Species Status Assessment

Class: **Bivalvia**
Family: **Unionidae**
Scientific Name: ***Leptodea ochracea***
Common Name: **Tidewater mucket**

Species synopsis:

Leptodea ochracea 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). The taxonomic placement of species *L. ochracea* in the genus Leptodea is in doubt (Bogan 1995) and it has been suggested that this species might better be placed in the genus Ligumia, based on its papilla (Smith 2000).

L. ochracea is a species that is usually found in depositional areas of waterbodies close to the ocean. Since 1970, *L. ochracea* has been found in only three New York waterbodies, but was common only in the freshwater tidal Hudson River (Strayer and Jirka 1997). Since the arrival of the zebra mussel (*Dreissena polymorpha*), its population has declined considerably (Strayer and Smith 1996) and it is expected to stabilize at 8 percent of its pre-invasion densities (Strayer and Malcom 2007). This species has also been reported from a couple of small Hudson River tributaries and from the Grass River in the St. Lawrence basin (Strayer and Jirka 1997). In New York, this species is ranked as "Critically imperiled," and is considered "Vulnerable" throughout its range.

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** _____G3G4 - Vulnerable______________________________________

ii. **New York** _____S1 – Critically Imperiled____ **Tracked by NYNHP?** ___Yes___

Other Rank:

IUCN Red List Category: Near threatened
American Fisheries Society Status: Special Concern (1993)
Species of Regional Northeast Conservation Concern (Therres 1999)

Status Discussion:

This is a widespread, though uncommon species along the coastal areas of the Atlantic Slope with noted declines in almost its entire range and some state level extirpations. Dispersal is limited to coastal plains ponds and rivers with direct connectivity to the Atlantic Ocean (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 _______ No data _______

i. Abundance

__X__ declining ____increasing ____stable ____unknown

ii. Distribution:

__X__ declining ____increasing ____stable ____unknown

Time frame considered: ____
Listing Status: __S2 - Threatened__________________________ SGCN? __________

MASSACHUSETTS Not Present _______ No data _______

i. Abundance

__X___ declining ____increasing ____stable ____unknown

ii. Distribution:

__X___ declining ____increasing ____stable ____unknown

Time frame considered: ____
Listing Status: ____S2 - Special Concern__________________ SGCN? __Yes______

NEW JERSEY **Not Present** _______ **No data** _______

i. **Abundance**

____ **declining** ____**increasing** ____**stable** __x__**unknown**

ii. **Distribution:**

____ **declining** ____**increasing** ____**stable** __x__**unknown**

Time frame considered: __1970-present________________________________

Listing Status: ____S2 - Threatened__________________ SGCN? ___Yes______

In New Jersey, *L. ochracea* is probably more abundant than reported from the Delaware River and tributaries. Several recent lake occurrences have been confirmed. Impacts to water quality, along with proposed in-stream projects, threaten existing populations. Sea level rise, salt water intrusion, and extreme weather events all pose long term threats (Davenport 2012). Bowers-Altman (personal communication 2013) states that "although I have chosen abundance and distribution as unknown, my gut feeling is that for both, some areas are relatively stable, while others are declining."

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: ___S1_____________________________________ SGCN? _________

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: 1990 to present

Monitoring in New York.

None

Trends Discussion:

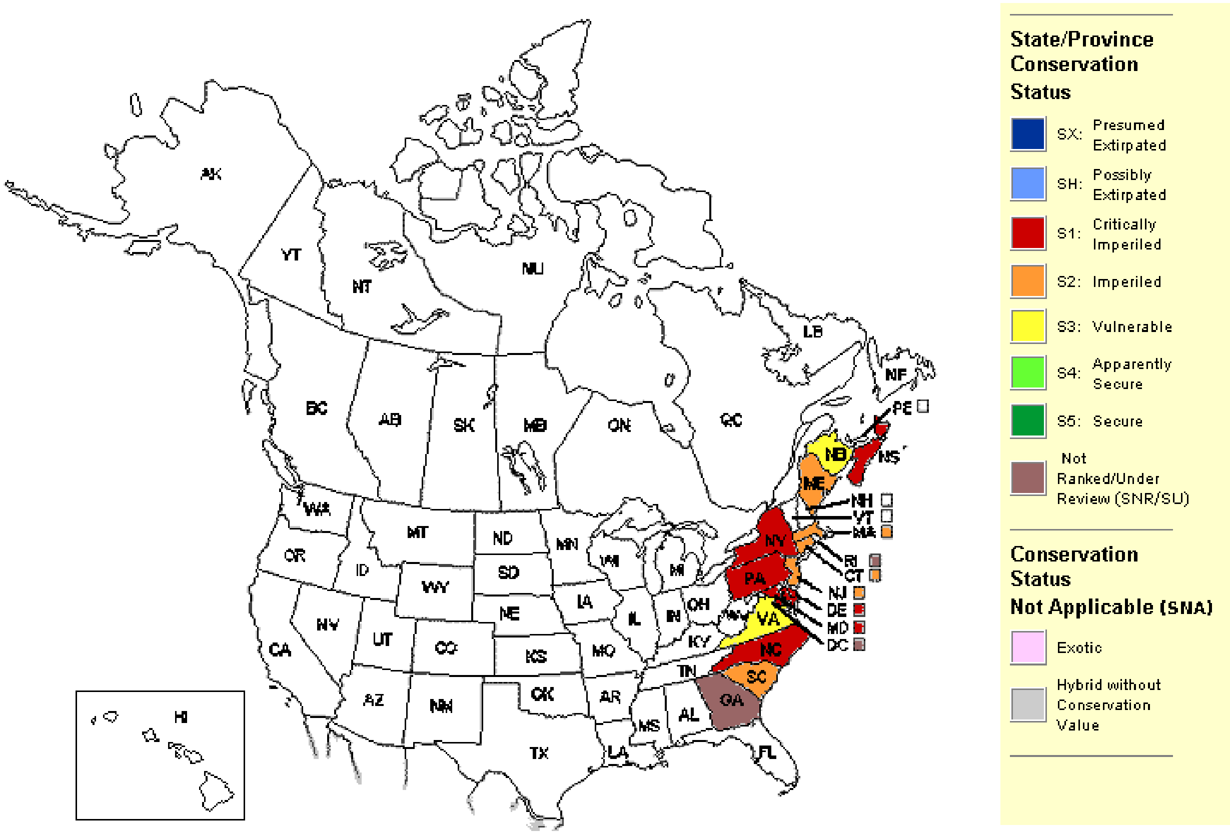

Figure 1. *L. ochracea* distribution in North America (NatureServe 2013).

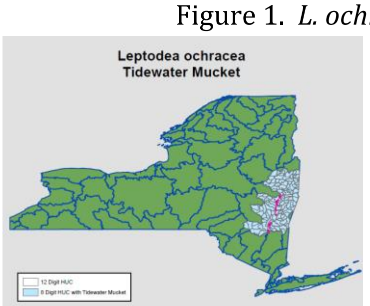

Figure 2: Post 1970 distribution of *L. ochracea* in New York State (Mahar and Landry 2013; Harman and Lord 2010; The Nature Conservancy 2009; New York Natural Heritage Program 2013; White et al. 2011).

III. New York Rarity, if known:

Historic	# of Animals	# of Occurrences	% of State
prior to 1970	unknown	4 waterbodies	3 of 56 HUC 8 watersheds
prior to1980			
prior to 1990			

Details of historic occurrence:

Historically, in New York, *L. ochracea* was common only in the freshwater tidal Hudson River (Strayer and Jirka 1997). NY Natural Heritage (2013) reports this species from the Hudson River in Troy, Normans Kill (pre-1890), and at Bristol Beach, however no live specimens were reported from these sites upon recent revisit. A single, old, spent shell of *L. ochracea* was collected in 1965 in the St. Lawrence basin from the Grass River at Louisberg (Strayer and Jirka 1997).

Current	# of Animals	# of Occurrences	% of State
	~4,000,000	3 waterbodies	3 of 56 HUC 8 watersheds

Details of current occurrence:

Since 1970, *L. ochracea* has been found in 3 waterbodies in New York State (Figure 2).

In New York, *L. ochracea* was common only in the freshwater tidal Hudson River, where its range extended almost continuously from Troy to Kingston (Strayer and Jirka 1997, White et al. 2011). In 1991-1992, it constituted about 5% of the freshwater tidal Hudson River unionoid community of over one billion animals. Since the arrival of the zebra mussel (*Dreissena polymorpha*), the population of *L. ochracea* in the Hudson River declined considerably at a rate of 43 percent per year until 1998 when it was no longer detected in surveys. Populations recovered slightly in 2000–2005 and models suggest that populations will stabilize at 8% of their pre-invasion densities rather than disappearing from the Hudson River (Strayer and Malcom 2007). Also, in 2011, live specimens were found in the South Bay Creek and Marsh area near the City of Hudson.

Erickson and Fetterman (1996) reported a questionable occurrence of this species from the Grass River (Strayer and Jirka 1997). Far from previously known populations of the species, the origins and status of this population are obscure. It may represent a remnant population that survived glaciation in an offshore refugium, or these specimens may have been strays, brought up the St. Lawrence by anadromous fish (Strayer and Jirka 1997).

New York's Contribution to Species North American Range:

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

IV. Primary Habitat or Community Type:

1. Large/Great River; Low Gradient; Assume Moderately Buffered (Size 3+ rivers); Warm
2. Large/Great River; Low-Moderate Gradient; Assume Moderately Buffered (Size 3+ rivers); Warm
3. Small River; Moderate-High Gradient; Moderately Buffered, Neutral; 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:

L. ochracea is a freshwater species that is usually found in waterbodies close to, but not necessarily connected, to the ocean. It occurs in small to large tidal rivers, canals, coastal ponds; including artificial impoundments; and lakes that have connections with coastal waters. It inhibits muddy, sandy, and gravely substrates. *L. ochracea has* been found in water depths of one to more than 25 feet, in a variety of conditions, but seem to prefer depositional areas with slow currents (Nedeau 2008, Strayer and Jirka 1997).

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, *L. ochracea* 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 nutrition 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 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).

L. ochracea is a long-term brooder as eggs are fertilized in late summer and glochidia are released the following spring (Nedeau 2008). The only confirmed fish host for this species is white perch (*Morone americana*) (Nedeau 2008). *L. ochracea* is also known to heavily infest banded killifish (*Fundulus diaphanus*), which is thought to be a potential host (Kneeland and Rhymer 2008). The potential role of alewife (*Alosa pseudoharengus*) and striped bass (*Morone saxatilis*) as host fish needs further investigation. Longevity is probably less than 15 years (Nedeau 2008).

VI. Threats:

Anecdotal observations suggest that this species is sensitive to channel modification, pollution, sedimentation and low oxygen conditions. Threats include dams and other impoundments, channelization and dredging (NatureServe 2013).

Invasive Species

Invasive zebra mussels (*Dreissena polymorpha*) 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).

L. ochracea was known from the Hudson River at the time of the zebra mussel invasion and was abundant enough to appear regularly in samples. This species declined steeply after the zebra mussel invasion, with an annual decline rate of 43 percent per year in 1993– 1999. By 1999, population densities had fallen by 100% from their pre-invasion values, with *L. ochracea* not collected at all in 1998 or 1999. Populations recovered slightly from 2000–2005, deviating strongly from the trajectories predicted by the 1990–1999 data. Recruitment and growth of young unionids recovered to preinvasion levels. Nevertheless, the body condition of unionids in 2000– 2005 was no better than in 1993–1999. Simple exponential decay models based on the entire 1990–2005 data set suggest that *L. ochracea* populations will stabilize at 8% of their pre-invasion densities rather than disappearing from the Hudson River (Strayer and Malcom 2007).

Treated and Untreated Waste Water

Dozens of combined sewer overflow outflows discharge to the Hudson River into known *L. ochracea* habitat between Troy and Saugerties. Municipalities with CSO's include Troy, Albany, Coxsackie, Hudson, and Catskill ("Combined Sewer Overflow" 2012). In addition, *L. ochracea* habitat receives stormwater runoff and treated waste water from adjacent municipalities (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 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.

The banks of the Hudson are bordered by a mix of developed/urban land, roads, forested land, wetlands, and agriculture, including pasture and row crops (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.

Runoff from Developed Land

Developed lands and roads adjacent to the Hudson River are likely sources of storm water runoff containing metals and road salts. Mussels are particularly sensitive to heavy metals, more so than many other animals used in toxicological tests (Keller and Zam 1991). Low levels of metals may interfere with the ability of glochidia to attach to the host (Huebner and Pynnonen 1992), suggesting that U.S. EPA ambient water quality criteria may not adequately protect mussels from toxic metals (Wang et al. 2011). In addition, increases in salinity from the runoff of salt used for clearing roads in winter may be lethal to glochidia and juvenile mussels (Keller and Zam 1991, Liqouri 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).

Agricultural Runoff

Agricultural practices and wood harvest may be sources of siltation and pollution. 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 Malcolm 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).

Habitat Modifications

In the Hudson River, the US Army Corps of Engineers is authorized to perform maintenance navigation dredging under the Rivers and Harbors Act of 1899 and the Federal Clean Water Act. The total length of the existing navigation project (NYC to Waterford) is about 155 miles and includes channel maintenance with shoal removal, maintaining channel widths and depths, and widening at bends and in front of the cities of Troy and Albany to form harbors ("Introduction To The Hudson River" 2012).

Navigational dredging, and other ecosystem modifications such as in-stream 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).

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 (describe mechanism and whether adequate to protect species/habitat)

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

Under Part 608, protection of unlisted species of mussels is general and relatively limited. More importantly, Class C and D waters with mussels do not receive protection under these regulations. A significant portion of the New York's mussel resources occur within Class C and D waters. 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 focus on the freshwater tidal Hudson River.

- 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.

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

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

- Update wastewater treatment facilities in Troy, Albany, Coxsackie, Hudson, and Catskill to eliminate combined sewer outflows.

- 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.

- Work with Army Corps of Engineers to reduce the impacts of Hudson River dredging activities on native mussels.

- 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 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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Date last revised: February 26, 2014