

Species Status Assessment

Class: Bivalvia
Family: Unionidae
Scientific Name: *Anodonta implicata*
Common Name: Alewife floater

Species synopsis:

Anodonta implicata belongs to the subfamily Unioninae, diagnosed by the presence of subtriangular glochidia with large, medial hooks, and the tribe Anodontini, which includes 16 extant and 1 likely extirpated New York species of the genera *Alasmidonta*, *Anodonta*, *Anodontoides*, *Lasmigona*, *Pyganodon*, *Simpsonaias*, *Strophitus*, and *Utterbackia* (Haag 2012, Graf and Cummings 2011). *A. implicata* can be distinguished by its subelliptical shell, toothless hinge, pink to purple nacre, and its double looped beak sculpture (Strayer and Jirka 1997).

In New York, this species is restricted mainly to the Hudson River estuary as well as the Lower Delaware River and is currently found in five water bodies. Since the invasion of zebra mussels in its range, the population number has declined dramatically (Strayer and Jirka 1997), but is expected to stabilize at 4% of its pre-invasion densities. Due to this decline, it is ranked as “critically imperiled” in New York, although its population is “secure” range-wide (NatureServe 2013). Unlike other *Anodonta* species, *implicata* prefers strong currents in the tidal Hudson River and can be found among cobbles in the Neversink River (Strayer and Ralley 1993, Strayer et al. 1994).

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 S1S2 – Critically imperiled/Imperiled Tracked by NYNHP? Yes

Other Rank:

American Fisheries Society Status: Currently Stable (1993)

Status Discussion:

Due to this decline following the arrival of zebra mussels in the Hudson River, it is ranked as “critically imperiled” in New York. This wide ranging Atlantic slope species is considered relatively common and secure throughout most of its range, but is limited to only the coastal areas of the North Atlantic Slope from North Carolina to Maine, with disjunct populations in North Carolina (NatureServe 2013).

II. Abundance and Distribution Trends

a. North America

i. Abundance

 declining increasing X stable unknown

ii. Distribution:

 declining increasing X stable unknown

Time frame considered: _____

b. Regional

i. Abundance

___ declining ___ increasing x stable ___ unknown

ii. Distribution:

___ declining ___ increasing x stable ___ unknown

Regional Unit Considered: 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: 2008 published data

Listing Status: SU SGCN? No

MASSACHUSETTS Not Present _____ No data _____

i. Abundance

___ declining ___ increasing ___ stable x unknown

ii. Distribution:

___ declining ___ increasing ___ stable x unknown

Time frame considered: _____

Listing Status: S4 SGCN? No

NEW JERSEY Not Present _____ No data _____

i. Abundance

____ declining ____ increasing x stable ____ unknown

ii. Distribution:

____ declining ____ increasing x stable ____ unknown

Time frame considered: 1970-present

Listing Status: S4-stable SGCN? No

A. implicata is NJ's 3rd most common freshwater mussel species. Ranked Secure/Stable during the 2012 status assessment (Davenport 2012).

ONTARIO Not Present X No data _____

PENNSYLVANIA Not Present _____ No data _____

i. Abundance

____ declining ____ increasing ____ stable X unknown

ii. Distribution:

____ declining ____ increasing ____ stable X unknown

Time frame considered: _____

Listing Status: S3S4 SGCN? No

QUEBEC Not Present _____ No data _____

i. Abundance

 X declining ____ increasing ____ stable ____ unknown

ii. Distribution:

 X declining ____ increasing ____ stable ____ unknown

Time frame considered: _____

Listing Status: S1

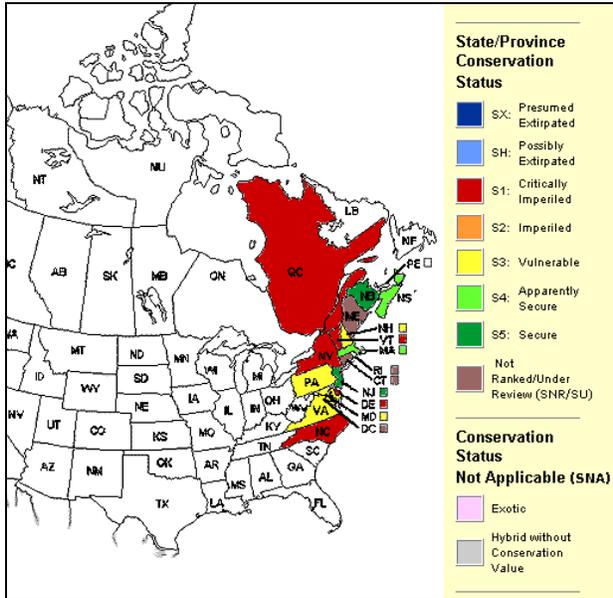


Figure 1. *A. implicata* distribution in North America (NatureServe 2013).

I. New York Rarity, if known:

	<u># of Animals</u>	<u># of Locations</u>	<u>% of State</u>
Historic prior to 1970	<u>unknown</u>	<u>4 waterbodies</u>	<u>5 of 56 HUC 8 watersheds</u>
prior to 1980	_____	_____	_____
prior to 1990	_____	_____	_____

Details of historic occurrence:

A. implicata was historically found in an almost continuous stretch of the freshwater tidal Hudson River from Troy downstream to Margarette Lewis Norris State Park (White et al. 2011), from the lower Mohawk River/Erie Canal at Schenectady, and in the Delaware River basin, including the Neversink and the Delaware Rivers (Strayer and Jirka 1997, NY Natural Heritage Program 2013).

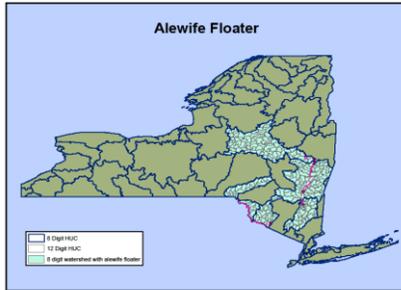


Figure 2. *A. implicata* post 1970 distribution in New York (Mahar and Landry 2013, The Nature Conservancy 2009, NY Natural Heritage Program 2013, White et al. 2011, Harman and Lord 2010).

Current	<u># of Animals</u>	<u># of Locations</u>	<u>% of State</u>
	<u>16,020,290 live</u>	<u>5 waterbodies</u>	<u>5 of 56 HUC 8 watersheds</u>

Details of current occurrence:

Since 1970, *A. implicata* has been found in five New York State waterbodies (Figure 2), including the Hudson, Mohawk, Neversink, and Delaware Rivers, and Catskill Creek, a Hudson River tributary (NY Natural Heritage Program 2013, White et al. 2011). Current occurrences are the same as historic occurrences (NY Natural Heritage Program 2013). In 2010, live specimens were found in the South Bay Creek and marsh area near the City of Hudson (NY Natural Heritage Program 2013). As of 1991-1992, the only location in New York where *A. implicata* had maintained a large population was in the Hudson River estuary (approximately 400 million individuals). Following the arrival of zebra mussels, this population has declined sharply with an annual decline rate of 57% per year from 1993 to 1999. Populations have since recovered slightly and are expected to stabilize at 4% of their pre-invasion densities (Strayer and Malcom 2007).

In the Delaware basin, in 1997, five individuals were found in the Neversink River in the vicinity of The Nature Conservancy Preserve and Cuddlebackville Dam. In 1991, the Neversink population was estimated at 20,000 individuals (NY Natural Heritage Program 2013). Between 2001 and 2002, at least 290 individuals were found in the Delaware River, with occurrences in every river mile within the continuous 76.9-mile stretch of river,

extending from just south of Hancock to Port Jervis, except at 4 locations where the distance of the gap ranged from 1 to 1.8 miles (NY Natural Heritage Program 2013).

New York's Contribution to Species North American Range:

% of NA Range in New York	Classification of New York Range
<input type="checkbox"/> 100 (endemic)	<input checked="" type="checkbox"/> Core
<input type="checkbox"/> 76-99	<input type="checkbox"/> Peripheral
<input type="checkbox"/> 51-75	<input type="checkbox"/> Disjunct
<input type="checkbox"/> 26-50	Distance to core population:
<input checked="" type="checkbox"/> 1-25	<input type="checkbox"/> -

IV. Primary Habitat or Community Type:

1. Medium River; Moderate-High Gradient; Assume Moderately Buffered (Size 3+ rivers); Warm (Delaware River, Mohawk River)
2. Large/Great River; Low Gradient; Assume Moderately Buffered (Size 3+ rivers); Warm (Hudson River)
3. Medium River; Low Gradient; Assume Moderately Buffered (Size 3+ rivers); Warm (Delaware River)

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:

Across its range, high densities of *A. implicata* are found in coastal ponds with a direct unimpeded connection to rivers that support yearly runs of alewife. In lakes, they are found in shallow areas with high wave intensity and in deep areas (>30 ft) below the thermocline. It may be more tolerant of mud and silt than many other species, and is abundant in tidal-depositional environments were

aquatic plant growth is high. This species also exists in small streams and large rivers, without clear preference for substrate, depth, or flow conditions. Habitat use and population density seems to be more strongly tied to where its host fish are likely to spawn or congregate. It occurs in gravel and cobble substrate in small rivers with fairly strong flows (Nedeau 2008). Although *Anodonta* species are usually said to prefer quiet waters, in New York, *A. implicata* lives in the strong currents of the tidal Hudson River and among cobbles in the Neversink River (Strayer and Jirka 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, *A. implicata* 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).

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).

A. implicata is bradytictic with fertilization occurring in late summer or early fall and glochidia released the following spring. Timing of release is thought to coincide with the spawning migration of its three fish hosts: alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and American shad (*Alosa sapidissima*) (Nedeau 2008). Striped bass (*Morone saxatilis*) white sucker (*Catostomus commersoni*), threespine stickleback (*Gasterosteus aculeatus*), pumpkinseed (*Lepomis gibbosus*), and white perch (*Morone americana*) are additional potential host species (Nedeau 2008, Davenport and Warmuth 1965, Wiles 1975). Fecundity is not known, but is probably low because *A. implicata* glochidia are large and there is usually a tradeoff between offspring size and fecundity (Bauer 1994).

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 (COSEWIC 2003). Since *A. implicata*'s hosts fish are migratory, mussels may be dispersed more than 100 miles during the three to four week period over which the glochidia remain attached to their hosts (Nedeau 2008).

VI. Threats:

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). When vegetated buffers of adequate width are not present, downstream mussel populations 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

Lands adjacent to *A. implicata* habitat along the Upper Hudson and Mohawk River are highly urbanized, and include the municipalities of Cohoes and Waterford on the Mohawk River and Troy, Watervliet, Rensselaer, Albany and their suburbs on the Upper Hudson. *A. implicata* sites between Albany and Margaret Lewis Norrie State Park, are likely impacted by the stormwater runoff from Catskill, East Greenbush, Germantown, Saugerties, and Kingston (New York State Landcover 2010).

Although the Delaware watershed is mostly forested in the area where *A. implicata* has been found, roads and a railroad run adjacent to the Delaware River. Hancock, Callicoon, Narrowsburg, and Port Jarvis are likely sources of stormwater runoff. On the Neversink at Myers Grove residential development is located adjacent to *A. implicata* habitat (New York State Landcover 2010).

These developed areas 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

Cultivated cropland is present adjacent to several *A. implicata* occurrences. These include the south bank of the Mohawk River at Crescent Station, immediately adjacent to *A. implicata* occurrences on Neversink River, and at the Delaware River between Callicoon and Cochectcon. *A. implicata* habitat in the lower Hudson River is likely impacted to some degree by agriculture, although most agriculture in this region is in pasture or hay (New York State Landcover 2010).

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 aquatic systems (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 mussel 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 run-off is also a concern. High inputs of nitrogen from fertilizers can cause increases in ammonia in the water and the substrate, leading to direct toxicity for a wide range of mussel

species. Mussels, especially in their early life stages, are more sensitive to un-ionized ammonia than other organisms, and high sensitivity is seen across a range of species and life histories (Haag 2012). In addition, ammonia adsorbs to sediment particles, resulting in higher nitrogen concentrations in the substrate than in the overlying water. The nitrogen present in the interstitial spaces in the substrate is thought to result in juvenile mortality and to prevent recruitment by some mussel species (Strayer and Malcom 2012). Studies have suggested decreasing sediment loads entering aquatic systems as the best way to decrease the impact of numerous stressors for mussels in general (Roley et al. 2012).

Treated and Untreated Waste Water

Multiple combined sewer overflows (CSOs) discharge into known *A. implicata* habitat (“Combined Sewer Overflow” 2012, NY Natural Heritage Program 2013), including six CSOs that discharge into the Mohawk River and 49 that discharge into the Hudson River. In addition, dozens of CSO outflows discharge to the Hudson River into known *A. implicata* habitat between Troy and Saugerties, from municipalities such as the City of Hudson near the South Bay Creek, Catskill upstream of the Bristol Beach State Park, and Kingston upstream of the Margaret Lewis Norrie State Park site. In addition, *A. implicata* habitat receives treated waste water from adjacent municipalities including Waterford on the Mohawk River; Rensselaer, East Greenbush, Germantown, and Kingston on the Hudson River; and Hancock, Callicoon, Narrowsburg, and Port Jarvis on the Delaware River (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 disruptors 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.

Invasive Species

Since the arrival of the zebra mussel, the population of *A. implicata* in the freshwater tidal Hudson River declined considerably (Strayer and Smith 1996). 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).

A. implicata 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 57 percent per year in 1993–1999. By 1999, population densities had fallen to 100% from their pre-invasion values, with *A. implicata* not collected at all in 1998 or 1999. Populations recovered slightly in 2000–2005. Recruitment and growth of young unionids recovered to pre-invasion 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 *A. impleiata* populations will stabilize at 4% of their pre-invasion densities, rather than disappearing from the Hudson River (Strayer and Malcom 2007).

Didymo (*Didymosphenia geminata*), a filamentous diatom, can form extensive mats that can smother stream bottom and occlude habitat for mussels (Spaulding and Elwell 2007). This invasive has been found in the East Branch of the Delaware River. If it becomes as abundant in the Delaware basin as it has elsewhere, it could have enormous negative consequences for mussels, including *A. implicata* (Nedeau 2008).

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, maintenance of channel widths and depths, widening at bends, and widening in front of the cities of Troy and Albany to form harbors (“Introduction To The Hudson River” 2012).

Maintenance, navigational dredging, and other ecosystem modifications such as 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).

Climate Change

In a recent assessment of the vulnerability of at-risk species to climate change in New York, Schesinger et al. (2011) ranked this species as “moderately vulnerable.” This indicates that abundance and/or range extent within New York is likely to decrease by 2050.

Impoundments – Range wide

Range wide, impoundments likely contributed to the reduced distribution 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:

- Priority conservation efforts for this species should focus on, but not be limited to, the freshwater tidal Hudson River, the Neversink River, and the Delaware River.

- Modify marine mussel regulations or the definition of protected wildlife in NYCRR to clarify that freshwater mussels are protected under Environmental Conservation Law (ECL). Current regulations could be interpreted that freshwater mussels may only be protected as shellfish without a season within the Marine District.
- The shad-restoration program on the Connecticut River increased the range of *A. implicata* in the Connecticut River (Smith 1985). Such native fish restoration programs may be beneficial in historic New York waters.
- 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 et al. 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).
- Update wastewater treatment facilities in Troy, Albany, Coxsackie, Hudson, and Catskill to eliminate combined sewer outflows.
- Work with Army Corps of Engineers to reduce the impacts of Hudson River dredging activities on native mussels.
- Establish a protocol whereas DEC staff work closely with state and local highway departments to reduce impacts to native mussels during maintenance and construction projects.
- Replace culverts that disrupt aquatic habitat connectivity to allow for passage of small fish species.
- NYSDEC should consider sensitivity of freshwater mussels to specific pollutants in the establishment and setting of water quality standards and TMDLs for waters containing freshwater mussels. A Total Maximum Daily Load (TMDL) specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. TMDLs account for all contributing sources (e.g. point 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.

- Modify marine mussel regulations or the definition of protected wildlife in NYCRR to clarify that freshwater mussels are protected under Environmental Conservation Law (ECL). Current regulations could be interpreted that freshwater mussels may only be protected as shellfish without a season within the Marine District.
- 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.

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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