Species Status Assessment

Class: **Bivalvia**
Family: **Unionidae**
Scientific Name: ***Pleurobema clava***
Common Name: **Clubshell**

Species synopsis:

Pleurobema clava belongs to the subfamily Ambleminae and the tribe Pleurobemini, which includes four extant and one likely extirpated New York species in the genera Elliptio, Fusconaia, and Pleurobema (Haag 2012). In general, the shells are of this tribe are unsculptured and larvae are brooded only in the outer demibranchs (with exceptions) (Graf and Cummings 2011). *Pleurobema clava* is the only member of the *Pleurobema* genus with an orange viscera and foot. The genus name *pleurobema,* meaning step, refers to the ribs found between the shell annulae. The species name, *clava,* means club and refers to the general shape of the shell (Watters et al. 2009).

P. clava prefers small, gravelly riffles of creeks and is commonly found burrowed deep into sediment (Strayer and Jirka 1997). It is known from Cassadaga Creek, in the Allegheny basin where four individuals were found at two sites during recent surveys by The Nature Conservancy (2009). Historically, the species may have been scattered through the upper Allegheny basin (Strayer and Jirka 1997). *P. clava* is listed as endangered at both the Federal and State levels. New York populations are thought to be declining, as no new recruits have been found during recent surveys.

Status

a. Current and Legal Protected Status

i. **Federal** ___Endangered_____**Candidate?** ___No_____

ii. **New York** __Endangered – Species of Greatest Conservation Need_____

b. Natural Heritage Program Rank

i. **Global** ___G1G2 - Critically Imperiled_____

ii. **New York** __S1 - Critically Imperiled__ **Tracked by NYNHP?** ___Yes_

Other Rank:

U.S. Endangered Species Act (USESA): Listed endangered, nonessential experimental population (1993)
IUCN Red List Category: Critically endangered
Convention on International Trade in Endangered Species Protection Status (CITES): Appendix II
American Fisheries Society Status: Endangered (1993)

Status Discussion:

P. clava was once found from Michigan to Alabama, and from Illinois to West Virginia. Extirpated from Alabama, Illinois and Tennessee, it occurs today in portions of only 12 streams (USFWS 1994). This species has been extirpated from most of its range in this century. It is thought that less than 20% of historical range remains. Continued loss of habitat and water quality deterioration threatens the remaining populations (NatureServe 2013).

II. Abundance and Distribution Trends

a. North America

i. **Abundance**

__X__ declining ____increasing _____stable ____unknown

ii. **Distribution:**

__X__ declining ____increasing _____stable ____unknown

Time frame considered: _____

b. Regional

i. Abundance

__X__ declining ____increasing ____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 ___X___**	**No data _____**
PENNSYLVANIA	**Not Present _____**	**No data _____**

i. Abundance

_x___ declining ____increasing ____stable ____unknown

ii. Distribution:

__x___ declining ____increasing ____stable ____unknown

Time frame considered: _____
Listing Status: _____S1S2 - Endangered_____ SGCN? ___Yes____

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: __Since 1970_____

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:

This species is rare and decreasing throughout its range.

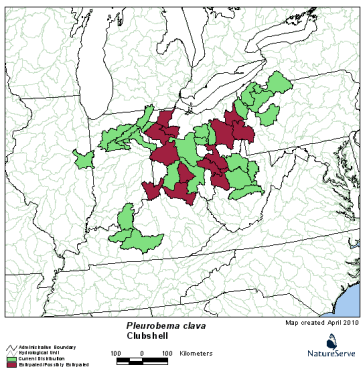

Figure 1. Range wide distribution of *P. clava* in North America (NatureServe 2013).

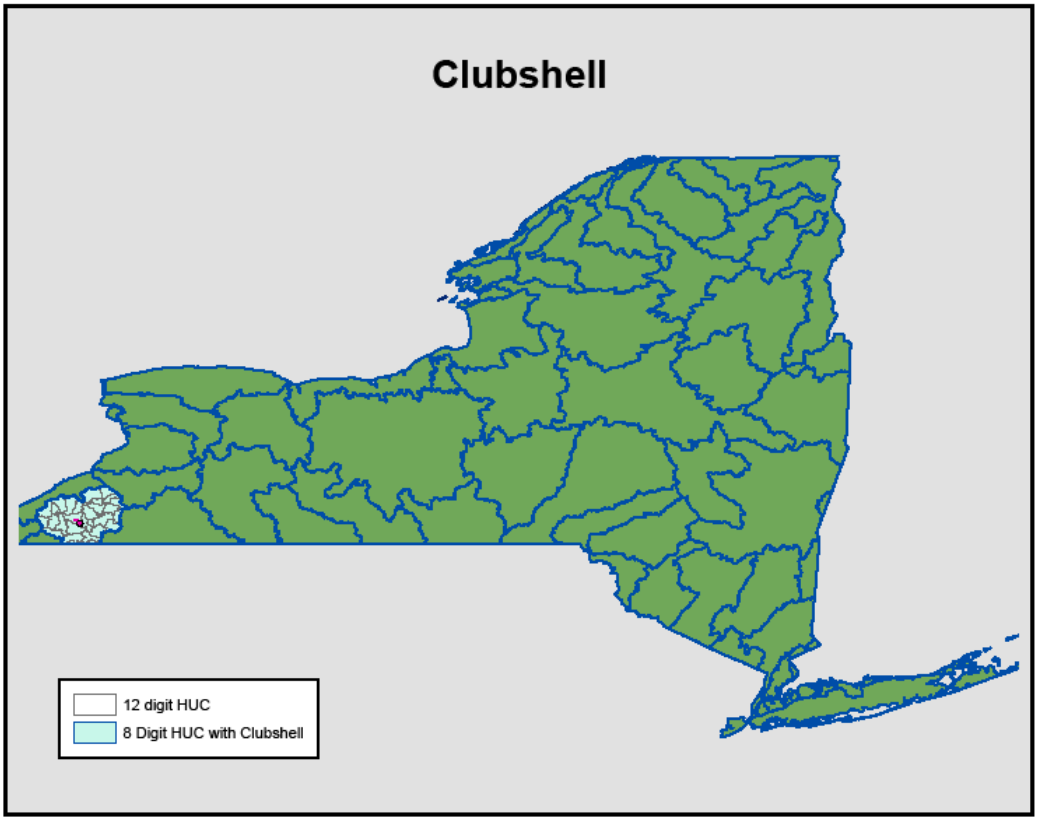

Figure 2. Post 1970 distribution of *P. clava* in New York (Mahar and Landry 2013, Harman and Lord 2010, The Nature Conservancy 2009, New York Natural Heritage Program 2013, White et al. 2011).

III. New York Rarity, if known:

Historic	# of Animals	# of Locations	% of State
prior to 1970	Unknown	1 waterbody	1 of 56 HUC 8 watersheds
prior to 1980	_____	_____	_____
prior to 1990	_____	_____	_____

Details of historic occurrence:

Historically, *P. clava* may have been scattered throughout the upper Allegheny basin in New York (Ortmann 1919), although prior to 1970, only a single record of this species, from Cassadaga Creek, exists (Strayer and Jirka 1997).

Current	# of Animals	# of Locations	% of State
	4 live	1 waterbody	1 of 56 HUC8 watersheds

Details of current occurrence:

P. clava currently only exists in one waterbody in New York State (Figure 2). In a recent survey of the Allegany basin, The Nature Conservancy documented *P.* clava at only one of the 105 excavation survey sites. At the site, two live individuals were found in Cassadaga Creek at a rate of 0.4 per hour. Two additional individuals were found alive during quantitative sampling of a site further downstream on Cassadaga Creek. Unfortunately, at both sites, no recently recruited individuals were found. The long-term viability of this species remains in question given the very low numbers of only older animals (The Nature Conservancy 2009).

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	___55 miles_____

IV. Primary Habitat or Community Type:

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

2. Headwater/Creek

Habitat or Community Type Trend in New York:

____ Declining____Stable ____ Increasing __X__ Unknown

Time frame of decline/increase: _____N/A_____

Habitat Specialist? __X__ Yes _____ No

Indicator Species? __X__ Yes _____ No

Habitat Discussion:

The habitat of *P. clava* has been reported as creeks and small rivers (Strayer and Jirka 1997), small to medium-sized rivers and streams (USFWS 1994), and medium to large rivers (Cummings and Mayer 1992). This species is generally found in clean, coarse sand and gravel or cobble, where it may live several inches beneath the surface of the substrate (USFWS as cited in NatureServe 2013, Cummings and Mayer 1992, Watters et al. 2009, Strayer and Jirka 1997). It is most common in the current at downstream ends of riffles and islands (Watters et al. 2009) or in riffles (Strayer and Jirka 1997), or runs, often just downstream of a riffle (USFWS 1994). It cannot tolerate mud or slackwater conditions, and is very susceptible to siltation (USFWS 1994). Because it deeply buries itself beneath the substrate, living animals may be hard to find even in places where it is believed to occur in some numbers (Strayer and Jirka 1997, USFWS 1994).

VIII. 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. clava* 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).

Virtually nothing is known specifically for *P. clava*. This species may live to be over 20 years old (Watters et al. 2009), with some individuals thought to live over 30 years of age (NatureServe 2013). It is not known at what age reproductive maturity begins and ends. Because of the rarity of live material, it is not known if existing populations are reproductively active, and because of their small size, it is not known if juveniles are present in any of the populations (NatureServe 2013).

This species is thought to be tachytictic, with eggs appearing in May, and glochidia present in June and July. In Ohio, glochidia had been released by the end of June (Watters et al. 2009). Glochidia are reported to have transformed on central stoneroller (*Campostoma anomalum*), striped shiner (*Luxilus chrysocephalus*), logperch (*Perca caprodes*), and blackside darter (*Percina maculate*) (Watters and O'Dee (1997) and O'Dee and Watters (2000) in Watters et al. 2009).

IX. Threats:

P. clava's decline in the upper Ohio and Wabash watersheds has been principally due to pollution from agricultural run-off and industrial wastes, and extensive impoundments for navigation (USFWS 1997, Roley et al. 2012). These, along with channelization, siltation, in-stream sand and gravel mining, and zebra/quagga mussel infestation, are thought to be responsible for its decline across its range (USFWS 1994).

Because there are only two known locations for *P. clava* in New York, both of which are located in a single stream, in close proximity to each other, a single disturbance could decimate the entire population of this species in the state. Land use in this reach of Cassadaga Creek is mostly forest cover with some, limited agriculture (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 2013), indicating that runoff is a major threat to resident mussel populations.

Agricultural Runoff

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. 2007b, 2007c in Haag 2012) and environmental levels of atrazine altered mussel movement and aggregation behavior (Flynn and Spellman 2009 in Haag 2012). Pesticides can affect mussels in many ways, but the full range of long-term effects remains unknown (Haag 2012).

Fertilizer run-off 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 both *P. clava* and mussels in general (Roley et al. 2012).

Runoff from Developed Land

Several roads cross and run adjacent to Cassadaga Creek; these are likely sources of runoff containing metals and road salts (New York State Landcover 2010). 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 as cited in Watters et al. 2009), 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, Liqouri and Insler 1985 as cited in Watters et al. 2009, 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).

Habitat Modifications

Ecosystem modifications, such as in-stream work associated with bridge replacements or gravel mining 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). These habitat modification activities have long term impacts on mussels and their distribution (Aldridge 2000). The impact of such activities on a species with limited distribution, such as *P. clava,* would be devastating.

It has been noted that this species is intolerant of impoundments (USFWS 2004). While it is highly unlikely that new impoundments will be constructed in this area, culverts and bridge crossings

should be properly maintained so that water does not collect upstream of the structures, due to debris build up or an inadequate sized installation.

Invasive Species

Zebra mussels (*Dreissena polymorpha*) are present in the lower reaches of Cassadaga and Conewango Creeks and may threaten upstream *P. clava* populations and their habitat. Chautauqua Lake's connection to Cassadaga Creek, Chadakoin Creek, is the main source of this exotic invasive. In free-flowing, relatively shallow rivers, zebra mussels do not appear to be as devastating to native mussels as they are in impounded rivers or lake environments largely because their planktonic larval stage combined with downstream flow of rivers continually depletes populations and prevents establishment (Haag 2012). However, in slower, more lentic waters, native mussel populations were virtually eliminated in much of the Great Lakes, St. Lawrence River system, and the Hudson River, where greater than 90 percent declines in mussel abundance occurred typically within four years of *Dreissena* colonization (Ricciardi et al. 1998 in Haag 2012). Invasive zebra and quagga mussels (*Dreissena polymorpha* and *Dreissena bugenis*) have 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

The NatureServe Climate Change Vulnerability Index has been used in several states to help identify species that are particularly vulnerable to the effects of climate change. While *P. clava* vulnerability was not evaluated for New York, the populations within West Virginia are ranked as "highly vulnerable" to climate change (2013) and Michigan populations were considered "extremely vulnerable" to climate change (Hoving et al. 2013).

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.

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

_____ No ____ Unknown

__X__ Yes

New York State Environmental Conservation Law, § 11-0535. 6 NYCRR Part 182: Endangered and Threatened Species of Fish and Wildlife; Species of Special Concern; Incidental Take Permits

Section 7(a) of the Federal Endangered Species Act, as amended, requires Federal agencies to evaluate their actions with respect to any species that is proposed or listed as Federally endangered or threatened. Regulations implementing this interagency cooperation provision of the Act are codified at 50 CFR Part 402. Section 7(a)(4) requires Federal agencies to confer informally with the Service on any action that is likely to jeopardize the continued existence of a proposed species or result in destruction or adverse modification of proposed critical habitat. If a species is listed subsequently, Section 7(a)(2) requires Federal agencies to ensure that any activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of such a species or to destroy or adversely modify its critical habitat. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into formal consultation with the Service.

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.

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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:

- Conservation efforts for this species should focus on 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.

- Opportunities for population augmentation of *P. clava* exist just a few dozens of miles to the south. The Allegheny River and significant tributaries in Pennsylvania such as French Creek, contain viable populations that would seemingly be the best sources of supplemental individuals. A single bridge replacement project on the Allegheny River will yield 1,000s of *P. clava* which must be translocated out of the construction footprint. The future restoration of clubshell in New York appears promising due to both a large potential supply of animals from nearby basins, and *P. clava*'s only known habitat in New York, Cassadaga Creek, which continues to support a diverse and healthy mussel population (The Nature Conservancy 2009).

- 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 both *P. clava* and mussels in general (Roley and 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.
- 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.
- In areas subject to tree harvest, promote best forestry practices to reduce/eliminate sedimentation and to ensure that substantial woody vegetation in areas directly adjacent to streams continue to provide temperature-moderating shade to the stream.
- 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 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.

The New York State 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.

X. References

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Date last revised: February 25, 2014