Species Status Assessment

Class: **Bivalvia**
Family: **Unionidae**
Scientific Name: ***Ptychobranchus fasciolaris***
Common Name: **Kidneyshell**

Species synopsis:

Ptychobranchus fasciolaris 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). *P. fasciolaris* is grouped into the genus *Ptychobranchus,* named for its series of folds in the outer gills of a gravid female. The species name refers to banding pattern on the periostracum (Watters et al. 2009).

Since 1970, *P. fasciolaris* has been found in eight New York State waterbodies. It has recently been confirmed in multiple locations in the Allegheny basin, as well as in Lake Erie tributaries (The Nature Conservancy 2009, Mahar & Landry 2013). *P. fasciolaris* inhabits gravel riffles in large streams and small rivers.

Although rare and ranked as "imperiled" in New York, this edge of range species is considered secure throughout its range**.** 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, based on sparse historical information it is assumed that they too are declining due to a myriad of environmental stressors.

Status

a. Current and Legal Protected Status

i. Federal ____ _____ None_________________________ **Candidate?** ___No__

ii. New York ___None – Species of Greatest Conservation Need____________

b. Natural Heritage Program Rank

i. Global ___G4G5 – Apparently Secure/Secure________________________

ii. New York ___S2 - Imperiled_________ **Tracked by NYNHP?** ___Yes_____

Other Rank:

Canadian Species at Risk Act (SARA) Schedule 1/Annexe 1 Status: E (2005)
Committee on the Status of Endangered Wildlife in Canada (COSEWIC): Endangered (2003)
IUCN Red List Category: Least concern
American Fisheries Society Status: Currently Stable (1993)

Status Discussion:

This species is found throughout the Mississippi River system, including the Ohio, Tennessee, and Cumberland Rivers. It has declined to some extent in certain places, although many sites still report large populations. In particular, significant declines have occurred in Canada, while U.S. occurrences have been more stable (NatureServe 2013).

II. Abundance and Distribution Trends

a. North America

i. Abundance

____ declining ____increasing ___X___stable ____unknown

ii. Distribution:

___X__ declining ____increasing _____stable ____unknown

Time frame considered: ____

b. Regional

i. Abundance

____ declining ____increasing __X__stable _____unknown

ii. Distribution:

__X__ declining ____increasing ____stable ______unknown

Regional Unit Considered:_______Northeast_______________________________
Time Frame Considered: ____

c. Adjacent States and Provinces

CONNECTICUT	**Not Present __X____**	**No data _______**
MASSACHUSETTS	**Not Present __X____**	**No data _______**
NEW JERSEY	**Not Present __X____**	**No data _______**
ONTARIO	**Not Present ________**	**No data _______**

i. Abundance

____ declining ____increasing __X__stable ____unknown

ii. Distribution:

____ declining ____increasing ___X__stable ____unknown

Time frame considered: __2003-2013___________________________________
Listing Status: ____S1 Federally and Provincially Endangered______________

PENNSYLVANIA **Not Present** ________ **No data** _______

i. **Abundance**

____ **declining** ____**increasing** __X__**stable** ____**unknown**

ii. **Distribution:**

____ **declining** ____**increasing** __X__**stable** ____**unknown**

Time frame considered: ____

Listing Status: ____S4____________________________ SGCN? ___No_____

QUEBEC **Not Present** ___X___ **No data** _______

VERMONT **Not Present** ___X___ **No data** ________

d. NEW YORK **No data** _______

i. **Abundance**

__X__ **declining** ____**increasing** ____**stable** _____**unknown**

ii. **Distribution:**

__X__ **declining** ____**increasing** ____**stable** _____**unknown**

Time frame considered: ____

Monitoring in New York.

As part of a State Wildlife Grant, NYSDEC Region 8 Fisheries and Wildlife staff is conducting a baseline survey of tributaries in central and western New York for native freshwater mussels 2009 – 2017.

Trends Discussion:

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 & Landry 2013). 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.

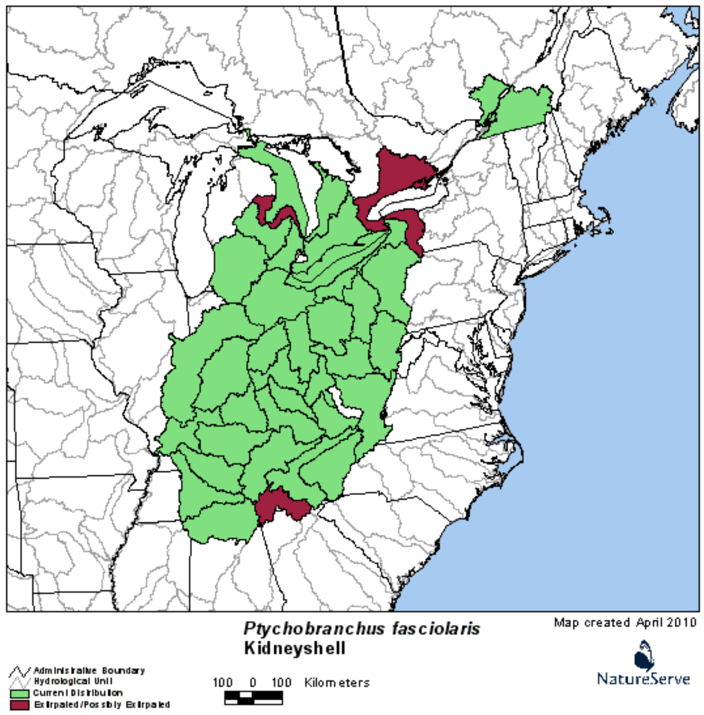

Figure 1. *P. fasciolaris* distribution in North America (NatureServe 2013).

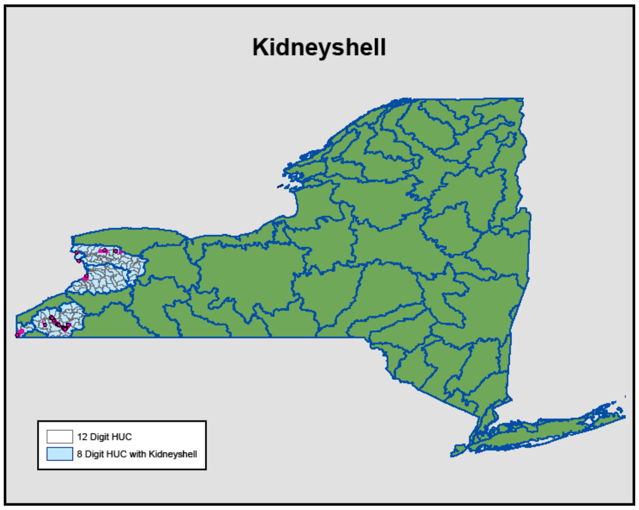

Figure 2. Post 1970 distribution *of P. fasciolaris* in New York (Mahar & Landry 2013; Harman and Lord 2010; The Nature Conservancy 2009; New York Natural Heritage Program 2013; White et al. 2011).

III. New York Rarity, if known:

Historic	# of Animals	# of Locations	% of State
prior to 1970	unknown	~8 waterbodies	6 of 56 HUC 8 watersheds
prior to 1980			
prior to 1990			

Details of historic occurrence:

Although *P. fasciolaris* does not have a wide range in New York, it is often abundant where it does occur. This species reached New York via both the Allegheny River and Lake Erie. It is common and widespread in the western parts of the Allegheny basin in New York, but it seems to be missing from the eastern parts of the basin. It also occurs in Lake Erie, the Niagara River, and their tributaries. It was historically reported from Johnson Creek, Orleans County, in the Lake Ontario drainage (Strayer & Jirka 1997).

Current	# of Animals	# of Locations	% of State
	~600 live	__8 verified waterbodies	4 of 56 HUC 8 watersheds

Details of current occurrence:

Since 1970, *P.fasciolaris* has been found in eight New York State waterbodies (Figure 2).

In the Allegheny watershed, 347 live *P. fasciolaris* were found in Conewango Creek and Cassadaga Creek, with most of the individuals found in the Cassadaga. This species was found at 16 of 105 Allegheny basin survey sites, with a mean catch of 1.65 per hour; its population was considered viable at 69% of these sites. A single unverified *P. fasciolaris* was reported from Oswayo Creek (The Nature Conservancy 2009). *P. fasciolaris* has also been found in French Creek (Mahar & Landry 2013; New York National Heritage Program 2013) and in abundance in Chautauqua Lake at Midway Park (2008, one live), Bemus Point (1987-1990, shells), and hundreds of live, some with mature glochidia, at Long Point (1989) (New York National Heritage Program 2013).

Since 1987, *P. fasciolaris* has been found in the Lake Erie basin, including locations in Lake Erie (shells at Athol Springs), an unnamed tributary to Lake Erie at Mount Vernon, west of Hamburg, and the Niagara River (live at Beaver Island and shells at Buckhorn Island) (Strayer & Jirka 1997, New York National Heritage Program 2013, White et al. 2011). In addition, live *P. fasciolaris* has recently been confirmed in Tonawanda Creek (Mahar & Landry 2013).

Post 1970, *P. fasciolaris* has not been found in Johnson Creek, despite recent survey efforts (Mahar & Landry 2013).

New York's Contribution to Species North American Range:

% of NA Range in New York	Classification of New York Range
____ 100 (endemic)	____ Core
____ 76-99	__X__ Peripheral
____ 51-75	____ Disjunct
____ 26-50	Distance to core population:
__X__ 1-25	___340 miles_____

IV. Primary Habitat or Community Type:

1. Small River; Low Gradient; Moderately Buffered, Neutral; Transitional Cool

2. Small River; Low-Moderate Gradient; Moderately Buffered, Neutral; Transitional Cool

3. Medium River; Low Gradient; Assume Moderately Buffered (Size 3+ rivers); Warm

Habitat or Community Type Trend in New York:

____ Declining ____Stable ____ Increasing __X__Unknown

Time frame of decline/increase: ______________________________

Habitat Specialist? __X__ Yes _______ No

Indicator Species? __X__ Yes _______ No

Habitat Discussion:

P. fasciolaris is a high-water-quality species (Watters et al. 2009). It is most common in large creeks and small rivers, although can be found in large rivers (Niagara River) and some lakes (Erie, Chautauqua), where it attains a much smaller size (Strayer & Jirka 1997). It may be found at depths of less than three feet up to those as great as 18 to 24 feet (Parmalee & Bogan 1998, Spoo, 2008). It is usually absent from headwater creeks less than 3 meters wide (COSEWIC 2003).

It is said to favor riffle areas with firmly-packed coarse gravel and sand substrate with moderate to swift flows, and to have an aversion to ponded or backwater conditions (COSEWIC 2003; Watters et al. 2009; Metcalfe-Smith et al. 2005; Strayer & Jirka 1997). However, there is some evidence that it occurs most frequently in low gradient streams (Strayer & Jirka 1997). Furthermore, this species is often found near beds of aquatic vegetation (Metcalfe-Smith et al. 2005).

V. New York Species Demographics and Life History

__X____ Breeder in New York

___X__ Summer Resident

__X__ Winter Resident

____ Anadromous

____ Non-breeder in New York

____ Summer Resident

____ Winter Resident

____ Catadromous

____ Migratory only

____Unknown

Species Demographics and Life History Discussion:

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, *P. fasciolaris* 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 habitat, 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, as cited in NatureServe 2013).

This species has an equilibrium life history strategy, characterized primarily by long life span, mostly short term brooding, low to moderate growth rate, and late maturity, with low reproductive effort and fecundity that increases slowly after maturation. This life history strategy is considered to be favored in stable, productive habitats (Haag 2012).

P. fasciolaris is bradytictic, with eggs appearing in August and glochidia developing by September and overwintering until the following June to August (Ortmann 1919), however in Ohio, glochidial release has been observed in April and May (Watters et al. 2009). Various darter species (*Etheostoma spp.*) serve as hosts for this species (Strayer & Jirka 1997). Glochidia transformations have been confirmed on brook stickleback (*Culaea inconstans*), rainbow darter *(Etheostoma caeruleum)*, and fantail darter *(Etheostoma flabellare)*. Other potential hosts may include greenside darter (*Etheostoma blennioides*), johnny darter (*Etheostoma nigrum*), and banded darter (*Etheostoma zonale*). Individuals of this species can commonly live for over 30 years (Watters et al. 2009).

VI. Threats:

Agricultural Runoff

Both French Creek watershed and Tonawanda Creek watershed are highly agricultural. And although the mid reaches of Cassadaga Creek are quite forested, both the up and downstream portions of Cassadaga Creek and Conewango Creek, in which *P. fasciolaris* have been found, are shaped by agriculture (NYS 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 & Landry 2013), indicating that runoff is a major threat to resident mussel populations.

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).

Runoff from fertilizers 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

All five of the streams in which this species occurs in New York are located adjacent to roads and residential structures (NYS Landcover 2010). These developed lands are likely sources of stormwater runoff containing metals and road salts. Mussels are particularly sensitive to heavy metals, more so than many other animals used in toxicological tests (Keller & Zam 1991). Low levels of metals may interfere with the ability of glochidia to attach to the host (Huebner & 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 & Zam 1991; Liquori & 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).

Treated and Untreated Waste Water

Populations of *F. flava* in the Niagara River, Chautauqua Lake, and Cassadaga Creek receive effluent from wastewater/sewage treatment plants either directly or through nearby tributaries (SPDES 2007). In addition, Niagara River populations are subject to input from numerous combined sewer outflows (CSOs) from the City of Buffalo ("Combined Sewer Overflow" 2012). Recent studies show that mussel richness and abundance decrease with increased proximity to sewage effluent (Wildenberg, 2012). The input of biomaterial from waste water 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 increasingly 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 waste water treatment plants were responsible for reductions in mussel species of greatest conservation need.

Habitat Modifications

Ecosystem modifications, such as in-stream work associated with canal dredging, bridge replacements, 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 and quagga mussels (*Dreissena polymorpha* and *Dreissena bugenis*) remain a threat to *P. fasciolaris* populations in Chautauqua Lake, Lake Erie, and Niagara River (iMapInvasives 2013). The invasion of zebra and quagga mussels has compromised the continued presence of many mussel populations. Native mussels have been effectively eliminated from the western basin of Lake Erie by these exotics. 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).

Impoundments – Range wide

Across its range, impoundments likely contributed to the reduced distribution 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 & 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.

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

____ No **____ Unknown**

__X___ Yes

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. 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, Cassadaga Creek.

- Modify marine mussel regulations or the definition of protected wildlife in NYCRR to clarify that freshwater mussels are protected under ECL. Current regulations could be interpreted that freshwater mussels may only be protected as shellfish without a season within the Marine District.

- Through landowner incentive programs or regulation, riparian buffers, particularly those that also provide shade, should be added/maintained/widened, along agricultural fields, subdivisions, and along major roads to decrease the levels of nitrogen, pesticides, sediment, heavy metals, and salts from entering these aquatic systems, as well as to moderate water temperature. 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 & Tank 2012).

- 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.
- Update wastewater treatment facilities in Buffalo to eliminate combined sewer outflows.
- 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 state and local highway departments to reduce impacts to native mussels during maintenance and construction projects.
- Replace culverts that disrupt aquatic habitat connectivity to allow for passage of small fish species.
- 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 & 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.

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.

Anderson, K. B., Sparks, R. E., & Paparo, A. A. (1978). Rapid assessment of water quality, using the fingernail clam, *Musculium transversum*: Final Report. University of Illinois, Urbana. 130p.

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

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

Combined Sewer Overflow (CSO) Outfalls: New York State Department of Environmental Conservation Interactive Maps for Google Maps and Earth. (2013). Retrieved from Department of Environmental Conservation website: http://www.dec.ny.gov/pubs/42978.html

COSEWIC. (2003). COSEWIC assessment and status report on the kidneyshell *Ptychobranchus fasciolaris* in Canada. Ottawa, Canada:Committee on the Status of Endangered Wildlife in Canada.

Flynn, K., & 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., & 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 & Pharmacology*, *153*(1), 99-106.

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., & Sheehan, R. J. (1993). Effects of wastewater treatment plant effluents on freshwater mollusks in the upper Clinch River, Virginia, USA. *Hydrobiologia*, *252*(3), 211-230.

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.

Huebner, J. D., & 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.

iMapInvasives (2013) The Nature Conservancy: an online mapping tool for invasive species locations. Available at: imapinvasives.org. (Date accessed: [03,06,2013].)

Keller, A. E., & 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., & 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. (2013). 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. Avon, NY. *In progress*.

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.

Nalepa, T.F. & Schloesser, D.W. (2012) eds*.* Quagga and Zebra Mussels: Biology, Impacts, and Control*.* (2).

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).

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.

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 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.

Ortmann, A. E. (1919). *Monograph of the Naiades of Pennsylvania.. 8(1)*. Board of Trustees of the Carnegie Institute.

Pandolfo, T. J., Cope, W. G., Young, G. B., Jones, J. W., Hua, D., & 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. & Bogan, A.E. (1998). The Freshwater Mussels of Tennessee. Knoxville, Tennessee. University of Tennessee Press.

Roley, S.S. 2012. The influence of floodplain restoration on stream ecosystem function in an agricultural landscape. (unpublished doctoral dissertation). University of Notre Dame, Notre Dame, Indiana. Submitted for publishing with Tank, J.L.

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.*Spoo, A. (2008). The Pearly Mussels of Pennsylvania. Landisville, Pa. Coachwhip Publications.

Stansbery, D. H., & 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., & 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. & Jirka, K.J. (1997). The Pearly Mussels of New York State. New York State Museum Memoir (26)

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

Strayer, D.L. (1983). The effects of surface geology and stream size on freshwater mussel distribution in southeastern Michigan, U.S.A. *Freshwater Biology 13*,253-264.

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 & Western NY 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

Wang, N., Mebane, C. A., Kunz, J. L., Ingersoll, C. G., Brumbaugh, W. G., Santore, R. C., ... & 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., & 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 & 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.

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