Species Status Assessment

Common Name: Plain pocketbook **Date Updated:** 3/12/2025

Scientific Name: *Lampsillis cardium* **Updated By:** Amy Mahar

Class: Bivalvia

Family: Unionidae

Species Synopsis *(a short paragraph which describes species taxonomy, distribution, recent trends, and habitat in New York):*

Lampsilis cardium belongs to the subfamily Ambleminae and the tribe Lampsilini, which includes 17 extant and 6 likely extirpated New York species of the genera Actinonaias, Epioblasma, Lampsilis, Leptodea, Ligumia, Obovaria, Potamilus, Ptychobranchus, Toxolasma, Truncilla, and Villosa (Haag 2012; Graf and Cummings 2011). *L. cardium* is one of seven species of the genus Lampsilis that have been found in New York (Strayer and Jirka 1997).

Although the NYS CWCS (2006) combines *L. ovata* and *L. cardium* under the *L. ovata* listing, almost all New York material is "L. cardium," with only specimens from the Allegheny River basin classified as "*L. ovata*" (Strayer and Jirka 1997, The Nature Conservancy 2009). Additionally, NY Natural Heritage Program (2013), NatureServe (2013) and most recent species reference guides (Watters et al. 2009, Cummings and Mayer 1992, Parmalee and Borgan 1998) regard *L. ovata* and *L. cardium* as separate species. For the purpose of this assessment, *L. ovata* as described in the NYS CWCS will be divided into *L. ovata* and *L. cardium*.

Since 1970, *L. cardium* has been found in 45 New York waterbodies. In New York, it has been found in the Allegheny, Erie-Niagara, West Lake Ontario, Genesee, Oswego, and St. Lawrence River basins, as well as a few places in the Champlain basin and the upper Hudson basins (Strayer and Jirka 1997, NY Natural Heritage Program 2025). *L. cardium* is most commonly found in medium sized rivers. It tolerates many substrates and water flows (Watters et al. 2009).

In New York, *L. cardium* is ranked as imperiled/vulnerable, and as secure throughout its range (NatureServe 2013). In North America, approximately 2/3 to ¾ of native mussel species are extinct, listed as endangered or threatened, or are in need of conservation status (Williams et al. 1993, Stein et al., 2000). While population trends in New York are unknown, it is assumed that they too are declining, due to a myriad of environmental stressors.

I. Status

a. Current legal protected Status

i. **Federal:** None **Candidate:** No

ii. **New York:** None

b. Natural Heritage Program

i. **Global:** G5 - Secure

ii. **New York:** S2S3 - Imperiled/ Vulnerable **Tracked by NYNHP?:** No

Other Ranks:

-New York 2025 SGCN status: Species of Greatest Conservation Need

-IUCN Red List: Least Concern (2015)

-Northeast Regional SGCN: No (2023)

- American Fisheries Society Status: Special Concern (1993)

Status Discussion:

This species can be found in the entire upper Mississippi River drainage from northern Arkansas and Tennessee, north to Minnesota and Wisconsin, and from New York west to eastern Kansas; as well as the Winnipeg, Red, and Nelson River systems of central Canada. It is also found throughout the Great Lakes- St. Lawrence system except most of Lake Superior. It is considered stable throughout the majority of its wide range (NatureServe 2013).

II. Abundance and Distribution Trends

Region	Present?	Abundance	Distribution	Time Frame	Listing status	SGCN?
North America	Yes	Stable	Stable	Short-term		(blank)
Northeastern US	Yes	Stable	Stable			No
New York	Yes	Unknown	Unknown			Yes
Connecticut	No	N/A	N/A			No
Massachusetts	No	N/A	N/A			No
New Jersey	No	N/A	N/A			No
Pennsylvania	Yes	N/A	N/A		S4	No
Vermont	No	N/A	N/A			No
Ontario	Yes	Stable	Stable	2003-2013	S4	(blank)
Quebec	Yes	N/A	N/A		S3S4	(blank)

Column options
Present?: Yes; No; Unknown; No data; (blank) or Choose an Item
Abundance and Distribution: Declining; Increasing; Stable; Unknown; Extirpated; N/A; (blank) or Choose an item
SGCN?: Yes; No; Unknown; (blank) or Choose an item

Monitoring in New York *(specify any monitoring activities or regular surveys that are conducted in New York):*

As part of a State Wildlife Grant, NYSDEC Region 8 Fish and Wildlife staff conducted a native freshwater mussel baseline inventory of tributaries in central and western New York, 2009 to 2020 (Mahar and Landry 2016, 2019). Baseline surveys out of Regions 8 and 9 will continue in unsurveyed portions of the Erie and Allegheny basins in 2025 to 2028. Regulatory surveys are conducted in known or likely habitat as part of the project review process.

Trends Discussion *(insert map of North American/regional distribution and status):*

Across its range, *L. cardium* has shown long-term trends of relatively stable to declines of < 30%. Its short-term trends are relatively stable with ≤ 10% change (NatureServe 2025).

Trends for New York populations are difficult to determine as most historic data comes from opportunistic naturalist collections, as opposed to more comprehensive baseline surveys. For example, mussels were documented for the first time in 50 of the 106 streams surveyed to date by the Southern Lake Ontario mussel inventory project (Mahar and Landry 2016). This is because many of these streams had never before been surveyed for mussels, not because mussel distribution has dramatically increased. In North America, approximately 2/3 to ¾ of native mussel species are extinct, listed as endangered or threatened, or are in need of conservation status (Williams et al. 1993; Stein et al. 2000). Based on New York's Natural Heritage S-rank, sparse historical data, and the plight of North America's freshwater mussels, it is assumed that trends are declining due to a myriad of environmental stressors.

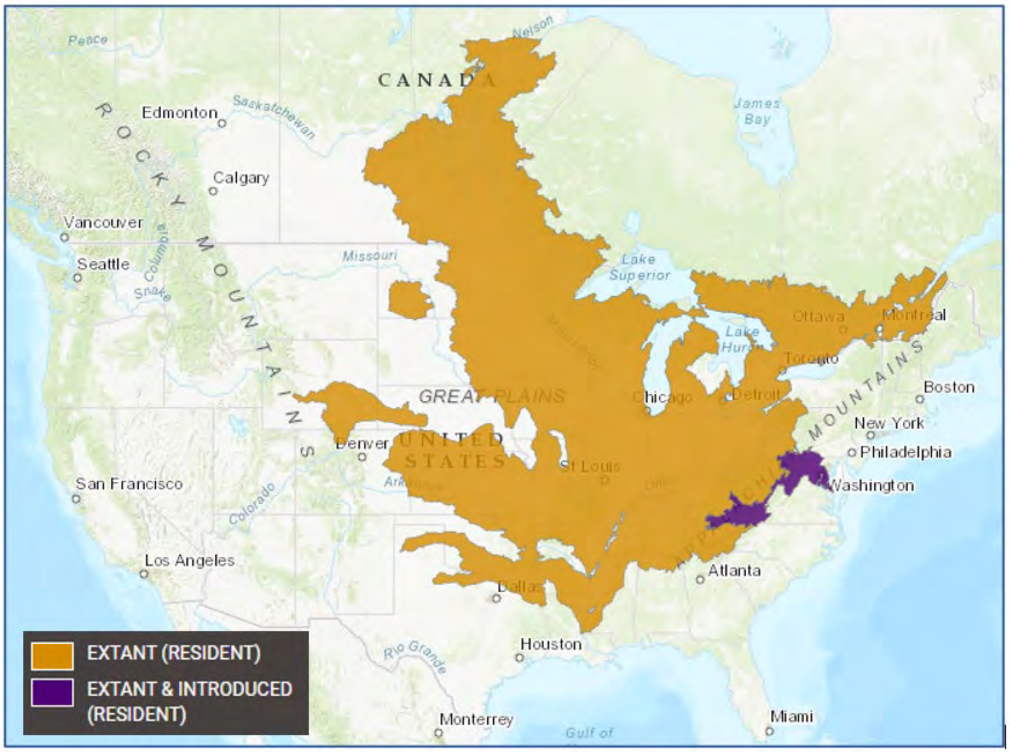

Figure 1. Plain pocketbook distribution (IUCN Redlist 2024)

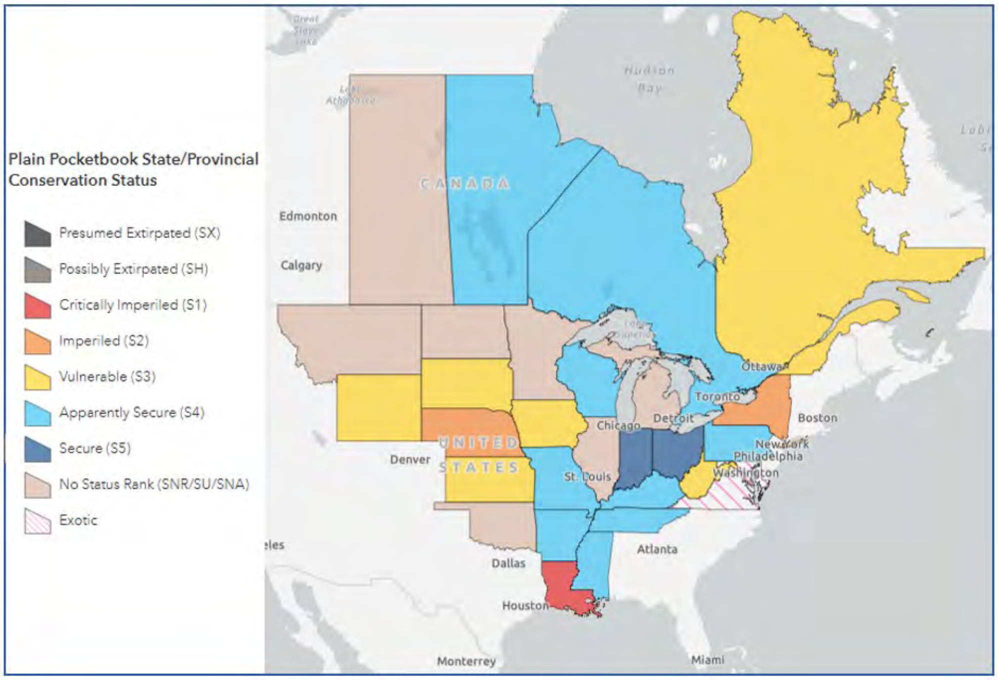

Figure 2. Plain pocketbook status (NatureServe 2024)

III. New York Rarity *(provide map, numbers, and percent of state occupied)*

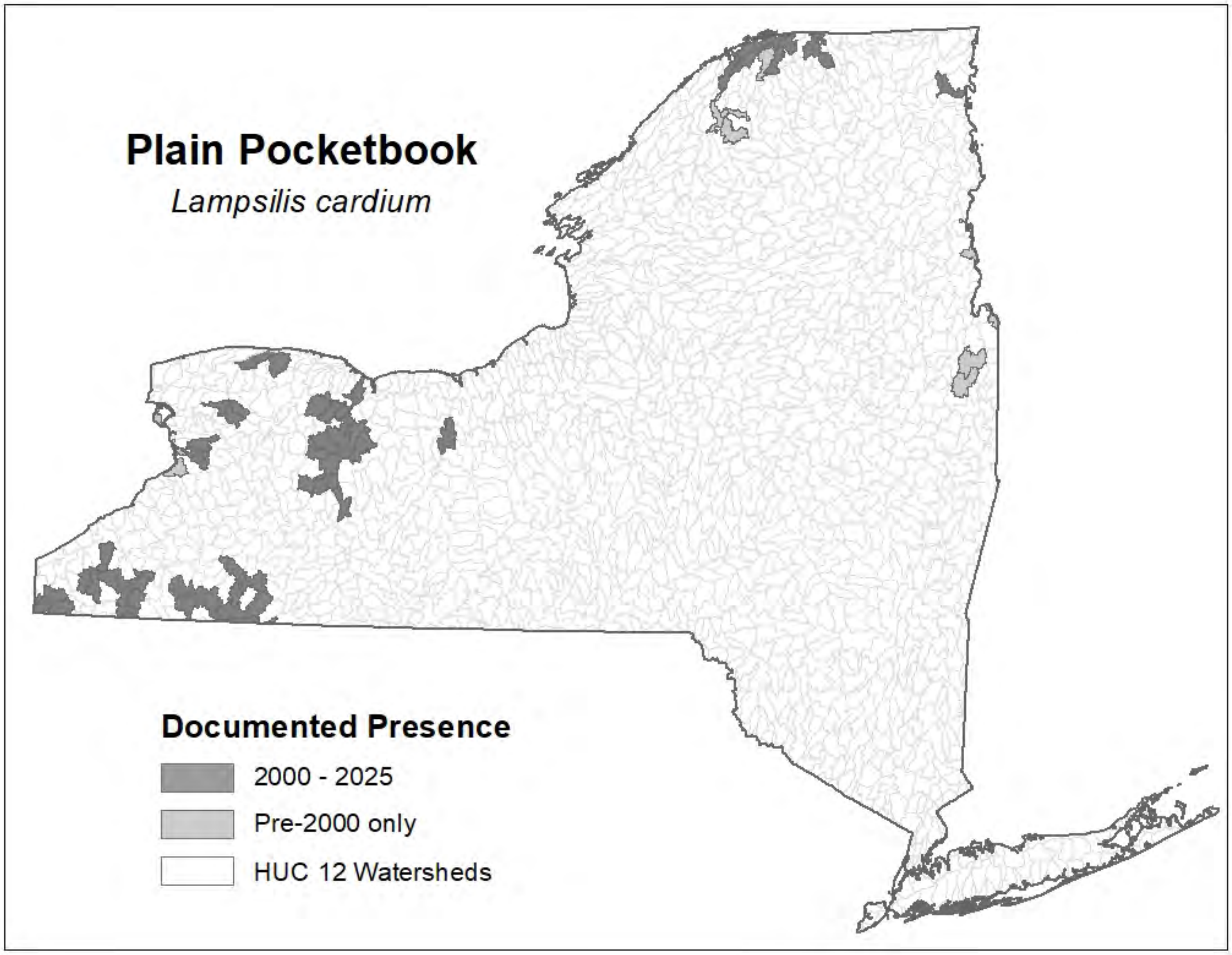

Figure 3. Records of plain pocketbook in New York (NYSDEC 2022)

Years	# of Records (survey sites with *L. cardium*)	# of Distinct Waterbodies	% of State
Total	**235**	45	3.8%
2000-2005	197	34	3.2%

Table 1. Records of plain pocketbook in New York.

Details of historic and current occurrence:

Since 1970, L. cardium has been found in 45 waterbodies and 3.8% of New York's HUC 12 watersheds. This species has been found in many sites in the Allegheny, Erie-Niagara, West Lake Ontario, Genesee, Oswego, and St. Lawrence River basins, as well as a few places in the Champlain basin and the upper Hudson basins (Strayer and Jirka 1997).

In the Allegheny basin, *L. cardium* was found at 48 of 105 sites surveyed (The Nature Conservancy 2009). *L. cardium* was distributed throughout the Upper Allegheny and Conewango sub-basins but at relatively low numbers and was considered viable at 21 of the sites where they were found. During this survey effort, a total of 405 *L. cardium* were found in Oswayo Creek, Olean Creek, Allegheny River, Conewango Creek, Cassadaga Creek (The Nature Conservancy 2009). This species is also present in Red House Brook (Mahar and Landry 2016, 2019), French Creek (Smith and Crabtree 2010, Walsh 2022), Dodge Creek (Jirka survey records personal communication, Oil Creek (Meyer and Wash 2013), Chautauqua Lake (Jirka survey records),and Brokenstraw Creek (Walsh 2022).

In the Erie-Niagara basin, *L. cardium* was found in Buffalo River, Cazenovia Creek, Cayuga Creek, and Slate Bottom Creek (Mahar and Landry 2019) and from Tonawanda Creek, Murder Creek and Ledge Creek, in the Tonawanda Creek watershed (Mahar and Landry 2016, Marangelo and Strayer 2000, NY Natural Heritage Program 2013). It has also been found in the Niagara River.

In West Lake Ontario, L. cardium has been found in Johnson (ESI 2021b) and Oak Orchard Creeks (Mahar and Landry 2016). In the Lower Genesee basin, *L. cardium* has been found in Black Creek, Canaseraga Creek, Conesus Creek, Genesee River, Honeoye Creek (Mahar and Landry 2016, 2019). In the Oswego basin, this species was found in Canandaigua Outlet (Mahar and Landry 2016).

Recent records (2000-2025) from the St. Lawrence River basin include Grass River (Harper 2013, 2016), Raquette River (Harper 2013), St. Regis River (Jock 2016, Harper 2013), Salmon River, Little Salmon River and West Branch Deer Creek (NY Natural Heritage Program 2025), while recent records in the Champlain basin only include the Saranac River (Jirka personal communication).

Strayer and Jirka (1997) reported additional records (1970-1997) from the upper watersheds of the Grass River (Little River, Harrison Creek, Unnamed Water) and Raquette River (Squeak Brook), as well as several records from southern Champlain basin (Poultney River and tributary) and the Upper Hudson basin (Big Creek, Moses Kill) near the entrance of the Champlain Canal. This is likely more a result of a lack of survey effort in these basins than an indication of a restriction in the northern and eastern portions of this species' New York range.

Streams of greatest *L. cardium* abundance include the Genesee River with 1,914 live, Honeoye Creek with 352 live, Tonawanda Creek with 339 live (Mahar and Landry 2016, Belt 2013, Jirka survey records, Dunford 2019, Sansom et al. 2018), and the Allegheny River upstream of Olean, and Oswayo Creek (The Nature Conservancy 2009). As expected, *L. cardium* was not found in recent Susquehanna basin survey (Mahar and Landry 2019, Harman and Lord 2010).

New York's Contribution to Species North American Range:

Percent of North American Range in NY	Classification of NY Range	Distance to core population, if not in NY
1-25%	Peripheral	550 miles

Column options
Percent of North American Range in NY: 100% (endemic); 76-99%; 51-75%; 26-50%; 1-25%; 0%; Choose an item
Classification of NY Range: Core; Peripheral; Disjunct; (blank) or Choose an item

IV. Primary Habitat or Community Type *(from NY crosswalk of NE Aquatic, Marine, or Terrestrial Habitat Classification Systems):*

a. Size/Waterbody Type: Medium River

b. Geology: Moderately Buffered

c. Temperature: Warm to Transitional Cool

d. Gradient: Low to Moderate-High Gradient

Habitat or Community Type Trend in New York

Habitat Specialist?	Indicator Species?	Habitat/ Community Trend	Time frame of Decline/Increase
No	Yes	Unknown	

Column options
Habitat Specialist and Indicator Species: Yes; No; Unknown; (blank) or Choose an item
Habitat/Community Trend: Declining; Stable; Increasing; Unknown; (blank) or Choose an item

Habitat Discussion:

Watters et al. (2009) notes that *L. cardium* is widespread in creeks, rivers, ponds, and lakes and tolerates many substrates and water flows. However, other sources state only that this species is found in flowing water, with moderate to strong current, and stable substrates of mud, silt, sand, or gravel (McMurry et. al. 2012; Cummings and Mayer 1992; Metcalfe-Smith et al. 2005, Parmalee and Bogan1998).

V. Species Demographic, and Life History:

Breeder in NY?	Non-breeder in NY?	Migratory Only?	Summer Resident?	Winter Resident?	Anadromous/ Catadromous?
Yes	No	No	Yes	Yes	(blank)

Column options
First 5 fields: Yes; No; Unknown; (blank) or Choose an item
Anadromous/Catadromous: Anadromous; Catadromous; (blank) or Choose an item

Species Demographics and Life History Discussion *(include information about species life span, reproductive longevity, reproductive capacity, age to maturity, and ability to disperse and colonize):*

Upstream males release sperm into the water. Females downstream take up the sperm with incoming water. Fertilization success may be related to population density, with a threshold density required for any reproductive success to occur. Eggs are fertilized within the female. Like nearly all North American mussels, *L. cardium* must parasitize an often specific vertebrate host to complete its life cycle. It is suspected that some mussel populations are not recruiting because their hosts no longer occur with them. Once released by the female, glochidia must acquire a suitable host or die, usually within 24-48 hours. After attaching to a suitable host, glochidia encyst, usually at the fish's gills or fins and receive food and dispersal. Once the glochidia metamorphose into juveniles, they drop from the host. If they land in suitable substrate, they will burrow into the substrate, where they may remain for several years (Watters et al 2009).

In the adult form, freshwater mussels are basically sessile; movement is limited to a few meters of the lake or river bottom. The only time that significant dispersal can take place is during the parasitic phase. Infected host fishes can transport the larval unionids into new habitats, and can replenish depleted populations with new individuals. Dispersal is particularly important for genetic exchange between populations. Dispersal is likely to be a slow process for mussels which use resident fishes with limited home ranges as their hosts (COSEWIC 2003 in NatureServe 2013).

Specimens older than 30 years of age are rare. Sexual maturity may be reached at about 4 years of age (Watters et al. 2009). *L. cardium* has been reported to have either a single brood per year, with spawning occurring in July and August and glochidia released in April or May of the following year or to have two broods per year with egg-bearing or gravid females occurring from July through October and again from May to July (Watters et al. 2009).

Most of the known hosts for *L. cardium* are centrarchids. Glochidia transformation has been confirmed on tiger salamander (*Ambystoma tigrinum* ssp.), green sunfish (*Lepomis cyanelllus*), pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), white crappie (*Pomoxis annularis*), black crappie (*Pomoxis nigromaculatus*), and walleye (*Sander vitreus*) (Watters et al. 2009). Based on infestation, sauger (*Sander canadensis*) is a potential host (Watters et al. 2009).

VI. Threats *(from NY 2015 SWAP or newly described):*

Agricultural Runoff

Many known New York State *L. cardium* habitats are found in areas potentially subject to agricultural runoff. Although primarily a forested watershed, agriculture is present in the valleys adjacent to the Allegheny River and its tributaries near Olean, Allegany, Portville, and adjacent to Cassadaga and Conewango Creeks. The Lower Genesee basin is primarily agricultural with large and often continuous blocks of cultivated cropland adjacent to the Genesee River and Honeoye Creek near *L. cardium* habitat. Hay and pasture lands are more prevalent adjacent to Black Creek, Tonawanda Creek, Salmon River, Little Salmon River, Raquette River, and Grass River, as well as some adjacent agriculture in the Lake Champlain watershed (New York State Landcover 2010). Aquatic habitats lacking vegetated buffers of adequate width are threatened by runoff from urban areas, roads, lawns, and agricultural land (Gillis 2012). If best management practices are not closely adhered to, mussel habitat adjacent to wood harvest or agricultural land is subjected to pesticide, fertilizer, and silt/sediment runoff. During recent mussel surveys in Western and Central New York, it has been documented that sufficient vegetated riparian buffers are often lacking along known mussel streams (Mahar and Landry 2016), indicating that runoff is a major threat to resident mussel populations.

Species such as *L. cardium L. ovata* that have a mantle modified to attract host fish are thought to rely on the visual acuity of their fish hosts to facilitate transfer of glochidia from the female to the host. This indicates that increases in turbidity associated with runoff may in interfere with reproduction and be especially detrimental to the species (Nedeau 2008).

The presence of pesticides and fertilizers in our rural watersheds is nearly ubiquitous (Haag 2012). And because pesticides and their associated surfactants adsorb onto sediment particles, sedimentation may act as a vector for their transport into the aquatic system (Haag 2012). Mussels are more sensitive to pesticides than many other animals (Watters et al. 2009). Although effects of pesticides are species-specific, sub-lethal levels of PCBs, DDT, malathion, and other compounds inhibit respiratory efficiency and accumulate in the tissues. Atrazine and permethrin at sublethal concentrations reduced juvenile growth (Bringolf et al. 2007a, 2007b) and environmental levels of atrazine altered mussel movement and aggregation behavior (Flynn and Spellman 2009). Pesticides can affect mussels in many ways, but the full range of long-term effects remains unknown (Haag 2012).

Fertilizer runoff is also a concern. High inputs of nitrogen from fertilizers can cause increases in ammonia in the water and the substrate, leading to direct toxicity for a wide range of mussel species. Mussels, especially in their early life stages, are more sensitive to un-ionized ammonia than other organisms, and high sensitivity is seen across a range of species and life histories (Haag 2012). In addition, ammonia adsorbs to sediment particles, resulting in higher nitrogen concentrations in the substrate than in the overlying water. The nitrogen present in the interstitial spaces in the substrate is thought to result in juvenile mortality and to prevent recruitment by some mussel species (Strayer and Malcom 2012). Studies have suggested decreasing sediment loads entering aquatic systems as the best way to decrease the impact of numerous stressors for mussels in general (Roley et al. 2012).

Runoff from Developed Land

The habitat of *L. cardium* receives storm water runoff from the cities of Olean and Salamanca, and the villages of Allegany and Portville, either directly to the Allegheny River or through tributaries. Cassadaga Creek receives Jamestown's urban runoff via the Chadokoin River. Known habitat in Cayuga Creek receives runoff from Buffalo's suburbs, the Genesee River receives runoff from Geneseo, and the Grass River receives runoff from Massena. In addition, all 19 New York waterbodies that host *L. cardium* populations are intermittently bordered by interstate highways, state routes, and/or local roads (New York State Landcover, 2010). These developed lands are likely sources runoff containing metals and road salts. Mussels are particularly sensitive to heavy metals, more so than many other animals used in toxicological tests (Keller and Zam 1991). Low levels of metals may interfere with the ability of glochidia to attach to the host (Huebner and Pynnonen 1992), suggesting that U.S. EPA ambient water quality criteria may not adequately protect mussels from toxic metals (Wang et al. 2011). In addition, increases in salinity from the runoff of salt used for clearing roads in winter may be lethal to glochidia and juvenile mussels (Keller and Zam 1991; Liquori and Insler 1985; Pandolfo et al. 2012). Based on these studies, the U.S. EPA's ambient water quality criterion for acute chloride exposures may not be protective of all freshwater mussels (Pandolfo et al. 2012).

Remediation efforts

Remediation efforts, such as those that have recently taken place in the Grass River, the lower Genesee River, and the Hudson River, often involve dredging and/or capping of polluted substrate. These remediation actions devastate the biotic community, typically removing all mussels and benthic life during the clean up. If mussels have been removed from large areas, recolonization and recovery may take many decades or longer.

Treated and Untreated Wastewater

The habitat of *L. cardium* receives treated wastewater from Olean and Portville, either directly to the Allegheny River or through tributaries. Cassadaga Creek receives treated effluent from the city of Jamestown sewage treatment plant. Geneseo releases treated effluent into *L. cardium* habitat in the Genesee River. In the St. Lawrence River basin, Salmon River receives wastewater from Fort Covington and Grass River receives effluent from Massena. In addition, combined sewer outflow (CSO) outfalls from the cities of Massena (Grass River, Raquette River) and Potsdam (Raquette River) may be found in the vicinity of *L. cardium* sites ("Combined Sewer Overflow" 2012). Both Fort Ann and Whitehall release treated effluent to known habitat in the Champlain Canal (SPDES 2007). Recent studies show that mussel richness and abundance decrease with increased proximity to sewage effluent (Wildenberg 2012). The input of biomaterial from wastewater treatment plants depletes dissolved oxygen levels, negatively impacting mussels. Ammonia from wastewater treatment plants has been found to be toxic to glochidia (Goudraeu et al. 1993) and at sub-lethal exposure, adult mussels exhibit decreased respiratory efficiency (Anderson et al*.* 1978). Endocrine disrupters from pharmaceuticals are also present in municipal sewage effluents and are increasing common in rivers and lakes (Haag 2012). In mussels, chronic exposure to estrogenic compounds in effluents caused feminization of male mussels, but these individuals did not produce eggs, suggesting major disruption of reproductive function (Gagne et al. 2011). The long-term effects of these compounds on mussels are unknown (Haag 2012). It should be noted that in the Susquehanna Basin, Harman and Lord (2010) found no evidence that wastewater treatment plants were responsible for reductions in mussel species of greatest conservation need.

Flood Control Projects

Large stretches of *L. cardium* habitat are within the leveed portions of the Allegheny River (in Olean and Portville), Olean Creek (in Olean), and Oswayo Creek (in Portville) ("New York State Flood Protection" 2013). These structures confine larger rivers, preventing the river from inundating its natural floodplains and wetlands to minimize flood damage. Additionally, many smaller streams have been channelized and bermed by landowners and highway departments to protect farm fields and other structures. Channelization and dredging associated with flood control projects are catastrophic to mussels and have been implicated in the decline of some populations (Watters et al. 2009). The result of these projects is altered seasonality of flow and temperature regimes, increased stream velocities, unstable substrates, changed patterns of sediment scour and deposition, including streambank erosion, altered transport of particulate organic matter (the food base for mussels), and a general degradation of stream habitat (Benke 1999; Yeager 1993; Nedeau 2008).

Habitat Modifications

Ecosystem modifications, such as isolated occurrences of flood control channel dredging, instream work associated with bridge replacement, or gravel mining, and vegetation removal kill mussels and destroy their habitat. For example, dredging for vegetation removal has been shown to remove up to 23% of mussels in spoils (Aldridge 2000). Further evidence for disruption was provided by mussel surveys adjacent to approximately 20 river miles of Conewango Creek that had been channelized and straightened in the first half of the 20th century. The resulting "dredge" had no riffle or run habitat and sites just below and above this channelized section contained few or no mussels (The Nature Conservancy 2009). Although limited in geographic scope these habitat modification activities have long term impacts on mussels and their distribution (Aldridge 2000).

Invasive Species

Invasive zebra mussels (*Dreissena polymorpha*) pose a potential threat to *L. cardium* populations in Cassadaga and Conewango Creeks, where they are present in the lower reaches. Chautauqua Lake's connection to Cassadaga Creek, Chadakoin Creek, is the main source of this exotic invasive (The Nature Conservancy 2009), which has been repeatedly cited as a threat to native mussel populations (Strayer and Jirka 1997; Watters et al. 2009). En masse, Dreissenids outcompete native mussels by efficiently filtering food and oxygen from the water. They reduce reproductive success by filtering native mussel male gametes from the water column and they can foul the shells of the native mussels to the point that their valves can no longer open. In heavily invested areas, they may transform a habitat by hardening the substrate, such that dislodged mussels are not able to rebury (USFWS 1994). Although zebra mussels will continue to cause problems for Chautauqua Lake, they currently appear to have minimal impact downstream. However, precautions should be taken to avoid invasions by zebra mussels to upstream locations, especially the headwater lakes in the Cassadaga system. Monitoring for zebra mussels in these lakes may provide early detection of this invader (The Nature Conservancy 2009).

Climate Change

Global climate change is expected (among other disruptions) to cause an increase in surface water temperatures in southern Ontario. Although many species are tolerant of warm water, higher water temperatures may be an added stress for some. Increased water temperatures may also increase algal growth, which could result in reductions in dissolved oxygen levels at night

(Morris and Burridge 2006). Galbraith et al. (2010) recently showed how regional climate patterns coupled with changing local water regimes and management strategies have shifted mussel populations from thermally sensitive species to thermally tolerant species.

Impoundments – Range wide

Across its range, impoundments likely contributed to the reduced distribution of mussels that we see today. Vaughn and Taylor (1999) observed a mussel extinction gradient with a gradual, linear increase in mussel species richness and abundance with increasing distance downstream from impoundments. Species and their hosts that require shallow, oxygenated, fast-flowing water quickly are eliminated. Continuously cold water from both increased water depth upstream of the dam and dam discharges downstream of the dam may prevent reproduction. Impoundment increases silt load and eutrophication, resulting in changes in the fish fauna, and therefore the availability of hosts. Dams represent distributional barriers to fish hosts, and therefore to the mussels themselves. The zoogeographic patterns of several species suggest a dam-limited range. Dams also act as sediment traps, often having many feet of silt and debris caught on their upstream side. These areas generally are without mussels. Below the dam, the tailwaters often have dense mussel beds, as these reaches are the only areas left that still have oxygenated, fast moving water. This is exemplified by the distribution of beds in the lower Muskingum River, Ohio (Stansbery and King 1983; ESI 1993c).

In addition, improperly sized and poorly installed or poorly maintained culverts have impacts similar to dams in that they fragment habitat, preventing the movement by host fish, and effectively isolating mussel populations. And because culverts are located at nearly every road-stream intersection, there is the potential for landscape level fragmentation of mussel habitat.

Threat Level 1	Threat Level 2	Threat Level 3	Spatial Extent	Severity	Immediacy	Trend	Certainty
1. Residential and Commercial	1.3 Tourism & Recreation Areas	1.3.5 Docks & marinas	Small	Moderate	Immediate	Stable and ongoing	Choose an item.
3. Energy Production & Mining	3.3 Renewable Energy	3.3.1 Hydroelectric dams	Small	Moderate	Long-term	Stable and ongoing	Choose an item.
4. Transportation & Service Corridors	4.1 Roads & Railroads	4.1.3 Bridges	Small	Serious	Near-term	Stable and ongoing	Choose an item.
4. Transportation & Service Corridors	4.3 Shipping Lanes	4.3.2 Dredging of shipping lanes	Small	Extreme	Immediate	Stable and ongoing	Choose an item.
6. Human Intrusions & Disturbance	6.3 Work & Other Activities	6.3.1 Research activities	Small	Slight	Near-term	Intensifying	Choose an item.
7. Natural System Modifications	7.2 Dams & Water Management/Use	7.2.1 Water level management using dams	Small	Moderate	Long-term	Stable and ongoing	Choose an item.
7. Natural System Modifications	7.2 Dams & Water Management/Use	7.2.3 Water management using culverts	Small	Moderate	Near-term	Stable and ongoing	Choose an item.
7. Natural System Modifications	7.2 Dams & Water Management/Use	7.2.6 Withdrawl of surface water	Small	Moderate	Near-term	Intensifying	Choose an item.
7. Natural System Modifications	7.3 Other Ecosystem Modifications	7.3.1 Shoreline alteration	Small	Moderate	Near-term	Intensifying	Choose an item.
8. Invasive & Other Problematic Species	8.1 Invasive Non-Native Plants & Animals	8.1.3 Aquatic animals	Restricted	Extreme	Immediate	Stable and ongoing	Choose an item.
9. Pollution	9.1 Domestic & Urban Wastewater	9.1.1 Domestic wastewater	Restricted	Moderate	Immediate	Intensifying	Choose an item.
9. Pollution	9.1 Domestic & Urban Wastewater	9.1.2 Runoff	Large	Moderate	Immediate	Intensifying	Choose an item.

9. Pollution	9.3 Agricultural & Forestry Effluents	9.3.1 Nutrient loads	Pervasive	Moderate	Immediate	Stable and ongoing	Choose an item.
9. Pollution	9.3 Agricultural & Forestry Effluents	9.3.2 Soil erosion, sedimentation	Large	Moderate	Near-term	Stable and ongoing	Choose an item.
9. Pollution	9.3 Agricultural & Forestry Effluents	9.3.3 Herbicides & pesticides	Large	Moderate	Near-term	Unknown	Choose an item.
11. Climate Change	11.3 Changes in Temperature Regimes	11.3.3 Gradual temperature change	Large	Moderate	Long-term	Intensifying	Choose an item.
11. Climate Change	11.4 Changes in Precipitation & Hydrological Regimes	11.4.2 Droughts	Large	Slight	Long-term	Intensifying	Choose an item.
11. Climate Change	11.4 Changes in Precipitation & Hydrological Regimes	11.4.4 Increase in fluctuations in precipitation regime	Restricted	Slight	Long-term	Intensifying	Choose an item.
11. Climate Change	11.5 Storms & Severe Weather	11.5.1 Storms & severe weather	Restricted	Extreme	Immediate	Intensifying	Choose an item.
4. Transportation & Service Corridors	4.3 Shipping Lanes	4.3.3 Locks & canals	Small	Serious	Long-term	Stable and ongoing	Choose an item.
5. Biological Resource Use	5.4 Fishing & Harvesting Aquatic Resources	5.4.4 Management/control of aquatic species	Small	Moderate	Unknown	Stable and ongoing	Choose an item.

Table 2. Threats to plain pocketbook.

Are there regulatory mechanisms that protect the species or its habitat in New York?

Yes: _✓__ **No:**_____ **Unknown:**_____

If yes, describe mechanism and whether adequate to protect species/habitat:

Mussel habitats receive some generic protection under several New York State regulations (NYCRR) promulgated under the authority of the New York Environmental Conservation Law (ECL), specifically Part 608 of the NYCRR: Use and Protection of Waters, and Part 617 of the NYCRR: State Environmental Quality Review (SEQR). Part 608 provides protection of some mussel habitats by regulating and requiring environmental review of the modification or disturbance of any “protected stream”, its bed or bank, and removal of sand, gravel or other material from its bed or banks (608.2 Disturbance of Protected Streams). This does not provide adequate protection of mussels and their habitats as it only protects streams or particular portions of a streams for which there has been adopted by NYSDEC or any of its predecessors any of the following classifications or standards: AA, AA(t), A, A(t), B, B(t) C(t), or Streams designated (t)(trout) also include those more specifically designated (ts)(trout spawning). Mussel habitats may also receive some additional protections as the construction, repair, breach or removals of dams, and the excavation and placement of fill in navigable waters are subject to regulation and environmental review under Part 608, 608.3 and 608.5 respectively. Under Part 608, projects requiring a permit can be conditioned by NYSDEC to include best management practices, such as sediment and erosion protections. Through the review process, these projects can also be modified to reduce impacts in order to meet permit issuance standards.

Under Part 608, protection of unlisted species of mussels is general and relatively limited. More importantly, Class C and D waters with mussels do not receive protection under these regulations. A significant portion of the New York’s mussel resources occur within Class C and D waters (see species specific streams in threats/management discussion) An additional but not insignificant gap in protection occurs because agricultural activities consisting of the crossing and re-crossing of a protected stream by livestock or wheeled farming equipment normally used for traditional agricultural purposes or of withdrawing irrigation water in a manner which does not otherwise alter the stream, are exempt from these regulations and environmental review.

Water quality certifications required by Section 401 of the Federal Water Pollution Control Act, Title 33 United States Code 1341(see subdivision (c) of this Section) may provide protection for freshwater mussels and their habitats from some activities that would potentially have adverse impacts by regulating construction or operation of facilities that may result in any discharge into navigable waters. Water quality certifications set water quality-related effluent limitations, water quality standards, thermal discharge criteria, effluent prohibitions and pretreatment standards for projects on navigable waters.

The State Environmental Quality Review (SEQR, Part 617 NYCRR) may also protect mussels and their habitats by requiring the consideration of environmental factors into the existing planning, review and decision-making processes of state, regional and local government agencies for activities that require discretionary approval. SEQR requires the preparation of an Environmental Impact Statement, including an alternatives analysis, for those activities that may result in a substantial adverse change in ground or surface water quality; a substantial increase in potential for erosion, flooding, leaching or drainage problems; the removal or destruction of large quantities of vegetation or fauna; substantial interference with the movement of any resident or migratory fish or wildlife species; impacts on a significant habitat area; substantial adverse impacts on a threatened or endangered species of animal or plant, or the habitat of such a species; other significant adverse impacts to natural resources; or, a substantial change in the use, or intensity of use, of land including agricultural, open space or recreational resources, or in its capacity to support existing uses.

New York State has numerous laws and regulations that both directly or indirectly protect waters of the state (mussel habitats) including regulations governing direct discharges to surface and groundwater, storm water, agricultural activities, pesticides, flood control, and dams. Without these regulations, mussels would certainly be in worse shape; however, most of these generic protections are not adequate in scope or specific enough to mussel threats to protect the mussel resources of New York State.

Describe knowledge of management/conservation actions that are needed for recovery/conservation, or to eliminate, minimize, or compensate for the identified threats:

- Priority conservation efforts for this species should focus on, but not be limited to, Honeoye Creek between Rush and the confluence with the Genesee River, the Genesee River, especially between the Mt. Morris dam and Geneseo, Oswayo Creek, the Allegheny River upstream of Olean, and Tonawanda Creek.

- Through landowner incentive programs or regulation, riparian buffers should be added/maintained/widened, along agricultural fields, subdivisions, and along major roads to decrease the levels of nitrogen, pesticides, sediment, heavy metals, salts from entering these aquatic systems.

- Require all state agencies to maintain appropriate vegetative buffers along streams, rivers and lakes on state-owned or state managed properties.

- Develop and implement a comprehensive monitoring strategy that identifies protocols, including locations and specific intervals, for regular monitoring of known mussel populations to detect assess trends and detect dangerous declines.

- Mussel sensitivity to particular pollutants should be considered or addressed in the regulation of wastewater and stormwater discharges to groundwater and surface waters, State Pollutant Discharge Elimination Systems (SPDES). This should be reflected in effluent limitations for discharges, including discharges from P/C/I facilities (Private/Commercial/Industrial), CAFO facilities (Concentrated Animal Feeding Operations), High Volume Hydraulic Fracturing Discharges, and Wastewater treatment plants, etc. Discharges whose receiving waters have mussels, particularly those with known populations of mussels listed as Endangered, Threatened, Special concern or SGCN, should be carefully reviewed for potential impacts to mussels. For example, deleterious levels of ammonia (a component of many types of discharges) and molluscicides (a commonly used water treatment chemical in discharged water) should not be permitted.

- Coordinate with local wastewater treatment facilities to improve ammonia removal of treated discharge. This has been documented as a threat to Unionids at multiple life stages, and therefore needs to be addressed (Gillis 2012).

- Establish a protocol whereas DEC staff work closely with Flood Control management to reduce or impacts to native mussels during maintenance flood control projects.

- NYSDEC should consider sensitivity of freshwater mussels to specific pollutants in the establishment and setting of water quality standards and TMDLs for waters containing freshwater mussels. A Total Maximum Daily Load (TMDL) specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. TMDLs account for all contributing sources (e.g. point and nonpoint sources, and natural background levels), seasonal variations in the pollutant load, and incorporate a margin of safety that accounts for unknown or unexpected sources of the pollutant. In essence, a TMDL defines the capacity of the waterbody to absorb a pollutant and still meet water quality standards. The Clean Water Act requires states to identify waterbodies that do not meet water quality standards after application of technology-based effluent limitations. For these "impaired waters," states must consider the development of alternative strategies, including TMDLs, for reducing the pollutants responsible for the failure to meet water quality standards.

- Within the Great Lakes and Champlain watersheds, lamprey control efforts should consider specific, potentially adverse, impacts to native freshwater mussels when determining methods, including selection of lampricide formulations and concentrations.
  Lampricide treatment managers should use caution when using the combination of TFM and niclosamide in streams with known mussel populations and every effort should be made to maintain lampricide concentrations at or near the MLC for sea lamprey to minimize the risk to this important faunal group (Boogaard 2006).

Action Category	Action	Description
A.1 Direct Habitat Management	A.1.2.4.1 Plant for erosion management	Implement vegetated riparian buffers on state owned or managed properties to reduce water pollution, nutrient loading, and sedimentation
A.1 Direct Habitat Management	A.1.3.0.0 Mitigate human environmental impact	-Mitigation involving the cleanup of toxins in occupied substrate must include a remediation plan for mussels -Mitigation should address disturbance caused by routine dredging -Mitigate impacts to streams in occupied waters
A.1 Direct Habitat Management	A.1.3.3.0 Remove and improve anthropogenic infrastructure	Replace culverts that disrupt habitat connectivity
B.3 Outreach	B.3.1.3.0 Targeted Communication	-Coordinate with local wastewater treatment to improve ammonia removal in treated discharge -Work with Army Corps of Engineers to reduce impacts of lower Genesee River dredging -Work with NYSDEC Flood Control to decrease impacts of flood control projects and maintenance on mussels - Work with Highway Departments to reduce impacts on mussels by directing road and bridge runoff away from waterbodies and minimizing impacts to mussels during maintenance and construction activities
B.5 Economic and other Incentives	B.5.4 Economic incentives and disincentives	- Through landowner incentive programs, riparian buffers that provide shade, should be added/ maintained/ widened, along agricultural fields,

		subdivisions, and along major roads to moderate temperature, decrease nitrogen, pesticides, sediment, heavy metals, and salts from entering aquatic systems -Update wastewater treatment facilities in Rochester, Massena, and Potsdam to eliminate combined sewer outflows. -Coordinate with local wastewater treatment facilities to improve ammonia removal of treated discharge.
C.6 Design and Plan Conservation	C.6.4.0.0 Conserve via zoning or informal designations	Protection through acquisition, easements, registry, and/or working with local, state, and federal government on issues relating to zoning and streamside development
C.6 Design and plan conservation	C.6.5.1.2 Develop a strategy, guideline, monitoring plan or follow-up in a protected area	Develop a plan to monitor mussel population trends
C.7 Legislative and regulatory framework or tools	C.7.2.3.0 Create or amend standards	- Consider mussel sensitivity to pollutants in the regulation of wastewater and stormwater discharges to surface waters, State Pollutant Discharge Elimination Systems (SPDES). -Implement TMDLs that are protective of mussels to meet water quality standards -Require state agencies to maintain vegetative buffers along water on state land
C.8 Research and Monitoring	C.8.1.1.1 Characterization, demographic study, population, or inventory	-Surveys to determine trends should take place throughout its range. - Historic locations in the St. Lawerence and Lake Champlain basin should be surveyed to determine current distribution
C.8 Research and Monitoring	C.8.2.1.2 Monitoring and evaluating the results of project activities	Monitor lampricide treatment site, especially those using a combination of TFM and niclosamide

Table 3. Recommended conservation actions for plain pocketbook

The Comprehensive Wildlife Conservation Strategy (NYSDEC 2006) includes recommendations for the following actions for freshwater mussels:

Habitat management:

- Manage areas of important mussel populations by controlling degradation factors (e.g.. Controlling livestock access, point source or non-point source pollution, flow alteration, etc.)
- Develop methods to improve and restore freshwater bivalve habitat.

Habitat research:

- Conduct research to determine habitat parameters necessary for good populations of each species of species-at-risk listed mussels.
- Research flow requirements of freshwater bivalves and model the effects of flow changes both in volume and timing.
- Research all parameters of mussel habitat requirements including temperature, substrate, fish, flow, food, etc.

Habitat restoration:

- Restore degraded habitat areas to allow for recolonization or reintroduction of listed mussels.

Invasive species control:

- Develop a monitoring/control plan that includes measures to detect invasive species problematic to freshwater bivalves in all New York watersheds and actions that will be taken to control them before they become threats.
- Conduct research on control of exotic bivalve species that compete with native mussels and exotic crustaceans or fish which may prey on them.

Life history research:

- Research effects of pesticides and other chemicals, including ammonia, on all life stages of freshwater bivalves: sperm/egg, glochidia, larva, adults.
- Research potential interbreeding between *Alasmidonta varicosa* and *Alasmidonta marginata* and, if occurring, evaluate the potential threat to *A. varicosa* population integrity.
- Determine fish hosts for species where this is not known for populations living in New York.
- Research population dynamics of listed mussel species including connectivity of populations or subpopulations and genetic distinctness of populations or subpopulations.
- Determine or confirm breeding phenology and habitat conditions necessary for successful breeding for listed mussels (e.g.. mussel density, pop. level of fish host, temp, flow).

Modify regulation:

- Modify marine mussel regulations to be clearer that freshwater mussels are protected under ECL.

New regulation:

- Ban the importation of fish that feed on freshwater mollusks (e.g.. black carp).
- Require inclusion of all stages of freshwater mussels in testing for approval of new pesticides in New York.

Other action:

- Develop an outreach program to private landowners through the Landowner Incentive Program to educate the public about freshwater mussel protection and initiate projects to prevent or repair impacts from land use on mussels.
- Increase regional permit control of development and highway projects that may impact native mussels.
- Develop standard monitoring/survey protocols for development projects in all watersheds in New York.
- Evaluate threats to mussels in each New York watershed and prioritize areas for actions to address the threats.
- Research the best survey methods both for detection of rare species and evaluation of population status and trends.
- Begin evaluation of members of the family Sphaeridae (fingernail clams) for inclusion into the species at risk list.

Population monitoring:

- Conduct population estimates of species-at-risk listed mussel species in NY
- Conduct surveys to determine distribution of species-at-risk listed mussel species in NY.

Regional management plan:

- Incorporate freshwater mussel goals and objectives into regional water quality and fish management plans and policies.

Relocation/reintroduction:

- Where appropriate, reintroduce listed mussels into appropriate habitat within their historic range.

Statewide management plan:

- Incorporate freshwater mussel goals and objectives into statewide water quality and fish management plans and policies.

VII. References

Aldridge, D. C. (2000). The impacts of dredging and weed cutting on a population of freshwater mussels (Bivalvia: Unionidae). *Biological Conservation*, *95*(3), 247-257.

Belt, E. 2013. Final Report: Unionid survey in the Genesee River at highway 63 bridge. Prepared for: New York State Department of Transportation. Ecological Specialists, Inc. Special Licenses Report to NYSDEC.

Benke, A.C. (1990). A perspective on America's vanishing streams. *Journal of the N. American Benthological Society: 9*: 77-88.

Boogaard, Michael A., *Acute Toxicity of the Lampricides TFM and Niclosamide to Three Species of Unionid Mussels,* USGS Open-File Report 2006-1106, April 2006.

Bringolf, R. B., Cope, W. G., Eads, C. B., Lazaro, P. R., Barnhart, M. C., and Shea, D. (2007). Acute and chronic toxicity of technical-grade pesticides to glochidia and juveniles of freshwater mussels (unionidae). *Environmental Toxicology and Chemistry*, *26*(10), 2086-2093.

Bringolf, R. B., Cope, W. G., Barnhart, M. C., Mosher, S., Lazaro, P. R., and Shea, D. (2007). Acute and chronic toxicity of pesticide formulations (atrazine, chlorpyrifos, and permethrin) to glochidia and juveniles of *Lampsilis siliquoidea*. *Environmental Toxicology and Chem*, *26*(10), 2101-2107.

Cummings, K. S., and Mayer, C. A. (1992). *Field guide to freshwater mussels of the Midwest* (p. 194). Champaign, Illinois: Illinois Natural History Survey.

Dunford, D. 2019. Final: Mussel salvage for the New York State route 63 bridge over the Genesee River, Livingston County, New York. Prepared for Barton & Loguidice. EnviroScience, Inc. Special Licenses Report to NYSDEC.

Flynn, K., and Spellman, T. (2009). Environmental levels of atrazine decrease spatial aggregation in the freshwater mussel, *Elliptio complanata*. *Ecotoxicology and Environmental Safety*, *72*(4), 1228-1233.

Gagné, F., Bouchard, B., André, C., Farcy, E., and Fournier, M. (2011). Evidence of feminization in wild *Elliptio complanata* mussels in the receiving waters downstream of a municipal effluent outfall. *Comparative Biochemistry and Physiology Part C: Toxicology and Pharmacology*, *153*(1), 99-106.

Galbraith, H. S., Spooner, D. E., and Vaughn, C. C. (2010). Synergistic effects of regional climate patterns and local water management on freshwater mussel communities. *Biological Conservation*, *143*(5), 1175-1183.

Gillis, P. L. (2012). Cumulative impacts of urban runoff and municipal wastewater effluents on wild freshwater mussels (*Lasmigona costata*). *Science of the Total Environment*, *431*, 348-356.

Goudraeu, S. E., Neves, R. J., and Sheehan, R. J. (1993). Effects of wastewater treatment plant effluents on freshwater mollusks in the upper Clinch River, VA. *Hydrobiologia*, *252*(3), 211-230.

Graf, D. and K. Cummings. (2011). MUSSELp Evolution: North American Freshwater Mussels. The MUSSEL Project. The University of Wisconsin. Available: http://mussel-project.uwsp.edu/evol/intro/north_america.html.Haag, W. R. (2012). *North American freshwater mussels: natural history, ecology, and conservation*. Cambridge University Press.

Haag, W. R. (2012). *North American freshwater mussels: natural history, ecology, and conservation*. Cambridge University Press.

Harman, W.N. and P.H. Lord (2010). Susquehanna Freshwater Mussel Surveys, 2008-2010. Final report submitted to New York State Department of Environmental Conservation. SUNY Oneonta. Cooperstown, NY. 24 pp, plus appendix.

Harper, L. 2016. Mussel survey study results for the lower reach of the Grasse River, New York. Riveredge Environmental Inc. Special Licenses Report to NYSDEC.

Harper, L. 2013. St. Lawrence River tributary surveys. Riveredge Environmental, Inc. Special Licenses Report to NYSDEC.

Huebner, J. D., and Pynnönen, K. S. (1992). Viability of glochidia of two species of Anodonta exposed to low pH and selected metals. *Canadian Journal of Zoology*, *70*(12), 2348-2355.

Jirka, K.J. Survey records: 1998-2020. EcoLogic, LLC. Personal communication 2018, 2019, 2020, 2021.

Jock, J.L. 2016. Pre-construction mussel surveys, mussel salvage and relocation to proactively mitigate loss of native species associated with the Hogansburg Dam removal. St. Regis Mohawk Tribe, Environment Division, Akwesasne. Personal communication 2018.

Keller, A. E., and Zam, S. G. (1991). The acute toxicity of selected metals to the freshwater mussel, *Anodonta imbecilis*. *Environmental Toxicology and Chemistry*, *10*(4), 539-546.

Liquori, V. M., and Insler, G. D. (1985). Gill parasites of the white perch: Phenologies in the lower Hudson River. *New York Fish and Game Journal*, *32*(1), 71-76.

Mahar, A.M. and J.A. Landry. 2019. State Wildlife Grants Annual Report: Native freshwater mussel distributions in New York's Upper Susquehanna, Erie, and Allegheny basins. New York State Department of Environmental Conservation, Division of Fish and Wildlife, Avon, NY.

Mahar, A.M. and J.A. Landry. 2016. State Wildlife Grants Final Report: Inventory of Freshwater Mussels in New York's Southeast and Southwest Lake Ontario Basins, 2008-2013. New York State Department of Environmental Conservation, Division of Fish and Wildlife, Avon, NY.

.

Mahar, A.M. and J.A. Landry. 2013. NYSDEC SWAP 2015 Species Status Assessment for Plain pocketbook. Prepared on June 2013. Revised by Samantha Hoff on February 26, 2014.

Marangelo, P. J., and Strayer, D. L. (2000). The freshwater mussels of the Tonawanda Creek basin in western New York. *Walkerana*, *11*(25), 97-106.

McMurray, S.E., Faiman, J.S., Roberts, A., Simmons, B., and Barnhart, C.M. 2012. *A guide to Missouri's freshwater mussels.* Missouri Department of Conservation, Jefferson City, Missouri.

Metcalfe-Smith, J., A. MacKenzie, I. Carmichael, and D. McGoldrick. (2005). Photo Field Guide to the Freshwater Mussels of Ontario. St. Thomas Field Naturalist Club. St. Thomas, ON, 60pp.

Meyer, E. and M. Walsh. 2013. Final report to USFWS: Evaluating the presence of endangered freshwater mussels in the Allegheny River basin in western New York. Pennsylvania Natural Heritage Program.

Morris, T. J. and M. Burridge. 2006. Recovery Strategy for Northern Riffleshell, Snuffbox, Round Pigtoe, Mudpuppy Mussel and Rayed Bean in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa, x + 76 pp.

Natural Heritage Program Element Occurrences [ARC/INFO coverages] (2013). New York Natural Heritage Program, Albany, NY. Available: NYS Department of Environmental Conservation Master Habitat Data Bank's Data Selector.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: February 12, 2013).

Nedeau, E.J. 2008. *Freshwater Mussels and the Connecticut River Watershed.* Connecticut River Watershed Council, Greenfield, Massachusetts. Xviii+ 132 pp.

New York State Department of Environmental Conservation. (2006). *New York State Comprehensive Wildlife Conservation Strategy*. Albany, NY: New York State Department of Environmental Conservation.

New York State Flood Protection Project Details and Maps (2013). Retrieved from Department of Environmental Conservation website: http://www.dec.ny.gov/lands/59934.html

New York State Landcover, Version 1. [SDE raster digital data] (2010). National Gap Analysis Program. Moscow, Idaho. Available: NYS Department of Environmental Conservation Master Habitat Data Bank's Data Selector.

Northeastern Aquatic Habitat Classification System (NAHCS) GIS map for streams and rivers, [vector digital data] (2010). US Environmental Protection Agency, the US Geological Survey, and The Nature Conservancy Eastern Conservation Science. Boston, MA. Available: NYS Department of Environmental Conservation Master Habitat Data Bank's Data Selector.

Pandolfo, T. J., Cope, W. G., and Arellano, C. (2010). Thermal tolerance of juvenile freshwater mussels (Unionidae) under the added stress of copper. *Environmental Toxicology and Chemistry*, *29*(3), 691-699.

Pandolfo, T. J., Cope, W. G., Young, G. B., Jones, J. W., Hua, D., and Lingenfelser, S. F. (2012). Acute effects of road salts and associated cyanide compounds on the early life stages of the unionid mussel *Villosa iris*. *Environmental Toxicology and Chemistry*, *31*(8), 1801-1806.

Parmalee, P.W. and A.E. Bogan. 1998. The Freshwater Mussels of Tennessee. University of Tennessee Press: Knoxville, Tennessee. 328 pp.

Roley, S. S., J. Tank, and M. A. Williams (2012), Hydrologic connectivity increases denitrification in the hyporheic zone and restored floodplains of an agricultural stream, *J. Geophys. Res.*

Sansom, B.J., S.J. Bennett, J.F. Atkinson and C.C. Vaughn. 2018. Long-term persistence of freshwater mussel beds in labile river channels. Freshwater Biology. 2018;1–13.

Smith, T.A. and D. Crabtree. 2010. Freshwater mussel distributions and densities in French Creek, PA. Northeastern Naturalist 17(3):387-414.

Stansbery, D. H., and King, C. C. (1983). Management of Muskingum River mussel (unionid mollusk) populations. Final Report to the U.S. Department of Commerce, and the Ohio Department of Natural Resources. *Ohio State University Museum of Zoology Reports*. 79 p.

State Pollutant Discharge Elimination System (SPDES) - New York State [vector digital data]. (2007). Albany, New York: New York State Department of Environmental Conservation. Available: http://gis.ny.gov/gisdata/inventories/details.cfm?dsid=1010&nysgis=

Stein, B. A., Kutner, L. S., Hammerson, G. A., Master, L. L., and Morse, L. E. (2000). State of the states: geographic patterns of diversity, rarity, and endemism. *Precious heritage: the status of biodiversity in the United States. Oxford University Press, New York*, 119-158.

Strayer, D.L. and K.J. Jirka. 1997. The Pearly Mussels of New York State. New York State Museum Memoir (26): 113 pp., 27 pls.

Strayer, D.L. and Malcom, H.M. 2012. Causes of recruitment failure in freshwater mussel populations in southeastern New York. Ecological Applications 22:1780–1790.

The Nature Conservancy (2009). Freshwater Mussel (Unionidae) Distributions, Catches, and Measures of their Viability across the Catches, and Measures of their Viability across the Allegheny River Basin in New York. Report submitted New York State Department of Environmental Conservation. The Nature Conservancy, Central and WNY Chapter. Rochester, NY. 63 pp.

U.S. Fish and Wildlife Service. 1994. Clubshell *(Pleurobema clava)* and Northern Riffleshell *(Epioblasma tondosa rangiana)* Recovery Plan. Hadley, Massachusetts. 68 pp.

Vaughn, C. C. and Taylor, C. M. (1999), Impoundments and the Decline of Freshwater Mussels: a Case Study of an Extinction Gradient. *Conservation Biology*, 13: 912–920

Walsh, M. 2022. Pennsylvania Natural Heritage Program, Western Pennsylvania Conservancy. Personal Communication.

Wang, N., Mebane, C. A., Kunz, J. L., Ingersoll, C. G., Brumbaugh, W. G., Santore, R. C., ... and Arnold, W. (2011). Influence of dissolved organic carbon on toxicity of copper to a unionid mussel (*Villosa iris*) and a cladoceran (*Ceriodaphnia dubia*) in acute and chronic water exposures. *Environmental Toxicology and Chemistry*, *30*(9), 2115-2125.

Watters, G. T., Hoggarth, M. A., and Stansbery, D. H. (2009). *The freshwater mussels of Ohio*. Columbus: Ohio State University Press.

White, E.L., J.J. Schmid, T.G. Howard, M.D. Schlesinger, and A.L. Feldmann. 2011. New York State freshwater conservation blueprint project, phases I and II: Freshwater systems, species, and viability metrics. New York Natural Heritage Program, The Nature Conservancy. Albany, NY. 85 pp. plus appendix.

Wildenberg, A. (2012, August). Mussel Community Response to Wastewater Effluent in a Midwestern River. In *AFS 142nd Annual Meeting*. AFS.

Williams, J.D., M.L. Warren, K.S. Cummings, J.L. Harris and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries. 18(9):6-22.

Yeager, B. (1993). Dams. Pages 57-92 in C.F. Bryan and D. A Rutherford, editors. Impacts on warm water streams: guidelines for evaluation. *American Fisheries Society,* Little Rock, Arkansas.