RECOVERY PLAN FOR TWELVE VERMONT FRESHWATER MUSSEL SPECEIS

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July 2002

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Vermont has 18 species of native mussels representing two families, Unionidae and Margaritiferidae. Currently three mussel species are state listed as threatened and seven are state listed as endangered (Table 1). Only one mussel species is both state and federally listed as endangered, the dwarf wedgemussel (*Alasmidonta heterodon*). In 1992, the introduction of the nonindigenous zebra mussel (*Dreissena polymorpha*) to the Lake Champlain region prompted the state to list ten mussel species (Fichtel and Smith 1995).

Table 1. List of mussels found in Vermont and their current status.

Species Name	State Listing	Federal Listing
Brook floater	T	
Black sandshell	E	
Cylindrical papershell	E	
Dwarf wedgemussel	E	E
Eastern pearlshell	T	
Flutedshell	E	
Fragile papershell	E	
Giant floater	T	
Pink heelsplitter	E	
Pocketbook	E	

T = threatened and E = endangered.

Two major physiographic regions influence Vermont's unique mussel fauna. The first region is known as the Mississippi River Basin or Interior Basin. The mussel fauna found in Lake Champlain and its tributaries was connected to the Mississippi River Basin species by way of the St. Lawrence River during the Pliocene (Smith 1985). Most of these mussel species from the Mississippi River Basin are restricted to Lake Champlain and its tributaries. The second physiographic region is the North Atlantic Coastal Region (Smith 1985). Most of these species are restricted to the Connecticut River Basin and its tributaries. The convergence of the two physiographic regions in Vermont supports two very unique mussel faunas that are separated by only the Green Mountain range.

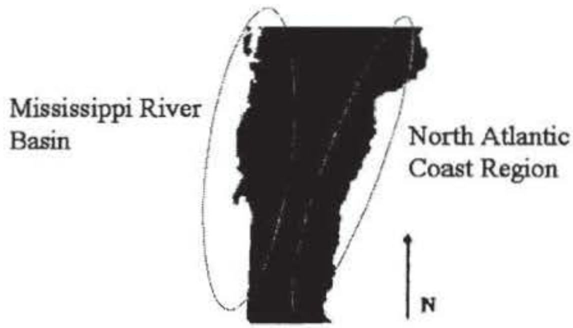

Figure 1. Map of Vermont showing the Mississippi River Basin and North Atlantic Coastal Region influence in Vermont.

Mussel populations have been declining nationally. Of the 304 species of mussels identified, 6% have become extinct, 15% are federally listed as endangered or threatened, and 23% are candidates for federal listings (Neves 1992, Williams et al. 1992). The reasons for the decline are not well understood, but a combination of threats may have negatively impacted their populations (Ortmann 1912, Fuller 1974, Williams et al. 1993).

The recovery of Vermont's mussels requires monitoring, mapping the spread of the zebra mussel, management, research, and fundraising. The objectives of this plan are to prioritize the actions needed to accomplish mussel recovery goals in Vermont.

1 INTRODUCTION

Mussels play an important role in the aquatic ecosystem. They provide food for wildlife, and are also good bioindicators because they are relatively sessile organisms that are long lived, bio-accumulate toxins, sensitive to environmental changes, widespread, and occur in a variety of aquatic habitats (Stansbery 1971, Bauer and Wächtler 2001). Some Unionidae species have been reported to live as long as 100 years. Among the Margaritiferidae, the eastern pearlshell (*Margaritifera margaritifera*) lives up to 200 years (Mutvei et al.1994). The drastic decline in mussel populations over the past several decades has prompted scientists to focus their attention on finding ways to reverse the trend.

North America is known for its rich mussel fauna, with 304 species currently recognized (Turgeon et al. 1998). Since the early 1900s, 6% of the mussel fauna have become extinct, 15% are federally listed as endangered or threatened, and 23% are candidates for federal listings (Neves 1992, Williams et al. 1993). The reasons for theses declines are not well known.

However, loss of suitable habitat (resulting from poor land and river management practices), introduction of exotic species, pollution, and commercial exploitation are thought to have a negative impact on the mussel populations (Ortmann 1912, Fuller 1974, Williams et al. 1992). In addition, because mussels are obligate parasites on fish, recent declines in the North American fish fauna may also have a negative effect on mussel populations (Allan and Flecker 1993). In fact, aquatic species of North America have been found to have an imperilment rate three to eight times greater than the imperilment rate of avian and mammalian fauna (Master 1990).

2 BACKGROUND

2.1 Mussel Reproductive Biology

Mussels are unique among bivalves in that most require a host fish to complete their life cycle. Unlike male and female marine bivalves, which release sperm and eggs into the water column where fertilization takes place, fertilization of mussels takes place within the broodchambers of the female mussel (Jirka and Neves 1992). The female mussel carries the fertilized eggs in the gills until they develop into a parasitic stage called glochidia. Female mussels then release the glochidia into the water column where they must come into contact with the suitable host fish species. Once the glochidia are released they will survive for only a few days if they do not successfully attach to a host fish (O'Brien and Brim Box 1999). After successfully attaching to the host fish for a few weeks, the glochidia metamorphose and drop to the substrate to become free-living juveniles (Jones 1950, Howard 1951). The time required for glochidial metamorphosis varies with water temperature and among mussel species. Properly encysted glochidia will metamorphose, with little change in size (Coker et al. 1921), into free-living juveniles, displaying abductor muscles, gill buds, and a ciliated foot with protractor and retractor muscles (Karna and Millemann 1978).

The mussel/fish relationship is usually species-specific (Lefevre and Curtis 1912), only certain species of fish can serve as suitable hosts for a particular mussel species. The number of host fish utilized by a mussel species varies. Some mussel species have a very restricted number of host fish species (Watters 1994, Michaelson and Neves 1995) while other mussels parasitize a wide range of fish species (Watters 1994, Haag and Warren 1997). Lefevre and Curtis (1912) found glochidia belonging to the genus *Strophitus* were capable of metamorphosing without the aid of a host fish. Knowledge of the reproductive biology of many mussels remains incomplete (Jansen 1990). Only 25% of the 304 mussel species in North America have had their host fish identified by way of field and/or laboratory experiments (Watters 1994). A confirmed host fish for a mussel species will have been identified as metamorphosing glochidia via laboratory experiments and also found to have encysted glochidia, from the same mussel species, on wild caught fishes.

Some mussels attempt to improve the chance of their glochidia contacting a host fish by releasing glochidia into the water column when light sensitive spots are stimulated by the shadow of a passing fish (Kraemer 1970, Jansen 1990). Other mussel species have evolved elaborate lures resembling fish food as mechanisms to attract specific host fishes (Coker et al. 1921, Kraemer 1970, Jansen 1990, Haag et al. 1995, Hartfield and Butler 1997, O'Brien and Brim Box 1999).

Mussels were categorized into two groups based on their embryo incubation period (Lefevre and Curtis 1912, Waller et al. 1988). One group is categorized as tachytictic (short-term) breeders, which fertilize eggs in the spring and release glochidia in the fall of the same year. The second group, bradytictic (long-term) breeders, fertilize eggs in late summer and release glochidia in the spring or early summer the following year. However, a recent study on the periods of glochidial release indicates the mussel reproductive cycle may be more complex than the earlier thought. For example, there is evidence that some mussel species release glochidia multiple times during their breeding season and some species of glochidia over-winter on their host, which would not be considered tachytictic or bradytictic (Watters and O'Dee 2000).

2.2 Food Requirements

Mussels are suspension feeders. The adult mussels siphon water into the incurrent opening and expel it via the excurrent opening. Cilia-lined membranes move the water through a series of sorting organs towards the stomach (Allen 1914). Juvenile mussels usually pedal feed during the first several weeks of life until their siphoning system is developed (Yeager et al. 1994). When a juvenile mussel is pedal feeding the shell is slightly gaped, the foot extended, and tiny cilia on the foot tease the food towards the digestive gland. During the pedal feeding phase the juvenile mussel maybe more susceptible to water pollutants because the shell is gaped and not fully developed and may ingest pollutants absorbed to sediment particles. Food requirements vary among mussel species and age. Earlier studies by Churchill (1916) discovered mussels are capable of absorbing nutrients (e.g., protein, starch, fat) from the water column. Although the exact diet requirement has not been identified, it is known that mussels eat plankton comprised of a variety of algae, diatoms, detritus, bacteria, and viruses (Coker et al. 1921, Cummings and Mayer 1992, Parmalee and Bogan 1998).

3. MUSSEL SPECIES INFORMATION

3.1 Brook floater (*Alasmidonta varicose*) (Lamarck, 1819)

Description:

The brook floater is considered a small to medium sized mussel, growing to lengths of about 70 mm (Fichtel and Smith 1995). The posterior ridge of the shell has wrinkles and ridges (Nedeau et al. 2000). The shell color ranges form a yellowish brown to dark brown and is heavily rayed with green. The nacre (internal mother-of-pearl layer) is bluish to pink in color. The pseudocardinal teeth are reduced and dull, lateral teeth are lacking. The foot is orange to pink in color.

Life history and Ecology:

Potential host fishes for the brook floater have been identified via laboratory experiments as the slimy sculpin, pumpkinseed, yellow perch, golden shiner, margined madtom, blacknose dace, and longnose dace (Wicklow and Richards 1995) (see appendices for list of scientific names for fishes). The brook floater is a long-term brooder and releases glochidia from April to June. In Vermont, glochidial release is most likely May to July, but this has not been confirmed.

The brook floater is found in low to medium grade streams with low to moderate flows. The preferred habitat for the brook floater is consolidated gravel, cobble, and sand (Fichtel and Smith 1995). The brook floater is considered a riverine species.

Distribution, Abundance, and Current Status in Vermont:

The brook floater is known to occur from the St. Lawrence Drainage, Canada, to the upper Savannah River in Georgia and South Carolina (Burch 1975). In Vermont, the brook floater is only found in the lower portion of the West River, in the Connecticut River system. For the most part, this species is not common throughout its range, but can be locally abundant (Fichtel and Smith 1995). The highest densities were located between Brookline, Newfane, and Townshend, VT. Fichtel (1992) reported finding 42.8 brook floaters in one person-hour of surveying near Green Bridge, VT. During a survey below the Townshend Dam, VT, Fichtel (1993) reported finding 80.4 brook floaters in one person-hour.

Williams et al. (1993) listed the brook floater as threatened. There has been a marked decline in the distribution throughout its range. In 1995, the brook floater was a category 2 candidate for listing under the Endangered Species Act, but this level of candidate status is no longer used. (Nedeau et al. 2000). The brook floater is listed as endangered in New Hampshire, Massachusetts, Connecticut, Maryland, and Virginia. In Maine, the brook floater is listed as a species of special concern (Nedeau et al. 2000).

Current Threats in Vermont:

The following are threats to the current brook floater populations in Vermont: reservoirs; restricted range (e.g., occurs in a single stream); chemical pollution in the form of stormwater and agricultural runoff, and sedimentation as a result of floodplain, stream bank, and instream modifications.

3.2 Black sandshell (*Ligumia recta*) (Lamarck, 1819)

Description:

The black sandshell shell is thick and elongate-elliptical in shape. Black sandshells are medium to large in size growing to 160–200 mm in length (Cummings and Mayer 1992, Parmalee and Bogan 1998). The periostracum is smooth and dark brown to black in color. The nacre is usually white, but can be purple to pinkish in color. The posterior end is pointed and the anterior end is rounded. Pseudocardinal teeth are serrated and triangular in shape, with one in right valve and two in the left valve.

Life history and Ecology:

Watters (1994) reported the following as potential host fish for the black sandshell; banded killifish, bluegill, green sunfish, orangespotted sunfish, largemouth bass, sauger, and white crappie. Results from Hove et al. (1994) also named the largemouth bass as a host and added the walleye as hosts for the black sandshell (see appendices for list of scientific names for fishes). However, Hove et al. (1994) mentioned there were discrepancies with these results and warranted further investigations. It is unclear if these host fish were confirmed as hosts in the wild.

Ortmann (1912) described the black sandshell as a long-term breeder. Female black sandshells were found releasing glochidia in late July and in August they were found with eggs in their gills. The black sandshell found in Vermont most likely release glochidia in August, but this has not been confirmed.

The black sandshell is found in sand, gravel, and consolidated sand habitats in medium-sized rivers (Parmalee and Bogan 1998, Cummings and Mayer 1992). Williams and Fuller (1992) categorized the black sandshell as intolerant fo impoundments. The black sandshell is considered a riverine species.

Distribution, Abundance, and Current Status:

The black sandshell is found throughout the Mississippi River drainage south to the Gulf of Mexico, west to Okalahoma, and north and east to the St. Lawrence River (Parmalee and Bogan 1998).

Cummings and Mayer (1992) reported the black sandshell as being widespread, but uncommon in the Midwest. In Vermont, the black sandshell is considered rare. Historically, the black sandshell was found in four streams, but the most recent sightings were in three streams: the Poultney and Missisquoi rivers and Otter Creek (Marangelo 1999, Fichtel and Smith 1995). Live individuals have not been found in Hospital Creek for over 30 years.

Williams et al. (1993) listed the black sandshell as a species of special concern and Cummings and Mayer (1992) report it as threatened in Ohio. In Vermont, the black sandshell is listed as endangered.

Current Threats in Vermont:

The black sandshell is threatened by, but not limited to the following: zebra mussels (*Dreissena polymorpha*); disjunct populations; occurs in low densities; chemical pollution in the form of stormwater and agricultural runoff; sedimentation as a result of floodplain, streambank, and instream modifications.

3.3 Cylindrical papershell (*Anodontoides ferussacianus*) (Lea, 1834)

Description:

The cylindrical papershell is a small to medium sized mussel growing to an average length of 80 mm. The thin elongate shell is slightly inflated. The shell has faint green rays over a yellowish to light brown periostracum. The lateral teeth are lacking, but there can be remnant irregularities along the hinge line below the beak. The nacre is bluish to white (Parmalee and Bogan 1998). This species is most easily confused with floaters (*Pyganodon* sp.). Cylindrical papershells have papillae lining both the incurrent and excurrent opening; *Pyganodon* sp. have papillae lining only the incurrent opening (Baker 1898).

Life history and Ecology:

A variety of host fish have been identified for the cylindrical papershell. Wilson and Ronald (1967) identified the sea lamprey as a potential host fish after finding cylindrical papershell glochidia encysted on wild caught sea lamprey. Fuller (1978) listed the common shiner, Iowa darter, and white sucker as potential hosts after finding cylindrical papershell glochidia attached to these wild caught fishes. Hove et al. (1997) identified the black crappie and spotfin shiner as hosts for the cylindrical papershell after conducting laboratory experiments. O'Dee and Waters (2000) identified the largemouth bass as a host after conducting laboratory experiments (see appendices for list of scientific names for fishes). However, the effectiveness of each of the hosts mentioned above to metamorphose cylindrical papershell glochidia was not discussed. Ortmann (1912) reported finding individuals discharging glochidia in May. In Vermont, glochidial release is most likely June or July, but this has not been confirmed.

The cylindrical papershell is found along riverbanks in low flow environments in silt, sand, and gravel habitats (Cummings and Mayer 1992, Marangelo 1999, O'Brien 2002a). This species is considered a river species.

Distribution, Abundance, and Current Status:

The cylindrical papershell has a fairly wide range from the Mississippi River System east to the Great Lakes Region and St. Lawrence River (Burch 1975). In Vermont, the cylindrical papershell is found in only a few streams. Fichtel and Smith (1995) reported finding the cylindrical papershell in the Missisquoi River and in Stone Bridge Brook. Recent surveys identified the species in the Lamoille River above and below the fall-line (O'Brien 2002a).

Cummings and Mayer (1992) reported the distribution of the cylindrical papershell as widespread and locally abundant. Williams et al. (1993) considered the cylindrical papershell as currently stable. In Vermont, this species is listed as endangered and appears to be confined to only two streams and is found mostly in low densities (O'Brien 2002a, Marangelo 1999). However, one site on the Missisquoi River had cylindrical papershell densities of $0.44/m^2$ (Marangelo 1999).

Current Threats in Vermont:

The cylindrical papershell is threatened by: zebra mussel; chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

3.4 Dwarf wedgemussel (*Alasmidonta heterodon*) (Lea, 1829)

Description:

The dwarf wedgemussel is a small species that grows to a length of 45 mm. The slanted posterior ridge of the shell forms a trapezoidal shape and the color varies from a dark brown, greenish, or slightly yellow (Nedeau et al. 2000, Fichtel and Smith 1995). Two lateral teeth are found in right valve, and one in the left valve (Burch 1975).

Life history and Ecology:

Host fish for the dwarf wedgemussel have been identified via laboratory experiments as the tessellated darter, Johnny darter, and mottled sculpin (Michaelson and Neves 1995). The mottled sculpin metamorphosed 5 to 10 times as many juvenile dwarf wedgemussels when compared to the tessellated and Johnny darters. However, the size of fish used in the experiment was not mentioned (Mickelson and Neves 1995). Wicklow (1999) reported the Atlantic salmon as a potential host for the dwarf wedgemussel (see appendices for list of scientific names for fishes). Dwarf wedgemussels are gravid in the fall, but release their glochidia in the spring (Michaelson and Neves 1995). In Vermont, glochidial release is most likely from April to May, but this has not been confirmed.

The dwarf wedgemussel is found in small to large streams in low to moderate flow. The preferred habitat varies from mud, sand, to gravel (Strayer and Ralley 1993). The dwarf wedgemussel is considered a riverine species.

Distribution, Abundance, and Current Status:

The dwarf wedgemussel is federally listed as endangered. Historically dwarf wedgemussels were found from the Petitcodiac River system, Brunswick, Canada, south to the Neuse River System, North Carolina (Burch 1975). However, dwarf wedgemussels have not been reported from several of these for decades (Nedeau et al. 2000). In Vermont, dwarf wedgemussels are only found in the Connecticut River and upper Black River, part of the Connecticut River system in Vermont. Although the distribution of the dwarf wedgemussel is fairly large, the populations are sparse and occur in low densities ($0.0001/m^2$ to $0.04/m^2$) (Strayer et al. 1996). Some of the largest populations occur in the upper Connecticut River in Vermont and New Hampshire (Strayer et al. 1996). Population monitoring for the dwarf wedgemussel over the past 10 years have indicated that at least 3 populations have remained relatively stable in Vermont (O'Brien 2002b).

Current Threats in Vermont:

The current threats to the dwarf wedgemussel include the following: maintenance of reservoirs; distinct range (e.g., occurs only in the Connecticut River, VT and NH); chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

3.5 Eastern pearlshell (*Margaritifera margaritifera*) (Linnaeus, 1758)

Description:

The eastern pearlshell is a medium sized mussel growing to lengths of 120 mm. The shell is thick, elongate, and slightly curved downward. The periostracum is a smooth dark brown. The nacre is white. Lateral teeth are lacking as well as the soft part division between the inhalant and exhalent opening (Fichtel and Smith 1995, Nedeau et al. 2000). The lack of division between the inhalant and exhalant openings is diagnostic for the family Margaritiferidae (Ortmann 1912).

Life history and Ecology:

Smith (1976) identified the brook trout and Atlantic salmon as hosts for the eastern pearlshell via laboratory experiments (see appendices for list of scientific names for fishes). This species has been reported to have the ability to self-fertilize when populations are sparse (Bauer 1987). The eastern pearlshell is long lived, with individuals reported living 200 years (Mutvei et al. 1994). The breeding season for the eastern pearlshell is July and August (Ortmann 1912). In Maine, the eastern pearlshell releases glochidia from late August to October (Nedeau et al. 2000).

The eastern pearlshell is restricted to cool water streams, habitat also utilized by its host, salmonids. The preferred habitats of the eastern pearlshell are consolidated sand and sand gravel mix (Fichtel and Smith 1995, Nedeau et al. 2000). This species is considered riverine.

Distribution, Abundance, and Current Status:

The distribution of the eastern pearshell is widespread in northern latatitudes covering an area from Newfoundland and Labrador west to the headwaters of the Missouri River, and south to Pennsylvania (Burch 1975). In Maine, the eastern pearlshell is widespread, but was reported as not common (Nedeau et al. 2000). In Vermont, the eastern pearlshell is found in five streams above the fall-line. This species is considered common to rare in the following five Vermont streams: Lewis Creek, Moose, Nulhegan, West, and Winooski rivers.

Williams et al. (1993) considered the eastern pearlshell a species of special concern. In Vermont, the eastern pearlshell is listed as threatened.

Current Threats in Vermont:

The eastern pearlshell is threatened by the following: reservoirs (i.e., impeding migratory host fish) any action which would increase stream water temperature (i.e., interfere with host fish habitat requirements); disjunct populations, chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

3.6 Flutedshell (*Lasmigona costata*) (Rafinesque, 1820)

Description:

The flutedshell is a medium sized mussel growing to lengths of 190-200 mm (Parmalee and Bogan 1998). The shell is compressed and elongate with course wrinkles along the posterior ridge. The periostracum color ranges from a yellowish to dark brown in the older individuals (Cummings and Mayer 1992, Fichtel and Smith 1995, Parmalee and Bogan 1998). The nacre can be bluish, white, or even a yellowish-white. Lateral teeth are underdeveloped, but pseudocardinal teeth are thick.

Life History and Ecology:

A variety of host fish have been identified for the flutedshell. Luo (1993) identified the following as hosts via laboratory experiments: rainbow darter, fantail darter, striped darter, green sunfish, longear sunfish, rockbass, smallmouth bass, banded sculpin, central stoneroller, brown bullhead, and northern studfish. The list was again expanded with the identification of the following fish hosts via laboratory experiments, complements of Hove et al. (1994): bowfin, northern pike, bluegill, largemouth bass, yellow perch, and walleye. However, the effectiveness of the host fish metamorphose glochidia was not discussed (Hove et al. 1994). Weiss and Layzer (1995) named the following potential host fish after identifying encysted glochidia on wild caught fishes: gizzard shad and river redhorse (see appendices for list of scientific names for fishes). The flutedshell spawns in the late summer; the glochidia are held over the winter, and are released late spring (Parmalee and Bogan 1998). In Vermont, glochidia are most likely release in May, but this has not been confirmed.

The flutedshell is found in streams and rivers in low to moderate flow (Cummings and Mayer 1992). The flutedshell is found a variety of sediments ranging form silt to sand to gravel (Cummings and Mayer 1992, Fichtel and Smith 1995). This species is considered riverine.

Distribution, Abundance, and Current Status:

The flutedshell is found throughout the Mississippi River drainage south to northern Alabama, Louisiana, Georgia, and Mississippi. The flutedshell is also known from the Great Lakes region, east to the St. Lawrence system, including Lake Champlain (Parmalee and Bogan 1998). In Vermont, the flutedshell is mainly found below the fall-line (Otter Creek is the exception) in several tributaries of Lake Champlain (Fichtel and Smith 1995).

Past surveys in the Poultney River indicate the flutedshell was not very common (Fichtel 1990). A more recent survey of the Poultney recorded a flutedshell density of $0.28/m^2$ (O'Brien 2001) and a survey of the Missisquoi River reported only finding flutedshell shells (Marangelo 1999).

Cummings and Mayer (1992) reported the flutedshell as widespread and common. Williams et al. (1993) identified the flutedshell as a species currently stable. In Vermont the flutedshell is listed as endangered.

Current Threats in Vermont:

The current threats of the flutedshell include: zebra mussels; reservoirs; its restricted range (e.g., below the fall-line); chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

3.7 Fragile papershell (*Leptodea fragilis*) (Rafinesque, 1820)

Description:

The fragile papershell is considered a medium to large mussel growing to lengths of 150-160 mm (Parmalee and Bogan 1998). The shell is thin and compressed and subelliptical in shape. The periostracum is a yellow to a yellowish green color. Nacre is white and at times slightly pink to iridescent (Cummings and Mayer 1992, Fichtel and Smith 1995, Parmalee and Bogan 1998). Two pseudocardinal teeth are found in the left valve and only one in the right valve. The pseudocardinal teeth are thin, long, and compressed.

Life history and Ecology:

The freshwater drum named the host fish after finding fragile papershell glochidia on wild caught freshwater drum (Fuller 1974) (see appendices for list of scientific names for fishes. The fragile papershell releases its glochidia from June to July (Fuller 1974). In Vermont, the fragile papershell most likely releases its glochidia from July to August, but this has not been confirmed.

The fragile papershell is found in a variety of habitats ranging from streams to lakes in mud, sand, and gravel substrates (Cummings and Mayer 1992, Parmalee and Bogan 1998). The fragile papershell appears to be tolerant, to some extent, to sedimentation (Brim Box and Mossa 1999), but Williams et al. (1992) reported the fragile papershell as intolerant of impoundments.

Distribution, Abundance, and Current Status:

The fragile papershell has a wide range including the entire Mississippi River drainage from the Gulf of Mexico north into Canada, and east including the St. Lawarence River system (Burch 1975). In Vermont, the fragile papershell is limited to below the fall-line of five rivers and their deltas in Lake Champlain (Fichtel and Smith 1995).

In the Poultney River fragile papershell densities ranged form $0.03/m^2$ at The Nature Conservancy access to $0.15/m^2$ near the Coggman Bridge (O'Brien 2001). Fichtel (1992) reported fragile papershell densities of $0.27/m^2$. In the Missisquoi River fragile papershell densities were reported ranging from 0.25 to 0.96 $/m^2$ (Marangelo 1999).

Williams et al. (1993) considered the fragile papershell currently stable. Cummings and Mayer (1992) describe the fragile papershell as widespread and common. In Vermont, the fragile papershell is considered uncommon (Fichtel and Smith 1995) and is listed as endangered.

Current Threats in Vermont:

The current threats of the fragile papershell include the following: zebra mussels; reservoirs (i.e., impeding migratory host); restricted range (e.g., below the fall-line); chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

3.8 Giant floater (*Pyganodon grandis*)

Description:

The giant floater is a medium to large sized mussel growing to lengths of at least 130-140 mm. The shell is thin and subelliptical in shape. The color of the periostracum ranges from a greenish- brown to yellowish-brown and black. Smaller individuals may have faint green rays. Umbos are raised above the hinge line and have double loose looped sculpturing. The nacre is usually white, but some individuals may have a salmon to pink color. The lateral teeth and pseudocardinal teeth are lacking (Parmalee and Bogan 1998).

Life history and Ecology:

Host fish for the giant floater are reported as; golden topminnow, common shiner, redfin shiner, longear sunfish, green sunfish, orangespotted sunfish, white crappie, pearl dace, freshwater drum, gizzard shad, largemouth bass, carp, creek chub, river carpsucker, skipjack herring, white bass, white sucker, yellow bullhead (Watters 1994). However, not all of these host fish relationships have been confirmed with laboratory and field experiments. Trdan and Hoeh (1982) identified the following host fish via laboratory experiments; pumpkinseed, bluegill, rock bass, black crappie, yellow perch, Iowa darter, Johnny darter, rainbow darter, longnose gar, banded killifish, brook silverside, brook stickleback, blacknose dace, central stoneroller, creek chub, golden shiner, bluntnose minnow, blackchin shiner, blacknose shiner (see appendices for list of scientific names for fishes).

The giant floater is gravid from August to May (Oesch 1984) and releases its glochidia from April to May (Ortmann 1912, Oesch 1984). In Vermont, glochidia release is most likely from May to June, but this has not been confirmed.

Preferred habitat for the giant floater has been identified as sand and gravel in areas with little to no flowing water (Parmalee and Bogan 1998). Giant floaters are found in protected areas of streams, lakes, and reservoirs. The giant floater was considered as a species tolerant of siltation (Brim Box and Mossa 1999).

Distribution, Abundance, and Current Status:

The giant floater has a large range extending from the Great Lakes south throughout the Mississippi River drainage, to the Gulf of Mexico, east into the St. Lawrence River drainage, and into the Canadian Interior Basin (Burch 1975). In Vermont, the giant floater is found in seven streams, including deltas of the larger streams. The giant floater has also been reported as occurring above and below the fall-line (Fichtel and Smith 1995). Giant floater densities range from $0.08/m^2$ in the Poultney River (O'Brien 2001) to $1.0/m^2$ in the Missisquoi River (Marangelo 1999).

Cummings and Mayer (1992) and Parmalee and Bogan (1998) consider the giant floater as widespread and common common. Williams et at. (1993) considered the status of this species as currently stable. The giant floater is listed as threatened in Vermont.

Current Threats in Vermont:

Currently the giant floater is threatened by the following: zebra mussels; occurs in low densities; chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

3.9 Pink heelsplitter (*Potamilus alatus*) (Say, 1817)

Description:

The pink heelsplitter is a medium to large mussel growing to lengths of 185 mm. The shell is moderately thick and compressed (Fichtel and Smith 1995). The periostracum is dark brown to dark green in color. The nacre is purple to pink and iridescent in color. The posterior ridge has a large dorsally extended wing. The shell shape is ovate. The lateral teeth are slightly curved and the pseudocardinal teeth are serrated (Parmalee and Bogan 1998).

Life history and Ecology:

The freshwater drum has been identified as the host fish for the pink heelsplitter after the glochidia were found encysted on wild-caught specimens (Howard 1912, Watters 1994, Weiss and Layzer 1995) (see Appendices for list of scientific names for fishes). This host fish information has not been confirmed by laboratory experiments, but the range restriction (below reservoirs) of the pink heelsplitter is most likely a result of the restricted range of its migratory host fish. Based on this information the freshwater drum is the most likely host fish (Thomas Watters, OSUMZ, personal communication).

The pink heelsplitter is found in a variety of habitats including silt, sand, and gravel mixtures in streams and lakes (Fichtel and Smith 1995, Parmalee and Bogan 1998).

Holland-Bartels and Kammer (1989) identified the pink heelsplitter as a long-term breeder. The pink heelsplitter releases glochidia from May to June. In Vermont, glochidial release most likely occurs from June to July, but this has not been confirmed.

Distribution, Abundance, and Current Status:

The pink heelsplitter has a wide range including the Mississippi River drainage south to Alabama and Arkansas, north to the St. Lawrence drainage including Lake Champlain and Lake Huron (Burch 1975). In Vermont, this species is considered not common (Fichtel and Smith 1995). A survey conducted in Lewis Creek indicated pink heelsplitters were present at very low densities (0.02 individuals/m^2) (O'Brien 2001). In the Poultney River, pink heelsplitter densities were calculated at 0.23 individuals/m^2 (O'Brien 2001). The highest densities (0.8 individuals/m^2) were found during a survey in the Missisquoi River (Marangelo 1999).

Williams et al. (1993) consider the pink heelsplitter as being currently stable. In Vermont, this species is listed as endangered.

Current Threats in Vermont:

The current threats of the pink heelsplitter include the following: zebra mussels; reservoirs (i.e., impeding migratory host); its restricted range (e.g., below the fall-line); chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

3.10 Pocketbook (*Lampsilis ovata*) (Say, 1817)

Description:

The pocketbook is a medium to large mussel that grows to lengths of 120 mm. The pocketbook shell is thick ovate and slightly inflated (Cummings and Mayer 1992, Fichtel and Smith 1995). The periostracum is smooth and is yellow to yellowish brown in color with fine faint green rays sometimes occurring on the posterior ridge. The nacre is white.

Life history and Ecology:

The host fish for the pocketbook has not been determined. However, the host fish for the closely related plain pocketbook (*Lampsilis cardium*) are the smallmouth bass, white crappie, largemouth bass, bluegill, sauger, and yellow perch, but have not been confirmed (Watters 1994). The green sunfish and the banded killifish were also identified as hosts after conducting laboratory experiments (O'Dee and Watters 2000) (see appendices for list of scientific names for fishes). Female plain pocketbooks hold their glochidia over winter and release them in June to July (Holland-Bartels and Kammer 1989). In Vermont, pocketbook glochidia are most likely released from July to August, but this has not been confirmed. Female pocketbooks visually attract their host fish by waving a mantle lure resembling a fish. Increased suspended sediment, which impedes sight-feeding fishes, may interfere with the reproduction of this species.

The pocketbook is found in a variety of habitats including; silt, sand, and gravel (Fichtel and Smith 1995, Marangelo 1999, O'Brien 2001, O'Brien 2002a). In Vermont, the pocketbook is found mainly in streams, but is also found in Lake Champlain in several deltas at the mouth of larger streams (Fichtel and Smith 1995).

Distribution, Abundance, and Current Status:

There is currently controversy surrounding as to whether the species in Vermont is the pocketbook or the plain pocketbook. These two species appear to exist side by side in some parts of the United States making identification difficult (Parmalee and Bogan 1998). For now, we recognize the species in Vermont as the pocketbook, *L. ovata*. The range of the pocketbook is widespread from the Mississippi River to the St. Lawrence River and north to Hudson Bay. In Vermont, the pocketbook is found in seven Lake Champlain tributaries and is restricted to below the fall-line.

The pocketbook was reported as having densities ranging from 0.04 to $0.88/m^2$ in the Missisquoi River (Marangelo 1999). Pocketbook densities were less in the Poultney River (ranging from 0.065 to $0.14/m^2$), and Lewis Creek ($0.09/m^2$) (O'Brien 2001).

Williams et al. (1993) considers the pocketbook as a species of special concern. Cummings and Mayer (1992) reported the pocketbook as endangered in Ohio and most likely extirpated from Illinois. In Vermont the pocketbook is listed as endangered.

Current Threats in Vermont:

The pocketbook is threatened by the following: zebra mussels; limited range (e.g., below the fall-line); chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

4. THREATS

4.1 Exotic species

The most recent and major threat to the existence of mussels in Vermont is the introduction to the exotic zebra mussel. The zebra mussel is a native of eastern Europe. In 1989, the zebra mussel was first discovered in North America in Lake St. Clair. Zebra mussels were thought to have been introduced by way of ballast water in cargo ships. In 1993 the first zebra mussel was discovered in Lake Champlain near Benson Landing (Fichtel and Smith 1995). Surveys in 2000 mapped the distribution of adult zebra mussels from southern Lake Champlain to just south of the Missisquoi Bay and reported veligers throughout Lake Champlain. Veligers were also reported in several Vermont lakes (Eliopoulos and Stangel 2000). In the United States, several animals (e.g., freshwater drum, carp, and ducks) have been reported as consuming zebra mussels, but the population has continued to spread for the past 14 years (Molloy et al. 1997, Lyttle 1996).

Zebra mussels are not like the native mussels that burrow into the sediment and require a host fish to complete the reproductive cycle; fertilization takes place in the water column resulting in a free-living veliger. After 3 to 12 weeks the veliger attaches to a hard surface where it grows into the adult zebra mussel. Zebra mussels attach to a variety of surfaces including, but not limited to rocks, boat hulls, and native mussel shells.

The introduction of the zebra mussel has threatened the existence of many native mussel communities throughout its invaded North American range (Williams et al. 1993). Zebra mussels are able to grow in very dense beds. In fact, one native mussel shell was reported as having up to 10,000 zebra mussels attached to it (Nedeau et al. 2000). These dense zebra mussel beds filter out the available food and oxygen utilized by native mussels (Parker et al. 1998, Strayer et al. 1999). When zebra mussels attach to native mussels they interfere with vertical and horizontal movement of the native mussels. Zebra mussels have also been responsible for disrupting the food chain by depleting the water column of phytoplankton and zooplankton (Strayer et al. 1999).

4.2 Predators & Parasites

Mussels have natural predators that consume them as part of their diet. Newly metamorphosed juveniles are consumed by a number of invertebrate predators including flatworms, dragonfly larvae, and midges (Robert Butler, USFWS, personal communication).

Parasites are commonly found on mussels, but most have been found to be more of a nuisance than a threat to the mussel. Some common types of parasites include: water mites, flukes, leeches, and distomids (i.e., trematodes). Many of these parasites infest the body cavity, gills, foot, or reside between the mantle and shell of mussels (Paramalee and Bogan 1998). Compared to other threats (human induced) parasites and predators have little effect on the overall demise of mussel populations (Parmalee and Bogan 1998). The most commonly predator, however is the muskrat (Oesch 1984). Zahner-Meike and Hanson (2001) found muskrats were selective eaters and selected mussels depending on species present, size of shell, and thickness of shell. Muskrats tended to select a species of mussel if they were easily opened (e.g., mussels with thin shells, lacked pseudocardinal and lateral teeth). Zahner-Meike and Hanson (2001) also found that smaller streams, where access was easier for the muskrat, had higher predation rates when compared to larger streams or lakes. Although the consumption of mussels by muskrats has not lead to the extinction of a mussel species, muskrats consuming mussels from an already fragmented population may inhibit the recovery of that mussel species (Neves and Odom 1989).

4.3 Habitat Alterations

Dams

Upstream

The construction of a dam affects many components of a river including, but not limited to: bank erosion, streambed scour, species changes, sedimentation, hydrology, water quality, and ecologic barriers (Williams et al. 1993, Watters 1996, Watters 2000). The most obvious habitat alteration is the conversion of a flowing stream, with riffles and runs, into a stagnant reservoir.

As the water flow is reduced, suspended sediment falls to the bottom of the reservoir, providing habitat for silt tolerant species. Many researchers have documented drastic changes in the mussel fauna (e.g., silt intolerant to silt tolerant species) after the construction of a dam (Bates 1962, Williams et al. 1992, Williams et al. 1993).

Chemical changes in water quality have also been documented, such as increased temperatures and decreased oxygen levels (Allan 1995). Many dams release water in pulses as a result of dam maintenance, production of electricity, and recreation. These water pulses have an adverse effect on the downstream habitat and biota. The temperature of water released from the bottom of dams is usually cooler. Many life stages of mussels are temperature dependent; growth, gametogenesis, glochidial release, and time required for glochidial metamorphosis (Waller et al. 1988, Watters 2000, O'Brien and Brim Box 1999). These water quality changes also change the phytoplankton and zooplankton community (Allan 1995), which may alter the food source available for mussels.

Dams act as physical and genetic barriers for many species (Allan 1995, Watters 1996). A common example is that of the disappearance of salmon runs as a result of dams blocking their upstream movement. Mussel populations that rely on migratory host fish for reproduction and dispersal will also be negatively affected by the construction of reservoirs (Watters 1996, Watters 2000).

Downstream

Dams that release high discharges cause scouring of the riverbed, undercutting of banks, and channel erosion (Allan 1995, Watters 2000). As a result of the increased erosion, suspended fines settle into the interstitial areas of porous sediment forming a hardpan. The reduction of interstitial areas reduces the habitat for particularly juveniles, and could restrict the movement and anchoring ability of adult mussels.

Removal

Recent efforts to remove dams have been successful in some cases. Unfortunately, the effects of dam removal on mussel communities are not well understood. Johnson (2001) monitored the effects of dam removal on mussel communities before and after the Kettle River Dam, Minnesota, was removed. After dam removal, there was a significant reduction in the downstream mussel densities below the reservoir (from 5.3 mussels/m^2 to 0.6 mussels/m^2). Johnson (2001) identified the large amount of sediment released from behind the dam as the major factor resulting in the decrease of the mussel community.

Sedimentation

The increased sedimentation in streams throughout the United States is thought to be one of the contributing factors leading to the decrease in the freshwater mussel populations (Brim Box 1999, Fraley and Ahlstedt 2001). Increased suspended sediment clogs the gills of mussels, which has been linked to a decrease in the filter time (e.g., feeding time) and overall growth rates of some mussel species (Ellis 1936, Kat 1982). However, the degree to which the mussel is affected by sedimentation appears to be species dependent (Brim Box 1999). Suspended sediment may also interfere with the delicate mussel/host fish relationship. As previously mentioned, a group of mussels visually attracts their host fish by displaying elaborate lures that mimic fish food items (Kreamer 1970, O'Brien and Brim Box 1999, Watters 1999). Increased suspended sediment can reduce water clarity, which may reduce the effectiveness of these visual lures to attract host fish (O'Brien and Brim Box 1999). Without the proper mussel/host fish interaction, reproduction is hindered.

The source of stream sedimentation varies. Most likely sedimentation within a watershed comes from an accumulation of non-point sources (e.g., logging, road runoff, agriculture, destruction of floodplains). Agriculture has been identified as the most widespread activity that contributes the most sediment and habitat alterations to the rivers and streams of the United States (Allan 1995). There are estimates that agriculture is responsible for 80% of the 4.9 billion metric tons of soil that is lost each year. The most detrimental effect is the removal of vegetation and alteration of the floodplain, which cause increased sedimentation from runoff, bank failure, and channel modifications. However, proper land management practices (e.g., vegetated buffer zones along stream banks) have proven to reduce the amount of sedimentation in agricultural areas (Allan and Flecker 1993, Allan 1995). Roell (1994) recommended a 50 ft. vegetative buffer along streams without floodplains and a 100 ft. buffer along streams with floodplains.

Other actions that affect stream sedimentation may not be as obvious. Instream alterations (e.g., dredging, canalization, bank stabilization) may have a chain reaction of events leading to sedimentation both up and down stream (Hartfield 1993). The most obvious result of instream alterations is headcuts. This secondary event leads to streambed widening, an increase of unconsolidated sediment, bank failure, and degraded channels (Hartfield 1993).

4.4 Hydrology

Hydrologic fluctuations can be deadly for mussels. Most mussel species attempt to avoid the dropping water levels by slowly moving towards deeper water (Matteson 1948, Oesch 1984). However, at times a mussel can be diverted and move the wrong way, only to find itself on drying substrate. Hundreds of mussels were found stranded on dry land following an unnatural drawdown of the Peterson Reservoir, Vermont. Rather than move with the dropping water levels, some mussel species bury themselves in the soft substrates and wait out the drought. If the water level drops too low or for extended periods of time the buried mussels may expire (Oesch 1984).

The hydrology of a stream can be altered (e.g., increased frequency of flooding, and prolonged drought) as a result of agricultural, urban, and or reservoir activities. In agricultural and urban areas floodwaters are diverted off the land and into ditches and or holding ponds (Allan 1995). Water that is diverted never enters the soil to recharge the aquifer, but instead flows rapidly into streams, artificially increasing the discharge, which can result in streambed scour. During a drought an already low aquifer level is even further depleted as a result of an increase in irrigation for crops and water from private wells is used for nonessential purposes (e.g, watering lawns). The constant demand for water from the aquifer leads to the reduction in the base flow of streams (Allan 1995). Smaller streams are the first to become effected by the reduction in base flows.

Reservoirs, which alter the hydrologic fluctuation for the production of electricity, recreational usage, or dam maintenance, may have an adverse effect on mussel populations. In stream base flow requirements for mussels is species dependent (Layzer and Madison 1995). In order to determine the instream flow needs for a stream several factors will need to be addressed: 1) mussel species present, 2) habitat requirements for adult and juvenile mussels, 3) period of glochidial release, and 4) base flow requirements for the host fish. Layzer and Madison (1995) recommended not allowing the water flow to reach zero for long periods of time.

4.5 Contaminants

Mussels have been selected as bioindicators for streams and lakes because they are long lived, moderately sessile organisms that are sensitive to pollution (Stansbery 1971, Bauer and Wächtler 2001). Over the past several decades, studies have used mussel shells to determine the types of toxic chemicals present in an aquatic system (Imlay 1982). Studies have shown toxins are deposited in the shell layers as the mussel grows. However, concentrations of toxins in the environment are not comparably represented in the shell (Dermott and Lum 1986, Naimo et al. 1992). In fact, the metal concentrations found in mussels vary depending on a variety of factors (e.g., species, sex, metabolism, size, metal) (Pip 1995). Keller and Zam (1991) concluded a low concentration of a single metal in an aquatic system was not as toxic to mussels when compared to a combination of metals at low concentrations.

As fragile as the glochidial stage may be, there are indications that this stage of life is relatively tolerant to chemical pollution (Bauer 2001). However, Pynnönen (1995) found glochidia exposed to low concentrations of cadmium (4.1 mg cadmium/g) and (14.8 mg copper/g) copper while in the female marsupia were more tolerant to pollution after they were released, but added glochidia with high concentrations of cadmium (9.7 mg cadmium/g) and copper (26.1 mg copper/g) had lowered viability rates after they were released.

4.6 Population Dynamics

Recent declines in the mussel fauna have left many populations fragmented or at very low densities. There are some concerns that the low mussel densities will further reduce the success of reproduction and lead to decreased recruitment. For example eastern elliptio reproductive success was reduced when the bed density dropped to 10 indviduals/m^2 (Dowing et al. 1993). The minimum density required for successful reproduction varies for each mussel species depending on their reproductive strategy (Bauer 2001). For example, some mussel species are known to self-fertilize (Bauer 2001). A mussel that is able to self-fertilize would require a lower population density when compared to those that do not self-fertilize. Mussel populations that become fragmented or exist in low-density beds also risk the chance of lowering genetic variability (Bauer 2001).

4.7 Host Fish Population Decline

Most mussel species are obligate parasites on fishes. This host fish/ mussel relationship is essential for the survival of a mussel population. Like mussels, fish may also be sensitive to habitat alterations (Shields et al. 1994). Streams that were altered or degraded were found to have a lower diversity of fishes when compared to streams with little or no degradation. Watters (1992) suggested fish diversity and mussel diversity is correlated in larger rivers. Declines in the host fish population have been identified as a major factor that reduces mussel reproduction, especially for those species that utilizes a limited number of host fishes (Bauer 2001). Mussels in streams where the host fish density is low may infest the same fishes repeatedly with their glochidia. Fish that are exposed to mussel glochidia multiple times have been known to develop glochidial immunity (Coker et al. 1921, Kirk and Layzer 1997). Fish populations with an acquired immunity to glochidia will no longer be able to effectively serve as hosts for the mussel population.

5. RECOVERY GOAL

The recovery goal for the Vermont imperiled mussels is to attain multiple reproducing populations (e.g., minimum viable population) that are stable or increasing, are comprised of multiple year/size classes, and cover at least 80% of their historical range in Vermont.

- A population defined as having a minimum viable population size.
- Multiple populations are defined as populations occurring in separate Vermont watersheds.
- A watershed is defined as an area drained by one river system.
- Size classes will be used as a substitute for year class because aging has not been validated for mussels.

As more information is gained through research, a regular review (every five years from approval date of this plan) of the recovery plan should be conducted as needed. This review is intended to allow for a recovery team to amend the current recovery plan as new information regarding these mussel species or newly state listed species is made available.

5.1 Justification for Goal

Many of the mussels listed in Vermont are at the periphery of their natural range (Table 2). The introduction of the zebra mussel and human activities in the lakes and watersheds (e.g., agriculture, urbanization) has negatively impacted the current mussel community. The establishment of multiple stable populations in multiple watersheds is an important strategy for minimizing the danger of losing entire populations as a result of a catastrophic event .

Table 2. List of mussel species and where they occur in Vermont.

Name	Lake Champlain	Connecticut River	Steep Gradient Rivers
Alewife floater*		X	
Black sandshell	XB		
Brook floater		X	
Cylindrical papershell	XAB		
Dwarf wedgemussel		X	
Eastern pearlshell			X
Elktoe*	XA		
Fragile papershell	XB		
Flutedshell	XB		
Giant floater	XAB		
Pink heelsplitter	XB		
Pocketbook	XB		

X indicates where the mussel species is present, A = above the fall-line, and B= below the fall-line, * indicates a species of special concern (see section 6.0 of this plan).

5.2 Down-listing criteria

A mussel species will be down-listed from endangered status when the following criteria are met and maintained for at least five years.

- At least 5 distinct populations in 5 watersheds and 80% of its known historical populations are established; or established throughout its known historical range; and
- each population is stable/reproducing (multiple year classes indicating recruitment into the adult population are found for five consecutive years); and
- limiting threat(s) is/are alleviated; and ensure that the known host fish population is present, stable, and without threats.

5.3 De-listing criteria

A threatened species will be de-listed (removed from the Vermont Endangered and Threatened Species List) if the species' population status meets or surpasses all of the listing criteria and is maintained for at least 10 years. This includes the continued removal of threats to current populations.

5.4 Re-listing criteria

Re-listing of a species will become necessary if a new threat risks the status of the mussel species' population or populations become unstable (below the status criteria in the down-listing section mentioned above).

6. RECOMMENDED ACTIONS FOR RECOVERY

Recovery efforts will include monitoring native mussel and zebra mussel populations; management, research, developing and maintaining partnerships; and fundraising. Recovery efforts will focus on streams that have been identified as hot spots (e.g, areas of high diversity).

6.1 Monitor

1. Mussel populations

   Develop and initiate methods to monitor low-density mussel populations to detect population trends.
   Estimated cost for annual monitoring; $5,000.00 per stream.

2. Survey host fish populations

   Once host fish have been identified for a mussel species, a status survey of the host fish populations will be conducted, if needed, every three years. This information can be coordinated with ongoing surveying efforts in Vermont.

   Estimated cost for annual monitoring; $5,000 per stream.

3. Zebra mussel populations

   The Vermont Department of Environmental Conservation is currently monitoring the zebra mussel population in Lake Champlain. We propose the zebra mussel monitoring program continue with yearly updates on its current distribution in Lake Champlain and expand the survey to known range of the threatened and endangered mussel species.

Yearly reports should be submitted to the person(s) overseeing the mussel recovery efforts so proper action can be taken in the event the zebra mussel population further threatens the native mussel populations.

Estimated annual cost for expanding the monitoring program; $10,000.

6.2 Management

Proper protection for the mussel populations will include protecting the habitat as well as the individuals. The following actions will need to be addressed to ensure mussel populations are protected.

1. Incorporate the threatened and endangered mussels distributions into the current Vermont Area Spill Contingency Plan. The Vermont Natural Heritage Program should be contacted directly in the event of a toxic spill.

   Mussels that are threatened by toxic spills may be relocated or monitored until threat is removed (see 3, below).

   Estimated cost; $0.

2. Incorporate threatened and endangered mussel protection in the dam licensing and re-licensing process, dam maintenance (e.g., desilting, drawdowns), or any activity that will manipulate water level and flow. Encourage enforcement of existing dam regulations.

   Estimated cost; $0.

3. Identify or create refugia and establish an emergency plan of action.

   In the event a mussel population is threatened (e.g., toxic spill), a refugium may be used to protect the population until it is no longer threatened.

   Estimated cost; $12,000.

4. Incorporate threatened and endangered mussel protection for land acquisition and/or landowner (e.g., private, agricultural, silvacultural) incentives to provide stream buffers for the long-term protection of stream habitat. Work through ANR, USFWS, USDA, NGOs, and other organizations will promote stream habitat protection through land acquisition, easements, and landowner incentives for the protection of stream habitat. Minimal stream buffers have proven to reduce runoff by reducing the amount of sedimentation and input/runoff of chemicals (e.g., pesticides, fertilizers).

   Estimated cost; $0 (not including land acquisition).

5. Develop a propagation, augmentation, and reintroduction plan to establish minimum viable populations of native Vermont species. The plan will include cost estimates for implementation. Once this plan is established it will become part of the recovery plan.

   Current mussel populations may be enhanced through augmentation and or reintroduction using Vermont native species whenever possible. Zebra mussels can be removed from Lake Champlain threatened and endangered mussel species to maintain current populations until alternative solutions are developed.

   Estimated cost; $15,000

6.3 Research

Research needs are one of the most important components of this recovery effort. Much of the information needed to obtain the recovery goals is lacking.

1. Determine historical distributions via a thorough search of museum, literature, and unpublished records.

   Estimated cost; $18,000

2. Determine periods of glochidial release for Vermont mussel species. Glochidial release times stated in the literature are latitude specific and may not reflect the environmental conditions in Vermont.

   Estimated cost; see 3.

3. Identify host fish for all listed mussel species found in Vermont.

   Few Vermont mussels have had their host fish identified. Unfortunately, available host fish information may be anecdotal or identifies a fish species not found in Vermont. Host fish identified via laboratory experiments should be confirmed by identifying encysted glochidia on wild caught fish of the same species.

   Estimated cost; $15,000 to $20,000 (to complete 2 and 3, listed above) per species.

4. Test the effects of lampricide, 3-Trifluoromethyl-4-Nitrophenol (TFM), and TFM/Bayer-73 treatments on all mussel life stages.

   Currently, TFM is used in several Vermont streams to kill larval sea lampreys. Future control efforts may include adding a second chemical combination, Bayer-73.

Information on the effects of TFM and TFM/Bayer-73 on Lake Champlain basin mussel species is lacking for some of the life stages of the species addressed in this recovery plan.

Estimated cost; $25,000 per life stage per chemical.

5. Complete genetic and/or morphological testing to clarify the proper identification of the pocketbook in Vermont.

   Currently there remains some controversy regarding the identification of the pspecies of the pocketbook occurring in Vermont. The pocketbook, plain pocketbook, and yellow lampmussel (*Lampsilis cariosa*) are similar appearing species. The most effective way to determine which species is in Vermont would be to conduct genetic and/or morphological study.

   Estimated cost; $20,000.

6. Studies on the effect of dam removal in Vermont on the mussel populations.

   There are several dams in Vermont that will be up for hydroelectric relicensing. In the event a dam's permit is not renewed and is slated for removal, a thorough study on the existing mussel populations above and below the dam should be conducted. When the dam is removed a follow up survey should be conducted to determine the effects dam removal has on the diversity and abundance of mussels in the stream.

   Estimated cost; $ 30,000 per year (minimum of two years before and 10 years after removal).

6.4 Factors Potentially Limiting Recovery Efforts

1. Reduced funding.
2. The continued expansion of zebra mussel populations.
3. Land use changes (e.g., increased urbanization).
4. Hydroelectric licenses are currently effective for 50 years.

6.5 Recovery Plan Reviews

As more information is gained through research, a regular review of the recovery plan will need to be conducted. This review is intended to allow for a recovery team to amend the current recovery plan as new information regarding these mussel species or newly listed species is made available.

7. SPECIES OF SPECIAL CONCERN

Two mussel species, the elktoe (*Alasmidonta marginata*) and alewife floater (*Anodonta implicata*), are not currently state listed, but are considered species of special concern and require management. The status of the elktoe and the alewife floater should periodically be reevaluated for the possibility of adding them to the Vermont threatened and endangered species list.

7.1 Elktoe (*Alasmidonta marginata*) (Say 1818)

Description:

The elktoe shell is thin when young and thicker when older and is elongate with angular posterior slope and thick greenish to blackish rays (Parmalee and Bogan 1998, Oesch 1984). The dorsal margin is rounded and ventral margin is generally straight, the posterior ridge high and crenulated. The foot is a light peach to orange color.

Life history and Ecology:

Potential host fish for the elktoe have been identified as northern hogsucker, rock bass, shorthead redhorse, warmouth, and white sucker, but the data are anecdotal (Howard and Anson 1922) (see appendices for list of scientific names for fishes). Elktoe are gravid in middle to late summer (Baker 1928). Ortmann (1912) reported observing individuals discharging glochidia in May (in Vermont most likely June, but this has not been confirmed).

Elktoe are found in streams and rivers with moderately swift current and substrate comprised of small gravel and sand and they appear to be intolerant to changes in the sedimentation regime (Stein 1972). The elktoe is not found in impounded habitats (Parmalee and Bogan 1998). This species is considered riverine.

Distribution, Abundance, and Current Status:

The elktoe has a widespread range including the middle and upper Mississippi River drainages, Great Lakes region, and St. Lawrence River (Burch 1975 Parmalee and Bogan 1998). Recent surveys found elktoe populations as far-east as the Becancour and Bulstrode rivers in Quebec (Isabelle Picard, Societe de la Faune et des Parcs du Quebec, personal communication). The Becancour and Bulstrode rivers are part of the St. Lawrence River system, which drains into Lake Champlain. In Vermont, the elktoe has only recently been found in one unimpounded section of the Lamoille River (O'Brien 2002a).

Williams et al. (1993) considered the elktoe a species of special concern. Cummings and Mayer (1992) describe the distribution of the elktoe as widespread, but sporadic. Recent surveys of the Lake Champlain tributaries found the elktoe to be rare in short reach of the Lamoille River, Vermont (O'Brien 2002a).

Current Threats in Vermont:

The current threats to the elktoe include: reservoirs; very restricted range; chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

7.2 Alewife floater (*Anodonta implicata*) Say, 1829

Description:

The alewife floater shell is elongate elliptical and longer than wide or high. This medium to large sized mussel grows to lengths of 170 mm. The periostracum color ranges from yellow, to greenish, to brown, to black (Nedeau et al. 2000). The shell is slightly thicker on the posterior end. The nacre is a copper to salmon pink color. Lateral teeth and pseudocardinal teeth are lacking.

Life history and Ecology:

The only confirmed host for the alewife floater is the alewife (Davenport and Warmuth 1965). The shad and the blueback herring are suspected host fish (Nedeau et al. 2000) (see appendices for list of scientific names for fishes). The alewife floater releases its glochidia in the spring. In Vermont, glochidial release is most likely from late April into May, but this has not been confirmed.

The preferred habitat for the alewife floater ranges from silt and sand to gravel, and is found in rivers and lakes (Nedeau et al. 2000).

Distribution, Abundance, and Current Status:

The range of the alewife floater is restricted to the Atlantic slope from the Potomac River to New Brunswick and Nova Scotia (Burch 1975). In Vermont, it is restricted to the lower Connecticut River (Fichtel and Smith 1995). Fichtel and Smith (1995) reported the alewife floater as common below the Vernon Dam. Doug Smith (University of Massachusetts, personal communication) found the alewife near Walpole, New Hampshire.

Current Threats in Vermont:

The alewife floater is threatened by the following: reservoirs (i.e., impeding the migratory host fish), restricted VT range; chemical pollution in the form of stormwater and agricultural runoff; and sedimentation as a result of floodplain, streambank, and instream modifications.

8. ACKNOWLEDGEMENTS

Thanks to the mussel Recovery Team Members – Mark Ferguson (VT Fish and Wildlife, Waterbury, Vermont), Madeleine Lyttle (USFWS, Essex Junction, Vermont), Steve Fiske (VT DEC, Waterbury, Vermont), and Ellen Marsden (UMV Dept. of Natural Resources, Burlington, Vermont) for their input and direction. I would also like to thank the following people for their help with comments and reviews; Robert Butler (USFWS, Ashville, North Carolina), Jim Williams (USGS BRD, Gainesville, Florida), and Mike Davis (MN DNR, Lake City, Minnesota).

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10. Appendices

List of common and scientific names of the fishes referenced in this report.
* indicates species is found in Vermont.

Common name	Scientific name
Lampreys	**Petromyzontidae**
Sea lamprey*	*Petromyzon marinus*
Gars	**Lepisosteidae**
Longnose gar*	*Lepisosteus osseus*
Bowfin	**Amiidae**
Bowfin*	*Amia calva*
Herrings and shad	**Clupeidae**
Shad sp.?*	*Alosa* sp.
Blueback herring*	*Alosa aestivalis*
Alewife*	*Alosa pseudoharengus*
Skipjack herring	*Alosa chrysochloris*
Gizzard shad*	*Dorosoma cepedianum*
Trout and salmon	**Salmonidae**
Brook trout*	*Salvelinus fontinalis*
Atlantic salmon*	*Salmo salar*
Pikes	**Esocidae**
Northern pike*	*Esox lucius*
Minnows	**Cyprinidae**
Carp*	*Cyprinus carpio*
Golden shiner*	*Notemigonus crysoleucas*
Creek chub*	*Semotilus atromaculatus*
Pearl dace*	*Margariscus margarita*
Central stoneroller	*Campostoma anomalum*
Blacknose dace*	*Rhinichthys atratulus*
Longnose dace*	*Rhinichthys cataractae*
Common shiner*	*Luxilus cornutus*
Redfin shiner	*Lythrurus umbratilis*
Spotfin shiner*	*Cyprinella spiloptera*
Bluntnose minnow*	*Pimephales notatus*
Blackchin shiner*	*Notropis heterodon*
Blacknose shiner*	*Notropis heterolepis*

Suckers	**Catostomidae**
River carpsucker	*Carpiodes carpio*
White sucker*	*Catostomus commersoni*
Northern hog sucker	*Hypentelium nigricans*
River redhorse	*Moxostoma carinatum*
Shorthead redhorse	*Moxostoma macrolepidotum*
Bullhead catfish	**Ictaluridae**
Yellow bullhead*	*Ameiurus natalis*
Brown bullhead*	*Ameiurus nebulosus*
Margined madtom	*Noturus insignis*
Killifishes	**Fundulidae**
Banded killifish*	*Fundulus diaphanous*
Northern studfish	*Fundulus catenatus*
Golden topminnow	*Fundulus chrysotus*
Silversides	**Atherinidae**
Brook silverside	*Labidesthes sicculus*
Sticklebacks	**Gasterosteidae**
Brook stickleback	*Culaea inconstans*
Sculpins	**Cottidae**
Banded sculpin	*Cottus carolinae*
Slimy sculpin	*Cottus cognatus*
Mottled sculpin*	*Cottus bairdi*
Temperate basses	**Moronidae**
White bass	*Morone chrysops*
Sunfishes and basses	**Centrarchidae**
Black crappie*	*Pomoxis nigromaculatus*
White crappie*	*Pomoxis annularis*
Rock bass*	*Ambloplites rupestris*
Largemouth bass*	*Micropterus salmoides*
Smallmouth bass*	*Micropterus dolomieu*
Warmouth	*Lepomis gulosus*
Green sunfish	*Lepomis cyanellus*
Bluegill*	*Lepomis macrochirus*
Pumpkinseed*	*Lepomis gibbosus*
Longear sunfish	*Lepomis megalotis*
Orangespotted sunfish	*Lepomis humilis*

Darters, walleye, and sauger	**Percidae**
Walleye*	*Stizostedion viteum*
Sauger*	*Stizostedion canadense*
Yellow perch*	*Perca flavescens*
Johnny darter	*Etheostoma nigrum*
Tessellated darter*	*Etheostoma olmstedi*
Rainbow darter	*Etheostoma caeruleum*
Fantail darter	*Etheostoma flabellare*
Striped darter	*Etheostoma virgatum*
Iowa darter*	*Etheostoma exile*
Drums	**Sciaenidae**
Freshwater drum*	*Aplodinotus grunniens*