. (From General Zoology by T. I. Storer, 1951, fig. 20-12; used with the permission of McGraw-Hill Book Company.)

Baker (1928b, p. 7-15) and Coker and others (1921, p. 135-155).

A shell increases in size as the edge of the mantle successively adds the periostracum and prismatic layer; the shell increases in thickness by the surface of the mantle adding successive laminae of nacre. On the periostracum are narrow, inconspicuous growth lines and wide and dark, prominent rest rings (fig. 1) (also called "growth" rings, growth annulae, winter rings, and rest periods), which are commonly counted to estimate the age of a mussel; the rest ring, therefore, represents arrested growth during winter, such as found with tree rings. However, one must be careful with this approach. Similar, non-seasonal rings can be produced by fluctuation in water level or physical disturbance, such as handling by man or a natural predator. Also, one must first determine, with some degree of certainty, how much a mussel grows in one year or the first rest ring. Shell length at the first rest ring varies with species and water body. For example, Chamberlain (1931) found median values for "Lampsilis anodontoides" of 1.61 cm (n=100) and 4.60 cm (n=56) from the Mississippi River in Iowa and the Rio Grande River in Texas; for "Lampsilis siliquoidea pepinensis" median values were 1.98 cm (n=200) and 2.25 cm (n=100) from Lake Pepin and Cross Lake, Minnesota. (It must be realized that the first rest ring may represent an actual age of less than one year; Negus, 1966). The rate of growth is rapid in early life and later slows down, especially after sexual maturity; this is reflected by closer rest rings in later formed parts of older shells. The rate of growth is also generally greater in thinner-shelled species than in thicker-shelled species (Coker and others, 1921, p. 128-129). Mussels may live for many years. Isely (1931) recovered individuals of Amblema plicata that he had tagged and released 15 years earlier. Since the recovered mussels were more than 10 years old when released, he estimated their age as 25-30 years.

Pearls form when an irritating foreign object, as a sand grain, enters between the mantle and shell, and is covered with nacre. Similarly, mud entering may form a blister on the surface of the shell. Pearls may also be secreted by the muscles.

Fuller (1974, p. 222-240) has provided a detailed summary of the biotic associations of mussels. Of particular interest are flukes, water mites, fish hosts (already referred to), and predators. Parasitic flukes (trematode flatworms) may damage or destroy the gonads, irritate the mantle to form pearls, and discolor the nacre (Baker, 1928b, p. 31) in Anodonta. Water mites (Unionicolidae), commensal or parasitic, may cause the shedding of parts of the gills or death if the infestation is heavy. Mite eggs or larvae can serve as pearl nuclei, forming small blisters or pimples on the inside of the shell. Predators include fishes (especially catfish and the fresh-water drum, Aplodinotus grunniens), amphibians, turtles, birds, and mammals, including the otter, mink, muskrat, raccoon, hog, and man. The raccoon seems to be the primary mussel predator in North

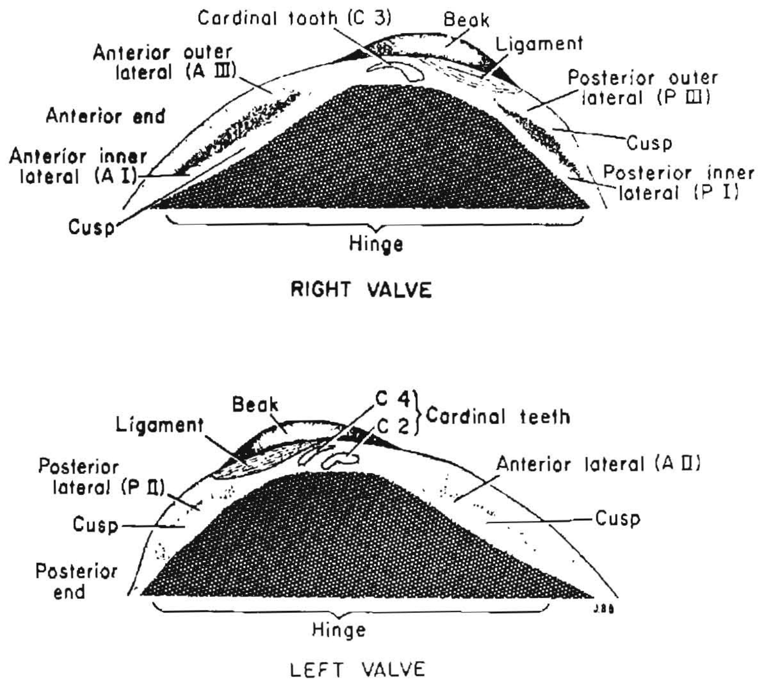

Figure 4. Hinge tooth terminology for pill clams, as depicted for Pisidium. (From Herrington, 1962, fig. 2).

Dakota.

Pill clams.--Pill clams, or fingernail, pea, or nut clams, are the smaller fresh-water clams, less than about 2.5 cm long. They are known also as the sphaeriid clams, referring to the family to which they belong. A complete classification of the pill clams is given in the Systematics.

The shell differs from that of the mussels besides smaller size: Lateral teeth are both anterior and posterior to the cardinals (fig. 4) (except the South American genus Byssanodonta that lacks teeth); the ligament is shorter and poorly developed; ridges in the area of the beaks are uncommon; muscle scars and the pallial line are usually obscure; and the inner shell is porcelaneous, not nacreous.

The soft-part morphology is generally similar to that of mussels. However, considerable anatomical variation exists within the pill clams, resulting in the recognition of three subfamilies (Burch, 1975a, p. 1). Detailed accounts of pill clam shell morphology have been given by Herrington (1962, p. 9-11), and of the soft-part morphology by Drew (1896), Gilmore (1917), and Monk (1928).

Pill clams are hermaphroditic--even self-fertilization occurs--and the newborn young are essentially miniature adults. Hermaphroditism allows a single individual to extend a species' range. Developing young are incubated, as in mussels, within brood sacs or marsupia of the gills, specifically within the anterior parts of the inner gills. No secondary parasitic stage exists, however, as in mussels. Considerable variation in number and size of developing young per parent, number of broods, time of birth, and life span occurs in the many species of pill clams. Heard (1965, 1977) has provided considerable detailed information on pill clam reproduction, and has summarized much of the literature on the subject.

The shell increases in size and thickness in essentially the same manner as for mussels. As with mussels, one must use care in estimating age from the rest rings. Heard (1977, p. 433, 435) used rest rings ("annuli") to denote general age classes, but considered them unreliable in determining life span. Sphaerium simile is one of the longest living pill clams. Gilmore (1917, p. 26) reported individuals of this species with up to eight "growth" rings, and Heard (1977, p. 436) found up to six. The larvae can grow slower, as fast, or faster than their parents, depending on the species and habitat (Mackie, 1979).

Organisms intimately associated with pill clams include parasitic flukes (trematode flatworms; summarized by Mackie, 1976) and leeches (Gale, 1973) and numerous predatory fish (e.g., Baker, 1916; Jude, 1968) and several predatory aquatic birds (e.g., Illinois Natural History Survey, 1977; Thompson, 1973).

Snails.--Snails or gastropods usually possess a single or univalved shell, in contrast to the bivalved shell of mussels and pill clams. Fresh-water snails are either prosobranchs or pulmonates, referring to the two subclasses to which they belong. (A complete classification of North Dakota species is given in the Systematics.) Prosobranchs possess true gills, an operculum for closing the opening or aperture (fig. 6), relatively thick shells, and are relatively slow-moving. Pulmonates (fig. 7) lack the gills and an operculum, have relatively thin shells, and are relatively fast-moving.

The fresh-water shell is conispiral (coiled out of a plane), planispiral (coiled within a plane or nearly so), or cap-shaped or patelliform (forms a depressed cone); cap-shaped shells are secreted by the so-called fresh-water limpets, similar to the unrelated rocky shore marine limpets. Some idea of shape can be gained from the width/length (these two dimensions are explained in the Systematics) ratio, given for all species in North Dakota (table 4). Each complete coil is a whorl, several of which constitute the spire (fig. 5) in conispiral shells. Sutures mark places of contact of adjoining whorls. Whorls may be smooth, except for growth lines (parallel or subparallel to axis of coiling), or sculptured with spiral (parallel to sutures) carinae (ridges or keels), axial (subparallel to axis of coiling) costae (ridges), striae (grooves), malleations (flat surfaces resembling hammered metal), spines (rare), and various forms of microsculpture. The opening or aperture consists of the outer and inner lips. Internally may be toothlike lamellae, as in two species of Planorbula in North Dakota. Surrounding the axis of coiling is the columella, a solid or hollow rod or pillar. Where hollow, the cavity or depression so formed is the umbilicus, which may be covered by shell material of the inner lip. Conispiral shells are dextral, with right-handed or clockwise coiling (when viewed from the apex or point of initial growth), or sinistral, with left-handed or counterclockwise coiling. Strictly, however, a dextral or sinistral snail is one with genitalia on its right or left side. Dextral or sinistral planispiral shells are difficult to recognize since a presumed umbilicus, or a depressed spire, is the only point of reference, and distinguishing the two types of shells is somewhat artificial. For instance, shells of the Planorbidae may be considered both dextral and sinistral but the animals are all sinistral, based on the position of the genitalia. Conispiral shells are usually carried on the dorsal part of the animal (fig. 6), aperture down, with the apex pointing obliquely toward the rear. Planispiral shells are also carried aperture down, but with the axis of coiling about normal to the direction of travel. "Right" and "left" may be applied to the shell as its orientation during transport is kept in mind. The shell structure consists of an outer, corneous periostracum and three or more calcareous lamellar layers.

The animal (fig. 7) consists of two basic entities: the head-foot that is protrusible but can be withdrawn into the shell, and the visceral mass that remains permanently within the shell. Columellar muscles (attached to the columella and foot) draw the head-foot mass into the shell. The locomotory foot is flattened dorsoventrally instead of laterally as in bivalves. The head, in fresh-water snails, has a single pair of sensory tentacles with an eye at the base of each. Food--in most cases algae or organic detritus--is usually taken by the combined action of jaws and a rasp-like ribbon, the radula, beset with transverse rows of numerous, microscopic teeth. It passes through the esophagus, stomach, and into the long, coiled intestine surrounded by the digestive gland that forms most of the coiled mass in conispiral snails. Salivary glands, a kidney, and other structures are also part of the digestive-excretory complex. Waste is discharged through the anus anteriorly. The front part of the visceral mass is covered by the shell-secreting mantle that surrounds a respiratory space, the mantle cavity. In prosobranchs, the cavity is occupied by a true gill. In pulmonates, respiration occurs by a gill-like struc-

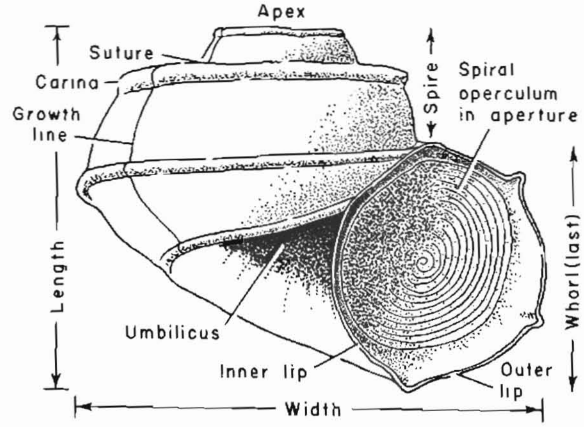

Figure 5. Snail shell morphology, as depicted for Valvata tricarinata (Say).

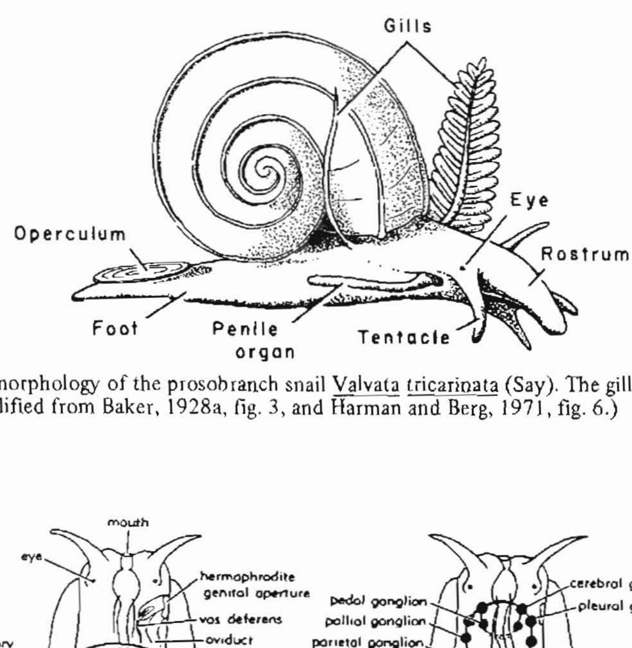

Figure 6. General external morphology of the prosobranch snail Valvata tricarinata (Say). The gill on the animal's right side is rudimentary. (Modified from Baker, 1928a, fig. 3, and Harman and Berg, 1971, fig. 6.)

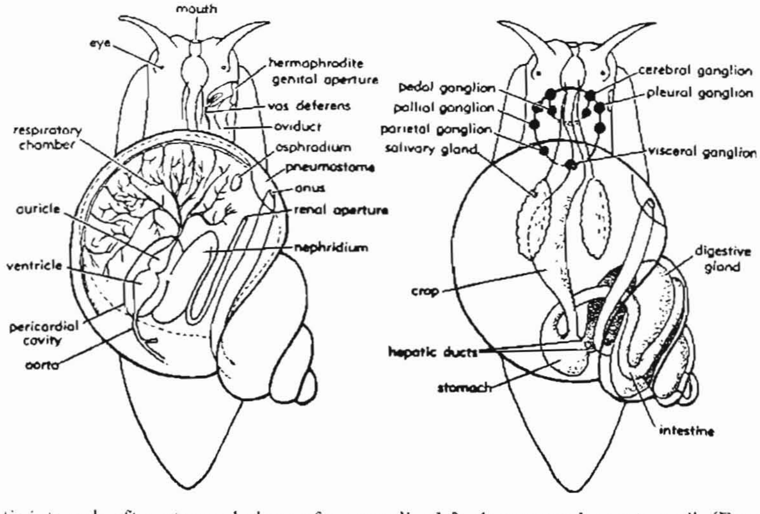

Figure 7. Diagrammatic internal soft-part morphology of a generalized fresh-water pulmonate snail. (From Cox, 1960, fig. 88.)

ture outside the mantle cavity, or by a pulmonary sac or lung--as the mantle cavity becomes roofed by tissue with numerous blood vessels, and enclosed except for a small opening. The heart, from which radiate numerous blood vessels, is behind the gill in prosobranchs and behind the pulmonary sac in pulmonates. The nervous system is of several nerve centers or ganglia connected by nerve cords; in prosobranchs it is relatively dispersed and the visceral loop (of pleural, visceral, and intermediate ganglia and associated nerve cords) is twisted in a figure 8; in pulmonates, the nervous system is concentrated (anteriorly) and the visceral loop is not twisted. Gonads are embedded in or lie upon the digestive gland; position and type of other parts of the reproductive system vary considerably. Female organs typically consist of ovary, oviduct or uterus, albumen gland (produces fluid that surrounds eggs), vagina, and spermatheca (stores sperm); male organs are testis, vas deferens, and penis. Cox (1960, p. I88-I135) has given a detailed account of shell and soft-part morphology.

Fertilization is internal in fresh-water snails, as for mussels and pill clams. Parthenogenesis (reproduction within fertilization) is also known to occur (e.g., in the prosobranch Campeloma; van der Schalie, 1965). In prosobranchs (except in the Valvatidae), sexes are separate, and the males have a conspicuous penile organ near the right tentacle (fig. 6). Pulmonates are hermaphroditic, and produce both sperm and ova in a single hermaphrodite gland. Cross-fertilization is usual, although each individual produces sperm, and self-fertilization may occur as well. (Hermaphroditism may account, in part, for the greater dispersal of pulmonates over prosobranchs, but the pulmonary sac for respiration and greater ability to withstand exposure to air is probably more significant.) Both prosobranchs and pulmonates can store sperm for a time before fertilization. Eggs are laid in gelatinous masses in the water for development, except for the Viviparidae (includes Campeloma) in which eggs are hatched internally, and the young are partly grown before being released. Detailed accounts of reproduction have been given by several workers cited in the Systematics section.

The embryonic shell, of one or more whorls, is formed in the egg and usually differs markedly in form and sculpture from the post-embryonic shell. Growth of the shell occurs parallel to the outer lip, and successive stages of growth are marked by growth lines. In general, the age of a shell cannot be estimated by rest rings as in mussels or pill clams. An adult shell can be determined by the number of whorls characteristic of a species, or, in certain cases, by thickening or a turning back of the outer lip or expansion of the aperture. In temperate regions, the smaller species of fresh-water snails tend to live one year. The larger pulmonates may live two years, and the larger prosobranchs tend to live two or three years (Harman, 1974, p. 279-281). The longest known life span of a fresh-water snail is 10 years for the prosobranch Viviparus viviparus (Linne') (Cox, 1960, p. I87, cited data by P. Pelseneer).

Aquatic snails are associated with many organisms. Plants provide food and cover, and greatly increase the space snails can occupy (Harman and Berg, 1971, p. 8); certain snails apparently prefer associations with particular plant species and others do not (Pip, 1978). Many animals prey on snails, including fish (Baker, 1928a, p. 5-6), salamanders, turtles, ducks, shrews, muskrats, and raccoons (Leonard, 1959, p. 24); leeches (Klemm, 1976; Sawyer, 1974); dragonfly nymphs and sciomyzid (dipteran) fly larvae (Eisenberg, 1966); and water bugs (Belostoma, Lethocerus, Nepa) and the diving beetle Dytiscus (Leonard, 1959, p. 24). Snails are parasitized by flukes (trematode flatworms), roundworms (nematodes), and horsehair worms (nematomorphs) (Malek, 1974) as well as leeches (Klemm, 1976). Certain water mites may lay reddish egg masses on the shells of live snails, and presumably increase the risk of predation on these mollusks (Lanciani and Harman, 1968).

Significance of Aquatic Mollusks to Man

Biologic monitors of water quality.--The quality of natural waters can be lessened in several ways, either naturally or by man-induced changes. Man-induced changes are most common, and include: the addition of chemical pollutants, such as from industrial wastes and pesticides; thermal pollution, as from industrial processes or power plants; and organic enrichment, as from human or other animal waste and soil fertilizers. Fresh-water mollusks can serve to detect anomalous values of water quality parameters, and monitor changes in such values. Fuller (1974) and Imlay (1982) have summarized the use of mussels in water quality monitoring; Harman (1974) has provided a similar summary for snails. Examples of the use of pill clams in water quality monitoring are by Paparo and Sparks (1976) and Mackie (1978).

Dramatic changes in water quality have been documented, particularly with mussels. For example, the mussel fauna of the Illinois River decreased from 49 kinds (species and subspecies) to 24 during 1900-1966, largely because of domestic and industrial pollution (Starrett, 1971). Another example: On the Muskingum River, Foster and Bates (1978) found 60 percent and 30 percent mortalities in the mussel *Quadrula quadrula* at 5 km and 21 km downstream from a copper electroplating plant effluent. In North Dakota, I pointed out earlier that water pollution seems to have been responsible for mussel decrease or depletion downstream from Minot (Cvancara, 1975) and at three places on the Red River (Cvancara, 1970a). Fresh-water mollusks vary widely in their tolerance to anomalous water quality: Species widely distributed tend to be more tolerant; those more restricted in their occurrence tend to be less tolerant. For example, species occurring in North Dakota tolerant to decomposable organic waste include *Physa integra*, *Helisoma trivolvis*, *Sphaerium transversum*, and *Pisidium compressum*. Species intolerant to organic pollution include *Amnicola limosa*, *Ferrissia rivularis*, and *Proptera alata* (Weber, 1973, table 7). Examining the distribution of these species in North Dakota (figs. 32, 34, 38, 44, 49, 53, 58), one can see they follow the generalization given above except for *S. transversum* and *F. rivularis*.

Food for fish, birds, and mammals.--Fresh-water mollusks serve as food for numerous animals, as already mentioned in the previous general account of mollusks. More important to man, however, such mollusks can form a significant part of the diet of food and game fish, game birds, and fur-bearing animals. About 20 percent of the fresh-water fishes feed on mollusks--mostly snails--and rely on them 1-100 percent (Baker, 1928a, p. 5) as a food source. In Gravel Lake, North Dakota, Joseph (1976) found that snails (three genera) were the dominant food source for the rainbow trout during summer and early fall; snails formed up to 93.2 percent of the average total stomach volume of this fish. Several fish also consume appreciable amounts of pill clams (Baker, 1928b, p. 309-310; Jude, 1968), and a few bottom-feeding fish feed on mussels as well (Baker, 1928b, p. 13-14).

Certain aquatic birds of significance to man feed on mollusks considerably. For example, on the Mississippi River in southeastern Iowa, five diving ducks utilized all groups of mollusks as an important food source, but particularly the pill clams. Considering data for the fall of 1966 and 1967, up to 76 percent of the gizzards of the lesser scaup contained pill clams, and up to 68 percent of the gizzards contained snails (Thompson, 1973). In North Dakota, snails have accounted for 32 percent of the animal food of the blue-winged teal during the breeding season (Swanson, Meyer, and Serie, 1974).

A few fur-bearers--otter, mink, muskrat, and raccoon--feed appreciably on mussels (summarized briefly by Fuller, 1974) and prehistoric man has fed on them rather heavily as well (Parmalee and Klippel, 1974). Today, man feeds relatively little on mussels. At least one company, however, is investigating the merits of producing mussel meat commercially for human consumption (Peach, 1982, p. 167). Indirectly, too, man frequently uses the flesh of mussels as fish bait.

Prehistoric man probably fed on aquatic snails as well as mussels. Data from an archaeological site along the Wabash River in southwestern Indiana strongly suggests the snail *Campeloma* was utilized as human food (Dorwin and Claflin, 1977).

Shell for implements and ornaments.--Native Americans have utilized mussel shell in numerous ways. (Gradwohl, 1982 has given a brief, documented summary.) Uses as implements include spoons, cups, dishes, scoops, knives, scrapers (pl. 2, fig. 8), gaming pieces, hoes, fish lures and fishhooks, fish scalers, and green corn shellers. A particularly intriguing implemental use was that of the Osage Indians, who carried fire between mated valves (Hough, 1926, p. 3). Embers in fungus tinder--taken from inside a hollow tree--were enclosed in earth and placed between the valves. The shell was wrapped carefully and bound with cord. The "fire" was said to be kept for several days.

Uses as ornaments by Native Americans include pendants (pl. 2, fig. 6), beads (pl. 2, fig. 9), pins, and gorgets. One of the more ornate and distinctive ornaments is the thunderbird effigy (pl. 2, fig. 9, lower left). Pearls from mussels were utilized as ornaments as well (Parmalee, 1967, p. 1).

The pearl button industry based on mussel shell began in the United States in the early 1890s, centered in Muscatine, Iowa. This multimillion-dollar industry flourished until the advent of plastics after World War II, and ceased by the mid-1960s (details summarized by Parmalee, 1967, p. 1-4). Before the pearl button industry terminated, the use of mussel shell for the cultured pearl industry was initiated, in the early 1960s. Mussel shells are cut and ground into spheres that are inserted into pearl oysters; within one to two years a cultured pearl is produced. Spheres from mussel shells are preferred because of their hardness and because the resulting pearl is mostly of nacreous shell. In 1966, a peak year, about 25,000 tons of mussel shells were exported from the United States, mostly to Japan. The tonnage has dwindled to about 4,700 tons in 1980. With the decreased demand for exported shells, pilot studies for a pearl culture industry in the United States have been initiated (Peach, 1982).

Mussels in North Dakota most suitable for pearl button manufacture or for the growth of cultured pearls are Amblema plicata (three ridge), Fusconaia flava (pig toe), Quadrula quadrula (maple leaf), Lampsilis ovata (pocketbook), and L. radiata (fat mucket).

Snails as vectors of human disease.--Certain debilitating human diseases are caused by parasitic worms that require aquatic snails as intermediate hosts to complete their life cycles. Passively infected by the larvae of such parasitic worms, these snails become of extreme medical significance to man. The occurrence and ecology of host snails must be known to prevent and combat the snail-borne diseases. A common combatting technique is to eradicate infected host snails by the application of copper sulfate or other chemicals (Malek and Cheng, 1974, p. 290-298).

The most common snail-transmitted human diseases, produced by parasitic flukes (trematode flatworms), are blood fluke disease (schistosomiasis or bilharziasis), liver fluke disease (fascioliasis), intestinal fluke disease (fasciolopsiasis), and lung fluke disease (paragonimiasis) (Cheng, 1973). These diseases are largely endemic to tropical and subtropical regions as the snails that serve as intermediate hosts are generally intolerant of temperate climates. Species of aquatic snails that most commonly act as intermediate hosts are of the genera Biomphalaria, Bulinus, Oncomelania, Segmentina, and Thiara (Malek and Cheng, 1974, table 5-1).

Another less serious human affliction transmitted by snails serving as intermediate hosts for parasitic flukes is a rash called "swimmer's itch" (cercarial dermatitis). As mentioned in the Systematics section, three species occurring in North Dakota that act as intermediate hosts are Lymnaea stagnalis, Stagnicola elodes, and Gyraulus parvus (Cort, 1950).

Geologic Setting

The regional slope of North Dakota is generally to the east-northeast, from an elevation of 1069 m at the top of White Butte (Slope County) in the southwesternmost part of the state to 229 m along the Red River in the northeastern corner (Pembina County) (fig. 8). The relief can be grouped into five general physiographic areas (west to east): Missouri Slope, Coteau Slope, Missouri Coteau, Drift Prairie, and Red River Valley. The Missouri Slope, south and west of the Missouri River Valley, is a region of dissected and undulating topography and well integrated drainage; topography is particularly dissected in the Badlands along the Little Missouri River. Potholes and lakes, mostly man-made, are uncommon in the Missouri Slope. To the east and north of the Missouri River Valley is the Coteau Slope, a region of undulating and dissected topography, mostly integrated drain-

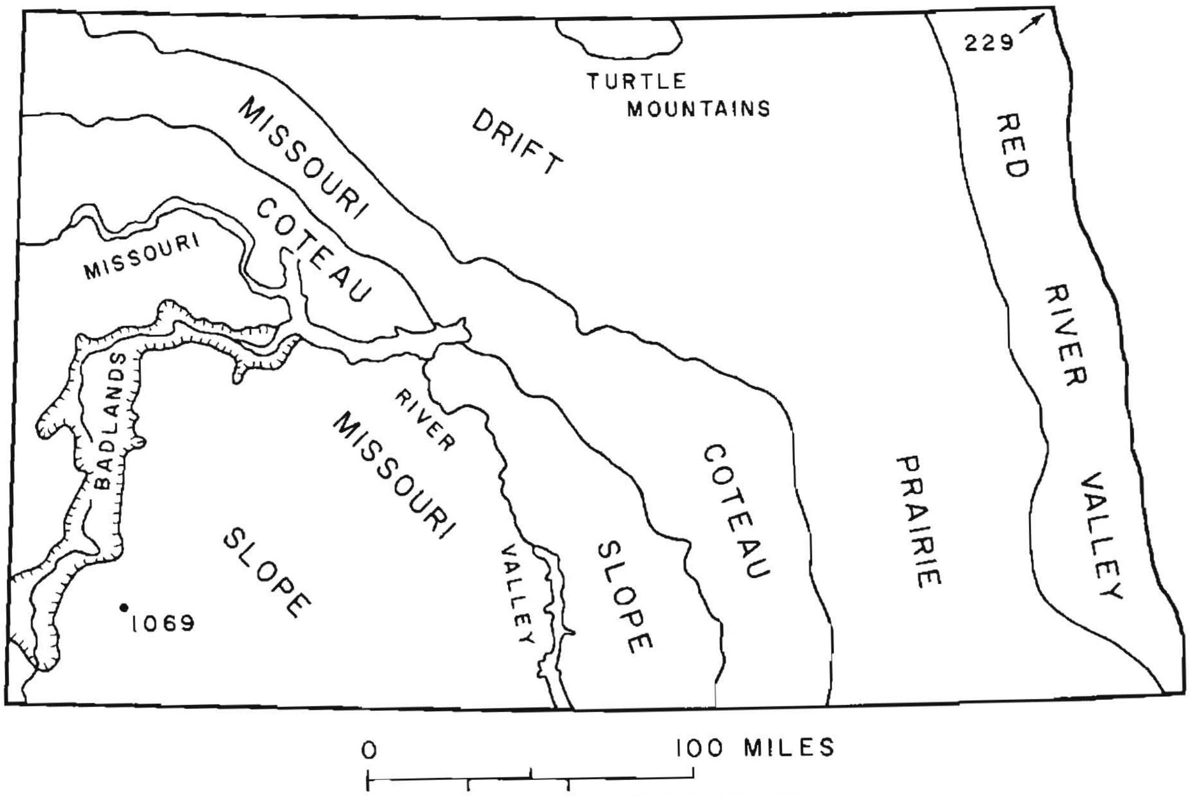

Figure 8. General physiographic areas of North Dakota. (Modified from Clayton and Freers, 1967, fig. R-1). The highest—1069 m— and lowest—229 m—elevations are in the southwestern and northeastern parts of the state.

age, and uncommon to common potholes and lakes. Contrary to the regional slope of the state, the Coteau Slope drains south and west toward the Missouri River Valley. Trending northwest diagonally across the state is the Missouri Coteau, a hilly region with nonintegrated drainage and abundant potholes and lakes. To the northeast is the Drift Prairie, a hilly, undulating and dissected region with nonintegrated and integrated drainage, and common to abundant potholes and lakes. The Turtle Mountains, within the Drift Prairie, resemble a wooded Missouri Coteau. Along the eastern border of the state is the Red River Valley, an essentially flat region with integrated drainage and uncommon potholes and lakes.

Parts of two major drainages occur in the state, the Mississippi River and Hudson Bay (fig. 9). About 60 percent of the state is within the Mississippi River drainage that encompasses the Missouri Slope, Coteau Slope, Missouri Coteau (although the Coteau lacks stream drainage), and a part of the Drift Prairie drained by the James River and its tributaries. The other major drainage besides that of the James River is that of the Missouri River. Major tributaries of the Missouri are the Little Missouri, Knife, Heart, and Cannonball-Cedar. The remaining 40 percent of the state is within the Hudson Bay drainage. Major drainages here are those of the Red and Souris Rivers. Major tributaries of the Red are the Pembina, Park, Forest, Turtle, Goose, Maple, Sheyenne, and Wild Rice.

More than three-fourths of the state has been glaciated, and is covered by a regolith of Late Quaternary (perhaps 75,000 years and younger; Bluemle, 1977, p. 10) glacial and glacier-related sediments (fig. 10): glacier-deposited till (mixture of gravel, sand, silt, and clay), meltwater-related sand and gravel, and lacustrine clay and silt with sand. The region

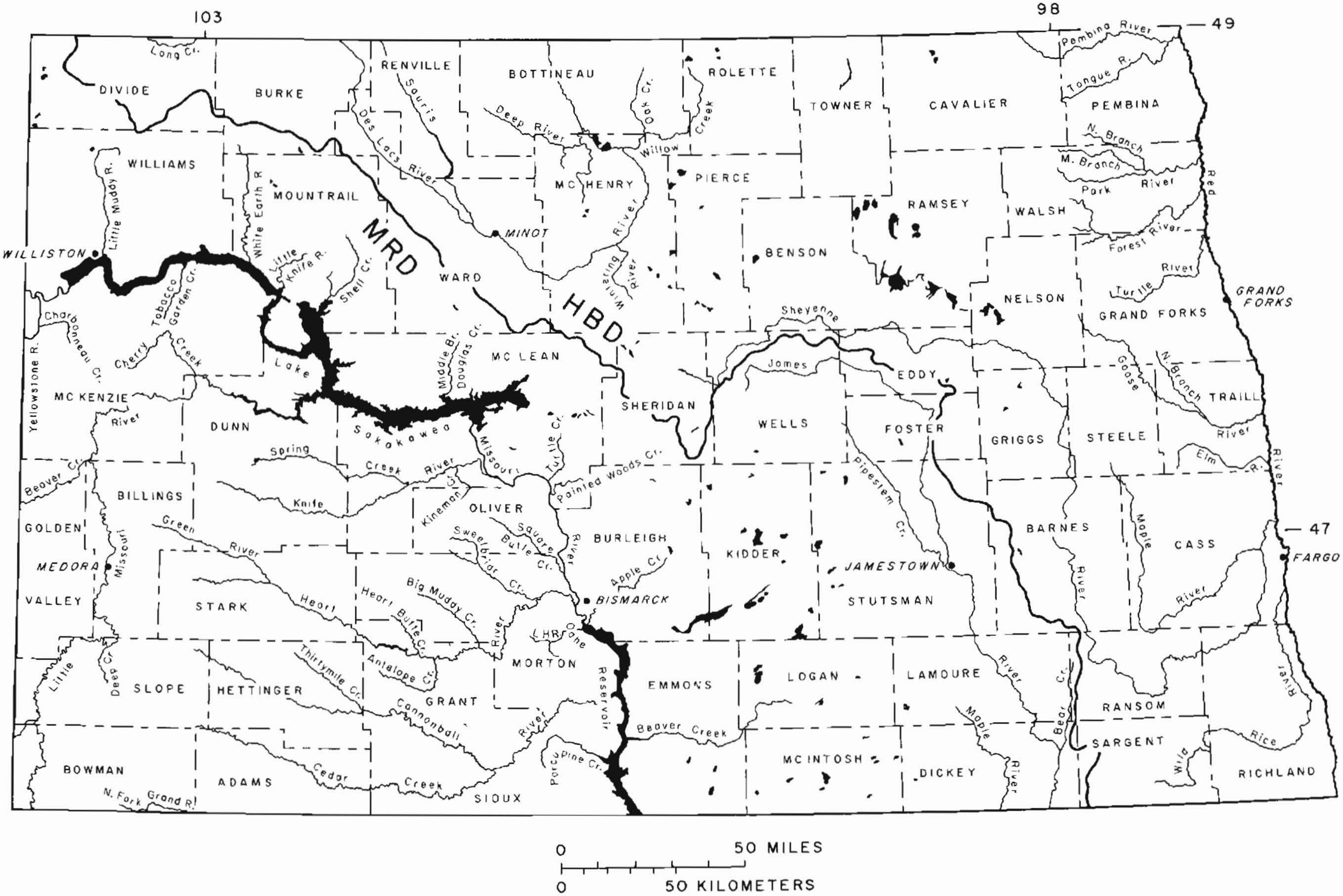

Figure 9. Streams, major lakes, and drainage areas of North Dakota. MRD = Mississippi River drainage, HBD = Hudson Bay drainage; L.H.R. = Little Heart River.

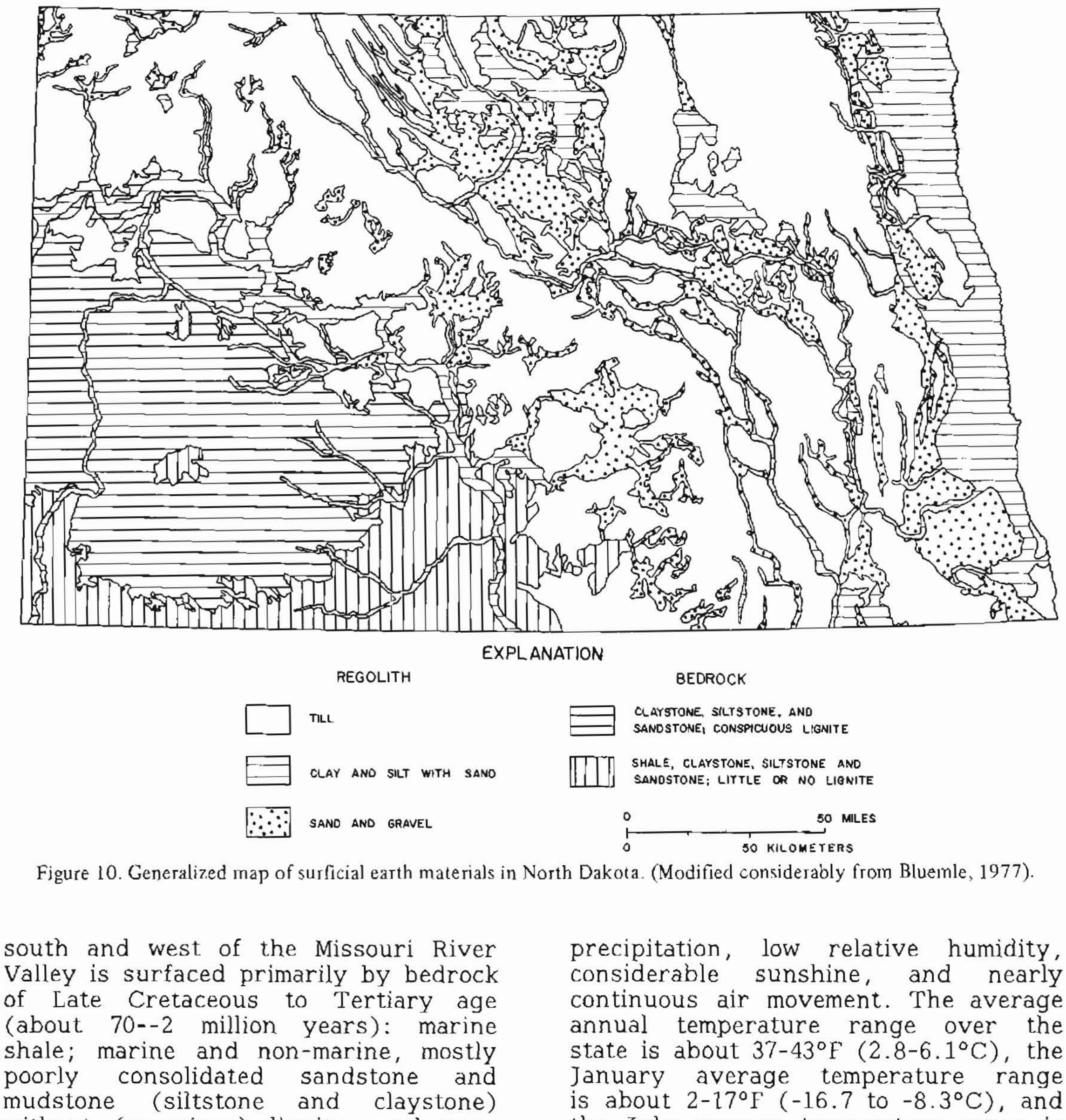

Figure 10. Generalized map of surficial earth materials in North Dakota. (Modified considerably from Bluemle, 1977).

south and west of the Missouri River Valley is surfaced primarily by bedrock of Late Cretaceous to Tertiary age (about 70--2 million years): marine shale; marine and non-marine, mostly poorly consolidated sandstone and mudstone (siltstone and claystone) without (or minor) lignite; and non-marine, mostly poorly consolidated sandstone and mudstone with conspicuous lignite. In the northern and eastern parts of this region, glacial and glacier-related sediments are present but are thin and discontinuous.

Climate

North Dakota is dry subhumid in the eastern part and semiarid in the western part (Visher, 1954, p. 365). It is characterized by large annual temperature changes, low to moderate precipitation, low relative humidity, considerable sunshine, and nearly continuous air movement. The average annual temperature range over the state is about 37-43°F (2.8-6.1°C), the January average temperature range is about 2-17°F (-16.7 to -8.3°C), and the July average temperature range is about 67-73°F (19.4-22.8°C). The average annual precipitation range over the state is about 13-20 inches (33-51 cm) (fig. 11), the December (lowest) average precipitation range is about 0.3-0.7 inches (0.8-1.8 cm), and the June (highest) average precipitation range is about 3.0-4.2 inches (7.6-10.7 cm) (temperature and precipitation data from maps by Jensen, 1972).

Evaporation exceeds precipitation; the average annual lake evaporation ranges from about 38 inches (96.5 cm)

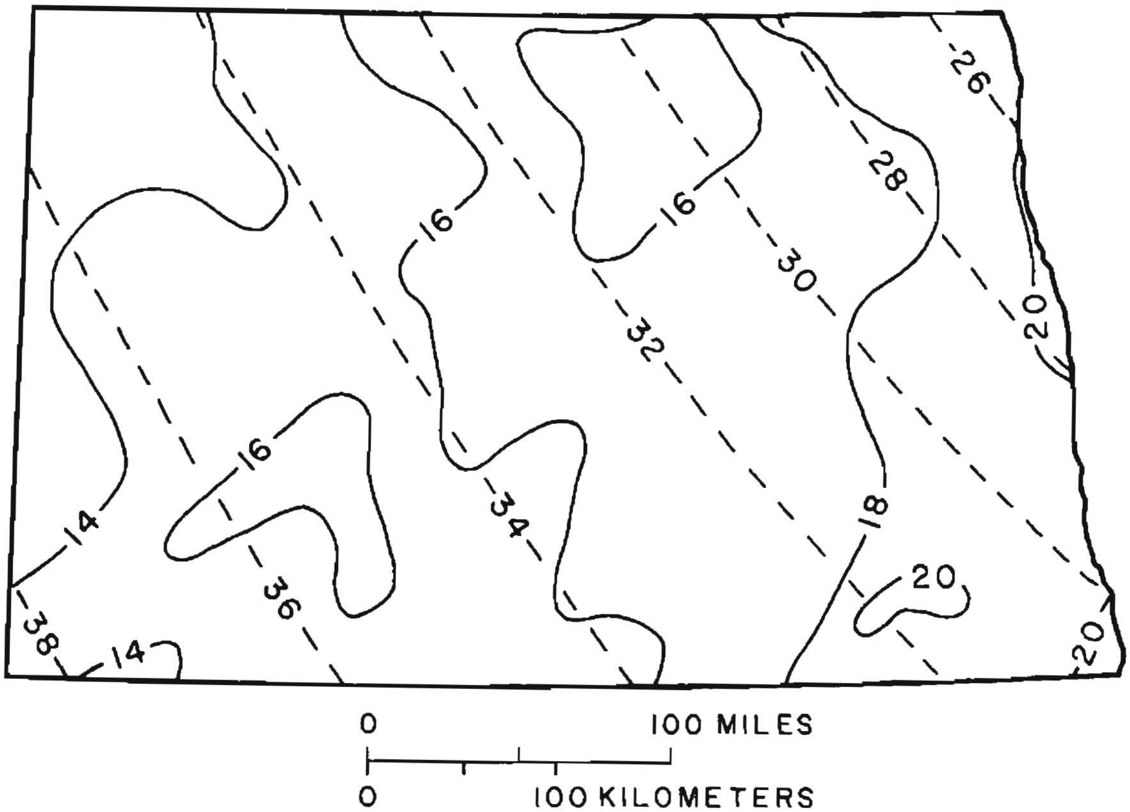

Figure 11. Average annual precipitation (solid lines; Jensen, 1972) and average annual lake evaporation (dashed lines; Kohler and others, 1959) in North Dakota. All values are in inches.

in the southwest to 26 inches (66 cm) in the northeast (fig. 11). The average annual runoff over the state is about 1 inch (2.5 cm) or less (Busby, 1966).

Vegetation

The natural vegetation of North Dakota was dominated by grasses (Kuchler, 1964). Tall bluestem prairie, dominated by big and little bluestem, switchgrass, and Indian grass, covered the Red River Valley (fig. 8). Mixed-grass prairie covered the remainder of the state. A wheatgrass-bluestem-needlegrass prairie, dominated by western wheatgrass, big bluestem, and needlegrass, covered the Drift Prairie. A wheatgrass-needlegrass prairie, dominated by western wheatgrass, blue grama, needle-and-thread grass, and green needlegrass, covered the Missouri Coteau, Coteau Slope, and Missouri Slope.

Woody vegetation of the eastern forest extended westward along the major watercourses, resulting in a northern flood-plain forest dominated by cottonwood, black willow, and elm; other conspicuous trees are green ash and box elder. Outliers of this eastern forest were also established in the Turtle Mountains (fig. 8), Pembina Mountains (Cavalier and Pembina Counties), the Devils Lake region (along the Benson-Ramsey County line), the Killdeer Mountains (Dunn County) (fig. 9), and elsewhere. In these areas aspen and paper birch may be conspicuous, as well as bur oak in the drier habitats. In places, as a sandy area flanking the lower Sheyenne River in Ransom and Richland Counties (fig. 8), the forest has given way to an oak savanna dominated by bur oak and big and little bluestem. A notable isolated derivative of the western forest is a small ponderosa pine forest south of the Little Missouri River in Slope

County.

Stream Discharge and Surface Water Chemistry

Stream discharge for many gaging stations across the state is shown in figure 12. Using mean discharge as an indicator of stream size, it is clear that the Missouri, Red, and Little Missouri Rivers are the largest streams in the state, and all others are considerably smaller. Of perhaps most ecological significance, though, is the minimum discharge and number of years--for the period 1959-68--in which zero discharge was recorded at a gaging station. With the exception of the Missouri, Red, and lowermost Sheyenne Rivers, minimum discharge at most stations was either zero or nearly zero. And only in the exceptional Missouri, Red, and lowermost Sheyenne were there no years with zero discharge. At many of the gaging stations zero discharge was recorded for few to several years. In particular, at the three stations on the Little Missouri River, zero discharge was recorded for nine of ten years--even though the mean discharges were relatively high.

Mean total-dissolved-solids concentration in the state is less than 400 mg/l to more than 900 mg/l (fig. 13). Relatively higher concentrations occur in the southeastern and southwestern parts of the state, as well as in the north-central part. Mean total alkalinity (fig. 14) is less than 200 mg/l to more than 400 mg/l. Mean total sulfates (fig. 15) is less than 50 mg/l to more than 400 mg/l. Areas of relatively higher concentrations of total alkalinity and total sulfates occur in similar places as for total-dissolved-solids. Mean total chlorides (fig. 16) is less than 10 mg/l to more than 40 mg/l. Higher concentrations in the southeastern and north-central parts of the state parallel those of the other chemical factors depicted here. However, an area of higher total chlorides does not appear to occur in the southwest, but one does occur in the northeast (fig. 19).

Materials and Methods

Aquatic mollusks were searched for at 298 stations, 35 of which were re-examined once (fig. 20, app. A). Most of the fieldwork was done during 1965-69, with supplemental collecting and re-examination of previous stations in 1970, 1973, 1974, and 1976. Data from several additional stations on the Turtle (Cvancara and Harrison, 1966) and Forest (Cvancara, Erickson, and Delimata, 1972) Rivers were not included in this study because distributional patterns of species would not have been affected. More stations are on streams than on lakes or ponds because a principal interest of the funding agency initially was the use of mollusks in monitoring water quality in streams.

Collecting time at a station was usually one-half to two hours; two collectors were present for nearly all stations--myself and an assistant. Mussels were collected primarily by handpicking when water levels were low. In relatively clear water, collecting was aided by a Turtox Fishscope, an aluminum alloy cylinder (0.61 m long by 0.15 m in diameter) fitted with a glass plate at one end; in turbid water, collecting was accomplished by feel with hands and feet. A 2.4-m-long crowfoot dredge (Cvancara, 1970a) or basket dredge was used in the deeper rivers and lakes. Mussel abundance was expressed as the number of live individuals collected per hour by handpicking by two collectors. Pill clams and snails were collected at the same time as were the mussels from sediment and plants with a sieve (wire food strainer) with openings of about 1.5 mm. It was difficult to quantify the relative abundance of these smaller mollusks: The generally sporadic occurrence of pill clams precluded obtaining reasonable values of numbers per unit area, and snails occurred on plants as well as on the bottom. The relative abundance, therefore, was estimated in the field, and the following numbers were arbitrarily assigned per hour of collecting time: abundant = $>$ 20 individuals, common = 9-20, uncommon = 4-8, and rare = 1-3.

Chemical parameters and turbidity (values summarized in app. B) were measured in the field with a Hach Chemical Company portable chemical kit (Model DR-E) and a Taylor pH Slide Comparator. Specific conductance was also measured at many stations with a Beckman Solu-Bridge, Model RB3-338. Observations were made at each station of bottom sediment, width of stream channel (where applicable), and associated organisms.

Specimens collected are in the

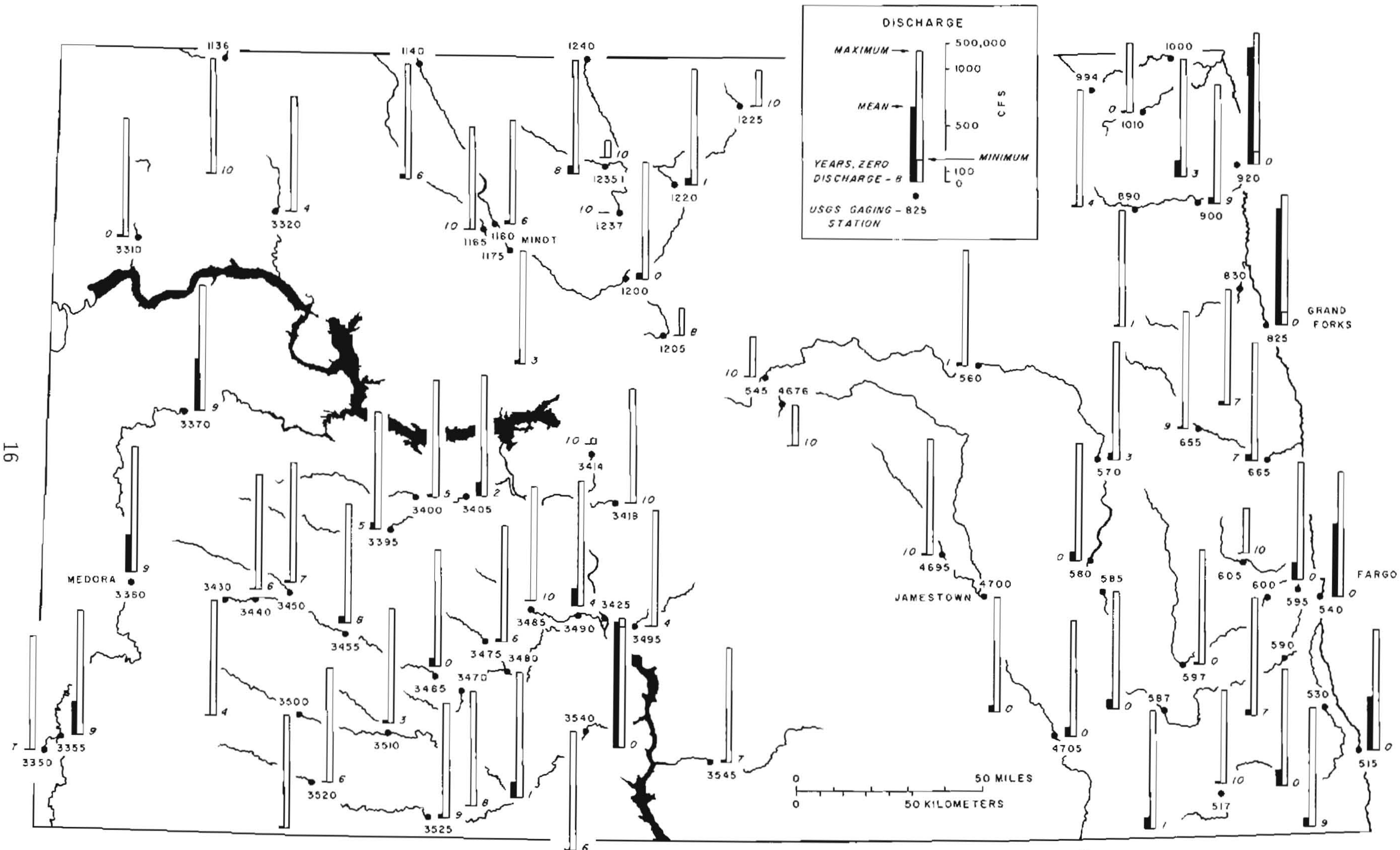

Figure 12. Stream discharge in North Dakota for the calendar years 1959-68. Discharge is given in cubic feet per second (cfs); 1 cfs = 0.028 m^3/s. The single- or double-digit number at the base of each bar couplet is the number of years in which zero discharge was recorded. Discharge data are from U.S. Geological Survey (1960-62, 1961-64, 1965, and 1966-69).

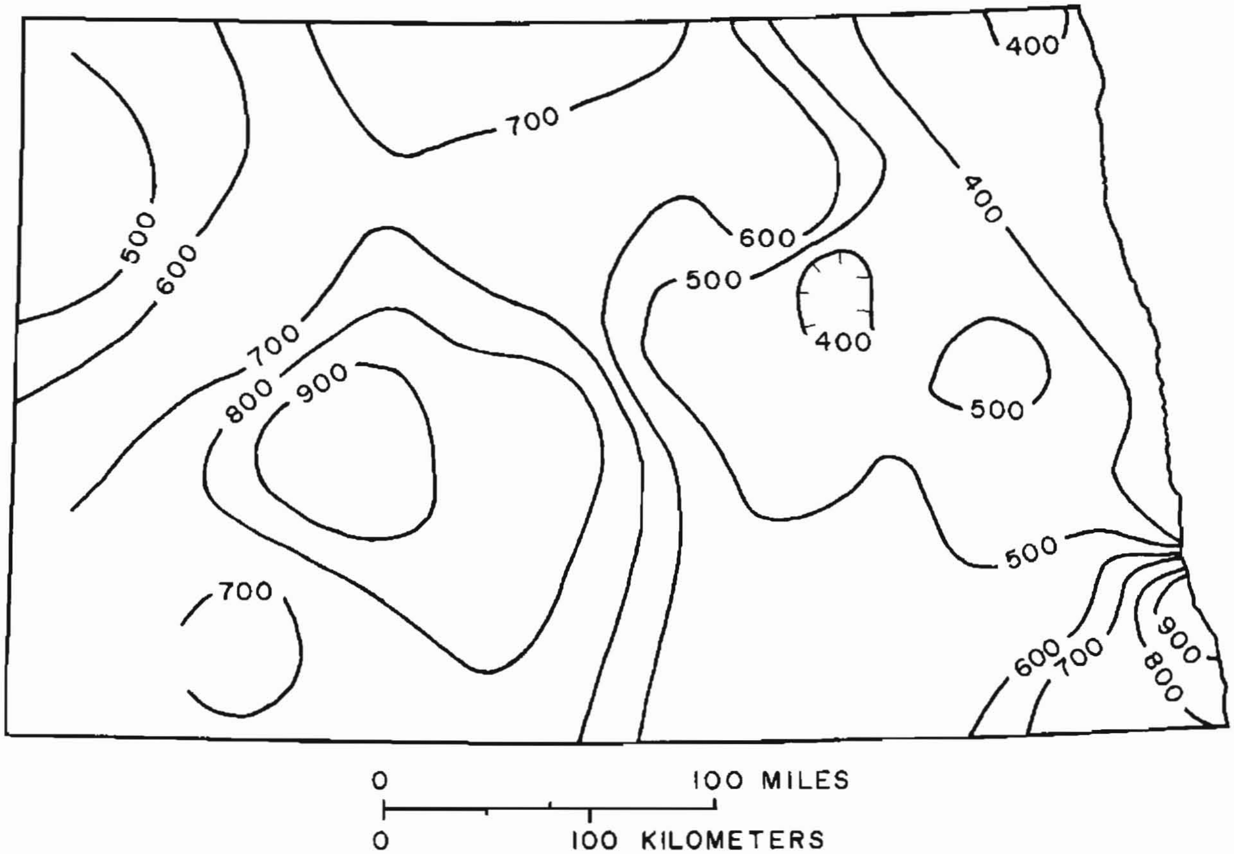

Figure 13. Mean total-dissolved-solids concentration of streams in North Dakota for the period October 1, 1958 to September 30, 1969. Values are in mg/l. Control points = 24. Broken contours are in areas of insufficient data.

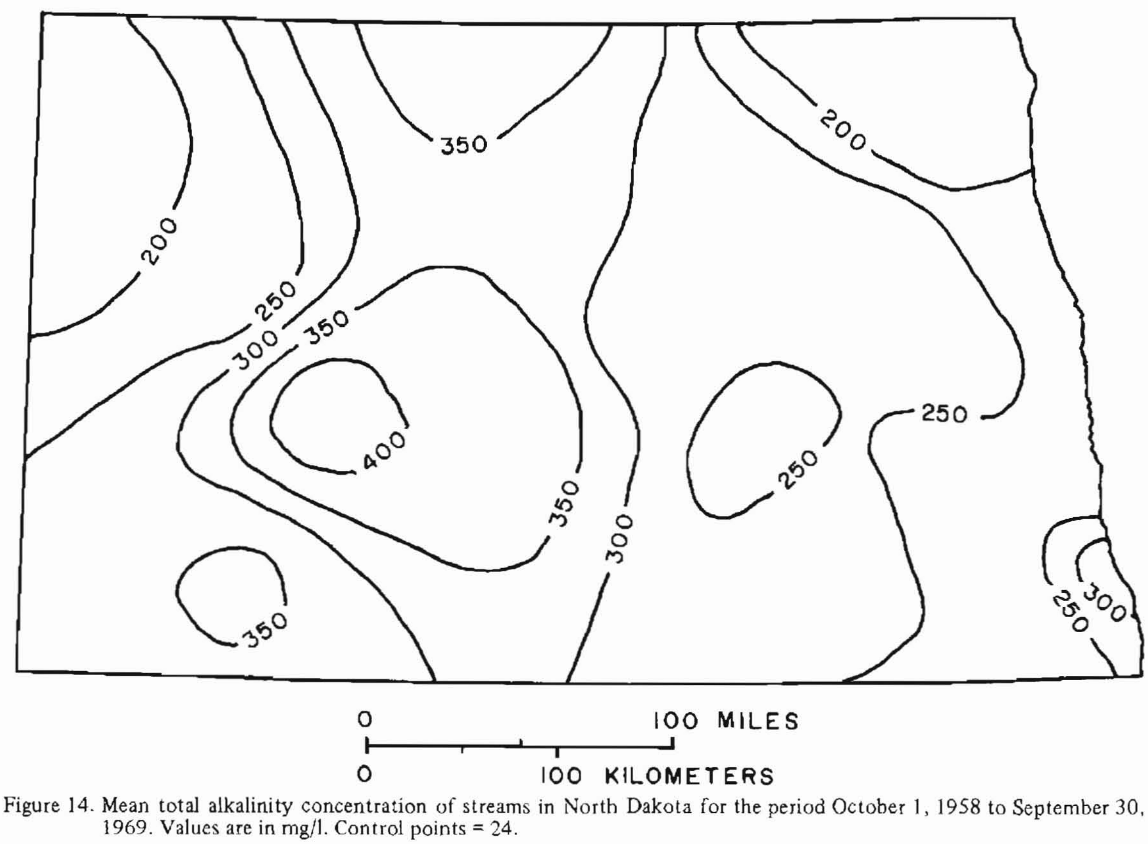

Figure 14. Mean total alkalinity concentration of streams in North Dakota for the period October 1, 1958 to September 30, 1969. Values are in mg/l. Control points = 24.

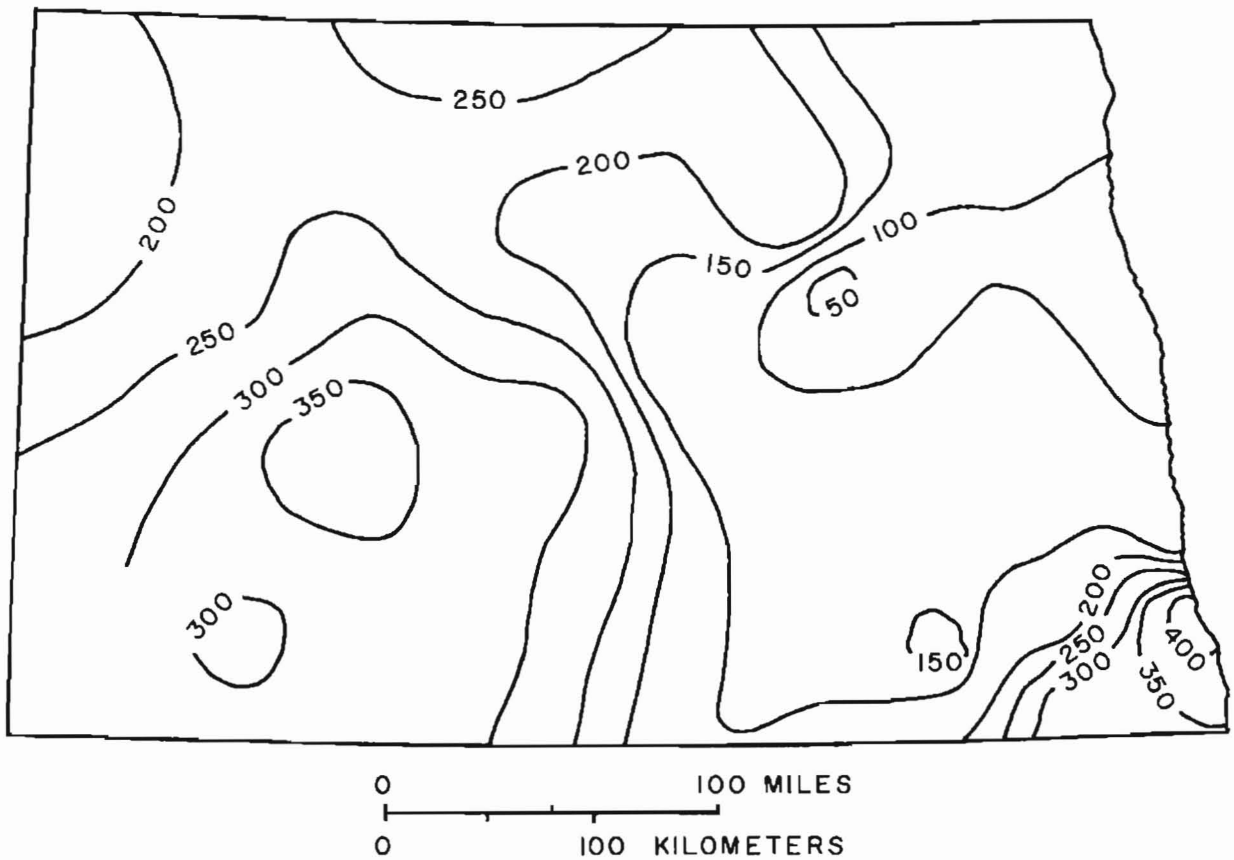

Figure 15. Mean total sulfates concentration in North Dakota for the period October 1, 1958 to September 30, 1969. Values are in mg/l. Control points = 24. The broken contour is in an area of insufficient data.

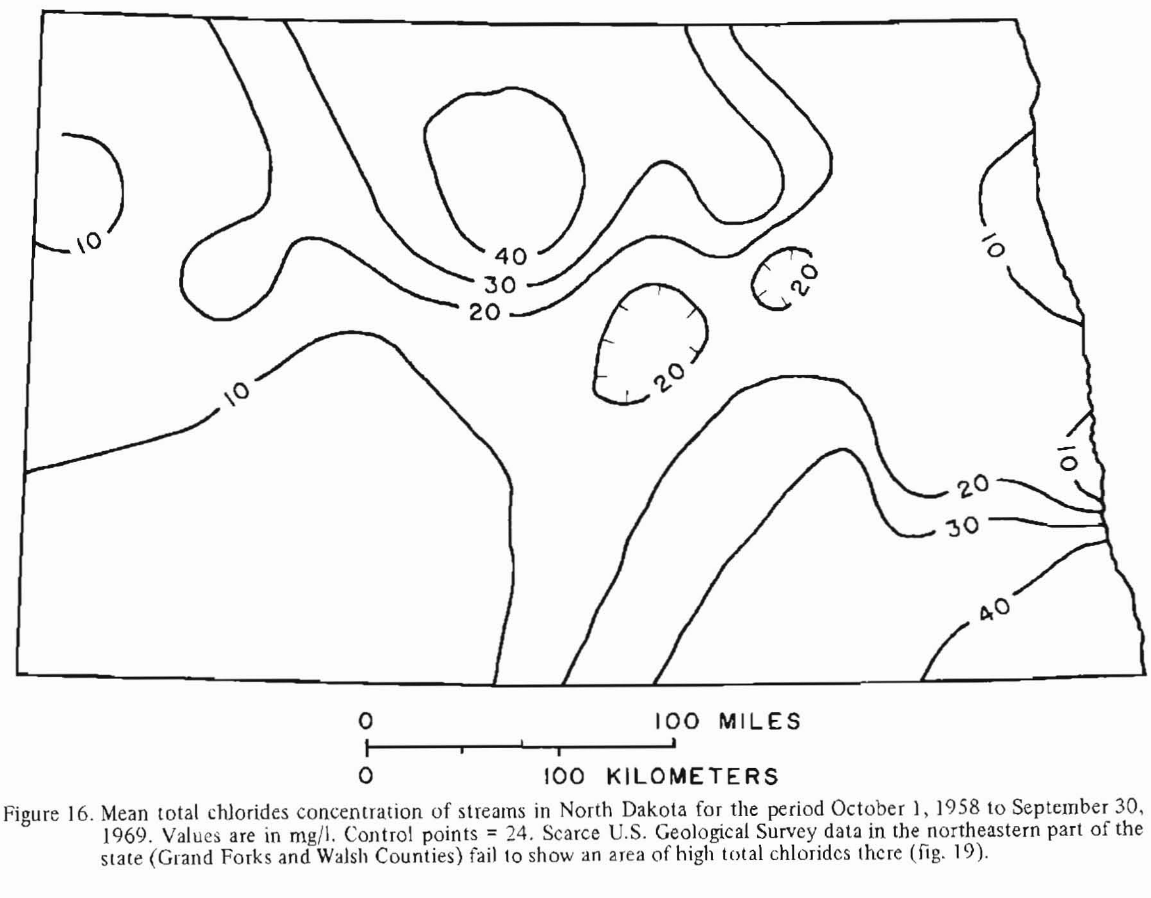

Figure 16. Mean total chlorides concentration of streams in North Dakota for the period October 1, 1958 to September 30, 1969. Values are in mg/l. Control points = 24. Scarce U.S. Geological Survey data in the northeastern part of the state (Grand Forks and Walsh Counties) fail to show an area of high total chlorides there (fig. 19).

paleontological collection of the Department of Geology, University of North Dakota, and bear the accession numbers given in appendix A.

The chemical maps (figs. 13-16) were computer-generated from data summarized and supplied by R. L. Houghton of the U.S. Geological Survey, Water Resources Division, Bismarck.

RESULTS

Composition of the Fauna

At least 44 species of aquatic mollusks are known to inhabit North Dakota: 13 mussels, 9 pill clams, and 22 snails (table 1). The most frequently occurring mussel, pill clam, and snail are Anodonta grandis, Pisidium compressum, and Physa gyrina (figs. 24, 38, 57). Of the snails, only four are gill-breathing (prosobranch), operculate forms (species 23-26, table 1), the remainder being lung-breathing (pulmonate), nonoperculate forms. The dominant snail family is the Planorbidae, represented by nine species (species 32-40), followed by the Lymnaeidae (species 27-30) and Physidae (species 41-44) with four species each. Other species that may occur in the state are discussed in the Systematics section.

Malacogeography

Species and major drainage.--More species of aquatic mollusks are known from the Hudson Bay than from the Mississippi River drainage in the state--42 versus 30 (table 1). Twelve species of mussels are known from the Hudson Bay drainage, five from the Souris River drainage and all 12 from the Red River drainage. A sixth species for the Souris River drainage, Strophitus undulatus, is known only from empty shells (fig. 28). The most prevalent mussels for the Hudson Bay drainage are Anodonta grandis, Lasmigona complanata, and Lampsilis radiata. Six species are restricted to the Red or lower Sheyenne Rivers (figs. 21-23, 31, 32).

Eleven species of pill clams are known from the Hudson Bay drainage in the state based on my collecting; species numbers for the Souris and Red River drainages are similar. The most prevalent species are Sphaerium lacustre, S. striatinum, S. transversum, and Pisidium compressum.

Twenty-one species of snails are known for the Hudson Bay drainage in the state based on my collecting; species numbers for the Souris and Red River drainages are similar. The most prevalent species are Ferrissia rivularis, Gyraulus parvus, Helisoma trivolvis, Physa gyrina, and P. integra. The anomalous occurrence of empty shells of Campeloma decisum in this drainage (fig. 41) is discussed in the Systematics section.

Six mussels are known from the Mississippi River drainage in the state, all six from the Missouri River drainage and at least three from that of the James. No mussels are known from the Missouri Coteau (fig. 8). Strophitus undulatus is known only from empty shells from the James; this species occurs only sporadically in the Red River drainage. The most prevalent mussels are the same as for the Hudson Bay drainage. Proptera laevissima, restricted to the lower reaches of a few Missouri River tributaries (fig. 32), appears to be at the northern and western limit of its range in the Missouri River drainage of North Dakota (not reported by Brandauer and Wu, 1978; Clarke, 1973; or Henderson 1936). Lampsilis ovata is known alive from the Missouri drainage at only a single locality on Spring Creek, a tributary of the Knife River (fig. 29) (app. A, 144-89-14CD). This occurrence may be at or near the western edge of the range of this species.

Six species of pill clams are known from the Mississippi River drainage, and species numbers from the two major included drainages are similar. The most prevalent species are the same as for the Hudson Bay drainage with the exclusion of Sphaerium transversum, which was not found within the Mississippi River drainage (fig. 34). The apparent restriction of S. simile to the James River drainage is notable (fig. 35).

Eighteen snails are known from the Mississippi River drainage based on my collecting, and species from the two major included drainages are similar. The most prevalent species are the same as those for the Hudson Bay drainage with the exclusion of Helisoma trivolvis. The apparent absence of Cincinnatia cincinnatiensis in the Mississippi drainage--except for empty

TABLE 1.--Aquatic mollusks with occurrence by major drainage and general habitat in North Dakota.

	SPECIES	MAJOR DRAINAGE Mississippi River	Hudson Bay	GENERAL HABITAT[a] 1	2	3	4	5
	Mussels (unionacean bivalves)							
1.	*Amblema plicata* (Say)		X					19
2.	*Fusconaia flava* (Rafinesque)		X					12
3.	*Quadrula quadrula* (Rafinesque)		X					7
4.	*Anodonta grandis* Say	X	X	1		23	75	22
5.	*Anodontoides ferussacianus* (Lea)	X	X			5	23	9
6.	*Lasmigona complanata* (Barnes)	X	X			3	53	20
7.	*L. compressa* (Lea)		X				6	3
8.	*Strophitus undulatus* (Say)		X				2	5
9.	*Lampsilis ovata* (Say)	X	X				1	22
10.	*L. radiata* (Gmelin)	X	X	2			38	39
11.	*Ligumia recta* (Lamarck)		X					9
12.	*Proptera alata* (Say)		X					4
13.	*P. laevissima* (Lea)	X					5	
	Pill clams (Sphaeriid bivalves)							
14.	*Sphaerium (Musculium) lacustre* (Muller)	X	X	8	1	15	18	
15.	*S. (M.) transversum* (Say)		X			1	8	8
16.	*S. (Sphaerium) simile* (Say)	X	X	1		2	6	
17.	*S. (S.) striatinum* (Lamarck)	X	X			11	46	8
18.	*Pisidium (Cyclocalyx) casertanum* (Poli)	X	X	1		1	1	
19.	*P. (C.) compressum* Prime	X	X	12		23	49	2
20.	*P. (C.) ferrugineum* Prime		X	1				
21.	*P. (C.) nitidum* Jenyns	X	X	14		3	10	
22.	*P. (C.) ventricosum* Prime		X			1		
	Snails (prosobranch, 23-26, and pulmonate, 27-44, gastropods)							
23.	*Valvata tricarinata* (Say)	X	X	10		3	7	1
24.	*Cincinnatia cincinnatiensis* (Anthony)	X?	X	4			11	3
25.	*Probythinella lacustris* (Baker)	X	X			1	17	1
26.	*Amnicola limosa* (Say)	X?	X	4			1	
27.	*Fossaria obrussa* (Say)	X	X	1		1	3	1
28.	*Stagnicola caperata* (Say)	X	X	10	1		5	
29.	*S. elodes* (Say)	X	X	28	10	7	7	
30.	*Lymnaea stagnalis* (Linnaeus)	X	X	10	2	4		
31.	*Ferrissia rivularis* (Say)	X	X	3		15	41	4
32.	*Gyraulus parvus* (Say)	X	X	33	6	23	15	
33.	*G. circumstriatus* (Tryon)	X	X	4	5	2		
34.	*Armiger crista* (Linnaeus)	X	X		3			
35.	*Helisoma (Helisoma) anceps* (Menke)	X	X	7		6	4	1
36.	*H. (Pierosoma) trivolvis* (Say)	X	X	23	6	4	6	2
37.	*Promenetus exacuous* (Say)	X	X	7	4	1		
38.	*P. umbilicatellus* (Cockerell)	X	X	2	2			
39.	*Planorbula armigera* (Say)		X?	Not collected alive				
40.	*P. campestris* (Dawson)		X		1			
41.	*Aplexa hypnorum* (Linnaeus)	X	X	5	5			
42.	*Physa gyrina* Say	X	X	31	5	36	36	4

TABLE 1.--Aquatic mollusks with occurrence by major drainage and general habitat in North Dakota. (Continued)

SPECIES	MAJOR DRAINAGE Mississippi River	Hudson Bay	GENERAL HABITAT[a] 1	2	3	4	5
43. P. integra Haldeman	X	X	5		15	35	5
44. P. jennessi Dall	X	X	11	5	2	2	
Live occurrences with drainage	30	42					

[a] Numbers opposite species refer to the number of collecting localities for each habitat from which a species was collected. 1=permanent pond or lake; 2=intermittent pond or lake; 3=intermittent stream; 4=small stream (permanent); and 5=large stream (permanent). Permanent water bodies are those known or presumed to be in existence 50% or more of the time and intermittent water bodies are known or presumed to be in existense less than 50% of the time. Large streams are the Yellowstone, Missouri, Red, and lower Sheyenne Rivers where the mean discharge is about 1.5 m^3/s or more and the channel width is about 15 m or more; all other streams in the state are small.

shells in the James (fig. 42)--and the apparent absence of Probythinella lacustris in the James (fig. 43) is notable.

Molluscan provinces.--North Dakota may be subdivided into three malacogeographic provinces: Northeastern--including the Red River Valley and Drift Prairie (fig. 8); Intermediate--encompassing the Missouri Coteau; and Southwestern--including the Coteau and Missouri Slopes (Cvancara, 1975). The Northeastern has the most species (41); unique species are several mussels, such as Amblema plicata, Quadrula quadrula, and Proptera alata. The Southwestern province contains an intermediate number of species (26); it has fewer mussels, pill clams, and snails than the Northeastern province. Unique to this province is the mussel Proptera laevissima. The Intermediate province has the fewest species (23); it presumably lacks mussels, contains about the same number of pill clams as the other provinces, and has about the same number of snails as the Southwestern province.

Density of Mussels

Mussels reach greater densities in the Hudson Bay drainage than in the Mississippi River drainage in the state (fig. 17), and generally in the larger streams--the Red and Sheyenne. In the Hudson Bay drainage, Lampsilis radiata generally occurred at greater densities at more stations than any other species, followed by Anodonta grandis. At a few stations, Amblema plicata, Lampsilis ovata, or Proptera alata occurred at greater densities than other species. In the Mississippi River drainage, Anodonta grandis occurred at greater densities than any other species, followed by Lasmigona complanata.

INTERPRETATIONS

Species Associations and General Habitats

Cluster analysis suggests four aquatic mollusk associations in North Dakota (fig. 18): Anodonta grandis-Lasmigona complanata Association, Helisoma trivolvis-Lymnaea stagnalis Association, Aplexa hypnorum-Gyraulus circumstriatus Association, and the Amblema plicata-Fusconaia flava Association. The associations are named after those species that best characterize them, or are those species most frequently associated. Certain species, such as Proptera laevissima and Pisidium casertanum, occurred so infrequently as to make it difficult to place them readily in any association. Others occurred so rarely (table 1) that they could not be incorporated in the cluster analysis. The associations are not inclusive, as a particular species may occur in more than one asso-

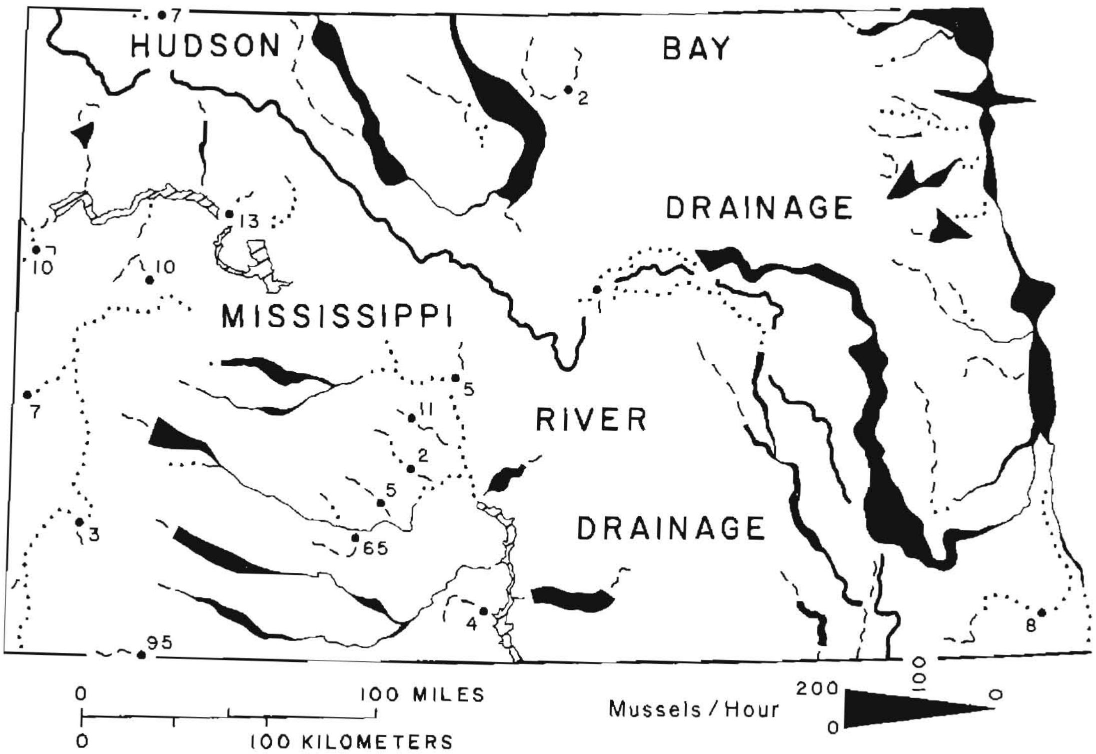

Figure 17. Density of individual mussels in North Dakota. This map depicts densities derived from handpicking by two collectors. Small dots = rivers or parts of rivers where no mussels or only empty shells were collected; large, numbered dots = spot densities of mussels per hour of collecting; dashed lines = rivers or parts of rivers that were not sampled.

ciation.

The four associations seem to relate reasonably well to four of the five general aquatic habitats in the state (table 1): the A. grandis-L. complanata Association indicates a permanent small stream habitat; the H. trivolvis-L. stagnalis Association indicates a permanent lake or pond habitat; the A. hypnorum-G. circumstriatus Association indicates a temporary or intermittent lake or pond habitat; and the A. plicata-F. flava Association indicates a permanent large stream habitat. In the last association, Lasmigona compressa is somewhat out of place as it is typically a small-stream indicator. The intermittent stream habitat (table 1) is not reflected in the dendrogram (fig. 18), perhaps because species found in intermittent streams represent a hardy or tolerant residuum of those that occur in permanent streams, as well as certain stagnant-water forms. For example, Anodonta grandis, generally the only mussel found in highly intermittent streams, is a common component of permanent stream faunas as well.

Ecological Factors Limiting Molluscan Distribution

Because aquatic mollusks are relatively readily dispersed (discussed in the section on origin of the molluscan fauna)--but mussels less so than pill clams and snails--a species' distribution tends to be limited by its adaptation to various ecologic factors. These can be subdivided into physical, chemical, and biological factors, and man-related effects.

Physical factors.--Unsuitable water body, whether flowing or not and as related to size and permanency, is presumably a primary limiting ecologic factor. Mussels, for example, were collected almost solely from streams,

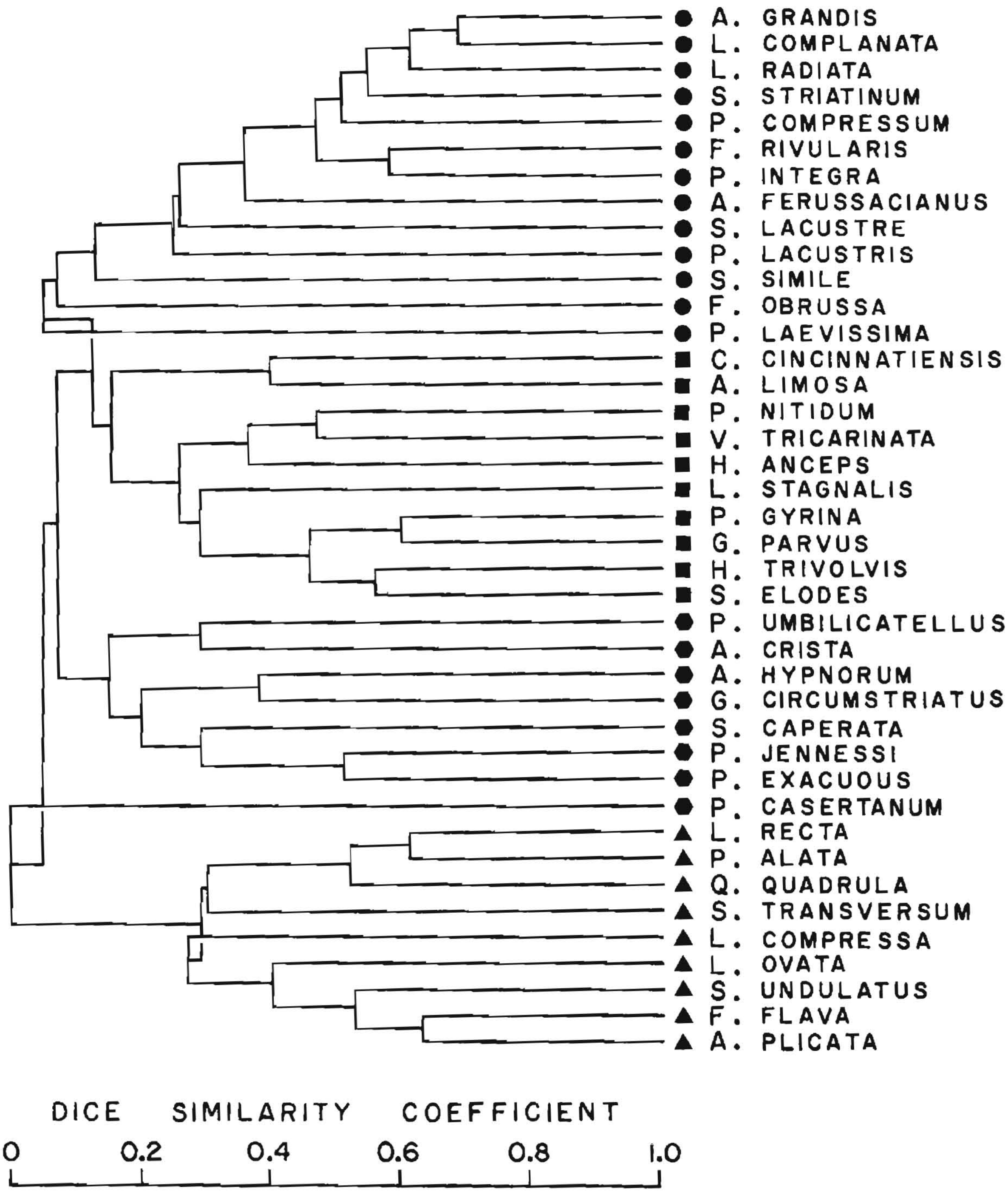

Figure 18. Dendrogram of aquatic molluscan species associations in North Dakota. Circles = Anodonta grandis - Lasmigona complanata Association (small stream); squares = Helisoma trivolvis - Lymnaea stagnalis Association (permanent lake or pond); hexagons = Aplexa hypnorum - Gyraulus circumstriatus Association (intermittent pond or lake); and triangles = Amblema plicata - Fusconaia flava Association (large stream). Species collected at only one locality or not alive are excluded.

with few exemptions (table 1). Certain mussels, as Proptera alata, are characteristic of larger streams, others--as Anodontoides ferussacianus--prefer small streams. Other species, as Lymnaea stagnalis and Stagnicola caperata, seem to prefer stagnant, nonflowing water bodies; here, again, certain species show tendencies toward water bodies of certain size (table 1). Temporary or intermittent lakes and ponds and intermittent--with long periods of no discharge--streams tend to contain fewer species than do corresponding permanent water bodies. But other species, like Armiger crista, are characteristic of intermittent water bodies (ponds). Type of water body is probably strictly not a physical ecologic factor. For example, small, impermanent water bodies may be unsuitable to certain mollusks because of high total-dissolved-salts, low oxygen, increased predation (especially for mussels) and perhaps other factors.

Bottom instability may explain, at least in part, the apparent lack of mollusks in the Missouri, Yellowstone, and Little Missouri Rivers. Water quality seems satisfactory, and all groups of mollusks occur in tributaries of all three streams where the bottom is relatively stable. The bottom in the main channels of the Missouri and Yellowstone is generally of shifting sand. Mollusks (including mussels), however, have been collected from Lake Trenton, an oxbow lake of the Missouri; they may inhabit certain backwater areas of the main streams as well, although I searched backwater areas and did not find them. Elsewhere in the state, I have seen mollusks only rarely on a shifting, unstable bottom. In the lower Sheyenne River, where it cuts through the Sheyenne delta, an unstable sand bottom predominates and mollusks were generally sparse (Cvancara, Norby, and Van Alstine, 1976). A shifting, unstable bottom presumably makes it difficult for a mollusk to maintain its position for normal life activity.

Bottom type does not seem to be a primary limiting factor affecting molluscan distribution regionally, and I have collected most species on a variety of bottom types. Bottom type may, however, have a notable effect on the local occurrence of a species, and more species tend to occur in those habitats with a greater variety of substrate types (Harman, 1972).

High turbidity may cause, in part, the scarcity or decrease of mollusks in certain streams. The lesser mussel density in the lower reaches of the main western Missouri River tributaries (fig. 17)--indicated primarily by Anodonta grandis and Lasmigona complanata (Cvancara, and Van Alstine, 1977, figs. 4.1, 4.3)--may reflect the effect of this factor. In the Little Missouri River, periodic high turbidity, coupled with erratic discharge and unstable bottom, may contribute to the apparent lack of mollusks there. For mussels, a high silt content limits light penetration, retards growth, and may choke gills, resulting in death (effects summarized by Fuller, 1974, p. 250).

Chemical factors.--It is difficult to ascertain which chemical factors, if any, are truly limiting for mollusks in the state. The chemical data in appendix B seem insufficient; plots of mollusk abundance against chemical factor concentration were inconclusive. As might be expected, however, the data show that variable relationships of abundance and chemical factor exist and the more nearly cosmopolitan species in the state are associated with greater ranges of chemical factors. Pip (1978), in a study of 41 snails in Manitoba and adjacent areas, showed that snail species varied considerably in their occurrence in waters of low or high values of selected chemical parameters. (She measured pH, total alkalinity, total chlorides, total sulfates, total nitrates-nitrites, and molybdenum blue phosphorus.) Many species, too, showed no significant tendencies. Three of the species she studied that also occur in North Dakota--Stagnicola elodes, Physa jennessi, and Armiger crista--tended to occur in waters with significantly higher values for several of the chemical parameters. Such species would likely not be limited by chemical factors.

In North Dakota, high total chlorides and high total sulfates seem to be limiting. In the Turtle, Forest, and Park Rivers, the total chloride content increases notably in the lower reaches (fig. 19). Mollusk species decrease correspondingly where the chloride values are high, down to one or no species collected. This relationship is evident only in the lower reaches of these streams, and does not extend into the Red River, which has normal

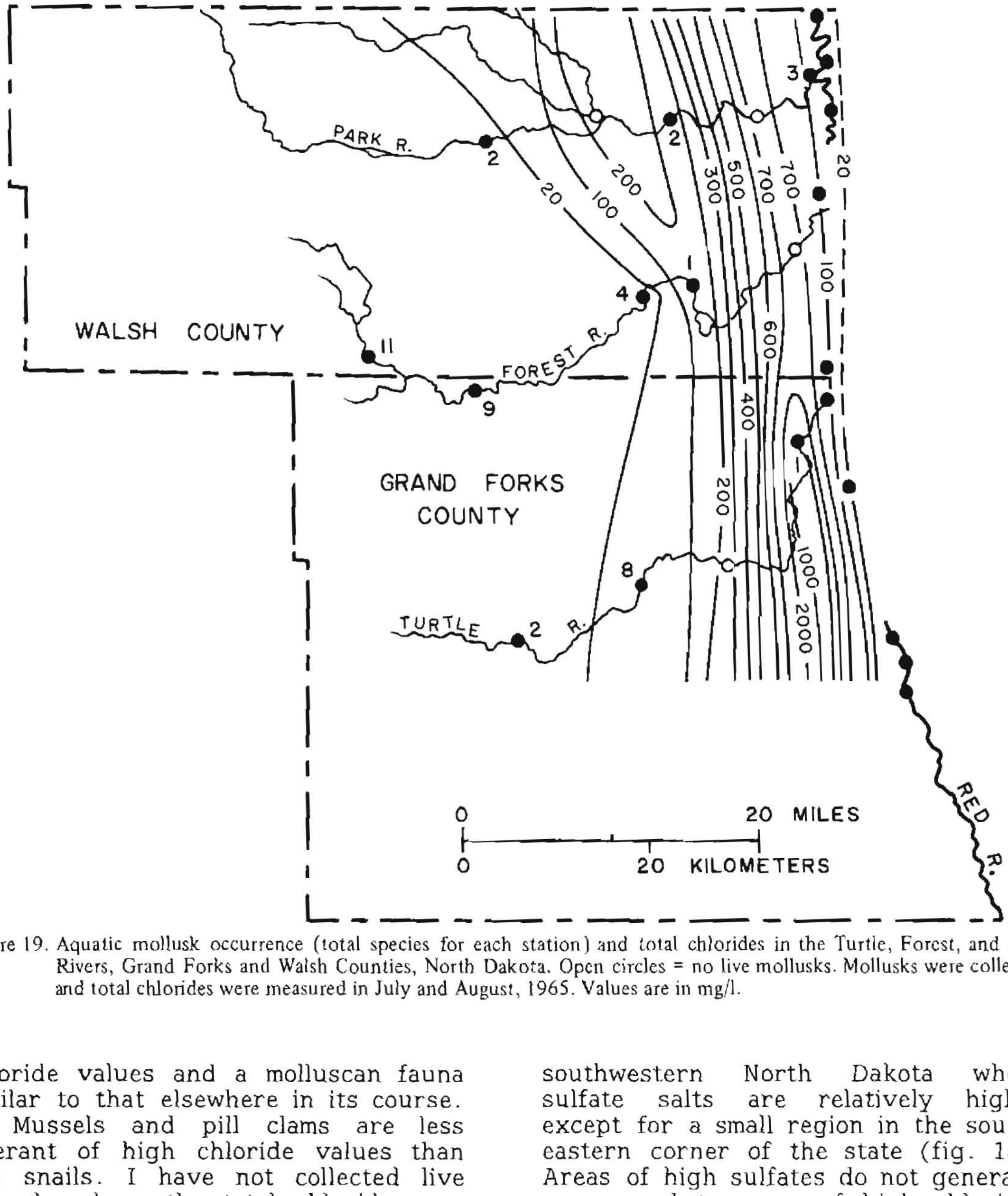

Figure 19. Aquatic mollusk occurrence (total species for each station) and total chlorides in the Turtle, Forest, and Park Rivers, Grand Forks and Walsh Counties, North Dakota. Open circles = no live mollusks. Mollusks were collected and total chlorides were measured in July and August, 1965. Values are in mg/l.

chloride values and a molluscan fauna similar to that elsewhere in its course.

Mussels and pill clams are less tolerant of high chloride values than are snails. I have not collected live mussels where the total chloride content was greater than 160 mg/l (Anodonta grandis) or live pill clams where the chloride value was greater than 107 mg/l (Sphaerium lacustre, S. simile, and S. striatinum). For live snails, the highest chloride value was 3,500 mg/l (Physa jennessi) (app. B). A high chloride content of a water body presumably results in osmoregulation problems for mollusks, which tend to lose water and necessary salts to a hypersaline surrounding medium (Robertson, 1964). Interestingly, in certain mussels, at least, the major negative ions of the blood are Cl^- and HCO_3^{--} and the major positive ions are Na^+ and Ca^{++} (Dietz, 1979).

The possible limiting effect of high total sulfates would occur primarily in southwestern North Dakota where sulfate salts are relatively higher except for a small region in the southeastern corner of the state (fig. 15). Areas of high sulfates do not generally correspond to areas of high chlorides (fig. 16). Mussels and pill clams are less tolerant of high sulfates than are snails. I have not collected live mussels or pill clams where the total sulfate content was greater than 1,300 mg/l (Anodonta grandis, Anodontoides ferussacianus, and Sphaerium striatinum). For live snails, the highest sulfate value was 3,300 mg/l (Stagnicola elodes, Physa gyrina, and P. jennessi). High values of sulfate and perhaps other chemical factors (fig. 13) may relate to generally lesser maximum densities of mussels in the southwestern part of the state, as well as to the presumed absence of such species as Lasmigona compressa, Sphaerium transversum, S. simile, and Cincinnatia cincinnatiensis. Perhaps high total sulfate may create osmoregulation difficulties for mollusks as for high chloride content, or cations associated with sulfate may be limiting.

Biological factors.--Availability of suitable fish hosts seems to be of some significance for mussel distribution in the state. Regionally, it quite likely accounts for the presence of mussels in the tributaries of the Missouri and Little Missouri Rivers, although these mollusks presumably do not inhabit the main streams. As mentioned in the Systematics section, the restricted distribution of the mussel Proptera laevissima in southwestern North Dakota (fig. 32) seems to be linked with that of one of its host fishes, the fresh-water drum. The live occurrence of Lampsilis ovata and Ligumia recta in the Sheyenne River only downstream from Lake Ashtabula (figs. 29, 31) may be because of the lack of suitable fish hosts upstream of the lake (Cvancara, Norby, and Van Alstine, 1976). Locally, the concentration of mussels may be related more to where larvae leave the fish host than bottom sediment type (Cvancara, 1970a). Other biological factors, as predation and parasitism, seem to be of minor importance in limiting mollusk distribution.

Man-related effects.--Alteration or destruction of habitat, degradation of water quality, and alteration of drainage patterns are among man's activities that ecologically limit mollusks and affect their distribution. The building of dams encourages stagnant-water species at the expense of flowing-water forms, and affects the composition of molluscan faunas in other ways. For example, only four species of mussels are known from Lake Ashtabula. This compares to eight species above the lake and 11 species below it. Anodonta grandis is the most common species in the lake, and occurred at most stations in the Sheyenne River (Cvancara and Freeman, 1978). Other ways that habitat has been altered in the state is channel dredging or straightening and the draining of ponds and lakes.

Degradation of water quality has been mentioned already--with North Dakota examples--in the Introduction section dealing with mollusks as biologic monitors. Gratifyingly, at two areas, where repeated collecting was done at widely separated times, little degradation of water quality as reflected by mollusks was apparent. Eight stations on the Sheyenne River (1966 versus 1973-74 collecting) (Cvancara, Norby, and Van Alstine, 1976) and 25 stations in southwestern North Dakota (1967-69 versus 1976 collecting) (Cvancara and Van Alstine, 1977) substantiate this.

Man's alteration of drainage patterns could have a marked effect on the occurrence of mollusks. A most dramatic alteration--should it be completed--is that brought about by the irrigation Garrison Diversion Project in North Dakota. This will mix the waters of the Mississippi River and Hudson Bay drainages. Mussels, particularly, will pass from one drainage to another via their fish hosts, providing ecological requirements are met. One can only surmise how the species distribution maps might change.

Origin of the Molluscan Fauna

About three-fourths of northeastern North Dakota was affected by several ice advances during late Quaternary time. Ice-margin positions, although complexly interrelated in places, tend to be progressively younger to the north and east. Consequently, the drainage in the eastern part of the state developed later than that in the western part, after about 8,500 years ago when Glacial Lake Agassiz drained from the Red River Valley (Clayton, Moran, and Bluemle, 1980, figs. 8, 32, 35). One might expect that southwesternmost North Dakota was populated by aquatic mollusks before the eastern and northeastern part. But dated fossils do not presently support this. The oldest dated Quaternary shells--about 13,500 years--are of Lampsilis radiata from fluvial sediments of the "ancestral" Sheyenne River. Associated with this mussel were the pill clam and snail Sphaerium striatinum ad Probythinella lacustris (Cvancara, Norby, and Van Alstine, 1976). During the interval 12,000-10,000 years ago at least 25 species of aquatic mollusks are known to have occurred in the state. Since that time, species numbers have generally increased toward the present (Cvancara, 1976; Ashworth and Cvancara, 1983). Three species--Valvata sincera, Fossaria decampi, and Helisoma campanulatum--may have become regionally extinct in the state about 9,000 years ago when the climate became drier and dissolved salts became more concentrated in surface waters (Cvancara, 1976).

Since mussels generally undergo a fish host-dependent larval stage, dispersal occurs during this stage, and normally a direct stream connection is required for passage of mussels from one region to another (van der Schalie, 1939). Mussels, however, are known from lakes not connected to streams, and have been observed attached to birds and other animals (Kew, 1893, p. 78-81, 83; Rees, 1965). All mussel species of North Dakota occur in the Mississippi River drainage to the south and east, and all must have been derived from that drainage and those directions. Mussels of the Hudson Bay drainage in the state must have entered that region from the south via their fish hosts during confluence over a low divide--between Big Stone Lake (source of the Minnesota River) and Lake Traverse (ultimate source of the Red River)--now separating the Hudson Bay and Mississippi River drainages (Cvancara, 1970). This migration occurred at least as early as about 13,500 years ago (dated shells of Lampsilis radiata mentioned above). Glacial Lake Agassiz was populated by mussels at or near the beginning of its existence; at least five species are known to have occurred in the lake 12,000-10,000 years ago (Ashworth and Cvancara, 1983).

Pill clams and snails lack a host-dependent larval stage, and are generally more readily dispersed overland, perhaps chiefly by birds (Baker, 1945, p. 39-40; Kew, 1893, p. 46-47, 51-54, 81; Rees, 1965) but also by insects and other animals (Kew, 1893, p. 61-77, 84-89; Rees, 1965). A greater similarity of pill clams and snails than mussels in the Hudson Bay and Mississippi River drainages (table 1) attests to the greater ease of dispersal of the smaller mollusks.

The pill clams and snails of North Dakota generally occur throughout much of central, eastern, and northern North America. They probably entered North Dakota from the south and east where more diverse assemblages of these mollusks exist today. Many waterfowl, of course, have north-south migration routes, like that of the white-fronted goose (Anser albifrons) that extends from the U.S. Gulf Coast to the Arctic. Such birds would allow for a southern origin for certain mollusks. Others, though, have west- or northwest-trending migration routes and could provide for an eastern or southeastern source. The whistling swan (Olor columbianus), for example, has a migration corridor from Chesapeake Bay to northeastern North Dakota and beyond to the Arctic. Still others, as the blue-winged teal (Anus discors), have broad, diverse migratory routes that involve both the U.S. Gulf and Atlantic Coasts (Palmer, 1976, p. 101, 78, 471-76). Such a bird, too, as the blue-winged teal might enhance the survival of an introduced mollusk since it arrives back in the central and northern parts of the continent comparatively late, when surface waters are more apt to be warmer.

Endangered, Threatened, or Special Species

No aquatic mollusk in North Dakota is an endangered or threatened species as defined in the Endangered Species Act of 1973 (Public Law 93-205), nor does any aquatic mollusk appear on a list of such species as published in the Federal Register. However, five species of mussels appear on a list of special animals of the North Dakota Natural Heritage Program (Soine and others, 1982). Quadrula quadrula (maple leaf) is considered "state threatened"; Proptera laevissima (fragile heel splitter) is considered "possibly in peril"; and Fusconaia flava (pig toe), Ligumia recta (black sand shell), and Proptera alata (pink heel splitter) are all considered as "apparently secure in state and throughout range."

SYSTEMATIC ACCOUNT OF SPECIES

General

In a departure from common practice, subspecific names are not used here. They have been used inconsistently, are frequently difficult to apply where the ranges of two so-called subspecies overlap, and make a trinomial awkward when communicating, especially verbally. It seems reasonable to simply portray the variation of a species by descriptive or statistical means, thereby not making a third formal name really necessary.

Synonymies are omitted to reduce cost of publication. Published sources of synonymies are given for each group of mollusks. A few relatively recent synonyms are listed separately if not discussed under the Remarks for a species.

Ecological data for each species are given in appendix B.

Identification of Species

Identification of species using this handbook can be accomplished similarly to the use of field guides for organisms. If a mussel is to be identified, go to plate 1 or 2 and match up the shell with the most similar photograph. Read the short characterization of the presumed species on the plate explanation. Check further the information on the species in the text. Proceed in this manner for the other mollusks as well. If you are uncertain of a shell term, consult the glossaries in this section and the figures and plates where most of the shell features are illustrated. Pill clams (pl. 3) are more difficult to identify than mussels, and the key characters must be examined more closely. For snails, determine first whether the unknown shell is conispiral (pl. 4), planispiral (pls. 5 and 6), or cap-shaped (pl. 6), and go to the appropriate plate(s).

Mussels

Classification of the mussels is that of Heard and Guckert (1970), and summary characterizations of the families and subfamilies are from them. Simpson (1914), Baker (1928b), and Clarke (1973) have given synonymies for this group.

Measurements (table 2) were made of shells from only live individuals with four or more rest rings (fig. 1) retained for a reference collection; larger individuals were usually selected for the collection. In sexually dimorphic species, only the males were measured.

A glossary of shell terms is as follows:

Anterior (fig. 1). Front part of valves; direction toward which beaks positioned and directed; in living animal, foot directed toward anterior.

Beak (fig. 1). Pointed initial part of valve along hinge.

Beak ridge (fig. 1). Low ridge on beak; ridges may be concentric (pl. 1, figs. 2, 5), double-looped (pl. 1, fig. 1), or chevron-like (pl. 2, fig. 1).

Dorsal (fig. 1). Upper part of valves, or that part of valves near hinge.

Fold (pl. 1, fig. 9). Corrugation involving entire thickness of shell.

Height. Maximum distance from dorsal to ventral margin of shell, measured normal to hinge.

Length. Maximum distance from anterior to posterior margin of shell, measured parallel to hinge.

Hinge (fig. 1). Valve edge along dorsal margin; usually thickened and with hinge teeth.

Hinge tooth. Projection of hinge; complete hinge teeth of both lateral and pseudocardinal hinge teeth.

Hinge tooth, lateral (fig. 1). Elongate projection of hinge, and approximately parallel to it, posterior to beak.

Nacre (fig. 1). Pearly, inner shell layer.

Periostracum (fig. 1). Darker, thin, outer shell layer; flakes when dry.

Posterior (fig. 1). Rear part of valves; direction opposite toward which beaks positioned and directed; in living animal, siphons at posterior part of valves.

Posterior ridge (pl. 1, fig. 4). Ridge extending from beak to posterior or ventroposterior margin of each valve.

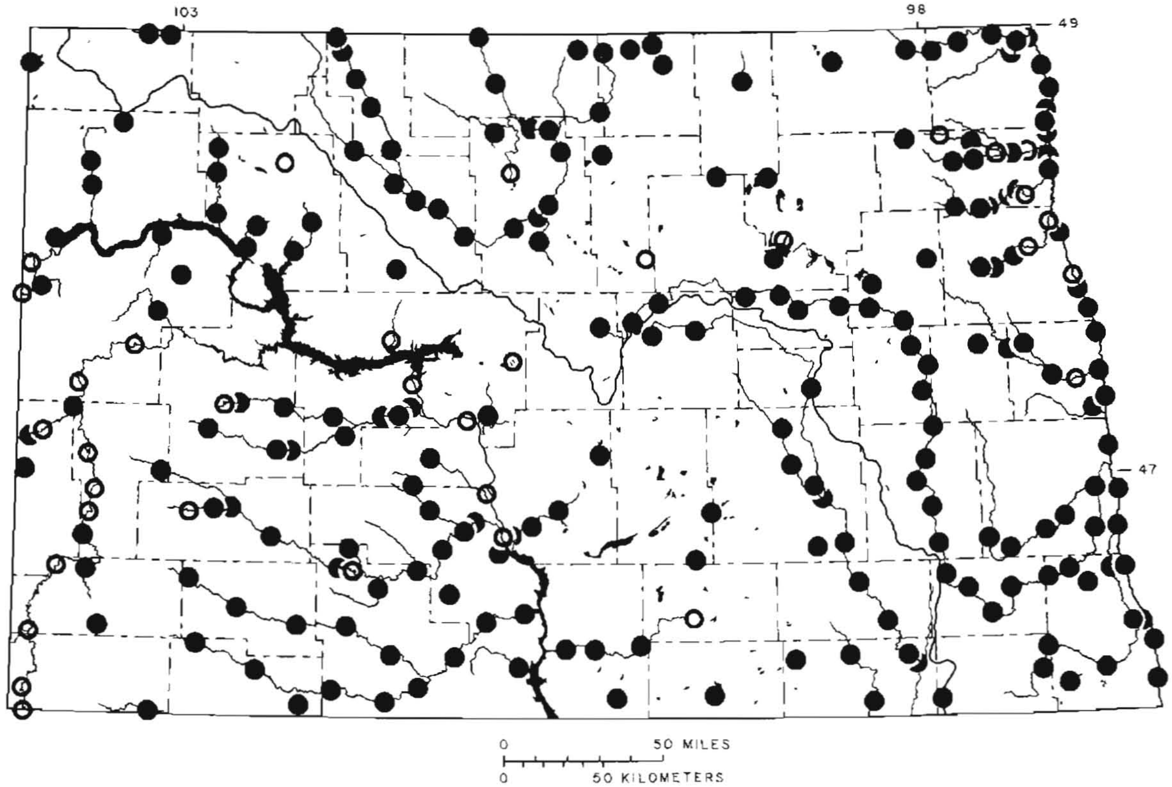

Figure 20. Collecting localities for aquatic mollusks in North Dakota. Filled circles = live mollusks, open circles = no live mollusks.

Pustule (pl. 1, fig. 3). Pimple-like or blister-like protruberance on outer surface of shell.

Rest ring (fig. 1). Darker, prominent, concentric band on surface of valve normally representing arrested growth during winter (=growth ring or winter ring).

Shell. Hard parts of mussel, of two valves.

Subelliptical. Shell shape approaching that of an ellipse.

Subovate. Shell shape approaching that of an egg.

Subquadrate (pl. 1, fig. 3). Shell shape approaching that of a square or rectangle.

Subrhomboidal (pl. 1, fig. 8). Shell shape approaching that of a rhomboid.

Subtriangular (pl. 1, fig. 4). Shell shape approaching that of a triangle.

Sulcus (pl. 1, fig. 3). Radial furrow or depression involving entire thickness of valve.

Valve (fig. 1). One of two hard parts (right and left) constituting shell.

Ventral (fig. 1). Lower part of valves, or direction opposite that of hinge.

Width. Maximum distance across both valves measured normal to a plane passing between them and normal to length.

Phylum MOLLUSCA

Class BIVALVIA

Order EULAMELLIBRANCHIA

Superfamily UNIONACEA

Fresh-water bivalves with inner layer of shell nacreous; pseudocardinal and lateral teeth usually present but both may be lacking; beaks commonly with ridges. Larvae (glochidia or lasidia) nearly always temporarily parasitic on fish.

TABLE 2.--Summary of shell measurements of North Dakota mussels.

Species	Length[1]	Height/Length	Width/Height	Number Measured
Amblema plicata	108(70-145)	0.69(0.56-0.81)	0.56(0.43-0.72)	36
Fusconaia flava	77(58-101)	0.73(0.68-0.78)	0.54(0.50-0.61)	18
Quadrula quadrula	84(56-110)	0.79(0.73-0.87)	0.57(0.52-0.63)	23
Anodonta grandis	120(71-188)	0.53(0.38-0.64)	0.66(0.35-0.91)	327
Anodontoides ferussacianus	70(42- 94)	0.47(0.44-0.60)	0.68(0.48-0.95)	46
Lasmigona complanata	131(59-168)	0.65(0.56-0.77)	0.52(0.36-0.67)	209
L. compressa	84(75- 96)	0.55(0.51-0.59)	0.55(0.45-0.81)	15
Strophitus undulatus	62(56- 95)	0.56(0.50-0.59)	0.59(0.53-0.63)	11
Lampsilis ovata	101(78-130)	0.62(0.57-0.71)	0.63(0.52-0.76)	25
L. radiata	96(65-145)	0.53(0.38-0.68)	0.63(0.48-0.87)	264
Ligumia recta	117(103-139)	0.43(0.39-0.46)	0.57(0.50-0.71)	17
Proptera alata	126(93-152)	0.79(0.72-0.92)	0.40(0.34-0.47)	10
Proptera laevissima	102(92-107)	0.67(0.62-0.70)	0.41(0.36-0.49)	3

[1] In mm; first number given here, as well as for ratios, is the mean.

Family AMBLEMIDAE

Entire four demibranchs marsupial; septa and water tubes undivided, usually continuous (not perforated); sexual dimorphism in shell usually lacking.

Subfamily Ambleminae s.s.

Septa and water tubes continuous; glochidia hookless; short-term breeding (carrying glochidia only in summer).

Genus Amblema Rafinesque, 1820

Shell sculptured with diagonal folds that do not extend to beaks, which are prominent; hinge teeth complete, coarse.

Amblema plicata (Say, 1817)
Three Ridge, blue point
pl. 1, fig. 9

Diagnosis.--Shell subrhomboidal to subovate; moderately inflated; few folds subparallel with posterior ridge.

Range in North Dakota.--Red and Sheyenne Rivers (fig. 21).

Holocene (within interval of about 4,000 years to present; Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi and upper St. Lawrence River drainages from western New York to Minnesota and eastern Kansas; Gulf drainages from central Texas to Yellow River of Florida; Red River of the North and Lake Winnipeg drainages (after Burch, 1975b, p. 8 and Clarke, 1973, p. 36).

Geologic range is presumably unknown.

Biology and ecology.--Ortmann (1912, p. 246-247) and Baker (1928b, p. 81-82) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Baker (1928b, pl. 31, fig. 4), Howard (1914, pl. 5, fig. 32), and Surber (1912, pl. 2, fig. 34). No individuals were found gravid during the present study. Host fishes naturally or artificially infected by A. plicata that occur in North Dakota are (Coker and others, 1921, p. 153; Howard, 1914, p. 26; Stein, 1968, p. 46): shortnose gar (Lepisosteus platostomus), northern pike (Esox lucius), channel catfish (Ictalurus puntatus), rock bass (Ambloplites rupestris), green sunfish (Lepomis cyanellus), pumpkinseed (L. gibbosus), bluegill (L. macrochirus), largemouth bass (Micropterus salmoides), white and black crappie (Pomoxis annularis and P. nigromaculatus), and sauger (Stizostedion canadense).

A. plicata (broad sense) has been reported from small and large streams and river-lakes (Stansbery in Starrett, 1971, p. 298). In North Dakota it occurred only in larger streams where channel widths (n=19) were 11-88 m (mean=32±24 S.D.). This species occurred in greatest numbers in the lower Sheyenne River below Lisbon in Ransom County (134-55-32BA) where the maximum measured density along a 1968 transect was nearly 70 individuals/m^2. A. plicata was most frequently associated with Fusconaia flava, and is part of the A. plicata--F. flava Association (fig. 18).

Remarks.--I concur with Clarke (1973, p. 37) that A. plicata (Say, 1817) and A. costata (Rafinesque, 1820) are the same species, and that the name "A. plicata" should be used because it has priority. It is highly probable that A. peruviana (Lamarck, 1819) and A. rariplicata (Lamarck, 1819) are synonyms of A. plicata (Stansbery in Starrett, 1971, p. 297-298), representing variations with habitat, and other forms (A. undulata, A. perplicata, and A. quintardi) may be as well (Valentine and Stansbery, 1971, p. 17-18).

Genus Fusconaia Simpson, 1900

Shell subcircular, subrhomboidal, subtriangular or subeliptical, with moderate posterior ridge; beaks high; surface smooth; hinge teeth complete, coarse; nacre white, salmon or purple.

Fusconaia flava (Rafinesque, 1820)
Pig toe
pl. 1, fig. 4

Diagnosis.--Shell subtriangular, beaks not as high as in most other species of Fusconaia; posterior ridge subangular to narrowly rounded, with wide, shallow sulcus anterior to it, and sulcus does not extend to beak; nacre usually white, may

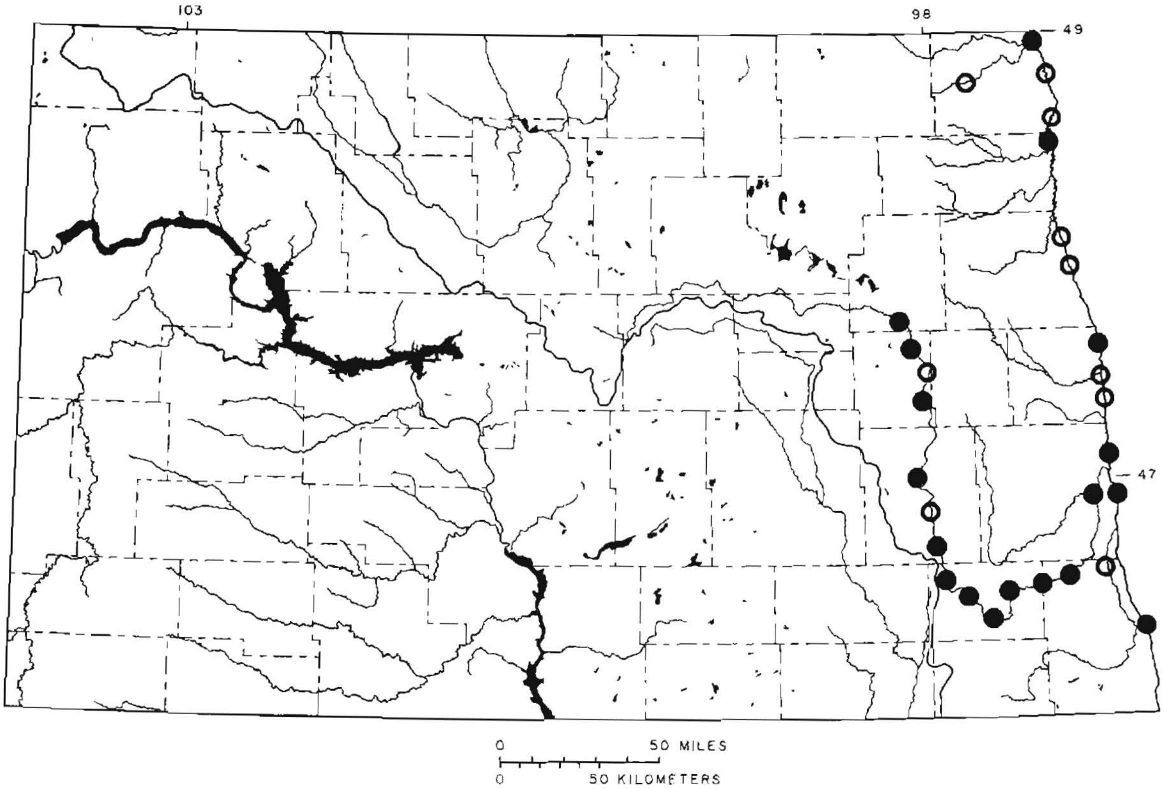

Figure 21. Distribution of Amblema plicata (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

be salmon-colored. Foot, mantle margin, and adductor muscles orange or salmon-colored.

Range in North Dakota.--Red and Sheyenne Rivers (fig. 22).

Holocene (within interval of about 4,000 years to present; Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi and St. Lawrence River drainages from Tennessee and Oklahoma to New York and southern Ontario and Minnesota; Red River of the North and Lake Winnipeg drainages and Nelson River (after Clarke, 1973, p. 30).

Pleistocene (Yarmouthian) to Holocene (Baker, 1920, p. 241).

Biology and ecology.--Ortmann (1912, p. 241) and Baker (1928b, p. 54-55) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Ortmann (1911, pl. 89, fig. 2) and Howard (1914, pl. 5, fig. 33). No individuals were found gravid during the present study. Host fishes (Coker and others, 1921, p. 153; Howard, 1914, p. 25) naturally or artificially infected by F. flava that occur in North Dakota are bluegill (Lepomis macrochirus) and white and black crappie (Pomoxis annularis and P. nigromaculatus).

F. flava (broad sense) has been reported from small and large streams as well as river-lakes (Stansbery in Starrett, 1971, p. 290-291). In North Dakota it occurred only in larger streams where channel widths (n=13) were 11-82 m (mean=26±20 S.D.). This species occurred in greatest numbers in the lower Sheyenne River above Fort Ransom in Ransom County (136-57-19DB; A985) (app. A). F. flava was most frequently associated with Amblema plicata, and is part of the A. plicata-F. flava Association (fig. 18).

Remarks.--Stansbery (in Starrett, 1971, p. 290-291) considered a F. flava complex with F. f. form flava in the headwaters of a stream and F. f. form undata in the lower reaches. F. f. form trigona may be an intermediate.

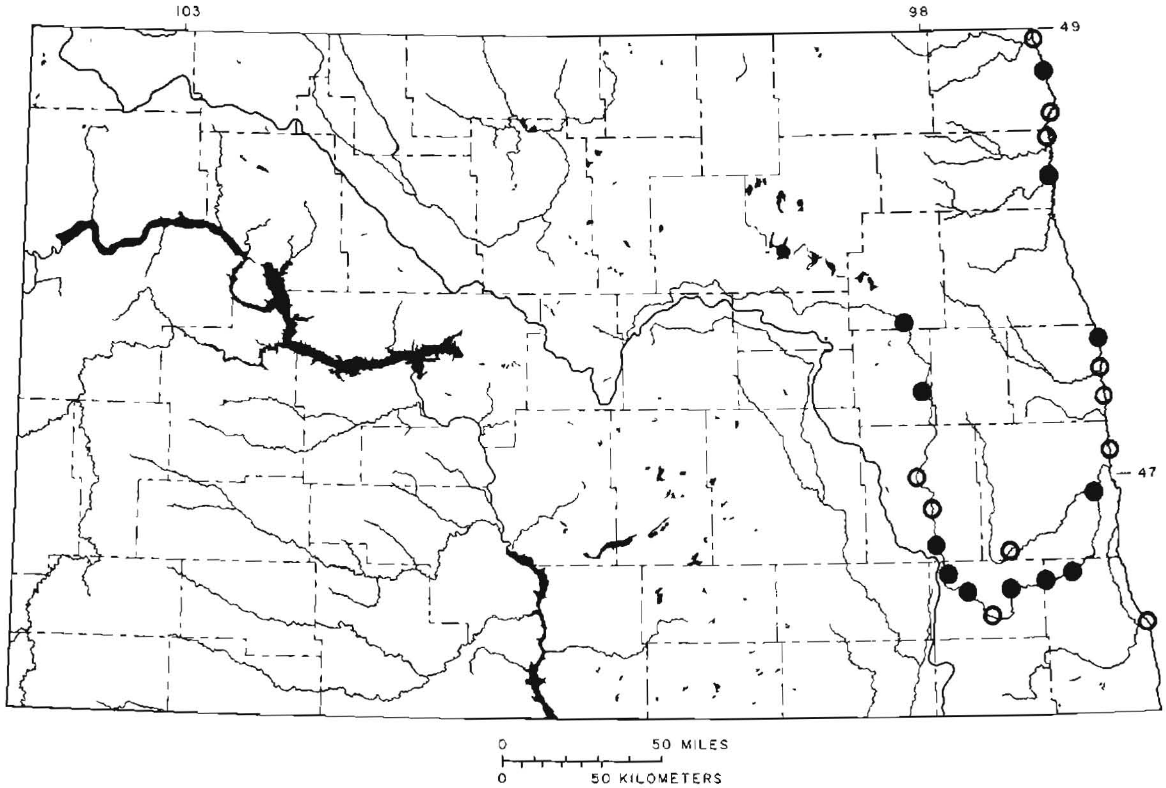

Figure 22. Distribution of Fusconaia flava (Rafinesque) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Genus Quadrula Rafinesque, 1820

Shell subtriangular, subquadrate, or subrhomboidal, with relatively prominent beaks; posterior ridge generally well developed; surface with distinct pustules (in most species) or smooth; hinge teeth complete, coarse.

Quadrula quadrula (Rafinesque, 1820)
Maple leaf
pl. 1, fig. 3

Diagnosis.--Shell subquadrate, not much longer than high; surface usually with many pustules; median sulcus extends from beak to ventral margin.

Range in North Dakota.--Red River and possibly Sheyenne Rivers (fig. 23). Holocene (within interval of about 4,000 years to present; Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi, St. Lawrence, and Alabama River drainages from Texas and Alabama to New York and Minnesota, and Red River of the North drainage (after Clarke, 1973, p. 33).

Pleistocene (Illinoian) to Holocene (Miller, 1966, p. 186).

Biology and ecology.--Ortmann (1912, p. 253) and Baker (1928b, p. 85-86) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Baker (1928b, pl. 31, fig. 8), Howard (1914, pl. 5, fig. 29), and Suber (1915, pl. 1, fig. 11). No individuals were found gravid during the present study. Host fishes naturally infected by Quadrula quadrula that occur in North Dakota are bluegill (Lepomis macrochirus) and sauger (Stizostedion canadense) (Howard, 1914, p. 16).

Q. quadrula has been reported commonly from large streams, as well as from small streams and even lakes (Parmalee, 1967, p. 43). In North Dakota, it was collected alive only in the Red River where the channel widths (n=7) were 30-88 m (mean=58±22 S.D.). Too, it seemed confined to the central or deeper parts of the

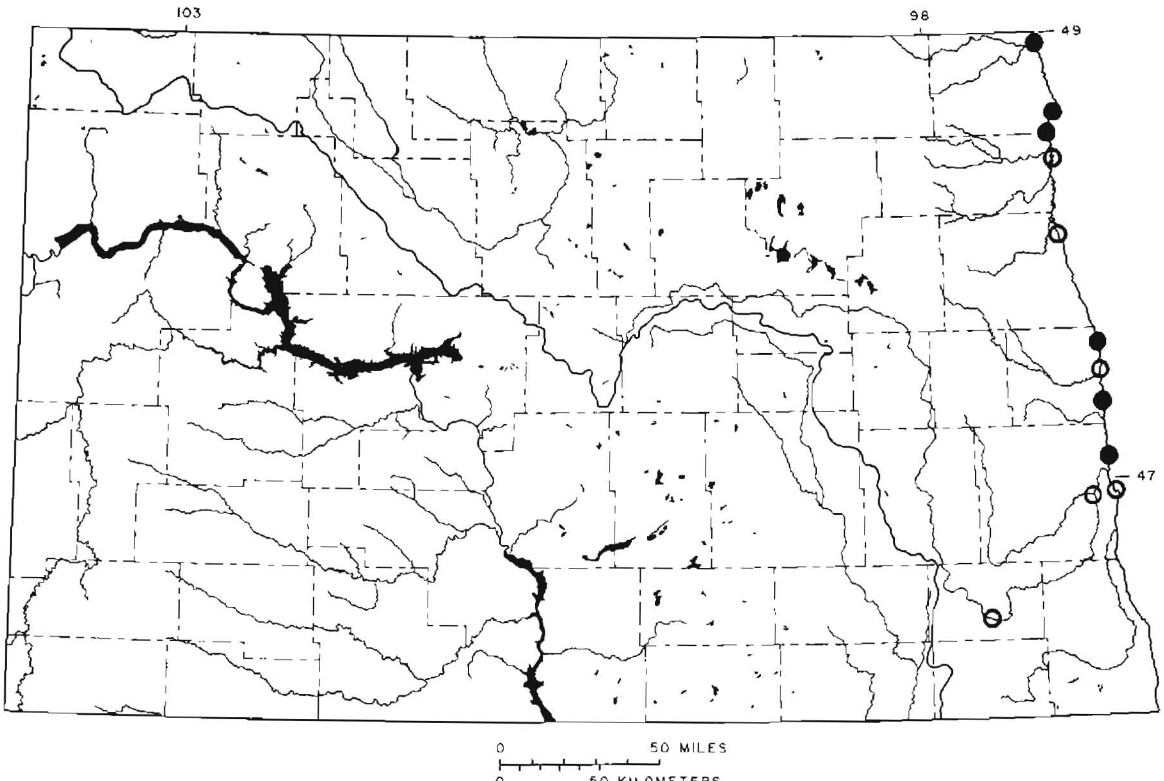

Figure 23. Distribution of Quadrula quadrula (Rafinesque) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

channel. This species was found in greatest numbers (probably largely because of low-water collecting) in the Red River near Caledonia in Trail County (148-49-26AD; A2366) (app. A). Q. quadrula was most frequently associated with Ligumia recta and Proptera alata, and is part of the A. plicata-F. flava Association (fig. 18).

Remarks.--Clarke (1973, p. 34) has reviewed the subspecific designations that have been assigned to Q. quadrula.

Family UNIONIDAE

Only outer two demibranchs marsupial; septa and water tubes undivided (except in Anodontinae) and continuous.

Subfamily Anodontinae

Entire outer two demibranchs marsupial; septa and water tubes divided, producing secondary septa and water tubes; glochidia hooked; long-term breeding (retaining developing glochidia except in summer); sexual dimorphism in shell lacking.

Genus Anodonta Lamarck, 1799

Shell thin, subelliptical to subovate, may be winged posterodorsally; beak ridges usually double-looped; hinge teeth lacking.

Anodonta grandis Say, 1829
Floater
pl. 1, figs. 1, 7

Synonyms.--Anodonta kennicotti Lea, A. marginata Say (of authors), A. pepiniana Lea?

Diagnosis.--Shell elongate-subovate, only slightly winged posterodorsally; beaks extend well above hinge line; beak ridges double-looped, generally tuberculose but

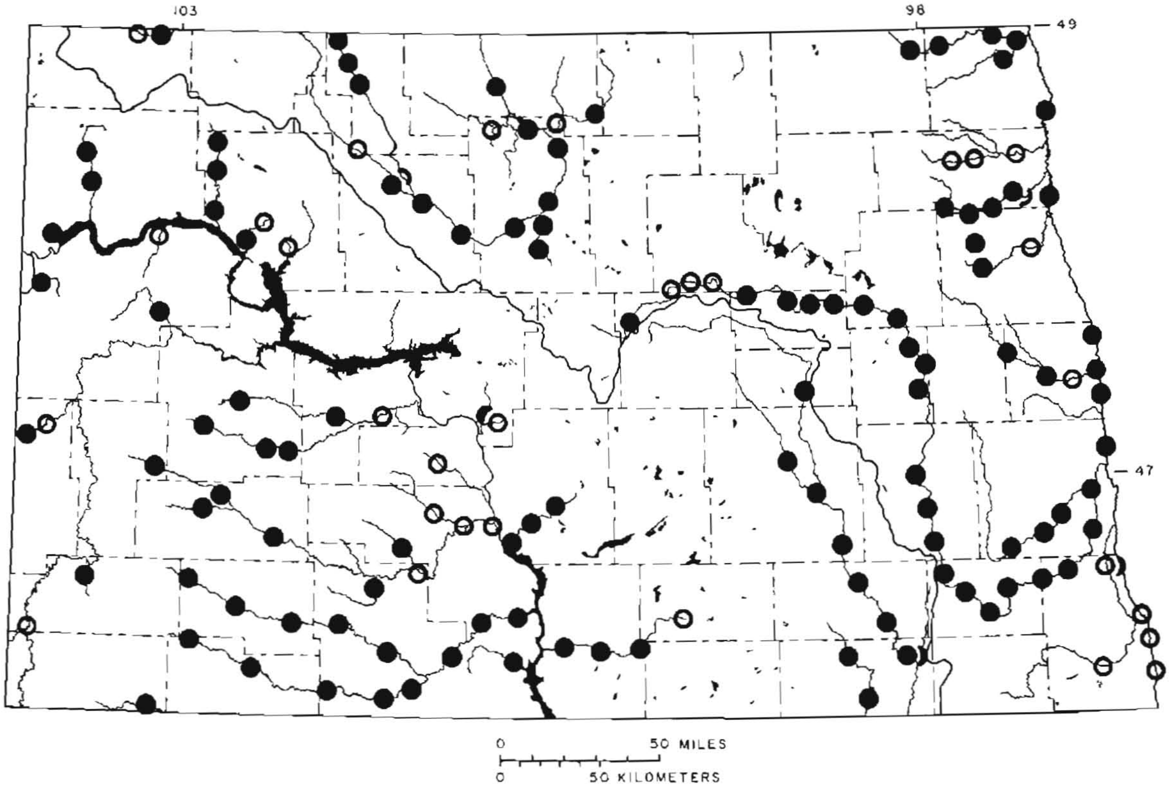

Figure 24. Distribution of Anodonta grandis (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

lacking tubercles in northern populations.

Range in North Dakota.--Generally throughout the state, the most frequently occurring mussel (fig. 24).

Pleistocene to Holocene (at least about 12,000-10,000 years to present; Cvancara, 1976, p. 1690).

General range.--Mississippi-Missouri River drainage, most of the St. Lawrence River drainage, Gulf of Mexico drainages in Louisiana and Texas, and Canadian Interior Basin from Mackenzie River Delta to Quebec (after Clarke, 1973, p. 82, 87-88).

Pleistocene to Holocene (Miller, 1966, p. 217).

Biology and ecology.--Baker (1928b, p. 153-154) and Ortmann (1912, p. 292) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Baker (1928b, pl. 31, fig. 20) and Surber (1912, pl. 3, fig. 45). Heard (1975) has discussed reproduction in eight species of Anodonta including A. corpulenta, which has been considered a subspecies of A. grandis (Burch, 1975b, p. 15). Many individuals were found gravid during the present study; the smallest (Lake Ashtabula; A1209) had a shell 61 mm long with 2-3 rest rings. Host fishes naturally or artificially infected by A. grandis that occur in North Dakota are (Clarke and Berg, 1959, p. 38-39; Lefevre and Curtis, 1910, p. 103; Tucker, 1928, p. 124, 126; Wilson, 1916, p. 338-340): carp (Cyprinus carpio), golden shiner (Notemigonus crysoleucas), river carpsucker (Carpiodes carpio), yellow bullhead (Ictalurus natalis), brook stickleback (Eucalia inconstans), rock bass (Ambloplites rupestris), green sunfish (Lepomis cyanellus), bluegill (L. macrochirus), largemouth bass (Micropterus salmoides), white and black crappie (Pomoxis annularis and P. nigromaculatis), Iowa darter (Etheostoma exile), johnny darter (E. nigrum), yellow perch (Perca flavescens), and fresh-water drum (Aplodinotus grunniens).

A. grandis has been reported from small and large streams, lakes, ponds, and canals (Clarke and Berg, 1959, p. 39). Reigle (1967) reported a deep-water occurrence of this species--18-31 m--in Lake Michigan. In North Dakota, it was collected mostly from small streams (both intermittent and permanent), but also from large streams and one lake (table 1). Channel widths (n=113) were 1-71 m (mean=15±14 S.D.) This species was found to tolerate higher total chlorides than any other mussel, relatively high total sulfates and total hardness, and occurred in waters with extreme high values of total alkalinity (app. B). A. grandis occurred in greatest numbers in the upper Forest River near Fordville in Walsh County (155-56-36BB; A43) (app. A). In the Sheyenne River, shells of this species were found to become longer, higher, wider, and more inflated downstream; an increase in shell weight, shell weight/ shell length, total weight, and total weight/shell length also occurred in a downstream direction (Cvancara, Bluemle, and Bluemle, 1978). A. grandis was most frequently associated with Lasmigona complanata and Lampsilis radiata, and is part of the A. grandis-L. complanata Association (fig. 18).

Remarks.--van der Schalie (1938, p. 51-52), Clarke and Berg (1959, p. 37-38), and Stansbery (in Starrett, 1971, p. 315-317) have discussed the extreme variation that exists in A. grandis and the several names that have been applied to these variations, most of which, if not all, are ecological. Clarke (1973, p. 81-90) recognized two subspecies of A. grandis in the Canadian Interior Basin, A. g. grandis and A. g. simpsoniana. A. g. grandis has double-looped, tuberculose beak ridges, and occurs in the south and southwest parts of the basin. (The North Dakota material could be placed in this subspecies.) A. g. simpsoniana has single- or faintly double-looped beak ridges that are not tuberculose; it occurs generally north and east of A. g. grandis. However, Clarke (1973, p. 84, 89) had difficulty distinguishing between the two subspecies where they overlap, and said (p. 84): "One is tempted to disregard subspecies entirely and to identify all populations seen simply as A. grandis, with the possible exception of a few peripheral populations." I am following the practice of disregarding subspecies.

Genus Anodontoides Simpson, 1898

Shell subelliptical, thin; beak ridges fine, concentric; hinge teeth lacking or rudimentary.

Anodontoides ferussacianus (Lea, 1834)
Cylindrical paper shell
pl. 1, figs. 5, 6

Diagnosis.--Beaks only slightly above hinge line; beak ridges bent sharply posteriorly, not parallel to growth lines; commonly slight thickenings of hinge line adjacent to beaks, representing rudimentary pseudocardinal teeth.

Range in North Dakota.--In much of the state (fig. 25).

Late Pleistocene? to Holocene (questionable occurrence from 12,000-10,000 years ago, otherwise known only from present; Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi and St. Lawrence River drainages from North Dakota and New York to Colorado and Tennessee; Albany River system and parts of Nelson River and Red River of the North drainages of Canadian Interior Basin (modified after Clarke, 1973, p. 93).

Late Pleistocene (late Wisconsinan) to Holocene (Baker, 1920, p. 383).

Biology and ecology.--Baker (1928b, p. 177) and Ortmann (1912, p. 294) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Baker (1928b, pl. 32, fig. 4), Ortmann (1911, pl. 89, fig. 12), and Surber (1912, pl. 3, fig. 43). Many individuals were found gravid during this study; the smallest gravid individual observed (Turtle River; A8) had a shell 37 mm long with about three rest rings. The northern muddler (Cottus bairdii) (Clarke and Berg, 1959, p. 36) and the sea lamprey (Petromyzon marinus) (Wilson and Ronald, 1967, p. 1085) have been cited as host fishes for A. ferrussacianus, but neither species occurs in North Dakota.

A. ferussacianus has been reported primarily from small streams (Baker, 1928b, p. 177; van der Schalie, 1938, p. 56) but is known also from large streams and lakes (Clarke and Berg, 1959, p. 36). In North Dakota, it was collected mostly from small streams (both permanent and intermittent) but also from large streams (table 1). Channel widths (n=27) were 1-30 m (mean=11±7 S.D.). The species was found to tolerate relatively high total sulfate values (app. B). It occurred in

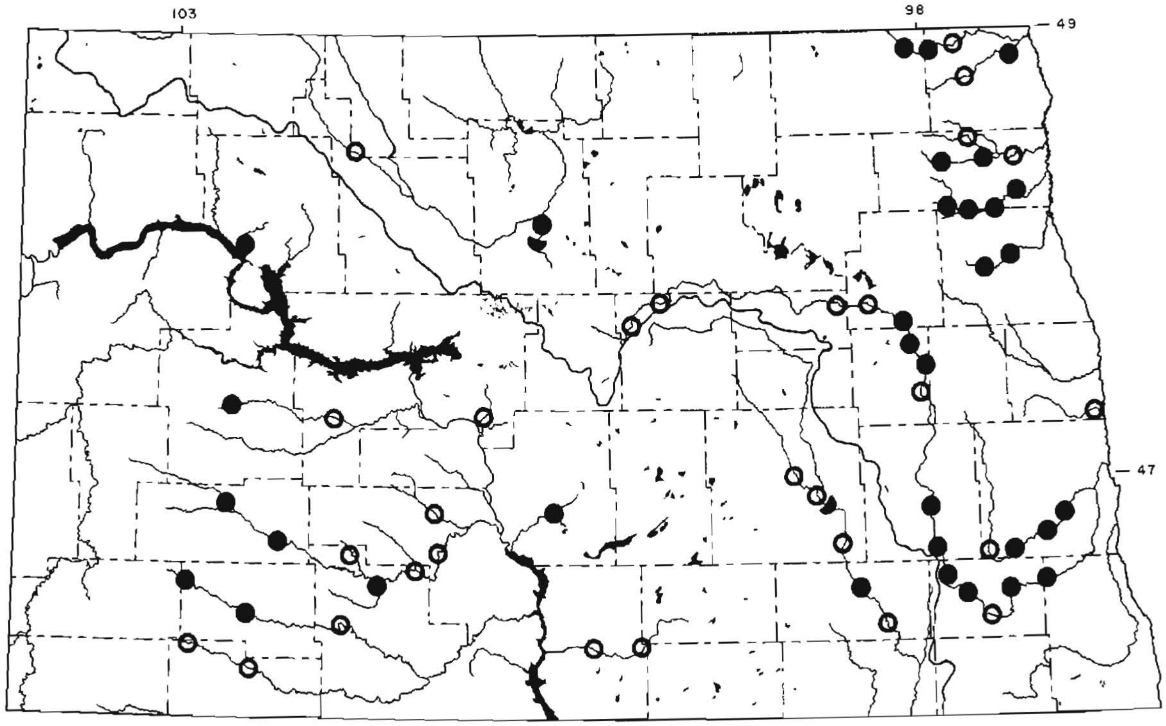

Figure 25. Distribution of Anodontoides ferussacianus (Lea) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

greatest numbers in the Turtle River near Larimore in Grand Forks County (152-54-33CB; A69) (app. A). A. ferussacianus was most frequently associated with Pisidium compressum, Sphaerium striatinum, Lampsilis radiata, Lasmigona complanata, and Anodonta grandis, and is part of the A. grandis-L. complanata Association (fig. 18).

Remarks.--Clarke (1973, p. 94-95) briefly summarized nomenclatural difficulties for A. ferussacianus and related forms. Burch (1973, p. 18, 80-81) recognized only one other species of Anodontoides in North America, A. radiatus (Conrad, 1834), from the southeastern United States.

Genus Lasmigona Rafinesque, 1831

Shell subrhomboidal to subelliptical, generally compressed; beaks low; beak ridges double-looped; pseudocardinal teeth well-developed, lateral teeth absent to completely developed.

Lasmigona complanata (Barnes, 1823)
White heel splitter
pl. 1, fig. 11; pl. 2, fig. 8

Diagnosis.--Shell relatively thick, subrhomboidal, high, with biangulate posterior margin and prominent posterodorsal wing, especially in young individuals; beak ridges coarse, may be tuberculose; pseudocardinal teeth coarse, lateral teeth lacking or rudimentary.

Range in North Dakota.--Generally throughout the state (fig. 26).

Holocene (within interval of about 4,000 years to present; Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi and upper St. Lawrence River drainages from Pennsylvania and Minnesota to Louisiana and Oklahoma; Alabama River drainage,

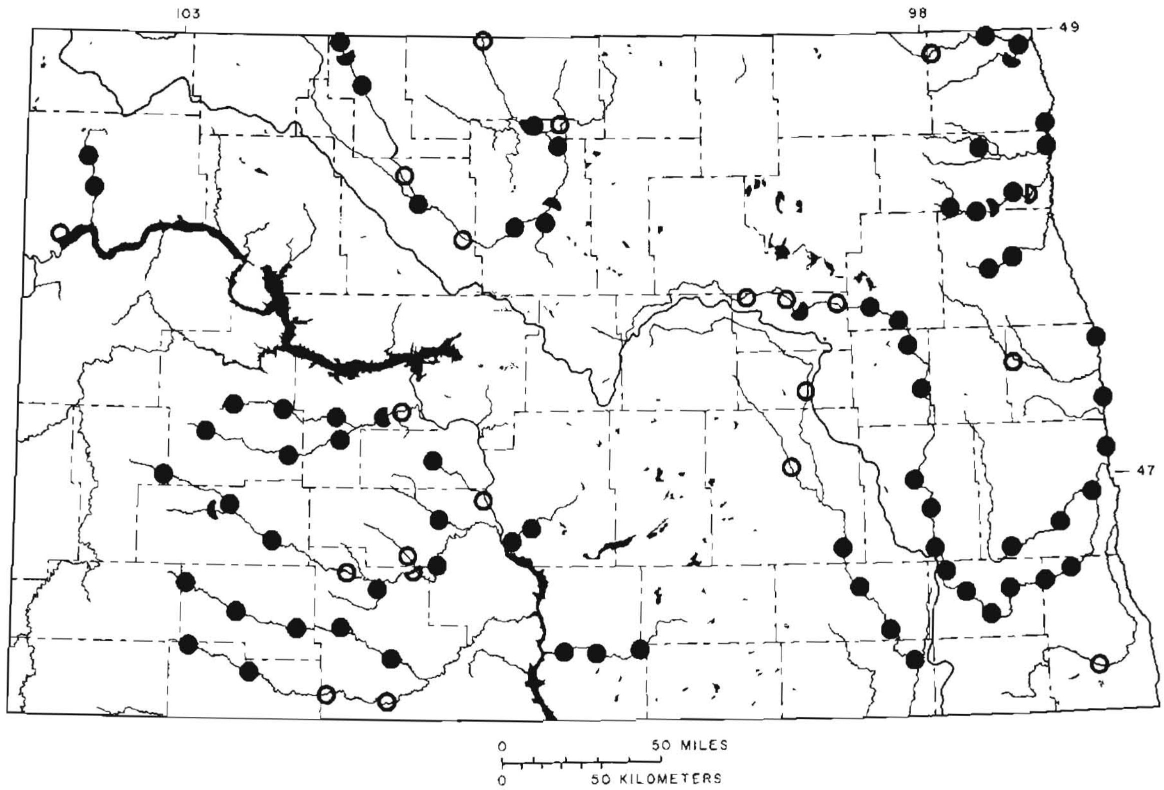

Figure 26. Distribution of Lasmigona complanata (Barnes) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Alabama; Lake Winnipeg-Nelson River drainage from western Ontario to Alberta (after Clarke, 1973, p. 48).

Pleistocene (Illinoian) to Holocene (Miller, 1966, p. 217).

Biology and ecology.--Ortmann (1912, p. 282) and Baker (1928b, p. 149-150) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Ortmann (1911, pl. 89, fig. 11), Surber (1912, pl. 1, fig. 6) and Baker (1928b, pl. 31, fig. 19). Several individuals were found gravid during this study; the smallest (Sheyenne River; A164) had a shell length of 86 mm and at least six rest rings. Host fishes artificially infected by L. complanata that occur in North Dakota are (Lefevre and Curtis, 1912, p. 158, 168): carp (Cyprinus carpio), green sunfish (Lepomis cyanellus), and white crappie (Pomoxis annularis).

L. complanata has been reported primarily from small and large streams, but occasionally from ponds and lakes (Parmalee, 1967, p. 52). In North Dakota, it was collected mostly from small streams (both intermittent and permanent) but also from large streams (table 1). Channel widths (n=76) were 2-98 m (mean=18±18 S.D.). L. complanata tolerated waters of relatively high total hardness (app. B). This species occurred in greatest numbers in the Sheyenne River near Kathryn in Barnes County (137-58-11BB; A145) (app. A). L. complanata was most frequently associated with A. grandis, and is part of the A. grandis-L. complanata Association (fig. 18).

Remarks.--Clarke (1973, p. 49-50) considered L. c. katherinae (discussed, for example, by Baker, 1928b, p. 151) not to be a valid subspecies (or variety?).

Lasmigona compressa (Lea, 1829)
Compressed Lasmigona
pl. 1, fig. 8

Diagnosis.--Shell relatively thin, elongate subrhomboidal (longer in relation to height than L. complanata); posterior margin biangulate; well-developed postero-

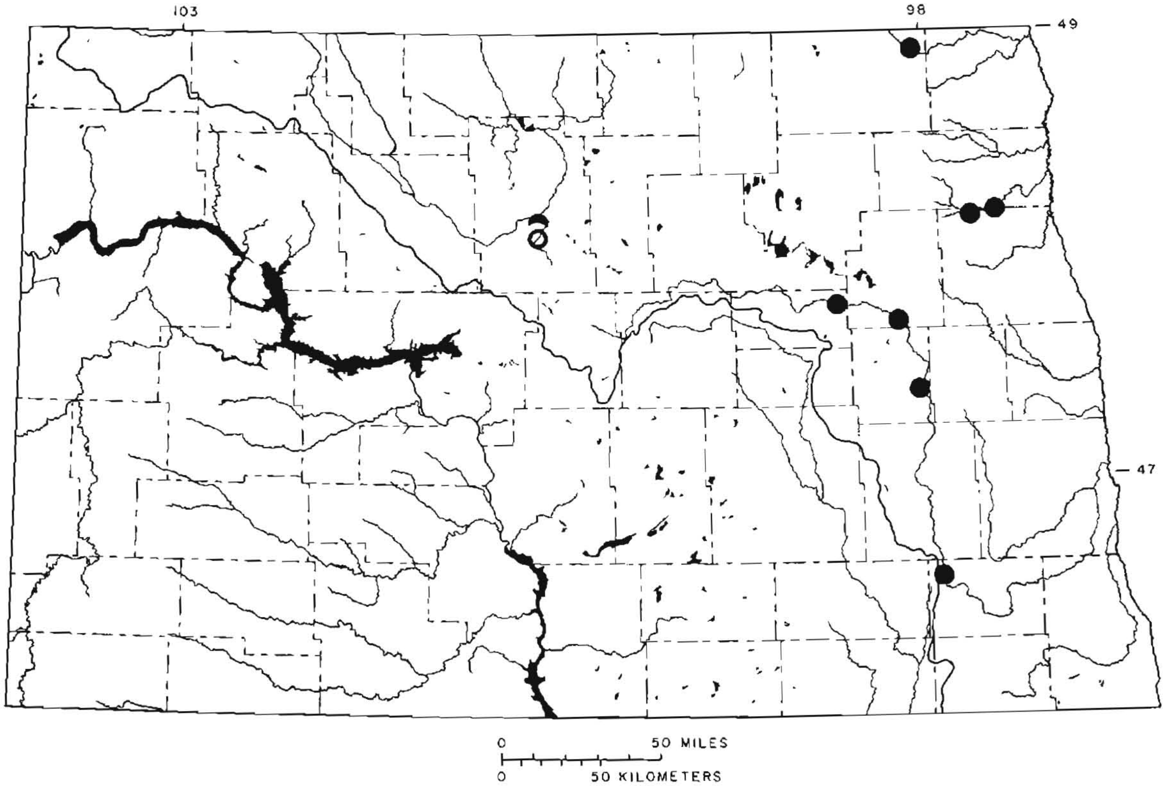

Figure 27. Distribution of Lasmigona compressa (Lea) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

dorsal wing on young individuals; beak ridges fine, irregular; both pseudocardinal and lateral teeth, fine; nacre white, salmon-, or cream-colored, especially near beaks.

Range in North Dakota.--Northeastern part of state, Pembina, Forest, Sheyenne, and Wintering Rivers (fig. 27).

Holocene (within interval of about 4,000 years to present (Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi, St. Lawrence, and Hudson River drainages from Quebec and West Virginia to Minnesota and Nebraska; Canadian Interior Basin in Ontario, Manitoba, Saskatchewan, Minnesota, and North Dakota (Clarke, 1973, p. 45-46).

Late Pleistocene (late Wisconsinan) to Holocene (Baker, 1920, p. 383).

Biology and ecology.--Ortmann (1912, p. 281) and Baker (1928b, p. 140-141) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Ortmann (1911, pl. 89, fig. 10), Surber (1912, pl. 3, fig. 44), and Baker (1928b, pl. 31, fig. 17). A few individuals were found gravid during this study; the smallest (Sheyenne River; A985) had a shell length of 67 mm with five rest rings. Host fishes for L. compressa are essentially unknown. Parmalee (1967, p. 100), however, has cited artificial infection of this species on "carp and other species."

L. compressa has been reported primarily from small streams and the headwaters of large streams (Parmalee, 1967, p. 53), and occasionally from lakes (Lake Erie; Ortmann, 1919, p. 120). In North Dakota, it was collected primarily from small streams and the upper reaches of a larger stream (Sheyenne River; table 1). Channel widths (n=9) were 8-34 m (mean=16±8 S.D.).

This species occurred in greatest numbers in the Wintering River near Karlsruhe in McHenry County (154-77-10DA; A201) (app. A). L. compressa was most frequently associated with Anodonta grandis, Anodontoides ferussacianus, L. com-

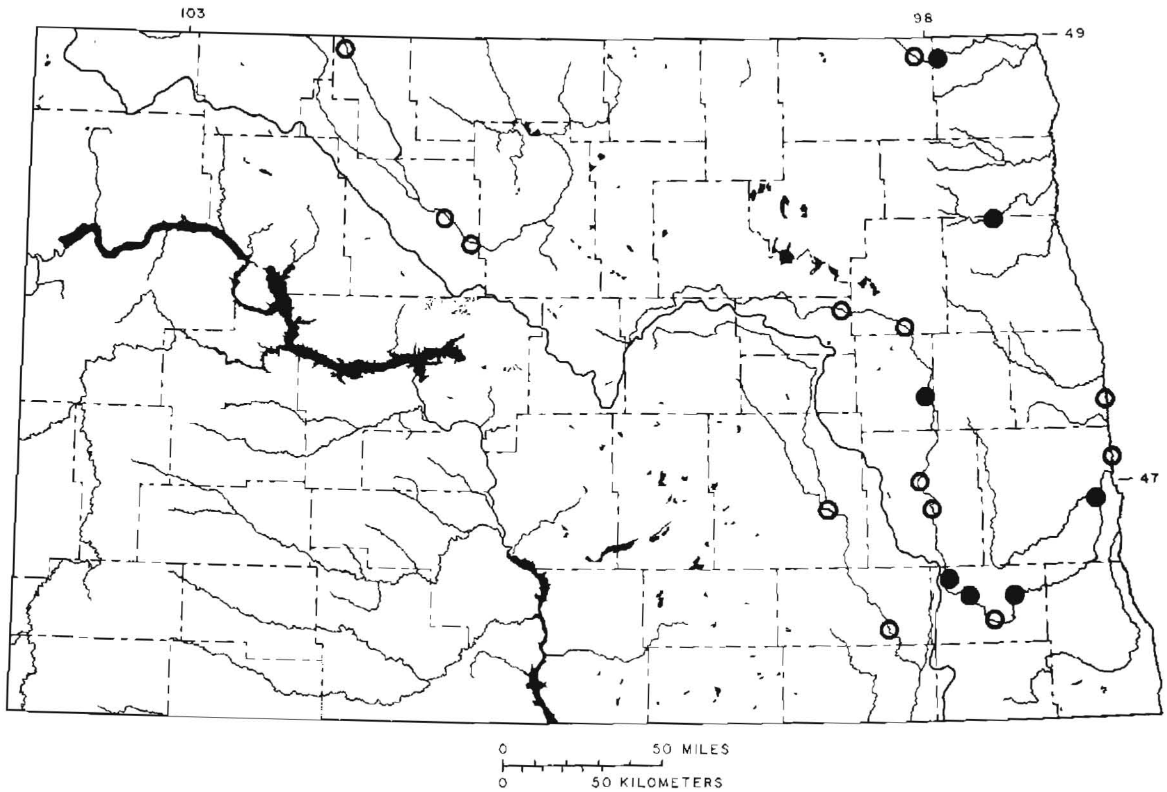

Figure 28. Distribution of Strophitus undulatus (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

planata, and Lampsilis radiata. Its occurrence, however, with large-stream mussels at three stations places it somewhat anomalously within the Amblema plicata-Fusconaia flava Association (fig. 18).

Genus Strophitus Rafinesque, 1820

Shell relatively thin, subelliptical to subrhomboidal; pointed or biangulate posteriorly; beak ridges coarse, concentric, curved abruptly posteriorly; hinge teeth rudimentary, laterals rarely present.

Strophitus undulatus (Say, 1817)
Squaw foot
pl. 1, figs. 2, 10

Diagnosis.--Shell subelliptical; beaks not much elevated above hinge line; pseudocardinal teeth present as swellings of hinge, lateral teeth absent; nacre white to bluish-white, commonly cream- or salmon-colored near beaks.

Range in North Dakota.--Sporadic in northeastern part of state (fig. 28).

Holocene (within interval of about 4,000 years to present (Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi River drainage from Pennsylvania to Minnesota and Tennessee to Texas; Atlantic drainages from South Carolina to St. Lawrence River system; Red River of the North and Nelson River drainages of Canadian Interior Basin from North Dakota to western Ontario and Saskatchewan (after Clarke, 1973, p. 97 and Johnson, 1970, p. 368-369).

Pleistocene (Illinoian) to Holocene (Miller, 1970, p. 41).

Biology and ecology.--Baker (1928b, p. 200) and Ortmann (1912, p. 299) have discussed the anatomy and reproduction of this species. The glochidium, illustrated by Surber (1912, pl. 1, fig. 3) and Baker (1928b, pl. 32, fig. 6), can metamorphose without attachment to a fish host (Lefevre and Curtis, 1911, p. 864-865).

However, fishes artificially infected by S. undulatus that occur in North Dakota include the creek chub (Semotilus atromaculatus), green sunfish (Lepomis cyanellus), and largemouth bass (Micropterus salmoides) (Baker, 1928b, p. 201; Ellis and Keim, 1918, p. 18). A few individuals were found gravid during the present study. The smallest (Sheyenne River, A167) had a shell 54 mm long with at least three rest rings.

S. undulatus has been reported from small and large streams (Parmalee, 1967, p. 56) as well as from lakes and canals (Clarke and Berg, 1959, p. 45). In North Dakota, it was collected from both large (mostly) and small streams (table 1). Channel widths (n=8) were 11-20 m (mean=17±3 S.D.). This species occurred in greatest numbers in the lower Sheyenne River above Fort Ransom (136-57-19DB; A985) (app. A). S. undulatus was most frequently associated with Amblema plicata and Fusconaia flava, and is part of the association named after these species (fig. 18).

Remarks.--Clarke and Berg (1959, p. 43-44) discussed the need for discarding the name "S. rugosus," as well as the synonym S. edentulus. The use of four subspecies or varieties of S. undulatus seems unjustified (discussed briefly by LaRocque, 1967, p. 211-212 and Clarke, 1973, p. 99).

Subfamily Lampsilinae

Various parts of outer two demibranchs marsupial: ventral part of entire demibranchs, posterior part (as in all North Dakota species), central part, lower region of posterior part and without vertical folds, and lower part of entire demibranchs with vertical folds; glochidia hookless or axehead-shaped (Proptera); long-term breeding (retaining developing glochidia except in summer) except in Obliquaria; sexual dimorphism in shell widespread, and development (in females) of flaps, papillae, or caruncles in mantle below branchial opening.

Genus Lampsilis Rafinesque, 1820

Shell subelliptical to subovate; female shell generally inflated posteroventrally and truncated posteriorly; periostracum commonly yellowish or brownish with greenish rays; hinge teeth well-developed; posterior mantle margins with ribbon-like flaps in females.

Lampsilis ovata (Say, 1817)
Pocketbook
pl. 2, fig. 5

Diagnosis.--Shell subovate, relatively high and inflated; posterior ridge variable, sharply angular to poorly defined; beak areas inflated, notably elevated above hinge line; beak ridges moderate to coarse, indistinctly double-looped; hinge relatively curved.

Range in North Dakota.--Red, Sheyenne, and possibly James Rivers in eastern part of state and at least Knife River system in western part (fig. 29). L. ovata seems to be at or near the western edge of its range in North Dakota (Burch, 1975, p. 19; Clarke, 1973, p. 112).

Holocene (within interval of about 4,000 years to present; Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi River drainages from New York to North Dakota and Tennessee to Oklahoma; St. Lawrence River drainage throughout; Potomac River system of Atlantic drainage; Canadian Interior Basin in Red, Winnipeg, and Nelson River drainages (after Clarke, 1973, p. 112).

Pleistocene (Illinoian) to Holocene (Miller, 1970).

Biology and ecology.--Ortmann (1912, p. 351) and Baker (1928b, p. 283-284) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Ortmann (1911, pl. 89, fig. 23), Surber (1912, pl. 2, fig. 24), and Baker (1928b, pl. 32, fig. 24).

The mantle flaps of L. ovata have been discussed and illustrated by Ortmann (1911, p. 319-320), Welsh (1969), and Kraemer (1970; also flapping behavior) and illustrated by van der Schalie (1970b, p. 19). I have observed these flaps on several females of this species in North Dakota. Many individuals were found gravid during the present study. The smallest (Red River; A49) had a shell 67 mm long with about four rest rings.

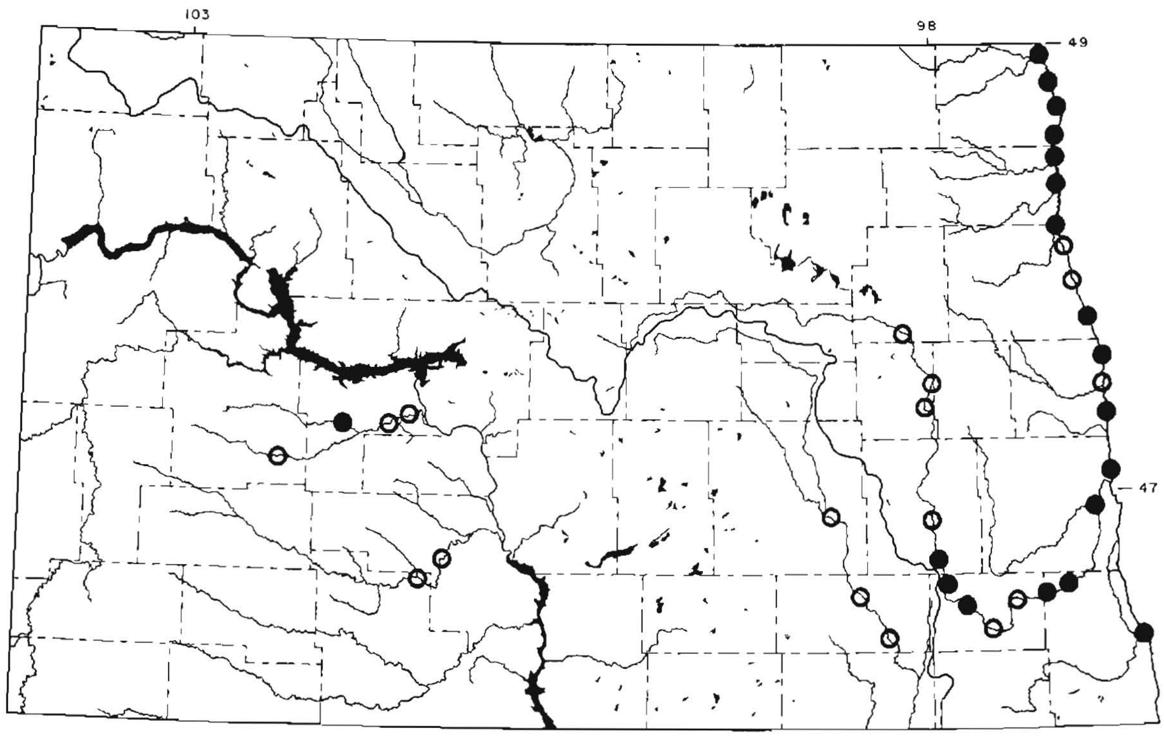

Figure 29. Distribution of Lampsilis ovata (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Host fishes naturally or artificially infected by L. ovata that occur in North Dakota are (Coker and others, 1921, p. 153): bluegill (Lepomis macrochirus), smallmouth and largemouth bass (Micropterus dolomieui, M. salmoides), white crappie (Pomoxis annularis), yellow perch (Perca flavescens), and sauger (Stizostedion canadense).

L. ovata has been reported from large and small streams as well as lakes (Clarke and Berg, 1959, p. 56). In North Dakota, it was collected almost exclusively from large streams (table 1). Channel widths (n=26) were 5-98 m (mean=48±28 S.D.). This species occurred in greatest numbers in the Red River near Buxton in Trail County (148-49-26AD; A2366) (app. A). L. ovata was most frequently associated with Strophitus undulatus, Fusconaia flava, and Amblema plicata, and is part of the A. plicata-F. flava Association (fig. 18). In the Red River, it was most frequently associated with Lampsilis radiata, especially near the banks.

Remarks.--Johnson (1970, p. 386-388) gave a rather comprehensive synonymy for L. ovata and discussed a few names (e.g., L. o. ventricosa, L. o. canadensis) that represent environmental variants. Numerous intergrades exist within the L. ovata complex (Ortmann, 1919, p. 298, 303; van der Schalie, 1938, p. 70). It is possible that L. excavata (Lea), a southern U.S. form, may be part of the L. ovata complex (Cvancara, 1963). The name "ventricosa," used as a subspecies of L. ovata (e.g., Burch, 1973), has been used also as a species name for L. ovata (e.g., Cvancara, 1970); L. ovata, however, clearly has priority. If L. ovata and L. ventricosa are biologically distinct species as has been suggested (Clarke, 1981, p. 346), the name "L. ventricosa" will be applicable for North Dakota populations.

Lampsilis radiata (Gmelin, 1792)
Fat mucket
pl. 2, figs. 1, 2, 8

Diagnosis.--Shell elongate-subovate to subelliptical; females prominently swollen

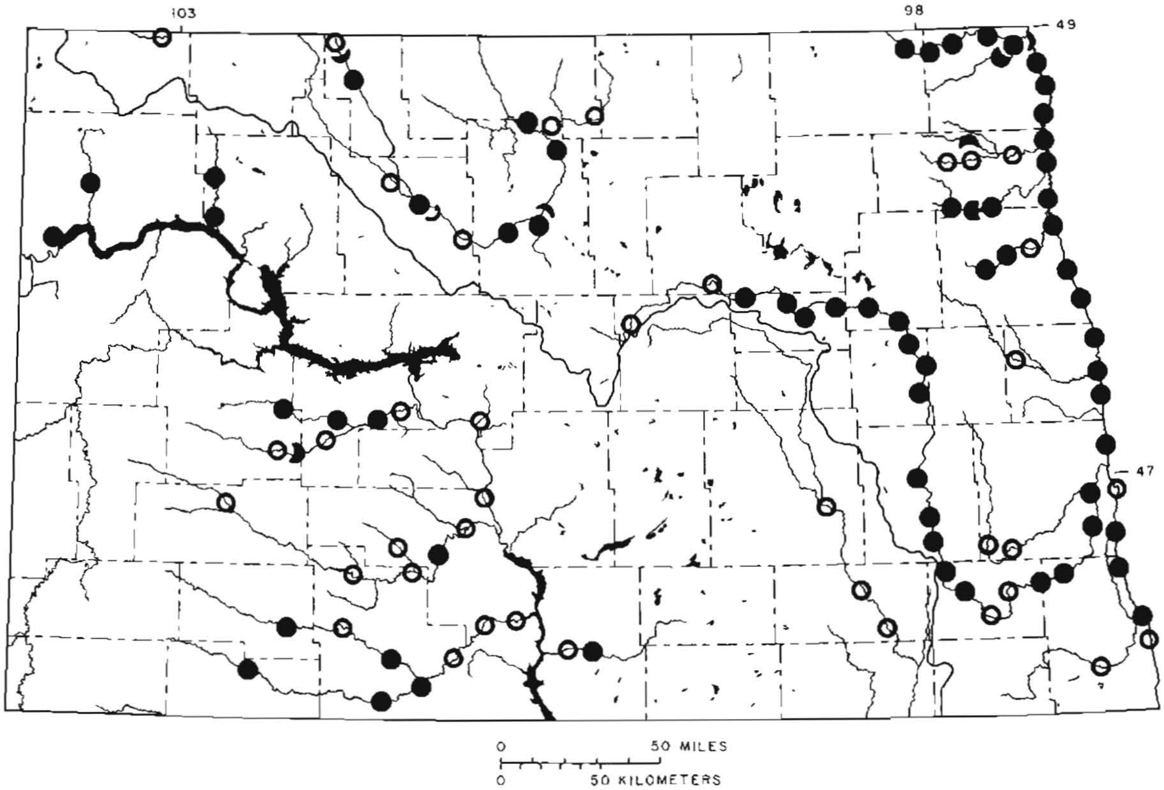

Figure 30. Distribution of Lampsilis radiata (Gmelin) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

posteroventrally (Interior Basin form) or not (Atlantic Slope form); beak areas relatively low, not much elevated above hinge line; beak ridges fine, chevron-like (="double-looped" of many authors); periostracum smooth and shiny (Interior Basin form) or rough, with close, concentric wrinkles (Atlantic Slope form); hinge relatively straight, pseudocardinal teeth relatively compressed (Interior Basin form) or pyramidal (Atlantic Slope form); nacre usually white, may be pink or salmon-colored (Atlantic Slope form).

Range in North Dakota.--Most of the state (fig. 30).

Late Pleistocene to Holocene (at least about 13,500 years to present (Cvancara, 1976, p. 1689).

General range.--Essentially throughout Ohio-Mississippi-Missouri drainages (but absent from Tennessee and Cumberland River systems; Ortmann, 1919, p. 289); St. Lawrence River drainage; Atlantic Slope south to South Carolina; Canadian Interior Basin from Quebec to Alberta and north to vicinity of Great Slave Lake (mainly after Clarke, 1973, p. 108, and Johnson, 1970, p. 393).

Pleistocene (Sangamonian) to Holocene (Baker, 1920, p. 383).

Biology and ecology.--Ortmann (1912, p. 348) and Baker (1928b, p. 272-273) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Surber (1912, pl. 2, fig. 15) and Baker (1928b, pl. 32, fig. 15). The mantle flaps of L. radiata have been described by Ortmann (1919, p. 319, 321), and described (including flapping behavior) and illustrated by Kraemer (1970). Many individuals were found gravid during the present study. The smallest (Red River; A68) had a shell length of 52 mm and about three rest rings.

Host fishes naturally or artificially infected by L. radiata that occur in North Dakota are (Coker and others, 1921, p. 153; Evermann and Clark, 1918, p. 260): tadpole madtom (Noturus gyrinus), rock bass (Ambloplites rupestris), bluegill (Lepomis macrochirus), smallmouth and largemouth bass (Micropterus dolomieui, M. salmoides), white and black crappie (Pomoxis annularis, P. nigromaculatus), yellow perch (Perca flavescens), sauger (Stizostedion canadense), and walleye (S. vitreum vitreum).

L. radiata has been reported from small and large streams, lakes, and canals (Clarke and Berg, 1959, p. 60, 62). In North Dakota, it was collected mostly from both small and large streams but also from lakes (table 1). Channel widths (n=84) were 1-98 m (mean=30±25 S.D.). L. radiata tolerated waters of relatively high total hardness (app. B).

This species occurred in greatest numbers in the Red River near Drayton in Pembina County (159-51-13AA; A48) (app. A). In the Sheyenne River, shells of L. radiata were found to become higher and more inflated downstream, and an increase in shell weight, shell weight/shell length, total weight, and total weight/shell length also occurred downstream (Cvancara, Bluemle, and Bluemle, 1978). L. radiata was most frequently associated with Anodonta grandis and Lasmigona complanata, and is part of the association bearing the names of those two species (fig. 18). In the Red River, it was most frequently associated with Lampsilis ovata, especially near the banks.

Remarks.--Considerable confusion and inconsistency has resulted in the nomenclature of this species (summarized by Johnson, 1969, p. 54, 1970, p. 392; and Clarke, 1973, p. 109). It seems clear now that the name "luteola" no longer applies in any sense. Clarke and Berg (1959, p. 58-62, 68-70) recognized two subspecies, L. r. radiata (Atlantic Slope form) and L. r. siliquiodea (Interior Basin form), that intergrade completely in the lower St. Lawrence drainage of New York. Under this scheme the North Dakota material would be called L. r. siliquoidea. I have attempted to encompass the basic characteristics of these so-called subspecies under Diagnosis of the species. Environmental variants also occur in this species, and small individuals from certain lakes have been called "L. siliquodea rosacea (DeKay)" (van der Schalie, 1938, p. 68-69).

Genus Ligumia Swainson, 1840

Shell notable elongate, subovate to subelliptical; female shell more or less inflated posteroventrally; beak ridges fine, double-looped; hinge teeth well-developed; posteroventral mantle margins papillate in females.

Ligumia recta (Lamarck, 1819)
Black sand shell
pl. 2, fig. 3

Diagnosis.--Shell elongate-subelliptical; posterior ridge generally indistinct; periostracum green, black or brown, commonly rayed; nacre white or pink to purple.

Range in North Dakota.--Red and lower Sheyenne Rivers (fig. 31).

Holocene (within interval of about 4,000 years to present; Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi River drainage from Pennsylvania to Minnesota and Alabama to Oklahoma; Alabama River drainage in Alabama and Georgia; St. Lawrence River drainage from Lake Huron to vicinity of Montreal; Canadian Interior Basin in Red River and Lake Winnipeg drainages (after Clarke, 1973, p. 103).

Pleistocene (Illinoian?) to Holocene (Miller, 1966, p. 220).

Biology and ecology.--Ortmann (1912, p. 344) and Baker (1928b, p. 258-259) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Ortmann (1911, pl. 89, fig. 21), Surber (1912, pl. 2, fig. 17), and Baker (1928b, pl. 32, fig. 19). The papillate posteroventral margins of the female have been illustrated by Walker (1918, p. 77) and Baker (1928b, p. 258 and pl. 29, fig. 2). Only a few gravid individuals were observed during the present study. The smallest (Sheyenne River, A985) had a shell length of 117 mm and at least seven rest rings. Host fishes naturally infected by L. recta that occur in North Dakota are bluegill (Lepomis macrochirus) and white crappie (Pomoxis annularis) (Coker and others, 1921, p. 153).

L. recta has been reported from small and large streams and lakes (Clarke and Berg, 1959, p. 53). In North Dakota, it was collected only from large streams (table 1). Channel widths (n=9) were 18-82 m (mean=47±23 S.D.). This species occurred in greatest numbers in the Red River near Drayton in Pembina County (159-50-6AC; A47) (app. A). L. recta was most frequently associated with Proptera

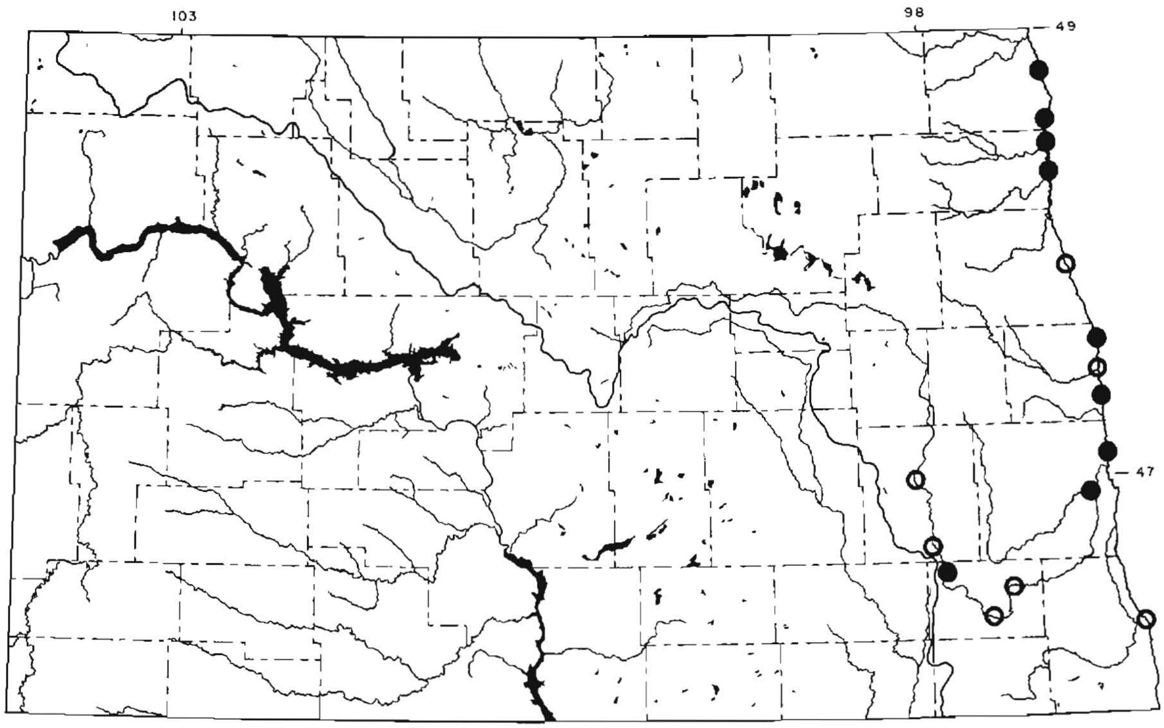

Figure 31. Distribution of Ligumia recta (Lamarck) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

alata and Quadrula quadrula, and is part of the Amblema plicata-Fusconaia flava Association (fig. 18).

Remarks.--Environmental variants also occur in this species. The lake form has been called L. recta and the river form L. r. latissima (Baker, 1928b, p. 255-259).

Genus Proptera Rafinesque, 1819

Shell subovate to subelliptical, gapes ventroanteriorly and posterodorsally, winged dorsally in young individuals and commonly also in adults; beak ridges fine, double-looped; hinge teeth relatively compressed, pseudocardinals may be weakly developed; nacre whitish, pink, or purple. Posterior mantle margins in females with granulations (but without papillae). Glochidia axehead-shaped.

Remarks.--Valentine and Stansbery (1971, p. 26) have pointed out that Potamilus Rafinesque, 1818, has priority over Proptera. I will, however, continue to use the more familiar name Proptera until future usage or the International Commission on Zoological Nomenclature decides finally.

Proptera alata (Say, 1817)
Pink heel splitter
pl. 2, fig. 7

Diagnosis.--Shell subovate, relatively compressed, winged prominently dorsally; relatively thick; beaks low, little elevated above hinge line; periostracum dull, generally brown to black; pseudocardinal teeth subtriangular; nacre pink or purple.

Distribution in North Dakota.--Red and lower Sheyenne Rivers (fig. 32).

Holocene (known only from the present; Cvancara, 1976, p. 1690).

General range.--Ohio-Mississippi River drainage from Pennsylvania to Minnesota and Alabama to Kansas; St. Lawrence River drainage from Lake Champlain to Lake Huron; and Canadian Interior Basin in parts of Winnipeg River and Red River drainages (Clarke, 1973, p. 100).

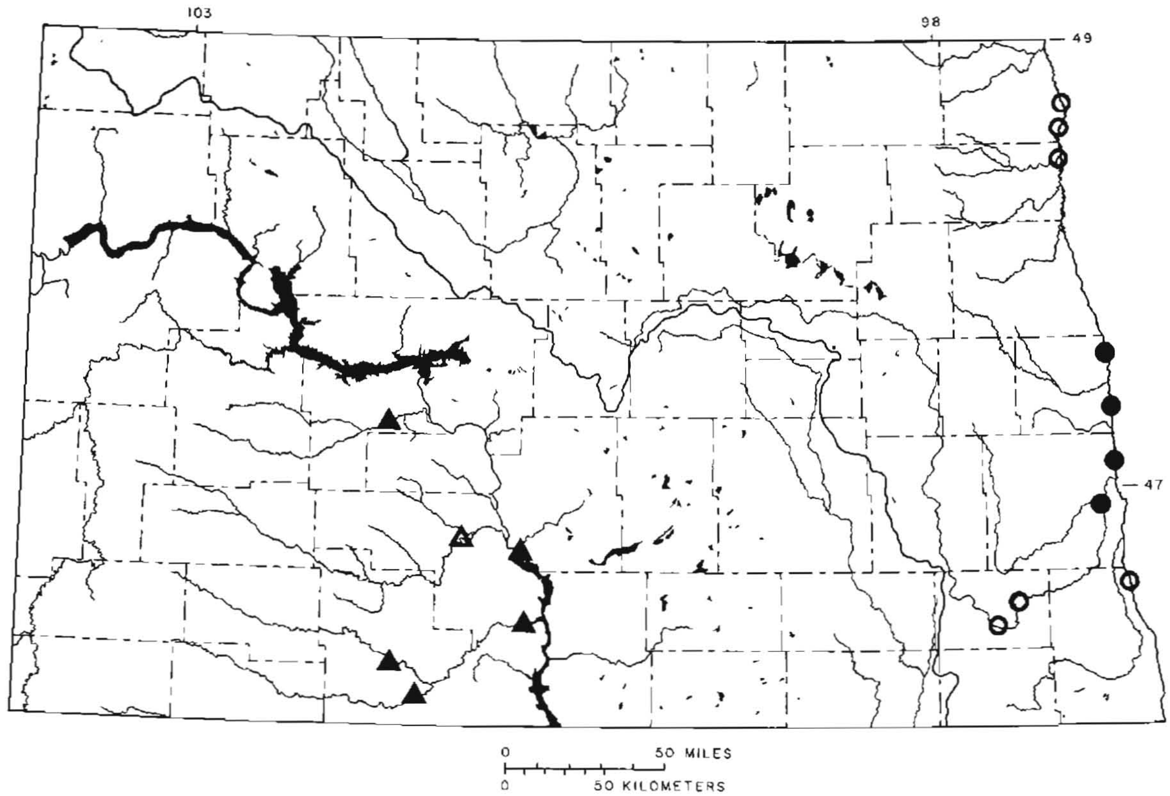

Figure 32. Distribution of Proptera alata (Say) (circles) and P. laevissima (Lea) (triangles) in North Dakota. Filled circles and triangles = live occurrences, open circles and triangles = no live occurrences.

Pleistocene (Wisconsinan) to Holocene (Baker, 1920, p. 383).

Biology and ecology.--Ortmann (1912, p. 333) and Baker (1928b, p. 245) have discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Ortmann (1911, pl. 89, fig. 18), Surber (1912, pl. 1, fig. 8), and Baker (1928b, pl. 32, fig. 14). Only a few individuals were found gravid during the present study. The smallest (Sheyenne River; A1062) had a shell 112 mm long and about six rest rings. A host fish for P. alata that occurs in North Dakota is the fresh-water drum (Aplodinotus grunniens) (Howard, 1913, p. 67).

P. alata has been reported primarily from large streams and lakes, as well as canals; it occurs rarely in small streams (Clarke and Berg, 1959, p. 46). In North Dakota, it was collected only from large streams (table 1). Channel widths (n=4) were 18-63 m (mean=54). This species occurred in greatest numbers in the Red River near Argusville (142-49-25AA; A2365) (app. A). P. alata was most frequently associated with Ligumia recta and Quadrula quadrula, and is part of the Amblema plicata-Fusconaia flava Association (fig. 18).

Remarks.--Environmental variants also occur in this species. P. alata has been applied to the smaller lake form and P. a. megaptera to the larger river form (e.g., Baker, 1928b, p. 241-246).

Proptera laevissima (Lea, 1830)
Fragile heel splitter
pl. 2, fig. 4.

Diagnosis.--Shell subelliptical to subovate, relatively compressed; dorsal wings both anterior and posterior of beaks; relatively thin; beaks low, only little elevated above hinge line; periostracum shiny, yellowish, greenish, or brownish; pseudocardinal teeth fine, lamellar; nacre whitish, pink, or purple. Male and female shells nearly alike.

Range in North Dakota.--Lower reaches of few Missouri River tributaries, rare (fig. 32).

Holocene (known only from the present; Cvancara, 1976, p. 1690).

General range.--Generally Mississippi River drainage; western New York to southwestern North Dakota and south to eastern Texas (modified after Simpson, 1914, p. 183).

Geologic range is presumably unknown.

Biology and ecology.--Baker (1928b, p. 247-248) has discussed the anatomy and reproduction of this species. The glochidium has been illustrated by Surber (1912, pl. 1, fig. 10) and Baker (1928b, pl. 32, fig. 16). No individuals were found gravid during this study. Host fishes found naturally infected by P. laevissima that occur in North Dakota are white crappie (Pomoxis annularis) and fresh-water drum (Aplodinotus grunniens) (Surber, 1913, p. 107-108). The distribution of P. laevissima in southwestern North Dakota (fig. 32) seems to be linked with that of the fresh-water drum (Reigh and Owen, 1979, p. 98). Both the mussel and fish occur presumably only in the lower reaches of Missouri River tributaries.

P. laevissima has been reported primarily from medium and large streams as well as lakes (Baker, 1928b, p. 248; Parmalee, 1967, p. 74). In North Dakota, however, it was collected only from small streams (table 1). Channel widths (n=5) were 14-30 m (mean=21±7 S.D.). This species always occurred rarely, and only a single individual was collected at a given station. Because of its rarity, P. laevissima was not frequently associated with any molluscan species. However, it can be considered part of the Anodonta grandis-Lasmigona complanata Association (fig. 18).

Remarks.--This species has been inconsistently assigned to Proptera and Leptodea by later workers. Its shell more closely resembles that of the type species of Leptodea (L. fragilis) but its axehead-shaped glochidium is similar to that of the type species of Proptera (P. alata). (L. fragilis has a subovate glochidium). The soft-part anatomy of both L. fragilis and P. laevissima is similar to that of P. alata (Baker, 1928b, p. 235, 247). Because aspects of reproduction seem basic for demonstrating relationships, I believe that the species under consideration should be assigned to Proptera.

Other Mussels in North Dakota

It seems highly unlikely that mussel species other than those reported here occur in North Dakota. Dawley (1947, p. 679) reported two other species, Obliquaria reflexa (Rafinesque) and Actinonaias carinata (Barnes), for the Red River. I have not been able to verify the occurrence of these species in North Dakota, and later (written communication dated January 20, 1967) she indicated that the reported occurrences are probably in error. Clarke (1973, p. 113, 130-131) discussed these and other erroneously recorded mussel species from the Canadian Interior Basin. Dr. J. K. Neel, Department of Biology, University of North Dakota, pointed out the occurrence of an empty shell of Alasmidonta marginata (Say) from the Red River near Halstad, Minnesota (cited in Cvancara, 1970, p. 2). I have seen no evidence of this species in North Dakota during my collecting. Winslow (1921, p. 15) listed "?Anodonta kennicotti Lea" and A. pepiniana Lea from Gravel Lake in the Turtle Mountains. A. kennicotti is a synonym of A. grandis and A. pepiniana may be as well (Clarke, 1973, p. 85, 88).

Pill Clams

Classification of the pill clams is that used by Burch (1975a), and subfamilial characterizations are after him. Subgeneric characterizations are after Clarke (1973) and Heard (1966). Herrington (1962) and Burch (1975a) have given synonymies for this group.

Measurements (table 3) were made of 30 individuals, where possible, that exhibited adult characters; shell length, height, and width as are described for the mussels.

Pill clam shell morphology is similar to that of mussels, and differs as discussed in the Introduction. Hinge tooth terminology is depicted in figure 4. Supplemental shell terms for pill clams are as follows:

TABLE 3.--Summary of shell measurements of North Dakota pill clams.

Species	Length[1]	Height/Length	Width/Height	Number Measured	Longest Observed in State[1]
Sphaerium lacustre	9.8(9.1-10.7)	0.88(0.83-0.92)	0.72(0.69-0.83)	30	12.9
S. transversum	10.1(8.6-13.0)	0.72(0.66-0.75)	0.73(0.66-0.81)	30	13.0
S. simile	13.7(10.6-16.0)	0.75(0.71-0.90)	0.67(0.63-0.71)	30	17.8
S. striatinum	13.4(12.3-14.8)	0.80(0.77-0.85)	0.69(0.65-0.75)	30	16.4
Pisidium casertanum	- - - -	- - - -	- - - -	- - -	- - -
P. compressum	2.9(2.5- 3.2)	0.94(0.82-1.14)	0.67(0.53-0.76)	30	3.5
P. ferrugineum	- - - -	- - - -	- - - -	- - -	- - -
P. nitidum	2.2(1.6- 2.5)	0.92(0.80-1.35)	0.65(0.50-0.82)	30	2.5
P. ventricosum	- - - -	- - - -	- - - -	- - -	- - -

[1] In mm; first number given for length, height/length, and width/height is the mean.

Cusp (fig. 4). Most pronounced projection of a lateral tooth.
Hinge tooth, cardinal (fig. 4). Relatively short projection at center of hinge in vicinity of beaks; analogous to pseudocardinal tooth of mussels.
Stria. Raised, concentric line or ridge or furrow on shell surface.
Subtrapezoidal (pl. 3, figs. 16, 17). Shell shape approaching that of a trapezoid.
Umbone (pl. 3, fig. 9). Region of valve directly surrounding the beak; may be capped or raised above rest of shell surface.

Superfamily SPHAERIACEA

Fresh-water to marine bivalves with porcelaneous shells; lateral teeth both anterior and posterior to cardinal teeth; pallial line entire or with small sinus. Young held in mantle cavity during juvenile growth; no parasitic stage.

Family SPHAERIIDAE Jeffreys, 1862

Fresh-water bivalves with small (less than about 25 mm long) shells; ligament short; two pairs lateral teeth in right valve, two single laterals in left; one cardinal tooth in right valve, two in left (tooth numbers vary in cases where tooth reversal occurs); pallial line entire, indistinct. Monoecious and ovoviviparous.

Subfamily Sphaeriinae Baker, 1927

Branchial and anal siphons partially fused together; embryos develop in anterior parts of gills in thin-walled longitudinal sacs; byssal gland absent.

Genus *Sphaerium* Scopoli, 1777

Shell about 5-25 mm long, beaks central or anterior of center.

Subgenus *Musculium* Link, 1807

Shell generally relatively thin; striae fine; umbones usually capped (calyculate); siphons fused for greater part of their length; young many, more generally than in *S*. (*Sphaerium*).

Sphaerium (*Musculium*) *lacustre* (Müller, 1774)
pl. 3, figs. 8, 9

Diagnosis.--Shell up to about 14 mm long, thin, subtrapezoidal, high, moderately inflated; beaks somewhat anterior, prominent, well above dorsal margin; capped umbones common; striae uneven, periostracum with dull gloss.

Range in North Dakota.--Throughout the state (fig. 33).

Holocene (about 10,000-8,000 years to present, Cvancara, 1976, p. 1690).

General range.--Throughout North America, except north of tree line and in southwestern states; also in Central and South America, Hawaii, Australasia, and Eurasia (Burch, 1975a, p. 6).

Middle Pleistocene (Kansan) to Holocene (Miller, 1966, p. 220).

Biology and ecology.--A brood size of up to 45 young has been reported for *S. lacustre* from Michigan (Heard, 1977, p. 446). The life span is less than a year in Russia (Mitropolskji, 1965, cited by Heard, 1977, p. 436), but Heard (1977, p. 436) found up to two annuli for this species in Michigan. Reproduction and growth have been also studied by Mackie (1979).

S. lacustre has been reported mostly from small lakes and ponds, but also from large lakes and small and large streams, as well as bog-ponds (Herrington, 1962, p. 20). Of lacustrine occurrences, Clarke (1979b, p. 180) listed the species as frequently occurring in eutrophic lakes. In North Dakota, *S. lacustre* was collected mostly from small and intermittent streams but also from intermittent and permanent ponds and lakes (table 1). Channel widths (n=26) were 2-27 m (mean=9±7 S.D.). This species tolerated relatively high values of total hardness and total chlorides and extreme high values of pH (app. B). *S. lacustre* was most frequently associated with several species commonly found in small streams, and is part of the *Anodonta grandis*-*Lasmigona complanata* Association (fig. 18).

Remarks.--Two forms of *S. lacustre* have been recognized. Form *ryckholti* is subtriangular, has a distinctly curved hinge, a short dorsal margin, and a long, gently curved ventral margin. Form *jayense* is subrectangular, with relatively straight dorsal and ventral margins (Herrington, 1962, p. 20). The ecological relationships of these two forms are not clearly understood (Clarke, 1973, p. 155).

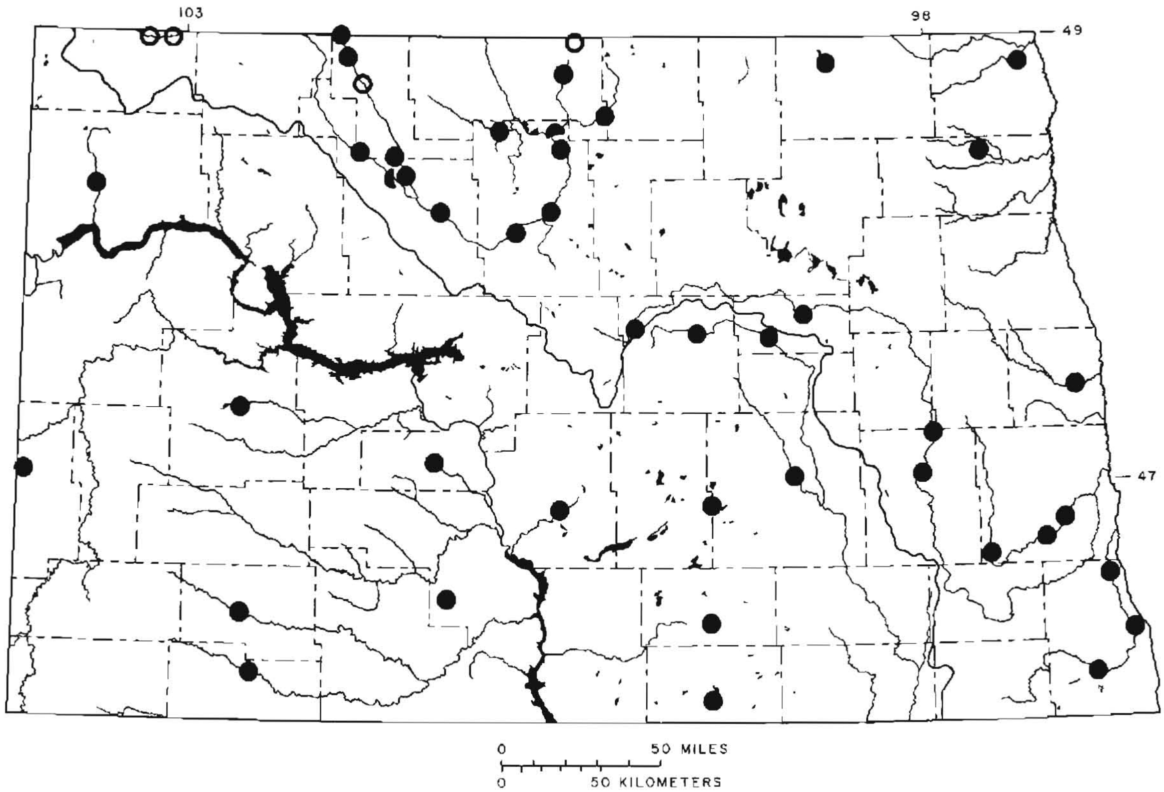

Figure 33. Distribution of Sphaerium (Musculium) lacustre (Müller) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Capped umbones are variably present in this species, as in other members of Musculium. I found no individuals capped, of six collected, from a station (131-50-25CB; A113) on the Wild Rice River in Richland County in 1966.

Sphaerium (Musculium) transversum (Say, 1829)
pl. 3, figs. 16, 17

Diagnosis.--Shell up to about 15 mm long, thin, elongate-subtrapezoidal, posterior end distinctly higher than anterior, moderately inflated; beaks anterior, prominent, well above dorsal margin; capped umbones uncommon; striae somewhat uneven, periostracum dull to slightly glossy.

Range in North Dakota.--Eastern and northern parts of the state, collected only from Hudson Bay drainage (fig. 34).

Holocene (present, no fossils known; Cvancara, 1976, p. 1690).

General range.--North America from southwestern Northwest Territories south and east through most of area east of Rocky Mountains to Florida, Texas, and Mexico; also Arizona (Burch, 1975a, p. 6); also introduced in England (Herrington, 1962, p. 30).

Early Pleistocene (Nebraskan) to Holocene (Miller, 1966, p. 222).

Biology and ecology.--Baker (1928b, p. 352) described the general anatomy of this species, and Heard (1977) has summarized reproductive data. A brood size of up to 86 young has been reported for S. transversum, and a life span of less than a year in Iowa (Gale, 1969, cited by Heard, 1977, p. 448). Heard (1977, p. 436) found up to two annuli for this species in Michigan.

S. transversum has been reported mostly from rivers, ponds, and lakes (Baker, 1928b, p. 352). Of lacustrine occurrences, Clarke (1979b, p. 180) listed the species as frequently occurring in mesotrophic lakes. In North Dakota, S. transversum was collected mostly from small and large permanent streams but also

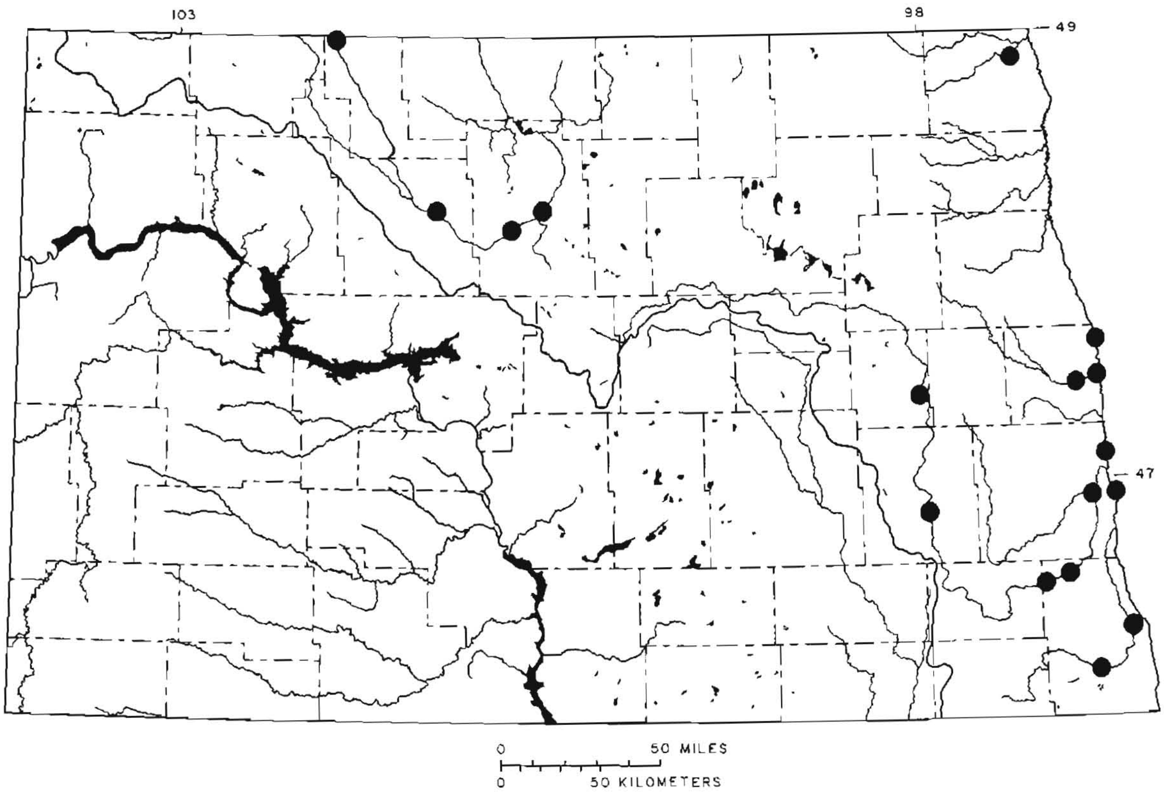

Figure 34. Distribution of Sphaerium (Musculium) transversum (Say) in North Dakota.

from an intermittent stream (table 1). Channel widths (n=14) were 8-39 m (mean= 18±8 S.D.). Gale (1977) showed experimentally that S. transversum prefers mud over sandy mud and sand. He found (Gale, 1976), too, this species burrowing to a depth of 16 cm in the substrate in pool 19 of the Mississippi River, and to a depth of 24 cm in Lake Texoma, Oklahoma sediment. This species was most frequently associated with Quadrula quadrula, Proptera alata, and Ligumia recta, and is part of the Amblema plicata-Fusconaia flava Association (fig. 18).

Remarks.--Gale (1972, p. 20) said capped umbones were formed during arrested growth in this species, so the feature is of questionable taxonomic importance.

Subgenus Sphaerium s. s.

Shell relatively thick, striae coarse to relatively fine, umbones usually not capped; siphons fused only at bases; young relatively few, generally fewer than in S. (Musculium).

Sphaerium (Sphaerium) simile (Say, 1816)
pl. 3, figs. 4, 5

Synonym.--Sphaerium sulcatum (Lamarck).

Diagnosis.--Shell up to about 25 mm long, thick, elongate-ovate, moderately inflated; beaks subcentral, low; striae coarse, evenly spaced, periostracum with dull gloss.

Range in North Dakota.--Eastern and northern parts of state, mostly in Hudson Bay drainage (fig. 35).

Late Pleistocene to Holocene (at least about 12,000-10,000 years to present; Cvancara, 1976, p. 1690).

General range.--New Brunswick to northern and central British Columbia, and south to Virginia, Iowa, and Wyoming (Burch, 1975a, p. 6).

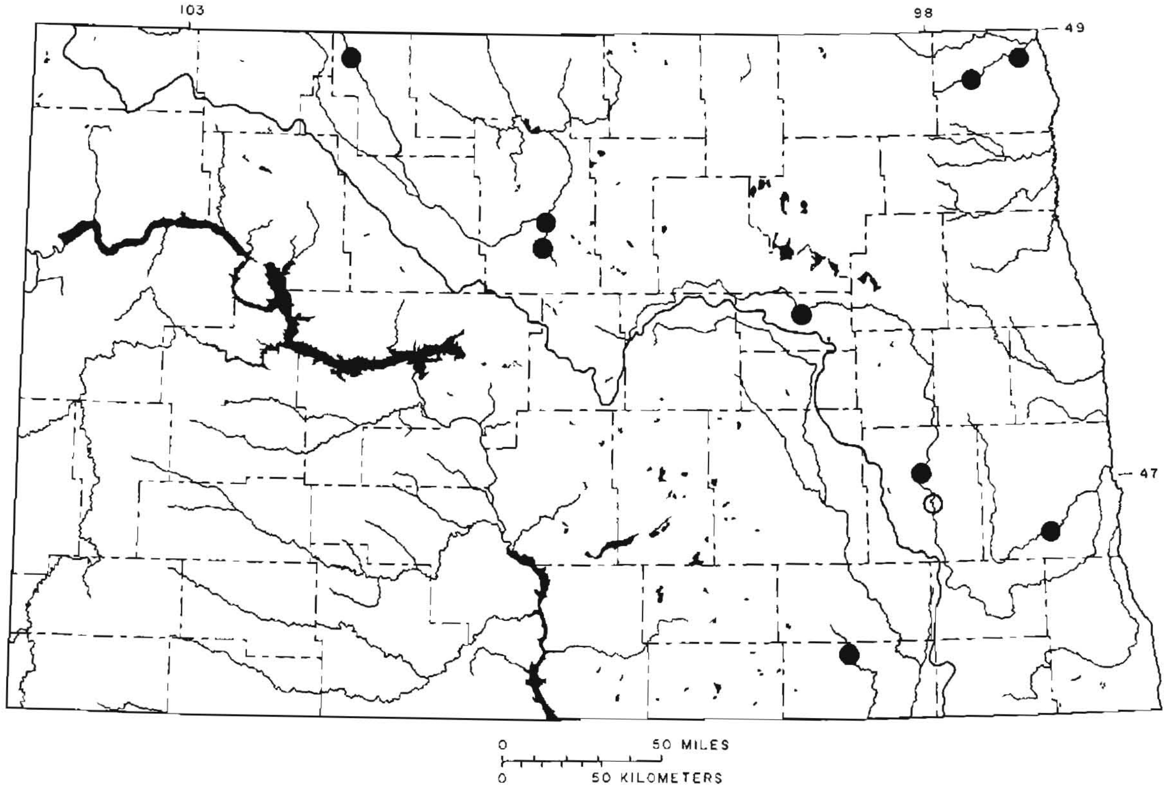

Figure 35. Distribution of Sphaerium (Sphaerium) simile (Say) in North Dakota. Filled circles = live occurrences, open circle = no live occurrences.

Late Pliocene to Holocene (Miller, 1966, p. 222).

Biology and ecology.--Drew (1896) and Gilmore (1917) have described the anatomy, and Heard (1977) has summarized reproductive data for this species. Clarke (1973, p. 144) reported a brood size of up to 17 shelled young for S. simile. Gilmore (1917, p. 26) reported up to eight "growth" rings for this species.

S. simile has been reported from permanent large and small lakes and large and small streams (Clarke, 1973, p. 143) but not from temporary ponds or swamps (Herrington, 1962, p. 29). Of lacustrine occurrences, Clarke (1979b, p. 180) singled out this species as characteristic of eutrophic lakes. In North Dakota, it was collected mostly from small permanent streams but also from intermittent streams and a permanent lake (table 1). Channel widths (n=7) were 3-21 m (mean=12±8 S.D.). This species tolerated relatively high values of total chlorides (app. B). S. simile was most frequently associated with several species commonly found in small streams, and is part of the Anodonta grandis-Lasmigona complanata Association (fig. 18).

Remarks.--The young of this species are compressed and subrectangular, with an almost straight dorsal margin.

Sphaerium (Sphaerium) striatinum (Lamarck, 1818)
pl. 3, fig. 2, 3

Synonyms.--Sphaerium solidulum (Prime), S. notatum Sterki.

Diagnosis.--Shell up to about 16 mm long, moderately thick, subovate to subtrapezoidal; moderately inflated; beaks slightly anterior, low to prominent; striae coarse to fine, unevenly spaced, periostracum dull.

Range in North Dakota.--Throughout the state (fig. 36).

Late Pleistocene to Holocene (at least about 13,500 years to present; Cvancara, 1976, p. 1689).

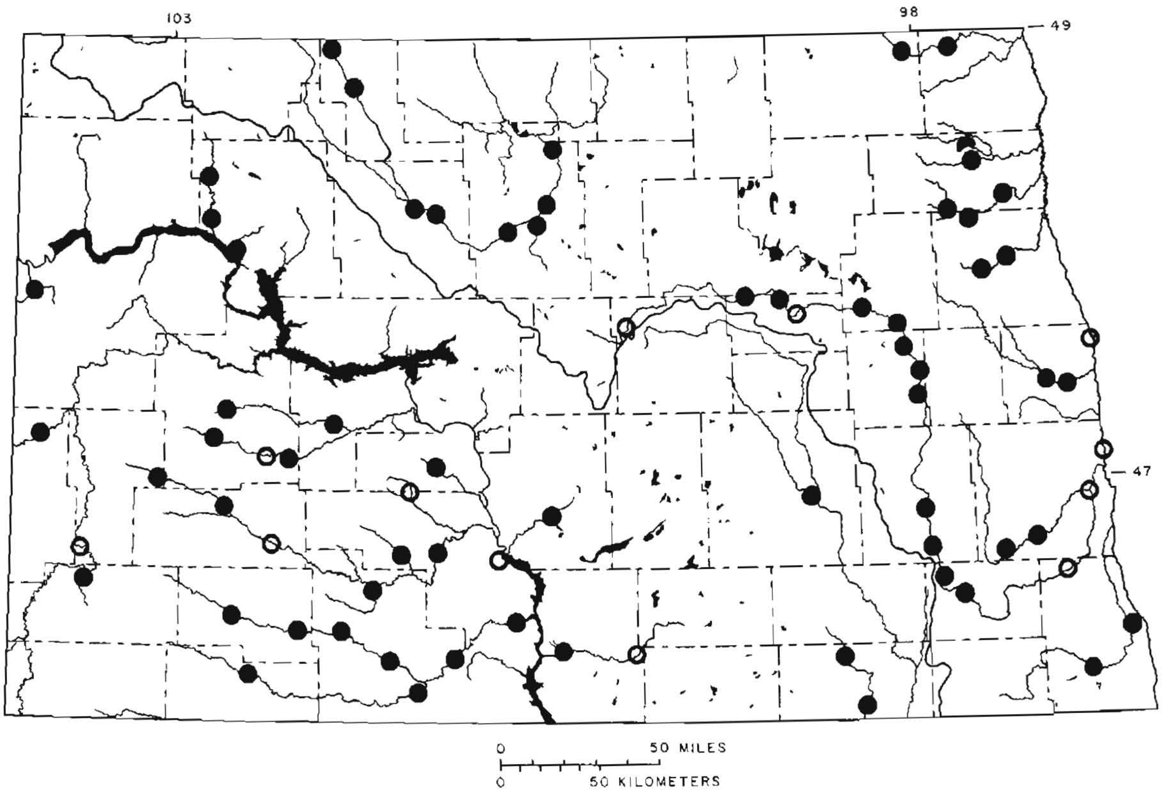

Figure 36. Distribution of Sphaerium (Sphaerium) striatinum (Lamarck) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

General range.--New Brunswick to Great Slave Lake and Upper Yukon River and south (throughout United States) into Mexico and Panama (Burch, 1975a, p. 6).

Late Pliocene to Holocene (Miller, 1966, p. 221).

Biology and ecology.--The anatomy of this species was described by Monk (1928), and reproductive data were summarized by Heard (1977). Avolizi (1971; cited by Heard, 1977, p. 444, 436) reported a maximum average brood size of 14.5 young, and a life span up to two years for S. striatinum from New York. Heard (1977, p. 436) listed up to four annuli for this species from Michigan.

S. striatinum has been reported from small and large streams and small and large lakes, but not ponds nor swamps (Herrington, 1962, p. 28). Of lacustrine occurrences, Clarke (1979b) singled out this species as characteristic of mesotrophic lakes. In North Dakota, S. striatinum was collected mostly from small, permanent streams but also large, permanent streams and intermittent streams (table 1). Channel widths (n=55) were 1-37 m (mean=12±8 S.D.). This species tolerated relatively high values of total chlorides, alkalinity, hardness, and sulfates (app. B). S. striatinum was most frequently associated with Anodonta grandis, Lasmigona complanata, and Lampsilis radiata, and is part of the A. grandis-L. complanata Association (fig. 18).

Remarks.--S. striatinum is considerably variable in shape and coarseness of striae, even on the same individual. Also, lake forms tend to be relatively higher than river forms (Herrington, 1962, p. 27).

The young are compressed and subrectangular, as in S. simile, but are somewhat shorter.

Subfamily Pisidiinae Baker, 1927

Branchial siphon absent or represented by slit in mantle, anal siphon present; embryos develop in anterior parts of gills in thick-walled sac with individual chambers for embryos; byssal gland absent.

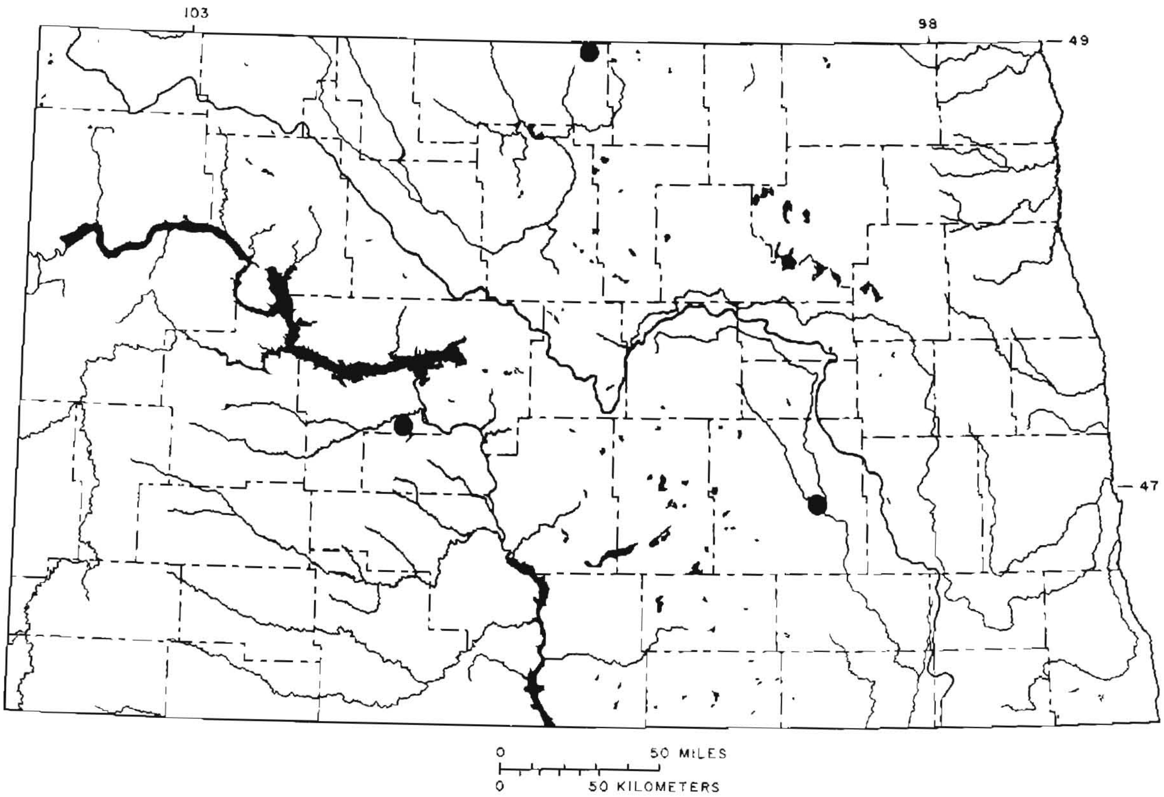

Figure 37. Distribution of Pisidium (Cyclocalyx) casertanum (Poli) in North Dakota.

Genus Pisidium Pfeiffer, 1821

Shell about 2-12 mm long, beaks posterior.

Subgenus Cyclocalyx Dall, 1903

Shell about 2.5-5 mm long; branchial siphon represented by short slit in fused mantle; small posterior gills (with inner lamellae only) in addition to larger anterior gills; annual, one small to large litter (average: 4-20).

Pisidium (Cyclocalyx) casertanum (Poli, 1791)
pl. 3, figs. 10, 11

Diagnosis.--Shell usually not more than about 6 mm long, moderately thick, subovate, posterior end truncate, moderately inflated; beaks slightly posterior, relatively low; striae fine, periostracum dull to slightly glossy; hinge longer than three-fourths of shell length; cardinal teeth near cusps of anterior laterals; C3 slightly curved, posterior end slightly enlarged; cusp of AII proximal or on proximal side of center, cusp of PII on distal side of center.

Range in North Dakota.--Presumably throughout the state, rare (fig. 37). Late Pleistocene to Holocene (at least about 12,000-10,000 years to present; Cvancara, 1976, p. 1690).

General range.--Nearly cosmopolitan, North America as far north as southern tier of Arctic Islands, Central and South America, Eurasia, most of Africa, Australia, Tasmania, and New Zealand (Clarke, 1973, p. 174).

Early Pliocene to Holocene (Hibbard and Taylor, 1960, p. 77).

Biology and ecology.--Hamill and others (1979) have studied the production and turnover ratio of this species. Reproduction and growth have been studied by Heard (1965) and Mackie (1979). Heard (1965, p. 403, 406) reported a brood size of up to 42 young and a life span of one year for P. casertanum from Michigan.

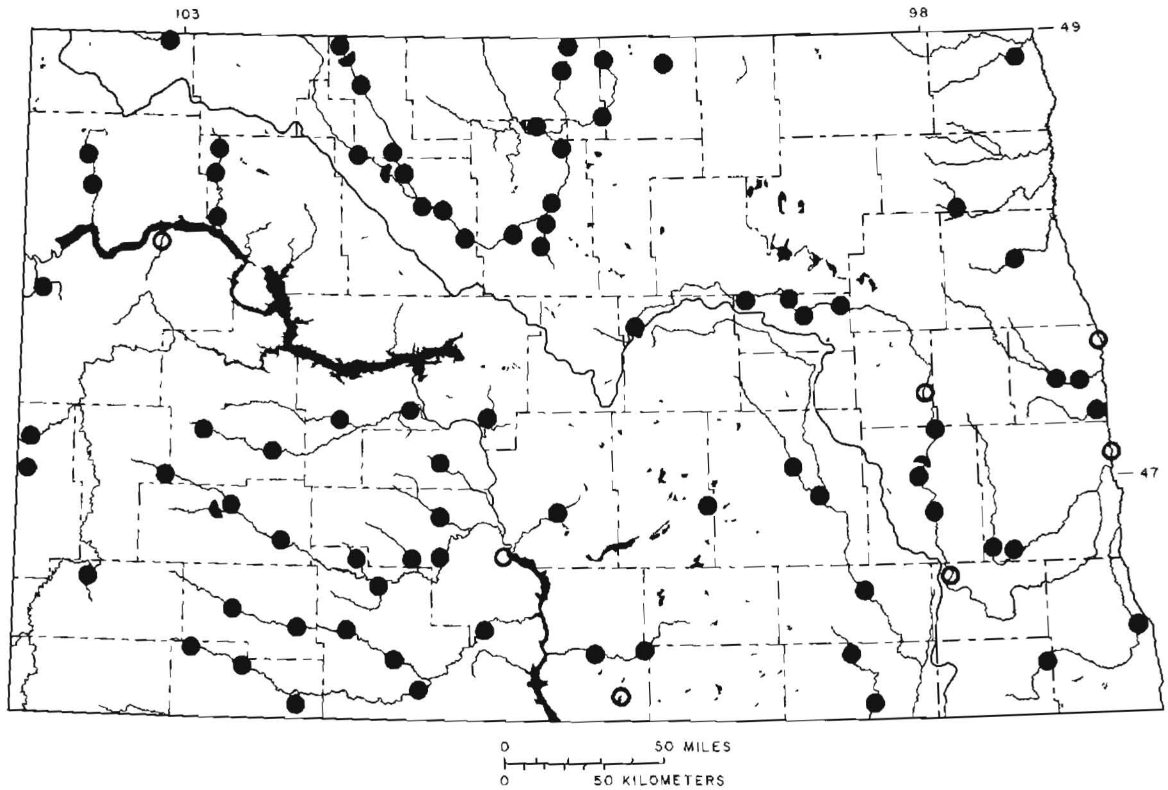

Figure 38. Distribution of Pisidium (Cyclocalyx) compressum Prime in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Swedish populations, however, have a life span greater than one year (Odhner, 1929, cited by Heard, 1965, p. 406).

P. casertanum has been reported from "bog ponds, ponds, swamps that dry up for several months of the year, swamp-creeks, creeks with considerable current, rivers, and lakes, including the Great Lakes" (Herrington, 1962, p. 34). In North Dakota, I have collected it from a permanent lake and an intermittent and small, permanent stream (table 1). Channel widths were 12 and 35 m. Because of its rare occurrence, the association of P. casertanum with other mollusks is unclear; it has been arbitrarily placed in the Aplexa hypnorum-Gyraulus circumstriatus Association (fig. 18).

Remarks.--P. casertanum has been cited as the most common Pisidium in North America (Herrington, 1962, p. 34) but I have collected it at only three localities in North Dakota.

Pisidium (Cyclocalyx) compressum Prime, 1852
pl. 3, figs. 12, 13

Diagnosis.--Shell up to about 4 mm long, thick, subtriangular, moderately inflated; beaks considerably posterior, prominent, usually with straight or slightly curved ridges; striae coarse to moderately fine, periostracum dull; hinge longer than three-fourths of shell length; cardinal teeth central; C3 considerably curved with much larger posterior end; cusps of AII and PII central or on distal side of center.

Range in North Dakota.--Throughout the state (fig. 38).

Late Pleistocene to Holocene (at least about 12,000-10,000 years to present; Cvancara, 1976, p. 1690).

General range.--Throughout most of Canada and the United States, and into Mexico (Burch, 1975a, p. 7).

Middle Pleistocene (Kansan) to Holocene (Miller, 1966, p. 223).

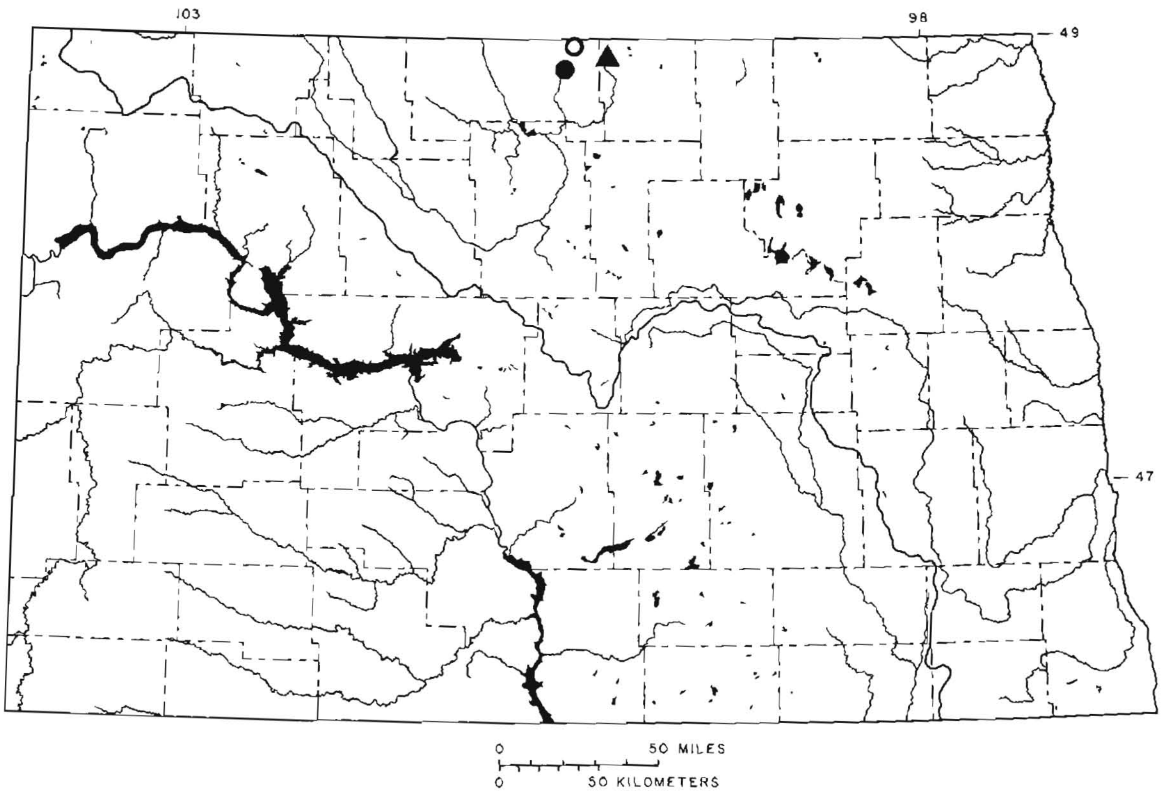

Figure 39. Distribution of Pisidium (Cyclocalyx) ferrugineum Prime (triangle) and P. (C.) ventricosum Prime (circles) in North Dakota. Filled circle and triangle = live occurrences, open circle = no live occurrences.

Biology and ecology.--Heard (1965, p. 403, 406) reported a brood size of up to 42 young, and a life span of one year for P. compressum from Michigan.

P. compressum has been reported from large and small lakes, permanent ponds, and large and small streams (Clarke, 1973, p. 176). In North Dakota, it was collected mostly from small, permanent streams, but also from large, permanent streams, intermittent streams, and permanent ponds and lakes (table 1). Channel widths (n=73) were 1-37 m (mean=11±8 S.D.). This species tolerated relatively high values of total chlorides, hardness, and sulfates, and extreme high values of total alkalinity (app. B). P. compressum was most frequently associated with Sphaerium striatinum, Lampsilis radiata, Lasmigona complanata, and Anodonta grandis, and is part of the A. grandis-L. complanata Association (fig. 18).

Remarks.--Young of P. compressum have lower beaks as is also true for P. (C.) casertanum. P. compressum is the second most common Pisidium in North America (Herrington, 1962, p. 35); it is the most frequently found Pisidium in North Dakota.

Pisidium (Cyclocalyx) ferrugineum Prime, 1852
pl. 3, fig. 1

Diagnosis.--Shell up to about 3 mm long, thin, subovate, usually much inflated; beaks slightly posterior, usually prominent, and tubercular; striae coarse to fine, periostracum glossy; hinge longer than three-fourths of shell length; cardinal teeth near cusps of anterior laterals; C3 straight or slightly curved; cusp of AII central or on proximal side of center, that of PII distal; cusp of AII nearly normal to plane passing between valves and commonly with parallel sides.

Range in North Dakota.--Rare; may be restricted to the Turtle Mountains in the north-central part of the state (fig. 39).

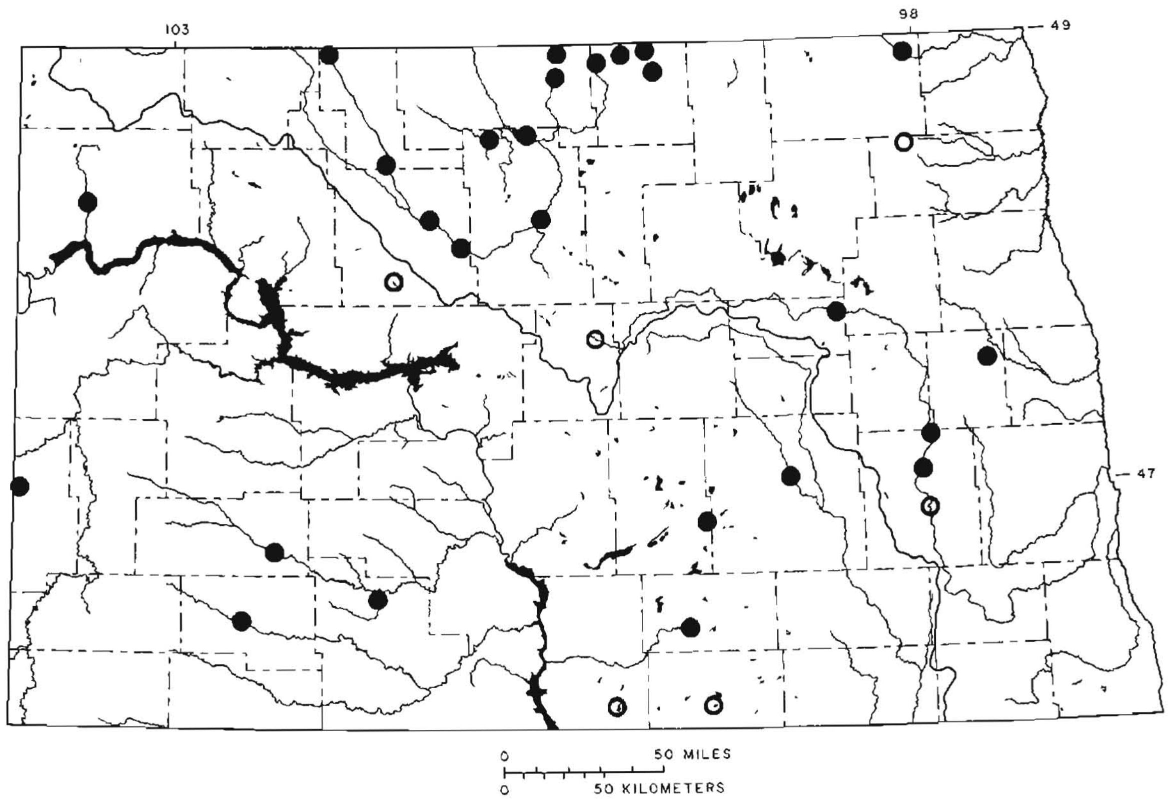

Figure 40. Distribution of Pisidium (Cyclocalyx) nitidum Jenyns in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Holocene (present, no fossils known; Cvancara, 1976, p. 1690).

General range.--Most of Canada and northern United States, south to Utah and New Jersey; also Europe (Burch, 1975a, p. 7; Herrington, 1962, p. 40).

Late Pleistocene to Holocene (Hibbard and Taylor, 1960, p. 8).

Biology and ecology.--The anatomy of P. ferrugineum has been only briefly described by Prime (1852, p. 362).

This species has been reported from large and small lakes, permanent ponds, and large and small streams (Clarke, 1973, p. 182). Of lacustrine occurrences, it is characteristic of mesotrophic and eutrophic lakes (Clarke, 1979b, p. 180). In North Dakota, it was recovered only from a permanent lake (table 1) where the bottom sediment was mud. Its rare occurrence in the state precludes an assignment to a molluscan association.

Pisidium (Cyclocalyx) nitidum Jenyns, 1832
pl. 3, figs. 6, 7

Diagnosis.--Shell up to about 3.5 mm long, thin, subrhomboidal to subtriangular, moderately inflated; beaks slightly posterior, usually relatively low; striae fine, periostracum glossy; hinge longer than three-fourths of shell length; cardinal teeth subcentral; C3 slightly curved, distinctly wider at posterior end; cusps of AII and PII distal.

Range in North Dakota.--Throughout the state (fig. 40).

Late Pleistocene to Holocene (at least about 12,000-10,000 years to present; Cvancara, 1976, p. 1690).

General range.--In all Canadian Provinces except Nova Scotia, continental United States except Alaska, and Mexico; also Eurasia and North Africa (Burch, 1975a, p. 7).

Early Pliocene to Holocene (Hibbard and Taylor, 1960, p. 78).

Biology and ecology.--Odhner (1929, p. 81) has described the anatomy and reproduction of P. nitidum. Heard (1965, p. 403, 406) reported a brood size of up to 13, and a life span of one year for this species from Michigan. Odhner (1929; cited by Heard, 1965, p. 406) reported a life span of more than a year for Swedish populations.

P. nitidum has been reported from large and small lakes, permanent ponds, and small and large streams (Clarke, 1973, p. 192). In North Dakota, it was collected mostly from permanent lakes and ponds and small, permanent streams, but also from intermittent streams (table 1). Channel widths (n=12) were 2-34 m (mean=12±10 S.D.). This species tolerated relatively high values of total hardness and extreme high values of pH (app. B). P. nitidum was most frequently associated with Valvata tricarinata and Helisoma anceps, and is part of the H. trivolvis-Lymnaea stagnalis Association (fig. 18).

Remarks.--Two forms of P. (C.) nitidum have been recognized: Form contortum is longer, with a nearly straight ventral margin, and with a produced, narrowly rounded anteroventral margin (Clarke, 1973, p. 191); form pauperculum has a thicker shell, is higher (with a highly curved dorsal margin), and has more nearly central cardinal teeth (Herrington, 1962, p. 45).

Pisidium (Cyclocalyx) ventricosum Prime, 1851
pl. 3, figs. 14, 15

Diagnosis.--Shell up to about 3.5 mm long, thin, subovate, much inflated; beaks slightly to well posterior, prominent; striae fine, periostracum glossy; hinge less than three-fourths of shell length; cardinal teeth near cusps of anterior laterals; C3 curved; cusp of AII proximal, cusp of PII central or on distal side of center.

Range in North Dakota.--Rare; may be restricted to the Turtle Mountains in the north-central part of the state (fig. 39).

Holocene (known only from the present; Cvancara, 1976, p. 1690).

General range.--Northern Canada to northern United States from Maine to Washington and south in Rocky Mountains to Mexico; also Oklahoma (Burch, 1975a, p. 8).

Middle Pleistocene (Kansan) to Holocene (Miller, 1966, p. 223).

Biology and ecology.--Nothing is apparently known of the anatomy or reproduction of P. ventricosum.

This species has been reported from large and small lakes, permanent ponds, and small and large streams (Clarke, 1973, p. 203). Of lacustrine occurrences, P. ventricosum is characteristic of mesotrophic and eutrophic lakes and "P. rotundatum" (see Remarks) is characteristic of eutrophic lakes (Clarke, 1979b, p. 180). In North Dakota, P. ventricosum was collected alive only from an intermittent stream (table 1). Channel width was 4 m, and the primary bottom sediment was cobble-boulder gravel (sediment as fine as very fine to medium muddy sand occurred in places). The species' rare occurrence in the state precludes an assignment to a molluscan association.

Remarks.--Herrington (1962, p. 46-47) considered two forms, rotundatum and ventricosum, within P. obtusale Pfeiffer, a European species. Later (Herrington, 1965), he accepted the application of P. ventricosum and P. ventricosum form rotundatum, both distinct from P. obtusale. Form rotundatum has slightly posterior beaks, and a narrow hinge plate between the cardinals and AII; in P. ventricosum s. s., the beaks are well posterior and the hinge plate is relatively wide between the cardinals and AII (Burch, 1975a, p. 19-20).

Other Pill Clams in North Dakota

Other small and rare pill clams may exist in North Dakota that were not collected during my survey. The only other species for which I have evidence is Pisidium (Cyclocalyx) variable Prime. I collected a white single valve of this species from Gravel Lake in the Turtle Mountains (163-71-10DA, A338) in 1968. Winslow (1921, p. 16) reported this species from Gravel Lake as well as from Upsilon Lake, which is directly west of Gravel Lake. She also listed "Pisidium apiculatum Sterki" (=P. (Cyclocalyx) subtruncatum Malm) for Upsilon Lake.

From the fossil record, I have questionably recognized Pisidium (Cyclocalyx) milium Held from the Cleveland site in Stutsman County (139-67-17DCD). Fossiliferous sediments at this site have been dated at 11,070 ± 300 years B.P. (Cvancara, 1976, p. 1690-1691).

Snails

Classification of the snails is that of Taylor and Sohl (1962). Clarke (1973) and LaRocque (1968) have provided synonymies for this group.

Shell measurement data are given in table 4.

A glossary of shell term is as follows:

Aperture (fig. 5). Opening of shell.
Apex (fig. 5). First-formed part of shell.
Carina (fig. 5). Prominent spiral ridge or keel.
Columella (pl. 4, fig. 2, 3, 8). Column or pillar surrounding axis of coiling.
Conispiral (pl. 4). Coiled outside of a plane; spire projects as a cone.
Costa (pl. 5, figs. 4-6). Rib or projection parallel to growth lines.
Dextral (fig. 5). Coiled to the right or clockwise; with apex directed upward, aperture facing observer is to the right.
Growth line (fig. 5). Line or mark that conforms to shape of outer lip, and denotes its former position.
Lamella (internal) (pl. 6, fig. 4). Plate or ridgelike denticle within shell.
Length (fig. 5). Maximum distance, parallel to axis of coiling; for low-spired or planispiral shells, equivalent to "height" of various authors.
Lip, inner (fig. 5). Margin of aperture adjacent to axis of coiling; extends to suture of last whorl.
Lip, outer (fig. 5). Margin of aperture away from axis of coiling; extends to suture of last whorl.
Malleation (pl. 4, fig. 2). Flat area on shell surface having appearance of hammered metal.
Operculum (fig. 5). Disc or plate for closure of aperture; multispiral (of numerous whorls, fig. 5) or paucispiral (of few whorls).
Periostracum. Darker, thin, outer shell layer; may form periostracal lamellae within striae (pl. 4, fig. 18, 19).
Planispiral (pls. 5, 6). Coiled within a plane; shell discoidal.
Reflected (pl. 5, fig. 1, 3). Turned outward and backward; refers usually to the outer lip.
Sculpture. Relief or ornament on shell surface; includes carinae, costae, growth lines, malleations, ridges, or striae.
Sinistral (pl. 4, figs. 4-6, 9, 10). Coiled to the left or counterclockwise; with apex directed upward, aperture facing observer is to the left.
Spiral. (1) Curved line or surface extending from point of origin outward with continuously increasing radius of curvature (fig. 5). (2) Essentially parallel with suture, as for sculpture.
Spire (fig. 5). Whorls, of generally conispiral shells, except the last whorl.
Stria. Narrowly incised shallow groove on shell surface, parallel to sutures.
Suture (fig. 5). Line on shell surface where adjacent whorls join.
Umbilicus (fig. 5). Cavity or depression around axis of coiling.
Whorl (fig. 5). Complete (360°) revolution of shell; last-formed revolution is last whorl.
Width (fig. 5). Maximum distance normal to axis of coiling; for low-spired or planispiral shells, equivalent to "diameter" of various authors.

Class GASTROPODA

Subclass PROSOBRANCHIA

Order MESOGASTROPODA

Superfamily VALVATACEA

Family VALVATIDAE

Shell small to medium; moderately thin; dextral; conispiral or planispiral; whorls rounded; surface smooth or carinate; umbilicus wide; aperture circular; operculum corneous, multispiral. Animal nearly transparent; gills external; foot bilobed anteriorly.

TABLE 4.--Summary of shell measurements of North Dakota snails.

Species	Whorls	Length(L)[1] or Width(W)[1]	Width/Length	Number Measured	Largest Observed in State[1]
Valvata tricarinata	≥3.0	W 5.0(4.2- 6.0)	1.2 (1.0 -1.4)	30	6.0
Cincinnatia cincinnatiensis	≥4.0	L 4.6(4.1- 6.5)	0.77(0.72-0.81)	30	6.5
Probythinella lacustris	≥4.0	L 4.2(3.0- 4.9)	0.71(0.63-0.77)	30	4.9
Amnicola limosa	≥4.0	L 4.2(3.6- 4.6)	0.79(0.70-1.00)	30	4.6
Fossaria obrussa	≥5.0	L 10.8(8.4-12.3)	0.51(0.46-0.56)	3	12.3
Stagnicola caperata	≥6.0	L 12.7(11.9-14.1)	0.51(0.47-0.54)	8	14.1
S. elodes	≥6.0	L 24.4(21.8-30.1)	0.47(0.43-0.55)	30	36.4
Lymnaea stagnalis	≥6.0	L 35.4(25.7-45.0)	0.48(0.44-0.51)	30	50.5
Ferrissia rivularis	≥4.5 mm	L 5.5(4.8- 7.0)	0.60(0.42-0.67)	30	7.0
Gyraulus parvus	≥3.5	W 4.9(4.2- 6.0)	3.2 (2.5 -3.8)	30	6.0
G. circumstriatus	≥3.0	W 3.6(3.2- 4.8)	2.9 (2.4 -3.3)	30	4.8
Armiger crista	≥2.0	W 2.1(1.8- 2.4)	3.4 (2.8 -4.0)	13	2.4
Helisoma anceps	≥3.0	W 10.6(9.1-13.0)	1.8 (1.6 -1.9)	30	17.7
H. trivolvis	≥4.0	W 22.5(16.8-31.4)	2.2 (1.9 -2.7)	30	31.4
Promenetus exacuous	≥3.5	W 7.7(6.5- 9.7)	3.3 (2.96-4.2)	24	9.7
P. umbilicatellus	≥3.5	W 6.2(5.2- 7.5)	2.7 (2.4 -3.0)	7	7.5
Planorbula armigera	≥4.0	W 6.6(6.5- 6.8)	2.4 (2.3 -2.6)	3	6.8
P. campestris	≥4.0	W 6.0(5.1- 7.2)	2.6 (2.2 -2.7)	6	7.2
Aplexa hypnorum	≥6.0	L 19.2(14.5-24.4)	0.43(0.39-0.47)	30	24.4
Physa gyrina	≥5.0	L 17.0(14.7-23.3)	0.57(0.52-0.63)	30	23.3
P. integra	≥4.0	L 10.4(9.0-12.0)	0.63(0.58-0.70)	30	12.0
P. jennessi	≥4.0	L 8.3(7.4- 9.9)	0.54(0.50-0.61)	30	9.9

[1] In mm; first number given for length or width and width/length is the mean.

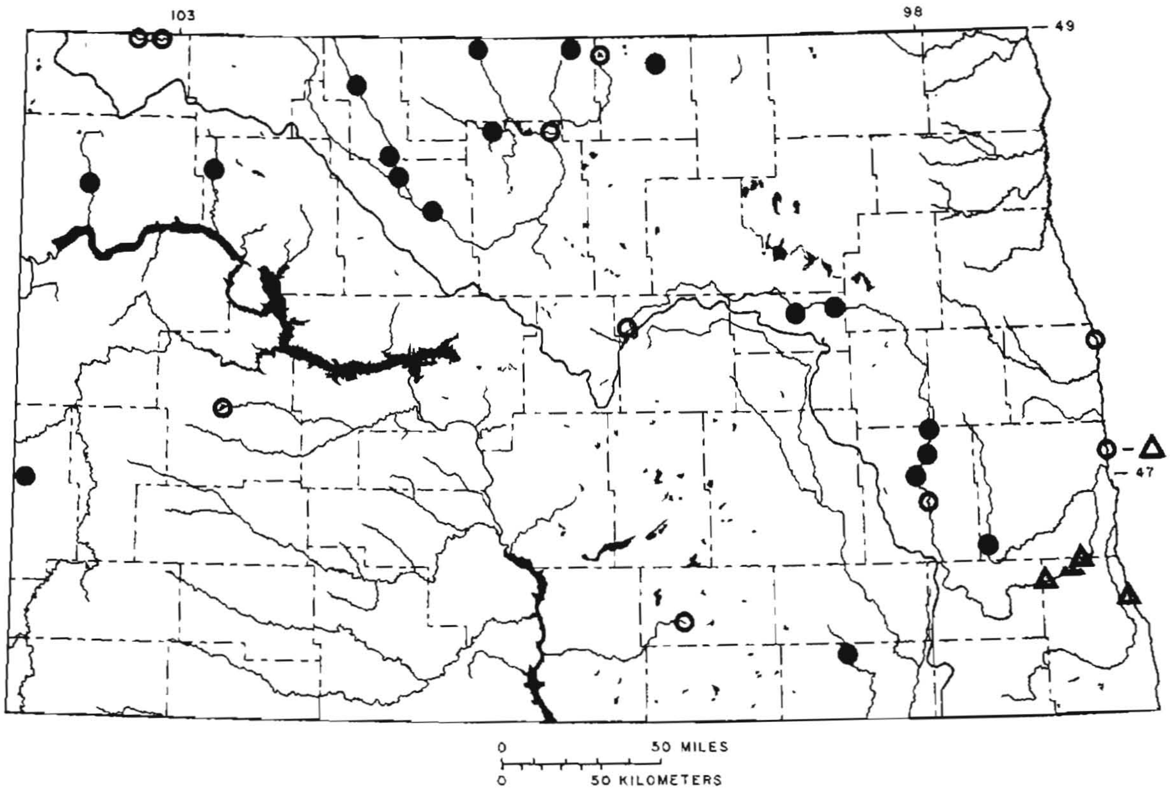

Figure 41. Distribution of Valvata tricarinata (Say) (circles) and Campeloma decisum (Say) (triangles) in North Dakota. The upper Red River locality for C. decisum is from Clarke (1973, p. 218). Filled circles = live occurrences, open circles and triangles = no live occurrences.

Genus Valvata Müller, 1774
Characters are for the family Valvatidae.

Valvata tricarinata (Say, 1817)
pl. 4, fig. 12

Diagnosis.--Shell up to about 6.5 mm wide, wider than long; whorls about four, abruptly enlarging; usually three spiral carinae but may be variably reduced or absent; umbilicus deep, funnel-shaped.

Range in North Dakota.--In much of the state (fig. 41).

Late Pleistocene to Holocene (at least about 12,000-10,000 years to present; Cvancara, 1976, p. 1690).

General range.--New Brunswick south to Virginia, west to Iowa and Nebraska, north to Hudson Bay, northwest to mouth of Mackenzie River, and west to Alberta (after Clarke, 1973, p. 237).

Early Pliocene to Holocene (Hibbard and Taylor, 1960, p. 79).

Biology and ecology.--Baker (1928b, p. 13-14) has described the anatomy and reproduction of V. tricarinata, and Heard (1963) has discussed reproduction. Hadžišče and others (1976, p. 3-5) described and illustrated the embryonic shell surface of V. tricarinata perconfusa.

V. tricarinata has been reported from large and small lakes, permanent ponds, subarctic muskeg pools, and small and large streams (Clarke, 1973, p. 237). In North Dakota, it was collected mostly from permanent lakes and ponds, but also from small and large streams, including intermittent streams (table 1). Channel widths (n=10) were 2-37 m (mean=16±13 S.D.). This species tolerated extreme high values of total alkalinity and pH (app. B). In New York, Harman (1972) found littoral silt and detritus to be the preferred substrate. V. tricarinata was most frequently associated with Pisidium nitidum and Helisoma anceps, and is part of the H. trivolvis-L. stagnalis Association (fig. 18).

Remarks.--Seven morphs of V. tricarinata--each with a distinct name--have been recognized on the presence of certain carinae (Baker, 1928a, p. 15-18). LaRocque (1956) suggested the morphs be designated by numerals relating to carina presence, not by names. Baker (1928a, p. 15) believed the morphs are not strictly ecologically controlled, and Clarke (1973, p. 239) observed little relationship of habitat with carina reduction. However, Harman and Berg (1971, p. 52) said dominant morphs vary with habitat, and, in certain lakes, they probably relate to eutrophy. All North Dakota individuals I have examined possess three distinct carinae. The dry shell color, however, varied considerably, from whitish-yellow to greenish-blue (especially around the umbilicus). Individuals with light-yellowish-brown to reddish-brown early whorls were also common.

A noncarinate species, V. sincera (includes V. lewisi of several authors), is known only as a fossil in the state, from sediments older than about 9,600 years (Cvancara, 1976, p. 1689). This species occurs essentially north and east of North Dakota today (Clarke, 1973, p. 223, 228, 232).

Superfamily RISSOACEA

Family HYDROBIIDAE

Shell small; thin to moderately thick; dextral; conispiral; smooth or sculptured; umbilicus present or absent; operculum corneous or calcareous, paucispiral. Animal transparent to gray; gills internal; foot usually auriculated anteriorly.

Genus Cincinnatia Pilsbry, 1891

Shell up to about 6 mm long; relatively thick; first whorl elevated above second whorl forming acute apex; whorls shouldered; smooth; umbilicus wide and deep; aperture broadly ovate; operculum corneous. Foot broad, not auriculated.

Cincinnatia cincinnatiensis (Anthony, 1840)
pl. 4, fig. 15

Synonym.--Amnicola integra (Say).

Diagnosis.--Shell broadly conical; whorls up to six; other shell characters as for genus. Animal yellowish-white.

Range in North Dakota.--Northern and eastern part of state, may be restricted to Hudson Bay drainage (fig. 42).

Holocene (within interval of about 4,000 years to present; Cvancara, 1976, p. 1690).

General range.--"New York and Pennsylvania west to southern Manitoba, southern Saskatchewan, North Dakota, Utah, and Texas" (Clarke, 1973, p. 242).

Pleistocene (Sangamonian) to Holocene (Baker, 1920, p. 385).

Biology and ecology.--Berry (1943, p. 33-35) has described the anatomy of C. cincinnatiensis, and said (p. 35) that the food of this species is mainly diatoms.

This species has been reported from large lakes and small and large streams (Clarke, 1973, p. 242). Baker (1928a, p. 123) said it is "largely a species of rivers." Of lacustrine occurrences, it is characteristic of mesotrophic lakes (Clarke, 1979a). In North Dakota, it was collected mostly from small streams, but also from large streams and permanent lakes and ponds (table 1). Channel widths (n=9) were 4-27 m (mean=17±7 S.D.). In New York, Harman (1972) found littoral silt and detritus to be the preferred substrate. C. cincinnatiensis was most frequently associated with Amnicola limosa, and is part of the H. trivolvis-L. stagnalis Association (fig. 18).

Remarks.--I concur with Baker (1928a, p. 63, 67) and Clarke (1973, p. 241) that Paludina integra Say, 1821 is a species of Campeloma and, therefore, not a species of Amnicola (as considered by many authors) or Cincinnatia. P. cincinnatiensis Anthony, 1840, then, is the original name available for the species at hand. Cincinnatia has also been considered as a subgenus of Amnicola (e.g., Berry, 1943, p. 32).

Genus Probythinella Thiele, 1928

Shell up to about 5 mm long; relatively thick; subcylindrical; first one or two whorls planispiral, sunken below following whorl forming truncated apex; smooth; umbilicus narrow; aperture ovate; operculum corneous. Foot narrow, auriculated.

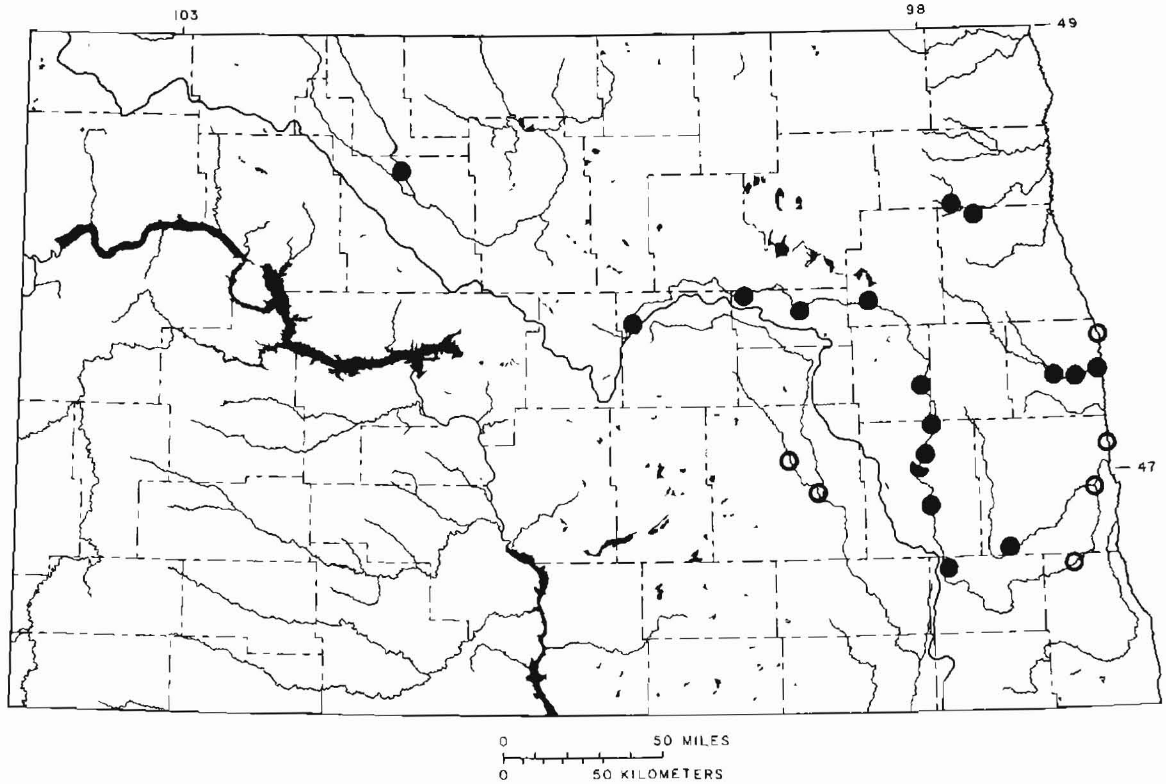

Figure 42. Distribution of Cincinnatia cincinnatiensis (Anthony) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Probythinella lacustris (Baker, 1928)
pl. 4, fig. 13

Diagnosis.--Shell spire slightly longer than last whorl; whorls about five. Animal white and waxy in appearance. Other characters as for genus.

Range in North Dakota.--Most of the state (fig. 43).

Late Pleistocene to Holocene (at least about 13,500 years to present; Cvancara, 1976, p. 1689).

General range.--Between Appalachian and Rocky Mountains, from New York, Alabama, and Arkansas to Great Slave Lake and Mackenzie River drainage (after Hibbard and Taylor, 1960, p. 80).

Late Pleistocene (Illinoian) to Holocene (Miller, 1966, p. 225).

Biology and ecology.--Berry (1943, p. 38-39) has discussed the anatomy of P. lacustris. It feeds primarily on diatoms, and whitefish are known to feed heavily on this species (Berry, 1943, p. 39).

P. lacustris has been reported from large lakes, permanent ponds, and small and large streams (Clarke, 1973, p. 252). Of lacustrine occurrences, it is characteristic of oligotrophic and mesotrophic lakes (Clarke, 1979a). In North Dakota, it was collected mostly from small, permanent streams, but also from a large, permanent stream as well as an intermittent stream (table 1). Channel widths (n=17) were 1-37 m (mean=15±10 S.D.). This species tolerated relatively high values of total alkalinity (app. B). P. lacustris was associated with several species found in small streams, and is part of the Anodonta grandis-Lasmigona complanata Association (fig. 18).

Remarks.--Berry (1943, p. 39-40), Morrison (1947), and Hibbard and Taylor (1960, p. 80, 83-84) have discussed the complex taxonomic history of this species. Names used for the species include Cincinnatia emarginata lacustris Baker (1928a, p. 127-130) and Amnicola (Probythinella) binneyana Hannibal (Berry, 1943, p. 36-41).

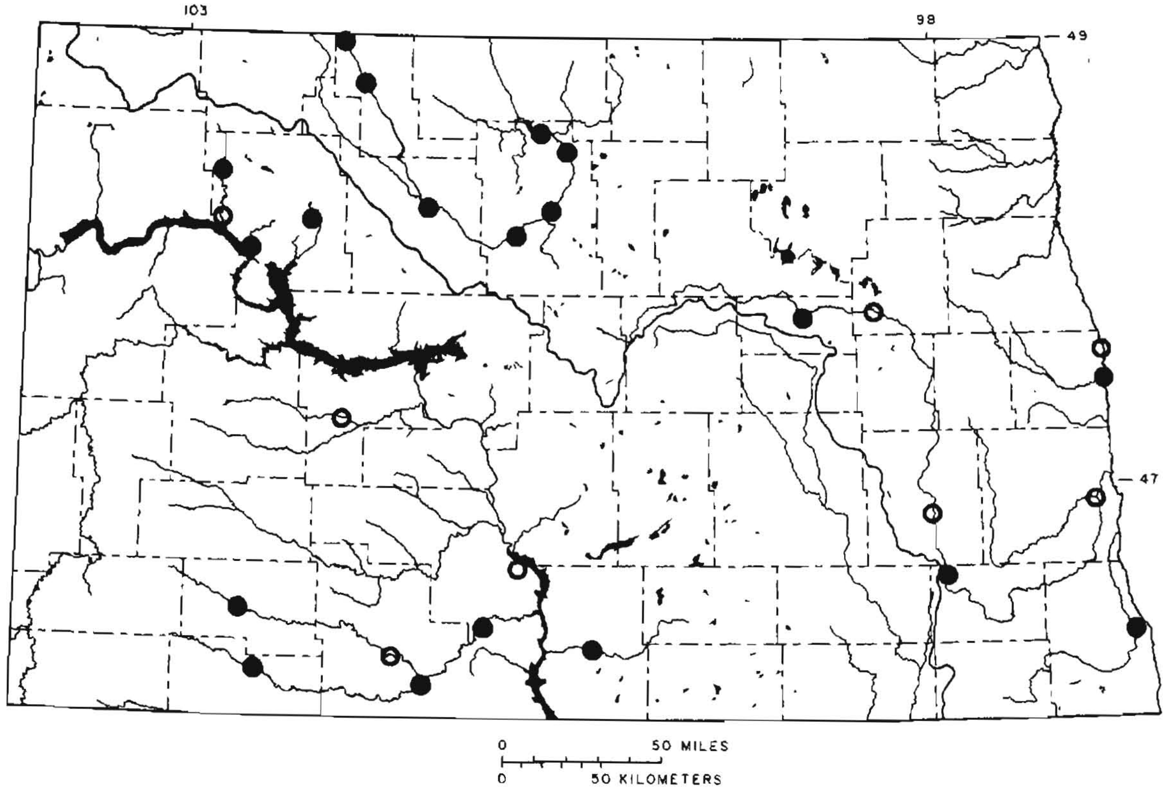

Figure 43. Distribution of Probythinella lacustris (Baker) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Genus Amnicola Gould and Haldeman, 1840

Shell up to about 5 mm long; relatively thin; first whorl planispiral, forming blunt apex, or elevated above second whorl; whorls rounded or slightly shouldered; smooth; umbilicus moderately wide and deep; aperture subovate to subcircular; operculum corneous. Foot longer than wide, auriculated.

Amnicola limosa (Say, 1817)
pl. 4, fig. 14

Diagnosis.--Shell up to about 5 mm long; broadly conical; first whorl planispiral, forming blunt apex; whorls rounded or slightly shouldered, about 4.5; aperture broadly subovate. Animal white or pink.

Range in North Dakota.--Essentially Sheyenne River (fig. 44); Clarke (1973, p. 258) reported it from the upper Red River and Tuthill and Laird (1963, p. 54) from Logan County.

Late Pleistocene to Holocene (at least 12,000-10,000 years to present; Cvancara, 1976, p. 1690).

General range.--Atlantic Coast from Florida to Labrador, west to Churchill River system (Saskatchewan and Manitoba) and Utah, and south to Texas (Baker, 1928a, p. 97; Berry, 1943, p. 23; Clarke, 1973, p. 259).

Pleistocene (Illinoian) to Holocene (Miller, 1970, p. 41).

Biology and ecology.--The anatomy and reproduction of A. limosa have been described by Baker (1928a, p. 94-97) and Berry (1943, p. 23-26). This species feeds on diatoms (Berry, 1943, p. 26).

A. limosa has been reported from large and small lakes, and small and large streams (Clarke, 1973, p. 259). Of lacustrine occurrences, it is particularly characteristic of eutrophic lakes (Clarke, 1979a). In North Dakota, it was collected from Lake Ashtabula (Sheyenne River reservoir) and the upper Sheyenne River (small stream) (table 1). Channel width was 12 m. In New York, Harman (1972) found

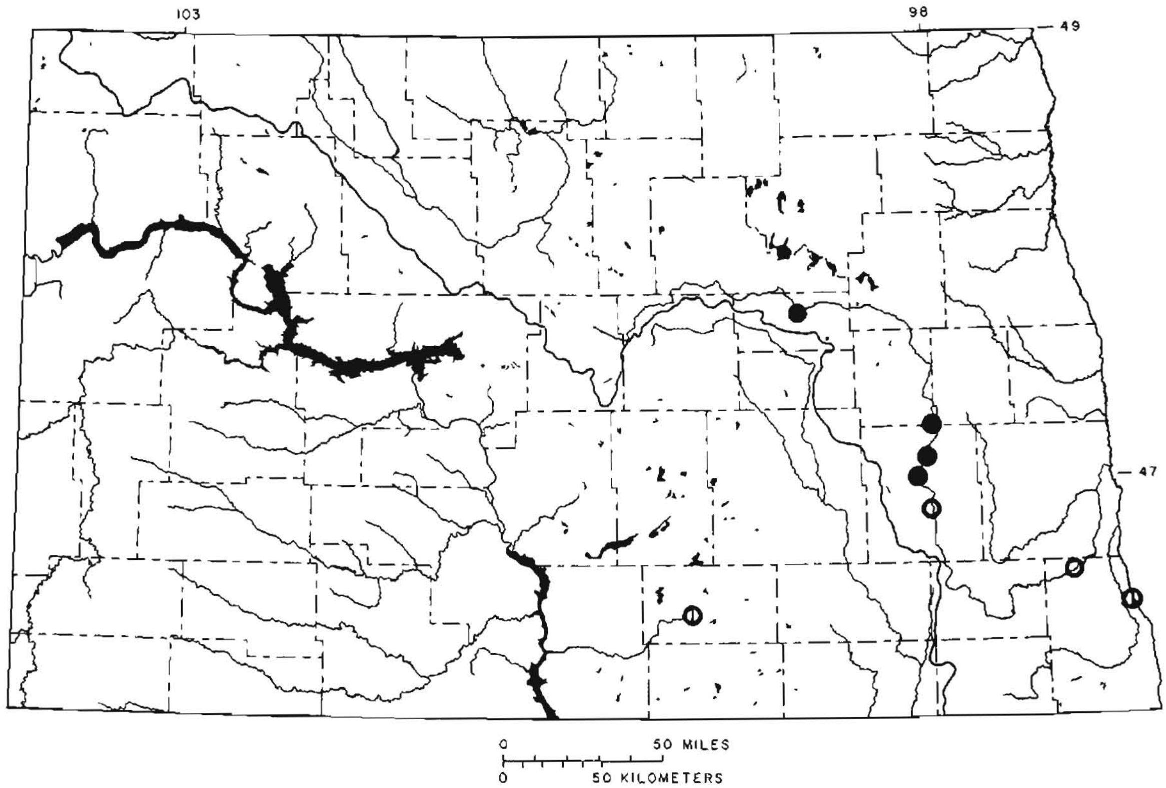

Figure 44. Distribution of Amnicola limosa (Say) in North Dakota. The split circle occurrence is from Tuthill and Laird (1963, p. 54). Filled circles = live occurrences, open circles = no live occurrences.

aquatic plants and their decaying remains to be the preferred substrate. A. limosa was most frequently associated with Cincinnatia cincinnatiensis and is part of the Helisoma trivolvis-Lymnaea stagnalis Association (fig. 18).

Remarks.--This species was apparently more prolific in North Dakota during late Wisconsinan time than it is now (Cvancara, 1976, p. 1691).

Subclass PULMONATA

Order BASOMMATOPHORA

Superfamily LYMNAEACEA

Family LYMNAEIDAE

Shell small to large; thin or moderately thick; dextral; conispiral; sculpture of growth lines and periostracal ridges, malleations, or microsculpture; umbilicus present or absent; operculum absent. Animal dark-gray to black; head with broad velum.

Genus Fossaria Westerlund, 1885

Shell up to about 19 mm long; spire as long or longer than aperture; distinct spiral sculpture absent; columella not twisted; umbilicus narrow.

Fossaria obrussa (Say, 1825)
pl. 4, fig. 1

Diagnosis.--Shell up to about 19 mm long; relatively thin; spire and aperture of about same length; whorls rounded, slightly shouldered near deeply indented sutures, about 5.5; umbilicus may be barely present; aperture elongate-subovate.

Range in North Dakota.--Most of the state (fig. 45); uncommon.

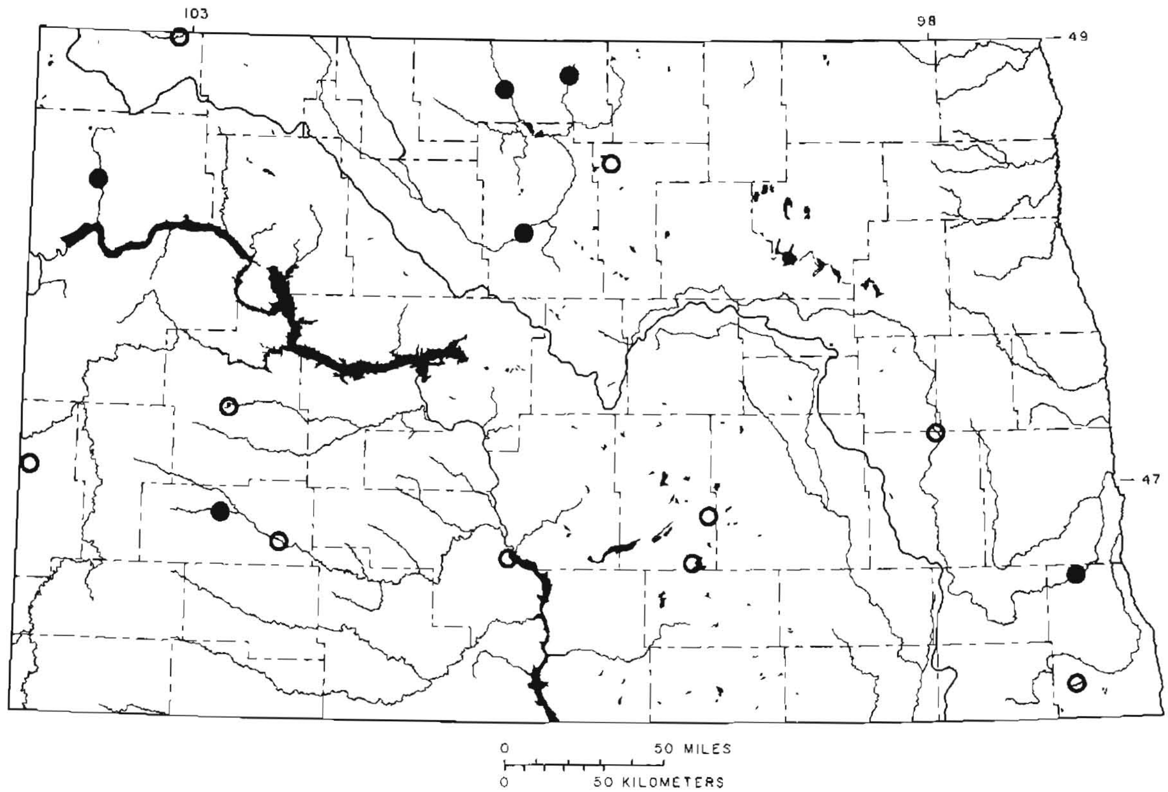

Figure 45. Distribution of Fossaria obrussa (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Holocene (within interval of about 8,000-4,000 years to present; Cvancara, 1976, p. 1691).

General range.--Across U.S., and from Mackenzie District, Canada south to Arizona and northern Mexico (Baker, 1928a, p. 296).

Late Pliocene to Holocene (Miller, 1966, p. 227).

Biology and ecology.--Baker (1928a, p. 294-296) has described the anatomy of F. obrussa.

This species has been reported from ponds and small streams (Baker, 1928a, p. 296). In North Dakota, it was collected alive from small and large permanent streams and an intermittent stream. Channel widths (n=5) were 4-33 m (mean=15±12 S.D.). F. obrussa was associated with several species found in small streams, and is part of the Anodonta grandis-Lasmigona complanata Association (fig. 18).

Remarks.--A similar species of Fossaria, F. decampi, is known only as a fossil in the state from sediments older than about 9,600 years (Cvancara, 1976, p. 1689). This species occurs north and east of North Dakota today (Clarke, 1973, p. 271). F. decampi is smaller (up to about 12 mm long), has more shouldered whorls, the aperture is narrower toward the apex, and the body whorl near the outer lip is more flattened.

Genus Stagnicola Jeffreys, 1830

Shell up to about 40 mm long; whorls increase gradually; distinct spiral sculpture present; columella usually twisted; umbilicus narrow or absent.

Stagnicola caperata (Say, 1829)
pl. 4, fig. 18, 19

Diagnosis.--Shell up to about 17 mm long; moderately thick; spire longer or about same length as aperture; whorls about 6; spiral sculpture of periostracal

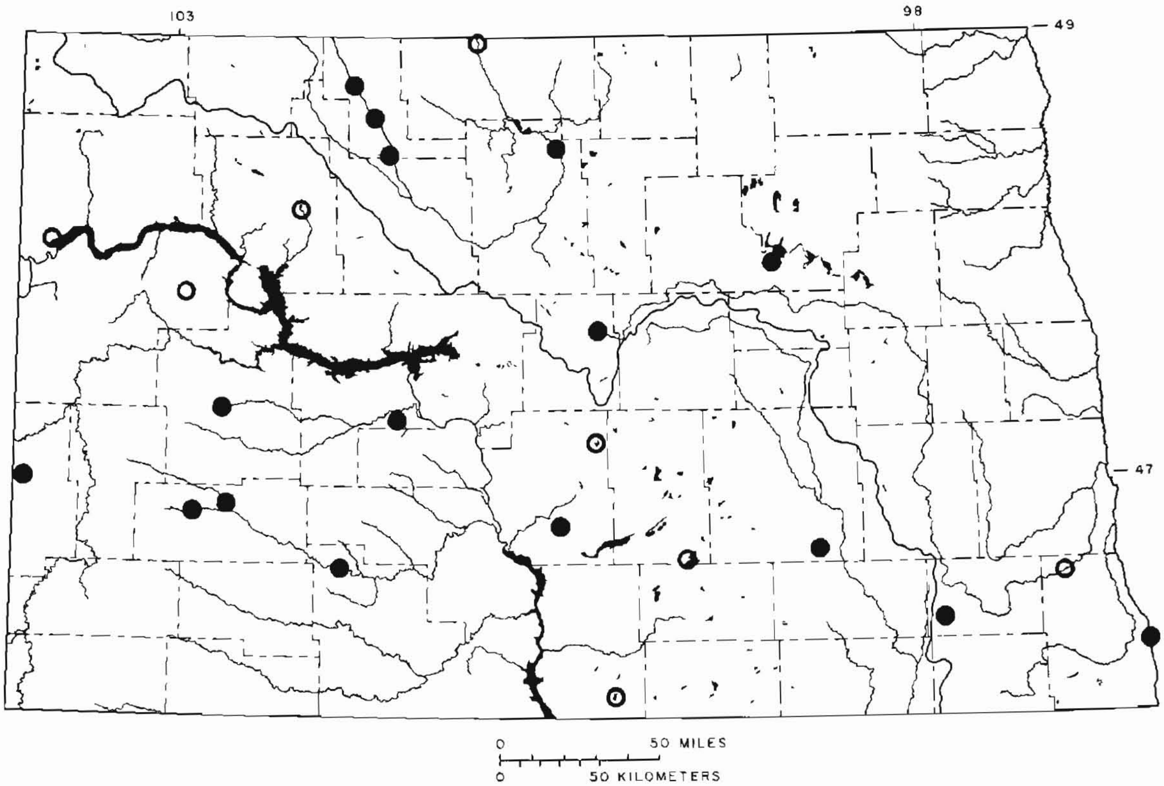

Figure 46. Distribution of Stagnicola caperata (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

ridges placed within striae; columella not twisted; umbilicus narrow; aperture subovate, commonly reddish or purplish within.

Range in North Dakota.--Most of the state (fig. 46).

Holocene (within interval of about 8,000-4,000 years to present; Cvancara, 1976, p. 1691).

General range.--Quebec and Massachusetts west to California, north to James Bay and Yukon Territory, and south to Maryland, Indiana, and Colorado (Baker, 1928a, p. 263). Clarke (1973, p. 315) believed that Baker's far northern and far eastern occurrences are probably incorrect.

Middle Pliocene to Holocene (Hibbard and Taylor, 1960, p. 92).

Biology and ecology.--The anatomy of S. caperata has been described by Baker (1928a, p. 261-263) and Taylor and others (1963, p. 253-254).

This species has been reported largely from seasonal water bodies (intermittent lakes, ponds, and streams), as well as from flooded or marginal parts of perennial water bodies that become dry for part of the year (Clarke, 1973, p. 315-316). This agrees closely for the occurrences in North Dakota. Although 10 permanent lake or pond localities are given (table 1) for the species, it occurred specifically along the margins of these water bodies that presumably become dry periodically. Channel widths (n=5) were 17-37 m (mean=28±8 S.D.). This species tolerated waters of high specific conductance (app. B). S. caperata was most frequently associated with Physa jennessi and Promenetus exacuous, and is part of the Aplexa hypnorum-Gyraulus circumstriatus Association (fig. 18).

Remarks.--Hubendick (1951, p. 127-128) placed all Fossaria-type lymnaeids in North America, and S. caperata, within Lymnaea humilis Say. Certain characters distinguishing species of Fossaria are subtle, but the periostracal ridges of S. caperata make this a most distinctive species.

Baker (1928a, p. 259-260) created the subgenus Hinkleyia for S. caperata, and Taylor and others (1963) placed two other species within it.

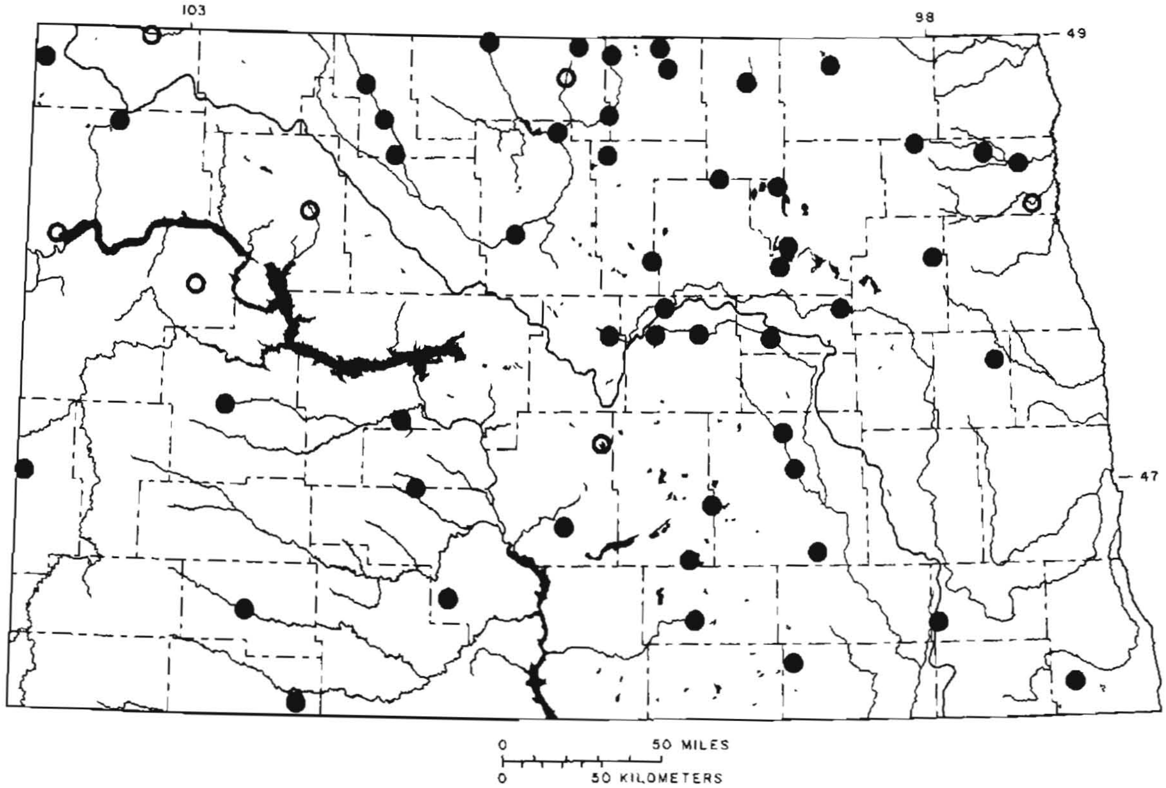

Figure 47. Distribution of Stagnicola elodes (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Stagnicola elodes (Say, 1821)
pl. 4, fig. 2, 3, 8

Diagnosis.--Shell up to about 37 mm long; relatively thin; spire about 0.5 to 0.6 length of shell; whorls about seven; spiral striae and low ridges result in growth lines separated into generally arcuate segments convex toward aperture; malleations common, especially on last whorl; columella twisted; umbilicus narrow or absent; aperture elongate-subovate, commonly with brownish-purple band within.

Range in North Dakota.--Throughout the state (fig. 47).

Late Pleistocene to Holocene (at least about 12,000-8,000 years to present; Cvancara, 1976, p. 1691).

General range.--Northern U.S. north of about 38°N (except near 33°N in California and New Mexico) and Canada from Ungava Bay to near Churchill, Manitoba, and to mouth of Mackenzie River and Yukon River system (Clarke, 1973, p. 353).

Early Pleistocene (Aftonian) to Holocene (Baker, 1920, p. 387).

Biology and ecology.--The anatomy of S. elodes has been described by Baker (1928a, p. 213-225). Growth and certain aspects of reproduction were studied by Hunter (1975), McGraw (1952, 1970). This species is omnivorous (Baker, 1911, p. 311; cited by Clarke, 1973, p. 354). S. elodes is an intermediate host of the flatworm trematode parasites Trichobilharzia ocellata and Schistosomatium douthitti that cause swimmer's itch (cercarial dermatitis) in man (Cort, 1950).

S. elodes has been reported from large and small lakes, permanent and intermittent ponds (including ditches), swamps, and large and small streams. Of lacustrine occurrences, this species is characteristic of mesotrophic and eutrophic lakes (Clarke, 1979a). In North Dakota, it was collected from all habitats except large streams (table 1). Channel widths (n=11) were 3-37 (mean=16±14 S.D.). This species tolerated high values of total chlorides and extreme high values of total sulfates (app.B). In New York, Harman (1972) found decaying, terrestrial plant matter to be the preferred substrate. S. elodes was most frequently associated with

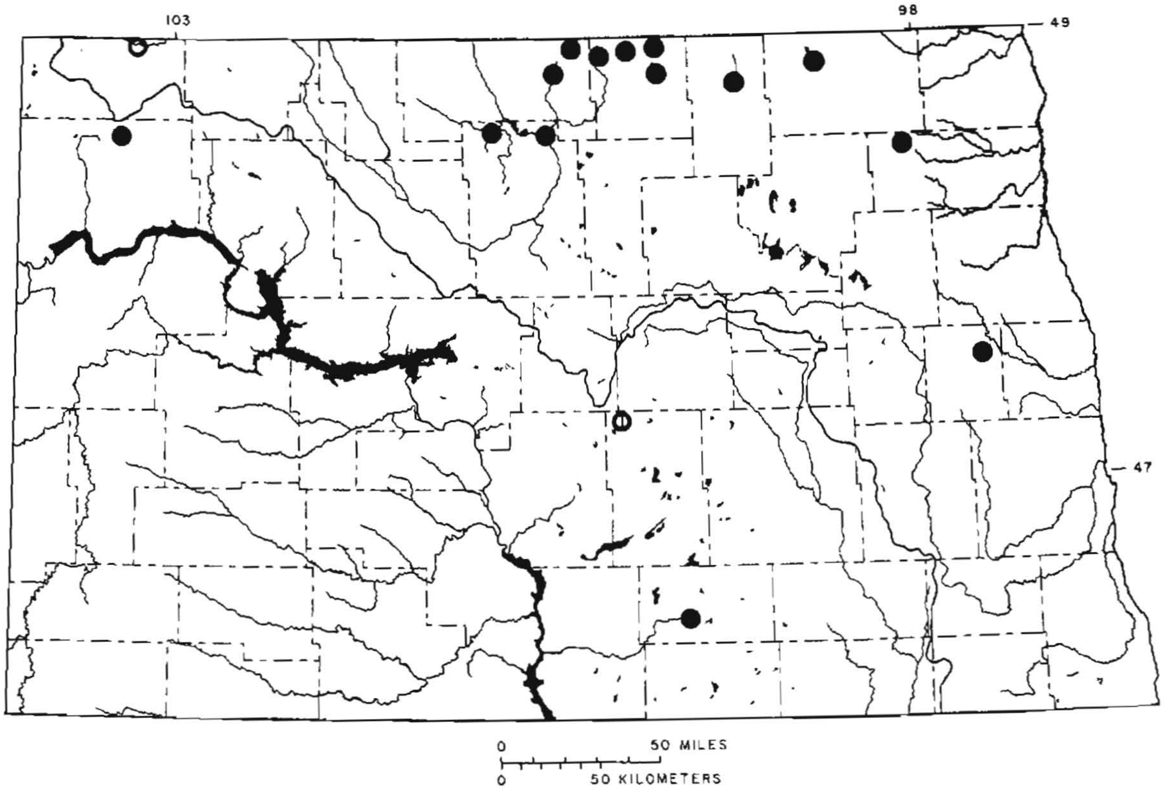

Figure 48. Distribution of Lymnaea stagnalis (Linnaeus) in North Dakota. The split circle occurrence is from Laird and Tuthill (1963, p. 54). Filled circles = live occurrences, open circles = no live occurrences.

Helisoma trivolvis, and is part of the H. trivolvis-Lymnaea stagnalis Association (fig. 18).

Remarks.--I am following Clark's (1973) practice of using "L. elodes" instead of L. palustris (Müller) in North America. He pointed out (p. 355) that the European L. palustris is specifically different.

Genus Lymnaea Lamarck, 1799

Shell up to about 57 mm long; relatively thin; spire narrow, last whorl expanded; distinct spiral sculpture present; columella twisted, umbilicus usually absent.

Lymnaea stagnalis (Linnaeus, 1758)
pl. 4, fig. 11, 16, 17

Diagnosis.--Spire whorls relatively flat-sided, last whorl convex; spire about half as long as aperture; whorls six to seven; spiral striae result in growth lines separated into generally arcuate segments convex toward aperture; malleations may also be present; aperture subovate; other characters as for genus.

Range in North Dakota.--About northeastern two-thirds of state (fig. 48). Holocene (within interval of 10,000-8,000 years to present; Cvancara, 1976, p. 1691).

General range.--Circumboreal; most of Europe, Noth Africa, and much of Asia except south-central and southeastern part and northern Siberia (Hubendick, 1951, p. 121). In North America, from about the 37th (Colorado) and 41st (Illinois) parallels north (Baker, 1928a, p. 203) to west side of Hudson Bay and northwest to Mackenzie and Yukon River drainages (Clarke, 1973, p. 299). Middle Pleistocene (Kansan?) to Holocene (Hibbard and Taylor, 1960, p. 85).

Biology and ecology.--McDonald (1969) has summarized biological and ecological data for L. stagnalis from the vast literature for this species. It is an omnivorous species (Clarke, 1973, p. 300). Scalariformy (uncoiling, or tendency of whorls to become disjunct) is known to occur (Pip, 1975).

L. stagnalis is a significant intermediate host of the flatworm trematode parasites Trichobilharzia ocellata and Schistosomatium douthitti that cause swimmer's itch (cercarial dermatitis) in man (Cort, 1950).

L. stagnalis has been reported from small and large lakes, permanent ponds, swamps, and small and large streams; water bodies are characteristically stagnant or slow-moving with substantial vegetation (Clarke, 1973, p. 299). Of lacustrine occurrences, this species is characteristic of eutrophic lakes (Clarke, 1979a). In North Dakota, it was collected mostly from permanent lakes and ponds, but also from intermittent ponds and streams (table 1). Channel widths (n=4) were 2-7 m (mean=4±2 S.D.). This species tolerated extreme high values of pH (app. B). In New York, Harman (1972) found L. stagnalis partial to two substrates: littoral silt and detritus and decaying aquatic vegetation at the water's surface. This species was most frequently associated with Physa gyrina, Gyraulus parvus, Helisoma trivolvis, and Stagnicola elodes, and is part of the H. trivolvis-L. stagnalis Association (fig. 18).

Remarks.--At least nine "subspecies" or "varieties" of L. stagnalis have been recognized for North America (Clarke, 1973, p. 301-305; McDonald, 1969, p. 12-13). It is generally accepted that L. s. jugularis (Say) and L. s. appressa (Say) are the same form. Clarke (1973, p. 300) has shown that L. s. appressa should be the name used. North Dakota individuals could be assigned to this subspecies.

Superfamily ANCYLACEA

Family ANCYLIDAE

Shell up to about 10 mm long; cap-shaped or patelliform; sculpture radial and concentric; aperture subovate to subelliptical, operculum absent.

Genus Ferrissia Walker, 1903

Shell up to about 10 mm long; microscopic radial striae on apex; horizontal, shelf-like septum may be present. Penis with club-shaped flagellum.

Ferrissia rivularis (Say, 1817)
pl. 6, fig. 11

Synonym.--Ferrissia tarda (Say).

Diagnosis.--Shell up to about 7 mm long; elevated; apex in midline or slightly to right, about one-third of distance from posterior end; aperture subovate to subelliptical; calcareous deposit commonly thick on inside of shell.

Range in North Dakota.--Most of the state (fig. 49).

Holocene (possibly within interval of about 10,000-8,000 years to present; Cvancara, 1976, p. 1691).

General range.--East Coast to Oregon, Arkansas to Hudson Bay Lowlands, and northwest to at least central Saskatchewan (Basch, 1963, p. 429-430; Clarke, 1973, p. 480).

Pliocene to Holocene (Taylor, 1960, p. 61).

Biology and ecology.--The anatomy of F. rivularis has been described by Hoff (1940) and Hubendick (1963, p. 24-28). The apical shell sculpture has been illustrated by Burch (1974, fig. 7). Individuals of this species apparently live from spring or summer to autumn of the following year (Basch, 1963, p. 432). F. rivularis is essentially a stream species (Basch, 1963, p. 430; Clarke, 1973, p. 480). In North Dakota, I collected it from mostly small and intermittent streams, as well as from large streams and lakes on streams (table 1). Channel widths (n=55) were 2-53 m (mean=12±10 S.D.). This species prefers a firm substrate of gravel (Basch, 1963, p. 430; Harman, 1972). In North Dakota, where gravel was absent, mussel shells--of living or dead individuals--commonly served as the species' substrate.

Remarks.--I expected but did not recognize F. parallela (Haldeman) in any of the Ferrissias collected from North Dakota. LaRocque (1968, p. 523) indicated it occurs in the state. This species is larger, has a narrow aperture with subparallel sides, and the apex is slightly posterior of midlength of the shell. It is characteristic of lakes (Basch, 1963, p. 440). F. parallela has been reported as a fossil in

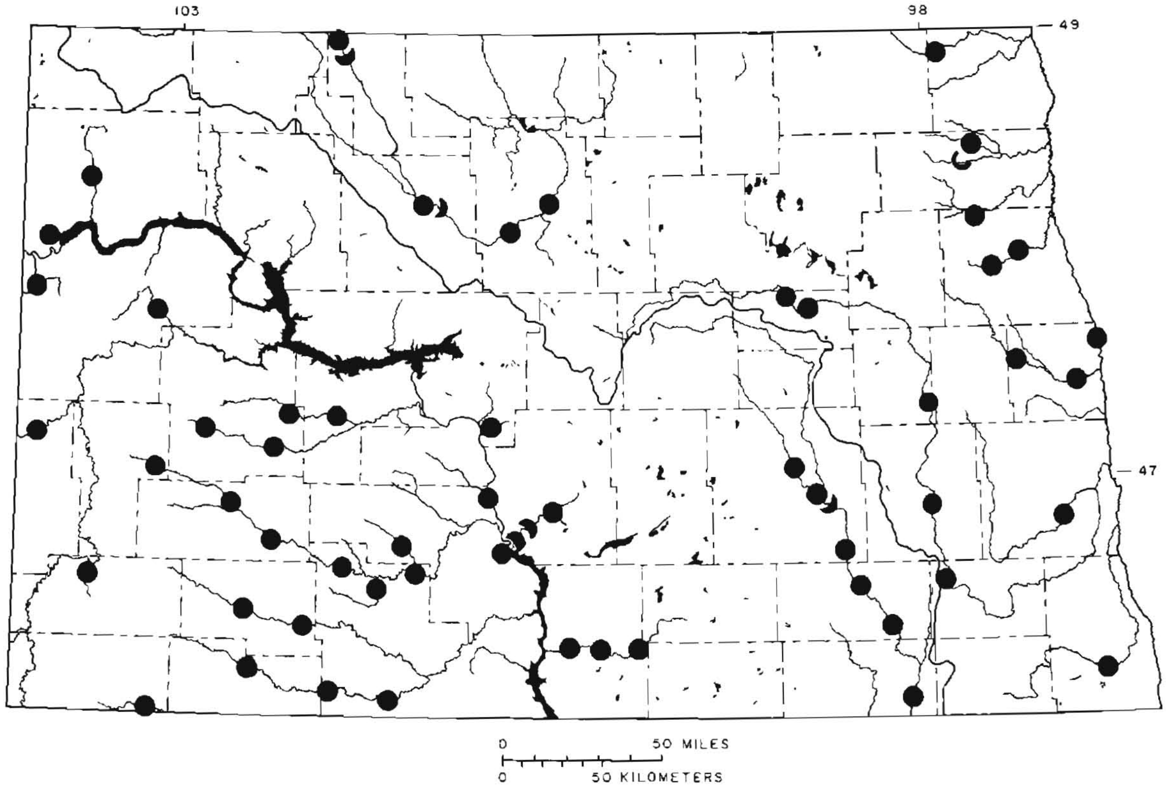

Figure 49. Distribution of Ferrissia rivularis (Say) in North Dakota. Filled circles = live occurrences, open circle = no live occurrence.

North Dakota from sediments inferred to be as old as 8,000-4,000 years (McAndrews and others, 1967, p. 106-107).

Family PLANORBIDAE

Shell small to large; planispiral (most) or low conispiral (few); umbilicus present; aperture with lip thickened and reflected in certain species with internal lamellae in few species; operculum absent. Animal gray to black, sinistral, head with large velar area.

Genus Gyraulus Charpentier, 1837

Shell small; dextral; planispiral or nearly so; few somewhat flattened whorls, fully visible on right and left sides; last whorl usually deflected; umbilicus relatively shallow; sculpture may include carinae and hirsute periostracum.

Gyraulus parvus (Say, 1817)
pl. 5, figs. 14-16

Diagnosis.--Shell up to about 6 mm wide; whorls abruptly enlarging, oval in cross section, about 3.5, last whorl deflected toward left side; early whorls planar on right side, concave on left; usually without distinct spiral sculpture; aperture elongate-subovate.

Range in North Dakota.--Throughout the state (fig. 50).

Late Pleistocene to Holocene (at least 12,000-10,000 years to present; Cvancara, 1976, p. 1691).

General range.--North America, Atlantic to Pacific Coast and Alaska, and northern Canada to Cuba; may also occur in northern Eurasia (Taylor, 1960, p. 58); northern limit corresponds fairly well with northern limit of boreal forest (Clarke, 1973, p. 403).

Late Pliocene to Holocene (Miller, 1966, p. 232).

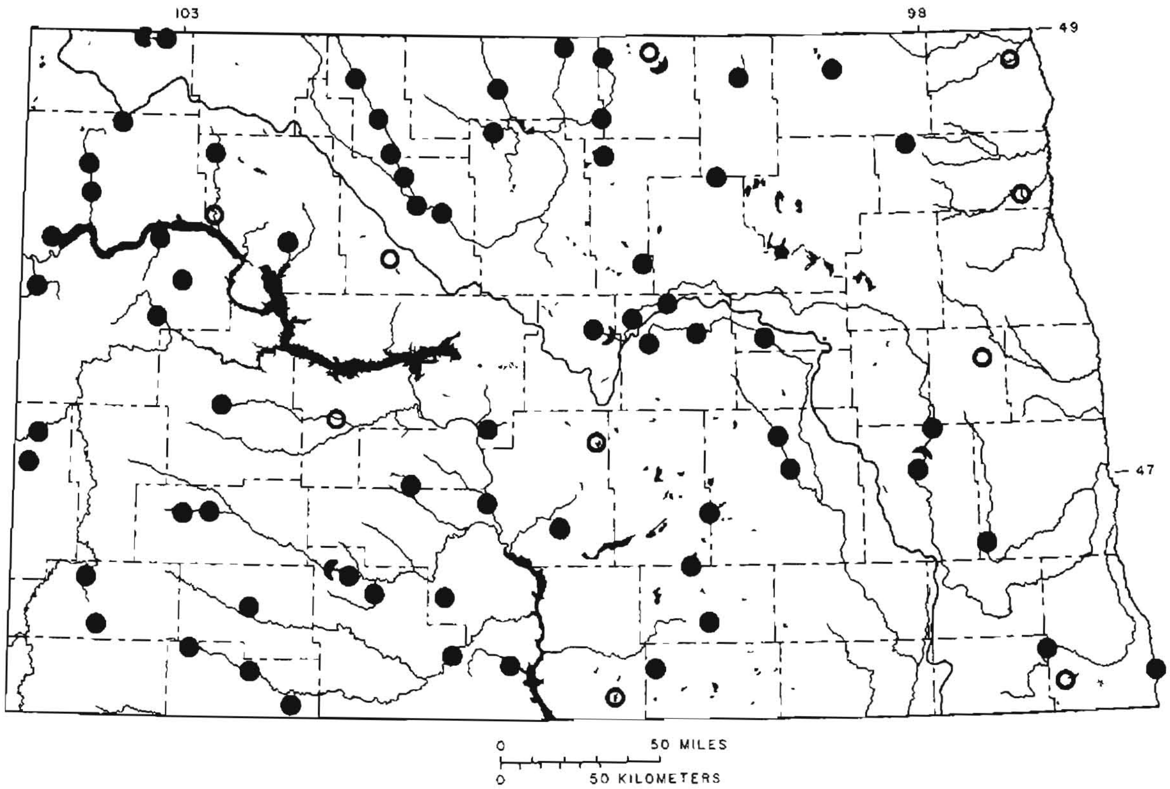

Figure 50. Distribution of Gyraulus parvus (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Biology and ecology.--The anatomy of G. parvus has been described by Baker (1928a, p. 376; 1945, p. 72-74).

Zebroid individuals--striped parallel to growth lines--have been observed in North Dakota, as in the Bois de Sioux River (130-47-15AA; A116) and Lake Ashtabula (142-58-32CD; A393). Certain caddis fly (Trichoptera) larvae use the shells of this species in the state partly in the construction of their cases. G. parvus is an intermediate host of the flatworm trematode parasite Gigantobilharzia gyrauli that causes swimmer's itch (cercarial dermatitis) in man (Cort, 1950).

G. parvus has been reported from large and small lakes, permanent and intermittent ponds (including ditches), swamps, and large and small streams, usually on aquatic vegetation (Clarke, 1973, p. 403). Of lacustrine occurrences, this species is characteristic of eutrophic lakes (Clarke, 1979a). In North Dakota, it was collected mostly from permanent lakes and ponds, but also from all other habitats except large, permanent, streams (table 1). Channel widths (n=35) were 2-37 m (mean=8±9 S.D.). This species tolerated extreme high values of total alkalinity (app. B). In New York, Harman (1972) found aquatic plants and their decaying remains to be the preferred substrate. G. parvus was most frequently associated with Physa gyrina, and is part of the Helisoma trivolvis-Lymnaea stagnalis Association (fig. 18).

Gyraulus circumstriatus (Tryon, 1866)
pl. 5, figs. 11-13

Diagnosis.--Shell up to about 6 mm wide; whorls gradually enlarging, subcircular in cross section, about 4.5, last whorl usually not deflected toward left side; early whorls nearly planar on both sides; spiral striae or ridges usually distinct, especially on left side; aperture circular-subovate.

Range in North Dakota.--About northeastern two-thirds of the state (fig. 51). Holocene (known with certainty only from the present; Cvancara, 1976, p. 1691).

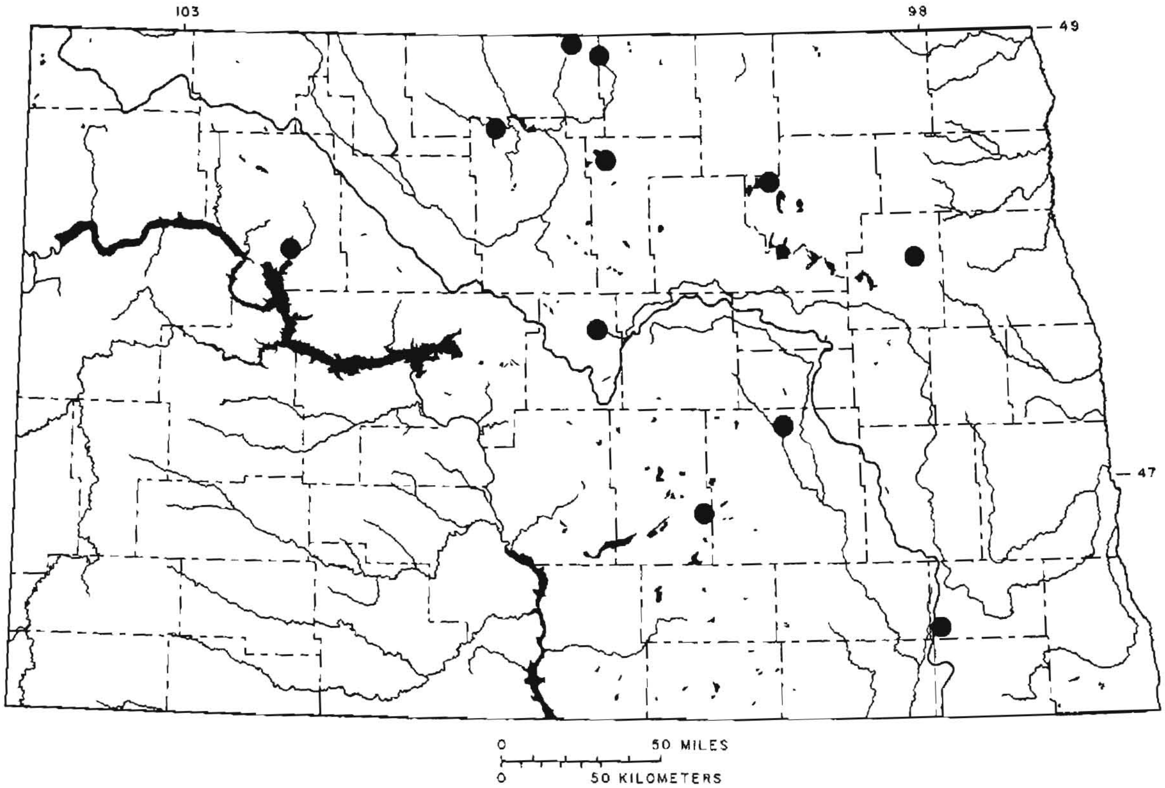

Figure 51. Distribution of Gyraulus circumstriatus (Tryon) in North Dakota.

General distribution.--Northern U.S. from Atlantic to Pacific coasts, south to Rocky Mountains to northern Arizona, and north in southern Canada to Quebec and northern Alberta (Hibbard and Taylor, 1960, p. 97-98; Clarke, 1973, p. 398).

Biology and ecology.--Baker (1945, p. 73-74) has discussed the anatomy of G. circumstriatus.

Certain caddis fly (Trichoptera) larvae use the shells of this species in the state partly in the construction of their cases. G. circumstriatus is characteristic of "small seasonal water bodies, such as woods pools, marshes, ponds on floodplains, or prairie ponds" (Taylor, 1960, p. 57), but has been also reported from swamps and small streams, and on vegetation (Clarke, 1973, p. 398-399). In North Dakota, it was collected from permanent and intermittent ponds and lakes and intermittent streams (table 1). Channel widths (n=2) were 2 and 3 m. This species tolerated extreme high values of pH (app. B). G. circumstriatus was most frequently associated with Aplexa hypnorum, and is part of the A. hypnorum-G. circumstriatus Association (fig. 18).

Remarks.--Hibbard and Taylor (1960, p. 99) said that G. circumstriatus is the only Gyraulus in North America that forms an apertural thickening or callus, but not frequently enough for consistent identification. Clarke (1973, p. 400), however, has reported thickened apertures also in G. deflectus and G. parvus. Therefore, apertural thickening seems to be of no taxonomic value.

Genus Armiger Hartmann, 1840

Shell very small; form generally similar to Gyraulus; few abruptly enlarging whorls; usually with many costae parallel to growth lines, prominent at periphery.

Armiger crista (Linnaeus, 1758)

pl. 5, figs. 4-7

Diagnosis.--Shell up to about 3 mm wide; thin; whorls flattened on right side,

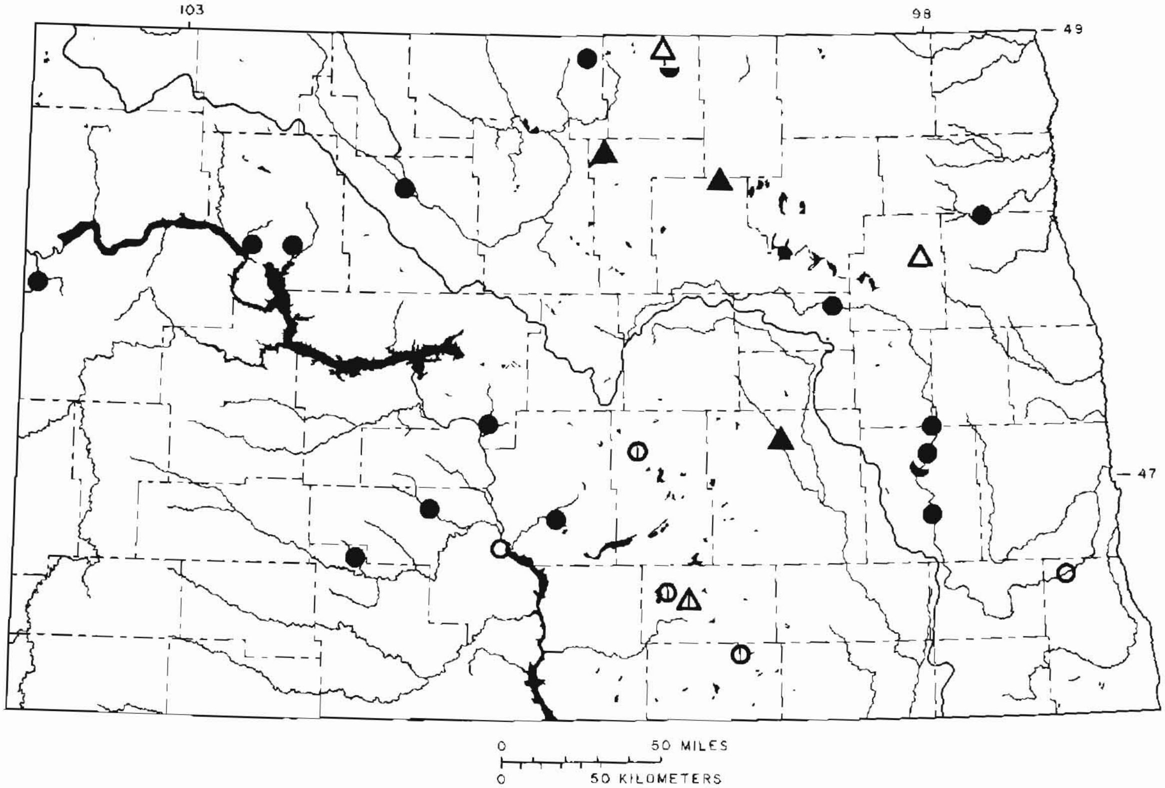

Figure 52. Distribution of Armiger crista (Linnaeus) (triangles) and Helisoma (Helisoma) anceps (Menke) (circles) in North Dakota. Split triangle and circle occurrences are from Laird and Tuthill (1963, p. 54). Filled triangles and circles = live occurrences, open triangles and circles = no live occurrences.

rounded on left side, about 2.5; costae project on periphery as periostracal lamellae; aperture subovate.

Range in North Dakota.--Presumably eastern part of the state (fig. 52).

Late Pleistocene to Holocene (at least 12,000-10,000 years to present; Cvancara, 1976, p. 1691).

General range.--Holarctic; in North America, north of about 41° and northwest to Alaska, but farther south on Pacific Coast to central California and to central Utah (Hibbard and Taylor, 1960, p. 101-102).

Late Pliocene to Holocene (Hibbard and Taylor, 1960, p. 101).

Biology and ecology.--The anatomy has been described by Baker (1945, p. 76-77).

A. crista has been reported primarily from ponds and small lakes (Mozley, 1938, p. 109), both permanent and temporary (LaRocque, 1968, p. 496-497; Kenk, 1949, p. 53), and also from small streams (Walker, 1897). It is characteristic of eutrophic lentic water bodies (Clarke, 1979a). In North Dakota, it was collected alive only from two intermittent ponds and an intermittent lake (table 1), associated with abundant aquatic vegetation. A. crista was most frequently associated with Promenetus umbilicatellus and is part of the Aplexa hypnorum-Gyraulus circumstriatus Association (fig. 18).

Remarks.--Although costae are characteristic of A. crista (and the genus Armiger), they may be inconspicuous or even absent. Where this occurs, the flattened whorls of the right side, small size, the few abruptly enlarging whorls, and subovate aperture serve to identify the species.

Genus Helisoma Swainson, 1840

Shell medium to large; planispiral or nearly so; width/length ratio relatively low (and much lower in young than in adults); spire depressed or elevated; spiral carinae present or absent.

Subgenus Helisoma s. s.

Shell medium; dextral; spire depressed; carinate usually on both sides; aperture expanded and outer lip thickened.

Helisoma (Helisoma) anceps (Menke, 1830)
pl. 5, figs. 8-10

Synonym.--H. antrosa (Conrad).

Diagnosis.--Shell up to about 19 mm wide; whorls about four; carina on right side near middle or on shoulder of whorl, carina on left side bordering umbilicus that is deep and relatively wide; aperture ear-shaped.

Range in North Dakota.--Sporadic, most of the state (fig. 52).

Late Pleistocene to Holocene (at least 12,000-10,000 years to present; Cvancara, 1976, p. 1691).

General range.--Maine to Oregon and Washington; south to Georgia, Texas, northern Mexico and New Mexico; and north to southern Hudson Bay and Great Slave Lake (Clarke, 1973, p. 431; Taylor, 1966, p. 209; Walker, 1909, p. 24-26, pl. 3); introduced into Italy (Henrard, 1968).

Late Pliocene to Holocene (Hibbard and Taylor, 1960, p. 103).

Biology and ecology.--Baker (1945, p. 124-128) has described the anatomy of H. anceps. Boerger (1975), who described reproduction in this species with a two-year life span, concluded the following: minimum mean size for egg laying = 8 mm; mean length of spawning season = 18 weeks; mean number of eggs per capsule = 14; date by which 50 percent of the eggs were laid (southern Ontario) = July 2; and number of breeding periods during the left cycle = 2.

H. anceps has been reported from large and small lakes, permanent ponds, and large and small streams (Clarke, 1973, p. 431, 444). Of lacustrine occurrences, this species is found in mesotrophic and eutrophic lakes (Clarke, 1979a). In North Dakota, it was collected mostly from permanent ponds and lakes and intermittent and small, permanent streams (table 1). Channel widths (n=10) were 1-34 m (mean= 10±12 S.D.). This species tolerated high values of total alkalinity (app. B). In New York, Harman (1972) found littoral silt and detritus to be the preferred substrate. In Douglas Lake, Michigan, Clampitt (1973) found (for "Helisoma antrosa percarinata (Walker)") sand to be the preferred substrate. H. anceps was most frequently associated with Valvata tricarinata and Pisidium nitidum, and is part of the Helisoma trivolvis-Lymnaea stagnalis Association (fig. 18).

Remarks.--From 12 so-called subspecies of H. anceps recorded for Canada, Clarke (1973, p. 433) recognized two as valid: H. a. anceps (Menke) and H. a. royalense (Walker). North Dakota individuals could be placed in H. a. anceps. H. a. royalense differs from H. a. anceps in having the carina of the right side at the shoulder of the whorl (as opposed to near the middle), a less depressed spire, flatter sides, and coarser sculpture parallel to growth increments (Clarke, 1973, p. 433).

Subgenus Pierosoma Dall, 1905

Shell medium to large; sinistral; spire depressed or at same level as last whorl; carinate usually on left side, may be carinate on right side; aperture usually expanded and with thickened outer lip.

Helisoma (Pierosoma) trivolvis (Say, 1817)
pl. 5, figs. 1-3

Diagnosis.--Shell up to about 32 mm wide; spire depressed; whorls about five, subcarinate to rounded on left side (but early whorls carinate), rounded on right side; umbilicus deep and narrow; aperture ear-shaped, outer lip reflected.

Range in North Dakota.--Essentially throughout the state (fig. 53).

Late Pleistocene to Holocene (at least 12,000-8,000 years to present; Cvancara, 1976, p. 1691).

General range.--Atlantic Coast and Mississippi River drainages, west to California, south to Tennessee and Missouri, and northwest to Yukon Territory (Baker, 1928a, p. 332; Clarke, 1973, p. 455, 458).

Early Pleistocene (Nebraskan or Aftonian) to Holocene (Hibbard and Taylor, 1960, p. 104).

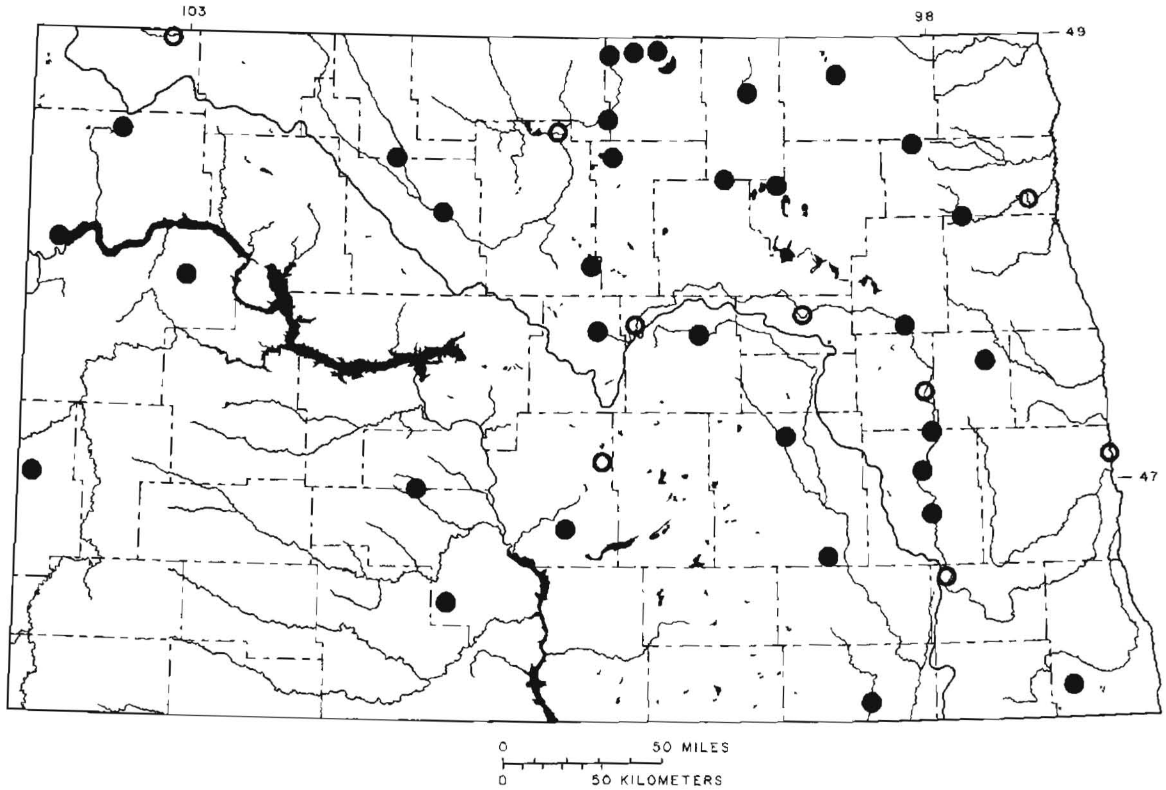

Figure 53. Distribution of Helisoma (Pierosoma) trivolvis (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Biology and ecology.--The anatomy of H. trivolvis has been described by Baker (1945, p. 135-147). Boerger (1975), who described reproduction in this species with a two-year life span, concluded the following: minimum mean size for egg laying = 18 mm; mean length of spawning season = 18 weeks; mean number of eggs per capsule = 24; date by which 50 percent of the eggs were laid (southern Ontario) = May 15; and number of breeding periods during the life cycle = 1.

H. trivolvis has been reported from large and small lakes, permanent ponds, swamps, and large and small streams. It is characteristic of permanent-water habitats (Clarke, 1973, p. 455, 458). Of lacustrine occurrences, this species is characteristic of eutrophic lakes (Clarke, 1979a). In North Dakota, it was collected mostly from permanent ponds and lakes (table 1). Channel widths (n=10) were 4-21 m (mean=10±6 S.D.). In New York, Harman (1972) found eulittoral silt and detritus to be the preferred substrate. H. trivolvis was most frequently associated with Stagnicola elodes, and is part of the H. trivolvis-Lymnaea stagnalis Association (fig. 18).

Remarks.--Clarke (1973, p. 452-459) has recognized two subspecies of H. (P.) trivolvis in southern Canada: H. (P.) t. trivolvis and H. (P.) t. subcrenatum. H. (P.) t. subcrenatum, to which most of the North Dakota populations could be placed, is shorter (generally less than 10 mm) and has more loosely coiled whorls and deeper sutures (Clarke, 1973, p. 457) than H. (P.) t. trivolvis.

Clarke (1973, p. 459-463) has also recognized another Helisoma, H. (P.) pilsbryi infracarinatum Baker, from one locality in the state: "Cut Bank River, 7 mi E of Mohall, N.D." (p. 461). This species somewhat resembles a large, sinistral Helisoma anceps. I have not recognized H. (P.) pilsbryi infracarinatum in any of my collected material.

Helisoma (Planorbella) campanulatum (Say) is known in the state only as a fossil, from sediments older than about 9,600 years. Today, it occurs essentially north and east of the state (Cvancara, 1976, p. 1689).

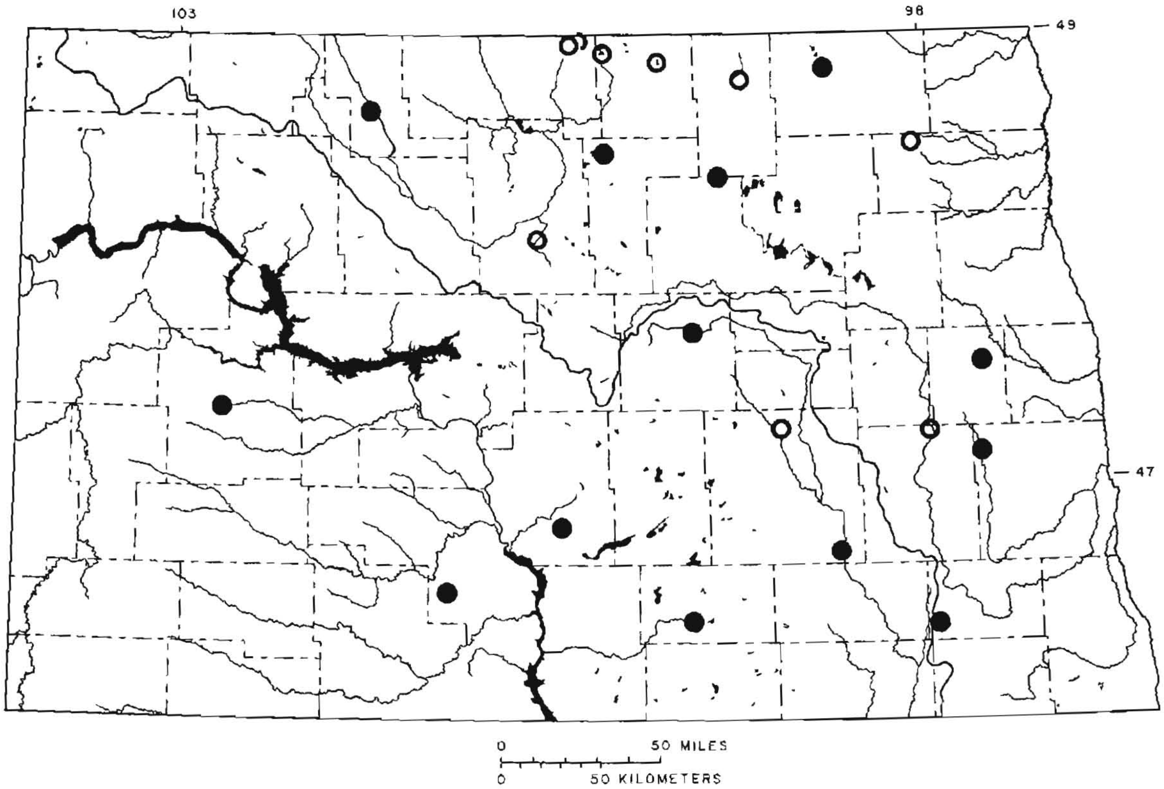

Figure 54. Distribution of Promenetus exacuous (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Genus Promenetus Baker, 1935

Shell small; dextral; planispiral or nearly so; spire flattened; whorls carinate or rounded; umbilical area deep but showing all whorls; aperture wider than long.

Promenetus exacuous (Say, 1821)
pl. 6, figs. 12-14

Diagnosis.--Shell up to about 10 mm wide; whorls abruptly enlarging, carinate at periphery, about four; umbilicus relatively narrow; fine spiral striae or ridges; aperture subtriangular to subovate.

Range in North Dakota.--Through much of the state (fig. 54).

Late Pleistocene to Holocene (at least 12,000-10,000 years to present; Cvancara, 1976, p. 1691).

General range.--North America north of about 39°--north to Alaska and the Mackenzie River--south to Colorado Plateau and Rocky Mountains to New Mexico and along Atlantic Coastal Plain to North Carolina; isolated occurrence in Meade County, Kansas (Baker, 1928a, p. 363; Hibbard and Taylor, 1960, p. 107).

Late Pliocene to Holocene (Miller, 1966, p. 233, 235).

Biology and ecology.--Baker (1945, p. 178-181) has described the anatomy of P. exacuous.

This species has been reported from permanent large and small lakes and ponds, swamps, large and small streams, as well as temporary ponds and marshes (Clarke, 1973, p. 412, 414; Mozley, 1938, p. 108). Of lacustrine occurrences, it is characteristic of eutrophic lakes (Clarke, 1979a). In North Dakota, this species was collected mostly from permanent and intermittent ponds and lakes (table 1). The channel width for the single stream occurrence was 5 m. In New York, Harman (1972) found allochthonous terrestrial plant matter to be the preferred substrate. Pip and Paulishyn (1971) said the sulfate concentration is seldom greater than 100 ppm where P. exacuous is present in southern Manitoba. I found the species alive

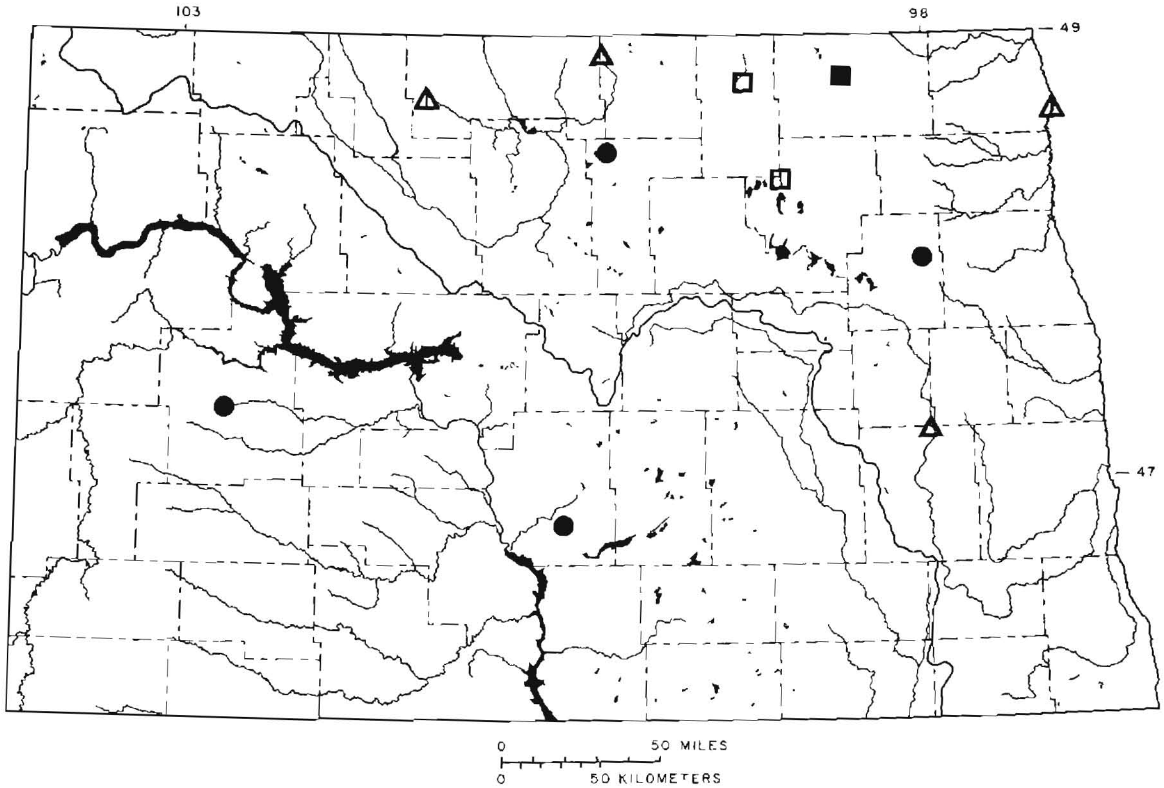

Figure 55. Distribution of Promenetus umbilicatellus (Cockerell) (circles), Planorbula armigera (Say) (triangles), and Planorbula campestris (Dawson) (squares) in North Dakota. Split triangle occurrences are from Clarke (1973, p. 421) and the split square occurrence is from Winslow (1921, p. 13). Filled symbols = live occurrences, open symbols = no live occurrences.

in North Dakota where the sulfate concentration was as high as 405 mg/l (app. B). P. exacuous was most frequently associated with Physa jennessi, and is part of the Aplexa hypnorum-Gyraulus circumstriatus Association (fig. 18).

Remarks.--Clarke (1973, p. 409-414) recognized two subspecies of P. exacuous in that part of North Dakota within the Hudson Bay drainage: P. exacuous exacuous (Say) and P. e. megas (Dall). However, he said (p. 412) that, except for the larger size of P. e. megas (and perhaps a periostracal extension on the keeled periphery in preserved specimens), no character will always distinguish this subspecies from P. e. exacuous. Hibbard and Taylor (1960, p. 109) considered P. e. megas not to be taxonomically valid because of its intergradation with typical P. exacuous and lack of demonstration of correlation with habitat.

Promenetus umbilicatellus (Cockerell, 1887)
pl. 6, figs. 8-10

Diagnosis.--Shell up to about 6 mm wide; whorls gradually enlarging, rounded at periphery, about four; umbilicus relatively wide, subcylindrical; fine spiral striae or ridges; aperture rounded, subtriangular.

Range in North Dakota.--Presumably in much of the state (fig. 55).

Holocene (possible within interval of 8,000-4,000 years to present; Cvancara, 1976, p. 1691).

General range.--North America north of about the forty-first parallel from Nevada and Alaska east and southeast to western New York; south in the Rocky Mountains to southern Colorado; sporadic in eastern Kansas and northeastern Oklahoma (Hibbard and Taylor, 1960, p. 110, 112).

Middle Pliocene to Holocene (Hibbard and Taylor, 1960, p. 110).

Biology and ecology.--The anatomy of P. umbilicatellus has been described by Baker (1945, p. 179-181).

This species has been reported primarily from temporary ponds but is also known from intermittent streams and drainage ditches (Mozley, 1938, p. 109; Clarke, 1973, p. 416-417; Hibbard and Taylor, 1960, p. 111). In North Dakota, it was collected from both permanent and intermittent ponds or lakes (table 1). For the permanent water bodies, however, the species occurred along their margins, which presumably become dry periodically. P. umbilicatellus was most frequently associated with Armiger crista, and is part of the Aplexa hypnorum-Gyraulus circumstriatus Association (fig. 18).

Remarks.--Both P. exacuous and P. umbilicatellus possess spiral lines on the shell but they tend to be more distinct in P. umbilicatellus.

Genus Planorbula Haldeman, 1840

Shell small to medium; dextral; planispiral or nearly so; spire depressed or flattened; whorls gradually enlarging, rounded or subcarinate; umbilicus wide, deep, funnel-shaped; internal lamellae well within aperture, which is subovate.

Planorbula armigera (Say, 1821)
pl. 6, figs. 1-4

Diagnosis.--Shell up to about 9 mm wide; spire depressed; whorls subcarinate on right and left sides, about five, last deflected to left near aperture; spiral striae and ridges discontinuous; up to six internal lamellae in up to two sets.

Range in North Dakota.--Known essentially only from the eastern part of the state (fig. 55).

Holocene (possibly within interval of 8,000-4,000 years to present; Cvancara, 1976, p. 1691).

General range.--New Brunswick northwest to Mackenzie River system (Clarke, 1973, p. 421-422), south to Georgia and Louisiana and west to Nebraska (Baker, 1928a, p. 359).

Middle Pleistocene (Kansan) to Holocene (Miller, 1966, p. 233).

Biology and ecology.--The anatomy of P. armigera has been described by Baker (1928a, p. 356-358; 1945, p. 174-176).

This species has been reported from lakes, ponds, marshes, swamps, and muskeg, as well as from slow-moving streams (Clarke, 1973, p. 420-422). Of lacustrine occurrences, it is restricted to eutrophic lakes (Clarke, 1979a). It is most characteristic of small, stagnant water bodies (Baker, 1928a, p. 358). In North Dakota, it was not collected alive but both occurrences were in lakes (fig. 55). In New York, P. jenksii, a related or synonymous species (Clarke, 1973, p. 422), prefers a substrate of allochthonous terrestrial plant matter (Harman, 1972).

Planorbula campestris (Dawson, 1875)
pl. 6, figs. 5-7

Diagnosis.--Shell up to about 12 mm wide; spire flattened to slightly depressed; whorls rounded, about 6.5, last not deflected to left near aperture; spiral striae continuous; up to five internal lamellae in up to four sets.

Range in North Dakota.--Known presently only from northeastern part of the state (fig. 55).

Holocene (known only from the present; Cvancara, 1976, p. 1691).

General range.--Southeastern Ontario west and north to British Columbia and Great Slave Lake, south to western Wyoming and east-central South Dakota (Miller, 1968).

Middle Pliocene? Middle Pleistocene (Kansan) to Holocene (Miller, 1968, p. 260).

Biology and ecology.--Clarke (1973, p. 424-425) has briefly mentioned the anatomy of P. campestris.

This species has been reported from ponds, swamps, and small, slow-flowing streams (Clarke, 1973, p. 424). It is characteristic of temporary ponds in relatively open grasslands (Miller, 1968). In North Dakota, it was collected alive only from an intermittent marsh (table 1); empty shells were also taken from an intermittent pond. Molluscan associates were Sphaerium lacustre, Stagnicola elodes, Lymnaea stagnalis, Gyraulus parvus, Helisoma trivolvis, Promenetus exacuous, Aplexa hypnorum, and Physa jennessi.

Family PHYSIDAE

Shell small to large; sinistral; conispiral; smooth or microsculptured; umbilicus absent; operculum absent.

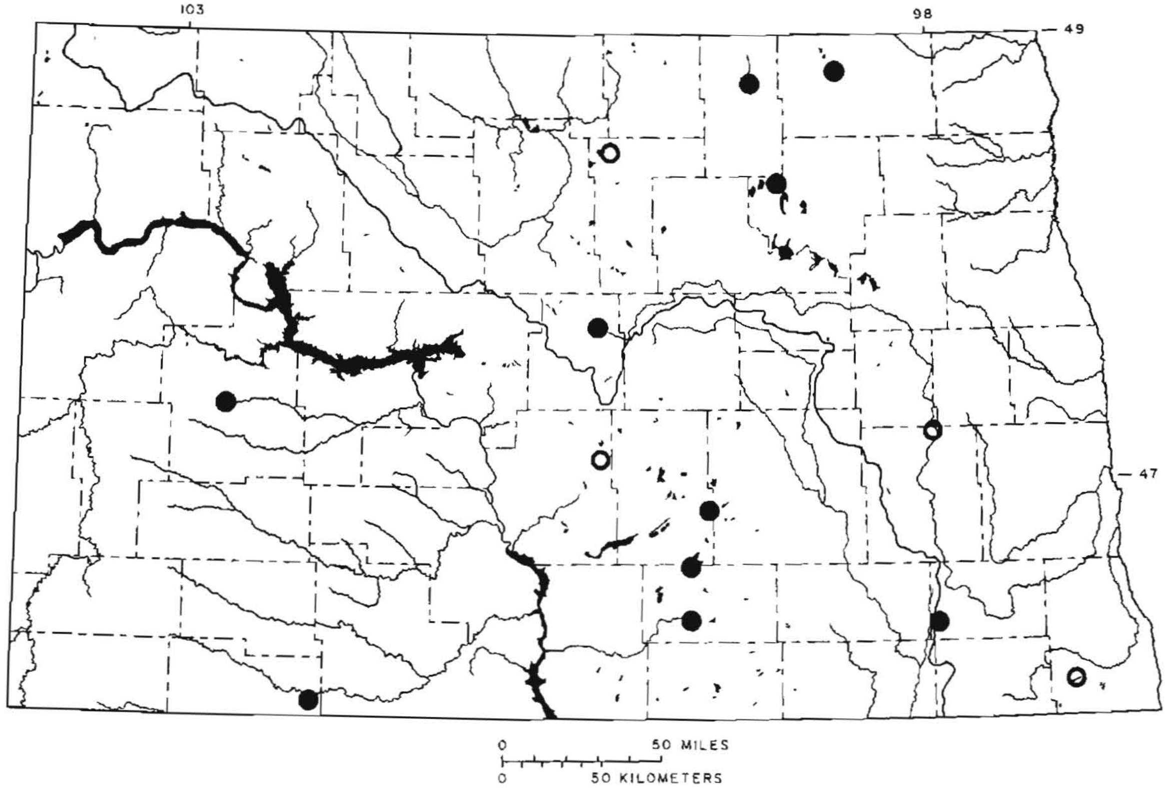

Figure 56. Distribution of Aplexa hypnorum (Linnaeus) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

Genus Aplexa Fleming, 1820

Shell medium; elongate; smooth and glossy, without prominent spiral sculpture. Edge of mantle not digitate and does not extend over shell.

Aplexa hypnorum (Linnaeus, 1758)
pl. 4, fig. 9

Diagnosis.--Shell up to about 25 mm long; thin; brownish; spire and aperture of about same length; whorls flatly rounded, up to about seven; spiral sculpture usually absent.

Range in North Dakota.--In most of the state (fig. 56).

Holocene (possibly within interval of 8,000-4,000 years to present; Cvancara, 1976, p. 1691).

General range.--Holarctic (including northern Europe and Asia); in North America, Cascade Mountains to Atlantic and south from Alaska and Hudson Bay to vicinity of Ohio River (Baker, 1928a, p. 474), Platte River, Colorado, and Nevada (Miller, 1966, p. 240).

Early Pleistocene (Nebraskan) to Holocene (Hibbard and Taylor, 1960, p. 121).

Biology and ecology.--Baker (1928a, p. 470-472) has described the anatomy of A. hypnorum, and Te (1975) has further described the penial complex. Den Hartog and De Wolf (1962) and Vlasblom (1971) have studied the life history of this species.

A. hypnorum has been reported from swamps, muskeg, temporary ponds (especially woods pools), lakes, and intermittent and permanent streams (Clarke, 1973, p. 383). It is most characteristic of temporary ponds (Mozley, 1938, p. 113). In North Dakota, it was collected from both permanent and intermittent ponds and lakes (table 1). In the permanent water bodies, the species occurred at depths of 0.3 m or less, including water-body margins that presumably become dry periodically. In New York, Harman (1972) found allochthonous terrestrial organic matter to

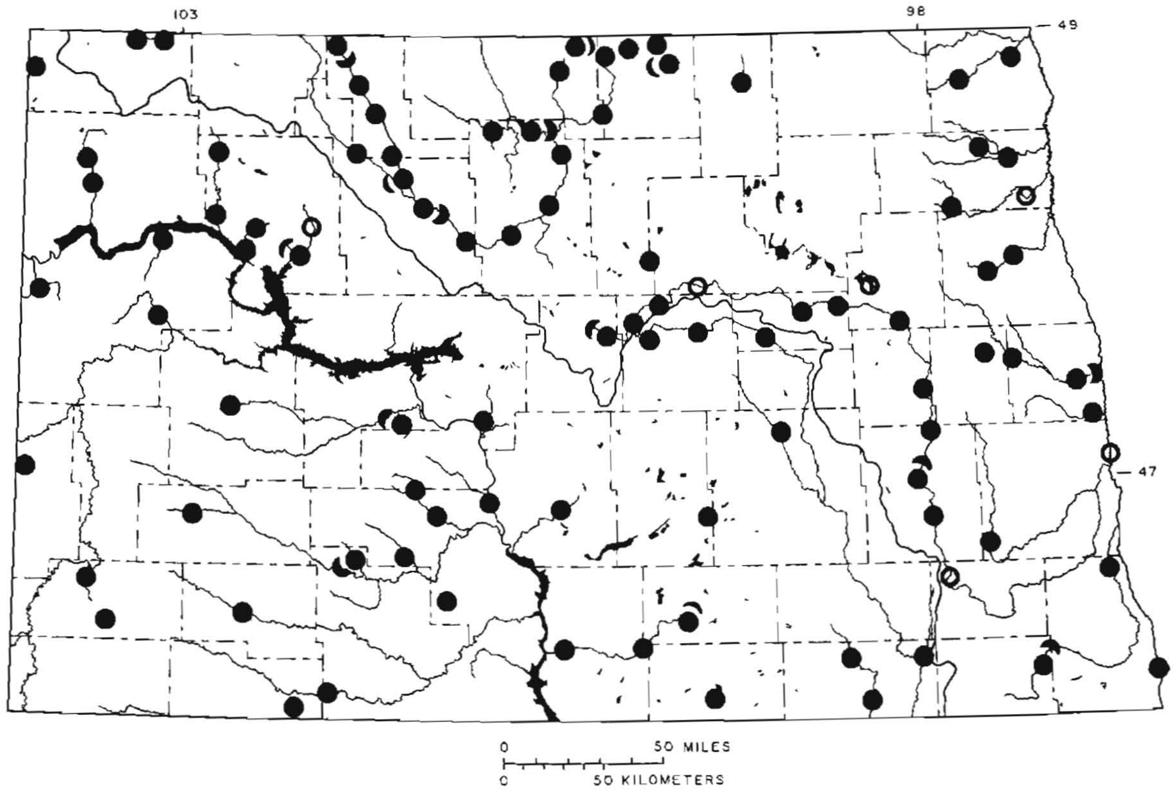

Figure 57. Distribution of Physa gyrina (Say) in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

be the preferred substrate. A. hypnorum was most frequently associated with Gyraulus circumstriatus, and is part of the A. h.-G. c. Association (fig. 18).

Genus Physa Draparnaud, 1801

Shell small to medium; subovate; smooth; may or may not be glossy, with or without prominent spiral sculpture. Edge of mantle digitate and extends partly over shell.

Physa gyrina Say, 1821
pl. 4, fig. 4, 5

Diagnosis.--Shell up to about 25 mm long; spire about 0.2-0.4 of shell length; sutures not deeply impressed, smooth transition between last whorl and spire; whorls up to about six; spiral striae usually conspicuous; outer lip usually with reddish band inside. Animal dark, blackish, or yellowish gray.

Range in North Dakota.--Throughout the state (fig. 57).

Late Pleistocene to Holocene (at least 12,000-10,000 years to present; Cvancara, 1976, p. 1691).

General range.--Mackenzie River drainage to Great Lakes-St. Lawrence drainage (Clarke, 1973, p. 378) and south to Alabama and Texas (Baker, 1928a, p. 452).

Early Pleistocene (Nebraskan) to Holocene (for P. g. form hildrethiana Lea; Hibbard and Taylor, 1960, p. 118).

Biology and ecology.--The anatomy of P. gyrina has been described by Baker (1928a, p. 450-451). Reproduction, life history, and ecology have been described by Clampitt (1970) and DeWitt (1954a-c, 1955).

Zebroid individuals have been observed in North Dakota, as in a lake on Spring Creek (134-94-8DC; A367) and in Bear Creek (131-59-8AA; A252).

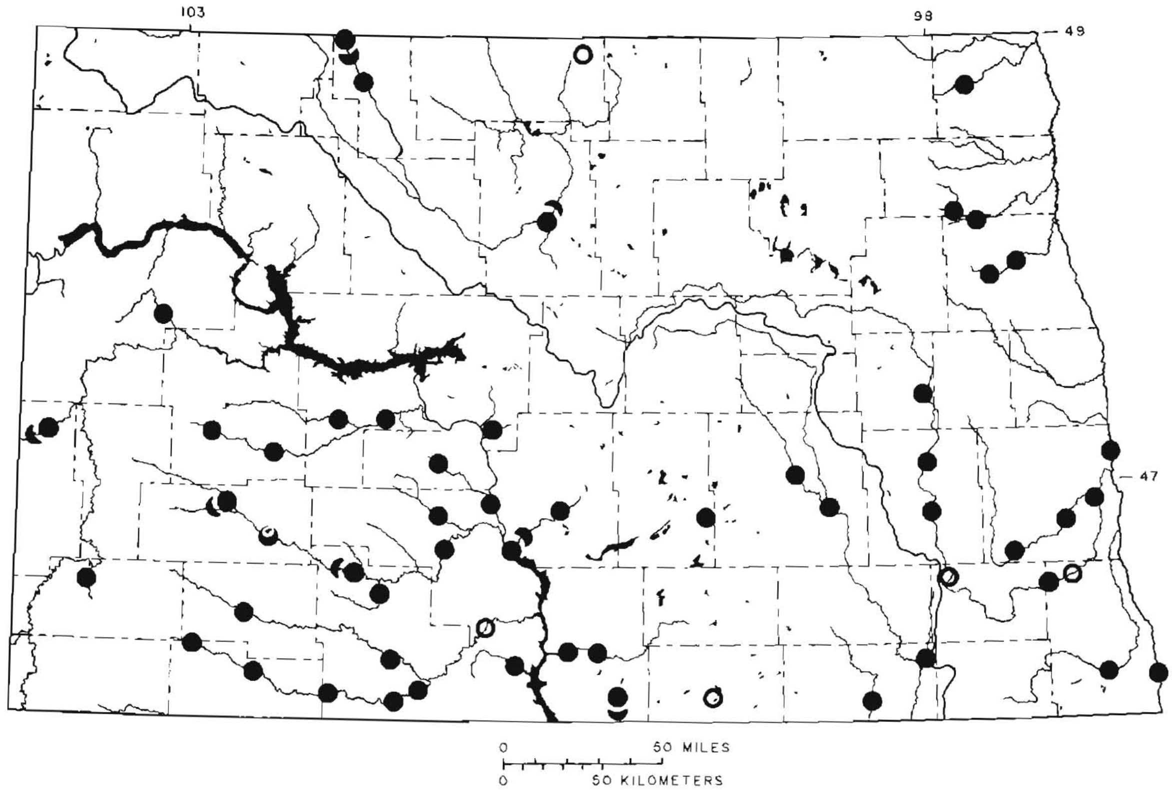

Figure 58. Distribution of Physa integra Haldeman in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

P. gyrina has been reported from permanent, flowing and nonflowing water bodies of all sizes (Clarke, 1973, p. 378), as well as from temporary ponds and intermittent streams (Mozley, 1938, p. 112). Clampitt (1970) considered it primarily a pond species. Of lacustrine occurrences, this species is characteristic of mesotrophic and eutrophic lakes (Clarke, 1979a). In North Dakota, it was collected mostly from permanent ponds and lakes and intermittent and permanent small streams (table 1). Channel widths (n=62) were 1-37 m (mean=9±8 S.D.). In New York, Harman (1972) found eulittoral silt and detritus to be the preferred substrate. In North Dakota, the species was found to tolerate extreme high values of total sulfates and total alkalinity and relatively high total chlorides (app. B). P. gyrina was most frequently associated with Gyraulus parvus, Helisoma trivolvis, and Stagnicola elodes, and is part of the Helisoma trivolvis-Lymnaea stagnalis Association (fig. 18).

Remarks.--P. gyrina is a highly variable species, and a proliferation of names has resulted from this variability. Several synonyms or presumed synonyms include P. gouldi Clench (Clarke, 1973, p. 380), P. altonensis Lea, P. hawnii Lea, P. saffordii Lea (Hibbard and Taylor, 1960, p. 118-119), and P. sayii Tappan (W. J. Clench, in Harman and Berg, 1971, p. 10). Te (1975), however, considered P. sayii a distinct species.

Physa integra Haldeman, 1841
pl. 4, fig. 10

Diagnosis.--Shell up to about 16 mm long; spire about 0.2-0.4 of shell length; sutures deeply impressed, conspicuous shoulder between last whorl and spire; whorls up to about five; spiral striae usually inconspicuous; outer lip usually with whitish band inside. Animal light, foot may be yellowish.

Range in North Dakota.--Throughout the state (fig. 58).

Holocene (within interval of about 4,000 years to present; Cvancara, 1976, p. 1691).

General range.--Ontario to Texas and New York to South Dakota (Baker, 1928a, p. 462; Crandall, 1901, p. 56).

Biology and ecology.--The anatomy of P. integra has been described briefly by Baker (1928a, p. 461-462) and Clampitt (1970). Reproduction, life history, and ecology have been described by Bickel (1965) and Clampitt (1970, 1973).

Zebroid individuals have been observed in North Dakota, as in the Knife (143-95-6BD; A223) and Bois de Sioux (130-47-15AA; A116) Rivers.

P. integra has been reported from a wide variety of streams and lakes, and does not occur in ponds (Clampitt, 1970). Of lacustrine occurrences, this species most frequently occurs in mesotrophic lakes (Clarke, 1979a). In North Dakota, it was collected mostly from small, permanent and intermittent streams (table 1). Channel widths (n=50) were 2-37 m (mean=12±8 S.D.). In New York, Harman (1972) found eulittoral silt and detritus to be the preferred substrate, but in Douglas Lake, Michigan, Clampitt (1973) found the species preferred "stones" over sand. In North Dakota, the species was found to tolerate high total chlorides (app. B). P. integra was most frequently associated with Ferrissia rivularis and several bivalves, and is part of the Anodonta grandis-Lasmigona complanata Association (fig. 18).

Remarks.--P. integra and P. anatina Lea may be the same species. Characters given in the literature are similar. Illustrations of P. integra by Baker (1928a, pl. 28, especially figs. 27-29) and of P. anatina by Hibbard and Taylor (1960, pl. 10, figs. 2, 3, 11, 12), for example, are also closely similar. The distribution of P. anatina has been considered (Hibbard and Taylor, 1960, p. 117) as generally more southerly: central and southern U.S.

For young individuals from a few lots I had difficulty distinguishing P. integra from P. gyrina.

Physa jennessi Dall, 1919
pl. 4, fig. 6

Diagnosis.--Shell up to about 13 mm long; spire about 0.2-0.3 of shell length, tip of spire relatively blunt; sutures not deeply impressed, slight shoulder between last whorl and spire; last whorl flattened peripherally; whorls up to about five; surface glossy, with usually inconspicuous spiral striae.

Range in North Dakota.--Throughout the state (fig. 59).

Holocene (known only from the present; Cvancara, 1976, p. 1691).

General range.--Alaska south to northern Utah (Hibbard and Taylor, 1960, p. 119), east across northern U.S. and southern Canada to eastern Ontario and eastern edge of Hudson Bay (Clarke, 1973, p. 364, 370-371).

Early Pleistocene (Nebraskan) to Holocene (Hibbard and Taylor, 1960, p. 119).

Biology and ecology.--The anatomy of P. jennessi has been briefly described by Clarke (1973, p. 365-368, 372-373) and Te (1975; penis complex of P. jennessi skinneri).

P. jennessi has been reported from small to large lakes, permanent and temporary ponds, marshes, muskeg, and small to medium streams (Clarke, 1973, p. 365, 367, 372). In North Dakota, it was collected mostly from permanent and intermittent ponds and lakes (table 1). Channel widths of the few (n=4) stream occurrences were 2-34 m (mean=17±16 S.D.). It was found to tolerate extreme values of total chlorides, pH, total hardness, and total sulfates (app. B). P. jennessi was most frequently associated with Promenetus exacuous, and is part of the Aplexa hypnorum-Gyraulus circumstriatus Association (fig. 18).

Remarks.--Clarke (1973, p. 362-372) placed P. skinneri Taylor in synonymy with the earlier named P. jennessi Dall, and used the name "skinneri" for one of three subspecies of P. jennessi in the Canadian Interior Basin. North Dakota populations could be placed in the subspecies P. j. skinneri.

Other Snails in North Dakota

The status of the viviparid snail (Campeloma decisum (Say) (pl. 4, fig. 7) in the state is uncertain as I have already discussed (Cvancara, 1976). Only empty shells are known from the Red (142-49-25AA and 134-48-4D; last locality from Clarke, 1973, p. 218) and lower Sheyenne (135-52-6DD, 136-51-22AD, and 137-50-33CD) Rivers (fig. 41). I have collected the species as a fossil from the lower Sheyenne south-southwest of Leonard in Richland County (135-52-6DD). The nearest live occurrence, of which I am aware, is in the Otter Tail River a few kilo-

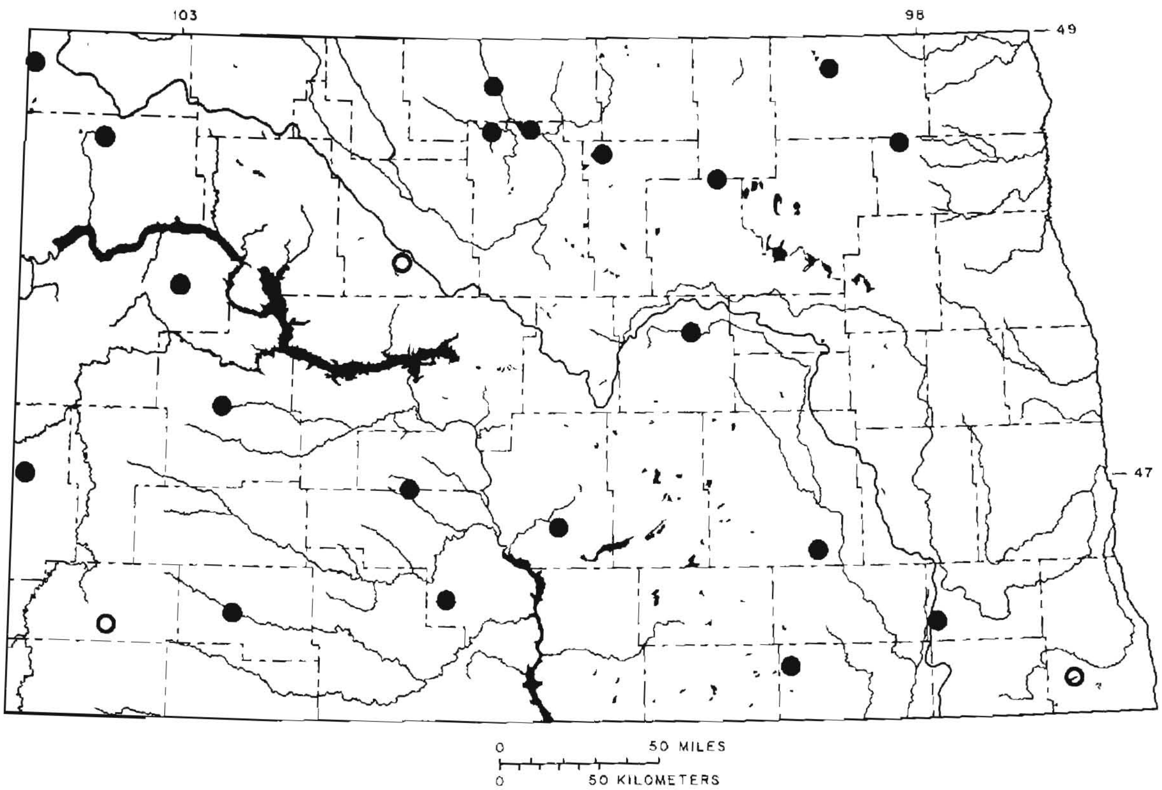

Figure 59. Distribution of Physa jennessi Dall in North Dakota. Filled circles = live occurrences, open circles = no live occurrences.

metres upstream from Fergus Falls, Minnesota (133-42-29BB). I have also collected the species alive in the Red Lake River 1.5 km east of Crookston, Minnesota (149-46-4BB).

I have already mentioned in the previous section that Valvata sincera (Say), Fossaria decampi (Streng), and Helisoma (Planorbella) campanulatum (Say) are known in the state only as fossils.

I fully expected to find the limpet Ferrissia parallela (Haldeman) but did not recognize it in any of my material. It has been reported from sediments presumed to be about 8,000-4,000 years old (McAndrews and others, 1967, p. 106-107), and should be looked for further in the state.

Clarke (1973, p. 278, 286) reported two "fossariaform" lymnaeid species from the Hudson Bay drainage in North Dakota: Lymnaea modicella (Say) and L. bulimoides (Lea). Winslow (1921, p. 10) reported L. bulimoides and another "fossariaform" species, Lymnaea dalli Baker, for the state. I did not recognize any of these species in my material. These and other Fossaria-type snails should be searched for further.

Clarke (1973, p. 461) also reported the planorbid Helisoma (Pierosoma) pilsbryi infracarinatum Baker, which I did not recognize in my material, from a single locality in North Dakota. He stated (p. 462) that this form "as a separate taxon requires additional research," and may be a morphological variant of H. trivolvis or a morph between H. corpulentum and H. trivolvis.

SUMMARY

1. Aquatic mollusks are significant to man as biologic monitors of water quality (all mollusks); food for game fish and birds and fur-bearing animals; implements and ornaments (mostly shells of mussels); and vectors of human disease (snails).

2. Based on 298 collecting stations, at least 44 aquatic mollusks are known to inhabit North Dakota: 13 mussels (unionacean bivalves), 9 pill clams (sphaeriid bivalves), and 22 snails (4 gill-breathing and 18 lung-breathing gastropods). The most frequently occurring mussel, pill clam, and snail in the state are *Anodonta grandis*, *Pisidium (Cyclocalyx) compressum*, and *Physa gyrina*.

3. Nearly one and one-half times as many aquatic mollusks occur in the Hudson Bay drainage (42 species) as in the Mississippi River drainage (30 species) in the state. Mussels reach greater densities, too, in the Hudson Bay drainage.

4. Four aquatic mollusk associations are recognized in the state, and each relates to a general habitat: *Anodonta grandis*-*Lasmigona complanata* Association (permanent small stream habitat), *Amblema plicata*-*Fusconaia flava* Association (permanent large stream habitat), *Helisoma trivolvis*-*Lymnaea stagnalis* Association (permanent lake or pond habitat), and the *Aplexa hypnorum*-*Gyraulus circumstriatus* Association (intermittent lake or pond habitat).

5. Ecologic factors presumably limiting the occurrence of aquatic mollusks in the state include unsuitable water body, flowing or nonflowing, and as related to size and permanency; bottom instability, as shifting sand; high turbidity; high total chlorides and sulfates; availability of fish host (for mussels); and man-related effects, such as alteration or destruction of habitat and water pollution.

6. Aquatic mollusks presumably all entered the state from the south and east. All the mussels occur in the Mississippi River drainage to the south and east, and greatest pill clam and snail diversity occurs south and east of the state. Three species existing today occurred here at least as early as 13,500 years ago, but the modern fauna probably developed after about 9,000 years ago.

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APPENDIX A

OCCURRENCE AND RELATIVE ABUNDANCE OF AQUATIC MOLLUSK SPECIES AT COLLECTING STATIONS IN NORTH DAKOTA

Appendix A. Occurrence and relative abundance of aquatic mollusk species at collecting stations in North Dakota.

Explanation of Symbols and Numerals

1. TWP = Township.

2. RNG = Range.

3. SEC = Section.

4. QTR = Quarter. A = NE¼, B = NW¼, C = SW¼, D = SE¼. So, e.g., 129-62-2DC = SW¼SE¼ Section 2, Township 129 North, Range 62 West.

5. ACC = University of North Dakota, Department of Geology accession number.

6. YEAR = Year of collecting. Where two years are given, a collecting station was visited twice.

7. HAB = General aquatic habitat; numbers representing habitats are as those given in table 1.

8. SPEC = Species; numbers of species are as given in table 1; e.g., 1 AP = 1. Amblema plicata.

9. Relative abundance.--For mussels (species 1-13), a given value is the number of individuals collected per hour by handpicking by two collectors. For pill clams and snails (species 14-44), a value is the estimated relative abundance with arbitrarily assigned numbers of individuals: 1 = rare (1-3 individuals), 2 = uncommon (4-8), 3 = common (9-20), and 4 = abundant (more than 20) DEAD = only empty shells observed.

TWP	129	129	129	129	129	129	129	130	130	130	130	130	130
RNG	62	75	87	92	99	106	106	47	51	52	70	75	85
SEC	2	4	9	11	32	5	31	15	8	12	33	28	8
QTR	DC	AC	AA	BC	CA	BC	CD	AA	AA	DC	BB	AD	DD
ACC	250	329	306	2039	316	0	0	116	388	389	330	328	305
YEAR	1967	1968	1968	1976	1968	1968	1968	1966	1969	1969	1968	1968	1968
HAB	3	1	4	1	4	4	3	3	1	1	1	1	4
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	52	--	5	--	95	--	--	DEAD	--	--	--	--	19
5 AF	--	--	--	--	--	--	--	--	--	--	--	--	--
6 LC	--	--	DEAD	--	--	--	--	--	--	--	--	--	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	--	--	--	--	--	--	--
10 LR	--	--	1	--	--	--	--	--	--	--	--	--	DEAD
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	1
14 SL	--	--	--	--	--	--	--	--	--	--	3.0	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	2.0	--	--	--	--	--	--	--	--	--	--	--	2.0
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	4.0	DEAD	--	3.5	--	--	--	--	--	--	--	DEAD	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	DEAD	--	--	--	--	--	--	--	--	DEAD	DEAD	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
28 SC	--	DEAD	--	--	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	4.0	--	--	--	--	4.0	4.0	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	3.0	--	1.0	--	3.0	--	--	--	--	--	--	--	--
32 GP	--	DEAD	--	3.5	--	--	--	3.0	--	DEAD	DEAD	DEAD	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	2.0	--	--	--	--	--	--	--	1.0	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	4.0	--	--	--	--	DEAD	--	--	--	--
42 PG	3.0	--	--	4.0	--	--	--	4.0	--	--	2.5	--	--
43 PI	3.0	2.5	2.0	--	--	--	--	4.0	--	--	DEAD	4.0	1.0
44 PJ	--	--	--	--	--	--	--	--	DEAD	--	--	--	--

TWP	130	130	131	131	131	131	131	131	131	132	132	132	132
RNG	85	90	50	53	59	66	81	94	94	47	53	59	63
SEC	8	29	25	14	8	3	1	20	20	16	25	31	27
QTR	DD	DA	CB	AA	AA	CD	DA	CB	CB	AB	AD	CC	BB
ACC	2038	309	113	2362	252	387	303	314	2040	126	2566	249	251
YEAR	1976	1968	1966	1966	1967	1969	1968	1968	1976	1966	1966	1967	1967
HAB	4	4	3	3	3	1	3	4	4	4	3	4	3
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	3	2	8	--	DEAD	--	4	15	23	DEAD	--	28	40
5 AF	--	--	--	--	--	--	--	DEAD	DEAD	--	--	--	--
6 LC	--	DEAD	DEAD	--	--	--	--	46	7	--	--	DEAD	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	--	--	--	--	--	--	--
10 LR	4	--	DEAD	--	--	--	--	1	1	DEAD	--	--	--
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	1	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	2.0	--	--	--	--	--	1.0	--	--	--	--
15 ST	--	--	2.0	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	4.0
17 SS	--	--	2.0	--	--	--	--	2.0	1.0	--	--	--	4.0
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	1.5	--	--	3.5	--	--	--	2.0	2.0	--	--	--	1.5
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	2.0
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	1.0	--	--	--	--	--	--	--	2.5	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	2.0	--	--	--
29 SE	--	--	--	--	--	3.0	--	--	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	2.0	3.0	--	--	--	--	2.0	4.0	--	--	--	--
32 GP	--	--	--	3.0	--	2.0	2.5	2.0	3.0	--	2	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	--	3.0	--	4.0	2.0	--	--	--	--	--	3	--	3.0
43 PI	3.5	4.0	1.0	--	1.0	--	2.0	4.0	4.0	--	--	--	--
44 PJ	--	--	--	--	--	2.5	--	--	--	--	--	--	--

TWP	132	132	132	132	132	132	132	133	133	133	133	133	133
RNG	74	76	78	83	87	87	97	47	48	61	89	91	102
SEC	11	18	14	31	26	26	7	16	23	11	4	7	12
QTR	DD	AD	AA	AB	CC	CC	CA	CD	BA	AA	DD	BB	AC
ACC	229	228	230	304	308	2042	315	127	2567	248	307	311	369
YEAR	1967	1967	1967	1968	1968	1976	1968	1966	1966	1967	1968	1968	1969
HAB	3	4	4	4	4	4	3	5	3	4	4	4	1
SPEC													
1 AP	--	--	--	--	--	--	--	2	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	DEAD	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	68	43	11	1	14	1	4	DEAD	--	13	3	8	--
5 AF	DEAD	DEAD	--	--	--	--	DEAD	--	--	DEAD	DEAD	--	--
6 LC	34	43	72	--	22	DEAD	1	--	--	1	2	17	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
9 LO	--	--	--	--	--	--	--	2	--	DEAD	--	--	--
10 LR	--	1	DEAD	DEAD	3	4	--	6	--	DEAD	DEAD	1	--
11 LR	--	--	--	--	--	--	--	DEAD	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	1	--	--	--	--	--	--	--
14 SL	--	--	--	--	--	--	--	--	4	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	4	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	DEAD	--	1.0	2.5	2.0	DEAD	--	--	3	--	2.0	2.0	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	2.0	1.0	--	--	3.0	1.0	1.0	--	2	--	1.0	3.0	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	2.0	--	--	--	DEAD	--	--	4	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	--	--	--	--	--	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	4.0	4.0	4.0	--	--	--	--	--	--	3.0	--	3.0	--
32 GP	--	--	--	2.0	--	--	4.0	--	--	--	--	--	3.5
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	2.0	--	2.0	--	--	--	--	--	--	--	--	--	--
43 PI	--	2.0	2.0	--	--	1.0	4.0	--	--	--	--	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	133	133	133	133	134	134	134	134	134	134	134	134	134
RNG	102	105	105	105	55	58	71	71	71	71	80	82	82
SEC	12	30	30	30	32	27	21	28	32	34	26	36	36
QTR	AC	DB	DB	DB	BA	BB	BA	DA	AB	BB	AD	DB	DB
ACC	2029	0	0	2030	107	390	331	0	231	332	302	256	2022
YEAR	1976	1968	1976	1976	1966	1969	1968	1968	1967	1968	1968	1967	1976
HAB	1	4	4	4	5	2	2	1	3	1	4	4	4
SPEC													
1 AP	--	--	--	--	29	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
4 AG	--	--	--	DEAD	1	--	--	--	DEAD	DEAD	4	DEAD	1
5 AF	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
6 LC	--	--	--	--	4	--	--	--	--	--	--	DEAD	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
10 LR	--	--	--	--	DEAD	--	--	--	--	--	DEAD	DEAD	--
11 LR	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	1	--	--
14 SL	--	--	--	--	--	--	--	--	--	2.0	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	--	--	--	--	--	--	--	--	--	2.0	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	--	--	--	--	--	--	--	--	--	--	--	1.0
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	1.0	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	--	--	--	--	2.0
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	4.0	--	--	--	--	--	--	--
29 SE	--	--	--	--	--	4.0	3.0	--	--	DEAD	--	--	--
30 LS	--	--	--	--	--	--	--	--	2.0	2.0	--	--	--
31 FR	--	--	--	--	--	--	--	--	--	--	--	--	--
32 GP	4.0	--	--	--	--	--	3.0	--	4.0	3.0	--	--	--
33 GC	--	--	--	--	--	2.5	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	--	--	3.0	--	--	--	2.0	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	4.0	4.0	--	--	--	--	--	--
42 PG	4.0	--	--	--	--	--	2.0	--	3.0	3.0	--	--	--
43 PI	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
44 PJ	DEAD	--	--	--	--	3.0	--	--	--	--	--	--	--

TWP	134	134	134	135	135	135	135	135	135	135	135	135	135
RNG	94	94	95	52	52	54	56	62	84	84	87	87	95
SEC	8	17	13	6	6	17	18	3	25	25	8	8	13
QTR	DC	AB	AA	DD	DD	AA	DC	BD	CC	CC	AB	AB	AA
ACC	367	368	2041	168	1061	109	146	247	385	2023	301	2024	312
YEAR	1969	1969	1976	1966	1974	1966	1966	1967	1969	1976	1968	1976	1968
HAB	1	1	4	5	5	5	5	4	1	1	4	4	4
SPEC													
1 AP	--	--	--	--	1	34	63	--	--	--	--	--	--
2 FF	--	--	--	--	2	16	13	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	--	--	40	1	1	3	14	35	--	--	1	DEAD	10
5 AF	--	--	1	DEAD	1	1	2	5	--	--	10	1	2
6 LC	--	--	49	1	2	14	30	8	--	--	54	17	35
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	1	1	--	--	--	--	--	--
9 LO	--	--	--	1	1	DEAD	1	DEAD	--	--	--	--	--
10 LR	--	--	--	7	10	DEAD	16	DEAD	--	--	--	--	--
11 LR	--	--	--	--	--	DEAD	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	DEAD	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	1.0	--	--	--	--	--	DEAD	--	--	--	--
15 ST	--	--	--	--	1.0	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	--	1.0	--	--	--	2.0	--	--	--	3.0	1.0	2.0
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	--	4.0	--	--	--	--	1.0	--	--	2.5	2.5	4.0
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	1.0	--	--	--	--	--	--	--	--	1.0	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	4.0	--	--	--	--	--	--	--	--	--	2.0
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	4.0	DEAD	--	--	--	--	--	--	4.0	4.0	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	--	3.5	--	--	--	--	3.0	--	--	2.0	3.5	3.0
32 GP	3.0	2.5	--	--	--	--	--	--	1.0	4.0	3.0	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	3.0	2.0	--	--	--
37 PE	--	--	--	--	--	--	--	--	2.5	1.0	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	4.0	3.0	--	--	--	--	--	--	3.0	DEAD	--	--	4.0
43 PI	--	--	4.0	--	1.0	--	--	--	--	--	4.0	2.0	--
44 PJ	2.0	--	--	--	--	--	--	--	--	4.0	--	--	--

TWP	135	136	136	136	136	136	136	136	136	136	136	136	136
RNG	97	48	49	51	51	57	57	85	89	89	89	89	89
SEC	5	29	27	22	22	19	19	9	8	8	11	11	13
QTR	AA	BA	BB	AD	AD	DB	DB	CB	CA	CA	CB	CB	AD
ACC	313	128	112	110	986	164	985	300	384	2026	0	0	310
YEAR	1968	1966	1966	1966	1973	1966	1973	1968	1969	1976	1969	1976	1968
HAB	4	5	3	5	5	5	5	4	1	1	1	1	4
SPEC													
1 AP	--	--	DEAD	--	1	14	47	--	--	--	--	--	--
2 FF	--	--	--	--	1	15	74	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	17	4	DEAD	--	2	18	38	DEAD	--	--	--	--	--
5 AF	3	--	--	--	--	3	DEAD	DEAD	--	--	--	--	--
6 LC	51	--	--	4	2	2	38	DEAD	--	--	--	--	DEAD
7 LC	--	--	--	--	--	3	1	--	--	--	--	--	--
8 SU	--	--	--	--	--	9	26	--	--	--	--	--	--
9 LO	--	--	--	1	--	3	DEAD	DEAD	--	--	--	--	--
10 LR	--	2	--	1	3	27	84	DEAD	--	--	--	--	DEAD
11 LR	--	--	--	--	--	DEAD	4	--	--	--	--	--	--
12 PA	--	DEAD	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	4.0	--	--	--	--	--	--	--	--	--	--
15 ST	--	--	--	--	2.0	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	--	--	--	DEAD	--	3.0	--	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	DEAD	--	4.0	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	3.0	--	--	--	--	--	--
26 AL	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	2.0	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	DEAD	--	--	--	--	2.0	--	--	--
29 SE	--	--	--	--	--	--	--	--	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	--	--	--	--	--	3.0	1.0	1.0	--	--	--	--
32 GP	--	--	--	--	--	--	--	--	--	1.0	--	--	2.0
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	--	--	4.0	--	--	--	DEAD	--	2.0	--	--	--	--
43 PI	--	--	--	--	DEAD	--	DEAD	--	3.0	2.0	--	--	1.0
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	136	136	137	137	137	137	137	137	137	137	137	137	137
RNG	103	104	54	55	58	63	64	71	71	80	83	83	85
SEC	24	16	14	4	11	11	16	24	36	18	6	6	7
QTR	AC	AA	BB	DB	BB	AB	DC	CD	DD	AB	CC	CC	CB
ACC	323	0	105	106	145	246	391	333	334	2044	299	2025	298
YEAR	1968	1968	1966	1966	1966	1967	1969	1968	1968	1976	1968	1976	1968
HAB	3	4	4	4	5	4	1	1	1	3	4	4	4
SPEC													
1 AP	--	--	--	--	15	--	--	--	--	--	--	--	--
2 FF	--	--	DEAD	--	9	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	3	--	2	--	13	39	--	--	--	--	--	--	5
5 AF	--	--	4	DEAD	2	DEAD	--	--	--	--	--	DEAD	--
6 LC	--	--	2	--	94	8	--	--	--	--	1	3	DEAD
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	4	--	--	--	--	--	DEAD	--	--
10 LR	--	--	DEAD	DEAD	81	--	--	--	--	--	1	1	DEAD
11 LR	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	2.0	--	--	--	--	--	--	--	--	--
15 ST	--	--	1.0	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	2.0	--	2.0	--	2.0	--	--	--	--	DEAD	--	1.0	2.0
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	1.0	--	2.0	2.0	--	--	--	--	--	DEAD	1.0	2.5	2.0
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	2.0	--	--	--	--	--	--	--	--	--
24 CC	--	--	1.0	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	DEAD	--	DEAD	--	--	--
28 SC	--	--	--	--	--	--	2.5	DEAD	--	--	--	--	--
29 SE	--	--	--	--	--	--	2.5	DEAD	3.0	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	2.0	--	--	--	--	3.0	--	--	--	3.0	--	--	2.0
32 GP	3.0	--	--	3.0	--	--	--	--	2.5	--	--	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
36 HT	--	--	--	--	--	--	1.0	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	2.5	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	2.0	--	--	--	--
42 PG	4.0	--	--	3.0	--	--	--	--	--	--	--	--	3.0
43 PI	4.0	--	4.0	--	--	--	--	--	--	3.0	--	1.5	--
44 PJ	--	--	--	--	--	--	2.5	--	--	--	--	--	--

TWP	137	138	138	138	138	138	138	138	138	138	138	139	139
RNG	88	48	50	52	79	80	80	82	92	92	102	51	58
SEC	21	30	25	21	9	27	30	5	29	29	31	28	9
QTR	CD	AA	AA	DD	BA	DA	BB	DD	AA	AA	CB	DC	DD
ACC	348	129	111	103	254	253	0	325	317	2027	2364	104	147
YEAR	1968	1966	1966	1966	1967	1967	1968	1968	1968	1976	1967	1966	1966
HAB	3	5	5	4	4	4	5	4	4	4	4	4	5
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	--	--	3	4	60	4	--	DEAD	--	1	--	10	29
5 AF	DEAD	--	--	4	--	--	--	--	1	--	--	2	1
6 LC	--	--	--	--	49	2	--	--	2	DEAD	--	4	3
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
9 LO	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
10 LR	--	6	3	--	--	--	--	DEAD	--	--	--	--	4
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	1	--	DEAD	--	--	--	--	--
14 SL	--	--	--	3.0	--	--	--	--	--	--	--	2.0	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	3.0	--	--	--	--	--	--	--	--	--
17 SS	--	--	--	3.0	--	--	--	--	--	DEAD	DEAD	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	1.5	--	--	--	--	--	--	--	2.0	--	--	--	1.0
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	1.0
25 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	--	--	--	--	--	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	--	--	--	4.0	2.0	--	--	--	1.5	--	3.0	--
32 GP	--	--	--	--	--	--	--	--	--	--	--	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	1.0	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	4.0	--	--	--	--	--	--	--	--	--	--	--	--
43 PI	--	--	--	--	--	2.0	--	--	4.0	1.0	--	1.0	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	139	139	139	139	139	139	139	139	139	139	139	139	139
RNG	58	63	70	77	78	82	84	95	95	96	96	97	97
SEC	9	6	1	32	11	25	14	1	7	7	7	24	24
QTR	DD	BA	DC	DA	AB	AB	CA	DC	DA	CD	CD	AB	AB
ACC	984	245	392	386	255	0	257	318	319	0	0	372	2028
YEAR	1973	1967	1969	1969	1967	1967	1967	1968	1968	1969	1976	1969	1976
HAB	5	4	1	1	3	4	4	4	4	1	1	1	1
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	--	--
2 FF	DEAD	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	9	4	--	--	27	--	DEAD	4	6	--	--	--	--
5 AF	--	DEAD	--	--	2	--	DEAD	6	1	--	--	--	--
6 LC	39	--	--	--	--	--	2	3	2	--	--	--	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	DEAD	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	DEAD	--	--	--	--	--	--	--	--	--	--	--
10 LR	39	DEAD	--	--	--	--	--	DEAD	--	--	--	--	--
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	1.0	--	4.0	--	--	--	--	--	--	--	--
15 ST	1.0	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	DEAD	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	4.0	--	--	--	4.0	--	--	3.0	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	1.0	--	2.0	--	4.0	--	4.0	3.0	2.0	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	DEAD	--	3.0	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	DEAD	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	3.0	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	DEAD	--	--	--	--	--	--	--	--	--	--	--	--
26 AL	DEAD	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	DEAD	--	--	--	--	--	--	--	--	2.0	--
28 SC	--	--	--	3.5	--	--	--	1.0	--	--	--	4.0	1.0
29 SE	--	--	3.0	3.5	--	--	--	--	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	4.0	3.0	--	--	4.0	--	--	2.0	3.0	--	--	--	--
32 GP	--	--	4.0	2.5	--	--	--	--	3.0	--	--	3.5	4.0
33 GC	--	--	2.5	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	DEAD	--	--	--	--	--	--	--	--	--	--
35 HA	3.0	--	--	--	2.0	--	2.0	--	--	--	--	--	--
36 HT	1.0	--	--	2.0	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	1.5	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	1.5	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	4.0	--	--	--	--	--	--	--	--	--	--
42 PG	3.0	--	3.5	--	4.0	--	3.5	--	--	--	--	4.0	4.0
43 PI	1.0	2.0	3.5	--	4.0	--	4.0	4.0	4.0	--	--	--	--
44 PJ	--	--	--	3.5	--	--	--	--	--	--	--	--	--

TWP	139	140	140	140	140	140	140	140	140	140	141	141	141
RNG	102	48	49	49	64	81	81	81	81	102	58	59	85
SEC	22	19	19	19	21	21	21	21	29	27	18	24	36
QTR	AC	AB	BB	BB	AA	DD	DD	DD	AB	AB	AA	CA	CC
ACC	0	130	108	1062	215	0	0	2043	296	0	983	165	383
YEAR	1967	1966	1966	1974	1967	1968	1976	1976	1968	1976	1973	1966	1969
HAB	4	5	5	5	3	5	5	2	3	4	1	5	1
SPEC													
1 AP	--	DEAD	--	6	--	--	--	--	--	--	--	1	--
2 FF	--	--	--	6	--	--	--	--	--	--	--	DEAD	--
3 QQ	--	DEAD	--	DEAD	--	--	--	--	--	--	--	--	--
4 AG	--	--	DEAD	30	34	--	--	--	DEAD	--	2	16	--
5 AF	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
6 LC	--	--	--	30	--	--	--	--	DEAD	--	--	64	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	1	--	--	--	--	--	--	--	DEAD	--
9 LO	--	--	--	6	--	--	--	--	--	--	--	--	--
10 LR	--	DEAD	12	12	--	--	--	--	DEAD	--	7	31	--
11 LR	--	--	--	2	--	--	--	--	--	--	--	DEAD	--
12 PA	--	--	--	1	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	--	--	--	--	--	--	--	--	--	--
15 ST	--	--	1.0	3.0	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	1.0	--	--
17 SS	--	--	--	DEAD	2.0	--	--	--	--	--	--	--	--
18 PC	--	--	--	--	1.0	--	--	--	--	--	--	--	--
19 PC	--	--	--	--	3.0	--	--	--	--	--	4.0	1.0	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	4.0	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	4.0	1.0	--
24 CC	--	--	--	DEAD	DEAD	--	--	--	--	--	4.0	--	--
25 PL	--	--	--	DEAD	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	4.0	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	--	--	--	--	--	--	--	--	--	3.0
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	--	--	--	3.0	--	--	--	3.0	--	--	--	--
32 GP	--	--	--	--	--	--	--	--	3.0	--	3.0	--	4.0
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	3.0	--	--
36 HT	--	--	--	--	--	--	--	--	--	--	1.0	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	--	--	--	--	--	--	--	4.0	4.0	--	3.0	1.0	3.5
43 PI	--	--	1.0	DEAD	--	--	--	--	1.0	--	--	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	4.0

TWP	141	141	141	141	141	141	142	142	142	142	142	142	142
RNG	85	98	105	105	105	105	49	49	55	58	58	65	75
SEC	36	14	8	8	17	17	25	25	11	27	32	4	17
QTR	CC	DD	DC	DC	AB	AB	AA	AA	CB	CC	CD	AB	AA
ACC	2021	225	371	2031	370	2032	131	2365	395	166	393	214	335
YEAR	1976	1967	1969	1976	1969	1976	1966	1976	1969	1966	1969	1967	1968
HAB	1	4	1	1	1	1	5	5	1	1	1	3	1
SPEC													
1 AP	--	--	--	--	--	--	DEAD	2	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	DEAD	--	--	--	--	--
3 QQ	--	--	--	--	--	--	DEAD	6	--	--	--	--	--
4 AG	--	91	--	--	--	--	2	16	--	--	--	23	--
5 AF	--	--	--	--	--	--	--	--	--	--	--	DEAD	--
6 LC	--	63	--	--	--	--	2	7	--	--	--	DEAD	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	4	19	--	--	--	--	--
10 LR	--	--	--	--	--	--	44	47	--	--	--	--	--
11 LR	--	--	--	--	--	--	DEAD	2	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	36	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	4.0	DEAD	2.0	--	--	--	--	--	2.0	2.0	--
15 ST	--	--	--	--	--	--	--	1.5	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	DEAD	3.0	--	--	--	--	--	DEAD	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	2.0	4.0	DEAD	4.0	DEAD	--	DEAD	--	--	2.5	3.0	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	4.0	DEAD	4.0	DEAD	--	--	3.0	--	2.5	3.0	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	4.0	3.5	4.0	3.5	--	DEAD	--	3.0	2.0	--	--
24 CC	--	--	--	--	--	--	--	DEAD	--	4.0	4.0	DEAD	--
25 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	3.0	4.0	--	--
27 FO	--	--	--	DEAD	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	1.0	--	--	--	--	--	--	DEAD
29 SE	1.0	--	--	1.0	3.0	4.0	--	--	4.0	--	--	2.5	DEAD
30 LS	--	--	--	--	--	--	--	--	3.0	--	--	--	--
31 FR	--	2.0	--	--	--	--	--	DEAD	--	--	--	3.0	--
32 GP	4.0	--	--	4.0	4.0	4.0	--	--	DEAD	--	4.0	2.0	DEAD
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	3.0	3.0	--	--
36 HT	1.0	--	--	DEAD	2.0	2.0	--	DEAD	3.5	--	3.0	--	DEAD
37 PE	--	--	--	--	--	--	--	--	2.5	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
42 PG	4.0	--	--	4.0	3.0	4.0	--	DEAD	4.0	--	3.0	--	--
43 PI	--	--	--	--	--	--	--	1.0	--	1.0	--	3.0	--
44 PJ	2.0	--	--	--	--	2.0	--	--	--	--	--	--	--

TWP	142	142	142	142	142	143	143	143	143	143	143	144	144
RNG	81	84	91	92	102	58	66	89	95	104	105	49	81
SEC	9	19	9	9	12	12	2	14	6	3	26	16	20
QTR	DD	CB	CC	AA	CC	AD	DA	AA	BD	CD	BA	BB	AA
ACC	0	297	222	2035	0	394	336	221	223	226	227	2363	244
YEAR	1968	1968	1967	1976	1968	1969	1968	1967	1967	1967	1967	1966	1967
HAB	5	3	4	4	4	1	2	4	4	4	3	3	3
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	--	DEAD	7	2	--	--	--	--	8	DEAD	7	--	5
5 AF	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
6 LC	--	11	28	DEAD	--	--	--	2	2	--	--	--	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	DEAD	--	--	--	--	--	--	--	--	--
10 LR	--	--	11	DEAD	--	--	--	DEAD	--	--	--	--	DEAD
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	2.0	--	--	--	2.5	--	--	--	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	2.0	1.0	DEAD	--	--	--	--	1.0	1.0	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	2.0	--	1.0	--	3.0	--	--	1.0	--	1.0	1.0	3.5
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	3.0	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	4.0	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	2.0	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	2.0	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	DEAD	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	--	--	--	2.5	--	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	--	--	3.5	--	--	--	--	3.0	--	1.0	--	--
32 GP	--	--	--	--	--	3.0	3.0	--	--	--	1.0	--	--
33 GC	--	--	--	--	--	--	2.5	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	3.0	--	--	--	--	--	--
35 HA	--	--	--	--	--	2.5	--	--	--	--	--	--	2.0
36 HT	--	--	--	--	--	2.5	2.0	--	--	--	--	2.0	--
37 PE	--	--	--	--	--	DEAD	DEAD	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	DEAD	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	DEAD	--	--	--	--	--	--	--
42 PG	--	--	--	--	--	4.0	2.0	--	--	--	--	4.0	4.0
43 PI	--	4.0	--	3.5	--	--	--	--	3.0	1.0	2.0	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	144	144	144	144	144	144	144	144	144	144	144	145	145
RNG	81	82	85	86	86	86	86	89	89	91	103	49	49
SEC	27	14	6	13	16	16	18	14	14	33	2	25	25
QTR	DD	CC	BA	AA	BA	BA	DD	CD	CD	AD	AA	AB	AB
ACC	243	0	216	242	224	2037	217	218	2036	219	0	133	1223
YEAR	1967	1968	1967	1967	1967	1976	1967	1967	1976	1967	1967	1966	1970
HAB	3	5	4	4	4	4	4	4	4	4	3	5	5
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	DEAD	4
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
3 QQ	--	--	--	--	--	--	--	--	--	--	--	DEAD	5
4 AG	DEAD	--	--	--	DEAD	DEAD	DEAD	3	5	58	--	2	14
5 AF	--	--	--	--	--	--	--	DEAD	DEAD	--	--	--	--
6 LC	--	--	DEAD	--	6	DEAD	--	3	14	20	--	2	5
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
9 LO	--	--	DEAD	--	DEAD	DEAD	--	2	DEAD	--	--	12	8
10 LR	--	--	DEAD	--	2	1	DEAD	2	2	2	--	111	19
11 LR	--	--	--	--	--	--	--	--	--	--	--	DEAD	1
12 PA	--	--	--	--	--	--	--	--	--	--	--	DEAD	1
13 PL	--	--	--	--	1	--	--	--	--	--	--	--	1
14 SL	--	--	--	--	--	--	--	--	--	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	--	--	--	--	--	--	--	3.0	--	--	--	--
18 PC	--	--	--	1.0	--	--	--	--	--	--	--	--	--
19 PC	--	--	--	--	--	3.5	--	--	4.0	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	DEAD	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	2.0	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	2.0	--	--	--	--	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	3.5	--	--	--	--	--	--	--	2.5	4.0	--	--	--
32 GP	2.0	--	--	--	--	--	--	--	DEAD	--	--	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	--	--	--	4.0	--	2.0	--	--	--	--	--	--	--
43 PI	1.0	--	--	--	--	4.0	--	1.0	3.0	--	--	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	145	145	145	145	145	145	145	145	145	146	146	146	146
RNG	58	58	64	94	94	94	94	94	102	49	49	50	51
SEC	10	10	11	25	28	28	33	33	12	11	15	34	20
QTR	BA	BA	BB	DC	DA	DA	CD	CD	AB	BD	DA	BD	DD
ACC	167	982	213	220	0	0	373	2034	0	135	102	101	100
YEAR	1966	1973	1967	1967	1969	1976	1969	1976	1968	1966	1966	1966	1966
HAB	5	5	3	4	1	1	1	1	4	5	4	4	4
SPEC													
1 AP	DEAD	17	--	--	--	--	--	--	--	DEAD	--	--	--
2 FF	DEAD	11	--	--	--	--	--	--	--	DEAD	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
4 AG	15	23	27	24	--	--	--	--	--	--	2	DEAD	3
5 AF	DEAD	DEAD	--	2	--	--	--	--	--	--	--	--	--
6 LC	1	45	DEAD	4	--	--	--	--	--	--	--	--	--
7 LC	1	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	2	1	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	DEAD	--	--	--	--	--	--	--	DEAD	--	--	--
10 LR	22	113	--	--	--	--	--	--	--	9	--	--	--
11 LR	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	2.0	--	--	--	--	--	--	--	4.0	--
15 ST	1.0	1.0	--	--	--	--	--	--	--	--	1.0	2.0	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	4.0	2.5	--	2.0	--	--	--	--	--	--	--	4.0	3.5
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	DEAD	--	--	--	--	--	--	--	--	--	DEAD	1.0
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
24 CC	--	3.0	--	--	--	--	--	--	--	--	2.0	2.0	3.0
25 PL	--	--	--	--	--	--	--	--	--	--	2.0	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	DEAD	--	--	--	--	--
28 SC	--	--	--	--	--	--	3.5	1.0	--	--	--	--	--
29 SE	--	--	--	--	--	--	--	1.0	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	4.0	--	--	--	--	--	--	--	--	--	3.0	--
32 GP	--	--	--	--	--	--	3.0	2.5	--	--	--	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	DEAD	--	--	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	--	2.0	--	--	--	--	--
38 PU	--	--	--	--	--	--	2.0	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	2.0	--	--	--	--	--
42 PG	--	2.0	--	2.0	--	--	3.5	4.0	--	--	3.5	3.0	--
43 PI	--	2.0	--	--	--	--	--	--	--	--	--	--	--
44 PJ	--	--	--	--	--	--	--	1.0	--	--	--	--	--

TWP	146	147	147	147	147	148	148	148	148	148	148	148	148
RNG	84	53	53	58	80	49	49	59	66	72	85	99	99
SEC	29	1	20	36	28	26	26	36	10	10	7	35	35
QTR	CD	CB	BC	DC	AB	AD	AD	AC	AA	DC	DD	DC	DC
ACC	0	0	99	163	0	134	2366	162	212	210	0	0	0
YEAR	1968	1966	1966	1966	1969	1966	1976	1966	1967	1967	1967	1968	1976
HAB	5	3	3	5	1	5	5	5	3	3	3	4	4
SPEC													
1 AP	--	--	--	DEAD	--	2	20	1	--	--	--	--	--
2 FF	--	--	--	--	--	--	16	--	--	--	--	--	--
3 QQ	--	--	--	--	--	6	34	--	--	--	--	--	--
4 AG	--	--	2	8	--	2	5	43	--	--	--	--	--
5 AF	--	--	DEAD	1	--	--	--	1	--	--	--	--	--
6 LC	--	--	DEAD	--	--	--	3	7	--	--	--	--	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	DEAD	--	16	96	--	--	--	--	--	--
10 LR	--	--	DEAD	12	--	83	61	20	--	--	--	--	--
11 LR	--	--	--	--	--	DEAD	10	--	--	--	--	--	--
12 PA	--	--	--	--	--	DEAD	17	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	--	--	--	--	--	2.5	--	--	--	--
15 ST	--	--	--	--	--	--	4.0	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	--	--	3.0	--	--	DEAD	3.0	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	--	--	--	--	--	3.0	2.0	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	--	2.0	--	--	2.0	3.0	--	--	--	--	--	--
32 GP	--	--	--	--	--	--	DEAD	--	1.0	4.0	--	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	--	--	3.5	--	--	--	--	--	3.0	3.0	--	--	--
43 PI	--	--	--	--	--	--	--	--	--	---	--	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	149	149	149	149	149	149	149	149	149	149	149	150	150
RNG	59	64	64	69	73	73	74	74	74	75	97	49	60
SEC	23	3	3	32	24	24	33	33	33	25	8	33	30
QTR	AA	CA	CA	CB	DC	DC	DA	DD	DD	BB	DB	CC	DA
ACC	150	161	981	211	143	980	350	151	351	349	324	132	142
YEAR	1966	1966	1973	1967	1966	1973	1968	1966	1968	1968	1968	1966	1966
HAB	5	4	4	3	4	4	1	1	1	1	3	5	4
SPEC													
1 AP	1	--	--	--	--	--	--	--	--	--	--	--	--
2 FF	1	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	7	17	43	--	1	--	--	--	--	--	10	--	30
5 AF	19	--	--	--	DEAD	--	--	--	--	--	--	--	DEAD
6 LC	2	DEAD	5	--	--	--	--	--	--	--	--	--	8
7 LC	1	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	DEAD	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	DEAD	--	--	--	--	--	--	--	--	--	--	2	--
10 LR	25	23	24	--	DEAD	--	--	--	--	--	--	16	32
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	1.0	2.0	2.0	--	--	--	--	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	4.0	2.0	--	--	--	--	--	--	--	--	--	--
17 SS	4.0	--	DEAD	--	--	DEAD	--	--	--	--	--	--	4.0
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	2.5	3.0	--	4.0	4.0	--	--	--	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	DEAD	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	4.0	DEAD	--	DEAD	DEAD	--	--	--	--	--	--	--
24 CC	--	2.5	3.0	--	2.0	--	--	--	--	--	--	--	3.0
25 PL	--	2.5	--	--	--	--	--	--	--	--	--	--	DEAD
26 AL	--	2.5	DEAD	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	2.5	--	--	--
29 SE	--	--	--	2.0	--	--	DEAD	3.0	--	2.5	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	2.0	3.0	--	--	--	--	--	--	--	1.0	--	--
32 GP	--	--	--	3.5	--	2.5	2.0	--	--	4.0	1.0	--	--
33 GC	--	--	--	--	--	--	--	--	--	2.5	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	2.0	1.0	DEAD	3.0	2.0	DEAD	--	--	--	1.0	--	--	--
37 PE	--	--	--	1.0	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	3.0	--	--	--
42 PG	2.0	DEAD	3.0	4.0	--	4.0	--	2.0	3.0	2.0	3.0	--	--
43 PI	--	--	--	--	--	--	--	--	--	--	1.0	--	--
44 PJ	--	--	--	3.0	--	--	--	--	--	--	--	--	--

TWP	150	150	150	150	150	151	151	151	151	151	151	151	151
RNG	62	65	67	71	104	50	50	60	68	69	70	96	96
SEC	22	2	2	20	18	2	15	29	7	17	29	27	27
QTR	CB	DD	CC	AD	DC	CB	AD	AD	CD	CC	BC	BA	BA
ACC	149	148	159	144	0	0	59	402	153	160	152	374	2033
YEAR	1966	1966	1966	1966	1968	1965	1965	1969	1966	1966	1966	1969	1976
HAB	4	4	4	4	5	5	5	1	4	4	4	1	1
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	13	4	131	--	--	--	--	--	DEAD	DEAD	DEAD	--	--
5 AF	DEAD	--	--	DEAD	--	--	--	--	--	--	--	--	--
6 LC	DEAD	DEAD	DEAD	--	--	--	--	--	--	--	--	--	--
7 LC	3	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	DEAD	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	--	--	--	--	--	--	--
10 LR	DEAD	50	8	--	--	--	18	--	DEAD	--	--	--	--
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	--	--	--	--	--	--	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	4.0	3.0	--	--	--	--	--	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	2.0	1.0	1.0	--	--	--	--	--	--	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	2.0	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	2.5	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	2.5	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
29 SE	2.5	--	--	3.0	--	--	--	--	--	--	--	DEAD	DEAD
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	2.0	--	--	--	--	--	--	--	--	--	--	--
32 GP	--	--	--	2.0	--	--	--	--	--	--	--	2.0	DEAD
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	1.0	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	1.0	--	2.5	--	--	--	--	--	--	--	1.0	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	4.0	3.0	--	4.0	--	--	--	DEAD	--	DEAD	--	--	--
43 PI	--	--	--	--	--	--	--	--	--	--	--	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	4.0	1.5

TWP	151	152	152	152	152	152	152	152	152	152	152	152	153
RNG	104	50	52	53	54	57	65	72	72	85	85	104	50
SEC	36	33	2	11	33	7	16	12	12	3	3	35	7
QTR	DA	AB	BC	CC	CB	CB	BA	BB	BC	AD	DD	CD	AA
ACC	321	58	0	70	69	953	401	0	396	381	380	0	57
YEAR	1968	1965	1965	1965	1965	1969	1969	1969	1969	1969	1969	1968	1965
HAB	3	5	4	4	4	2	1	1	1	1	1	5	5
SPEC													
1 AP	--	DEAD	--	--	--	--	--	--	--	--	--	--	DEAD
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
4 AG	10	--	--	76	5	--	--	--	--	--	--	--	--
5 AF	--	--	--	2	37	--	--	--	--	--	--	--	--
6 LC	--	--	--	--	4	--	--	--	--	--	--	--	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	DEAD	--	--	--	--	--	--	--	--	--	--	DEAD
10 LR	--	2	--	178	12	--	--	--	--	--	--	--	7
11 LR	--	DEAD	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	--	--	--	--	--	--	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	3.0	--	--	3.5	3.0	--	--	--	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	2.5	--	--	2.0	--	--	--	--	--	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	DEAD	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	1.5	--	--	--	--	--	--
29 SE	--	--	--	--	--	3.0	1.5	--	3.5	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	3.0	--	--	2.5	2.5	--	--	--	--	--	--	--	--
32 GP	2.0	--	--	--	--	--	--	--	1.0	DEAD	--	--	--
33 GC	--	--	--	--	--	2.5	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	DEAD	--	--	--	--	--	--	--
35 HA	3.5	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	3.0	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	2.5	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	3.5	--	--	3.0	4.0	--	--	--	4.0	--	--	--	--
43 PI	--	--	--	2.0	4.0	--	--	--	--	--	--	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	DEAD	--	--

TWP	153	153	153	153	153	153	153	153	153	153	153	154	154
RNG	64	64	77	81	90	90	92	97	102	102	102	51	51
SEC	18	18	5	3	27	36	30	14	19	20	20	12	23
QTR	CB	CC	DD	CC	CC	DD	BA	CD	AA	AB	BA	BB	CC
ACC	0	400	202	199	234	233	235	347	346	322	0	56	1000
YEAR	1969	1969	1967	1967	1967	1967	1967	1968	1968	1968	1968	1965	1965
HAB	1	1	3	4	3	3	3	3	1	1	1	5	4
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	--	--	2	1	DEAD	--	11	DEAD	--	DEAD	--	--	--
5 AF	--	--	4	--	--	--	3	--	--	--	--	--	--
6 LC	--	--	--	DEAD	--	--	--	--	--	DEAD	--	--	--
7 LC	--	--	DEAD	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	DEAD	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	--	--	--	--	--	--	--
10 LR	--	--	--	DEAD	--	--	--	--	--	8	--	42	--
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	--	--	--	--	--	--	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	2.0	--	--	--	--	--	--	--	--	--	--
17 SS	--	--	--	--	--	--	3.0	--	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	--	2.0	3.5	--	--	--	DEAD	--	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	1.0	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	2.0	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
29 SE	--	1.0	--	--	--	--	--	--	--	DEAD	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	--	--	--	--	--	--	--	2.0	3.0	--	--	--
32 GP	--	--	--	--	4.0	4.0	--	2.0	2.5	1.0	--	--	--
33 GC	--	--	--	--	2.5	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	2.5	--	2.0	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	--	1.0	--	--	--
37 PE	--	--	DEAD	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	--	--	--	3.0	4.0	3.0	4.0	2.5	4.0	2.0	--	--	--
43 PI	--	--	--	--	--	--	--	--	--	--	--	--	1.0
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	154	154	154	154	154	154	154	155	155	155	155	155	155
RNG	54	55	77	78	89	92	94	51	52	52	52	53	53
SEC	1	12	10	30	15	35	3	36	4	15	22	1	15
QTR	AA	AA	DA	CD	AD	BB	BA	CA	AB	BD	AA	CC	AA
ACC	154	42	201	200	961	236	237	55	45	405	327	44	170
YEAR	1966	1965	1967	1967	1967	1967	1967	1965	1965	1969	1968	1965	1966
HAB	4	4	4	4	3	3	4	5	4	1	1	4	4
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	33	2	56	4	--	DEAD	8	2	1	--	DEAD	18	14
5 AF	13	5	18	--	--	--	--	--	--	--	--	1	2
6 LC	29	2	10	2	--	--	--	--	--	--	DEAD	1	2
7 LC	3	1	35	--	--	--	--	--	--	--	--	--	1
8 SU	1	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	--	2	--	--	--	--	--
10 LR	6	3	62	7	--	--	1	56	--	--	--	--	1
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	4.0	--	--	--	--	--	--	--	--	--
15 ST	--	--	--	4.0	--	--	--	--	--	--	--	--	--
16 SS	--	--	3.0	--	--	--	--	--	--	--	--	--	--
17 SS	--	2.5	3.0	4.0	--	--	3.0	--	--	--	--	2.0	3.0
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	--	2.0	3.0	--	--	2.0	--	--	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	2.5	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	4.0	--	--	DEAD	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	3.0	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
29 SE	--	--	--	2.5	DEAD	--	--	--	--	DEAD	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	--	--	2.5	--	--	--	--	--	--	--	--	--
32 GP	--	--	--	--	--	--	DEAD	--	--	DEAD	--	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	3.0	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	--	--	--	--	--	--	DEAD	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	--	--	--	2.5	DEAD	3.5	3.5	--	--	DEAD	--	--	--
43 PI	--	2.0	3.0	--	--	--	--	--	--	--	--	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	155	155	155	155	156	156	156	156	156	156	157	157	157
RNG	56	77	82	83	51	51	65	84	85	101	50	51	52
SEC	36	24	20	18	2	27	4	5	2	13	6	8	8
QTR	BB	CC	CC	AC	AB	BB	CC	BA	BA	AA	DD	AA	DA
ACC	43	203	326	198	54	0	355	194	195	241	53	0	46
YEAR	1965	1967	1968	1967	1965	1965	1968	1967	1967	1967	1965	1965	1965
HAB	4	4	4	4	5	4	2	4	3	4	5	4	4
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	DEAD	--	--
2 FF	--	--	--	--	2	--	--	--	--	--	DEAD	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	DEAD	--	--
4 AG	186	5	2	36	--	--	--	DEAD	3	14	--	--	DEAD
5 AF	20	--	--	--	--	--	--	--	--	--	--	--	DEAD
6 LC	17	80	--	18	--	--	--	DEAD	--	2	--	--	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	DEAD	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	8	--	--	--	--	--	DEAD	--	--
10 LR	13	24	DEAD	90	14	--	--	--	--	2	90	--	DEAD
11 LR	--	--	--	--	2	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	DEAD	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	2.5	3.5	--	--	--	--	1.0	3.0	1.0	--	--	--
15 ST	--	4.0	4.0	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	3.0	2.5	3.5	4.0	--	--	--	--	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	2.0	4.0	4.0	2.0	--	--	--	1.0	3.0	3.5	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	1.0	2.0	--	--	--	--	--	--	1.0	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	1.0	--	--	--	--	1.0	--	2.5	--	--	--
24 CC	2.0	--	--	--	--	--	--	2.0	--	--	--	--	--
25 PL	--	2.5	DEAD	4.0	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	2.5	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	--	--	--	4.0	--	--	--	--	--	2.0
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	2.5	2.5	2.5	2.5	--	--	--	--	--	3.0	--	--	--
32 GP	--	--	2.0	4.0	--	--	--	3.0	--	3.0	--	--	--
33 GC	--	--	--	--	--	--	2.5	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	4.0	--	--	--	--	--
36 HT	2.5	--	2.0	--	--	--	1.0	--	--	--	--	--	--
37 PE	--	--	--	--	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	1.0	--	--	--	--	--	--
42 PG	3.0	2.5	4.0	4.0	--	--	--	4.0	4.0	4.0	--	--	4.0
43 PI	2.0	4.0	--	--	--	--	--	--	--	--	--	--	--
44 PJ	--	--	--	--	--	--	--	--	--	--	--	--	--

TWP	157	157	157	157	157	157	157	157	157	157	158	158	158
RNG	53	54	55	68	78	84	90	90	94	100	50	51	51
SEC	9	17	19	36	29	31	22	22	36	4	19	1	25
QTR	AA	DD	CA	CC	CD	CB	AB	DA	CD	CC	DC	DC	CA
ACC	0	39	40	398	0	197	0	0	238	240	51	50	52
YEAR	1965	1965	1965	1969	1967	1967	1969	1969	1967	1967	1965	1965	1965
HAB	3	3	3	2	3	3	1	1	4	4	5	5	5
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	DEAD	1	DEAD
2 FF	--	--	--	--	--	--	--	--	--	--	DEAD	--	DEAD
3 QQ	--	--	--	--	--	--	--	--	--	--	2	--	DEAD
4 AG	--	DEAD	DEAD	--	--	38	--	--	36	136	--	--	--
5 AF	--	24	1	--	--	--	--	--	--	--	--	--	--
6 LC	--	--	--	--	--	--	--	--	--	2	--	DEAD	2
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	--	--	--	--	DEAD	4	10
10 LR	--	DEAD	DEAD	--	--	--	--	--	1	--	34	26	44
11 LR	--	--	--	--	--	--	--	--	--	--	DEAD	--	DEAD
12 PA	--	--	--	--	--	--	--	--	--	--	DEAD	--	DEAD
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	--	--	--	3.0	--	--	--	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	2.0	--	--	--	--	--	--	3.0	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	--	--	--	--	4.0	--	--	2.0	2.0	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	--	--	--	--	--	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	4.0	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	--	--	--	4.0	--	--	--	--	--	--	--	--	--
30 LS	--	--	--	--	--	--	--	--	--	--	--	--	--
31 FR	--	DEAD	--	--	--	--	--	--	--	--	--	--	--
32 GP	--	--	--	3.5	--	--	--	--	--	2.0	--	--	--
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	3.5	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	--	1.0	--	--	--	--	--	--	--	--	--
37 PE	--	--	--	3.5	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	--	--	--	--	--	4.0	--	--	--	4.0	--	--	--
43 PI	--	--	--	--	--	--	--	--	--	--	--	--	--
44 PJ	--	--	--	3.0	--	--	--	--	--	--	--	--	--

TWP	158	158	158	158	158	158	158	158	159	159	159	159	159
RNG	54	56	58	74	76	85	86	93	50	51	51	51	76
SEC	28	9	10	36	14	36	29	19	6	13	13	24	20
QTR	BB	AD	AA	AA	DB	AA	DA	CD	AC	AA	AA	DD	DA
ACC	41	0	403	397	204	379	196	239	47	48	140	49	209
YEAR	1965	1965	1969	1969	1967	1969	1967	1967	1965	1965	1966	1965	1967
HAB	3	3	1	2	4	1	3	3	5	5	5	5	3
SPEC													
1 AP	--	--	--	--	--	--	--	--	DEAD	DEAD	2	DEAD	--
2 FF	--	--	--	--	--	--	--	--	DEAD	DEAD	DEAD	DEAD	--
3 QQ	--	--	--	--	--	--	--	--	1	2	DEAD	DEAD	--
4 AG	--	--	--	--	6	--	DEAD	20	--	--	5	--	DEAD
5 AF	DEAD	--	--	--	--	--	DEAD	--	--	--	--	--	--
6 LC	--	--	--	--	15	--	--	--	--	DEAD	1	2	DEAD
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	--	--	12	22	8	30	--
10 LR	--	--	--	--	114	--	--	--	85	513	97	424	DEAD
11 LR	--	--	--	--	--	--	--	--	11	10	1	DEAD	--
12 PA	--	--	--	--	--	--	--	--	DEAD	DEAD	--	DEAD	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	3.0	--	--	--	4.0	3.0	3.0	--	--	--	--	--	3.0
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	3.0	--	--	--	4.0	--	--	--	--	--	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	--	--	--	--	3.0	3.0	3.0	2.0	--	--	--	--	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	--	--	DEAD	--	--	DEAD	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	--	--	--	--	2.0	--	4.0	--	--	--	--	DEAD
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	2.0	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	DEAD	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	2.5	3.0	--	--	--	--	--	--	--
29 SE	3.0	--	3.0	4.0	--	3.0	--	--	--	--	--	--	3.0
30 LS	--	--	1.0	--	--	--	--	--	--	--	--	--	3.0
31 FR	3.0	--	--	--	--	--	--	--	--	--	--	--	--
32 GP	--	--	4.0	2.5	--	4.0	--	1.0	--	--	--	--	--
33 GC	--	--	--	2.5	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	2.5	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	2.0	2.5	--	1.0	--	--	--	--	--	--	DEAD
37 PE	--	--	DEAD	3.0	--	--	--	--	--	--	--	--	--
38 PU	--	--	--	--	3.0	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	DEAD	--	--	--	--	--	--	--	--	--
42 PG	3.0	--	--	--	3.0	3.0	4.0	1.0	--	--	--	--	4.0
43 PI	--	--	--	--	--	--	--	--	--	--	--	--	--
44 PJ	--	--	2.5	3.0	--	--	--	--	--	--	--	--	--

TWP	159	159	159	160	160	161	161	161	161	161	162	162	162
RNG	77	79	99	74	85	50	55	66	79	86	51	52	62
SEC	17	22	23	36	20	32	11	9	14	2	35	10	14
QTR	BA	BB	AA	BA	CB	DB	CC	BA	AA	CD	AA	AB	DD
ACC	205	232	376	208	378	68	136	337	206	193	139	137	404
YEAR	1967	1967	1969	1967	1969	1965	1966	1968	1967	1967	1966	1966	1969
HAB	4	3	1	3	1	5	4	2	4	4	5	4	2
SPEC													
1 AP	--	--	--	--	--	--	--	--	--	--	DEAD	--	--
2 FF	--	--	--	--	--	--	--	--	--	--	2	--	--
3 QQ	--	--	--	--	--	--	--	--	--	--	--	--	--
4 AG	159	DEAD	--	2	--	--	--	--	44	51	--	4	--
5 AF	--	--	--	--	--	--	DEAD	--	--	--	--	2	--
6 LC	1	--	--	--	--	--	--	--	--	1	--	2	--
7 LC	--	--	--	--	--	--	--	--	--	--	--	--	--
8 SU	--	--	--	--	--	--	--	--	--	--	--	--	--
9 LO	--	--	--	--	--	20	--	--	--	--	32	--	--
10 LR	57	--	--	DEAD	--	300	--	--	--	5	148	2	--
11 LR	--	--	--	--	--	--	--	--	--	--	2	--	--
12 PA	--	--	--	--	--	DEAD	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	2.0	--	3.0	--	--	--	--	--	DEAD	--	3.0	3.0
15 ST	--	--	--	--	--	--	--	--	--	--	--	1.0	--
16 SS	--	--	--	--	--	--	2.0	--	--	--	--	2.0	--
17 SS	--	--	--	--	--	--	--	--	--	4.0	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	3.0	--	--	4.0	--	--	--	--	--	1.0	--	3.0	--
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	--
21 PN	1.0	2.0	--	--	--	--	--	--	--	--	--	--	--
22 PV	--	--	--	--	--	--	--	--	--	--	--	--	--
23 VT	--	3.0	--	--	--	--	--	--	--	3.0	--	--	--
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	2.0	--	--	--	--	--	--	--	--	2.0	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	--	2.5	--	--	--	--
28 SC	--	--	--	--	4.0	--	--	--	--	4.0	--	--	--
29 SE	--	--	4.0	4.0	4.0	--	--	3.0	--	2.5	--	--	2.5
30 LS	--	3.0	4.0	--	--	--	--	4.0	--	--	--	--	4.0
31 FR	--	--	--	--	--	--	--	--	--	--	--	--	--
32 GP	--	4.0	2.0	4.0	4.0	--	--	1.0	3.0	3.0	--	DEAD	3.5
33 GC	--	2.5	--	--	--	--	--	--	--	--	--	--	--
34 AC	--	--	--	--	--	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	--	--	--	--	--	--	--	--	--
36 HT	--	--	4.0	2.0	--	--	--	3.0	--	--	--	--	3.5
37 PE	--	--	--	--	2.0	--	--	DEAD	--	--	--	--	3.0
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	DEAD	--	--	--	--	2.0
41 AH	--	--	--	--	--	--	--	2.5	--	--	--	--	2.5
42 PG	3.0	4.0	--	4.0	2.0	--	4.0	3.0	--	4.0	--	4.0	--
43 PI	--	--	--	--	--	--	4.0	--	--	1.0	--	--	--
44 PJ	3.0	4.0	4.0	--	--	--	--	--	3.0	--	--	--	3.0

TWP	162	162	162	162	163	163	163	163	163	163	163	163	163
RNG	70	70	75	103	51	51	53	55	56	57	71	72	73
SEC	8	8	8	14	4	18	3	22	29	29	10	16	30
QTR	CB	DA	CD	DD	DC	BC	BB	BB	CC	BC	DA	BA	AA
ACC	340	339	343	375	138	121	120	119	118	117	338	341	342
YEAR	1968	1968	1968	1969	1966	1966	1966	1966	1966	1966	1968	1968	1968
HAB	1	1	3	2	5	4	4	4	4	4	1	1	1
SPEC													
1 AP	--	--	--	--	2	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	DEAD	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	4	--	--	--	--	--	--	--	--
4 AG	--	--	--	--	--	6	2	--	12	1	--	--	--
5 AF	--	--	--	--	--	--	--	DEAD	4	1	--	--	--
6 LC	--	--	--	--	--	18	4	--	DEAD	--	--	--	--
7 LC	--	--	--	--	--	--	--	--	--	1	--	--	--
8 SU	--	--	--	--	--	--	--	--	3	DEAD	--	--	--
9 LO	--	--	--	--	8	--	--	--	--	--	--	--	--
10 LR	--	--	--	--	152	294	92	6	33	20	--	--	--
11 LR	--	--	--	--	--	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
14 SL	--	--	2.0	--	--	--	--	--	--	--	--	--	--
15 ST	--	--	--	--	--	--	--	--	--	--	--	--	--
16 SS	--	--	--	--	--	--	--	--	--	--	--	--	--
17 SS	--	--	--	--	--	--	--	2.0	--	2.0	--	--	--
18 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
19 PC	3.0	4.0	4.0	--	--	--	--	--	--	--	--	--	1.0
20 PF	--	--	--	--	--	--	--	--	--	--	--	--	1.0
21 PN	--	2.0	1.0	--	--	--	--	--	--	2.0	2.0	2.5	3.0
22 PV	--	--	1.0	--	--	--	--	--	--	--	--	--	--
23 VT	3.0	4.0	--	--	--	--	--	--	--	--	--	--	DEAD
24 CC	--	--	--	--	--	--	--	--	--	--	--	--	--
25 PL	--	--	--	--	--	--	--	--	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--	--	--	--	--	--
27 FO	--	--	2.5	--	--	--	--	--	--	--	--	--	--
28 SC	--	--	--	--	--	--	--	--	--	--	--	--	--
29 SE	3.0	2.0	DEAD	4.0	--	--	--	--	--	--	2.5	--	3.0
30 LS	2.0	2.0	2.5	--	--	--	--	--	--	--	3.5	2.0	3.5
31 FR	--	--	--	--	--	--	--	--	2.5	--	--	--	--
32 GP	4.0	4.0	--	--	--	--	--	--	--	--	DEAD	--	3.0
33 GC	--	--	--	--	--	--	--	--	--	--	--	--	2.5
34 AC	--	--	--	--	--	--	--	--	--	--	DEAD	--	--
35 HA	3.0	4.0	--	--	--	--	--	--	--	--	--	--	--
36 HT	3.5	DEAD	--	--	--	--	--	--	--	--	1.0	3.0	3.0
37 PE	--	DEAD	--	--	--	--	--	--	--	--	--	--	DEAD
38 PU	--	--	--	--	--	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--	--	--	--	--	DEAD
40 PC	--	--	--	--	--	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--	--	--	--	--	--
42 PG	3.0	3.0	4.0	2.0	--	--	--	--	--	--	3.0	3.5	2.5
43 PI	--	--	--	--	--	--	--	--	--	--	--	--	--
44 PJ	--	--	--	2.0	--	--	--	--	--	--	--	--	--

TWP	163	163	163	163	164	164	164	164
RNG	75	87	87	97	75	75	79	96
SEC	3	3	23	4	35	35	30	36
QTR	DA	BC	CD	AD	DA	DB	DC	DC
ACC	352	191	192	344	354	353	207	320
YEAR	1968	1967	1967	1968	1968	1968	1967	1968
HAB	1	4	4	3	1	1	4	3
SPEC								
1 AP	--	--	--	--	--	--	--	--
2 FF	--	--	--	--	--	--	--	--
3 QQ	--	--	--	--	--	--	--	--
4 AG	--	3	33	DEAD	--	--	--	7
5 AF	--	--	--	--	--	--	--	--
6 LC	--	5	13	--	--	--	DEAD	--
7 LC	--	--	--	--	--	--	--	--
8 SU	--	DEAD	--	--	--	--	--	--
9 LO	--	--	--	--	--	--	--	--
10 LR	--	DEAD	94	--	--	--	--	DEAD
11 LR	--	--	--	--	--	--	--	--
12 PA	--	--	--	--	--	--	--	--
13 PL	--	--	--	--	--	--	--	--
14 SL	--	4.0	4.0	DEAD	DEAD	--	--	DEAD
15 ST	--	3.0	--	--	--	--	--	--
16 SS	--	--	4.0	--	--	--	--	--
17 SS	--	4.0	4.0	--	--	--	--	--
18 PC	--	--	--	--	--	1.0	--	--
19 PC	4.0	4.0	3.0	--	DEAD	3.0	--	2.0
20 PF	--	--	--	--	--	--	--	--
21 PN	3.0	1.0	--	--	2.0	--	--	--
22 PV	--	--	--	--	DEAD	--	--	--
23 VT	2.5	--	--	DEAD	2.0	2.5	DEAD	DEAD
24 CC	--	--	--	--	--	--	--	--
25 PL	--	4.0	3.0	--	--	--	--	--
26 AL	--	--	--	--	--	--	--	--
27 FO	--	--	--	--	--	--	--	DEAD
28 SC	--	--	--	--	--	--	DEAD	--
29 SE	3.0	--	--	DEAD	--	--	4.0	--
30 LS	3.0	--	--	DEAD	--	2.5	--	--
31 FR	--	3.0	3.0	--	--	--	--	DEAD
32 GP	4.0	--	--	3.0	2.5	4.0	--	4.0
33 GC	--	--	--	--	--	2.5	--	--
34 AC	--	--	--	--	--	--	--	--
35 HA	--	--	--	--	3.0	4.0	--	--
36 HT	2.5	--	--	DEAD	--	3.0	--	DEAD
37 PE	DEAD	--	--	--	DEAD	DEAD	--	--
38 PU	--	--	--	--	--	--	--	--
39 PA	--	--	--	--	--	--	--	--
40 PC	--	--	--	--	--	--	--	--
41 AH	--	--	--	--	--	--	--	--
42 PG	2.5	3.0	3.0	2.0	DEAD	4.0	--	3.0
43 PI	--	1.0	2.0	--	DEAD	--	--	--
44 PJ	--	--	--	--	--	--	--	--

APPENDIX B

SELECTED ECOLOGICAL DATA FOR AQUATIC MOLLUSK SPECIES IN NORTH DAKOTA

APPENDIX B.--Selected ecological data for aquatic mollusk species in North Dakota.

Species	Sediment type[a]	Turbidity (JTU)	Specific conductance (mmhos/cm)	Total chlorides (mg/l)	Total alkalinity (mg/l)	pH	Hardness Calcium (mg/l)	Hardness Total (mg/l)	Iron (mg/l)	Total phosphates (mg/l)	Total sulfates (mg/l)	Total nitrites (mg/l)
1. A. plicata	1.0-8.0[b] 5.0±3.0 (21)	30-230 102±72 (12)	680-1390 940±260 (6)	7-36 23±7 (13)	188-425 285±77 (13)	7.7-8.8 8.2±0.3 (17)	110-150 134±14 (13)	225-330 261±29 (13)	0.05-0.75 0.38±0.23 (12)	0.25-1.70 0.89±0.40 (13)	- - - -	0.00-0.55 0.09±0.19 (8)
2. F. flava	1.0-8.0 5.0±2.0 (13)	30-169 80±57 (7)	775-1080 890±135 (4)	23-37 27±5 (7)	194-425 293±73 (7)	8.1-8.5 8.2±0.1 (10)	120-160 137±13 (7)	225-300 259±23 (7)	0.12-0.75 0.36±0.24 (7)	0.25-1.08 0.77±0.31 (7)	- - - -	0.00-0.55 0 16±0.26 (4)
3. Q. quadrula	1.0-8.0 3.0±3.0 (8)	185-240 213±26 (5)	680-1390 960±380 (3)	18-38 28±8 (5)	190-300 241±39 (5)	8.0-8.6 8.2±0.2 (7)	150-170 154±9 (5)	250-330 286±30 (5)	0.72-0.75 0.73±0.02 (2)	1.03-1.70 1.23±0.27 (5)	- - - -	0.01-0.01 0.01±0.00 (2)
4. A. grandis	1.0-9.5 6.0±2.0 (132)	2-200 68±51 (93)	680-3600 1800±815 (31)	2-160 25±24 (95)	188-1050 437±186 (95)	7.7-9.6 8.4±0.3 (102)	50-320 162±62 (83)	130-710 335±112 (95)	0.04-2.80 0 39±0.34 (84)	0.06-3.80 0 93±0.73 (84)	47-1300 416±262 (53)	0.00-1.02 0 08±0.16 (71)
5. A. ferussacianus	1.0-8.5 6.0±2.0 (38)	13-195 68±50 (29)	660-2750 1615±820 (5)	4-107 27±26 (29)	171-1020 368±168 (29)	7.7-8.9 8.2±0.2 (29)	50-300 174±67 (27)	130-600 315±118 (29)	0.12-2.80 0.43±0.52 (25)	0 06-1.20 0.57±0.33 (27)	47-1300 420±371 (10)	0 00-0.55 0.07±0.13 (23)
6. L. complanata	1.0-9.5 6.0±2.0 (86)	6-210 72±54 (56)	660-3150 1420±745 (18)	4-95 22±18 (57)	171-800 395±147 (57)	7.7-8.8 8.3±0.2 (63)	100-300 164±50 (52)	198-710 316±100 (57)	0.05-2.80 0.44±0.40 (52)	0.06-3.80 0.92±0.80 (52)	47-680 326±173 (31)	0.00-0.55 0.06±0.10 (43)
7. L. compressa	5.0-8.0 6.0±1.0 (10)	15-195 57±63 (7)	895[c]	10-28 19±6 (7)	210-475 349±99 (7)	8.1-8.8 8.3±0.2 (8)	120-220 154±36 (7)	200-370 276±57 (7)	0.05-0.31 0.18±0.10 (6)	0.40-1.50 0.89±0.35 (7)	47[c]	0.00-0.31 0.08±0.11 (7)
8. S. undulatus	1.0-8.0 6.0±2.0 (9)	18-66 47±20 (5)	775-895 835±85 (2)	14-28 22±5 (5)	250-400 304±58 (5)	8.1-8.3 8.3±0.1 (7)	130-220 160±37 (5)	250-390 290±60 (5)	0.20-0.42 0.26±0.09 (5)	0.25-0.95 0.65±0.25 (5)	- - - -	0.00-0 07 0.04±0.04 (4)
9. L. ovata	1.0-8.0 3.0±2.5 (26)	20-240 144±71 (22)	805-1390 1100±415 (2)	7-37 24±9 (22)	188-590 268±85 (22)	7.9-8.6 8.2±0.2 (24)	110-200 146±21 (22)	225-360 269±32 (22)	0.15-0.86 0.55±0.23 (18)	0.10-1 70 0.98±0.43 (22)	370[c]	0.00-0.55 0.07±0.17 (10)
10. L. radiata	1.0-9.5 5.0±2.5 (92)	2-240 92±70 (70)	740-3600 1570±890 (17)	4-58 20±10 (71)	188-960 341±160 (71)	7.7-9.4 8.3±0.3 (78)	60-300 154±50 (64)	200-710 309±91 (71)	0.04-0.95 0.41±0.26 (61)	0.10-3.80 1.03±0.69 (64)	47-1100 362±264 (20)	0.00-0.55 0.05±0.09 (46)
11. L. recta	1.0-8.0 3.0±3.0 (10)	150-240 190±46 (5)	680-1390 940±310 (4)	20-37 28±7 (5)	188-240 218±25 (5)	8.0-8.6 8.2±0.2 (8)	130-160 146±11 (5)	250-290 268±15 (5)	0.60-0 75 0.67±0.08 (3)	1.03-1.23 1.11±0 07 (5)	- - - -	0.01[c]
12. P. alata	1.0-8.0 4 0±3.0 (4)	- - - -	680-1390 960±380 (3)	- - - -	- - - -	8.5-8.6 8 6±0.1 (2)	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
13. P. laevissima	4.0-9.0 6 0±2.0 (6)	2-144 55±54 (5)	1850-3600 2430±795 (4)	7-35 17±11 (5)	260-720 429±196 (5)	8 5-8.7 8.6±0.1 (5)	110-180 140±36 (3)	250-630 440±151 (5)	0.04-0.58 0.28±0.22 (5)	0.10-1.51 0.59±0 80 (3)	250-725 444±180 (5)	0.03-0.08 0.05±0.03 (3)
14. S. lacustre	1.0-10.5 5.0±2.0 (43)	2-188 52±49 (26)	325-3150 1240±890 (14)	4-107 32±26 (28)	146-690 392±134 (28)	7.6-10.0 8.5±0.4 (29)	60-320 182±76 (18)	60-710 362±164 (28)	0.04-2.80 0.47±0.61 (19)	0.10-3.80 1.20±0.93 (19)	33-825 314±188 (21)	0.00-0.43 0.10±0.11 (15)
15. S. transversum	1.0-8.0 5.0±2 0 (18)	13-188 82±65 (9)	680-1390 925±265 (6)	20-95 39±24 (9)	200-450 366±82 (9)	8.0-8.6 8 3±0.2 (13)	110-320 220±85 (8)	160-600 384±166 (9)	0.20-0.88 0.41±0.26 (8)	0.61-1.90 1.08±0.44 (9)	210-330 283±64 (3)	0.00-0.17 0.06±0.06 (6)
16. S. simile	1.0-6.0 4 0±2.0 (10)	23-166 65±68 (4)	740-870 805±90 (2)	10-107 61±51 (4)	370-525 419±72 (4)	8.3-9.6 8.7±0.5 (6)	120-290 165±84 (4)	200-560 331±161 (4)	0.08-0.58 0.28±0.22 (4)	0.40-1.90 1.19±0.79 (4)	47-220 134±122 (2)	0.02-1.02 0.36±0.58 (3)

APPENDIX B.--Selected ecological data for aquatic mollusk species in North Dakota.--Continued.

Species	Sediment type[a]	Turbidity (JTU)	Specific conductance (mmhos/cm)	Total chlorides (mg/l)	Total alkalinity (mg/l)	pH	Hardness Calcium (mg/l)	Hardness Total (mg/l)	Iron (mg/l)	Total phosphates (mg/l)	Total sulfates (mg/l)	Total nitrites (mg/l)
17. *S. striatinum*	2.0-9.5 6.0±2.0 (68)	6-195 55±43 (49)	660-3150 1695±760 (17)	4-107 24±23 (49)	171-1020 438±193 (49)	7.7-9.6 8.4±0.4 (53)	50-320 169±69 (42)	130-710 337±126 (49)	0.08-2.80 0.37±0.43 (42)	0.10-3.80 0.86±0.74 (43)	47-1300 442±301 (27)	0.00-1.02 0.08±0.18 (41)
18. *P. casertanum*	4.0-6.0 5.0±1.0 (3)	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
19. *P. compressum*	1.0-10.5 6.0±2.0 (94)	2-132 40±32 (60)	405-3600 1465±895 (35)	2-103 23±21 (63)	170-1050 440±192 (62)	7.9-9.6 8.5±0 4 (70)	60-310 148±60 (41)	152-710 327±127 (63)	0.04-2.80 0.30±0.41 (47)	0.06-3.80 1.10±0.91 (42)	8-1100 335±232 (49)	0.00-1.02 0.10±0.18 (38)
20. *P. ferrugineum*[c]	1.0	- - - -	410	4	465	9.5	- - - -	200	- - - -	- - - -	86	- - - -
21. *P. nitidum*	1.0-10.5 5.0±2.5 (28)	2-67 23±17 (21)	405-2750 975±670 (18)	4-60 20±17 (22)	170-690 349±134 (22)	8.0-10.0 8.6±0.4 (26)	110-220 156±40 (9)	152-690 320±127 (23)	0.04-2.80 0.44±0 79 (11)	0.10-3.60 1.31±0.98 (10)	55-825 268±186 (20)	0.00-0.31 0.09±0.10 (10)
22. *P. ventricosum*[c]	8.0	2.0	1360	6	465	8.1	- - - -	690	- - - -	- - - -	352	- - - -
23. *V. tricarinata*	1.0-8.0 5.0±2.0 (25)	3-75 27±21 (16)	405-5000 1465±1660 (13)	4-103 26±26 (18)	170-1050 367±209 (19)	8.1-10.0 8.8±0.4 (23)	100-220 135±39 (11)	152-1340 338±257 (19)	0.04-0.42 0.13±0.11 (10)	0.10-1.90 1.09±0.59 (12)	55-1000 347±302 (12)	0.02-1.02 0.20±0.32 (10)
24. *C. cincinnatiensis*	2.0-8.0 5.0±2.0 (20)	15-195 66±52 (13)	485-895 765±135 (7)	8-95 28±21 (15)	170-800 377±161 (15)	7.9-9.2 8.5±0.3 (19)	60-320 174±100 (13)	152-600 332±161 (15)	0.08-0 43 0.23±0.11 (10)	0.35-2.50 1.00±0.59 (13)	73-224 160±78 (3)	0.00-0.43 0.09±0.15 (10)
25. *P. lacustris*	2.0-9.0 6.0±2.0 (19)	5-115 36±28 (16)	895-3600 2515±965 (6)	8-50 22±12 (16)	295-1020 494±194 (16)	8.0-9.2 8.4±0.3 (17)	50-320 150±73 (12)	130-710 369±162 (16)	0.08-2.80 0.45±0.68 (16)	0.10-3.80 1.64±1.09 (12)	180-1300 382±288 (14)	0.01-0.17 0.07±0.06 (11)
26. *A. limosa*	2.0-6.0 5.0±2.0 (5)	15-67 37±27 (3)	485-760 662±153 (3)	8-24 16±7 (4)	170-525 312±152 (4)	8.5-9.2 8.8±0.3 (5)	110-130 120±14 (2)	152-325 236±72 (4)	0.08-0.08 0.08±0.00 (2)	0.70-1.85 1.27±0.81 (2)	73-182 128±77 (2)	0.02-0.03 0.02±0.01 (2)
27. *F. obrussa*	2.0-10.5 6 0±3.0 (6)	2-14 8±8 (2)	450-1360 965±465 (3)	6-8 7±1 (2)	465-690 578±159 (2)	8.1-8.3 8.2±0.1 (2)	200[c]	440-690 565±177 (2)	0.42[c]	0.10[c]	352-590 471±168 (2)	0.04[c]
28. *S. caperata*	1.0-8.5 3.0±2.0 (18)	13-140 68±53 (8)	300-12750 2235±3410 (13)	2-73 19±20 (10)	162-705 356±176 (10)	7.6-8.9 8 4±0.4 (12)	130-250 173±67 (3)	85-390 250±94 (10)	0.08-0.57 0 26±0.27 (3)	1.13-3.80 2.14±1.45 (3)	7-850 253±279 (7)	0.00-0.16 0.06±0.08 (3)
29. *S. elodes*	1.0-8.0 3.0±2.0 (53)	3-140 41±32 (31)	293-12750 1940±2485 (39)	2-182 34±47 (34)	110-705 366±153 (34)	7.6-9.8 8.7±0.5 (42)	60-280 133±71 (9)	40-1450 340±314 (35)	0.05-0 25 0.16±0.09 (6)	0.23-2.70 1.35±0.68 (8)	7-3300 366±657 (27)	0.02-0.31 0 12±0.10 (7)
30. *L. stagnalis*	1.0-10.5 4.0±2.5 (17)	2-36 18±12 (10)	400-1460 785±370 (12)	4-60 21±21 (10)	176-465 310±85 (10)	8.1-10.0 8.8±0.5 (13)	90-110 100±14 (2)	138-690 322±158 (11)	0.04-0 11 0.07±0.05 (2)	0.48-0.88 0.68±0.28 (2)	55-405 201±123 (10)	0.01-0.06 0.03±0.04 (2)
31. *F. rivularis*	1.0-9.5 6.0±2.0 (67)	6-200 63±48 (45)	605-3150 1670±825 (25)	2-94 23±18 (45)	156-850 453±182 (45)	7.9-9 3 8.4±0.3 (52)	50-320 174±66 (33)	122-710 338±122 (45)	0.08-2.80 0.44±0.45 (38)	0.06-2.60 0.88±0.70 (34)	78-2600 441±433 (34)	0.00-1.48 0.12±0.28 (32)
32. *G. parvus*	1.0-9.0 4.0±2.0 (85)	3-140 48±36 (47)	300-5000 1465±1190 (57)	2-74 20±19 (54)	110-1050 404±206 (53)	7.6-10.0 8.6±0.5 (67)	50-360 146±72 (21)	40-1340 298±218 (54)	0.04-0.95 0.28±0.21 (20)	0.06-2.70 0.83±0.74 (21)	8-2600 364±439 (44)	0.00-1.48 0.16±0.35 (18)

APPENDIX B.--Selected ecological data for aquatic mollusk species in North Dakota.--Continued.

Species	Sediment type[a]	Turbidity (JTU)	Specific conductance (mmhos/cm)	Total chlorides (mg/l)	Total alkalinity (mg/l)	pH	Hardness Calcium (mg/l)	Hardness Total (mg/l)	Iron (mg/l)	Total phosphates (mg/l)	Total sulfates (mg/l)	Total nitrites (mg/l)
33. *G. circumstriatus*	1.0-6.0 3.0±2.0 (9)	23-118 55±40 (5)	293-4650 1500±1610 (7)	4-73 30±29 (6)	196-705 372±197 (5)	7.6-10.0 8.7±0.9 (7)	110[c]	200-370 288±69 (6)	0.04[c]	0.48[c]	80-850 300±286 (6)	0.06[c]
34. *A. crista*	1 0-4.0 2.0±1.5 (3)	11-40 26±20 (2)	435-4650 1940±2350 (3)	3-10 6±5 (2)	110-374 242±187 (2)	7.6-8.5 8.1±0.5 (3)	- - - -	194-226 210±23 (2)	- - - -	- - - -	80-126 103±32 (2)	- - - -
35. *H anceps*	1.0-9.5 6.0±2.0 (19)	9-195 48±56 (10)	461-1870 765±470 (8)	4-26 14±8 (11)	170-1020 430±275 (11)	8.1-9.2 8.7±0.4 (15)	50-170 111±36 (7)	130-300 226±50 (11)	0.05-0.68 0 24±0.23 (6)	0.35-1.50 0.97±0.39 (7)	55-1300 326±409 (8)	0.02-0.43 0.17±0.16 (7)
36. *H. trivolvis*	1.0-8.0 3.5±2.0 (42)	3-140 44±38 (24)	293-5000 1185±1205 (32)	3-168 26±35 (27)	110-705 354±174 (26)	7.6-9.8 8.5±0.5 (34)	60-130 99±28 (7)	60-660 250±129 (27)	0.08-0.15 0.12±0.04 (3)	0.52-2.00 1 14±0.59 (7)	7-1150 233±292 (19)	0.02-0.12 0.05±0.04 (6)
37. *P. exacuous*	1.0-6.0 2.5±2.0 (13)	11-140 47±40 (9)	325-1500 880±420 (11)	2-48 14±15 (11)	110-544 304±144 (11)	7.6-8.9 8.1±0.5 (8)	95[c]	60-460 221±111 (11)	- - - -	- - - -	7-405 139±124 (9)	- - - -
38. *P. umbilicatellus*	1.0-4.0 2.0±2.0 (3)	40-140 90±71 (2)	300-1190 745±445 (3)	10-16 13±4 (2)	374-542 458±119 (2)	7.6-7.9 7.8±0.2 (2)	- - - -	85-226 156±100 (2)	- - - -	- - - -	80-120 100±28 (2)	- - - -
39. *P. armigera*	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
40. *P. campestris*[c]	1.0	36	900	39	324	- - - -	- - - -	270	- - - -	- - - -	126	- - - -
41. *A. hypnorum*	1.0-4.0 2.0±1.0 (8)	23-118 54±40 (5)	293-3900 1325±1120 (10)	2-73 25±27 (6)	196-705 342±186 (6)	7.8-8.9 8 6±0.4 (8)	- - - -	152-360 256±77 (6)	0.08[c]	- - - -	8-850 289±328 (5)	- - - -
42 *P. gyrina*	1.0-10.5 5.0±2.0 (117)	2-137 46±34 (67)	300-8000 1480±1465 (52)	2-182 27±32 (73)	116-1050 435±206 (72)	7.6-10.0 8.6±0.5 (90)	50-360 159±81 (44)	40-1450 329±226 (73)	0.04-0 70 0.23±0 15 (41)	0.10-3.80 1.09±0.87 (45)	8-3300 426±515 (51)	0 00-1.02 0.10±0.20 (40)
43. *P. integra*	1.0-9.0 6.0±2.0 (66)	2-195 63±52 (46)	605-3600 1815±840 (27)	2-2185 68±320 (46)	156-850 412±179 (46)	7.9-9.3 8.4±0.3 (51)	50-600 190±104 (31)	122-1050 366±176 (46)	0.04-2 80 0.42±0.45 (38)	0 06-1.90 0.65±0.55 (31)	47-2600 431±432 (35)	0.00-1.48 0.12±0.30 (27)
44. *P. jenessi*	1 0-6.0 2.5±2.0 (22)	11-140 40±35 (15)	375-32000 3295±7430 (18)	2-3500 221±820 (18)	110-660 330±164 (18)	7.6-10.0 8.7±0.6 (17)	95-160 122±34 (3)	40-4320 538±1004 (18)	0.04-0.08 0.06±0.03 (2)	0.04-3.60 2.04±2.21 (2)	7-3300 409±838 (15)	0.06-0.06 0.06±0 0 (2)

[a] Estimated predominant bottom sediment at collecting sites (not necessarily the sediment in which a species was found), given by the following numbers; a 0.5 value indicates a mixture of two adjacent sediment types:

1.0 = mud	6.0 = gravelly sand
2.0 = sandy mud	7.0 = muddy gravel
3.0 = gravelly mud	8.0 = sandy gravel
4.0 = muddy sand	9.0 = pebble gravel
5.0 = sand	10.0 = cobble gravel
	11.0 = boulder gravel

[b] Uppermost numbers are the range, middle numbers are the mean and standard deviation, and the lowest number (in parentheses) is the number of observations for the species.

[c] Ecological data only from a single site.

PLATES 1-6

Plate 1

MUSSELS

(All figures X½ unless otherwise noted.)

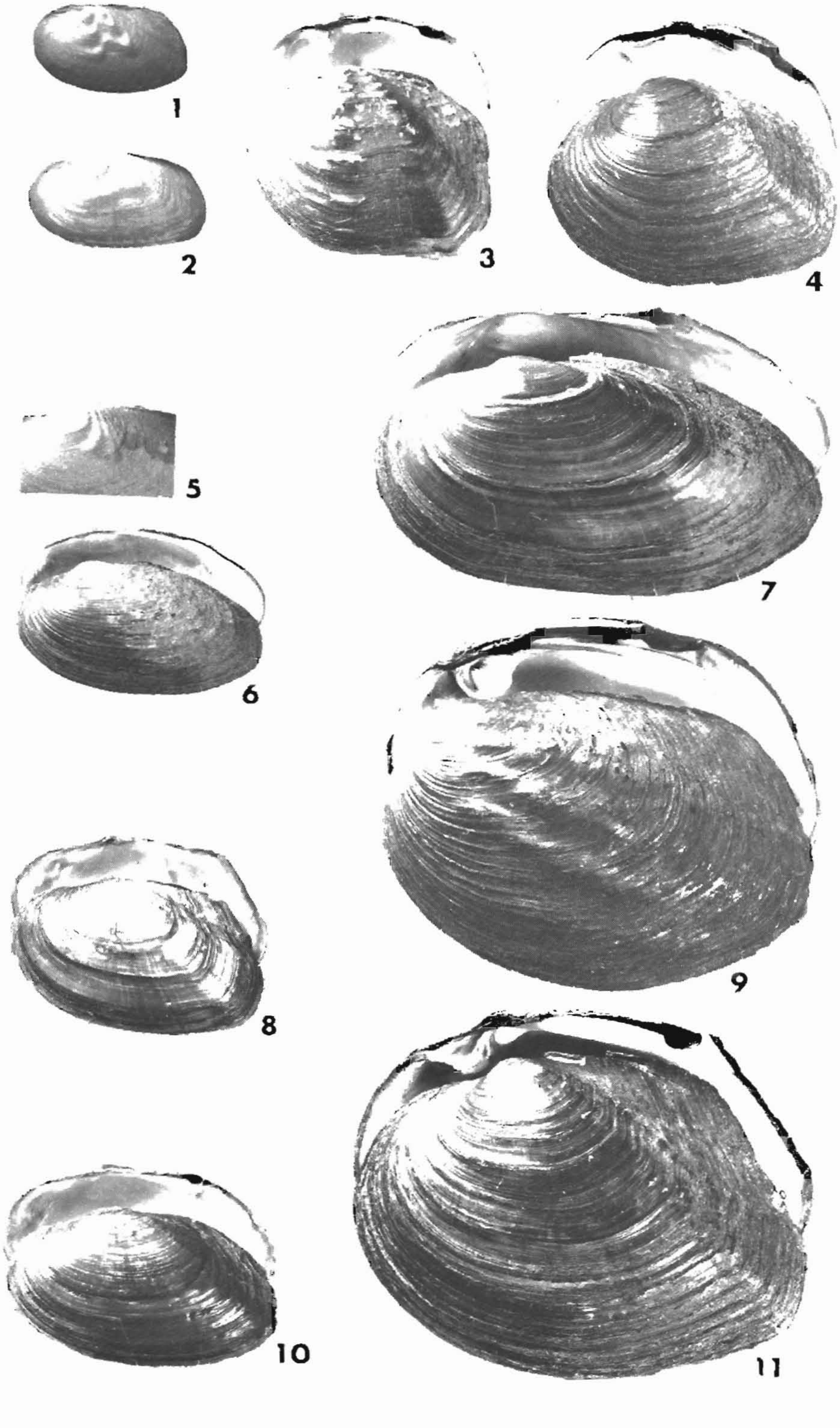
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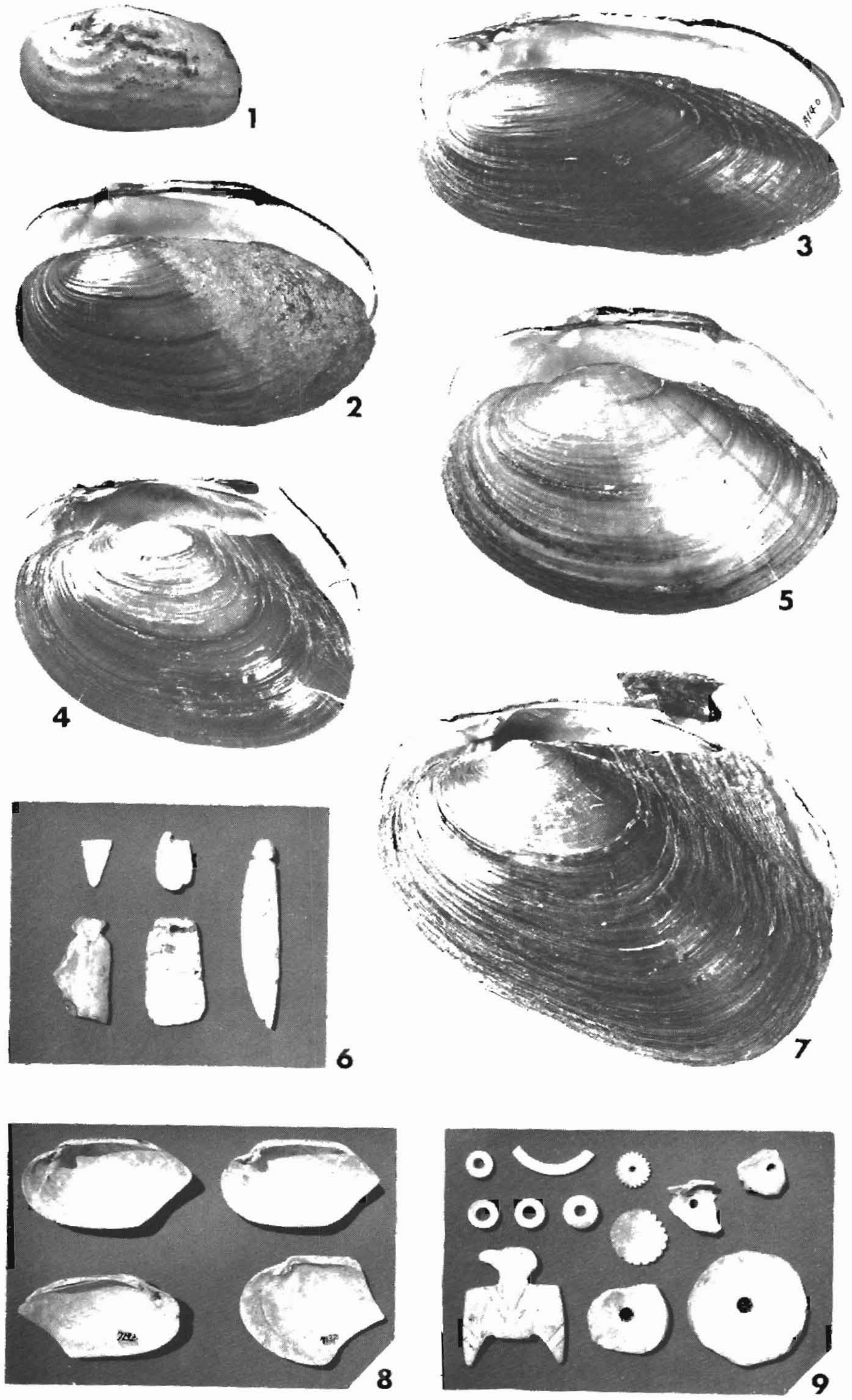
Plate 2

MUSSELS
(All figures X½ unless otherwise noted.)

Mussel shell pendants (6), scrapers (8), and ornaments (9).
In figure 8, shells are of Lampsilis radiata except for Lasmigona complanata in lower right. Manufactured by native North Americans; in collection of State Museum, Bismarck, North Dakota.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PILL CLAMS

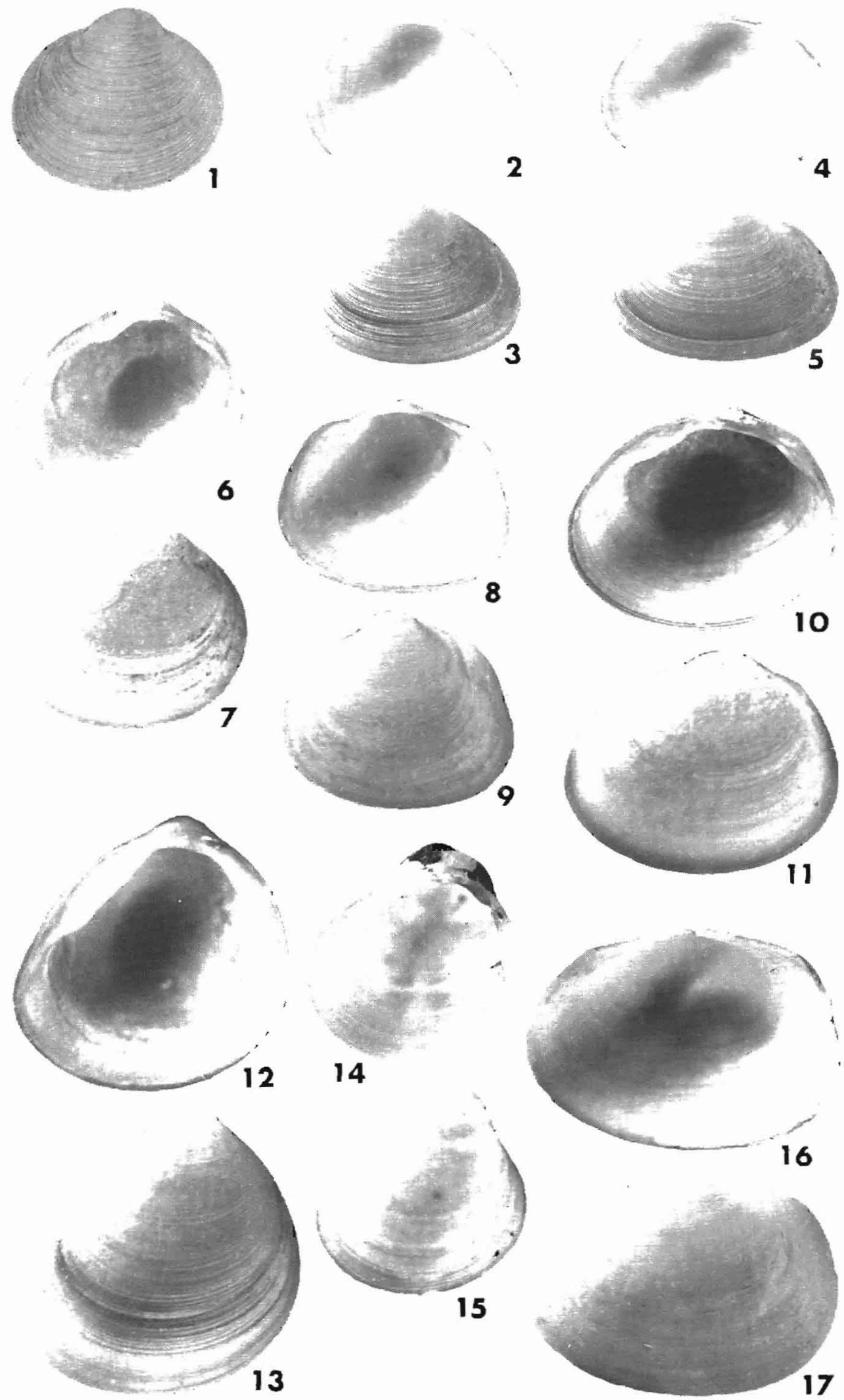
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Plate 4

CONISPIRAL SNAILS

Page

Fossaria obrussa. 1.
Spiral sculpture absent; columella not twisted (X2; UND 13020) 65

Stagnicola elodes. 2, 3, 8.
Spiral sculpture of ridges and striae, malleations (fig. 2) may be present; columella twisted (2, X1, UND 13025; 3, X1, UND 13023; 8, X2, 13024) 68

Physa gyrina. 4, 5.
Coiling sinistral; no shoulder where last whorl meets spire; spiral striae conspicuous; reddish band on inside of outer lip (4, X2, UND 13041; 5, X2, UND 13042) 81

Physa jennessi. 6.
Similar to *P. gyrina* but smaller, apex blunt, spiral striae inconspicuous, and reddish band absent (X5, UND 13044) 83

Campeloma decisum. 7.
Shell thick; whorls flatly rounded; umbilicus absent (X1, Nat. Mus. Canada 45781) 83

Aplexa hypnorum. 9.
Coiling sinistral; whorls flatly rounded; surface glossy; spiral striae absent (X2, UND 13040) 80

Physa integra. 10.
Similar to *P. gyrina* but smaller, with conspicuous shoulder where last whorl meets spire, spiral striae inconspicuous, and whitish band on inside of outer lip (X4, UND 13043) 82

Lymnaea stagnalis. 11, 16, 17.
Similar to *S. elodes* but larger, last whorl expanded, and spire whorls relatively flat-sided (X1; 11, UND 13028; 16, UND 13026; 17, UND 13027) 69

Valvata tricarinata. 12.
Broadly conispiral; prominent carinae (X10, UND 13016) 61

Probythinella lacustris. 13.
Narrowly conical; apex truncate; umbilicus narrow (X10; UND 13017) 63

Amnicola limosa. 14.
Broadly conical; apex blunt; umbilicus wide (X10; UND 13019) 64

Cincinnatia cincinnatiensis. 15.
Similar to *A. limosa* but apex pointed and whorls notably shouldered (X10; UND 13018) 62

Stagnicola caperata. 18, 19.
Spiral sculpture of periostracal ridges within striae; columella not twisted (X4; 18, UND 13021; 19, UND 13022) 66

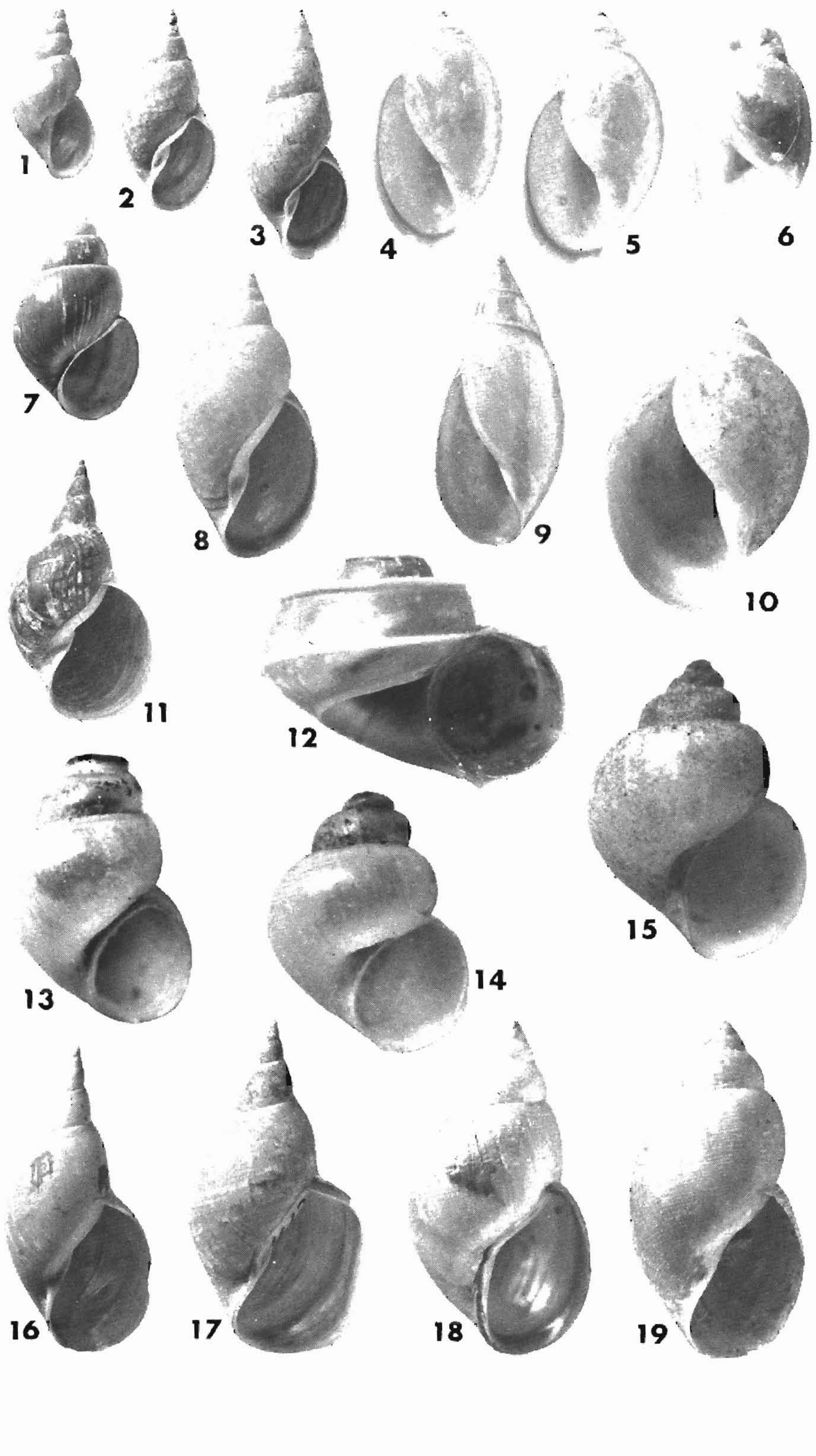
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Plate 5

PLANISPIRAL SNAILS

		Page
Helisoma trivolvis. 1, 2, 3.		
	Umbilicus narrow; outer lip reflected (X1, UND 13035)	75
Armiger crista. 4, 5, 6, 7.		
	Small (up to 3 mm wide); flattened on right side, rounded on left; costae parallel to growth lines, may be inconspicuous (fig. 7) (X10; 4-6, UND 13032; 7, UND 13033)	73
Helisoma anceps. 8, 9, 10.		
	Similar to *H. trivolvis* but smaller, umbilicus wide, and with conspicuous carinae (X2, UND 13034)	75
Gyraulus circumstriatus. 11, 12, 13.		
	Whorls gradually enlarging, subcircular in cross section; spiral sculpture usually distinct; last whorl not deflected toward left side (X10, UND 13031)	72
Gyraulus parvus. 14, 15, 16.		
	Similar to *G. circumstriatus* but whorls abruptly enlarging and oval in cross section, spiral sculpture indistinct, and last whorl deflected toward left side (X10, UND 13030)	71

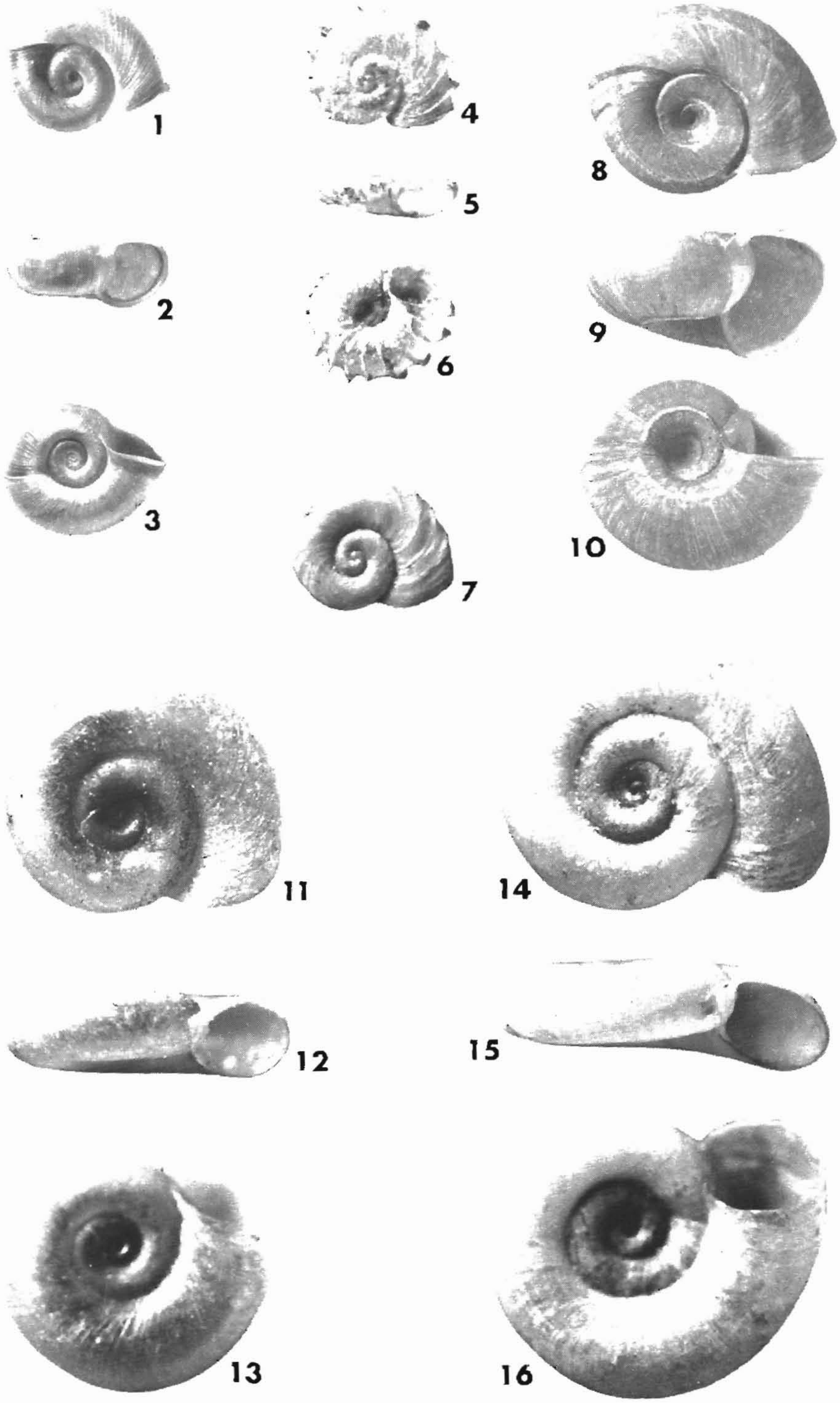
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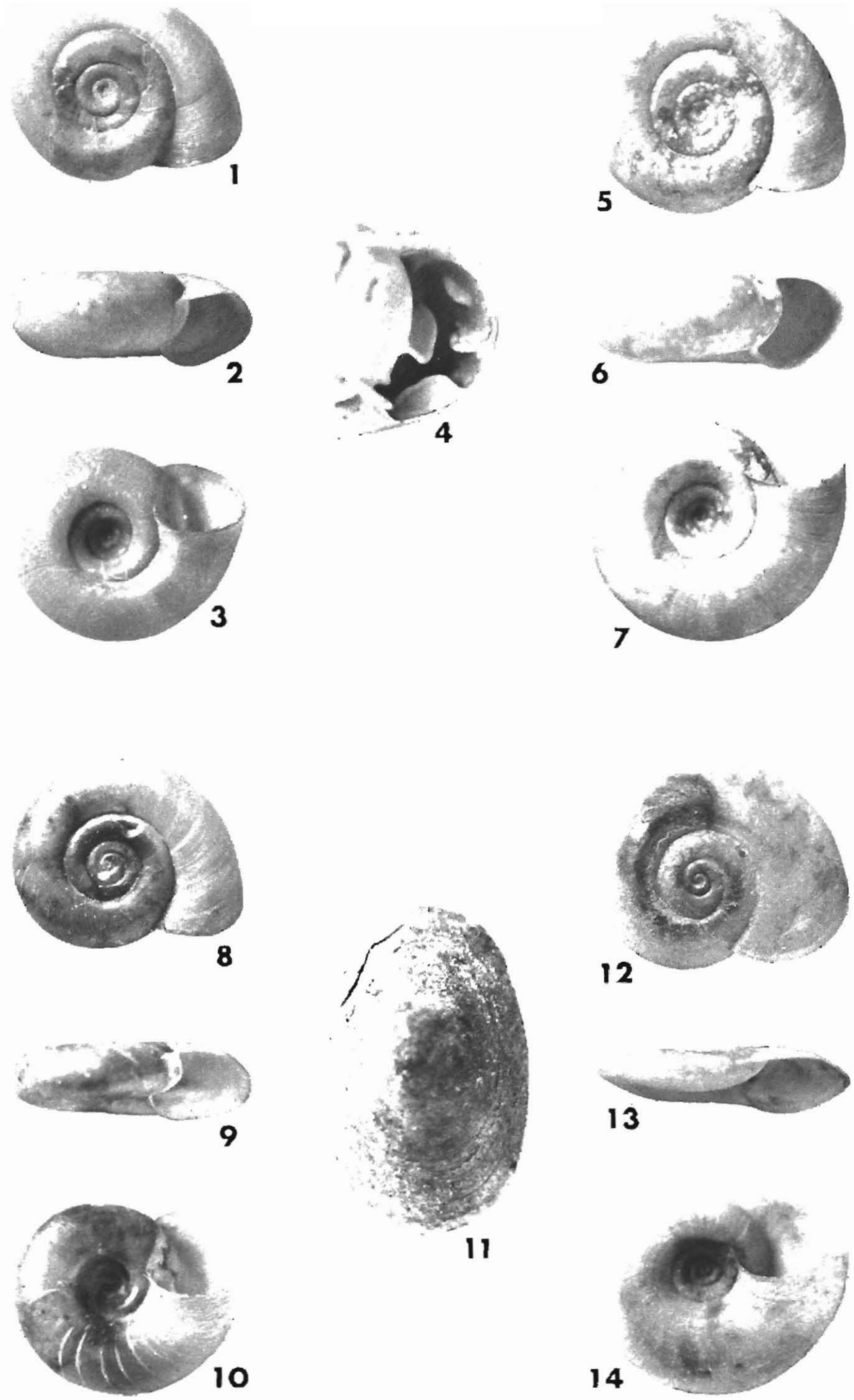
Plate 6

PLANISPIRAL AND CAP-SHAPED SNAILS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