

Species Status Assessment

Class: Bivalvia
Family: Unionidae
Scientific Name: *Truncilla truncata*
Common Name: Deertoe

Species synopsis:

Truncilla truncata 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, Ptychobranhus, Toxolasma, Truncilla, and Villosa (Haag 2012, Graf and Cummings 2011). The *Truncilla* genus is named for its oblique truncation, giving it a sharp posterior ridge and flat posterior slope. This characteristic is typical of *T. truncata* (Watters et al. 2009).

This species is most commonly found in rivers and lakes, rarely occupying smaller streams. It prefers packed sand and gravel and mud substrates (Strayer and Jirka 1997, Watters et al. 2009). Live specimens have been found in Tonawanda Creek in the Lake Erie basin, as well as Honeoye Creek and the Genesee River in the Genesee River basin. Shells have been found at additional sites on the Genesee River, Oak Orchard Creek, and the Erie Canal (Mahar and Landry 2013).

Although rare and 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 3/4 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.

I. 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 G5 - Secure
- ii. New York S1 – Critically imperiled Tracked by NYNHP? Yes

Other Rank:

American Fisheries Society Status: Currently Stable (1993)

Status Discussion:

This species is found throughout the Mississippi River system, as well as in some tributaries of Lake Erie and St. Clair and is considered stable throughout most of its range (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 stable unknown

ii. Distribution:

declining increasing stable unknown

Regional Unit Considered: Northeast

Time Frame Considered: _____

c. Adjacent States and Provinces

CONNECTICUT Not Present No data _____

MASSACHUSETTS Not Present No data _____

NEW JERSEY Not Present No data _____

ONTARIO Not Present _____ No data _____

i. Abundance

declining increasing stable unknown

ii. Distribution:

declining increasing stable unknown

Time frame considered: 2003-2013

Listing Status: S3

PENNSYLVANIA Not Present _____ No data _____

i. Abundance

 X declining ___increasing ___stable ___unknown

ii. Distribution:

 X declining ___increasing ___stable ___unknown

Time frame considered: _____

Listing Status: S1 _____ SGCN? No _____

QUEBEC Not Present X No data _____

VERMONT Not Present X No data _____

d. NEW YORK

No data _____

i. Abundance

____ declining X increasing ____ stable ____ unknown

ii. Distribution:

____ declining X 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 and 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.

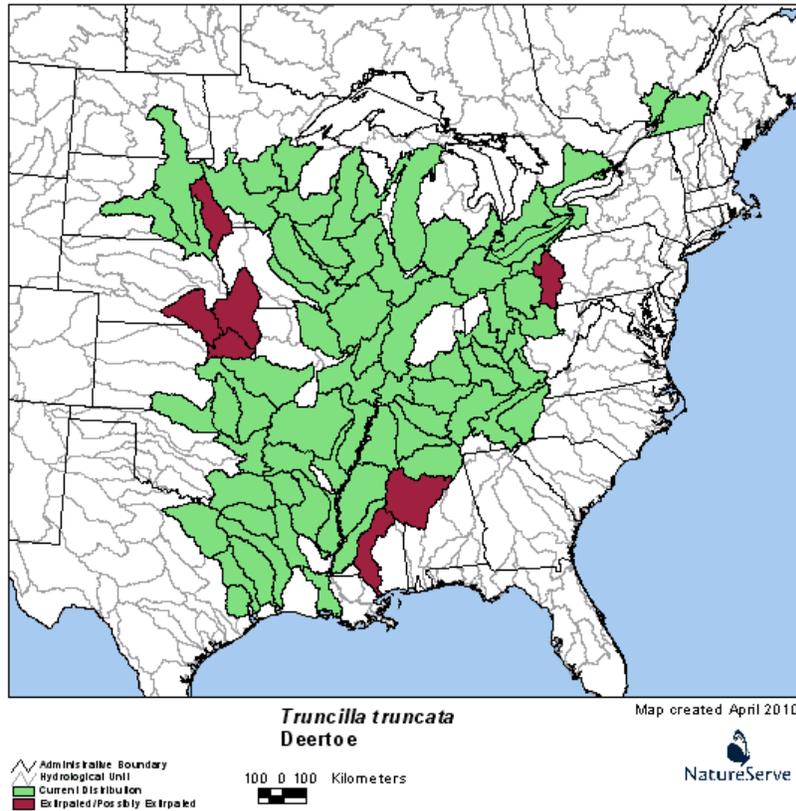


Figure 1. Range wide distribution of *T. truncata* in North America (NatureServe, 2013). **Note:** this map is incorrect, as it does not show the Genesee basin as a current population (Mahar and Landry 2013).

III. New York Rarity, if known:

Historic	<u># of Animals</u>	<u># of Locations</u>	<u>% of State</u>
prior to 1970	<u>3 specimens</u>	<u>1 waterbody</u>	<u>1 of 56 HUC 8 watersheds</u>
prior to 1980	_____	_____	_____
prior to 1990	_____	_____	_____

Details of historic occurrence:

There is only a single definite historic record for *T. truncata* from New York State. In 1948, Blakeslee found three specimens in the Erie basin's lower Tonawanda Creek (Strayer and Jirka 1997).

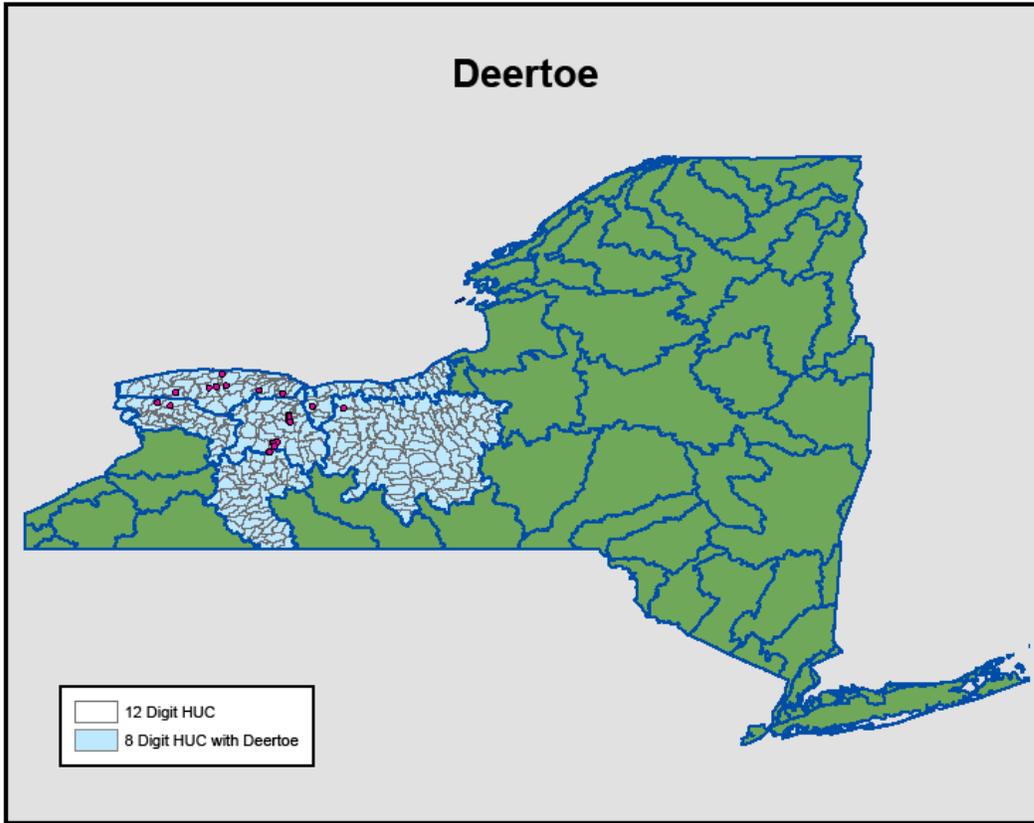


Figure 2. Post 1970 distribution of *T. truncata* in New York. (Mahar and Landry 2013, Harman and Lord 2010, The Nature Conservancy 2009, New York Natural Heritage Program 2013, White et al. 2011).

Current	<u># of Animals</u>	<u># of Locations</u>	<u>% of State</u>
	<u>8 live</u>	<u>5 waterbodies</u>	<u>6 of 56 HUC8 watersheds</u>

Details of current occurrence:

Since 1970, *T. truncata* has been found in five New York State waterbodies (Figure 2).

Between 2010 and 2013, *T. truncata* has been found live in the Erie basin in Tonawanda Creek at Rapids (8 live), and in the Genesee River basin in both lower Honeoye Creek (2 live) and the Genesee River at Mt. Morris (1 live) and Geneseo (at least 1 live). In addition, 238 shells, including fresh and juvenile specimens, were found in the Genesee River between the Honeoye Creek confluence in Rush and Rte 253 Erie Station Rd in Scottsville (Monroe County). Single shells were also found in the Genesee River in Leicester, Geneseo, and York (Livingston County). In the Southwest Lake Ontario basin, three shells were found in Oak Orchard Creek, downstream of the Waterport Reservoir, and one live mussel in Long Pond (Lake Ontario, Monroe Co., near Greece) (Burlakova et al., unpublished data). In addition, 16 shells, including one containing desiccated flesh, were found in the Erie Canal at nine locations between the Sulfur Springs Guard Lock south of Lockport (Niagara County) and Lock 32 in Macedon (Wayne County) (Mahar and Landry 2013).

This species has been found in nearby Presque Isle Bay in Pennsylvania (Masteller et al. 1993) but was later likely extirpated due to dreissenid invasion (Zanatta et al., in preparation). It is unknown whether any individuals remain in Lake Erie and the Niagara River in New York.

New York’s Contribution to Species North American Range:

% of NA Range in New York	Classification of New York Range
<u> </u> 100 (endemic)	<u> </u> Core
<u> </u> 76-99	<u> X </u> Peripheral
<u> </u> 51-75	<u> </u> Disjunct
<u> </u> 26-50	Distance to core population:
<u> X </u> 1-25	<u> 500 miles </u>

IV. Primary Habitat or Community Type:

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

- 3. Medium River; Low-Moderate Gradient; Assume Moderately Buffered (Size 3+ rivers); Warm
- 4. Canal
- 5. Summer-stratified Monomictic Lake

Habitat or Community Type Trend in New York:

Declining Stable Increasing Unknown

Time frame of decline/increase: _____

Habitat Specialist? Yes No

Indicator Species? Yes No

Habitat Discussion:

T. truncata prefers medium to large rivers and shallow areas of the Great Lakes, where it can live at depths of 12 to 18 feet, rarely straying into smaller streams. It may be locally abundant in packed sand and gravel, but may also be found in mud substrate (Cummings and Mayer 1992, Metcalfe-Smith et al. 2005, McMurray et al. 2012, Parmalee and Bogan 1998, Watters et al. 2009, Strayer, 1997).

V. New York Species Demographics and Life History

- Breeder in New York**
- Summer Resident**
- 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, *T. truncata* 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).

It has an opportunistic life history strategy. This strategy is often characterized by short life span, early maturity, high fecundity achieved soon after maturation, and, to a lesser extent, moderate to

large body size. Species in this group have the fastest growth rates and highest reproductive effort. Nearly all opportunistic species are long-term brooders. This life history strategy is considered an adaptation for rapid colonization and persistence in disturbed and unstable but productive habitats (Haag 2012).

T. truncata is thought to live up to 11 years of age. It is bradytictic, with glochidia overwintering on the female. Gravid females with glochidia were found in May and July; in Ohio they have been found in April (Watters et al. 2009). Sietman et al. (2009) confirmed freshwater drum (*Aplodinotus grunniens*) as a host species. Sauger (*Stizostedion canadense*) may also be a host for this species (Watters et al. 2009).

VI. Threats:

Agricultural Runoff

The bulk of New York's *T.truncata* population is found in the Genesee River and Tonawanda Creek, both highly agricultural areas (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.

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 and Untreated Waste Water

The Genesee River (at Geneseo, Avon, and Gates/Chili/Ogden) and Honeoye Creek (at Honeoye Falls, Honeoye, and Lima) receive treated effluent from sewage treatment plants (SPDES 2007). Illegal dumping of sewage from recreational boats in the Erie Canal may also be a concern. Recent studies show that mussel richness and abundance decreases 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.

Runoff from Developed Land

The Erie Canal and reaches of the Genesee River, which flows through various municipalities from Mt. Morris to Rochester, receive urban stormwater runoff. All five of the New York waterbodies in which live *T. truncata* populations have been found are intermittently bordered by interstate highways, state routes, and/or local roads and lawns, and receive runoff likely containing metals and road salts from these sources (Gillis, 2012; 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), suggesting that U.S. EPA ambient water quality criteria may not adequately protect mussels from toxic metals (Wang et al. 2011). In addition, increases in salinity from the runoff of salt used for clearing roads in winter may be lethal to glochidia and juvenile mussels (Keller and Zam 1991, Liquori and Insler 1985, Pandolfo et al. 2012). Based on these studies, the U.S. EPA's ambient water quality criterion for acute chloride exposures may not be protective of all freshwater mussels (Pandolfo et al. 2012).

Habitat Modifications

Ecosystem modifications, such as isolated occurrences of canal dredging, instream work associated with bridge replacement, 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).

Water Temperature Changes

Gailbreth et al. (2010) recently showed how regional climate patterns coupled with changing local water regimes and management strategies have shifted mussel populations from thermally sensitive species, such as deertoe, to thermally tolerant species.

Impoundments – Range wide

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

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

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

No **Unknown**

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:

- Conservation efforts for this species should be focused on the Genesee River downstream of Mt. Morris, especially between Rush and Scottsville.
- 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 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.
- To obtain a better handle on the current status of this species, survey the deep waters of the Genesee River between Mt. Morris and Lake Ontario.
- 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.
- Within the Great Lakes and Champlain watersheds, lamprey control efforts should consider specific, potentially adverse, impacts to native freshwater mussels when determining methods, including selection of lampricide formulations and concentrations. Lampricide treatment managers should use caution when using the combination of TFM and niclosamide in streams with known mussel populations and every effort should be made to maintain lampricide concentrations at or near the MLC for sea lamprey to minimize the risk to this important faunal group (Boogaard USGS 2006).
- 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.

- 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.

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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