Species Status Assessment

Class: **Bivalvia**
Family: **Unionidae**
Scientific Name: ***Epioblasma torulosa rangiana***
Common Name: **Northern riffleshell**

Species synopsis:

Epioblasma torulosa rangiana has never been recorded in New York State. However, this species was recorded from the Allegheny River and Conewango Creek only a few kilometers south of the New York-Pennsylvania boarder. Strayer & Jirka (1997) speculate that this species most certainly lived in the New York portions of these streams at one time. Range wide, *Epioblasma* species have declined sharply, with *rangiana* only occupying 5% of its former range (NatureServe 2013). If it were to be found in New York it would occupy the riffles in Cassadaga, Conewango and French Creeks or in the Niagara-Erie basin.

E. torulosa rangiana 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).

Status

a. Current and Legal Protected Status

i. **Federal** ____ __Endangered_________________**Candidate?** _________

ii. **New York** ___Endangered____

b. Natural Heritage Program Rank

i. **Global** ___G2T2 - Imperiled_______________________________________

ii. **New York** ____Not ranked for NYS___ **Tracked by NYNHP?** ___Yes__

Other Rank:

U.S. Endangered Species Act (USESA): Listed endangered (1993)
Canadian Species at Risk Act (SARA) Schedule 1/Annexe 1 Status: E (2003)
Committee on the Status of Endangered Wildlife in Canada (COSEWIC): Endangered (2010)
Comments on COSEWIC: Designated Endangered in April 1999. Status re-examined and confirmed 2010.

Status Discussion:

This small freshwater mussel is restricted to two rivers in southern Ontario. Since the original COSEWIC assessment (2000), a small, possibly reproducing population was discovered in the Ausable River although only 16 live individuals, including one juvenile, have been found over the last 10 years. Recruitment is occurring at several sites along the Sydenham River and the population appears to be stable, but the perceived recovery could be due to increased sampling effort over the past 12 years. The main limiting factor is the availability of shallow, silt-free riffle habitat. Both riverine populations are in areas of intense agriculture and urban and industrial development, subject to siltation and pollution. Only four populations in the world, including the two in Canada, show signs of recruitment (NatureServe 2013).

II. Abundance and Distribution Trends

a. North America

i. Abundance

__x__ declining ____increasing _____stable ____unknown

ii. Distribution:

__x__ declining ____increasing _____stable ____unknown

Time frame considered: ____

b. Regional

i. Abundance

__x__ declining ____increasing ____stable _____unknown

ii. Distribution:

__x__ declining ____increasing ____stable ______unknown

Regional Unit Considered:_______Northeast____________________________
Time Frame Considered: ____

c. Adjacent States and Provinces

CONNECTICUT **Not Present** __X__ **No data** ______

MASSACHUSETTS **Not Present** __X__ **No data** ______

NEW JERSEY **Not Present** __X__ **No data** ______

ONTARIO **Not Present** ________ **No data** ______

i. Abundance

____ declining ____increasing __x__stable ____unknown

ii. Distribution:

____ declining ____increasing __x__stable ____unknown

Time frame considered: 2003-2013
Listing Status: Federally and Provincially Endangered

PENNSYLVANIA **Not Present** ________ **No data** ______

i. Abundance

____ declining ____increasing ____stable __X__ unknown

ii. Distribution:

__X__ declining ____increasing ____stable ____unknown

Time frame considered: Since 1980 (PA Natural Heritage Program fact sheet)
Listing Status: Endangered SGCN? Yes

QUEBEC **Not Present** __X__ **No data** ______

VERMONT **Not Present** __X__ **No data** ______

d. NEW YORK **__X__ Not Present** **No data _______**

i. Abundance

____ declining ____increasing ____stable _____unknown

ii. Distribution:

____ declining ____increasing ____stable ______unknown

Time frame considered: ____

Monitoring in New York.

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

Trends Discussion:

In both the short and long term this species has declined between 70% and 90%, with only four reproductively viable populations still existing (NatureServe 2013).

III. New York Rarity, if known:

Historic	**# of Animals**	**# of Locations**	**% of State**
prior to 1970	**N/A**	________	________
prior to 1980	________	________	________
prior to 1990	________	________	________

Details of historic occurrence: *E. torulosa rangiana* was widespread in the Allegheny basin of Pennsylvania, nearly to New York. In the early 1900's this species was collected from the Allegheny River "near the New York boundary (presumably near Warren) and from Conewango Creek a few kilometers south of the New York border. Although *E. torulosa rangiana* has never been reported from New York, due to the close proximity of the Pennsylvania populations, it is likely that this species may have lived in New York portions of these streams at some point (Strayer and Jirka 1997).

Current	**# of Animals**	**# of Locations**	**% of State**
	N/A	________	________

Details of current occurrence:

It is doubtful whether this species still survives in New York. Although the most likely places to hold this species are Cassadaga and Conewango Creeks (Strayer and Jirka 1997), this species was not found during recent surveys by The Nature Conservancy (2009). Since the time of the historic records, the mussel fauna of lower Conewango Creek in New York was destroyed and much of the lower Allegheny River in New York has been impounded by the Kinzua Dam (Strayer and Jirka 1997). This species is also known from western Lake Erie and some of its tributaries, so there is a remote chance that this species may be found in the Niagara-Erie basin in New York (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)	____ Core
____ 76-99	__X__ Peripheral
____ 51-75	____ Disjunct
____ 26-50	**Distance to core population:**
__0%__ 1-25	___450 miles________

IV. Primary Habitat or Community Type:

1. N/A

Habitat or Community Type Trend in New York:

____ Declining ____Stable ____ Increasing __ X__Unknown

Time frame of decline/increase: ______________________________

Habitat Specialist? _____ Yes ______ No

Indicator Species? __X__ Yes ___ __ No

Habitat Discussion:

E. torulosa ragniana is found in large creeks to large rivers in swift current and shallow riffles (Metcalfe-Smith 2005, Cummings and Mayer 1992, Watters et al. 2009, Strayer and Jirka 1997). Suitable substrates include coarse sand and gravel with some cobble to firmly packed fine gravel (Metcalfe-Smith 2005). Although it is known form Lake Erie, it is not a pond or lake species. The Lake Erie specimens apparently occurred in areas with sufficient wave-action to approximate stream conditions (Watters et al. 2009).

V. New York Species Demographics and Life History

__N/A__ Breeder in New York

__N/A___ Summer Resident

__N/A__ 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, *E. torulosa ragniana* species must parasitize an often specific vertebrate host to complete its life cycle. It is suspected that some mussel populations are not recruiting because their hosts no longer occur with them. Once released by the female, glochidia must acquire a suitable host or die, usually within 24-48 hours. After attaching to a suitable host, glochidia encyst, usually at the fish's gills or fins and receive food and dispersal. Once the glochidia metamorphose into juveniles, they drop from the host. If they land in suitable habitat, they will burrow into the substrate, where they may remain for several years (Watters et al. 2009).

In the adult form, freshwater mussels are basically sessile; movement is limited to a few meters of the lake or river bottom. The only time that significant dispersal can take place is during the parasitic phase. Infected host fishes can transport the larval unionids into new habitats, and can replenish depleted populations with new individuals. Dispersal is particularly important for genetic exchange between populations. Dispersal is likely to be a slow process for mussels which use resident fishes with limited home ranges as their hosts (COSEWIC as cited in NatureServe 2013).

This species is thought to be bradytictic, with females gravid from September to the following June. Individuals may live to 15 years old. Glochidia transformation has been confirmed on mottled sculpin (*Cottus bairdi*), bluebreast darter (*Etheostoma camurum*), rainbow darter (*Etheostoma caeruleum*), banded darter (*Etheostoma zonale*), and brown trout (*Salmo trutta*) (Watters et al. 2009).

VI. Threats:

No threats to this species identified in New York, but general threats to mussels that are likely relevant range wide include:

Impoundments – Range wide
Range wide, 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.

Agricultural Runoff
Aquatic habitats lacking vegetated buffers of adequate width are threatened by runoff from urban areas, roads, lawns, and agricultural land (Gillis 2012). If best management practices are not closely adhered to, mussel habitat adjacent to wood harvest or agricultural land is subjected to pesticide,

fertilizer, and silt/sediment runoff. During recent mussel surveys in Western and Central New York, it has been documented that sufficient vegetated riparian buffers are often lacking along known mussel streams (Mahar & Landry 2013), indicating that runoff is a major threat to resident mussel populations.

Species that have a mantle modified to attract host fish are thought to rely on the visual acuity of their fish hosts to facilitate transfer of glochidia from the female to the host. For such species, this indicates that increases in turbidity associated with runoff may in interfere with reproduction and be especially detrimental to the species (Nedeau 2008).

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 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

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 also originate from 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).

Runoff from Developed Land

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).

Invasive Species

Invasive zebra and quagga mussels (*Dreissena polymorpha* and *Dreissena bugenis*) have been repeatedly cited as a threat to native mussel populations (Strayer & Jirka 1997; Watters et al. 2009). En masse, Dreissenids outcompete native mussels by removing food and oxygen from the water. They can also reduce reproductive success by filtering native mussel male gametes from the water column. 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). In addition, ammonia from Asian clam die offs has been shown to be capable of exceeding acute effect levels of some mussel species (Cherry et al. 2005). Didymo (*Didymosphenia geminata*), a filamentous diatom, can form extensive mats that can smother stream bottom and occlude habitat for mussels (Spaulding & Elwell 2007)

Sea lamprey control treatments

Climate Change

The NatureServe Climate Change Vulnerability Index has been used in several states to help identify species that are particularly vulnerable to the effects of climate change. In West Virginia's assessment, *E. torulosa rangiana* is ranked as "moderately vulnerable" to climate change, while the populations within Pennsylvania are ranked as "highly vulnerable" to climate change (2013) and in Michigan, the species was ranked as "extremely vulnerable" to climate change (Hoving, et al. 2013).

Global climate change is expected (among other disruptions) to cause an increase in surface water temperatures. Although many species are tolerant of warm water, higher water temperatures may be an added stress for some. Increased water temperatures may also increase algal growth, which could result in reductions in dissolved oxygen levels at night (Morris & Burridge 2006). Galbraith 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 to thermally tolerant species.

In addition, warmer stream temperatures due to the combined effects of land use, such as removal of shaded buffers, and climate change may contribute to the loss of coldwater fisheries and *mussel* populations in some watersheds (Nedeau 2008). Temperature induced changes in fish communities could have a profound influence on the availability of hosts for freshwater mussels. Mussels that inhabit small streams and rivers and rely on fish adapted for cooler water might be most affected by climate change (Nedeau 2008).

Habitat Modifications

Ecosystem modifications, such as in-stream work associated with canal, navigational channel, or flood control dredging, bridge replacements, gravel mining, and vegetation removal kill mussels and destroy their habitat. For example, dredging for vegetation removal has been shown to remove up to 23% of mussels in spoils (Aldridge 2000). Further evidence for disruption was provided by mussel surveys adjacent to approximately 20 river miles of Conewango Creek that had been channelized and straightened in the first half of the 20th century. The resulting “dredge” had no riffle or run habitat and sites just below and above this channelized section contained few or no mussels (The Nature Conservancy 2009). Although limited in geographic scope these habitat modification activities have long term impacts on mussels and their distribution (Aldridge 2000). Seasonal draw downs of water bodies have been shown to impact unionid age distributions (Richardson et al. 2002).

Levees and flood walls 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).

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

_______ No   _____ Unknown

___X___ Yes

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

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 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:

- Assess if this species does or has ever existed in New York.
- Assess the need and opportunity for relocation/reintroduction efforts. Conduct relocation or reintroduction where adequate sources can be identified and appropriate stream conditions exist (water quality, habitat, host species etc).
- Following any reintroduction efforts, 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.
- 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.

- 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.

- 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.

- 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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Date last revised: November 20, 2013