The ecology, distribution, and identification of native freshwater mussels (Unionidae) of Manitoba

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ABSTRACT

Hnytka, S.M., Watkinson, D.A., Enders, E.C, Friesen, C, Murray, C., and Church, C. 2022. The ecology, distribution, and identification of native freshwater mussels (Unionidae) of Manitoba. Can. Tech. Rep. Fish. Aquat. Sci. 3435: viii + 63 p.

Freshwater mussels of the Unionidae family are a diverse group of bivalves that live in rivers and lakes. Though widely distributed in Manitoba, mussels are poorly known by the general public. This report provides insight into the life cycle and critical roles played by mussels in freshwater ecosystems. This report further provides tools for species identification including a dichotomous key, colored shell images, and distribution maps. Current threats in Manitoba include aquatic invasive species and various anthropogenic activities that result in declining water quality and habitat degradation for mussels. Understanding current and future threats allows for better informed management decisions and conservation strategies for freshwater mussels in Manitoba.

RÉSUMÉ

Hnytka, S.M., Watkinson, D.A., Enders, E.C., Friesen, C., Murray, C., and Church, C. 2022. The ecology, distribution, and identification of native freshwater mussels (Unionidae) of Manitoba. Can. Tech. Rep. Fish. Aquat. Sci. 3435: viii + 63 p.

Les moules d’eau douce sont un groupe diversifié de bivalves qui vivent dans les rivières et les lacs. Bien qu'elles soient largement réparties au Manitoba, les moules sont relativement inconnues du grand public. Ce rapport donne un aperçu du cycle de vie et des rôles critiques joués par les moules dans un écosystème d’eau douce. En plus, ce rapport fournit des outils pour l’identification des espèces notamment une clé dichotomique, des images colorées de coquilles et des cartes de répartition. Les menaces actuelles comprennent les espèces aquatiques envahissantes et diverses activités anthropiques qui entraînent une baisse de la qualité de l’eau et une dégradation de l’habitat des moules. Comprendre les menaces actuelles et futures peut permettre de prendre des décisions de gestion et des stratégies de conservation mieux éclairées pour les moules d’eau douce au Manitoba.

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1.0 INTRODUCTION

Unionid freshwater mussels are a highly diverse group of aquatic invertebrates, with ~840 extant species found on all continents excluding Antarctica (Graf and Cummings 2007). The United States has the highest diversity in North America, with 298 species (Williams *et al*. 1993; Williams *et al.* 2017). Historically, freshwater mussels dominated the benthic biomass in many undisturbed rivers in North America. However, current research indicates that most populations have declined drastically (Williams *et al*. 1993). Due to threats from habitat alteration, water quality deterioration, and invasive species, freshwater mussels are considered one of North America's most imperiled groups of aquatic organisms with approximately 72% of species now threatened, endangered, or of special concern (Williams *et al.* 1993; Strayer *et al.* 2004). In 1994, COSEWIC (Committee on the Status of Endangered Wildlife in Canada) expanded its mandate and a subcommittee was subsequently established to assess the status of molluscs, including freshwater mussels (Cook and Muir 1984; COSEWIC 2021).

Freshwater mussels are a critical component of healthy riverine and lacustrine ecosystems and are ecosystem engineers because they are filter feeders and modify the surrounding habitat (Spooner and Vaughn 2006). Freshwater mussels engineer hydrodynamic processes in the benthic habitat (Sansom 2019), and are responsible for bioturbation of sediment and biodeposition of feces and pseudofeces which promote nutrient turnover and habitat enrichment (Vaughn *et al*. 2004). Local sediment enrichment stimulates productivity throughout different trophic levels, and influences the distribution and abundance of other benthic invertebrates and periphyton (Spooner and Vaughn 2006). Within the food web, mussels are prey for a variety of fish, mammal, and bird species (Cummings and Bogan 2006). Freshwater mussels can serve as an indicator of water quality and overall ecosystem health because of their significant water filtration capabilities.

Aside from an economic value, freshwater mussels have spiritual and artistic values, particularly for Indigenous people, and are used in ceremonies and gatherings (Classen 2008), and for pottery and jewelry creating (Vaughn 2018). Manitoba allowed licenses to harvest mussels in 1991 in the Assiniboine River (Scaife and Janusz 1992). Thick shelled mussel species such as the Threeridge (*Amblema plicata*) were commercially targeted and harvested to produce seed pearls for the Asian pearl industry (Pip 1995). The harvesting had unforeseen negative impacts on habitat quality, non-target mussel species, and smaller individuals of the targeted species; there were also concerns about illegal harvesting (Pip 1995).

2.0 BIOLOGY

2.1 TAXONOMY

Mussels are invertebrates in the class Bivalvia, which includes freshwater and marine molluscs. In Manitoba, there are native mussel species from the family Unionidae and Sphaeriidae. The Sphaeriidae include Fingernail and Pea clams that are native to the province but are not discussed in this report. Another freshwater mussel that now occurs in Manitoba is the invasive Zebra Mussel (*Dreissena polymorpha*), however, these are from the family Dreissenidae (Figure 1).

Figure 1. Zebra Mussel (*Dreissena polymorpha*).

2.2 MORPHOLOGY

Unionid mussels are an evolutionary diverse group that play important roles in shallow water ecosystems (Pechenik 2014). Filter feeding and an obligatory larval parasitic life stage have influenced internal and external morphological characteristics.

2.2.1 Internal Morphology

Mussels are efficient filter feeders, capable of filtering one liter of water every 45 min (Cummings and Bogan 2006). Filter feeding is an essential process for acquiring food, oxygen, and gametes; as well as excreting waste and dispersing gametes (Haag 2012). Common to bivalves, oxygenated water enters the mantle in a unidirectional current through the incurrent siphon where it is transported over the gills, allowing for gas exchange. Deoxygenated water exits the mantle cavity posteriorly and is expelled through the excurrent siphon. Mussels are omnivorous - feeding on particles under 20 μm in size including phytoplankton, zooplankton, bacteria, rotifers, fungal spores, and detritus (Vaughn *et al*. 2008). Suspended particles in the water are picked up by gill cilia, which also help generate water currents. The particles are sorted by size and nutritional value as they are transported to the food groove and the labial palps (McMahon and Bogan 2001). The food particles continue to the mouth, through the esophagus and into the stomach where digestion occurs (Pechenik 2014). The non-food particles are bound in mucus and released into the mantle cavity where they begin accumulating (Haag 2012). Periodically, the excess water and non-food particles are expelled via rapid valve closure through the incurrent siphon as pseudofeces creating food for other aquatic invertebrates (Vaughn and Hakenkamp 2001).

Although mussels in their adult life-stage are sedentary species, the muscular foot is important for pedal feeding for juveniles, movement, burying, and staying in place. It is extended by contracting and relaxing various muscles including the anterior and posterior adductor muscles and hinge ligament (Coker *et al*. 1921). A jet of water forced out from the pedal gape allows the foot to pull the shell forward creating small movements (McMahon and Bogan 2001). These movements help defend against predation, and allow mussels to reorient themselves in high water currents (Haag 2012). Epibenthic invertebrates such as mussels spend most of their adulthood partially or fully buried in benthic sediment (Vaughn *et al.* 2008). Siphons are tubular extensions protruding from the mantle cavity, extending beyond the shell allowing water intake when the mussel is covered in sediment (Pechenik 2014). In addition to the internal morphology described above, the central body mass includes a heart, kidney, liver, reproductive organs, intestine, rectum, and anus (Schainost 2016).

2.2.2 External Morphology

Shell structure

Shell structure is the defining characteristic of class Bivalvia; it is comprised of a two-valved shell and a laterally flattened body (Pechenik 2014). Shells protect the vulnerable inner body mass from the harsh external environment (Haag 2012). Several shell features are helpful for identifying species.

The two valves are held together by ligaments that form a hinge on the dorsal end (Figure 2). Contraction and relaxation of the adductor muscles are responsible for opening and closing the shell (Haag 2012). Adductor muscle scars can be found on the internal portion of shell specimens (Figure 2). Hinge teeth (i.e., pseudocardinal and lateral teeth) interlock, working together to keep the valves in proper alignment (Figure 2). Between the two sets of teeth is the beak, also referred to as an umbo, that is curved anteriorly and projects dorsally. The beak is the oldest part of the shell, and the beak cavity ranges in depth. (McMahon and Bogan 2001).

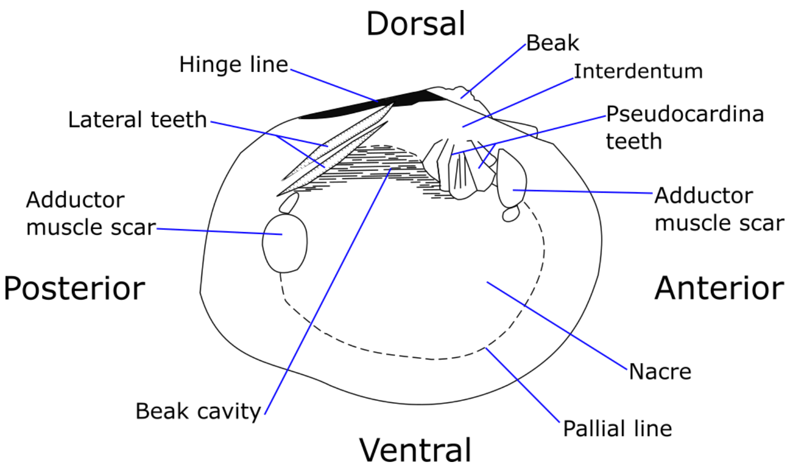

Figure 2. Internal shell structure.

The anterior end of the shell is commonly round and smooth, while the posterior end can have sculptures including plications, spines, bumps or nodules (Figure 3). The posterior portion of the shell may also have a posterior ridge, a groove (furrow or sulcus), or a projection that may extend into a wing in some species. Around 20% of North American freshwater mussels have some kind of shell sculpture as adults (Haag 2012). Beak sculptures are more common and are deposited on the beak during the first few months of growth. Beak sculptures appear as raised lines (i.e., single or double looped); but it is common for them to be partially or completely weathered in adults (Coker *et al*. 1921; Figure 4). Sculptures can be used for species identification although they can vary across biogeographical areas and habitat types making them a less reliable diagnostic tool (Haag 2012).

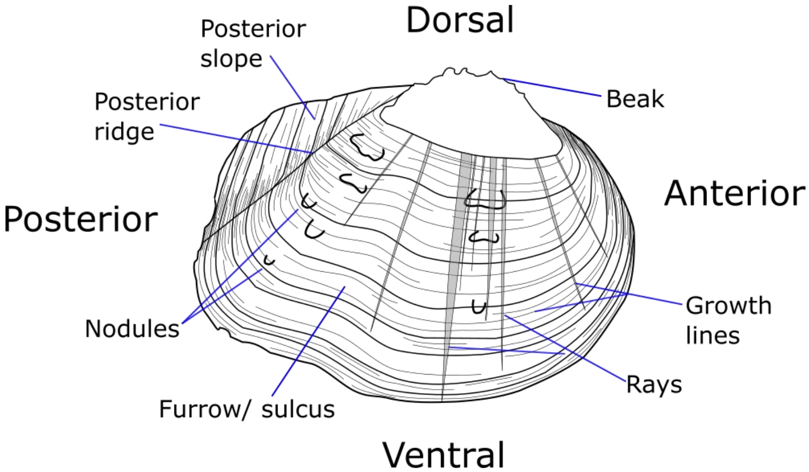

Figure 3. External shell structure.

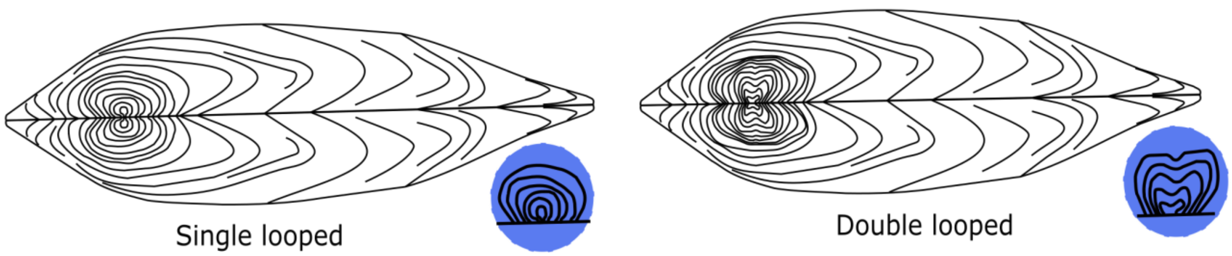

Figure 4. Common beak sculpture configurations.

Age is commonly determined by examining the external concentric growth lines on the shell (Figure 3), as they indicate annual variations in growth. During the warmer growing season, a higher proportion of calcium carbonate ($CaCO_3$) is deposited, while during the colder non-growing season more organic material is deposited creating distinct rings on the external shell (Lutz and Clark 1984; Haag 2012). Other natural environmental conditions such as droughts, extreme cold, handling stress or physical damage can also influence the growth lines (Coker *et al.* 1921). Recent work is focusing on using internal annuli for more accurate estimates of growth and age (Haag and Commens-Carson 2008).

Shell thickness

Shell thickness in North American mussels range from thin, fragile shells less than 1 mm thick to larger, heavy shells reaching up to 15 mm thick (Haag 2012). Varying amounts of layer secretions lead to different shell composition and overall thicknesses. There are three main shell layers and different species have differing compositions. The outer layer is referred to as the periostracum, which contains tanned proteins making the exterior impermeable to water. This defense mechanism protects the mussel from acidic water dissolving the underlying calcium carbonate layers (McMahon and Bogan 2001). Under the periostracum is the prismatic layer, which is made of a single layer of perpendicular calcium carbonate crystals. Both the periostracum and the prismatic layers are secreted by the cells near or at the mantle edge. The minerals associated with shell growth are extracted from the surrounding water (Coker *et al.* 1921). If physical damage is sustained in these layers, it is unrepairable, accumulates over time and extensive damage such as a perforation can lead to injury or death of the mussel. The inner-most layer is the nacre, or mother of pearl, and is composed of layers formed of parallel calcium carbonate crystals (McMahon and Bogan 2001). The nacre is produced by the underlying mantle epithelium and is continually produced to thicken and strengthen the inner shell (Coker *et al.* 1921). When a foreign object is trapped between the nacre and mantle, the object is covered in nacre forming a desirable pearl. Nacre can have a variety of colours ranging from iridescent white, pink or purple colour, and can be species specific.

Shell shape

Shells come in an assortment of shapes, and are commonly described in terms of length, width and height (Figure 5). North American species are commonly oval or elliptical with moderate asymmetry (Figure 6). Approximately one third of species have a triangular or quadrate shape, with a large forward pointing beak leading to asymmetry (Haag 2012). Other widely known shell shapes include trapezoidal, circular, and elongate. There is a vertical component referred to as diameter, with shells being compressed with a flatter profile, or inflated with an expanded and engorged profile. Shell length can vary from 35–250 mm in the largest species (Haag 2012).

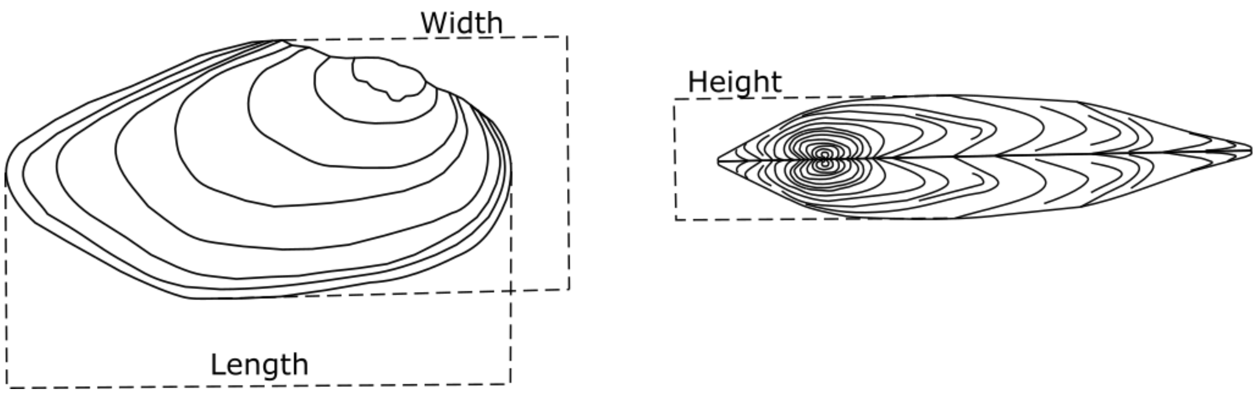

Figure 5. Common mussel shell terminology.

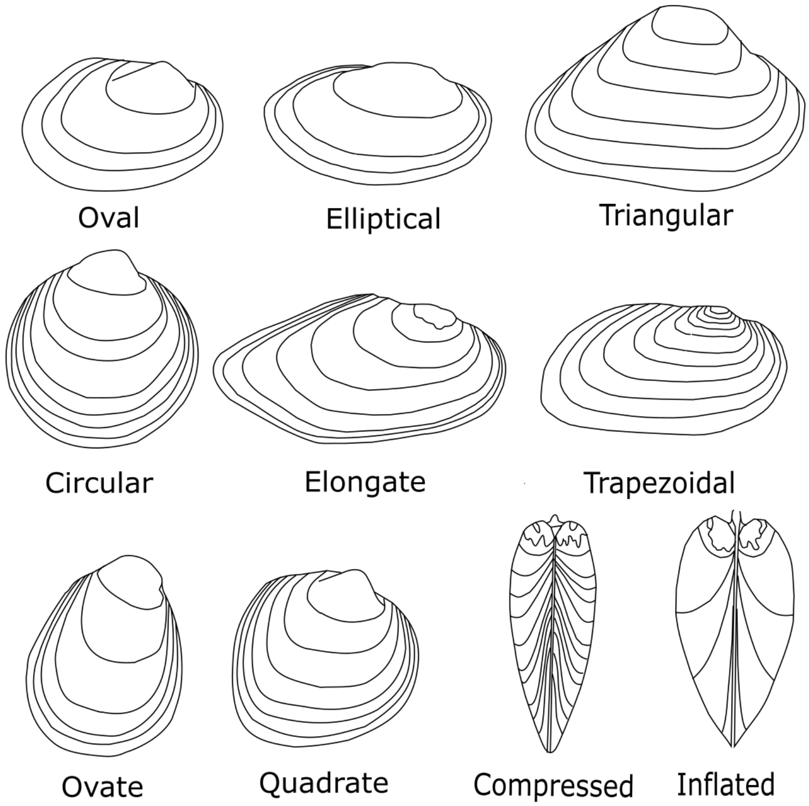

Figure 6. Common mussel shell shapes.

Sex can affect shell shape in certain species. In some Unionidae tribes like Lampsilini, it is common to observe sexual dimorphism between male and female shells (Haag 2012). The Plain Pocketbook (*Lampsilis cardium*) demonstrates sexual dimorphism where the female has an expanded ventral portion and is more inflated (Figure 7). It has been hypothesized that these modifications in shell shape in females have occurred to create more space to accommodate the gravid gills filled with glochidia (Haag 2012).

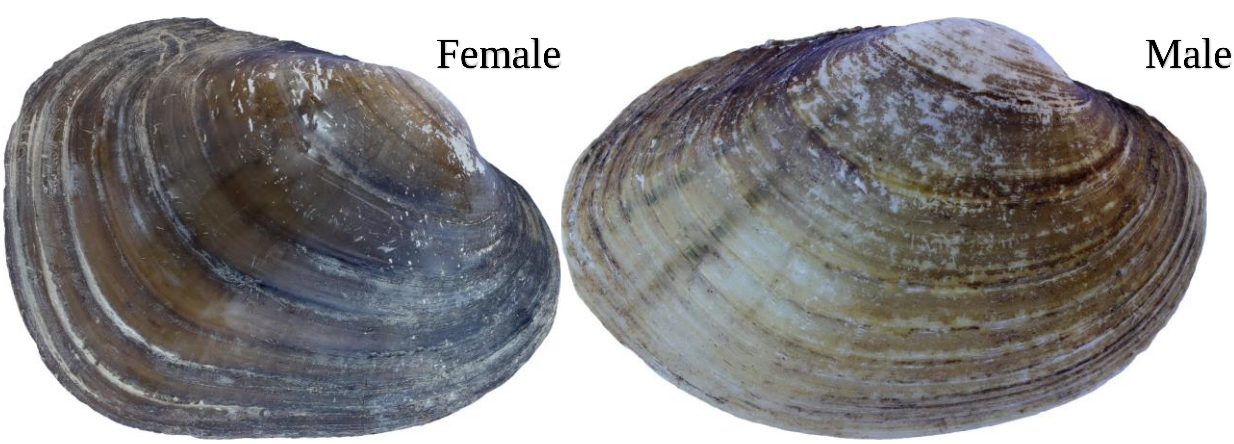

Figure 7. Sexual dimorphism in the Plain Pocketbook (*Lampsilis cardium*).

Habitat features such as substrate type, flow regime, water quality, and nutrients influence shell shape, as can geographical location and ecotype (Kesler and Bailey 1993). Ortmann's law of stream position describes interspecific variations in shell shape dependant on stream size, an overall trend where shells are more compressed in smaller streams, and progressively get more inflated in larger rivers (Ortmann 1920). Compressed shells in small rivers are often longer and more symmetrical, where inflated shells in larger rivers are often shorter in length (Ortmann 1920). Shells demonstrating this phenomena often have a primitive shell structure, and are located in large scale river systems.

3.0 LIFE HISTORY

3.1 LIFE CYCLE AND REPRODUCTION

Spawning occurs during spring and summer months, with warming water temperatures initiating the process (McMahon and Bogan 2001). Male mussels produce sperm during the spawning period and expel it via the excurrent siphon where it is transported downstream in the water column. Female mussels filter the sperm out of the water using their gills (Graf 1997). At the same time eggs are released from the gonads into the suprabranchial chamber to synchronize egg fertilization (Haggerty *et al*. 1995). The fertilized eggs continue to develop in the gills or marsupia, where they are retained and nurtured (Lefevre and Curtis 1912; Graf 1997). The eggs continue to develop into the larval phase termed glochidia, receiving nourishment from the yolk sack making them an ovoviviparous species (McMahon and Bogan 2001). Mussels are typically male or female, although some notable species like the Creek Heelsplitter (*Lasmigona compressa*) and Cylindrical Papershell (*Anodontoides ferussacianus*) are hermaphroditic, containing both male and female reproductive organs (Watson 2000; Cummings and Bogan 2006).

Two different common brooding strategies are employed depending on the pattern and timing of the glochidia release. Short term brooders (tachytictic) release gametes in the spring, spend less time brooding, and release glochidia by the end of the summer. Long term brooders (bradytictic) spawn in the late summer, brood the glochidia, and retain them through the winter to release them in the early spring (Graf 1997; DFO 2011). This is thought to be a strategy utilized at higher latitudes that experience colder climate with a shorter growing season, allowing the juveniles a prolonged growing period before the winter (Graf 1997). The mussel fauna throughout Manitoba is dominated by bradytictic species as they were the first to invade post glaciation, even so, some species like Mapleleaf (*Quadrula quadrula*), Threeridge, and Pigtoe (*Fusconaia flava*) are tachytictic brooders.

The attraction of a suitable host fish is an obligatory step in the reproductive cycle of most freshwater mussels. Increasing the probability of glochidia and a host encounter is the common goal, while different strategies are used (DFO 2011). Broadcasting is an effective strategy when host fish(es) are abundant, occurring when the brood is released as free larvae from the female without any elaborate adaption to attract fish species (Barnhart *et al.* 2008). Other strategies include releasing a "package" of glochidia, which are known as conglutinates to increase glochidia suspension in the water column and elicit a predatory response from the host fish(es). When a fish attempts to feed on the conglutinate, the glochidia are released in close proximity to the host gills (Barnhart *et al.* 2008). Mapleleaf form conglutinates that resemble the prey of their host fish (DFO 2011). Other elaborate examples of this strategy include conglutinates mimicking amphipods swimming, crayfish crawling, insect larvae, or minnows complete with an eye spot and lateral line (Haag *et al*. 1995). Luring strategies include gaping the shell valves open and extending the foot to attract host fish (Zale and Neves 1982). A brightly coloured mantle displaying sporadic movements also may lure fish in closer (Coker *et al.* 1921). When a fish attacks the marsupium it is easily ruptured and the glochidia are released (Barnhart *et al.* 2008).

Once released, glochidia can remain viable for over a week depending on the species and water temperature, with the longest survival observed in colder water temperatures between 0–10 °C (Zimmerman and Neves 2001). The overall survival rate of glochidia is thought to be extremely low around 0.000001%, which is why such high numbers are produced (DFO 2011). Mussel species can be host specialists and use a single fish species as a host or they can be generalists and metamorphose on a number of different fish species (Gordon and Layzer 1993). Glochidia attach to the fins or gills of the host fish by closing their shell valves tight and clamping down (Gordon and Layzer 1993). If glochidia attach to a fish species that is not a host, they will be rejected and sloughed off within a few days (Zale and Neves 1982). If an appropriate host is encountered, the glochidia will become encapsulated by the host's epithelial tissue within 6 hours (Rogers-Lowry and Dimock 2006).

Over the course of the encystment period the glochidia metamorphose into a juvenile mussel. The attachment time varies inter- and intra-specifically and appears to be in response of water temperature (Zale and Neves 1982). Encystment can last from 1–25 weeks. Most encysted glochidia do not grow, although smaller glochidia under 100 μm double in length before detaching (Barnhart *et al*. 2008). Mapleleaf glochidia encyst on the host fish in the upper Mississippi River for 51–68 days (Schwebach *et al.* 2002). Upon completion of the encapsulation phase, juvenile mussels drop off their host, settling into new habitats. Juvenile mussels bury themselves in the substrate and continue to grow. The growth rate of the mussel depends on the species, water temperature, water quality, food abundance, and the overall environment. Some growth trends include juveniles growing faster than adults, and thin shelled species growing faster, yet living shorter lives than thicker shelled species (Coker *et al*. 1921). Once the juvenile mussels reach maturity, they emerge from the substrate to the water interphase where they can reproduce, thus completing the life cycle. It is common to find freshwater mussels living over 10 years, while some records estimate ages upwards of 100 years (Cummings and Bogan 2006).

3.2 PHYSIOLOGY AND ADAPTABILITY

Adult mussels have a sedentary lifestyle and are highly influenced by the surrounding conditions. Unable to escape environmental disturbances, the only response to habitat threats is to burrow or close their shell valves. Studies conducted in Manitoba using the Giant Floater (*Pyganodon grandis*) and Fatmucket (*Lampsilis siliquoidea*) indicate the log of the respiration rate increases at a consistent rate as water temperature increases between 0–25 °C (Huebner 1982). Water temperatures over 25 °C are rare in benthic waters, although where they occur they may have a depressant effect on the mussel respiration rate. These extreme conditions are likely physiologically stressful on the mussels because oxygen concentration decreases with increasing water temperature, leading to lower oxygen availability for the mussel metabolism (Huebner 1982). The effects of multiple stressors was examined in laboratory experiments performed on

Fatmucket (*Lampsilis siliquoidea*) indicating that clearance rate and oxygen consumption increased with acclimation temperature and water velocity, and decreased with total suspended solid concentration and exposure to acute temperature change (Luck 2020).

Unionidae are very sensitive to environmental toxins, with some variations for different stages of their life cycle. Glochidia and juvenile mussels are extremely sensitive to heavy metals and ammonia (Lasee 1991; Goudeau *et al.* 1993). Goudeau *et al.* (1993) observed that high concentrations of ammonia discharged downstream of wastewater treatment plants on the upper Clinch River, VA, USA resulted in greatly depleted or total elimination of the downstream mussel fauna. Exposure from high concentrations of toxins may also kill glochidia or have sublethal effects, forcing glochidia to close their valves, reducing their survival chances as they are no longer capable of attaching to the host fish(s). Urban runoff and waste water effluent were studied in wild adult mussels in Grand River, Ontario. Mussel populations downstream of waste water effluent had significantly higher concentrations of Pb, Cu, Ni, Zn, Cr, and Al in their gill tissues compared to mussels collected from an upstream reference sites (Gillis 2012). Increased levels of xenobiotic conjugating activity, cellular membrane damage, and increased lysosome activity indicated oxidative stress and an elevated immune response (Gillis *et al.* 2014). Chronic immune system stimulation and overall increased physiological stress is thought to induce negative energy costs in the downstream mussel populations.

Mussels may be exposed to different contaminants. For example, mussel species from the Assiniboine River, Manitoba have been observed to accumulate metals including cadmium, copper, and lead in their tissues (Pip 1995). These metals are persistent, potentially toxic, and are widespread as many aquatic ecosystems are polluted by anthropogenic activities (Naimo 1995). Metals accumulate in the surface sediment layer putting them in direct contact with mussel habitat (Naimo 1995). When Plain Pocketbook (*Lampsilis cardium*) were exposed to high levels of cadmium (Cd), mean respiration rate dropped and individuals showed changes in food clearance rates, ammonia excretion, and assimilation efficiency (Naimo *et al.* 1992).

3.3 DISPERSAL AND MIGRATION

The dispersal of juvenile mussels is entirely dependent on the dispersal or migration patterns of their host fish(es). Ideally juveniles are transported upstream, so they can maintain a stable river population in the same geographic area. Adult mussels are sedentary and do not disperse or migrate, typically moving <10 m in their lifetimes (Schainost 2016). Higher activity levels have been documented in the warmer summer months, as movement can be influenced by substrate type (Haag 2012).

3.4 KNOWN DISTRIBUTION IN MANITOBA

The distribution of mussels in Manitoba is in part a reflection of sampling effort, with the majority of distribution records from the southern portion of the province. The majority of species are distributed in the southern portion of the province in the Red, Assiniboine and Winnipeg rivers or their tributaries and lakes Winnipeg, Manitoba, Winnipegosis and their tributaries.

3.5 HABITAT

3.5.1 Features

Freshwater mussels are conspicuous animals found in permanent bodies of water. They are most commonly found in rivers and streams, but they also inhabit lakes and ponds. Water velocities that allow for sediment stabilization, while preventing excess accumulation are ideal for many species (Strayer and Ralley 1993). Depth also contributes to mussel distribution, as habitats between 4–10 m in depth are preferred (Stone *et al.* 1982; McMahon and Bogan 2001). Vegetation is common in mussel habitat, with minimal mussel densities below depths colonized by vegetation (Machena and Kautsky 1988). Certain species are generalists, tolerant of high or low stream flow, siltation, and deep water, while other species cannot tolerate these conditions. Environmental and habitat requirements are species specific, but the benthic substrate has a clear affect on the distribution (McMahon and Bogan 2001). Clay, silt, sand, and gravel of different sizes have all been documented as successful habitat types. Mussels are rarely found in shifting sand or deep silt as this is less preferable habitat (Cummings and Bogan 2006).

3.5.2 Threats

Anthropogenic activities can alter the environment such that mussel populations are facing numerous intensifying threats. Habitat alteration and loss is one of the largest threats to current populations in Manitoba along with siltation, drought, pollution, and the introduction of exotic species (DFO 2011).

Stream impoundment can significantly alter habitat conditions both upstream and downstream of any control structure. Areas upstream of an impoundment tend to become deeper with slower flows and are prone to sediment accumulation (Schainost 2016). Deeper habitats may also be colder with altered nutrient inputs. Downstream areas may have altered flow, temperature and sediment regimes and may be subject to scouring and erosion. Ellis (1936) has shown that permanent silt layers from 0.5–2.5 cm thick can kill over 90% of the mussel community. Adult species can be more tolerant than juveniles and can use their foot and valves to emerge from the sediment, although the natural response for digging might not be triggered depending on the nature of the event and seasonality (Imlay 1972).

Shifts in sediment regimes alter the physical and chemical properties of the water, and the benthic habitat as the particles settle out of the water column (Ellis 1936). It may take years for sediment to accumulate to a visible level, however, the effects of siltation are commonly sub-lethal (Box and Mossa 1999). Many freshwater mussels evolved in habitats characterized by fast flowing streams with low levels of suspended solids and may not be able to distinguish between organic and nonorganic particles (Henley *et al.* 2000). Elevated levels of suspended solids have been shown to reduce food particle clearance rates (Aldridge *et al.* 1987; Luck 2020) and smaller particles including silt and clay can clog the mantle and gills, and affect the mussel’s ability to filter feed efficiently (Ellis 1936). These environmental conditions can force the bivalves to keep their valves closed more frequently and longer than normal, reducing the feeding efficiency and growth rates, and may lead to starvation (Ellis 1936). High levels of sediments can also have a detrimental effect on fish populations (Henley *et al*. 2000), thereby potentially impairing reproductive success and dispersal of mussels.

The frequency and timing of extreme flooding and drought events will likely be exacerbated by climate change (Oki and Kanae 2006). Flooding events can be beneficial as they remove built up debris and vegetation and import new rich sediment. Alternatively, exceptionally large flooding events can be catastrophic to mussel populations as mussels can be dislodged and washed downstream or onto riverbanks where they can become stranded and die when the water levels retreat (Strayer 1999; Sousa *et al*. 2012). Extended dry periods can create low water flow leading to higher water temperature and lower dissolved oxygen concentrations (Bogan 1993).With low water levels, mussel populations may be at risk of drying up, which can result in the elimination of the mussel population (Hastie *et al.* 2003).

Structures like dams can lead to habitat fragmentation and a disconnection between the mussels and their obligatory host fishes. If a suitable host fish is not found, glochidia are unable to mature into a juvenile mussel and complete their life cycle (Williams *et al.* 1993). If host fish(es) cannot migrate upstream due to a dam, there will be no new mussel recruitment in this area of the watershed unless other mussels and their host(s) already exist above the barrier. If a host fish disappears, the impacts on the mussel community can be devastating and the population can become functionally extinct (Bogan 1993).

River channelization is another type of man made habitat alteration that is threatening the habitat of mussels. Channelization alters the flow and water circulation patterns creating more fluctuating water levels. Areas of the Red and Assiniboine rivers have been diked or had been armoured with riprap for flood control and erosion protection thereby altering the natural clay and gravel habitat with large boulder habitats (COSEWIC 2016).

Pollution from oil mining operations, paper mills, and factory processes are known to use certain acids and chemicals that are released in concentrations high enough to kill mussels (Ortmann 1909). Depletion of mussel communities up to 5 km downstream of wastewater treatment plant effluents has been observed (Goudreau *et al*. 1993). Dissolved heavy metals including mercury, cadmium, zinc, copper, nickel, and arsenic accumulate in tissues and negatively impact fecundity and behaviour threatening the long term health of mussel populations (Keller and Zam 1991). In the Red and Assiniboine rivers, the threat from contaminants and toxic substances to mussel populations is rated as high (DFO 2011).

Other sources of pollution include household sewage, urban wastewater, pesticides, and agricultural runoff. Southern Manitoba supports intensive agricultural, including hog farming, whose waste management increases ammonia and phosphorus loads into the local water systems (Pip 2000). In the Red and Assiniboine river watersheds, the phosphorus and nitrogen levels exceed the set water quality guidelines (Environment Canada and Manitoba Water Stewardship 2011). Although the effects are commonly sub-lethal, nutrient loads adjunct with other factors may limit mussel populations (Bogan 1993).

The most recent major threat facing mussel populations in Manitoba are the invasive Zebra Mussel (*Dreissena polymorpha*), first discovered in the early stage of colonization in Lake Winnipeg in October 2013 (DFO 2014). Like many successful invasive species, Zebra Mussel lack natural predators, have a short maturation time of 1–2 years, with a high growth rate, fecundity, and densities (Mackie 1991). These life history traits provide a reproductive advantage when competing with native species and also make eradication efforts challenging once established. Zebra Mussel filter phytoplankton and suspended solids altering the water quality by removing food and nutrients, and inevitably changing the structure of the food web (Therriault *et al.* 2013). Zebra Mussel attach to native mussel shells partially buried in the substrate reducing their ability to open and close their valves exposing them to threats like predators, parasites, diseases, and toxic water (Mackie 1991). Clogged valve openings can impair feeding, growth, respiration, reproduction, and excretion (Mackie 1991; Therriault *et al.* 2013). The ability to build up sufficient energy reserves to last the winter can be impeded, and the native mussels can starve to death. Dense Zebra Mussel populations have led to local extirpation of native mussels after 4–8 years post invasion (Ricciardi *et al.* 1998). The North American Unionidae background extinction rate is 1.4%, however, extinction rates have increased 10-fold since the Zebra Mussel invasion (Ricciardi *et al.* 1998), demonstrated in the Detroit River system where Unionidae mussels were locally extirpated from the main channel in surveys conducted in 1998 due to Zebra Mussel (Schloesser *et al*. 1998). Recent Detroit River surveys confirmed that unionid mussels are still locally extirpated from the main channel, but do persist in the system, in reduced diversity and abundance, in low velocity habitat near tributaries (Keretz *et al.* 2021).

4.0 DICHOTOMOUS KEY FOR THE IDENTIFICATIO OF FRESHWATER MUSSELS OCCURRING IN MANITOBA[1]

1a. Shell sculpture present, bumps, flutes, or ridges
→ 2
1b. Shell sculpture absent, no bumps, flutes, or ridges
→ 4

2a (1a). Shell quadrate, thick, somewhat inflated, with two rows of bumps running down the shell, separated by a shallow furrow; anterior end rounded, posterior end squared with a small wing; ventral margin concave; shell surface yellowish-green (juveniles) to dark brown (adults), faint rays in juveniles; beak small, position central, extending above the hinge line, two rows of tiny, crowded nodules; nacre pearly white, iridescent posteriorly; pseudocardinal teeth heavy, serrated; lateral teeth elevated, straight, moderately long, finely striated …….....
Mapleleaf (*Quadrula quadrula*)
2b. Shell with more than two rows of ridges or flutes running down shell; beak position anterior
→ 3

3a (2b). Shell elongate, oval, moderately thick, compressed; anterior end rounded, posterior end rounded or bluntly pointed, 10–20 ridges (flutes) on posterior portion; shell surface yellowish-green to brownish with narrow green rays becoming obscure with age; beak sculpture 3–4 double looped ridges, heavy; nacre colour white or bluish-white with pink or salmon tinges; pseudocardinal teeth moderately strong, knobby, rough; lateral teeth poorly developed or absent; interdental tooth ……………………..……...…….…………….……….
Flutedshell (*Lasmigona costata*)
3b. Shell ovate, quadrate, thick, compressed, with three or more strongly developed ridges; dorsal margin may have a low wing; shell surface brown, blackish, without rays; beak slightly elevated above the hinge line, close to the anterior end, sculpture obscure (adults) or several concentric single looped ridges (juveniles); nacre white, iridescent in posterior portion; hinge teeth massive, pseudocardinal teeth triangular, serrated; lateral teeth moderately long, straight to slightly curved; no interdental tooth …...…...………….......…...
Threeridge (*Amblema plicata*)

[1] Dichotomous key created using information from the following sources: Field Guide to Freshwater Mussels of the Midwest (Cummings and Mayer 1992), Photo field guide to the freshwater mussels of Ontario (Metcalfe-Smith *et al.* 2005), and the Canadian Freshwater Mussel Guide (http://www.musselguide.ca/).

4a (1b). Shell very elongate (length to height ratio very close to 2:1), thick, anterior end rounded, posterior end pointed in males and distended in females, dorsal and ventral margins straight and parallel; shell surface shiny and dark green with numerous rays in juveniles, black with rays obscure in adults; beak anterior, nearly even with hinge line, 3–5 indistinct double-looped bars; nacre can be white tinged with pink dorsally, or entirely pink or purple; pseudocardinal teeth medium sizes, triangular; lateral teeth long and straight ..…..……..……
Black Sandshell (*Ligumia recta*)

4b. Shell not very elongate (length to height ratio less than 2:1); beak slightly anterior to anterior
→ **5**

5a (4b). Shell compressed with wing on dorso-posterior edge; beak anterior, even to slightly above hinge line
→ **6**

5b. Shell compressed to inflated without dorso-posterior wing; beak slightly anterior to anterior, extending slightly above to well above hinge line
→ **8**

6a (5a). Shell trapezoidal with less pronounced wing, thin, anterior end broadly rounded, posterior end bluntly pointed and square at tip, ventral margin curved; shell surface greenish or yellowish-brown to brown; beak extends slightly above the hinge line, sculpture 5–8 strong double-looped ridges (butterfly shaped); nacre white, sometimes with salmon or cream tinges; pseudocardinal teeth smooth; lateral teeth thin, undeveloped; prominent interdental tooth on left valve …………………………………………………….……....…….…….
Creek Heelsplitter (*Lasmigona compressa*)

6b. Shell circular or ovate, with distinct wing on dorso-posterior edge; beak is even with the hinge line; pseudocardinal teeth rough; no interdental tooth
→ **7**

7a (6b). Shell circular, ventral portion rounded; shell surface brown to blackish, rays few, indistinct (juveniles), absent (adults); beak sculpture 3–8 heavy double looped bars; nacre white, bluish-white, iridescent in posterior region; pseudocardinal teeth large variable in shape, short, flattened; lateral teeth vestigial along the hinge line or absent …….….….………
White Heelsplitter (*Lasmigona complanata*)

7b. Shell ovate, ventral portion straight; shell surface greenish brown (juveniles) to blackish (adults), rays green (juveniles); beak sculpture flattened, indistinct, 3–4 narrow lines; pink nacre; pseudocardinal teeth relatively small, rough; lateral teeth thin, elevated, slightly curved or straight ……………………………………………………………………...……….
Pink Heelsplitter (*Potamilus alatus*)

8a (5b). Shell triangular, thick, with sulcus (shallow furrow) in front of well-defined posterior ridge; shell surface chestnut to dark brown, faint green rays (juveniles); beak slightly anterior, extends well above hinge line, 3–5 faint bars; nacre whitish, sometimes with salmon tinge; pseudocardinal teeth large, serrated; lateral teeth heavy, short ……………….....……..
Wabash Pigtoe (*Fusconaia flava*)
8b. Shell oval or ovate to elliptical, no sulcus (shallow furrow); beak extends slightly to well above hinge line
→ 9

9a (8b). Shell elliptical, beak extends slightly above hinge line, weak ridges or wavy lines
→ 10
9b. Shell oval, or ovate; beak extends slightly above to well above hinge line, pronounced double looped bars or ridges
→ 11

10a (9a). Shell elliptical, elongate, thin; shell surface greenish or brownish, dark growth rings, fine green rays (juveniles); beak slightly anterior, sculpture 3–4 ridges not parallel to growth rings; nacre bluish-white, slightly iridescent; no pseudocardinal, lateral, or interdental teeth ...
Cylindrical Papershell (*Anodontoides ferussacianus*)
10b. Shell elliptical, thick, males have pointed posterior and females inflated, rounded posterior; shell surface yellow to brownish, narrow green rays that are widely spaced; beak anterior, sculpture 6–10 double looped bars that may appear as wavy lines; nacre white with bluish or pinkish tinge, iridescent in posterior portion; pseudocardinal teeth medium size; lateral teeth narrow, and straight or slightly curved ……..…………….……………………………………
Fatmucket (*Lampsilis siliquoidea*)

11a (9b). Shell ovate, trapezoidal, thin; shell surface greenish or brownish, fine green rays (juveniles); beak extends slightly above hinge line thickening of hinge line anterior to beak, sculpture 3–4 heavy concentric bars; nacre bluish-white with cream or salmon tinges near beak; pseudocardinal teeth vestigial; no lateral teeth ………..…………………….……….……….
Creeper (*Strophitus undulatus*)
11b. Shell oval to ovate; beak extends well above hinge line, 4 or more double looped ridges or bars
→ 12

12a (11b). Shell shape variable, usually oval to elongate, thin in juveniles, somewhat thicker in adults and inflated, anterior end broadly rounded, posterior end bluntly pointed; shell surface yellowish-green or greenish-brown with faint rays in juveniles, dark green or dark brown in older adults; beak position anterior, sculpture 4–5 nodulous double looped ridges; nacre silvery white with often tinged with cream, salmon, or pink; pseudocardinal and lateral teeth absent …………………………………………..……………………………….......…..……
Giant Floater (*Pyganodon grandis*)

12b. Shell oval, very inflated, thick, males have pointed posterior, end bluntly pointed, squared off in females; shell surface yellow to yellowish-green; beak position slightly anterior, sculpture 5–6 double looped ridges/bars, last 2–3 are prominent; nacre white, sometimes tinged pink; pseudocardinal teeth elevated, directed forward, compressed; lateral teeth moderately long, curved …..…………………….……………….……………………………………..
Plain Pocketbook (*Lampsilis cardium*)

4.1 Threeridge (3b)

Amblema plicata (Say, 1817)

Description: Shell ovate to quadrate in shape, extremely thick and heavy, and compressed, dorsal margin may extend into a wing, are 115 mm on average and reaching up to 200 mm in length (Metcalfe-Smith *et al*. 2005; Figure 8). Posterior surface with three or more heavy rounded ridges parallel with the posterior ridge, while the anterior end has no sculpturing and is smooth (Clarke 1981; Figure 8). Dorsal margin straight, ventral margin straight to curved. Periostracum yellowish green to light brown in smaller shells becoming darker brown or black in larger shells (Cummings and Mayer 1992). The beak position anterior, is slightly elevated above the hinge line, with younger shells having 3–5 thin concentric single looped ridges on the beak sculpture, commonly eroded in adults (Figure 9).

Pseudocardinal teeth thick, serrated and triangular; two in the left valve, and one in the right. Lateral teeth long, and slightly curved to straight; two in the left valve, and one in the right. Beak cavity medium to deep. Nacre is pearly white, occasionally stained iridescent blue or purple in the posterior end (Cummings and Mayer 1992).

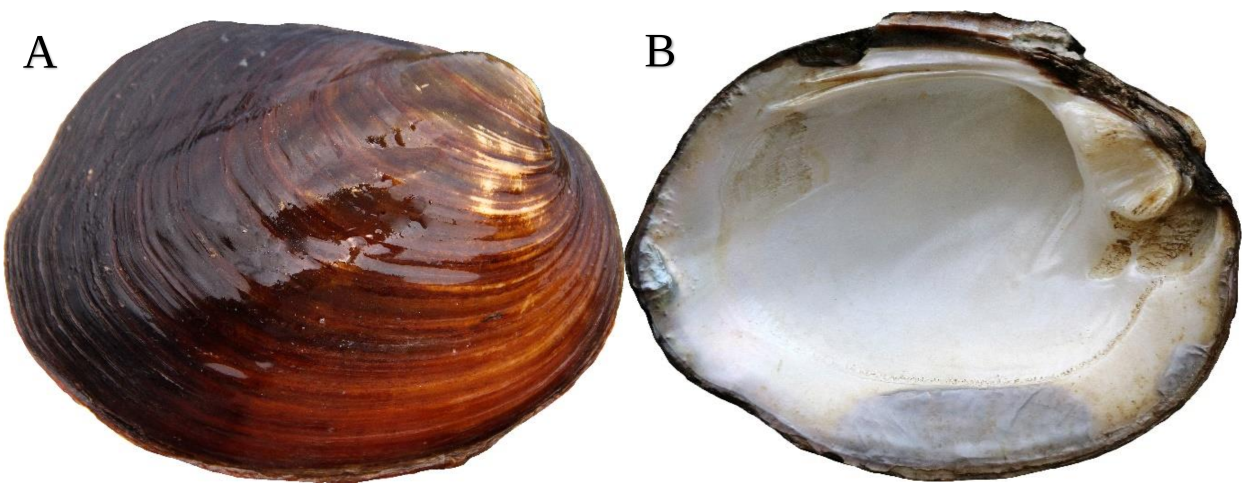

Figure 8. Lateral view of external right valve (A) and internal left valve (B) of the Threeridge (*Amblema plicata*).

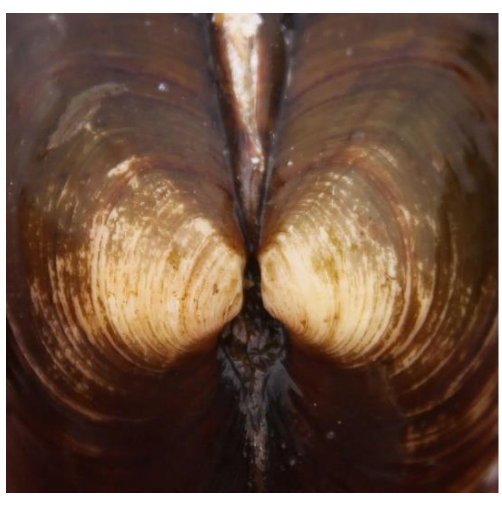

Figure 9. Beak of the Threeridge (*Amblema plicata*) with obscure sculpture.

Similar species: N/A

Status Designations: Threeridge is listed as Secure (G5) in North America; Apparently Secure / Secure (N4N5) in Canada; and Vulnerable in Manitoba (S3) (NatureServe 2021).

Hosts: Spotfin Shiner (*Cyprinella spiloptera*), Emerald Shiner (*Notropis atherinoides*), Channel Catfish (*Ictalurus punctatus*), Northern Pike (*Esox lucius*), White Bass (*Morone chrysops*), Rock bass (*Ambloplites rupestris*), Pumpkinseed (*Lepomis gibbosus*), Bluegill (*Lepomis macrochirus*), Largemouth Bass (*Micropterus salmoides*), White Crappie (*Pomoxis annularis*), Black Crappie (*Pomoxis nigromaculatus*), Yellow Perch (*Perca flavescens*), Sauger (*Sander canadensis*), and Freshwater Drum (*Aplodinotus grunniens*) are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004).
Shortnose Gar (*Lepisosteus platostomus*), Flathead Catfish (*Pylodictis olivaris*), Green Sunfish (*Lepomis cyanellus*), and Warmouth (*Lepomis gulosus*) are additional suitable hosts (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: Threeridge occur in small streams, shallower sections of larger rivers and areas with low flow like impoundments and lakes. They are commonly found in silt, sand or gravel (Cummings and Mayer 1992; Metcalfe-Smith *et al*. 2005).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, and Lake Winnipeg watersheds (Figure 10).

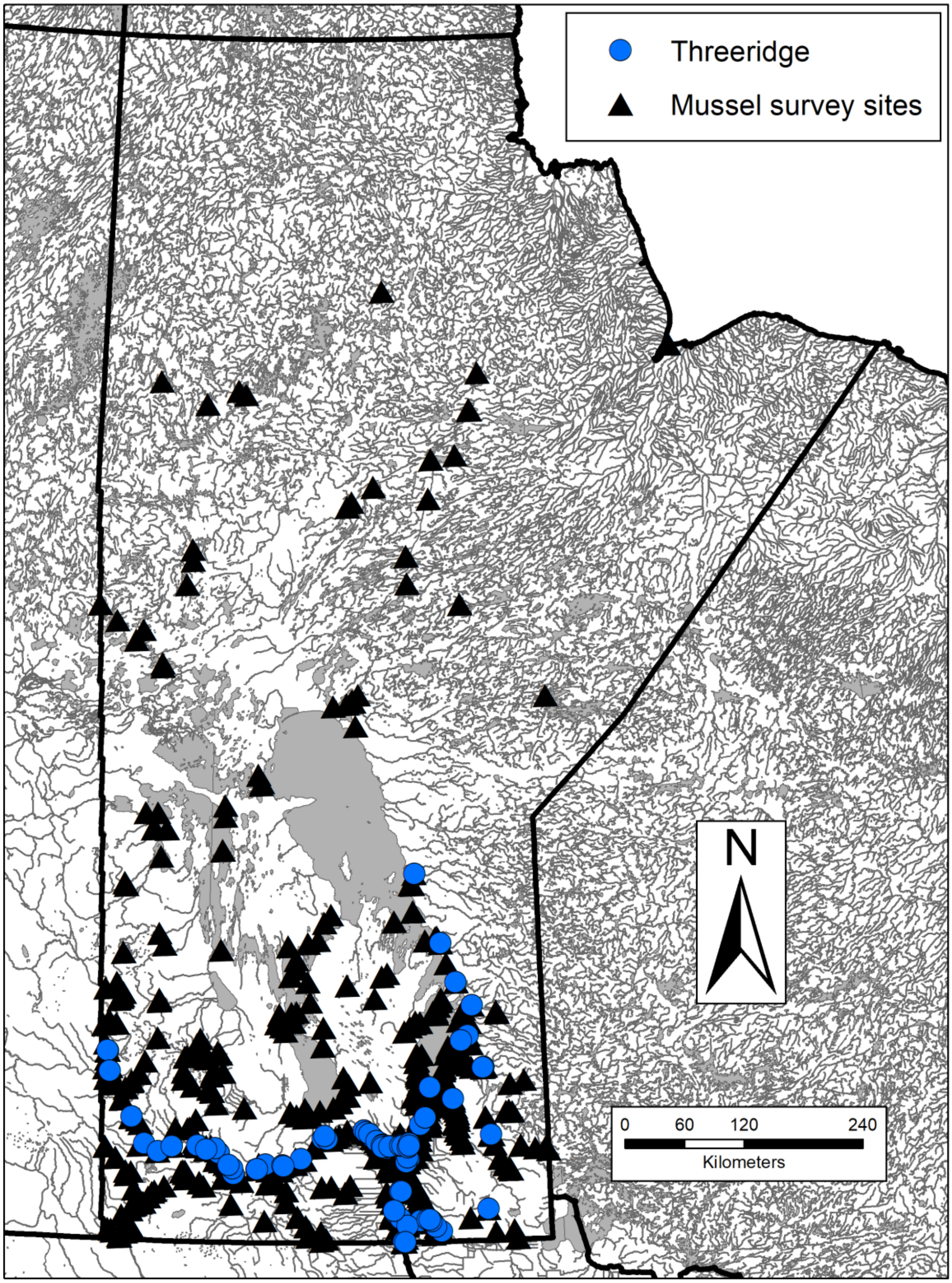

Figure 10. Distribution of the Threeridge (*Amblema plicata)* in Manitoba.

Comments: Threeridge has a tachytictic brooding strategy, with gravid females expelling glochidia between May and July (Clarke 1981). Glochidia are oval, without hooks, and 0.21 mm in length and 0.23 mm in height (Clarke 1981). Threeridge were commercially harvested for the pearl industry in the Assiniboine River in the 1990s (Pip 1995).

4.2 Cylindrical Papershell (10a)
Anodontoides ferussacianus (I. Lea, 1834)

Description: Shell elliptical, elongate, thin, and reaching 55 mm on average and up to 95 mm in length (Metcalfe-Smith *et al*. 2005). Anterior end rounded, posterior end bluntly pointed (Figure 11). Slightly compressed to inflated in females and older males. Posterior ridge noticeable, rounded and swollen in females (Cummings and Mayer 1992). Ventral margin straight, slightly curved or pinched in the middle. Periostracum smooth, yellowish green to brown with fine green rays and prominent growth rings. Older individuals are rayless, rough textured and dark brown to black in colour. Beak small, slightly anterior, and slightly above the hinge line; beak sculpture with 3–4 thin V-shaped ridges not parallel with the growth lines if present (Cummings and Mayer 1992; Figure 12).

Pseudocardinal teeth and lateral teeth both absent in valves, but swelling near the front of the beak may be present. Shallow beak cavity. Nacre silvery or blueish white, iridescent posteriorly (Cummings and Mayer 1992).

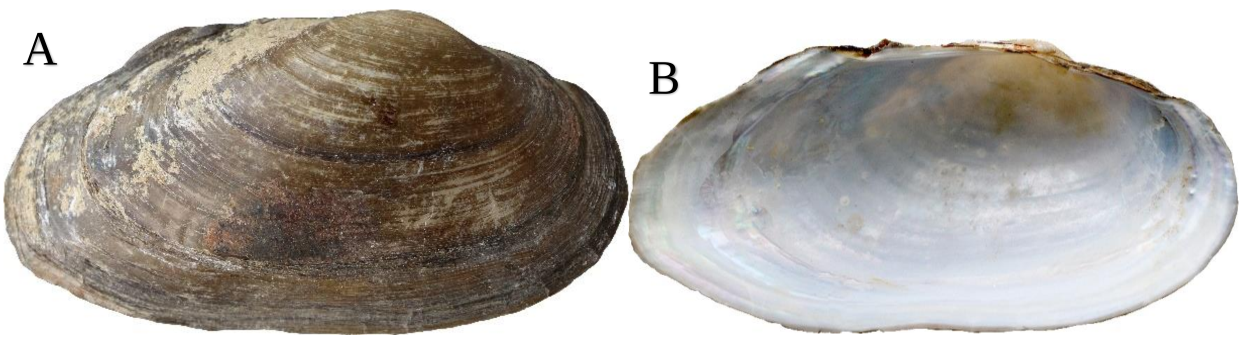

Figure 11. Lateral view of external right valve (A) and internal left valve (B) of the Cylindrical Papershell (*Anodontoides ferussacianus*).

Figure 12. Beak of the Cylindrical Papershell (*Anodontoides ferussacianus*) with 3–4 curved ridges not parallel to growth lines.

Similar species: Similar to a young Giant Floater with an elongate shell, however, beak sculptures differ; Giant Floater with 4–5 thick double looped ridges. Also similar to the Creeper with absent hinge teeth, but the Cylindrical Papershell is more inflated, elongated, has a thinner shell, and a less pronounced beak sculpture.

Status Designations: Cylindrical Papershell is listed as Secure (G5) in North America; Apparently Secure/Secure (N4N5) in Canada; and Apparently Secure in Manitoba (S4) (NatureServe 2021).

Hosts: Spotfin Shiner, Common Shiner (*Luxilus cornutus*), Blacknose Shiner (*Notropis heterolepis*), Bluntnose Minnow (*Pimephales notatus)*, Fathead Minnow (*Pimephales promelas*), White Sucker (*Catostomus commersonii*), Brook Stickleback (*Culaea inconstans*), Mottled Sculpin (*Cottus bairdii*), Bluegill, Largemouth Bass, Black Crappie, and Iowa Darter (*Etheostoma exile*) are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004).
The Sea Lamprey (*Petromyzon marinus*) and Tippecanoe Darter (*Etheostoma tippecanoe*) are additional suitable hosts (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: Cylindrical Papershell occupy small slow moving creeks, headwaters of larger streams, and in lakes. They prefer silt, sand, and fine gravel substrate (Cummings and Mayer 1992; Metcalfe-Smith *et al.* 2005).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, Nelson River, Little Saskatchewan River, and Lake Winnipeg watersheds (Figure 13).

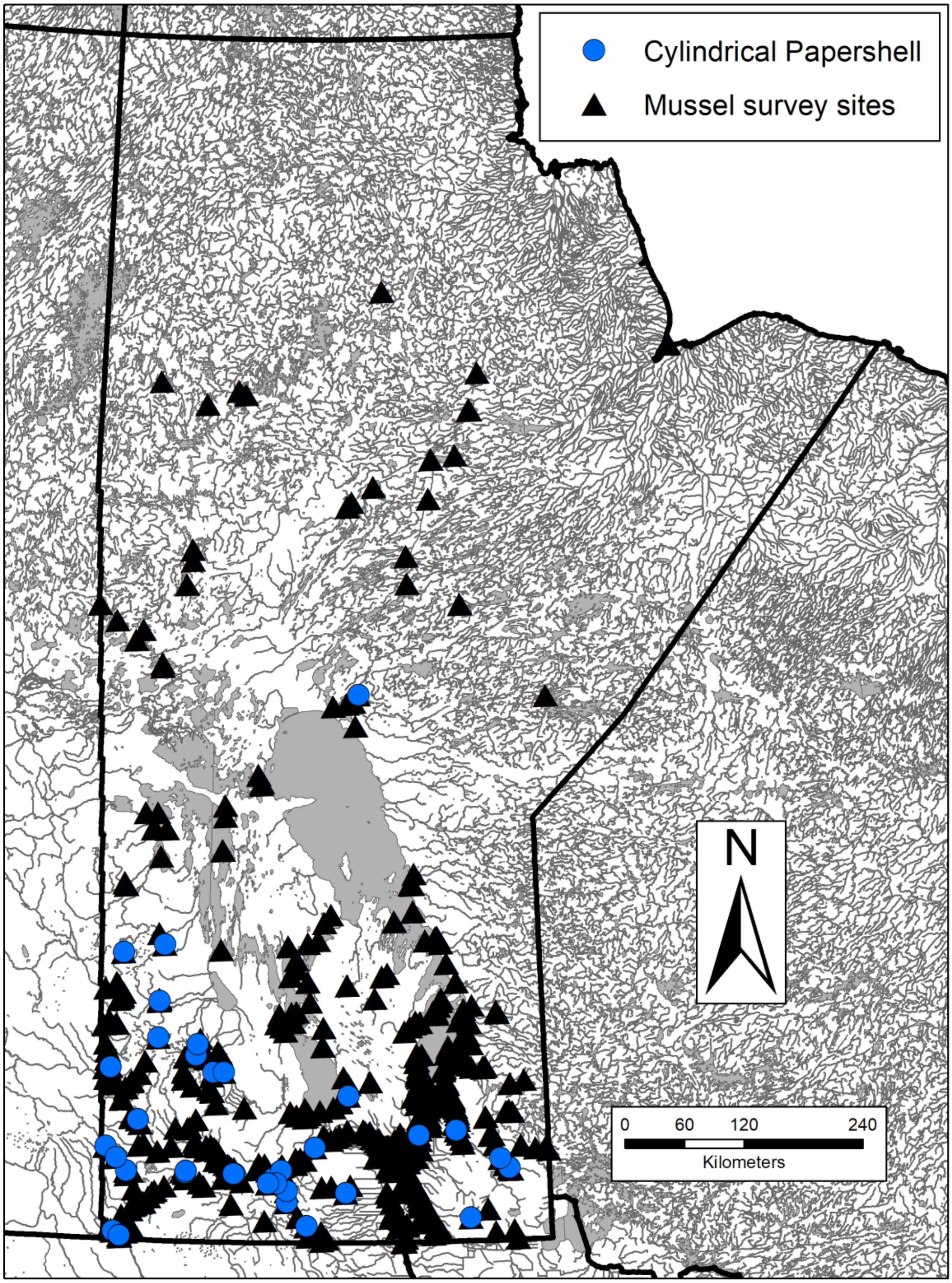

Figure 13. Distribution of Cylindrical Papershell (*Anodontoides ferussacianus*) in Manitoba.

Comments: Cylindrical Papershell have a bradytictic brooding strategy, females are gravid in August expelling glochidia the following May. Glochidia are triangular, with a hook, and up to 0.32 mm in length and height (Clarke 1981).

4.3 Wabash Pigtoe (8a)

Fusconaia flava (Rafinesque, 1820)

Description: Shell highly variable shape including quadrate or triangular, thick shallow depression or a furrow anterior to the posterior ridge (Figure 14), averaging 60 mm and reaching up to 140 mm in length (Metcalfe-Smith *et al*. 2005). Shell often compressed in creeks and small rivers, or inflated in large rivers (Cummings and Mayer 1992). Anterior end rounded and posterior end with a blunt point. Dorsal margin straight, ventral margin arched posteriorly. Periostracum rough, yellowish brown with faint green rays in younger individuals; darker brown and rayless in older individuals (Cummings and Mayer 1992; Metcalfe-Smith *et al*. 2005). Beak position slightly anterior, extends slightly to well above the hinge line; beak sculpture composed of 3–5 faint bars visible on the posterior ridge in young shells (Figure 15).

Pseudocardinal teeth heavy, serrated, and elevated; two in the left valve and one in the right. Lateral teeth heavy, serrated and straight or slightly curved; two in the left valve and one in the right, sometimes with a second smaller tooth. Beak cavity is wide and deep. Nacre white, tinged orange or pink and iridescent posteriorly (Cummings and Mayer 1992).

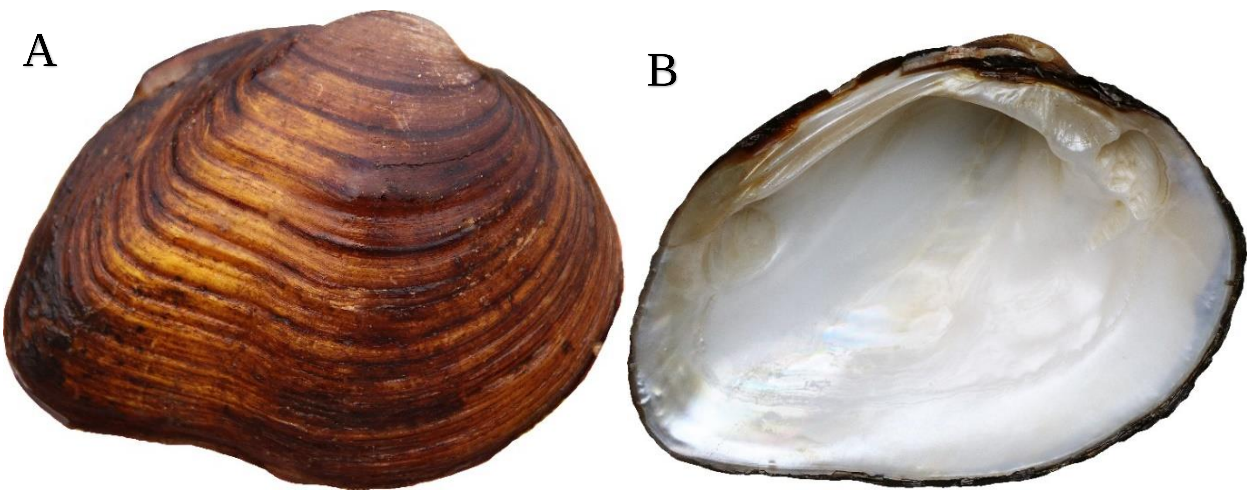

Figure 14. Lateral view of external right valve (A) and internal left valve (B) of the Wabash Pigtoe (*Fusconaia flava*).

Figure 15. Beak of the Wabash Pigtoe (*Fusconaia flava*) with 2–5 faint bars.

Similar species: The Creeper has some similar features, however, the beak sculpture of this species is more pronounced and it lacks a furrow/sulcus on the posterior part of the shell. In addition, Wabash Pigtoe have well developed hinge teeth whereas a Creeper does not. The Mapleleaf has a similar shell shape with a shallow furrow, however, it also has two rows of bumps running down the shell, whereas Wabash Pigtoe does not.

Status Designations: Wabash Pigtoe is listed as Secure (G5) in North America; Vulnerable (N3) in Canada; and Vulnerable in Manitoba (S3) (NatureServe 2021).

Hosts: Creek Chub (*Semotilus atromaculatus*), Bluegill, White Crappie, and Black Crappie are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004). Others must exist given the majority of the distribution of Wabash Pigtoe is outside the range of these fish species and Bluegill, White Crappie, and Black Crappie are not native to Manitoba.
The Silver Shiner (*Notropis photogenis*) is an additional suitable host (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: Wabash Pigtoe occurs in creeks, small streams to large rivers, often in quiet water less than 0.6 m in depth. They prefer stable substrate such as gravel, sand, and firm clay, and high siltation can have negative impact on this species (Parmalee 1967; Cummings and Mayer 1992).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, and Lake Winnipeg watersheds (Figure 16).

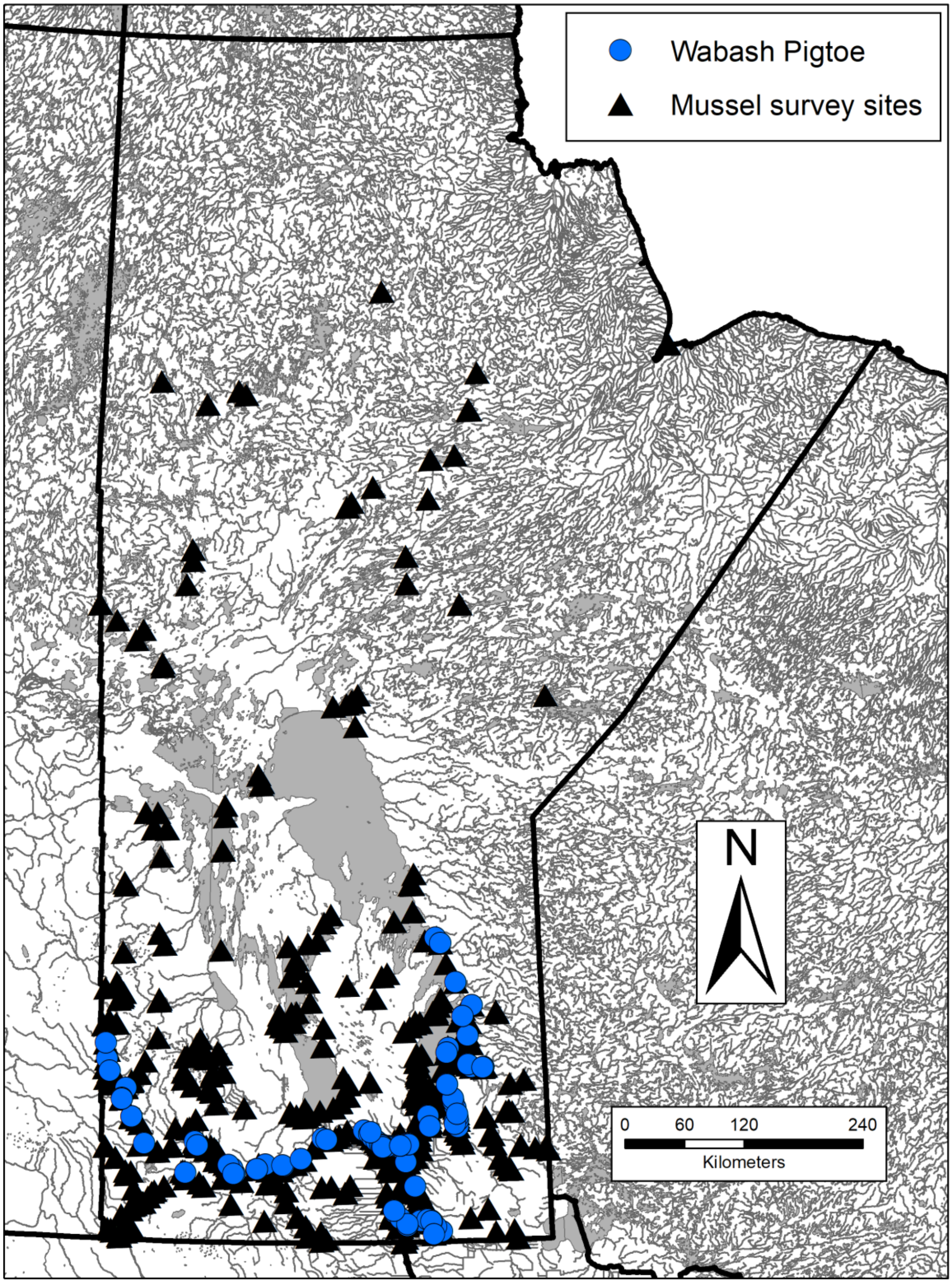

Figure 16. Distribution of Wabash Pigtoe (*Fusconaia flava*) in Manitoba.

Comments: Wabash Pigtoe is a tachytictic brooder, females are gravid in spring expelling glochidia later in summer. Glochidia are ovate in shape, without a hook, and up to 0.15 mm in height and width (Clarke 1981).

4.3 White Heelsplitter (7a)

Lasmigona complanata (Barnes, 1823)

Description: Shell is circular, thin in younger individuals, becoming thicker in adults especially at the anterior end, compressed, averaging 140 mm and reaching up to 200 mm in length (Metcalfe-Smith *et al*. 2005). Anterior end rounded, posterior end bluntly pointed extending into a dorsal wing complete with ridges extending onto the posterior margin (Cummings and Mayer 1992; Figure 17). Dorsal margin straight, ventral margin slightly curved. Periostracum smooth, brown, with faint rays in younger individuals; darker brown to black and rayless in older individuals (Cummings and Mayer 1992). Beak small, positioned anterior, extends slightly above the hinge line; beak sculpture, if present, with 3–8 heavy double looped ridges (Metcalfe-Smith *et al*. 2005; Figure 18).

Pseudocardinal teeth well developed, thick and flattened; two in left valve and one in right valve. Lateral teeth are poorly developed or absent in both valves, represented as wavy ridges or thickenings along the hinge line. Beak cavity varies from shallow to deep. Nacre is white or bluish, iridescent posteriorly (Clarke 1981; Cummings and Mayer 1992).

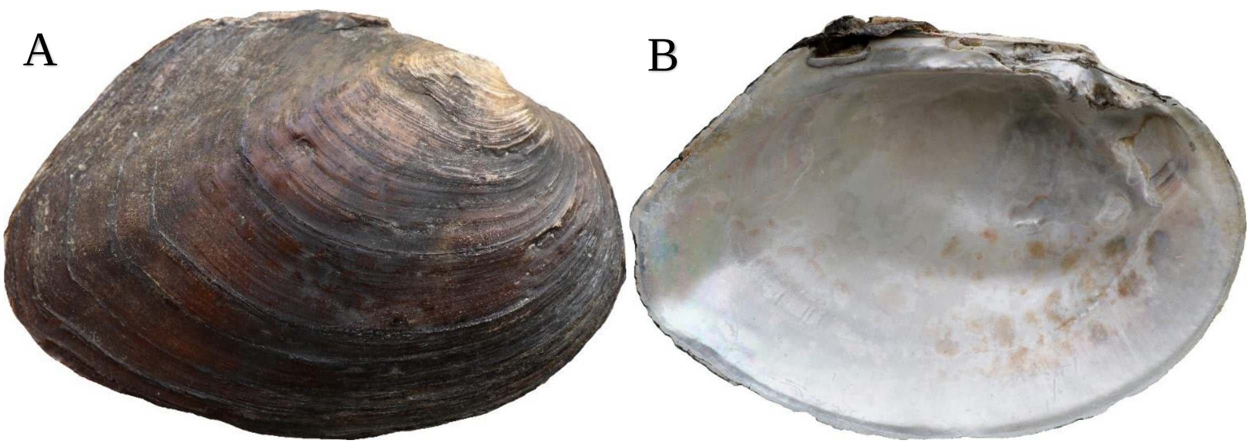

Figure 17. Lateral view of external right valve (A) and internal left valve (B) of the White Heelsplitter (*Lasmigona complanata*).

Figure 18. Beak of the White Heelsplitter (*Lasmigona complanata*) with up to 8 heavy double looped bars/ridges (butterfly shape).

Similar species: Creek Heelsplitter is similar with thin underdeveloped lateral teeth under the beak, white nacre and a strong double looped beak sculpture, however, is the shell of this species is more elongate and has a less developed posterior wing when compared to the White Heelsplitter. The Pink Heelsplitter also has a similar wing on the posterior portion of the shell, however it can be distinguished by its pink nacre colouration, indistinct beak sculpture and the presence of lateral teeth.

Status Designations: White Heelsplitter is listed as Secure (G5) in North America; Apparently Secure/Secure (N4N5) in Canada; and Vulnerable in Manitoba (S3) (NatureServe 2021).

Hosts: Common Carp (*Cyprinus carpio*), Banded Killifish (*Fundulus diaphanus*), Largemouth Bass, White Crappie, Black Crappie, Sauger, and Walleye (*Sander vitreus*) are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004). The Longnose Gar (*Lepisosteus osseus*), Gizzard Shad (*Dorosoma cepedianum*), River Redhorse (*Moxostoma carinatum*), Green Sunfish, and Orangespotted Sunfish (*Lepomis humilis*) are additional suitable hosts (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: The White Heelsplitter occurs in small streams to large rivers, pools and lakes in quieter water. They are commonly found in silt, sand, and gravel substrate in water less than 0.9 m deep (Parmalee 1967; Cummings and Mayer 1992).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, Nelson River, Little Saskatchewan River, Lake Manitoba, Lake Winnipegosis, and Lake Winnipeg watersheds (Figure 19).

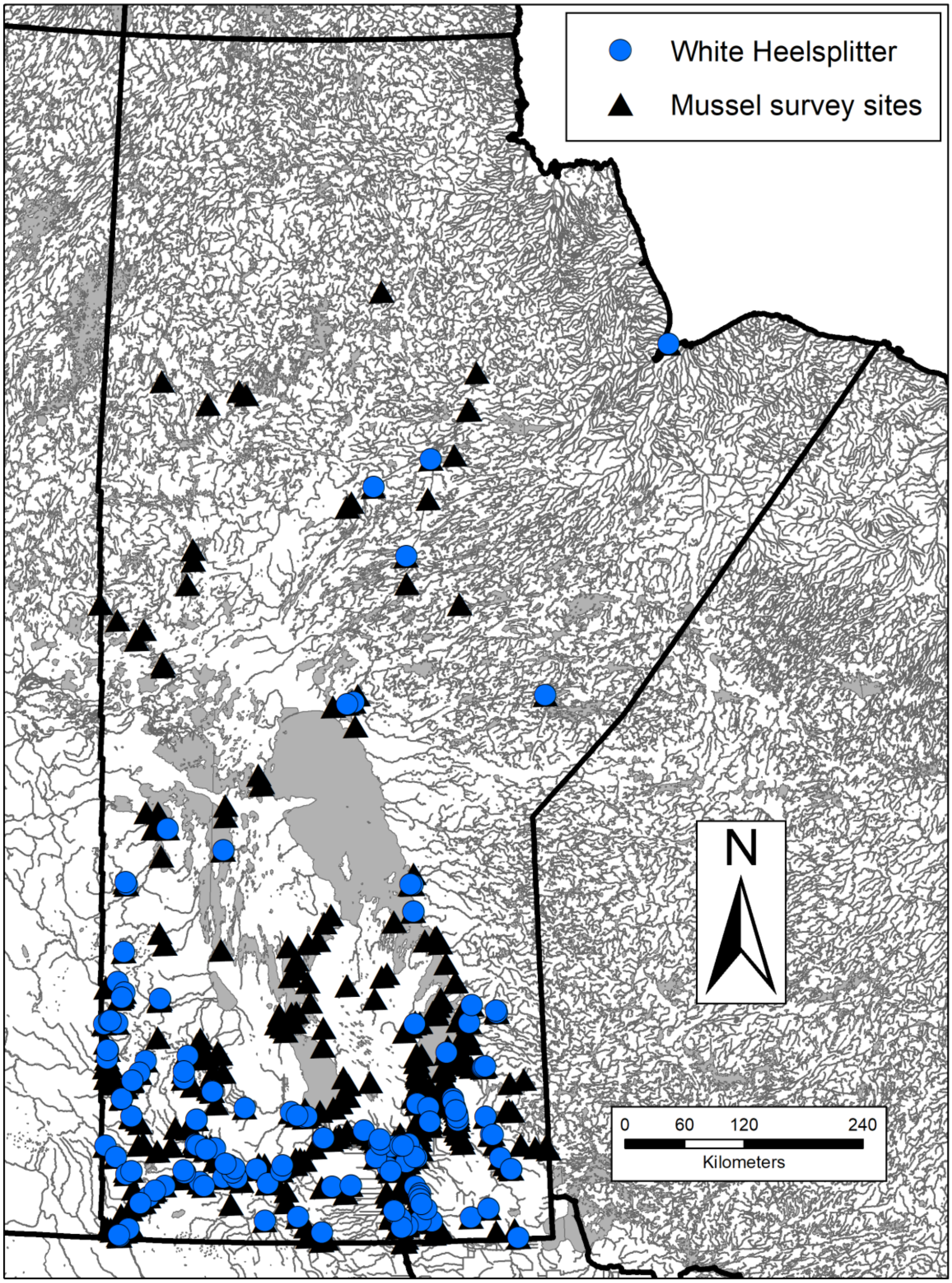

Figure 19. Distribution of the White Heelsplitter (*Lasmigona complanata*) in Manitoba.

Comments: White Heelsplitter have a bradytictic brooding strategy, females are gravid in August expelling glochidia the following May. Glochidia are triangular, hooked, and up to 0.34 mm in length and height (Clarke 1981).

4.5 Creek Heelsplitter (6a)

Lasmigona compressa (I. Lea, 1829)

Description: Shell trapezoidal, relatively thin, and compressed, averaging 80 mm and reaching up to 115 mm in length (Metcalfe-Smith *et al*. 2005). Anterior end rounded, posterior end bluntly pointed with squared tip and a small dorsal wing (Figure 20). Dorsal margin straight, ventral margin curved, rarely straight. Pronounced low rounded posterior ridge beginning at the umbo and running down the posterior side (Cummings and Mayer 1992). Periostracum yellowish brown, smooth with green rays in small individuals, becoming dark green or brown, rayless, and rougher in texture in larger individuals (Cummings and Mayer 1992). The beak position anterior, protrudes slightly above the hinge line, beak sculpture consisting of 5–8 irregular double looped ridges (butterfly shaped) (Figure 21).

Pseudocardinal teeth are well developed, smooth and low; two in the left valve and one in the right. Lateral teeth are narrow and serrated; two in the left valve and one in the right. Prominent interdental tooth in the left valve. The beak cavity is very shallow. Nacre is white to salmon coloured closer to the beak cavity (Cummings and Mayer 1992).

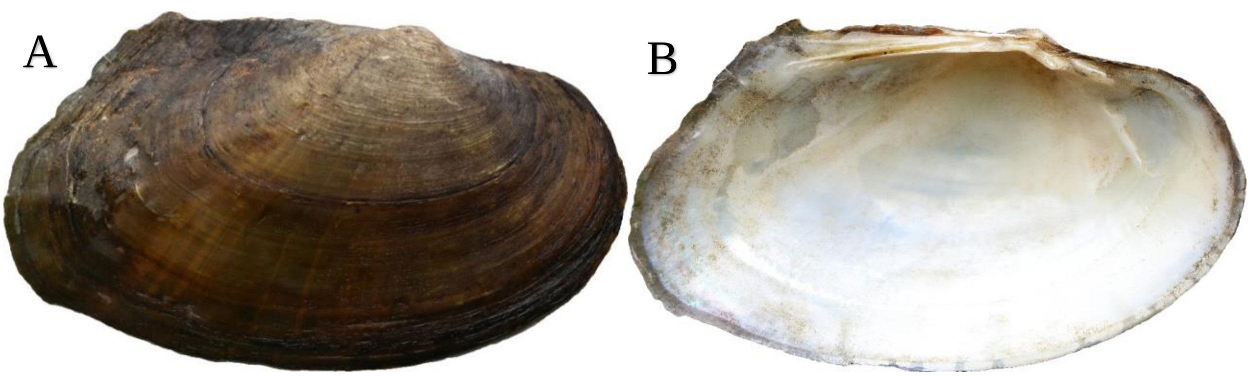

Figure 20. Lateral view of external right valve (A) and internal left valve (B) of the Creek Heelsplitter (*Lasmigona compressa*).

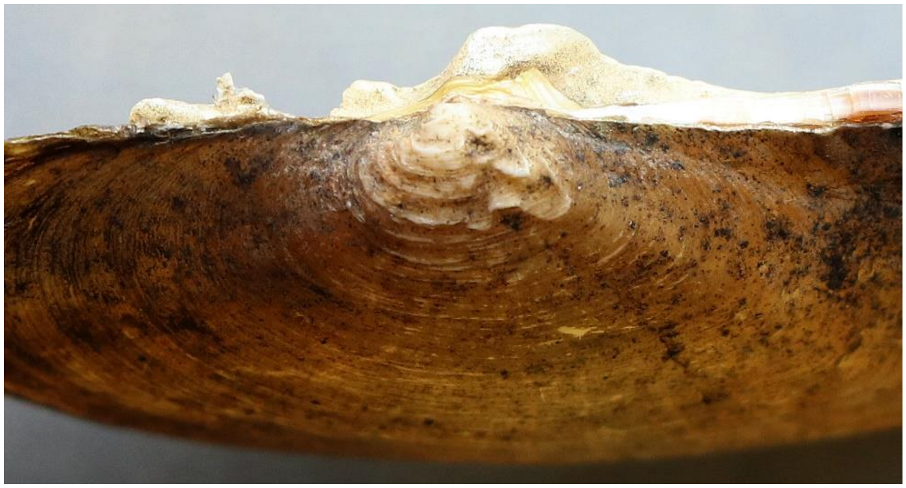

Figure 21. Beak of the Creek Heelsplitter (*Lasmigona compressa*) with, 5–8 double looped ridges (butterfly shape).

Similar species: Flutedshell and the White Heelsplitter share similar characteristics, but neither have well developed lateral teeth found in the Creek Heelsplitter. There is a distinct trapezoidal shell shape in the Creek Heelsplitter, where the White Heelsplitter has a heavier, more circular shell, and the Flutedshell has a more elongated and oval shell with 10–20 ridges on the posterior portion.

Status Designations: Creek Heelsplitter is listed as Secure (G5) in North America; Secure (N5) in Canada; and Imperiled in Manitoba (S2) (NatureServe 2021).

Hosts: Spotfin Shiner, Brassy Minnow (*Hybognathus hankinsoni*), Emerald Shiner, Mimic Shiner (*Notropis volucellus*), Longnose Dace (*Rhinichthys cataractae*), Creek Chub, Black Bullhead (*Ameiurus melas*), Brook Stickleback, Slimy Sculpin (*Cottus cognatus*), Bluegill, Smallmouth Bass (*Micropterus dolomieu*), Black Crappie, and Yellow Perch are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004). Shortnose Gar, Gizzard Shad, Silver Shiner, Yellow Bullhead (*Ameiurus natalis*), Flathead Catfish, Green Sunfish, and Orangespotted Sunfish are additional suitable hosts (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: The Creek Heelsplitter is found in creeks, small streams, and headwater of small to large rivers. They are found in silt, sand, and fine gravel substrate (Clarke 1981; Cummings and Mayer 1992).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, Lake Manitoba, and Lake Winnipeg watersheds (Figure 22).

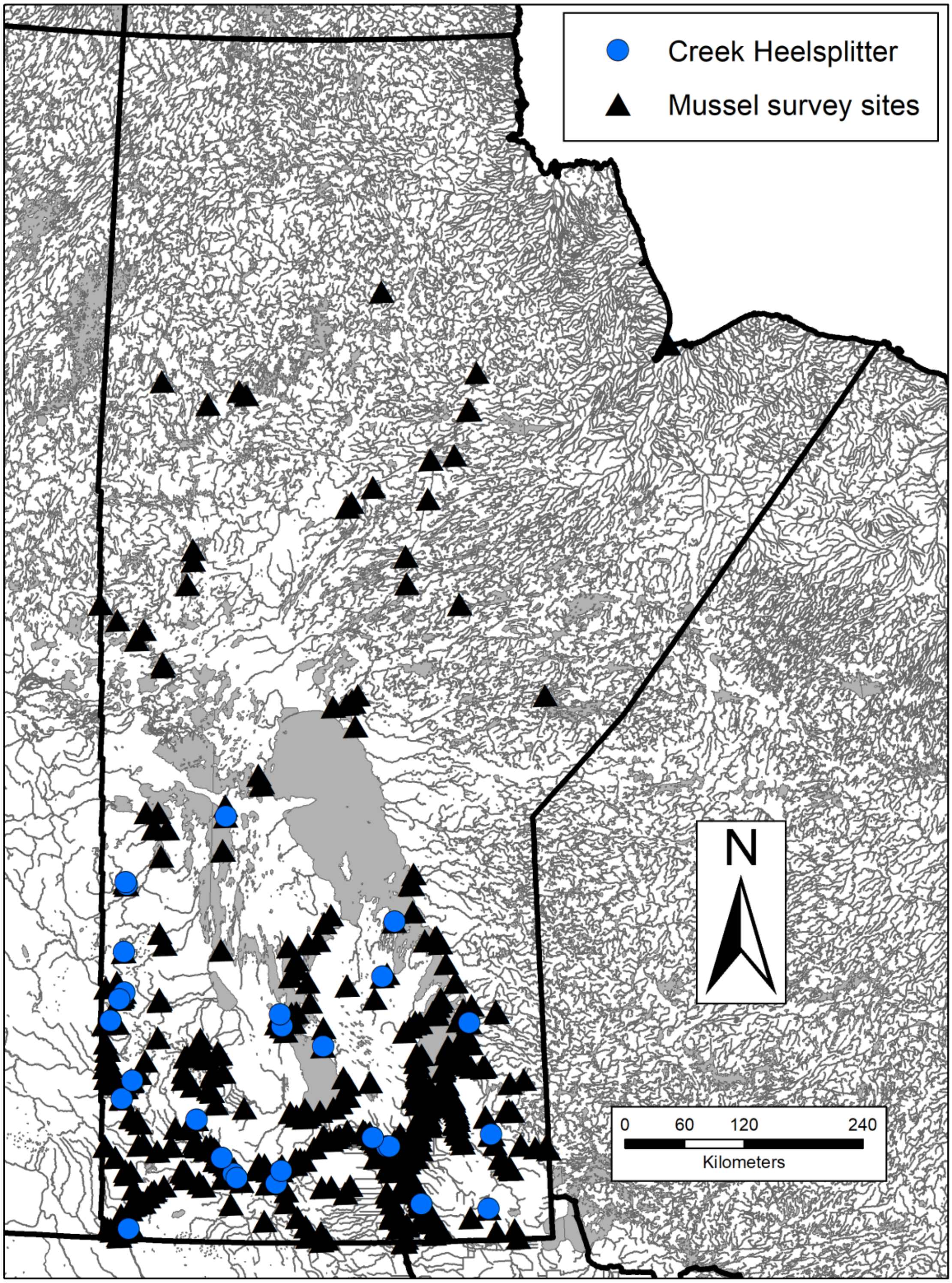

Figure 22. Distribution of the Creek Heelsplitter (*Lasmigona compressa*) in Manitoba.

Comments: Creek Heelsplitter have a bradytictic brooding strategy, females are gravid in August throughout the winter expelling glochidia the following June. Glochidia are triangular in shape, with hooks and are 0.34 mm in length and 0.28 mm in height. They are known to be hermaphroditic and capable of producing both sperm and eggs within the same individual (Clarke 1981; Fichtel and Smith 1995).

4.6 Flutedshell (3a)

Lasmigona costata (Rafinesque, 1820)

Description: Shells elongated, oval, moderately thick and compressed to somewhat inflated, averaging 105 mm and reaching up to 175 mm in length (Metcalfe-Smith *et al*. 2005). Series of 10–20 heavy rounded parallel ridges or flutes on the posterior slope creating a "washboard" effect. Straight dorsal and ventral margins with sharply rounded anterior and posterior ends (Figure 23). Low umbo not projecting above the hinge line (Cummings and Mayer 1992). Periostracum yellowish green in smaller shells with green rays, while larger shells are rayless with a yellowish brown to darker brown colouration (Cummings and Mayer 1992). Beak position anterior, sculpture includes 3–4 double looped raised ridges parallel to the hinge line radiating out from the beak (Clarke 1981; Figure 24). The foot is may be orange in live specimens (Fichtel and Smith 1995).

Pseudocardinal teeth thick and short; two in the left, one in the right valve. Poorly developed lateral teeth; short, indistinct, or absent all together. Prominent interdental tooth on left valve. The beak cavity is shallow. Nacre white, or blueish, commonly with a salmon or pink colouration closer to the beak cavity (Cummings and Mayer 1992).

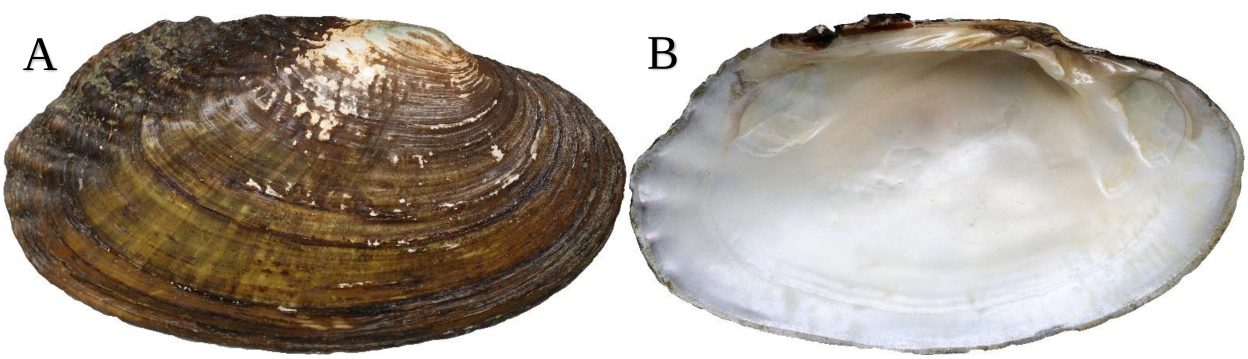

Figure 23. Lateral view of external right valve (A) and internal left valve (B) of the Flutedshell (*Lasmigona costata*).

Figure 24. Beak of the Flutedshell (*Lasmigona costata*) with 3–4 double looped, heavy ridges.

Similar species: Creek Heelsplitter is similar and has double looped beak sculptures, but has a more trapezoidal shell shape, and lacks the small flutes or parallel ridges found on the posterior end of the Flutedshell. The Creek Heelsplitter has narrow lateral teeth, whereas they are poorly developed in the Flutedshell.

Status Designations: Flutedshell is listed as Secure (G5) in North America; Secure (N5) in Canada; and Imperiled in Manitoba (S2) (NatureServe 2021).

Hosts: Goldfish (*Carassius auratus*), Common Carp, Longnose Dace, Creek Chub, Pumpkinseed, Bluegill, and Largemouth Bass are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004).
The Central Stoneroller (*Campostoma anomalum*), Northern Hog Sucker (*Hypentelium nigricans*), and the Banded Darter (*Etheostoma zonale*) are additional suitable hosts (Klocek *et al*. 2008) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: The Flutedshell is found in medium streams to larger rivers with slow to moderate water flow. Utilized substrates include silt, fine, and course sand, while course gravel is overall preferred (Cummings and Mayer 1992; Metcalfe-Smith *et al*. 2005).

Distribution: In Manitoba, this species occurs only in the Roseau and Birch rivers (Figure 25).

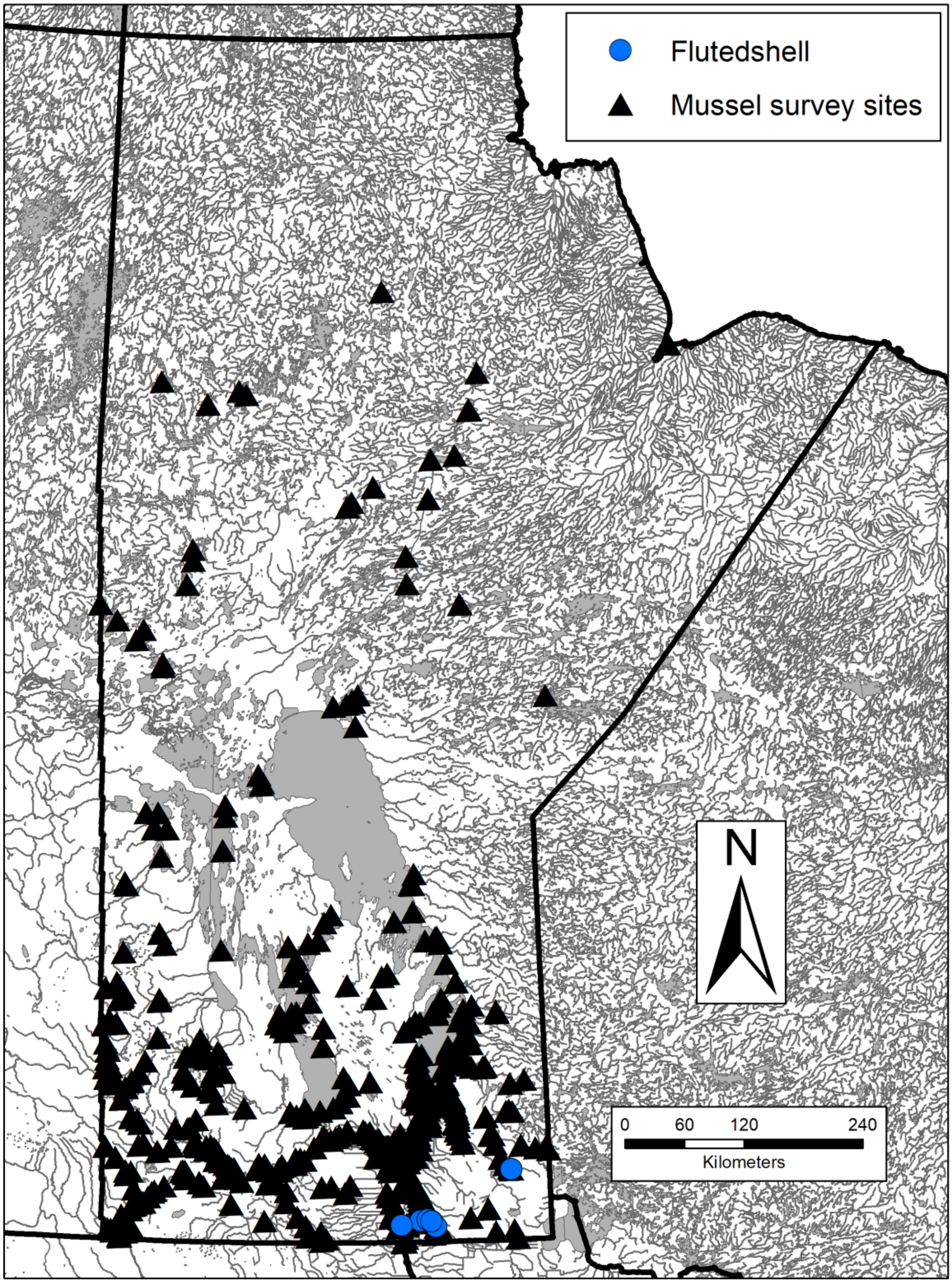

Figure 25. Distribution of the Flutedshell (*Lasmigona costata*) in Manitoba.

Comments: Flutedshell have a bradytictic brooding strategy, females are gravid in August expelling glochidia the following May. Glochidia are triangular, 0.36 mm in length and 0.38 mm in height (Clarke 1981).

4.7 Plain Pocketbook (12b)

Lampsilis cardium Rafinesque, 1820

Description: Shell oval to quadrate, inflated, becoming thicker with age, on average 95 mm reaching up to 155 mm in length (Metcalfe-Smith *et al*. 2005). Anterior end rounded, posterior end pointed (males), rounded (females) potentially forming a wing in some specimens (Figure 26). Dorsal and ventral margins are straight to slightly curved (Cummings and Mayer 1992). . Periostracum smooth, yellow, yellowish green or tan with widely separated dark green rays reduced in older individuals (Clarke 1981; Cummings and Mayer 1992). Beak slightly anterior, swollen, and raised above the hinge line. Beak sculpture with 5–6 double looped ridges, the last 2–3 more prominent (Figure 27).

Pseudocardinal teeth prominent and elevated; two in the left valve and one in the right. Lateral teeth long, striated, and straight to curved, two in the left valve and one in the right. Beak cavity broad and deep. Nacre white or blueish which, may be tinged salmon or pink, iridescent posteriorly (Cummings and Mayer 1992).

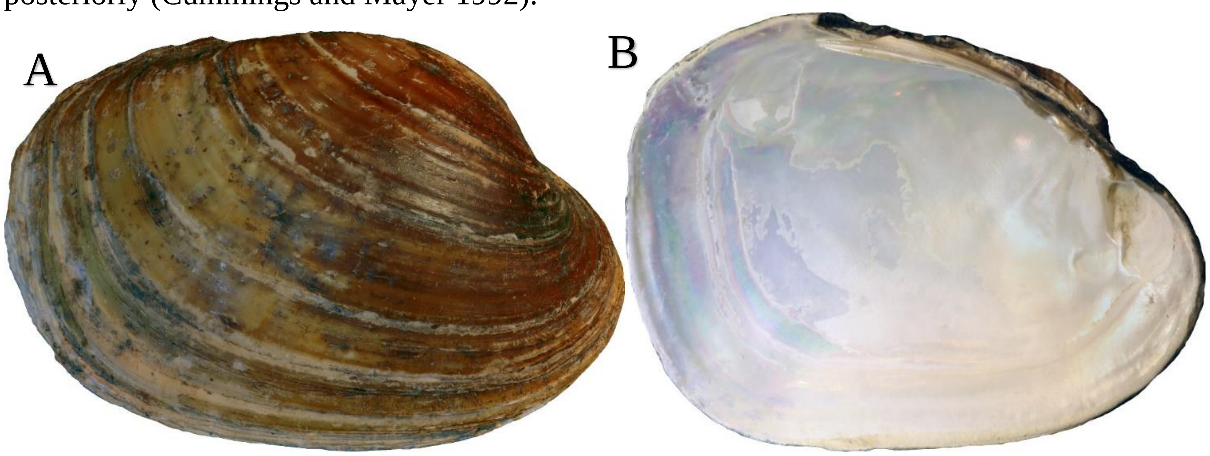

Figure 26. Lateral view of external right valve (A) and internal left valve (B) of the Plain Pocketbook **(***Lampsilis cardium*).

Figure 27. Beak of the Plain Pocketbook (*Lampsilis cardium*) with 4–6 double looped ridges/bars, only the last 2–3 are often visible.

Similar species: The Fatmucket differs by its elliptical shell shape, whereas the Plain Pocketbook has an oval or quadrate shape. The beak sculpture also has more double loops in the Fatmucket (6–10) compared to the Plain Pocketbook (5–6).

Status Designations: Plain Pocketbook is listed as Secure (G5) in North America; Apparently Secure/Secure (N4N5) in Canada; and Apparently Secure in Manitoba (S4) (NatureServe 2021).

Hosts: Pumpkinseed, Bluegill, Smallmouth Bass, Largemouth Bass, White Crappie, Black Crappie, Yellow Perch, Sauger, Walleye, and the Tiger Salamander (*Ambystoma tigrinum*) are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004).
Green Sunfish is also an additional suitable host (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: The Plain Pocketbook occur in small creeks to large rivers in moderate to strong currents, also inhabiting ponds and lakes. They are found in silt, sand, and gravel substrate (Cummings and Mayer 1992; Metcalfe-Smith *et al.* 2005).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Nelson River, Lake Manitoba, and Lake Winnipeg watersheds (Figure 28).

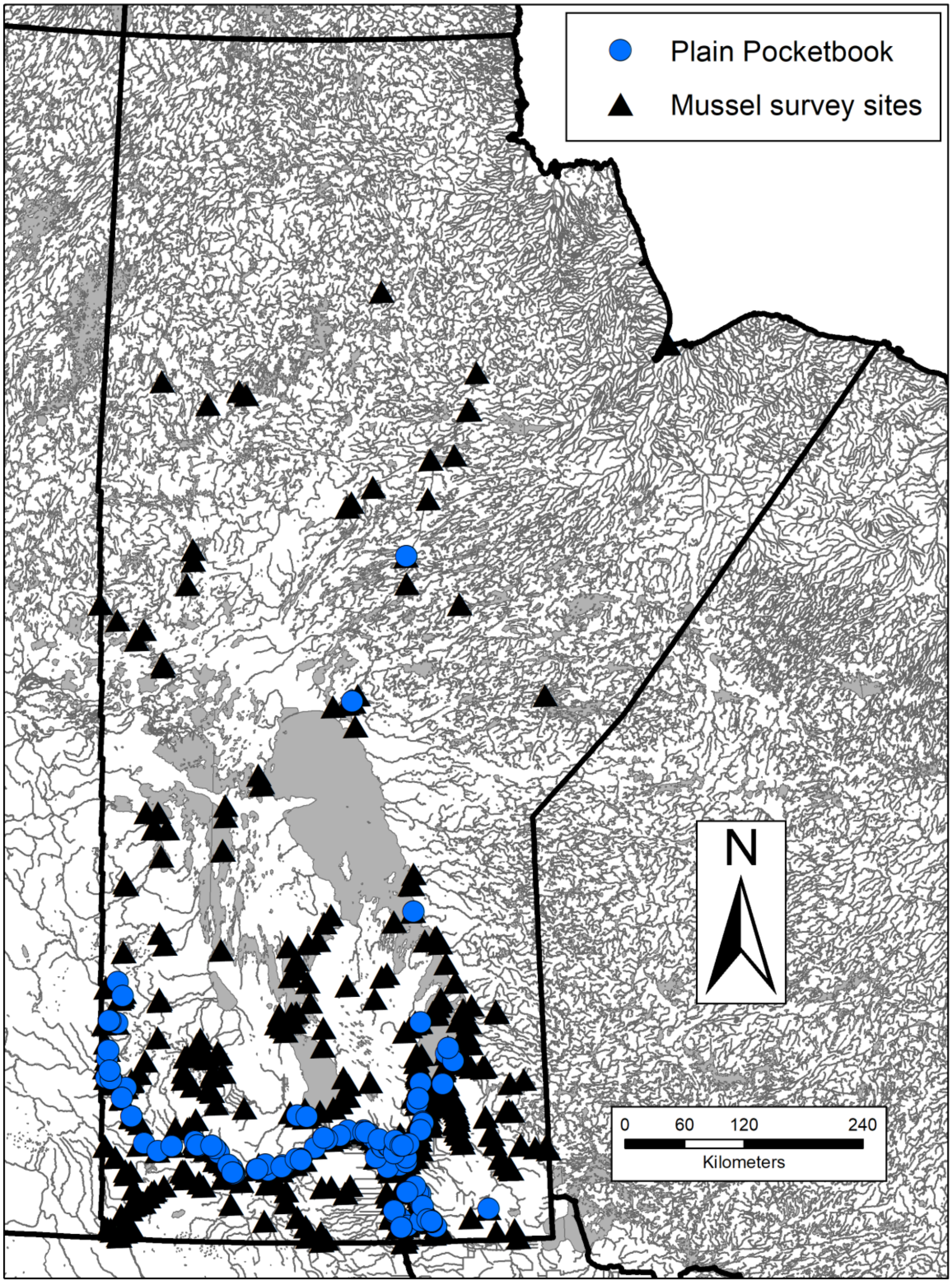

Figure 28. Distribution of the Plain Pocketbook **(***Lampsilis cardium*) in Manitoba.

Comments: Plain Pocketbook have a bradytictic brooding strategy, females are gravid in July throughout the winter expelling glochidia the following July. Glochidia are ovate in shape, reaching up to 0.25 mm long and 0.30 mm high. Females have been observed protruding the posterior edge of the mantle from the shell to resemble a fish, assisting in successful attachment of the glochidia to the host fish species (Clarke 1981).

4.8 Fatmucket (10b)

Lampsilis siliquoidea (Barnes 1823)

Description: Shell elliptical, thick, compressed in males, or inflated in females and in older individuals, 70 mm on average reaching up to 155 mm in length (Metcalfe-Smith *et al*. 2005). Sexually dimorphic; anterior end is rounded, posterior end bluntly pointed (males) or truncated and rounded (females) (Cummings and Mayer 1992; Figure 29). Ventral and dorsal margins are straight. Periostracum smooth, yellow to brownish with narrow green rays radiating from the beak in younger shells. Older shells with a rougher texture, often rayless, and tan to dark brown in colour (Cummings and Mayer 1992). Beak is positioned anterior, slightly raised above the hinge line; and if present, beak sculpture consists of 6–10 double looped wavy lines (Figure 30).

Pseudocardinal teeth elongated or triangular, thin to thick; two in the left valve and one in the right. Lateral teeth narrow, erect, and slightly curved to straight; two in the left valve and one in the right. Beak cavity is moderately deep. Nacre white, blueish, or pinkish, iridescent posteriorly (Clarke 1981; Cummings and Mayer 1992).

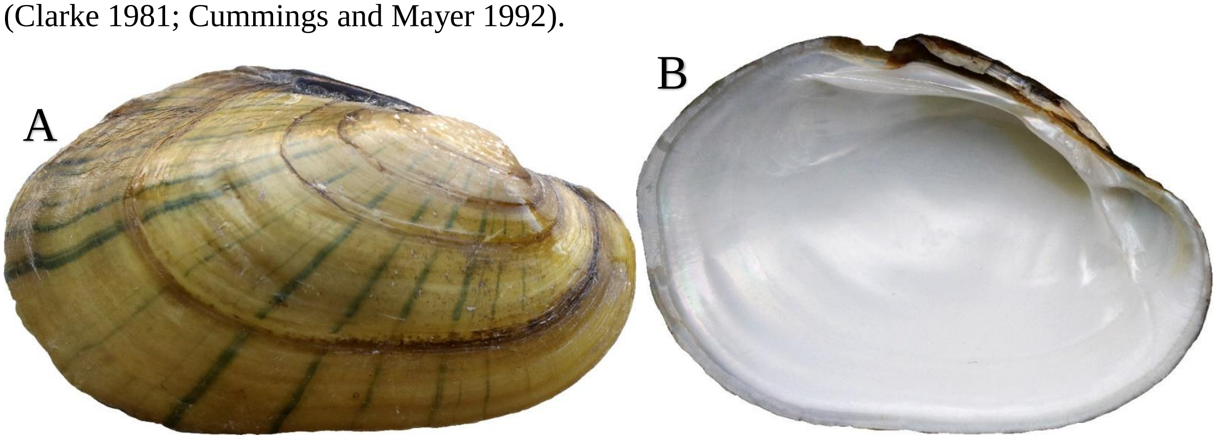

Figure 29. Lateral view of external right valve (A) and internal left valve (B) of the Fatmucket (*Lampsilis siliquoidea*).

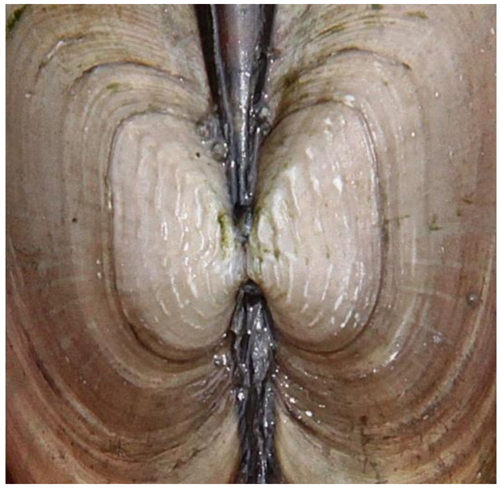

Figure 30. Beak of the Fatmucket (*Lampsilis siliquoidea*) with 6–10 double looped, wavy lines.

Similar species: The Creeper is similar, but has a thinner ovate shell compared to the thick elliptical shell of the Fatmucket. The Creeper also lacks distinct hinge teeth, and has a different beak sculpture. The Plain Pocketbook differs from the Fatmucket by its wide oval or quadrate shell shape. Plain Pocketbook also have heavier teeth and 5–6 double looped beak sculptures (only the last 2–3 visible), whereas the Fatmucket has thinner teeth with 6–10 double looped beak sculptures.

Status Designations: Fatmucket is listed as Secure (G5) in North America; Secure (N5) in Canada; and Secure in Manitoba (S5) (NatureServe 2021).

Hosts: Common Shiner, Sand Shiner, Bluntnose Minnow, White Sucker, Tadpole Madtom (*Noturus gyrinus*), White Bass, Rock Bass, Pumpkinseed, Bluegill, Smallmouth Bass, Largemouth Bass, White Crappie, Black Crappie, Yellow Perch, Sauger, and Walleye are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004). Striped Shiner (*Luxilus chrysocephalus*), Green Sunfish, Warmouth, and Northern Sunfish are additional suitable hosts (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: The Fatmucket occur in small to medium-sized streams, rivers and lakes, often in shallow water less than 0.9 m deep. They are found in silt, sand, and gravel substrate in variable flow regimes (Cummings and Mayer 1992; Metcalfe-Smith *et al*. 2005).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, Nelson River, File River, Little Saskatchewan River, Churchill River, Simonhouse Lake, Lake Manitoba, and Lake Winnipeg watersheds (Figure 31).

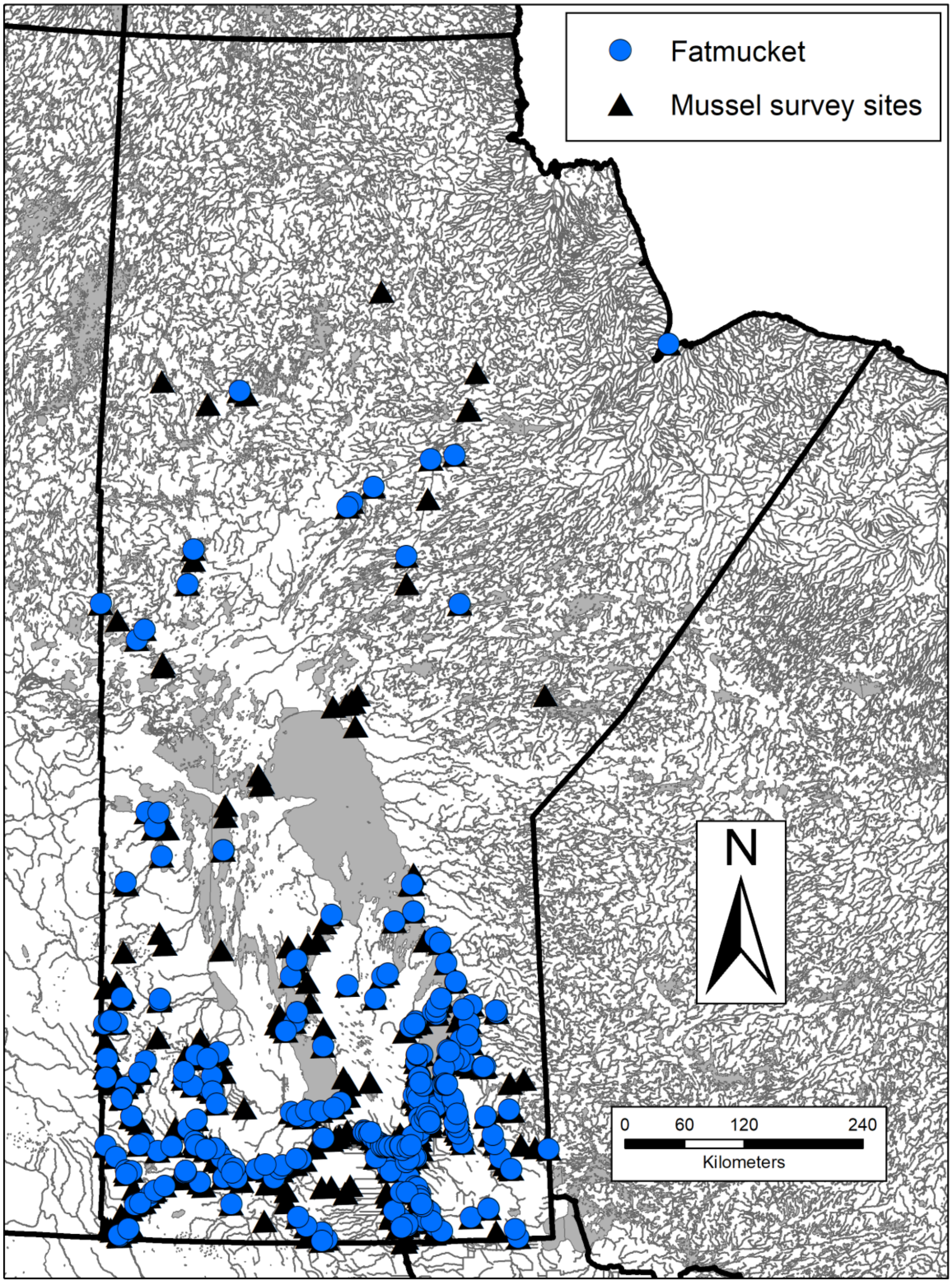

Figure 31. Distribution of the Fatmucket (*Lampsilis siliquoidea*) in Manitoba.

Comments: Fatmucket have a bradytictic brooding strategy, females are gravid in August throughout the winter expelling glochidia the following July. Glochidia are purse shaped, without hooks, and up to 0.26 mm in length and 0.30 mm in height (Clarke 1981). This species was highly valued in the button industry due to uniform shell thickness, and ideal nacre properties (Parmalee 1967).

4.9 Black Sandshell (4a)

Ligumia recta (Lamarck, 1819)

Description: Shell is thick, very elongate, and moderately inflated, average 150 mm and reaching up to 205 mm in length (Metcalfe-Smith *et al*. 2005). Anterior end rounded, posterior end pointed in males, and more broadly round in females (Figure 32). Dorsal margin straight, ventral margin straight to curved. Periostracum smooth, shiny and dark green, brown or black, with green or black rays in some individuals (Cummings and Mayer 1992). Low beak, positioned anteriorly, barely protruding above the hinge line; beak sculpture if present with 3–5 double looped raised bars (Metcalfe-Smith *et al.* 2005; Figure 33).

Pseudocardinal teeth medium sized, triangular and serrated; two in the left valve, and one in the right valve, occasionally with an additional small anterior tooth. Lateral teeth are thin, long, and straight; two in the left valve and one in the right (Cummings and Mayer 1992). Beak cavity is shallow. Nacre frequently purple, or silvery white, iridescent posteriorly (Metcalfe-Smith *et al*. 2005).

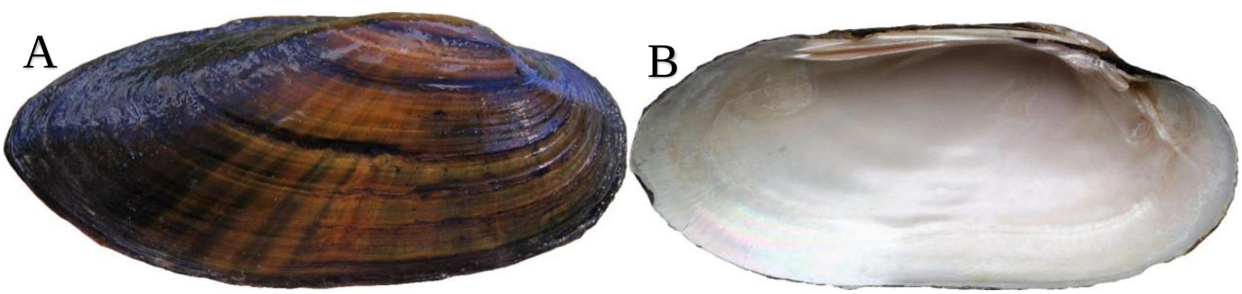

Figure 32. Lateral view of external right valve (A) and internal left valve (B) of the Black Sandshell (*Ligumia recta*).

Figure 33. Beak of the Black Sandshell (*Ligumia recta*) with 3–5 obscure double looped bars, if present.

Similar species: N/A

Status Designations: Black Sandshell is listed as Apparently Secure/Secure (G4G5) in North America; Apparently Secure (N4) in Canada; and Vulnerable in Manitoba (S3) (NatureServe 2021).

Hosts: Common Carp, Banded Killifish, Rock Bass, Pumpkinseed, Bluegill, Largemouth Bass, White Crappie, Black Crappie, Yellow Perch, Sauger, and Walleye are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004). The Central Stoneroller, American Eel (*Anguilla rostrata*), White Perch (*Morone americana*), Green Sunfish, Orangespotted Sunfish, and the Northern Sunfish are additional suitable hosts (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: The Black Sandshell occurs in medium to large rivers on gravel or firm sand (Cummings and Mayer 1992). They are commonly found in water depths up to 1.2 m in areas with a strong water current (Fichtel and Smith 1995).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, and Lake Winnipeg watersheds (Figure 34). A live specimen was found in the Carrot River watershed, and in the lower Qu'Appelle River suggesting the species is more wide spread in Manitoba with a distribution expected in the Saskatchewan River (Phillips *et al.* 2009; Water Security Agency 2020).

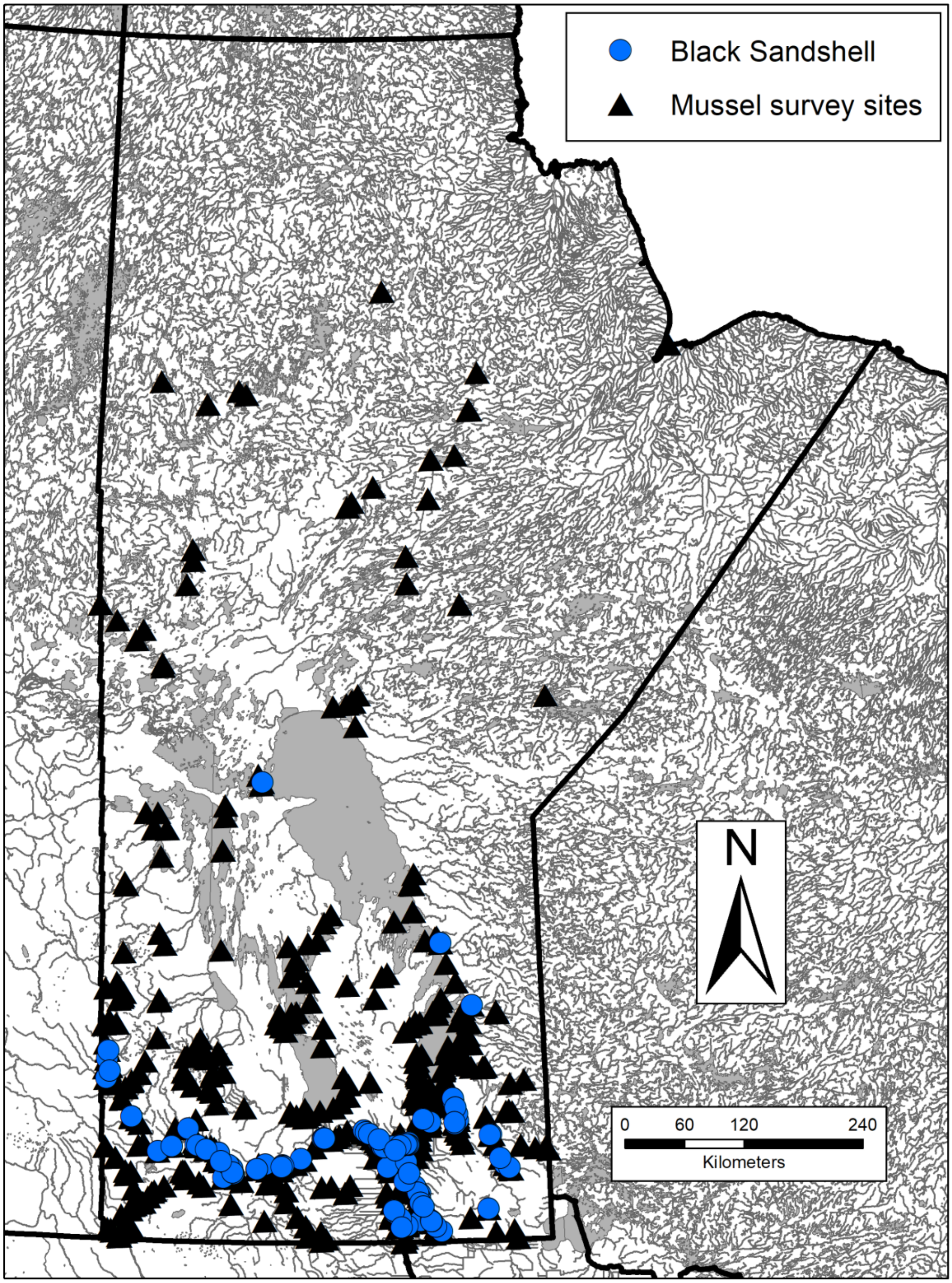

Figure 34. Distribution of the Black Sandshell (*Ligumia recta*) in Manitoba.

Comments: Black Sandshell have bradytictic brooding strategy, females are gravid from June throughout the winter expelling glochidia the following spring. Glochidia are ovate measuring 0.23 mm long and 0.27 mm high (Clarke 1981).

4.10 Pink Heelsplitter (7b)

Potamilus alatus (Say, 1817)

Description: Shell ovate to elongate, thin, becoming thicker in older individuals, compressed and on average 110 mm reaching up to 180 mm in length (Metcalfe-Smith *et al.* 2005). Anterior end rounded, ventral portion straight, posterior end rounded or square with a large wing present posterior to the beak (Figure 35). Periostracum dark green to brown with green rays in young individuals becoming dark brown to black in older individuals (Cummings and Mayer 1992; Metcalfe-Smith *et al.* 2005). Females tend to be more swollen then males although it can be challenging to tell the difference (Clarke 1981). Beak positioned anterior, flat and barely reaches above the hinge line; beak sculpture indistinct with 3–4 narrow concentric ridges visible only in small shells (Figure 36).

Pseudocardinal teeth small, thin, and rough; two in the left valve and one in the right. Lateral teeth thin, elevated, and straight or slightly curved; two in the left valve and one in the right. Beak cavity is shallow. Nacre pink or purple, highly iridescent (Clarke 1981; Cummings and Mayer 1992).

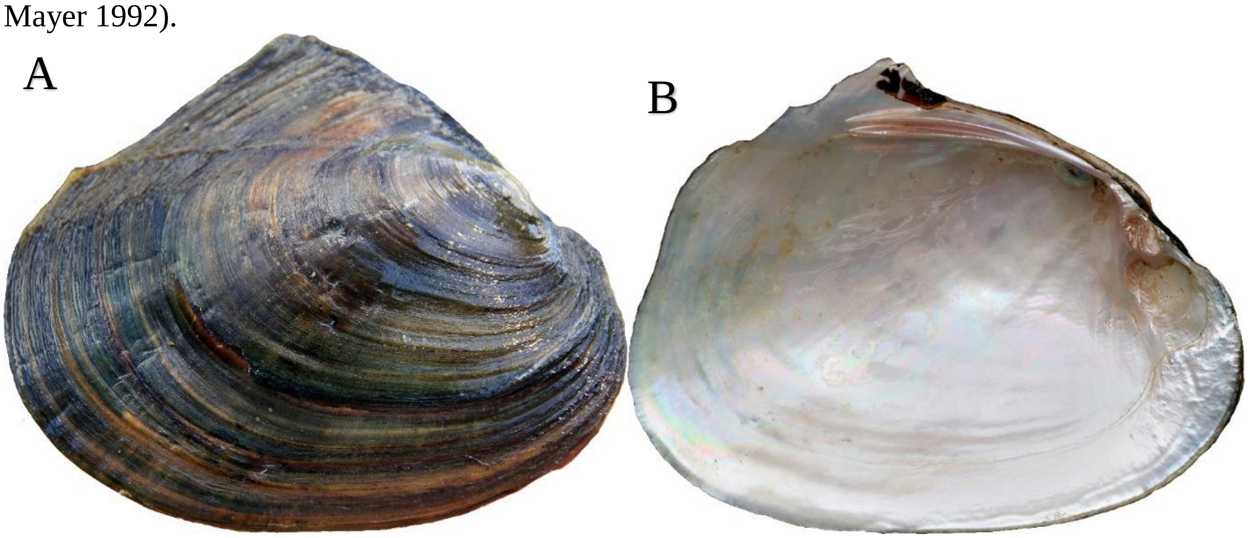

Figure 35. Lateral view of external right valve (A) and internal left valve (B) of the Pink Heelsplitter (*Potamilus alatus*).

Figure 36. Beak of the Pink Heelsplitter (*Potamilus alatus*) with flattened, indistinct, 3–4 narrow lines (only visible in juveniles).

Similar species: The White Heelsplitter has a similar shape, but has a thicker rougher shell than the Pink Heelsplitter. The Pink Heelsplitter also has indistinct single looped beak sculptures and characteristic pink nacre, whereas the White Heelsplitter has heavy double looped beak sculptures and white nacre.

Status Designations: Pink Heelsplitter is listed as Secure (G5) in North America; Apparently Secure (N4) in Canada; and Apparently Secure in Manitoba (S4) (NatureServe 2021).

Hosts: Freshwater Drum is the only known host species in Manitoba (Clarke 1981; Stewart and Watkinson 2004).

Habitat: The Pink Heelsplitter occurs in medium to large size rivers, in silt, gravel or cobble substrate (Cummings and Mayer 1992). They are frequently found in moving water at depths ranging between of 0.6–0.9 m in depth (Parmalee 1967).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, and Lake Winnipeg watersheds (Figure 37).

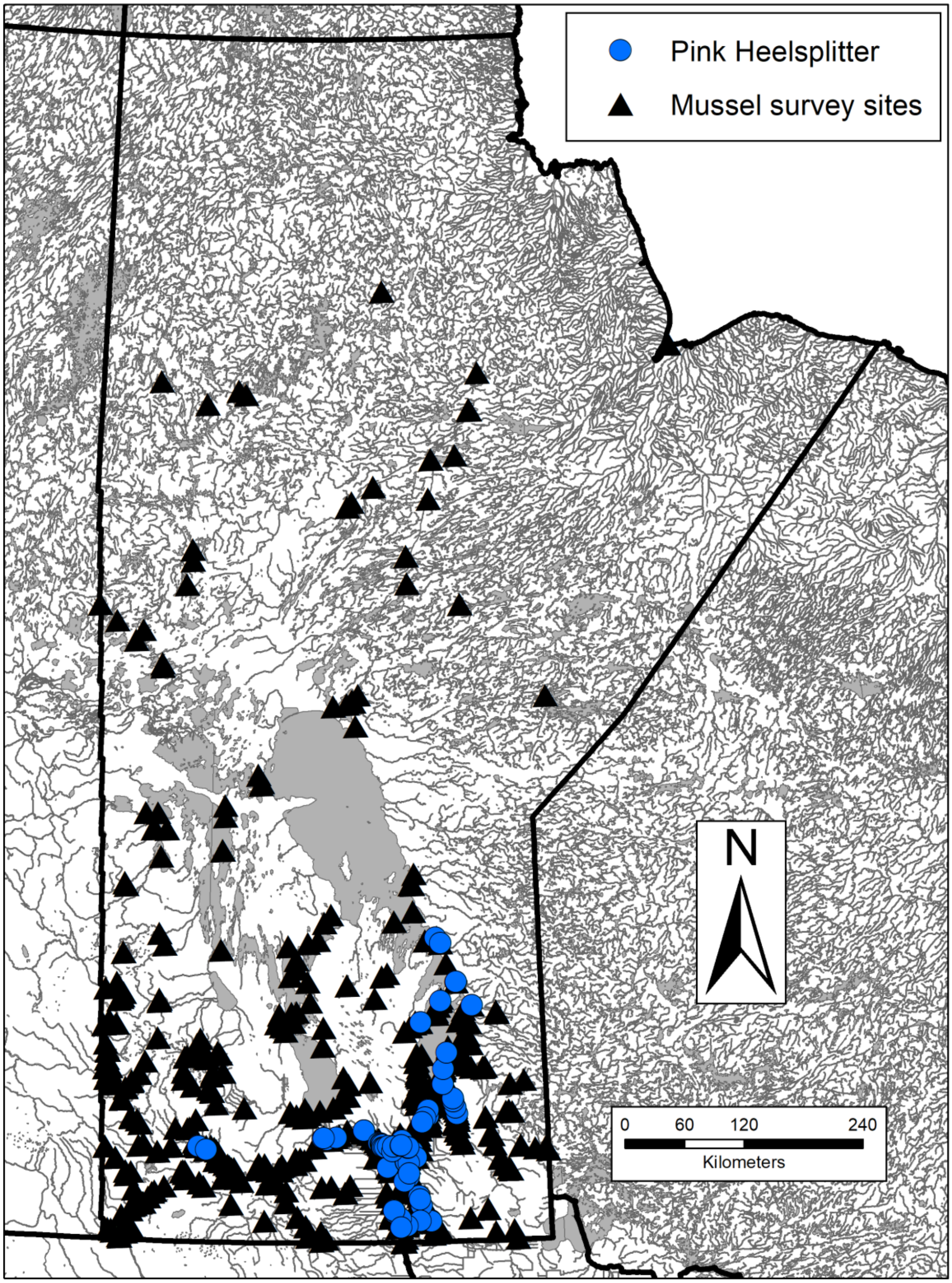

Figure 37. Distribution of the Pink Heelsplitter (*Potamilus alatus*) in Manitoba.

Comments: Pink Heelsplitter have a bradytictic brooding strategy, females are gravid in August throughout the winter expelling glochidia the following July. Glochidia are axe-head shaped with two spines per valve, measuring 0.22 mm in length and 0.40 mm in height (Clarke 1981).

4.11 Giant Floater (12a)

Pyganodon grandis (Say, 1829)

Description: Shell shape is highly variable, often ovate or elongate, thin and compressed in juveniles while thicker and more inflated in adults, on average 95 mm reaching up to 160 mm in length (Clarke 1981; Metcalfe-Smith *et al*. 2005). Anterior end rounded, posterior end bluntly pointed and the ventral margin is straight or slightly curved (Figure 38). Periostracum smooth, pale yellow or yellowish green with rays in younger individuals becoming dark green, brown or black and a rougher texture in older individuals (Metcalfe-Smith *et al*. 2005). Beak position anterior and extending well above the hinge line, beak sculpture with 4–5 thick double looped, nodulous ridges (Figure 39).

Pseudocardinal and lateral teeth are lacking, hinge line may be thickened and slightly curved. Beak cavity broad and shallow. Nacre variable and may be silvery white, tinged cream, salmon or pink coloured (Cummings and Mayer, 1992).

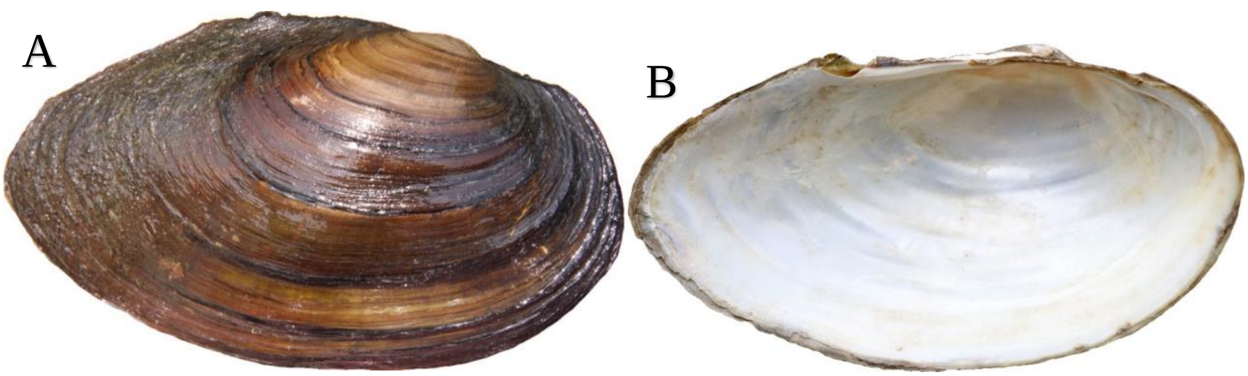

Figure 38. Lateral view of external right valve (A) and internal left valve (B) of the Giant Floater (*Pyganodon grandis*).

Figure 39. Beak of the Giant Floater (*Pyganodon grandis*) with 4–5 nodulous double looped ridges.

Similar species: The Cylindrical Papershell has a similar ovate and elongate shell shape, however, the shell is more elongated and smaller than the Giant Floater. The Giant floater can further be distinguished by its double looped beak sculpture, opposed to the single looped sculptures of the Cylindrical Papershell and 3–4 heavy concentric bars of the Creeper.

Status Designations: Giant Floater is listed as Secure (G5) in North America; Secure (N5) in Canada; and Secure in Manitoba (S5) (NatureServe 2021).

Hosts: Lake Sturgeon (*Acipenser fulvescens*), Goldfish, Common Carp, Common Shiner, Pearl Dace (*Margariscus margarita*), Golden Shiner (*Notemigonus crysoleucas*), Blacknose Shiner, Bluntnose Minnow, Western Blacknose Dace (*Rhinichthys obtusus*), Creek Chub, White Sucker, Brook Stickleback, White Bass, Rock Bass, Pumpkinseed, Bluegill, Largemouth Bass, White Crappie, Black Crappie, Iowa Darter, Johnny Darter (*Etheostoma nigrum*), Yellow Perch, and Freshwater Drum are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004).
Longnose Gar, Skipjack Herring (*Alosa chrysochloris*), Gizzard Shad, Central Stoneroller, River Carpsucker (*Carpiodes carpio*), Yellow Bullhead, Brook Silverside (*Labidesthes sicculus*), Green Sunfish, and the Orangespotted Sunfish are additional suitable hosts (Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: Giant Floater is found in nearly every type of substrate and water flow including small streams to larger rivers, lakes, and ponds (Metcalfe-Smith *et al.* 2005). Commonly found in sluggish water on silty bottoms as they are more tolerant to higher levels of silt and turbidity (Klocek *et al.* 2008).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, Little Saskatchewan River, Mystic Creek, Lake Manitoba, Clear Lake, Lake Winnipegosis, and Lake Winnipeg watersheds (Figure 40).

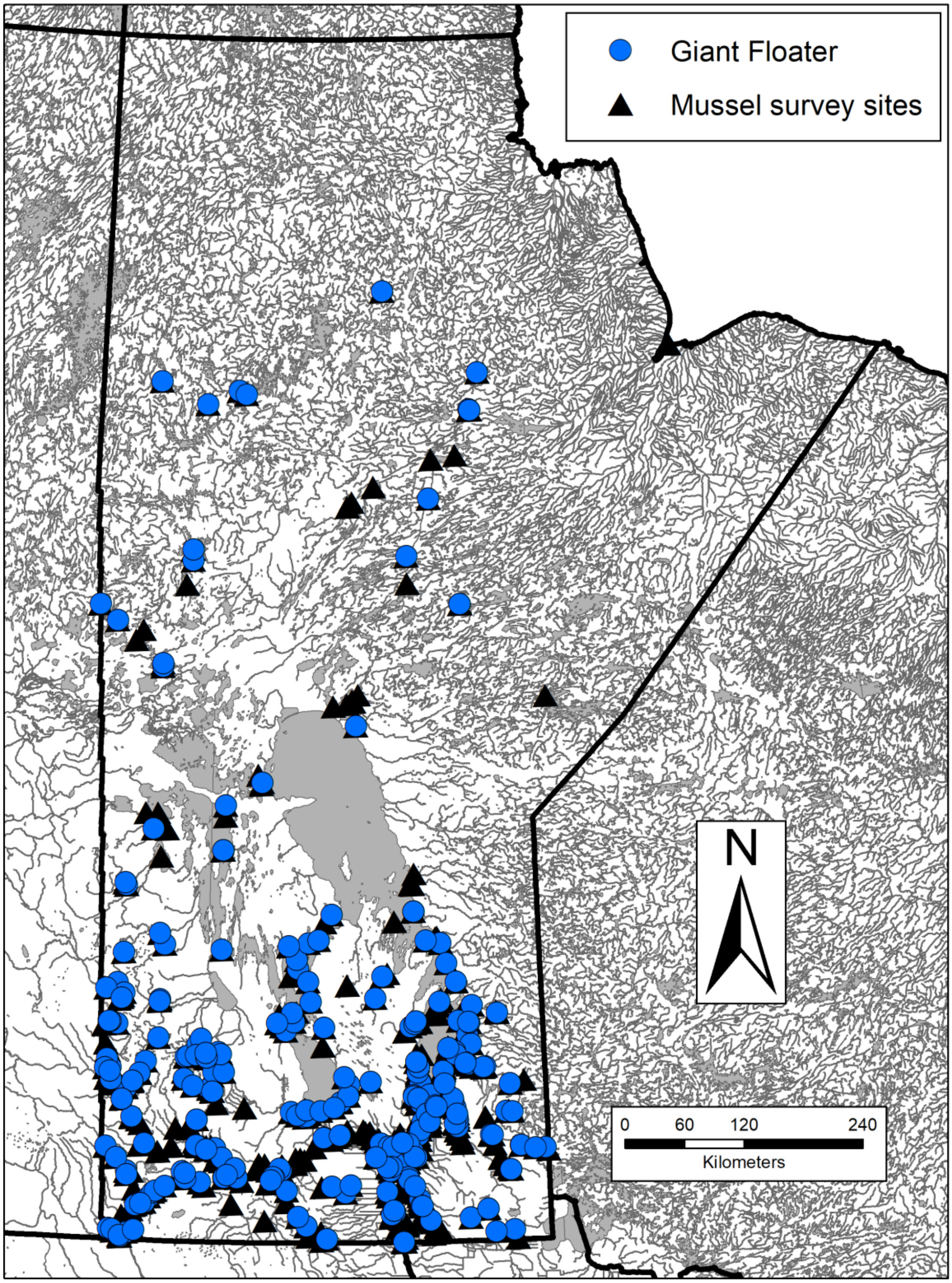

Figure 40. Distribution of the Giant Floater (*Pyganodon grandis*) in Manitoba.

Comments: Giant Floater have a bradytictic brooding strategy, females are gravid in August expelling glochidia the following April or May. Glochidia are triangular, have spines, reaching up to 0.36 mm long and 0.33 mm high. Species known to be dioecious using separated sexes and monoecious with hermaphroditic individuals (Clarke 1981).

4.12 Mapleleaf (2a)
Quadrula quadrula (Rafinesque, 1820)

Description: Shell is quadrate, thick, and somewhat inflated with two rows of bumps running down the shell, one near the center, the other on the posterior ridge separated by a furrow. The average shell length in Manitoba is 90 mm, reaching a maximum of 130 mm (Metcalfe-Smith *et al*. 2005; DFO 2011). The posterior end of the shell is square, and the anterior end is rounded (Metcalfe-Smith *et al*. 2005; Figure 41). Dorsal margin straight, ventral margin curved on the anterior end and straight on posterior end. Yellowish green to light brown in colour with faint rays in smaller individuals, becoming greenish brown or dark brown in larger individuals (Cummings and Mayer 1992). The beak is small, extending above the hinge line. Beak position central, sculptures form two rows of tiny crowded nodules that extend in a V-shape downwards from the beak allowing for easy identification (Figure 42**Error! Reference source not found.**).

Pseudocardinal teeth heavy, well developed, and deeply serrated; two in the left valve and one in the right. Lateral teeth are long, striated and straight; two in the left valve and one in the right. Beak cavity is deep. Nacre pearly white, iridescent posteriorly (Cummings and Mayer 1992).

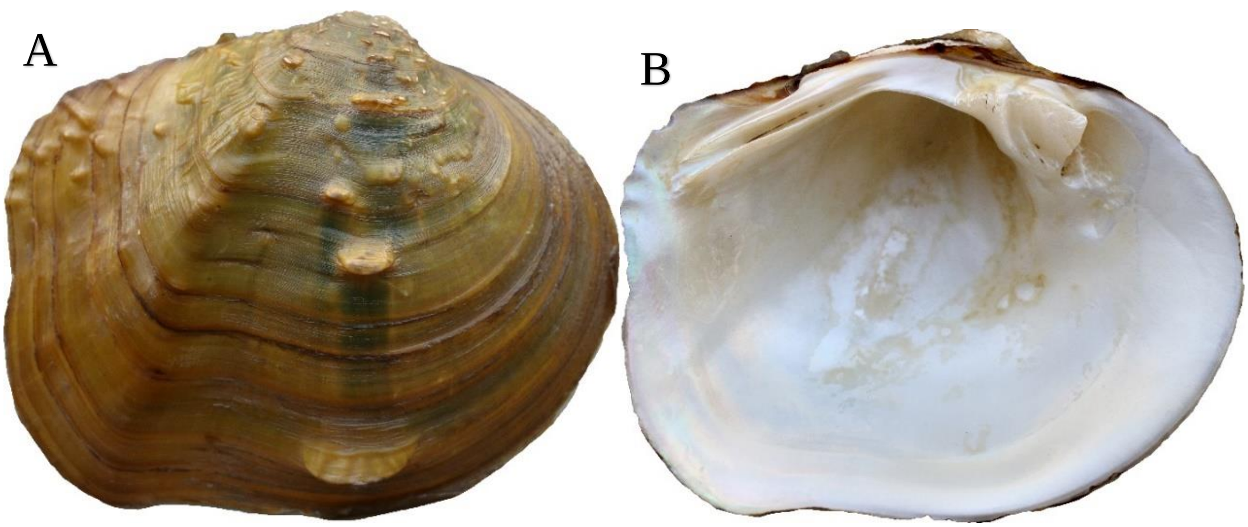

Figure 41. Lateral view of external right valve (A) and internal left valve (B) of the Mapleleaf (*Quadrula quadrula*).

Figure 42. Beak of the Mapleleaf (*Quadrula quadrula*) two rows of tiny, crowded nodules.

Status Designations: Mapleleaf is listed as Secure (G5) in North America; Imperiled / Vulnerable (N2N3) in Canada; and Critically Imperiled in Manitoba (S1) (NatureServe 2021). Mapleleaf in Manitoba was assessed as Threatened by COSEWIC in 2016 (COSEWIC 2016) and is listed as Threatened under the *Species at Risk Act* in Canada.

Similar species: The Wabash Pigtoe has a similar shell shape with a sulcus, but it lacks the two rows of bumps running down the shell.

Hosts: Channel Catfish is the only known host species in Manitoba.
The Flathead Catfish is an additional suitable hosts outside of Manitoba (DFO 2011).

Habitat: Mapleleaf occur in medium to large rivers and reservoirs with slow or fast moving water. Course gravel is preferred, but the species has been observed using sand, packed clay, and silt substrates (Cummings and Mayer 1992; DFO 2011).

Distribution: In Manitoba, this species occurs in the Red, Assiniboine, and Winnipeg rivers and other tributaries to Lake Winnipeg (Figure 43).

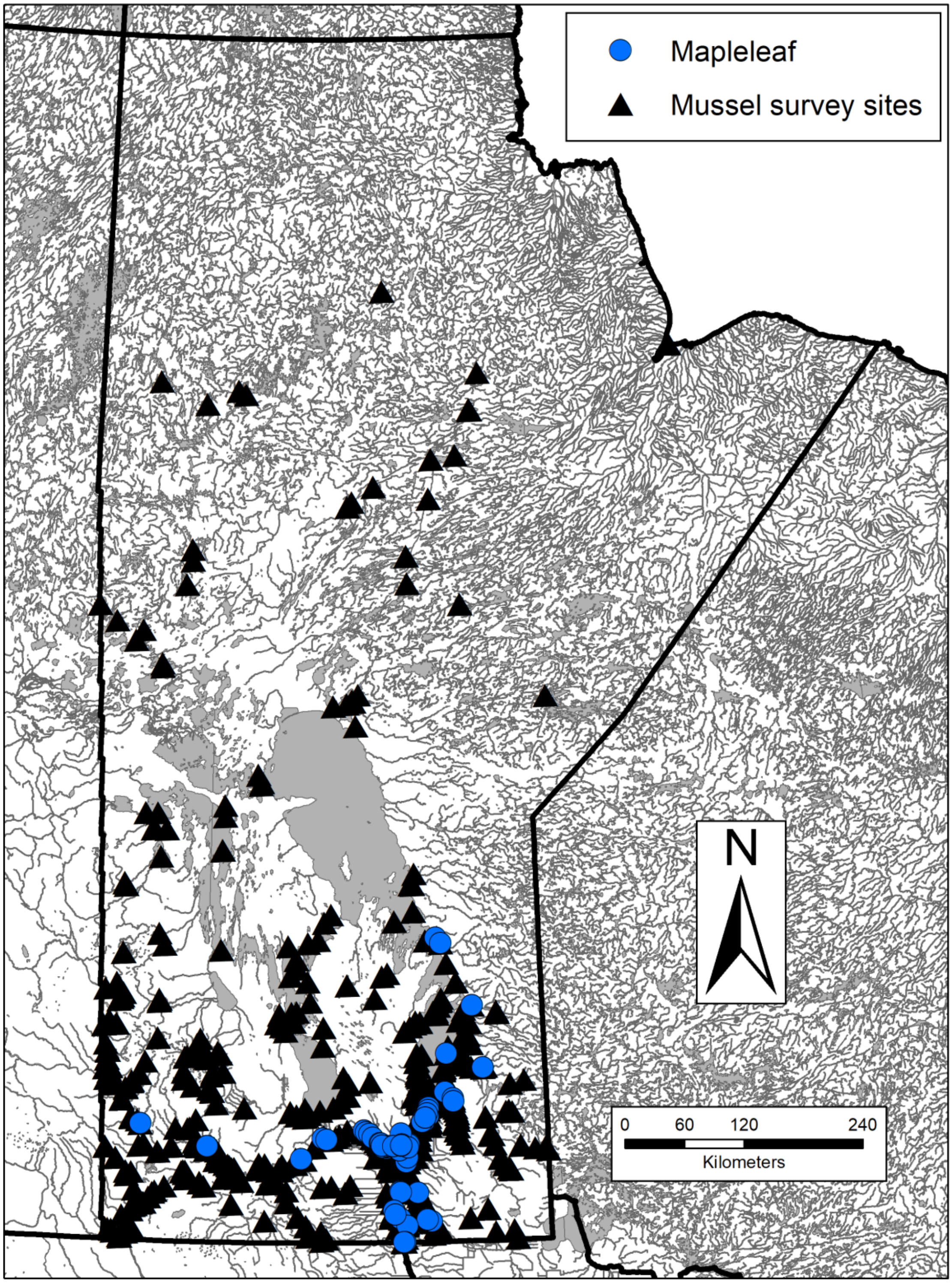

Figure 43. Distribution of the Mapleleaf (*Quadrula quadrula*) in Manitoba.

Comments: Mapleleaf have a tachytictic brooding strategy, and females are gravid in the late spring expelling glochidia in late summer. Glochidia are oval, without hooks and 0.08 mm in length and height (Clarke 1981). The average age of the Manitoba population is 22 years old, and the oldest found specimen was 64 years (DFO 2011). Estimates for Manitoba's Mapleleaf population range between 1–4 million mussels. Compared with historical records, the population appears to be declining. Populations are never abundant when found, often accompanied by fresh empty shells indicating a high level of recent mortality (COSEWIC 2016).

4.13 Creeper (11a)

Strophitus undulatus (Say, 1817)

Description: Shell ovate to trapezoidal, thin and moderately compressed when young becoming thicker and somewhat inflated in adults, on average 70 mm reaching up to 100 mm in length (Metcalfe-Smith *et al*. 2005). Anterior end rounded, posterior end bluntly tipped, and a straight to slightly concave ventral margin (Figure 44). Periostracum smooth, green or yellowish brown with green rays in younger individuals, becoming darker brown to black in older individuals. Live specimens have an orange foot (Metcalfe-Smith *et al.* 2005). Beak is positioned slightly anterior and extends slightly above hinge line; beak sculptures composed of 3–4 heavy V-shaped concentric ridges (Cummings and Mayer 1992; Figure 45).

Pseudocardinal and lateral teeth weakly developed or absent, may present as swellings near the hinge line. Beak cavity is shallow. Nacre is white or blueish, sometimes cream or salmon coloured closer to the beak (Clarke 1981; Cummings and Mayer 1992).

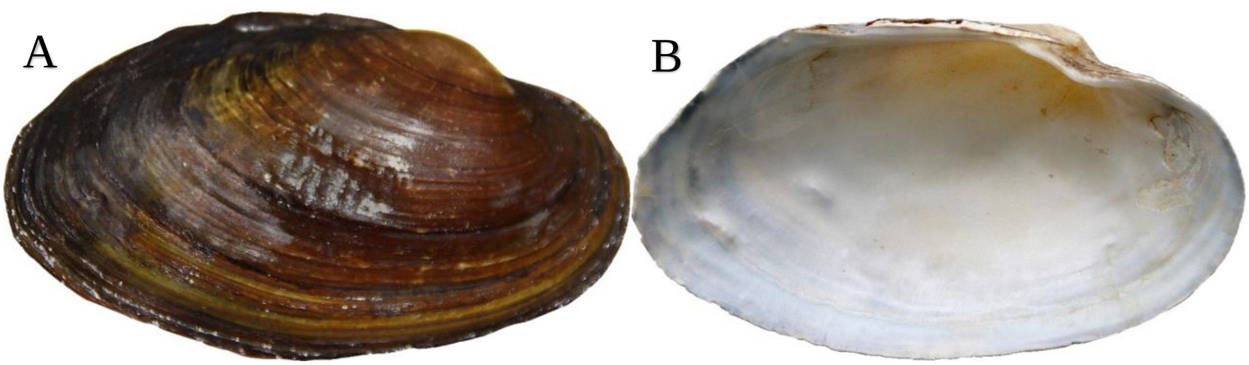

Figure 44. Lateral view of external right valve (A) and internal left valve (B) of the Creeper (*Strophitus undulatus*).

Figure 45. Beak of the Creeper (*Strophitus undulatus*) with 3–4 heavy concentric bars.

Similar species: Similar ovate shell and lack of hinge teeth as the Giant Floater, but the shell is more inflated and has double looped beak sculptures, whereas the Creeper has V-shape sculptures. The Cylindrical Papershell is also lacking hinge teeth, but the Cylindrical Papershell shell is more inflated and elongated than the Creeper, which has a more ovate, trapezoidal shell shape, and a more prominent beak sculpture.

Status Designations: Creeper is listed as Secure (G5) in North America; Secure (N5) in Canada; and Secure in Manitoba (S5) (NatureServe 2021).

Hosts: Spotfin Shiner, Common Shiner, Sand Shiner (*Notropis stramineus*), Northern Redbelly Dace (*Chrosomus eos*), Bluntnose Minnow, Fathead Minnow, Longnose Dace, Western Blacknose Dace, Creek Chub, Black Bullhead, Channel Catfish, Central Mudminnow (*Umbra limi*), Burbot (*Lota lota*), Brook Stickleback, Rock Bass, Pumpkinseed, Bluegill, Smallmouth Bass, Largemouth Bass, White Crappie, Black Crappie, Iowa Darter, Johnny Darter, Yellow Perch, Logperch (*Percina caprodes*), Blackside Darter (*Percina maculata*), and Walleye are known suitable hosts (Klocek *et al*. 2008; Schainost 2016) in Manitoba (Stewart and Watkinson 2004).
Central Stoneroller, Yellow Bullhead, Plains Killifish (*Fundulus zebrinus*), Green Sunfish, Northern Sunfish (*Lepomis peltastes*), Rainbow Darter (*Etheostoma caeruleum*), and Fantail Darter (*Etheostoma flabellare*) are additional suitable hosts (Klocek *et al*. 2008; Schainost 2016) outside of Manitoba (Stewart and Watkinson 2004).

Habitat: Creeper occur in creeks, small to medium sized streams, and occasionally in larger rivers in a range of flow velocities. Usually found in silt, sand, or gravel substrate (Cummings and Mayer 1992; Metcalfe-Smith *et al.* 2005).

Distribution: In Manitoba, this species occurs in the Red River, Assiniboine River, Winnipeg River, Nelson River, and Lake Winnipeg watersheds (Figure 46).

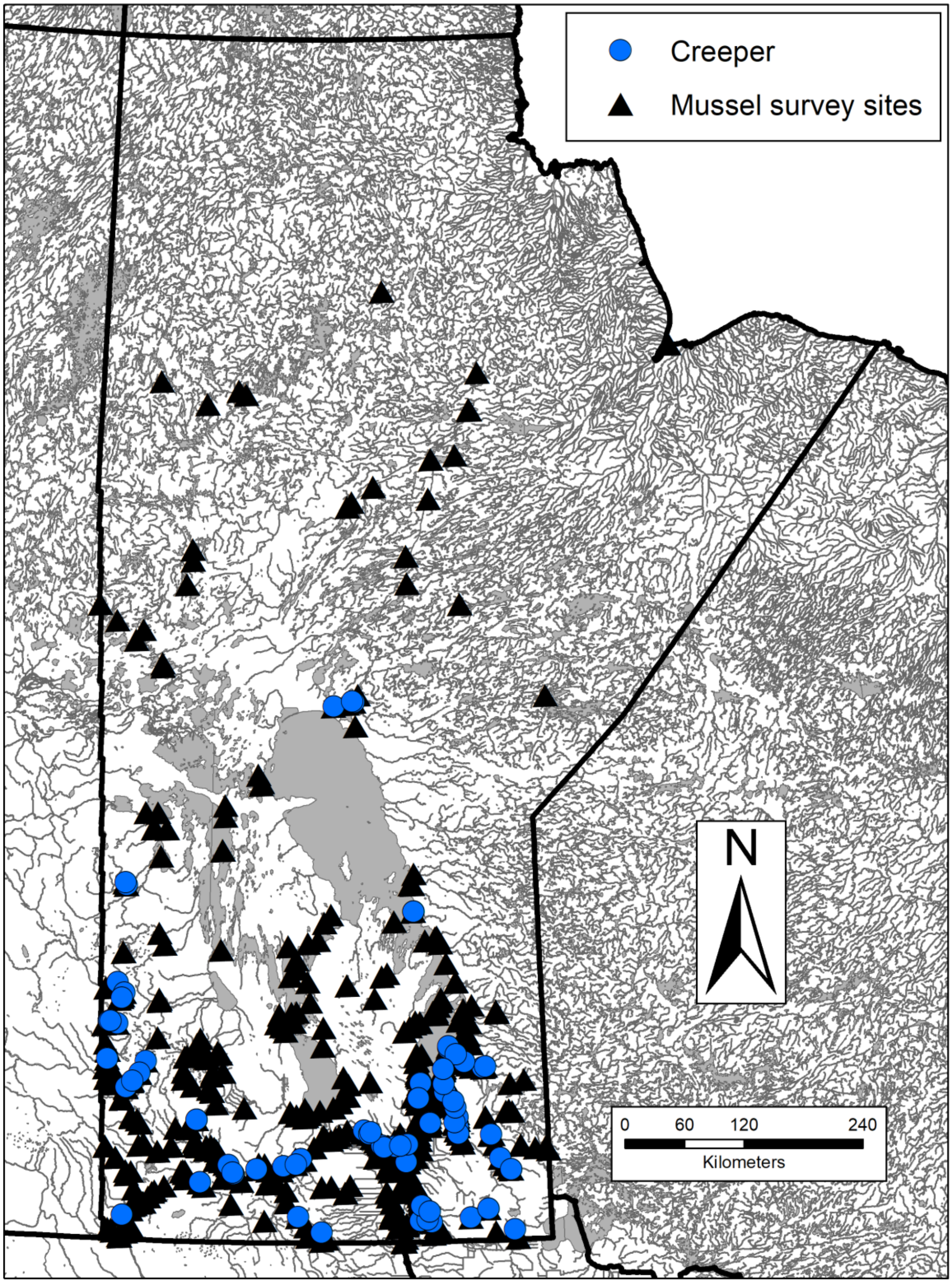

Figure 46. Distribution of the Creeper (*Strophitus undulatus*) in Manitoba.

Comments: Creeper have a bradytictic brooding strategy, females are gravid in July throughout the winter expelling glochidia the following April or May. Glochidia are subtriangular, hooked, and reach up to 0.36 mm long and 0.30 mm high. Some glochidia have been observed fully developing without a period of parasitism on fish (Clarke 1981).

5.0 SUMMARY AND FUTURE RECOMMENDATIONS

Freshwater mussels assisting in nutrient cycling, sediment mixing, and by serving as prey for other species in the food web. Overall, a healthy mussel population indicates good water quality and a healthy ecosystem. One of the largest threats to the survival and persistence of freshwater mussels in Manitoba is habitat loss and degradation.

In Manitoba, many species of mussels are lacking basic life history information, including glochidia and juvenile survival rates, longevity, and population growth rate data. These life history characteristics are important factors to consider when modeling potential threats and future risks to mussel populations (Dennis *et al.* 1991). Developing ecological niche or habitat suitability models can help better predict the habitat requirements and distributions for Manitoba's native mussel species (Parasiewicz *et al.* 2012). Prioritizing protection of required habitat areas, or areas less prone to future degradation may be critical to the persistence of some mussel populations.

Aquatic invasive species (AIS), such as Zebra Mussel (a recent invader) may also negatively impact native mussel populations. A better understanding of the distribution ranges of native mussels and predicting future spread of AIS is critical for safeguarding Manitoba's mussel populations. Using environmental DNA (eDNA) technologies to track AIS has been suggested as a time and cost effective way to monitor the dispersal and distribution of Zebra Mussels (Sigsgaard *et al*. 2015). Early Zebra Mussel detection can allow for better control programs to prevent further spread into unaffected water bodies (Gingera *et al.* 2017). Given the seriousness of the threats posed by habitat loss and AIS, the need for more species specific life history information, and proactively managing and conserving mussel habitat is critical for future mussels species and population protection.

Further information on freshwater mussels can be found by consulting the Canadian Freshwater Mussel Guide "http://www.musselguide.ca/", which provides a user-friendly platform to explore the fascinating world of freshwater mussels and contribute to the conservation of these imperiled animals. The app is available for iOS and Android in both French and English. The app collected data will help to map threatened and endangered freshwater mussels nationwide and contribute to recovery efforts.

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