Species Status Assessment

Class: **Bivalvia**
Family: **Unionidae**
Scientific Name: ***Actinonaias ligamentina***
Common Name: **Mucket**

Species synopsis:

Actinonaias ligamentina 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). *A. ligamentina* belongs to the genus *Actinonaias,* which is characterized by rays on the periostracum. *Ligamentina* is named for its large, strong ligament (Watters et al. 2009).

This species typically inhabits fast flowing sections of large streams and rivers in cobble and gravel, and is occasionally found in slow water (Strayer & Jirka 1997). Since 1970, it has been found in seven New York waterbodies. It is often the most abundant mussel in the Allegheny River system's medium gradient streams (The Nature Conservancy 2009). In addition to the upper Allegheny basin and Conewango Creek basin, *A. ligamentina* is also found in the French Creek and Lake Erie basins.

Although ranked as "critically 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 _____Species of Greatest Conservation Need__________________

b. Natural Heritage Program Rank

i. Global ____G5 - Secure____

ii. New York S1S2 – Critically imperiled/Imperiled_ **Tracked by NYNHP?** _Yes_

Other Rank:

American Fisheries Society Status: Currently Stable (1993)

Status Discussion:

This species is widely distributed and found throughout the Mississippi River system, with the exception of extreme southern and western reaches. It also occurs in the St. Lawrence River basin and tributaries of Lakes Erie, Michigan, and Ontario and is considered stable throughout much of its range and is globally secure (NatureServe 2013).

II. Abundance and Distribution Trends

a. North America

i. Abundance

____ declining ____increasing __X__stable ____unknown

ii. Distribution:

____ declining ____increasing __X__stable ____unknown

Time frame considered: ____

b. Regional

i. Abundance

____ declining ____increasing __X__stable _____unknown

ii. Distribution:

____ declining ____increasing __X__stable ______unknown

Regional Unit Considered:________Midwest___________________________________
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: ____S3____

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

____ declining ____increasing __X___stable _____unknown

ii. Distribution:

____ declining ____increasing __X___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 NY 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.

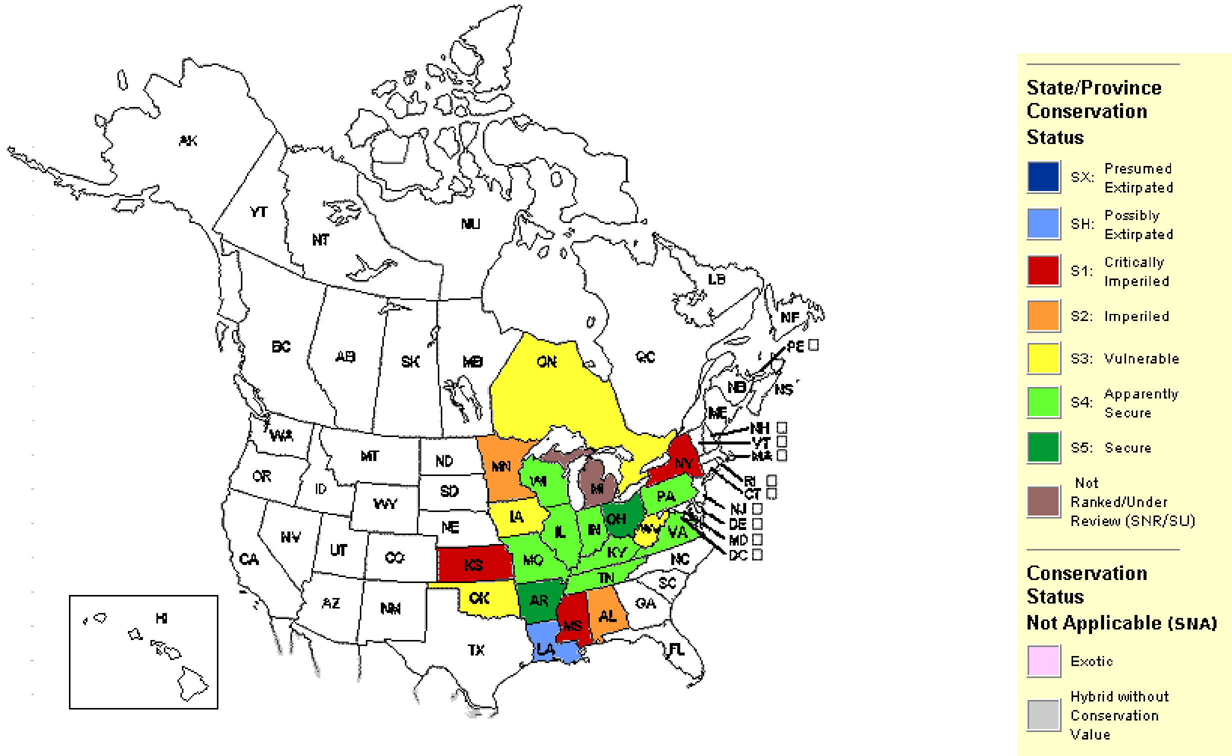

Figure 1. *A. ligamentina* distribution in North America (NatureServe 2013).

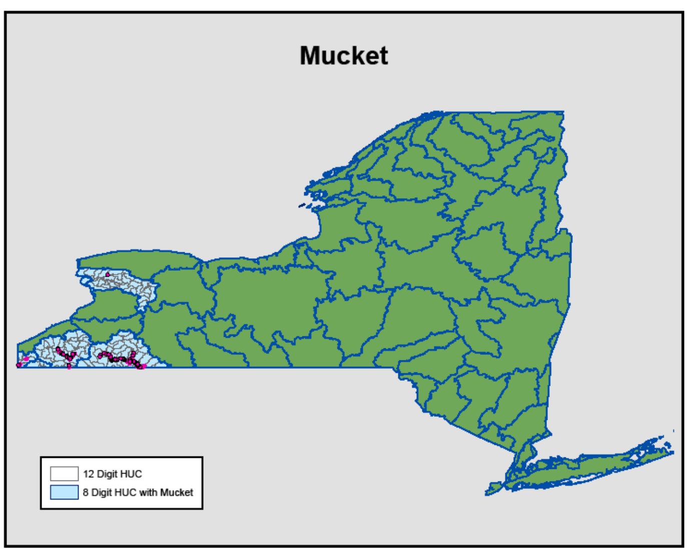

Figure 2. Post 1970 distribution of *A. ligamentina* in New York (Mahar & Landry 2013; Harman and Lord 2010; The Nature Conservancy 2009; New York Natural Heritage Program 2013; White et al. 2011).

New York Rarity, if known:

Historic	# of Animals	# of Locations	% of State
prior to 1970	_unknown_	_unknown_	5 of 56 HUC 8 watersheds_
prior to 1980	________	________	________
prior to 1990	________	________	________

Details of historic occurrence:

Historically, this species was widespread and abundant in the Allegheny basin. There are also old records from the Niagara River, Oak Orchard Creek, and possibly Tonawanda Creek (Strayer & Jirka 1997).

Current	# of Animals	# of Locations	% of State
	__~4,213 live__	__7 waterbodies_	4 of 56 HUC 8 watersheds

Details of current occurrence:

Since 1970, *A. ligamentina* has been found in seven New York State waterbodies.

A. ligamentina is currently found in medium and large creeks and rivers of the greater Allegheny River system, in which it is arguably the most abundant species (Strayer & Jirka 1997; Smith & Crabtree 2005; Smith & Meyer 2008; Smith and Crabtree 2009; The Nature Conservancy 2009), and often is the dominant species in medium-gradient habitats (such as the main stem of the Allegheny River) (The Nature Conservancy 2009). The Nature Conservancy found 4,163 live *A. ligamentina* at 61 of 105 survey sites with greatest total catches (up to 117 per hour) in the Allegheny River upstream of Olean. *A. ligamentina* populations were found throughout both the Upper Allegheny and Conewango sub-basins, including Oswayo Creek, Olean Creek, Conewango Creek, Cassadaga Creek, and the mainstem of the Allegheny River from downstream of Salamanca upstream to Portville. Populations were considered viable at 82% of the sites where they were found (The Nature Conservancy 2009).

Between 1988 and 1990, live *A. ligamentina* were found at several locations in the New York portion of French Creek. During this same time period, old shells were found in Tonawanda Creek in the Erie Basin (New York Natural Heritage Program 2013).

In 2013 over 50 live *A. ligamentina* were found in French Creek, southwest of French Creek town, Chautauqua Co (Burlakova, Karatayev, unpublished data).

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	____230 miles______

IV. Primary Habitat or Community Type:

1. Medium River; Low Gradient; Assume Moderately Buffered (Size 3+ rivers); Transitional Cool
2. Medium River; Low-Moderate Gradient; Assume Moderately Buffered (Size 3+ rivers); Warm
3. Medium River; Moderate-High Gradient; Assume Moderately Buffered (Size 3+ rivers); Transitional Cool

Habitat or Community Type Trend in New York:

____ Declining ____Stable ____ Increasing __X__Unknown

Time frame of decline/increase: ______________________________

Habitat Specialist? ____ Yes __X__ No

Indicator Species? __X__ Yes ____ No

Habitat Discussion:

Mucket typically inhabits large creeks and rivers (Strayer & Jirka 1997; Cummings & Mayer 2002; NatureServe 2013). It is "best fitted for the rough parts, riffles with strong current and heavy gravel and rocks," but may also be found in sandy mud or gravel along stream margins (Ortmann, 1919). This early habitat assessment is consistent with Watters et al. (2009) and Strayer & Jirka (1997), who note that the species is most common in cobble and sand in moving water, although habitats in

New York range from stony riffles to soft–bottomed pools. It may rarely occur in shallow water areas of large lakes (NatureServe 2013).

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, *A. ligamentina* 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 a slow process for mussels which use resident fishes with limited home ranges as their hosts (COSEWIC as cited in NatureServe 2013).

It 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).

A. ligamentina reaches sexual maturity at 4 to 6 years and can live up to 25 years. This species is bradytictic, with eggs developing in mid-summer and glochidia are present in the female from September to the following May to August (Watters et al. 2009). *A ligamentina* has been known to use many species of warm water fish as hosts and glochidia have been found to transform on rock bass (*Ambloplites rupestris)*, central stoneroller (*Campostoma anomalum)*, silverjaw minnow (*Notropis buccatus)*, banded killifish (*Fundulus diaphanus*), green sunfish (*Lepomis cyanellus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), white bass (*Morone chrysops*), yellow perch (*Perca flavescens*), white crappie (*Pomoxis annularis*), and black crappie (*Pomoxis nigromaculatus*). It is able to infest American eel (*Anguilla rostrata)*, common carp (*Cyprinus carpio*), bluegill (*Lepomis macrochirus*), tadpole madtom (*Noturus gyrinus*), and sauger (*Sander canadensis*) (Watters et al. 2009; Strayer & Jirka 1997).

VI. Threats:

Agricultural Runoff

New York's largest populations of *A. ligamentina* are found in the Allegheny River upstream of Olean, with additional viable populations between Olean and Salamanca (The Nature Conservancy 2009). Roughly half of these sections of stream are bordered by agriculture, primarily in the Olean/Allegheny area. Although the mid reaches of Cassadaga Creek are quite forested, both the upstream portions of Cassadaga Creek and the lower portions of Conewango Creek, in which *A. ligamentina* have been found, are influenced by limited agriculture. The French Creek watershed is also highly agricultural (New York State Landcover 2010). Aquatic habitat 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).

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).

Treated Waste Water

The habitat of *A. ligamentina* receives treated waste water from the cities of Olean, Salamanca, and the village of Portville, either directly to the Allegheny River or through tributaries. Cassadaga Creek receives treated effluent from the city of Jamestown sewage treatment plant (SPDES 2007). 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 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 waste water treatment plants were responsible for reductions in mussel species of greatest conservation need.

Runoff from Developed Land

The habitat of *A. ligamentina* receives storm water runoff from the cities of Olean, Salamanca, and the village of Portville, either directly to the Allegheny River or through tributaries. Cassadaga Creek receives Jamestown's urban runoff via the Chadokoin River. All seven New York waterbodies that host *A. ligamentina* 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 & 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).

Flood Control Projects

Large stretches of *A. ligamentina* habitat are within the leveed portions of the Allegheny River, Olean Creek, and Oswayo Creek ("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).

Other 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 *A. ligamentina* 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), that has been repeatedly cited as a threat to native mussel populations (Strayer & Jirka 1997; Watters et al. 2009). Studies have shown that *A. ligamentina* are significantly stressed by zebra mussels (Baker & Hornbach 1997). 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).

Impoundments

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 & 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). Mussels 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 certifcations 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, the Allegheny River upstream of Olean.

- 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.

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

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