Appendix A: Freshwater Mussels

Dwarf Wedgemussel

Alasmidonta heterodon

Photo by Ethan Nedeau

Federal Listing	E
State Listing	E
Global Rank	G4
State Rank	S1
Regional Status	Very High

Justification (Reason for Concern in NH)

Freshwater mussels have declined dramatically in diversity, abundance, and distribution within the last 200 years and are considered the most imperiled fauna in North America (Richter et al. 1997, Lydeard et al. 2004). In the genus *Alasmidonta* 9 of 13 species are threatened, endangered, or extinct (Williams et al. 1992). Historically, the dwarf wedgemussels was found from the Petitcodiac River in New Brunswick, Canada to the Neuse River in North Carolina, and was found in 15 major Atlantic slope river systems (United States Fish and Wildlife Service 1993). It is now extinct in Canada, extirpated in the Neuse River, and present in low densities throughout much of its former range (USFWS 2002). Only 54 populations remain globally; 41 of these are estimated to contain fewer than 50 individuals and of these, 32 have fewer than 10 individuals or are possibly extirpated; 8 or 9 are estimated at between 50 and 1,000 individuals; 4 are estimated at between 10,000 and 100,000 individuals (NH WAP Profile 2005). Recent surveys in the Ashuelot and Connecticut Rivers indicate an apparent decline in dwarf wedgemussels and therefore further reason for concern in New Hampshire (Nedeau 2013). Human impacts including riparian disturbance, pollution, sedimentation, impoundments, artificial flow regimes, and stream fragmentation disrupt mussel life cycles, prevent host fish migration, block gene flow, and prohibit re-colonization, resulting in reduced recruitment rates, decreased population densities and increased probability of local extinctions (Neves et al. 1997, Watters 1999, Strayer et al. 2004).

Distribution

Historically, the dwarf wedgemussel was found from the Petitcodiac River in New Brunswick, Canada to the Neuse River in North Carolina, and was found in 15 major Atlantic slope river systems (United States Fish and Wildlife Service 1993). It is now extinct in Canada, extirpated in the Neuse River, and present in low densities throughout much of its former range (USFWS 2002).

The Connecticut River drainage in New Hampshire has held the largest remaining dwarf wedgemussel populations and represents the northern limit of the distribution (USFWS 2002). Nevertheless, these populations are extremely patchy, clustered in scattered mussel beds.

Habitat

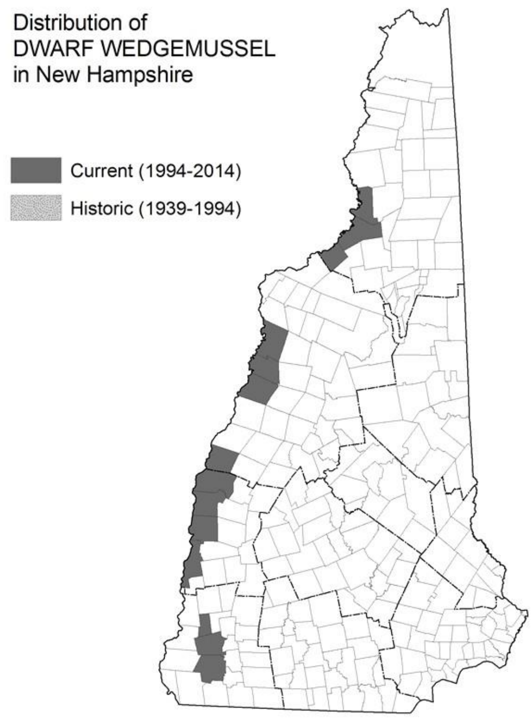
Dwarf wedgemussels, *Alasmidonta heterodon*, are Atlantic slope species inhabiting small streams to large rivers with moderate flow. They are found in hydrologically stable areas within a variety of substrates including gravel and coarse sands, fine sands, and clays in depths from a few centimeters to several meters. Mussels are suspension and deposit feeders, subsisting on phytoplankton, bacteria, fine particulate organic matter, and dissolved organic matter (Strayer et al. 2004).

The dwarf wedgemussel's life cycle is complex. Gametogenesis occurs from May through July (Michaelson and Neves 1995). Spawning occurs in summer when sperm are released into the water column and drawn into the inhalant aperture of the female. Eggs are fertilized, undergo development, and mature in the outermost demibranchs of each gill, which function as marsupia. Well-developed glochidia are present in the Connecticut River mussels as early as late August. Dwarf wedgemussels are long-term brooders, holding glochidia through the winter until release begins in early March and continues through mid-June (Wicklow unpublished data). Glochidia must attach to a host fish in order to complete development and to facilitate dispersal. Host fish include the tessellated darter (*Etheostoma olmstedii*), johnny darter (*Etheostoma nigrum*), mottled sculpin (*Cottus cognatus*), (Michaelson and Neves 1995), slimy sculpin (*Cottus cognatus*), and juveniles and parr of the Atlantic salmon (*Salmo salar*) (B. Wicklow, Saint Anselm College, unpublished data). Atlantic salmon restoration efforts ended during 2012 and therefore are not available as a fish host in NH (Matthew Carpenter, NHFG, personal communication). Due to fish range limitations, the tessellated darter and slimy sculpin are the only host fish available for dwarf wedgemussel glochidia in New Hampshire. The dwarf wedgemussel is the only species of *Alasmidonta* that uses a behavioral display to attract host fish (B. Wicklow, Saint Anselm College, unpublished data).

Dwarf wedgemussels require unpolluted streams or rivers with high dissolved oxygen, moderate current, and stable substrata within refugia (Strayer 1993b, Strayer and Ralley 1993). Stream fragmentation from dams, causeways, impoundments, channelization, and inhospitable stream segments results in spatially and genetically disjunct populations. Perhaps 50% or more of populations have densities that put them in jeopardy of extinction from catastrophes or stochastic demographic, genetic, or environmental events. Though populations range from 100 to 10,000 individuals, densities are low enough (mean = 0.01 to 0.05 per square meter, Strayer et al. 1996) to cause concern. Because mussels are broadcast spawners, populations with low densities may suffer reduced fertilization success (Downing et al. 1993, McLain and Ross 2005), which may strongly limit recruitment. Dwarf wedgemussels occupy small, linear ranges, putting populations at higher risk from impacts of pollution, habitat degradation, and disease (Strayer et al. 1996).

NH Wildlife Action Plan Habitats

- Large Warmwater Rivers
- Warmwater Rivers and Streams



Distribution Map

Current Species and Habitat Condition in New Hampshire

During the 2005 NH Wildlife Action Plan assessment for dwarf wedgemussels, it was determined that the north and south populations on the Connecticut River main stem and the Ashuelot population appear viable and that the north Connecticut River population appears to be most robust. Dwarf wedgemussels (Alasmidonta heterodon) were rediscovered in the middle portion of the upper Connecticut River in 2005 and a follow-up survey was initiated to determine the range and habitat of this population (Nedeau 2006a). Dwarf wedgemussels were encountered at 12 of 20 locations (14 of 29 for 2005 and 2006 combined) and occupied an 18-mile reach of the river, indicating the presence of a potentially regionally significant population (Nedeau 2006a). During 2006, dwarf wedgemussels were discovered in the Johns River in Dalton NH (Nedeau 2006b, Nedeau 2006c).

Recent surveys in the Ashuelot and Connecticut Rivers indicate an apparent decline in dwarf wedgemussels (Nedeau 2013). In recent surveys conducted as part of the relicensing of three TransCanada hydropower projects, dwarf wedgemussels were undetected at a number of formerly-occupied sites or were found in much lower numbers than in previous surveys (Melissa Grader, personal communicaton; Biodrawversity and Louis Berger 2012).

Population Management Status

A USFWS recovery plan for dwarf wedgemussels exists (USFWS 1993) and a 5-year review was published in 2007 (USFWS 2007). An assessment of the distribution, threats, and conservation actions needed for the dwarf wedgemussel (*Alasmidonta heterodon*) in the middle and northern macrosites of the Upper Connecticut River was completed during 2008 (Nedeau 2008b).

Dwarf wedgemussel assessments have been done for a variety of proposed construction projects (e.g., shoreline hardening, dam removal or repair, bridge replacement) in or along the Connecticut River (Nedeau 2003b, Nedeau 2004c, Nedeau 2008) and Ashuelot River (Oakhill Environmental Services. 2009, Nedeau 2012, Nedeau 2014). In some cases, these assessments have resulted in the relocation of dwarf wedgmeussels away from construction impacts (United States Fish and Wildlife Service 2003, Nedeau 2003b, Nedeau 2004a, Nedeau 2012).

Regulatory Protection (for explanations, see Appendix I)

- Federal Endangered Species Act
- Endangered Species Conservation Act (RSA 212-A)
- Fill and Dredge in Wetlands - NHDES
- Rivers Management and Protection Program - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Clean Water Act-Section 404
- Federal Energy Regulatory Commission (FERC)

Quality of Habitat

The north, middle, and south populations in the Connecticut River main stem have been estimated at between 10,000 and 100,000 individuals (Nedeau 2006). These populations have been surveyed qualitatively and are in need of quantitative, statistically valid monitoring. Nevertheless, the Lancaster, New Hampshire, and Lunenburg, Vermont sites have patches of high mussel density, with all age classes present, and a high density of tessellated darter host fish (Gloria and Wicklow 2000, Nedeau 2004). This section of river is free flowing from the Murphy Dam at Lake Francis in Pittsburg to the Moore Dam Reservoir in Littleton and hosts the most vigorous, viable population known. The Ashuelot River Population, also considered among the largest populations, extends from the Surry Mountain Dam to Swanzey and is estimated at 10,000 individuals. Two sites downstream of Surry Mountain Dam were monitored quantitatively. The site closest to the dam showed an age distribution skewed toward older individuals, with little evidence of recruitment, whereas the downstream site showed a wider age distribution, with evidence of recruitment (Nedeau 2004). Recent surveys at long- term monitoring sites below the Surry Dam indicated an apparent decline in dwarf wedgemussels between 2006 and 2013 and bank erosion was detected in these areas (Nedeau 2013).

Many NH tributaries were small, shallow, and rocky, thereby providing little or no habitat for freshwater mussels (Nedeau 2006). Some of the larger rivers (e.g., Mascoma River and Sugar River) were highly altered and degraded, and even if dwarf wedgemussels once inhabited these rivers, current conditions and/or long distances to source populations may prohibit them from becoming reestablished (Nedeau 2006).

Habitat Protection Status

Conservation lands are scattered along the Connecticut and Ashuelot Rivers. The Army Corps of Engineers operates the Surry Mountain Flood control dam and holds land downstream to the East Surry Road Bridge.

Habitat Management Status

Currently there are no management or restoration efforts targeting dwarf wedgemussel habitat in the state. However, the Nature Conservancy, the Monadnock Conservancy, the Society for the Protection of New Hampshire Forests, and the Southwestern Regional Planning Commission have developed a conservation plan for the Ashuelot River Watershed (Zankel 2004). The Connecticut River Joint Commission published a Connecticut River Management Plan for the main stem during 2008. An assessment of the distribution, threats, and conservation actions needed for the Dwarf Wedgemussel (*Alasmidonta heterodon*) in the middle and northern macrosites of the Upper Connecticut River was completed during 2008 (Nedeau 2008b).

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat degradation and mortality from dams that alter hydrology upstream and downstream (Threat Rank: High)

The conversion of free-flowing rivers to highly regulated rivers has seriously affected freshwater mussels. Dams, causeways, reservoirs, gravel mining, dredging, channelization, poor land use, and municipal and industrial pollution have resulted in scattered populations. Barriers cause direct mortality, prevent dispersal, block gene flow, prohibit re-colonization of unoccupied but rehabilitated habitat, and prevent host fish migration (Layzer et al. 1993, Parmalee and Hughes 1993, Vaughn and Taylor 1999, Watters 1996).

On the Connecticut River main stem the Moore, Comerford, and Wilder Dams have divided dwarf wedgemussels into 3 populations. Dams on the Ashuelot River are also barriers to dispersal; in a survey in the Ashuelot River dwarf wedgemussels were absent below the Swanzey Dam (Nedeau and Werle 2003), and historic water and habitat degradation was apparent (Nedeau and Werle 2003). Notably, the 1968 construction of a causeway across the Petitcodiac River in New Brunswick Canada transformed a macro-tidal estuary into a shallow freshwater impoundment thereby eliminating diadromous fish including the Atlantic salmon (Locke et al. 2003), a host fish of the dwarf wedgemussel (Wicklow, unpublished data). By the 1980s, the dwarf wedgemussel had disappeared from the Petitcodiac River and in 1999 the Committee on the Status of Endangered Wildlife in Canada declared the dwarf wedgemussel officially extinct (Hanson and Locke 2000). On the Ashuelot River, recent surveys at long-term monitoring sites below the Surry Dam indicated an apparent decline in dwarf wedgemussels between 2006 and 2013 and bank erosion was detected in these areas (Nedeau 2013).

Habitat impacts (fragmentation) from dams that cause inhospitable stream conditions (Threat Rank: High)

See 'Habitat degradation and mortality from dams that alter hydrology upstream and downstream' and 'Habitat degradation and mortality from increased flooding that destroys mussel beds' threat summaries.

Habitat degradation and mortality from increased flooding that destroys mussel beds (Threat Rank: High)

Cycles of extreme episodic flooding and dewatering causes direct mortality to mussels. Extreme fluctuations in flow disrupt mussel life cycles by exposing glochidia and juveniles to flood-induced damage, mortality, or displacement to potentially unfavorable habitat downstream (Layzer et al. 1993, Richter et al. 1997). Dewatering exposes mussels to heat, desiccation, and opportunistic predators. Predator foraging efficiency increases with decreasing depth.

In 1999, Wicklow showed a correlation between presence of glochidia in stream drift samples and high flow releases from the Surry Mountain Dam on the Ashuelot River (Wicklow, Saint Anselm College, unpublished data). In addition, over 100 dwarf wedgemussel valves were collected from muskrat middens in a 15 m segment of the Ashuelot River during a period of extremely low water (von Oettingen, USFWS and Wicklow, Saint Anselm College, unpublished).

Species impacts from reduction or loss of host fish from degraded habitat and species composition changes (Threat Rank: High)

Freshwater mussels require specific fish species as hosts for glochidia development. As such, reductions in fish densities or species available to host glochidia for mussels will adversely impact reproduction of dwarf wedgemussel populations.

Tessellated darters are often common in streams occupied by dwarf wedgemussels so the likelihood of this threat needs further evaluation. However, tessellated darters may have limited movement during dwarf wedgemussel glochidia release periods, which may limit the ability of dwarf wedgemussels to expand and recolonize new areas (McLain and Ross 2005).

Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins (Threat Rank: High)

As development increases and riparian vegetation buffers decrease, the effects of pollution on the biota in the Connecticut River and tributaries will increase. Runoff from municipalities, industrial waste, sewage outfalls, golf courses, poor agricultural and silviculture land contributes to sedimentation, organic pollution, and general water quality degradation (Poole and Downing 2004). Mussels are sensitive to toxins, such as chlorine and ammonia, and to heavy metals introduced through runoff and atmospheric deposition (Naimo 1995, Augsburger et al. 2003). Glochidia and juveniles are the most sensitive to pollutants, juveniles because they burrow into and feed within the sediments. Thus sediment, particularly when low in pore-water oxygen and high in toxins, may be a major contamination pathway for infaunal juveniles, as well as for adults, who may also deposit feed (Newton et al. 2003, Poole and Downing 2004).

The effect of acute pollution on freshwater mussels is well documented (Neves et al. 1997). Chemical and agricultural waste spills cause direct mussel mortality. The most widely reported sources of pollution are poor agriculture practices (Neves et al. 1997, Poole and Downing 2004)); 20 dwarf wedgemussels and hundreds of other mussel species were killed by waste runoff from a small farm in the Connecticut River Watershed (USFWS 2002). The effect of sediment toxicity is not well understood. However, recent toxicity tests for total residual chlorine showed that juvenile mussels are much more sensitive to toxins than are glochidia (Cherry et al. 2005).

Habitat impacts and disturbance from development of riparian habitats that increases stream temperature (Threat Rank: Medium)

Increased water temperatures and associated reduced oxygen availability were predicted to adversely impact mussel populations.

In the Delaware River, it was determined that in population centers of dwarf wedgmussels, maximum daily water temperature of 26.5°C lasting for more than 7 days is a rare event and consequently this condition should be avoided (Castelli et al. 2012). Thresholds for these stressors need further evaluation.

Mortality from recreational activities within a stream that can crush mussels (Threat Rank: Medium)

Mussels can be crushed when stepped on. Human recreation (swimming, fishing, boat access, vehicle crossing streams) in streams can result in killed mussels and reduced population densities.

There are reports of mussels crushed at high use recreation sites. A sizable number of tidewater mucket mussels, a thin-shelled mussel species, were found dead along lakefront properties in a Massachusetts pond and densities of tidewater muckets were greater in an undisturbed private beach compared to a busy public beach, suggesting trampling of mussels may be impacting those populations (Nedeau 2009).

List of Lower Ranking Threats:

Habitat degradation and mortality from streambank stabilization

Mortality from the introduction and spread of problematic diseases and parasites

Species impacts from introduced or invasive animals that result in competition, predation, and reduced habitat quality

Habitat impacts from introduced or invasive plants

Actions to benefit this Species or Habitat in NH

Restoration and management of streams and rivers, with an emphasis on reducing stream fragmentation and restoring natural flow regimes, reducing pollution and riparian disturbance

Primary Threat Addressed: Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Specific Threat (IUCN Threat Levels): Natural system modifications

Objective:
Restoration of fragmented rivers will allow increased dispersal, increasing the overall potential for persistence of mussels. As mussels are established in new habitat, linear range, re-colonization, and population size increase.

General Strategy:
Stream fragmentation, and attendant gene flow restrictions, will be reduced by removing barriers

such as nonfunctional dams, where feasible, by operating dams at “run of the river” flow regimes, and by rehabilitating degraded river reaches. These measures will increase dispersal and recolonization of mussels into rehabilitated river reaches. Mussel populations and habitats must be assessed prior to implementation. Mussels found below a dam removal site or rehabilitated river reach may appear within 3 to 5 years, but 10 to 20 years or more may be necessary to establish a viable population. Riparian protection and restoration will be a long-term effort. As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. Pollution may render stream reaches uninhabitable. Destruction and transformation of riparian corridors accelerates erosion, bank sloughing, and runoff leading to increased levels of stream toxins, sediment, and higher stream temperatures. Education should be provided to adjacent landowners about practices that contribute pollutants into nearby rivers, streams, and ponds. Protection of riparian corridors through fee simple land acquisition, conservation easements, and private landowner cooperation will reduce pollution runoff and sedimentation. Properly sized culverts will reduce sedimentation and mass mortality of mussel beds. Surveys are needed to choose long-term, quantitative monitoring sites in occupied rivers and streams to assess patterns of disturbance and pollution. Following riparian disturbance mitigation or efforts to decrease pollution, the initial response of mussel populations should be monitored with qualitative surveying. As mussel populations increase in size, quantitative methods will be used (Strayer and Smith 2003). As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. The number of reproducing subpopulations of mussels will indicate the success of the program.

Political Location:
Carroll County, Cheshire County, Coos County, Sullivan County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

Minimize threats from invasive species

Primary Threat Addressed: Mortality from the introduction and spread of problematic diseases and parasites

Specific Threat (IUCN Threat Levels): Invasive & other problematic species, genes & diseases

Objective:
Minimize threats from invasive species

General Strategy:
From Nedeau (2008b): Coordinate with existing local, state and federal agencies and conservation groups to prevent or reduce the spread of damaging invasive species. Public education and prevention is the only effective means of dealing with aquatic invasive species.

Political Location:
Cheshire County, Coos County, Grafton County, Sullivan County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

Minimize threats from nonpoint source pollution

Primary Threat Addressed: Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins

Specific Threat (IUCN Threat Levels): Pollution

Objective:
Minimize threats from nonpoint source pollution

General Strategy:
From Nedeau (2008b): Identify major sources of sediment to the upper Connecticut River and its tributaries (especially sources caused or exacerbated by humans) and seek ways to reduce sedimentation.
Identify sources of nutrients and reduce nutrient loading to the upper Connecticut River and its principal tributaries.
Expand water quality monitoring, including increasing the number of sampling stations, the frequency of sampling dates, and the number of parameters that are measured.
Reduce the quantity and improve the quality of storm water entering streams and rivers.
Develop, revise, or enforce BMPs for a variety of activities that affect rivers and their fauna (agriculture, livestock grazing, forestry, construction, golf courses, etc.).
Identify areas where riparian buffers provide inadequate shade, habitat, storm water retention, and nutrient retention. Encourage creative partnerships to address these problems.
Examine proposed development within river corridors in terms of their potential effect on streamside vegetation, bank stability, or storm water runoff. Minimize effects via alternative siting or BMPs.
Develop and enforce shoreline protection laws and regulations.
Use environmentally sound designs and BMPs for transportation projects (roads, railways, bridges, and culverts).
Identify unnaturally unstable banks that threaten critical mussel habitat and consider options for increasing bank stability and reducing sedimentation.

Political Location:
Cheshire County, Coos County, Grafton County, Sullivan County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

Identify and minimize point source pollution

Primary Threat Addressed: Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins

Specific Threat (IUCN Threat Levels): Pollution

Objective:
Identify and minimize point source pollution to river stretches within the current or historic range of dwarf wedgemussels.

General Strategy:
From Nedeau (2008b):
• New Hampshire and Vermont should review, modify, or develop (if necessary) effluent water quality standards that protect dwarf wedgemussels. More stringent standards should be applied for entities that dis-charge directly into actual dwarf wedgemussel habitat or a reasonable distance

upstream (given the amount and type of discharge, dilution factor, etc.)
- Ensure that wastewater treatment plants achieve high standards by reviewing NPDES permits and supporting funding and use of best available technology for facility upgrades.
- Expand water quality monitoring along the Connecticut River mainstem and its tributaries, including increasing the number of sampling stations, the frequency of sampling dates, and the number of parameters that are measured.
- Identify and characterize risk from concentrated animal feeding operations along the upper Connecticut River and its tributaries.
- Identify and remove or mitigate sources of groundwater and sediment contamination.
- When total maximum daily loads (TMDLs) are developed for impaired water bodies, review plans for potential effects on mussels.

Political Location:
Cheshire County, Coos County, Grafton County, Sullivan County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

Evaluate conservation actions for stream reaches.

Primary Threat Addressed: Habitat degradation and mortality from increased flooding that destroys mussel beds

Specific Threat (IUCN Threat Levels): Climate change & severe weather

Objective:
Evaluate whether species augmentation, translocation, or reintroduction feasible.

General Strategy:
Determine whether species active management techniques are warranted for certain stream reaches. Coordinate with USFWS and regional biologists on priority stream reaches for management and/or restoration. Evaluate husbandry, augmentation, and translocation techniques.

Political Location:
Northeast, Cheshire County, Coos County, Sullivan County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

Regional Coordination

Objective:
Participate in regional efforts to conserve the species.

General Strategy:
NHFG will continue to participate in regional discussions and meetings to further the conservation purposes of dwarf wedgemussels.

Political Location:
Northeast, Cheshire County, Coos County, Sullivan County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

Direct swimming and fishing access points away from mussel beds

Primary Threat Addressed: Mortality from recreational activities within a stream that can crush mussels

Specific Threat (IUCN Threat Levels): Human intrusions & disturbance

Objective:
Reduce mortality of mussels from recreational activities within a stream, river or pond.

General Strategy:
As additional information on mussel occurrences is collected and mapped, managers should consider ways to direct recreational activities away from sensitive mussel beds. This can include strategically placing docks, boat launches, parking areas, beaches, and trails away from documented mussel beds. This will help reduce disturbance to mussels, reduce the potential for direct mortality, and help reduce pollution and sedimentation into mussel habitat. Targeted outreach to fishermen may occur coinciding with this effort, advising that mussels not be cracked open and used for bait. This has been commonly observed during mussel surveys.

Political Location:
Carroll County, Cheshire County, Coos County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

Review projects that have potential to harm dwarf wedgemussel populations.

Primary Threat Addressed: Habitat degradation and mortality from streambank stabilization

Specific Threat (IUCN Threat Levels): Natural system modifications

Objective:
Review projects that have potential to harm dwarf wedgemussel and develop guidance for minimizing impacts.

General Strategy:
Dwarf wedgemussels are listed as endangered in New Hampshire. As such, NHFG will review any proposed activities (residential, commercial, road construction and maintenance, recreation, dam licensing) that has the potential to harm dwarf wedgemussel. NHFG will work with applicants and permitting staff from other state and federal agencies, primarily Department of Environmental Services (Wetlands Bureau) and U.S. Fish and Wildlife Services and U.S. Army Corps of Engineers, to identify avoidance and minimization conditions for permit applicants. NHFG will develop guidelines for consistent and effective review of projects potentially impacting dwarf wedgemussels. Guidelines will consider scenarios where impacts should be avoided and scenarios where impact minimization of mitigation may be appropriate. Pre- and post- construction monitoring of dwarf wedgemussel and

associated habitat should be considered as a component of project review.

Political Location:
Carroll County, Coos County, Sullivan County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

Monitor mussel populations

Objective:
Conduct surveys to detect mussel populations and collect additional land use data in mussel-occupied habitats to better inform management decisions and create conservation plans for the species.

General Strategy:
General distribution surveys should be focused on historic sites and areas where data is lacking. Data on population structure, age class distribution, sex ratio, recruitment, growth rates, and migration is needed, as well as distribution and abundance data on host fish. Studies may also examine the effects of predation and competition. Research is needed to determine the biological response of mussels to artificial flow regimes. Response variables include displacement of juveniles, interference of spawning success, larval release patterns, and host fish attachment success. Villella et al. (2004) used mark-recapture techniques to estimate survival, recruitment, and population growth of freshwater mussels, and this technique could provide valuable demographic information. Currently, much of the information on the condition of mussel populations and habitat is qualitative. Needed are quantitative studies to assess the physical habitat, including sediment type and hydrology, particularly shear, and water quality. As actions are initiated and populations potentially enlarge, mussel sites should be monitored using quantitative, statistically valid methods. Water quality monitoring stations upstream of mussel populations must be established.
From Nedeau 2008b:
Conduct mussel surveys to document the distribution, health, and habitat of dwarf wedgemussel populations in the Middle Macrosite, Northern Macrosite, and Johns River.
Integrate biological and physical data into fine-scale range maps across multiple spatial scales to fully understand the size and extent of dwarf wedgemussel populations.
Consider establishing aquatic reserves in areas that harbor the “best” dwarf wedgemussel populations. Within these reserves, increase scrutiny of threats, tighten environmental permitting, and encourage creative partnerships to protect and restore habitat.
Investigate potential habitat within tributaries, assess continuity with the mainstem, and seeks ways to improve continuity to encourage dwarf wedgemussels to become established in tributaries. Identify potential reintroduction sites for dwarf wedgemussels based on presence of host fish, habitat suitability, historic records, and threats.
Develop and implement a repeatable, robust, and long-term monitoring program for dwarf wedgemussels in the upper Connecticut River.
In areas where at-risk species occur, monitor water quality more frequently and expand the parameters that are measured, considering the sensitivity of mussels to such parameters.
Review the effects of toxic chemicals and heavy metals on freshwater mussels and assess the risk that such materials pose to mussel populations throughout the watershed.
Conduct a comprehensive geomorphic study of the reach between Wilder Dam and Moore Dam, similar to the work sponsored by the Connecticut River Joint Commissions for the reach upstream of the Moore Reservoir.

Assess how current water withdrawals (surface water and groundwater) and water resource management policies affect rivers and their fauna.
Assess the effects of altered flow regimes on mussel populations downstream of hydroelectric dams and flood control dams in order to recommend operational changes that might encourage the reestablishment of mussel populations in reaches currently affected by altered hydrology.

Political Location:
Cheshire County, Coos County, Sullivan County

Watershed Location:
Upper CT Watershed, Middle CT Watershed, Lower CT Watershed

References, Data Sources and Authors

Data Sources
Information on the life history, habitat requirements, and distribution of dwarf wedgemussels was obtained from the scientific literature, unpublished reports, databases, expert consultation, unpublished research results, and mussel recovery meetings. Threat assessments were completed by Michael Marchand (NHFG), Barry Wicklow (St. Anselms), and Susi von Oettingen (USFWS). Distribution data were obtained from the New Hampshire Natural Heritage Bureau Element Occurrence Database, unpublished reports, scientific literature, and consultation with experts.

Data Quality
Dwarf wedgemussels in the Connecticut River main stem have been surveyed and intermittently monitored since 1988. Early surveys were conducted by canoe and snorkeling in shallow water, usually within 15 meters of the bank. Later SCUBA surveys found a significant number of dwarf wedgemussels in depths greater than 1.5 meters. Most of the early monitoring efforts employed Catch Per Unit Effort (CPUE) methods. While helpful in determining presence or absence, CPUE methods are not statistically valid and therefore cannot be reliably used to determine population changes or trends.
Dwarf wedgemussels in the Connecticut River main stem have been surveyed and intermittently monitored since 1988. Dams and reservoirs divide mussels into 3 spatially and genetically disjunct populations.
Much of the information on the condition of dwarf wedgemussel populations and habitat is qualitative. Needed are quantitative studies to assess the physical habitat, including sediment type and hydrology, particularly shear, and water quality. Also needed are data on dwarf wedgemussel population structure, age class distribution, sex ratio, recruitment, growth rates, and migration, as well as distribution and abundance data on host fish. Studies that examine the effects of predation and competition would be helpful.

2015 Authors:
Michael Marchand, NHFG

2005 Authors:
Barry J. Wicklow, Saint Anselm College

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Triangle Floater

Alasmidonta undulata

Federal Listing	N/A
State Listing	SGCN
Global Rank	G4
State Rank	S4
Regional Status	High

Photo by Ethan Nedeau

Justification (Reason for Concern in NH)

Freshwater mussels have declined dramatically in diversity, abundance, and distribution within the last 200 years and are considered the most imperiled fauna in North America (Richter et al. 1997, Lydeard et al. 2004). Triangle floaters are listed as a Regional Species of Greatest Conservation Need due to the high regional responsibility and high concern for this species. Maine conducted a status review of triangle floaters in 2006, and determined their populations were not warranting special concern listing (Nedeau 2008). The triangle floater seems to be declining in its southern range, such as in Maryland where it is endangered (Nedeau et al. 2000). Triangle floaters can tolerate non-flowing water so it is less sensitive to the effects of dams compared with many other freshwater mussels. Still, as filter feeders, triangle floaters are especially sensitive to pollutants, oxygen levels and temperature levels, making them important indicators of waterbody health.

Distribution

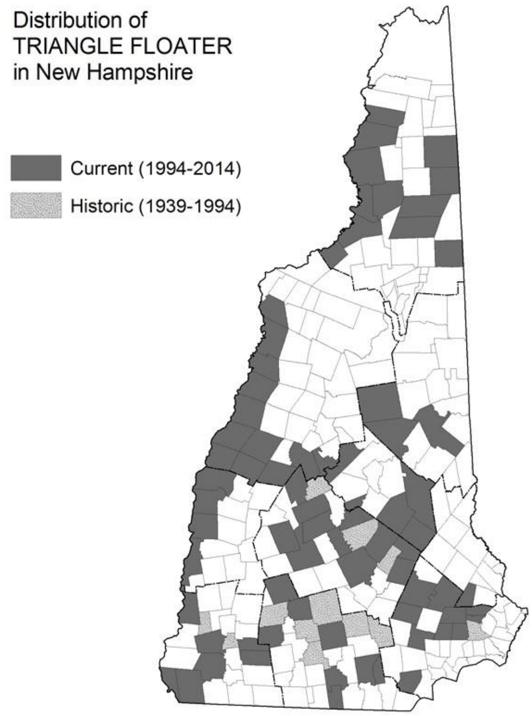
More populations of triangle floaters exist in New England than anywhere else throughout its known range along the Atlantic coast (Cordeiro 2011). Triangle floaters can be found in most major watersheds in the northeast, although are never common (Nedeau et al. 2000). It occupies the entire Connecticut River mainstem, and many of its minor and major tributaries, becoming more common going from south to north (Nedeau 2008). New Hampshire has over 295 documented sites where triangle floaters occur. Populations seem to be scattered statewide, reaching as far north as the Umbagog Lake region and the Upper Ammonoosuc River. Triangle floaters are usually at lower population densities in lakes and reservoirs than in rivers (Nedeau 2008).

Habitat

The triangle floater is a freshwater mussel that can be found in streams, rivers and lakes with sand or gravel substrates. It is most common in flowing water, but can tolerate a range of flow conditions and substrate types, and seems to prefer low-gradient rivers with low to moderate flow velocities (Nedeau 2008). As part of its life cycle, all mussel species must attach to the fins or gills of a fish in order to grow and reach their next life stage, where they sink to the bottom of the waterbody and spend the rest of their lives. Triangle floaters use a range of host fish including the common shiner (*Luxilus cornutus*), white sucker (*Catostomus commersonii*), and large-mouth bass (*Micropterus salmoides*), and thus will occur in habitats where these fish are commonly found.

NH Wildlife Action Plan Habitats

- Large Warmwater Rivers
- Warmwater Rivers and Streams
- Warmwater Lakes and Ponds



Distribution Map

Current Species and Habitat Condition in New Hampshire

Although the triangle floater is widely distributed in the state, it seems to be rarely abundant. It is expected that the species is experiencing declines particularly in southern parts of its range, and many states are currently gathering data to assess the distribution and abundance of the species (Nedeau et al. 2000). About 15% of NH surveys detected over 10 triangle floaters at a site, although several sites on the Ashuelot River had 100 or more triangle floaters present. Thirty-five percent of surveys consisted of 5 or fewer observations of triangle floater at a site. A small fraction (about 5%) of NH surveys reported numerous dead triangle floaters, but the cause of death is unknown (NH Survey Data).

Population Management Status

There is no targeted management for triangle floater populations in New Hampshire. Historically, surveys have focused on mussel species that more endangered, and thus have not adequately described the habitat, distribution and abundance of triangle floater in the state.

Regulatory Protection (for explanations, see Appendix I)

- Fill and Dredge in Wetlands - NHDES
- Rivers Management and Protection Program - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Clean Water Act-Section 404

Quality of Habitat

Very little habitat information exists. Most triangle floater populations have not been assessed and ecological attributes have not been measured. Although triangle floaters are capable of using a wide range of host fish, research on triangle floater larvae attachment to fish in natural populations has not been conducted. NH DES conducted an assessment of water quality in the Connecticut River mainstem in 2004. The assessment looked at dissolved oxygen content, pH, conductance and water temperature at 45 locations along the river. Of these 45 test locations, 14 areas did not meet state water quality standards, 13 areas had inconclusive results, and the remaining 18 areas met state water quality standards for dissolved oxygen content and pH (CRJC 2004). Bacterial problems have been noted in some areas of the mainstem and several tributaries (CRJC 2009).

Habitat Protection Status

Habitat protection is variable among stream reaches and regions of the state. Some protection of riparian areas is provided by the NH Shoreland Protection Act (NHDES).

Habitat Management Status

Currently there are no management or restoration efforts targeting triangle floater habitat in the state. However, the Nature Conservancy, the Monadnock Conservancy, the Society for the Protection of New Hampshire Forests, and the Southwestern Regional Planning Commission have developed a conservation plan for the Ashuelot River Watershed (Zankel 2004). The Connecticut River Joint Commission published a Connecticut River Management Plan in 2008 (http://crjc.org/pdffiles/WATER.final.pdf).

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Mortality from drawdowns for plant control and waterbody management (Threat Rank: Medium)

Drawdowns and the associated dewatering expose mussels to heat, desiccation, and opportunistic predators. Cycles of extreme dewatering can cause direct adult mortality by scouring. Extreme fluctuations in flow disrupt mussel life cycles by exposing young mussels to flood-induced damage, mortality, or displacement to potentially unfavorable habitat downstream (Layzer et al. 1993, Richter et al. 1997). Predator foraging efficiency increases with decreasing depth.

In New Hampshire, drawdowns typically occur in winter months for maintenance and flood control purposes, and occasionally for aquatic plant control. Drawdowns conducted under certain conditions allow drying and freezing of the sediments that become exposed, causing damage or death to certain aquatic weed species. Following a drawdown event, aquatic vegetation and organisms may exhibit changes in species composition and density by causing direct mortality to species and changes to habitat suitability.

Habitat degradation and mortality from increased flooding that destroys mussel beds (Threat Rank: Medium)

Cycles of extreme episodic flooding and dewatering use cause direct adult mortality by scouring. Extreme fluctuations in flow disrupt mussel life cycles by exposing young mussels to flood-induced damage, mortality, or displacement to potentially unfavorable habitat downstream (Layzer et al. 1993, Richter et al. 1997). Dewatering exposes mussels to heat, desiccation, and opportunistic predators. Predator foraging efficiency increases with decreasing depth.

Road stream crossings are extremely common and can impact habitat conditions and have negative impacts on aquatic life. Undersized culverts can be problematic in times of high flow or storm conditions, where flooding may result. In addition, dam maintenance often requires periodic de-watering and flooding that changes the habitat conditions, which has direct impacts on aquatic species (Nedeau 2008). Flooding typically leads to sedimentation, which can cause mass mortality of mussel beds.

List of Lower Ranking Threats:

Habitat degradation and mortality from streambank stabilization

Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins

Species impacts from reduction or loss of host fish from degraded habitat and species composition changes

Mortality from recreational activities within a stream that can crush mussels

Mortality from the introduction and spread of problematic diseases and parasites

Species impacts from introduced or invasive animals that result in competition, predation, and reduced habitat quality

Habitat impacts from introduced or invasive plants

Habitat impacts (fragmentation) from dams that cause inhospitable stream conditions

Habitat impacts and disturbance from development of riparian habitats that increases stream temperature

Habitat degradation and mortality from development of shorelines

Mortality from chemical treatments for nuisance plant control in waterbodies

Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Actions to benefit this Species or Habitat in NH

Restoration and management of streams and rivers, with an emphasis on reducing stream fragmentation and restoring natural flow regimes, reducing pollution and riparian disturbance

Primary Threat Addressed: Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Specific Threat (IUCN Threat Levels): Natural system modifications

Objective:

Restoration of fragmented rivers will allow increased dispersal, increasing the overall potential for persistence of mussels. As mussels are established in new habitat, linear range, re-colonization, and population size increase.

General Strategy:

Stream fragmentation, and attendant gene flow restrictions, will be reduced by removing barriers such as nonfunctional dams, where feasible, by operating dams at "run of the river" flow regimes, and by rehabilitating degraded river reaches. These measures will increase dispersal and recolonization of mussels into rehabilitated river reaches. Mussel populations and habitats must be assessed prior to implementation. Mussels found below a dam removal site or rehabilitated river reach may appear within 3 to 5 years, but 10 to 20 years or more may be necessary to establish a viable population. Riparian protection and restoration will be a long-term effort. As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. Pollution may render stream reaches uninhabitable. Destruction and transformation of riparian corridors accelerates erosion, bank sloughing, and runoff leading to increased levels of stream toxins, sediment, and higher stream temperatures. Education should be provided to adjacent landowners about practices that contribute pollutants into nearby rivers, streams, and ponds. Protection of riparian corridors through fee simple land acquisition, conservation easements, and private landowner cooperation will reduce pollution runoff and sedimentation. Properly sized culverts will reduce sedimentation and mass mortality of mussel beds. Surveys are needed to choose long-term, quantitative monitoring sites in occupied rivers and streams to assess patterns of disturbance and pollution. Following riparian disturbance mitigation or efforts to decrease pollution, the initial response of mussel populations should be monitored with qualitative surveying. As mussel populations increase in size, quantitative methods will be used (Strayer and Smith 2003). As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. The number of reproducing subpopulations of mussels will indicate the success of the program.

Political Location:

Statewide

Watershed Location:

Statewide

Monitor mussel populations

Objective:

Conduct surveys to detect mussel populations and collect additional land use data in mussel-occupied habitats is needed to better inform management decisions and create conservation plans for the species.

General Strategy:

General distribution surveys should be focused on historic sites and areas where data is lacking. Data on population structure, age class distribution, sex ratio, recruitment, growth rates, and migration is needed, as well as distribution and abundance data on host fish. Studies may also examine the effects of predation and competition. Research is needed to determine the biological response of mussels to artificial flow regimes. Response variables include displacement of juveniles, interference of spawning success, larval release patterns, and host fish attachment success. Villella et al. (2004) used mark-recapture techniques to estimate survival, recruitment, and population growth of freshwater mussels, and this technique could provide valuable demographic information. Currently, much of the information on the condition of mussel populations and habitat is qualitative.

Political Location:
Statewide

Watershed Location:
Statewide

Direct swimming and fishing access points away from mussel beds

Primary Threat Addressed: Mortality from recreational activities within a stream that can crush mussels

Specific Threat (IUCN Threat Levels): Human intrusions & disturbance

Objective:
Reduce mortality of mussels from recreational activities within a stream, river or pond.

General Strategy:
As additional information on mussel occurrences is collected and mapped, managers should consider ways to direct recreational activities away from sensitive mussel beds. This can include strategically placing docks, boat launches, parking areas, beaches, and trails away from documented mussel beds. This will help reduce disturbance to mussels, reduce the potential for direct mortality, and help reduce pollution and sedimentation into mussel habitat. Targeted outreach to fishermen may occur coinciding with this effort, advising that mussels not be cracked open and used for bait. This has been commonly observed during mussel surveys.

Political Location:
Statewide

Watershed Location:
Statewide

References, Data Sources and Authors

Data Sources

Literature review, expert review and consultation, and NH mussel survey data.
Distribution data was obtained from unpublished reports, scientific literature, and consultation with experts. The threat assessment was conducted by Michael Marchand (NHFG), Barry Wicklow (St Anselm College), and Susi von Oettingen (USFWS).

Data Quality

NHFG has kept records of all mussel occurrences reported from surveys. NHFG also maintains records of mussel species submitted through the NH Wildlife Sightings online reporting website (http://nhwildlifesightings.unh.edu). Many mussel surveys occurring in New Hampshire are monitoring efforts in response to hydroelectric projects or dam impact studies. Most mussel studies are focused on endangered mussel species, but usually record and report all mussel species observed. The Connecticut River main stem has been surveyed and intermittently monitored for mussels since 1988. Early surveys were conducted by canoe and snorkeling in shallow water, usually within 15 meters of the bank, and later SCUBA surveys were used to survey depths greater than 1.5 meters. Much of the information on the condition of triangle floater populations and habitat is qualitative.

Needed are quantitative studies to assess the physical habitat, including sediment type and hydrology, particularly shear, and water quality. Also needed are data on population structure, age class distribution, sex ratio, recruitment, growth rates, and migration. Studies that examine the effects of predation and competition would be helpful.

2015 Authors:
Loren Valliere, NHFG

2005 Authors:
N/A - Species not listed as SGCN during 2005 WAP

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Brook Floater

Alasmidonta varicosa

Federal Listing	N/A
State Listing	E
Global Rank	
State Rank	S1
Regional Status	Very High

Photo by Ethan Nedeau

Justification (Reason for Concern in NH)

Freshwater mussels are the most imperiled fauna in North America, having suffered steep declines in diversity, abundance, and distribution within the last 200 years (Richter et al. 1997, Lydeard et al. 2004). In the genus *Alasmidonta* 9 of 13 species are threatened, endangered, or extinct (Williams et al. 1992). An Atlantic slope species, the brook floater once ranged from Nova Scotia to South Carolina and was widespread throughout much of its range. Populations have since declined sharply and in many states are considered rare or are extirpated. Many populations are small, have low densities, and show little or no evidence of recruitment. Brook floaters have declined in much of the south and are critically imperiled in New Hampshire, Connecticut, Massachusetts, Maryland, and Virginia and are presumed extirpated in Rhode Island and Delaware. The range has contracted in New York, although a robust population still exists in the Neversink River (Strayer 1997, Strayer and Ralley 1991). It has disappeared from many other New York locations including the Housatonic and Passaic basin and has declined severely in the Susquehanna basin (Strayer 1997, Strayer and Fetterman 1999, O'Brien, New York Department of Environmental Conservation, personal communication). It occurs in fewer than 12 streams in Connecticut (Nedeau 2002). It is threatened in Vermont, where it is restricted to the West River (Fichtel and Smith 1995) and in Maine is a species of special concern, occurring in most rivers that historically supported Atlantic salmon (Nedeau et al. 2000). Human activity has jeopardized populations through riparian disturbance, pollution, sedimentation, dams, impoundments, and artificial flow regimes. Stream fragmentation disrupts mussel life cycles, prevents host fish migration, blocks gene flow, and prohibits recolonization resulting in reduced recruitment rates, decreased population densities, and increased probability of local extinctions (Neves et al. 1997, Watters 1999, Strayer et al. 2004).

Distribution

An Atlantic slope species, the brook floater once ranged from Nova Scotia to South Carolina and was widespread throughout much of its range. Populations have since declined sharply and in many states are considered rare or are extirpated. In New Hampshire, brook floaters occur in the Connecticut and Merrimack Rivers and coastal watersheds. Only one population occurs within the Connecticut River Watershed in NH: the North Branch of the Sugar River (Cutko 1993). Several populations are found within the Merrimack River Watershed: the Blackwater, Piscataquog, Suncook, Soucook Rivers and in Merrimack River main stem (Cutko 1993, Gabriel 1995, NHNHB 1996, Wicklow, Saint Anselm College, unpublished data). Brook floaters likely exist in very low numbers in the Nissitissit River in Hollis, Golden Brook in Windham, and Beaver Brook in Pelham where a population was first reported by

Athearn and Clarke in 1952 (Clarke 1981, Gabriel 1995). In the coastal drainage, brook floater populations are in danger of extirpation. They appear to be gone from the Exeter River and are scattered in very low numbers in the Lamprey River (Cutko 1993, Albright 1994, Gabriel 1996, Wicklow, Saint Anselm college, unpublished data, Nedeau 2011).

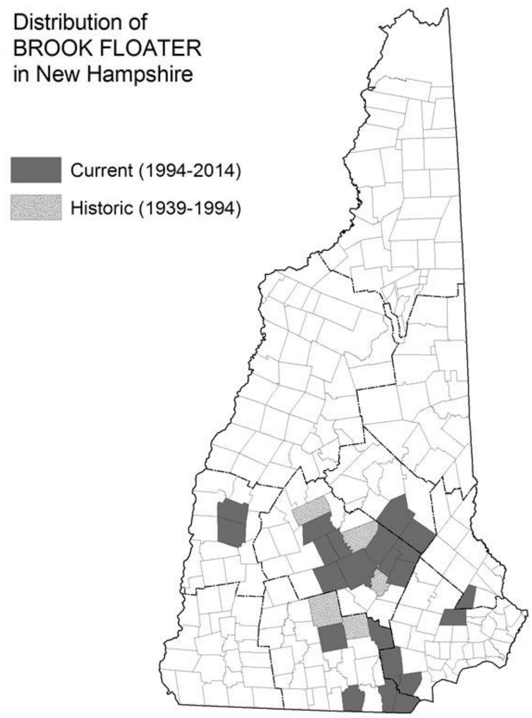
Habitat

Brook floaters are strictly riverine species inhabiting clean and well-oxygenated small streams to large rivers with high to moderate flows. They are absent in scour-prone areas of high gradient streams and avoid high velocity flow channels. Although they show no consistent substrate preference (Strayer and Ralley 1993), brook floaters in New Hampshire are often found in gravel and in sand among larger cobble in riffles, along shaded banks, and, in higher gradient streams, in sandy flow refuges behind large boulders (S. von Oettingen, USFWS, personal communication, B. Wicklow, Saint Anselm College, personal observation). They are found most often in nutrient-poor streams with low calcium levels (Strayer 1993). Mussels are suspension feeders, subsisting on phytoplankton, bacteria, fine particulate matter, and dissolved organic matter (Strayer 2004).

As in other unionid mussels, brook floaters' life cycle is complex and parasitic. Spawning occurs in summer as sperm are released into the water column, where they are drawn into the inhalent aperture of the female and into the outermost demibranchs of the gills, which function as marsupia. There the eggs are fertilized and develop and mature into larvae called glochidia. Brook floaters are long-term brooders. In New Hampshire, glochidia are held through the winter until release, which begins in mid-April and continues through May (B. Wicklow, Saint Anselm College, unpublished data). Glochidia must attach to a host fish in order to complete development and disperse.
The brook floater is a host generalist. Glochidia are capable of transforming on a variety of host fish species: longnose dace, *Rhinicthys cataractae*, blacknose dace, *Rhinicthys atratulus*, golden shiner, *Notemigonas chrysoleucas*, pumpkinseed sunfish, *Lepomis gibbosus*, yellow perch, *Perca flavescens*, tessellated darter, *Etheostoma olmstedi*, mad tom, *Noturus insignis*, and sculpin, *Cottus cognatus* (Wicklow and Wicklow, Saint Anselm College, unpublished data). Gravid female brook floaters release glochidia in loose masses that drift downstream. Transformation of encysted glochidia takes 3 to 4 weeks at 150 C. Upon release, juveniles burrow immediately into the substrate (Wicklow and Wicklow, Saint Anselm College, unpublished data).

NH Wildlife Action Plan Habitats

- Large Warmwater Rivers
- Warmwater Rivers and Streams



Distribution Map

Current Species and Habitat Condition in New Hampshire

Over 70 % of reported populations have less than 30 individuals. Stream fragmentation resulting from dams, causeways, impoundments, channelization, and inhospitable stream segments results in spatially and genetically disjunct populations. Many populations have densities that put them in jeopardy of extirpation from stochastic demographic, genetic, or environmental events. Brook floaters in New Hampshire have very small linear ranges making them especially vulnerable to human impacts. In the Connecticut River watershed, data from 2009 surveys suggest that the brook floater population in the Croydon Branch is fragmented, geriatric, and possibly declining (Nedeau 2006, Nedeau 2009). Mussel populations end abruptly at the North Branch and Sugar River confluence where water quality is low (von Oettingen, USFWS, personal communication).

Surveys in the Merrimack River watershed have been variable. The majority of the Merrimack River main stem has not been surveyed. However, relatively large numbers of brook floaters are known in the River at the Sewall’s Falls Bridge area of Concord (Nedeau 2015, Normandeau 2001), and in Franklin below the Eastman Falls dam (Kleinschmidt Group. 2014) and scattered individuals have been reported in Manchester (McLain 2004). Based on evidence of recruitment and abundance observed during CPUE surveys in 1993 and 1995, the Blackwater, Suncook, and the Soucook populations appeared to be the most robust tributaries to the Merrimack River. The Blackwater and Soucook Rivers haven't been surveyed systematically since. A large population on the Suncook River was discovered, and then lost, following an evulsion in the river that changed the course of the river (Wicklow 2008). Several other sections of the Suncook River have been surveyed in recent years associated with mussel relocation (Wicklow 2008, Nedeau 2013). Long-term monitoring of the Piscataquog River Henry Bridge population shows a decline in mussel density from 0.4 per meter squared in 1996 to 0.02 in 1999 (Wicklow, Saint Anselm College, unpublished data). A mussel bed on the South Branch of the Piscataquog River, monitored periodically since 1993, has been nearly extirpated. Brook floaters likely exist in very low numbers from the Nissitissit River in Hollis, Golden Brook in Windham, and Beaver Brook in Pelham where a population was first reported by Athearn and Clarke in 1952 (Clarke 1981, Gabriel 1995). A more recent survey on Beaver Brook found one A. varicosa near the Tallant Road Bridge in 2003 (Geiger, unpublished report, Oak Hill Environmental Services 2003).

The coastal watershed populations are at high risk of extirpation with only a few scattered individuals remaining from the Lamprey River (Nedeau 2011).

Population Management Status

Mussels are surveyed and occasionally relocated during bank stabilization, bridge replacement, or other projects with potential to harm species (e.g., Nedeau 2015). During extensive flooding in May of 2006, a section of the Suncook River in Epsom, NH breeched a glacial ridge to cut a new channel leaving a dewatered stretch where a large population of brook floater mussels, *Alasmidonta varicosa*, was discovered. Approximately 1100 brook floater mussels were collected then held for 3 months at the National Fish Hatchery, Nashua NH, for tagging and measurement. Mussels were then relocated to an upstream section of the Suncook River in North Chichester, NH. At the relocation site, one of the largest known brook floater populations range-wide was discovered. Both resident and relocated brook floaters were marked, measured, and mapped in 2 experimental plots.

Regulatory Protection (for explanations, see Appendix I)

- Endangered Species Conservation Act (RSA 212-A)
- Fill and Dredge in Wetlands - NHDES
- Rivers Management and Protection Program - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Alteration of Terrain Permitting - NHDES

Quality of Habitat

Very little habitat information exists. Historically robust sites in the Lamprey River are nearly gone with only a few scattered individuals detected, potentially at least partially resulting from large sediment deposits on mussel beds following major flood events (Nedeau 2011). Brook floaters appear to be in decline within the Croydon branch of the Sugar River, the only occupied tributary in the Connecticut River watershed within New Hampshire. Much of the Merrimack River watershed has not been surveyed for brook floaters nor has the habitat been assessed. A detailed habitat assessment was conducted at the Suncook River relocation site in Chichester and data supported a high quality riparian and within stream habitat (Wicklow 2008).

Habitat Protection Status

Riparian habitat protection varies among and within rivers, and some riparian habitat is protected by the NH Comprehensive Shoreland Protection Act. See Appendix B: Aquatic habitat profiles: Large warmwater rivers and warmwater rivers and streams for summary of habitat protection.

Habitat Management Status

There is no known management specifically for the purposes of benefitting brook floater mussels. Several dams have been removed in waterbodies where brook floater mussels previously occurred in the vicinity (e.g., Bunker pond dam, Lamprey River).

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat degradation and mortality from dams that alter hydrology upstream and downstream (Threat Rank: High)

The conversion of free-flowing rivers to highly regulated rivers has seriously affected freshwater mussels (Locke et al. 2003, Watters 1996, Watters 1999). Barriers cause direct mortality, prevent dispersal, block gene flow, prohibit recolonization of rehabilitated habitat, and prevent host fish migration (Layzer et al. 1993, Parmalee and Hughes 1993, Vaughn and Taylor 1999, Watters 1996). Cycles of extreme episodic flooding and dewatering use cause direct adult mortality by scouring. Extreme fluctuations in flow disrupt mussels by exposing glochidia and juveniles to flood-induced damage, mortality, or displacement to unfavorable habitat downstream (Layzer et al. 1993, Layzer and Madison 1995, Hardison and Layzer 2000). Dewatering exposes mussels to heat, desiccation, and opportunistic predators. Predator foraging efficiency increases with decreasing depth.

Dams have separated brook floater populations in every river system they inhabit. Barriers decrease the size of linear ranges. Isolated mussel populations are more susceptible to pollution and habitat degradation (Strayer et al. 1996). In 1999, Wicklow showed a correlation between presence of glochidia and high flow releases from the Surry Mountain Dam on the Ashuelot River (Wicklow, Saint Anselm College, unpublished data). During a period of low water in 1997, 163 brook floaters in a population downstream from the Gregg Falls Hydroelectric Dam on the Piscataquog River were lost to predation (Wicklow, Saint Anselm College, unpublished data). In addition, over 100 dwarf wedgemussel valves were collected from muskrat middens in a 15-meter segment of the Ashuelot River during a period of extremely low water (von Oettingen, USFWS and Wicklow, Saint Anselm College, unpublished).

Habitat degradation and mortality from increased flooding that destroys mussel beds (Threat Rank: High)

Excessive flood events can transport mussels downriver and or bury them in sediment, resulting in mortality to individuals. Extreme weather events can change river courses and sediment transport.

A population of brook floater mussels was discovered in the Soucook River following the mother's day floods in 2006. The Soucook River changed course and left a stretch of river and associated mussels stranded. Alive brook floater mussels were collected and maintained in a USFWS hatchery until they could be relocated upstream. A flood event in 2007, followed by a drought resulted in additional mortality to transported and resident mussels (Wicklow 2008). Surveys of the Lamprey River indicated a near extirpation of the species. Historically robust populations in the Lamprey river were apparently buried in several feet of sediment during flood events and associated eroding river banks (Nedeau 2011).

Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins (Threat Rank: High)

Runoff from municipalities, industrial waste, sewage outfalls, golf courses, and poorly managed agricultural and silvicultural land contributes to water quality degradation, increasing sedimentation and organic pollution. As development increases, impervious surfaces increase the volume and velocity of runoff, causing erosion, sedimentation, and high levels of toxins in rivers and streams. Riparian vegetation is critical in retarding these effects. Mussels are sensitive to heavy metals introduced through runoff and atmospheric deposition, as well as to toxins, such as chlorine and ammonia (Naimo 1995, Augsburger et al. 2003). Glochidia and juveniles are most sensitive to pollutants. Because juveniles and adults burrow into and feed within the sediments, oxygen-poor and toxin-rich sediment may be a major pathway for contamination (Newton et al. 2003, Poole and Downing 2004).

The effect of acute pollution on freshwater mussels is well documented (Neves et al. 1997). The most widely reported sources of pollution are poor land use practices (Neves et al. 1997, Poole and Downing 2004). For example, hundreds of mussels were killed, including federal and state listed species, by waste runoff from a small farm in the Connecticut River Watershed (USFWS 2002). Chemical and agricultural waste spills also cause direct mussel mortality, though the effect of sediment toxicity is not well understood. However, recent toxicity tests for total residual chlorine showed that juvenile mussels are more sensitive to toxins than glochidia (Cherry et al. 2005).

Habitat impacts and disturbance from development of riparian habitats that increases stream temperature (Threat Rank: Medium)

Increased water temperatures and associated reduced oxygen availability were predicted to adversely impact mussel populations.

Thresholds for these stressors need further evaluation.

Habitat impacts (fragmentation) from dams that cause inhospitable stream conditions (Threat Rank: Medium)

See 'Habitat degradation and mortality from dams that alter hydrology upstream and downstream' threat summary.

Mortality from recreational activities within a stream that can crush mussels (Threat Rank: Medium)

Brook floater mussels are thin shelled and easily crushed when stepped on. Human recreation (swimming, fishing, boat access, vehicle crossing streams) in streams can result in killed mussels and reduced population densities.

There are anecdotal reports of mussels crushed at high use recreation sites. A sizable number of tidewater mucket mussels, another thin-shelled mussel species, were found dead along lakefront properties in a Massachusetts pond and densities of tidewater muckets were greater in an undisturbed private beach compared to a busy public beach, suggesting trampling of mussels may be impacting those populations (Nedeau 2009).

Species impacts from reduction or loss of host fish from degraded habitat and species composition changes (Threat Rank: Medium)

Freshwater mussels require specific fish species as hosts for glochidia development. As such, reductions in fish densities or species available to host glochidia for brook floater mussels will adversely impact reproduction of brook floater populations.

However, brook floaters use a variety of fish species as hosts so the likelihood of this threat needs further evaluation.

List of Lower Ranking Threats:

Habitat degradation and mortality from streambank stabilization

Mortality from the introduction and spread of problematic diseases and parasites

Species impacts from introduced or invasive animals that result in competition, predation, and reduced habitat quality

Habitat impacts from introduced or invasive plants

Actions to benefit this Species or Habitat in NH

Direct swimming and fishing access points away from mussel beds

Primary Threat Addressed: Mortality from recreational activities within a stream that can crush mussels

Specific Threat (IUCN Threat Levels): Human intrusions & disturbance

Objective:
Reduce mortality of mussels from recreational activities within a stream, river or pond.

General Strategy:
As additional information on mussel occurrences is collected and mapped, managers should consider ways to direct recreational activities away from sensitive mussel beds. This can include strategically placing docks, boat launches, parking areas, beaches, and trails away from documented mussel beds. This will help reduce disturbance to mussels, reduce the potential for direct mortality, and help reduce pollution and sedimentation into mussel habitat. Targeted outreach to fishermen may occur coinciding with this effort, advising that mussels not be cracked open and used for bait. This has been commonly observed during mussel surveys.

Political Location:
Belknap County, Hillsborough County, Merrimack County, Rockingham County, Strafford County, Sullivan County

Watershed Location:
Lower CT Watershed, Merrimack Watershed, Coastal Watershed

Review projects that have potential to cause harm to brook floater populations.

Primary Threat Addressed: Habitat degradation and mortality from streambank stabilization

Specific Threat (IUCN Threat Levels): Natural system modifications

Objective:
Review projects that have potential to harm brook floater mussels and develop guidance for minimizing impacts.

General Strategy:
Brook floater mussels are listed as endangered in New Hampshire. As such, NHFG will review any proposed activities (residential, commercial, road construction and maintenance, recreation, dam licensing) that has the potential to harm brook floater mussels. NHFG will work with applicants and permitting staff from other state and federal agencies, primarily Department of Environmental Services (Wetlands Bureau) and U.S. Army Corps of Engineers, to identify avoidance and minimization conditions for permit applicants. NHFG will develop guidelines for consistent and effective review of projects potentially impacting brook floater mussels. Guidelines will consider scenarios where impacts should be avoided and scenarios where impact minimization of mitigation may be appropriate. Pre- and post- construction monitoring of brook floater mussels and associated habitat should be considered as a component of project review.

Political Location:
Belknap County, Hillsborough County, Merrimack County, Rockingham County, Strafford County, Sullivan County

Watershed Location:
Lower CT Watershed, Merrimack Watershed, Coastal Watershed

Regional Coordination

Objective:
Participate in regional efforts to conserve the species.

General Strategy:
A status assessment is underway for the brook floater in the northeast (Regional Conservation Need grant). NHFG will continue to participate in these regional discussions and meetings to further the conservation purposes of brook floater mussels.

Political Location:
Belknap County, Hillsborough County, Merrimack County, Rockingham County, Strafford County, Sullivan County

Watershed Location:
Lower CT Watershed, Merrimack Watershed, Coastal Watershed

Evaluate conservation actions for stream reaches.

Primary Threat Addressed: Habitat degradation and mortality from increased flooding that destroys mussel beds

Specific Threat (IUCN Threat Levels): Climate change & severe weather

Objective:
Evaluate whether species augmentation, translocation, or reintroduction feasible.

General Strategy:
Determine whether species active management techniques are warranted for certain stream reaches. Coordinate with USFWS and regional biologists on priority stream reaches for management and/or restoration. Evaluate husbandry, augmentation, and translocation techniques.

Political Location:
Northeast, Statewide

Watershed Location:
Statewide

Restoration and management of streams and rivers, with an emphasis on reducing stream fragmentation and restoring natural flow regimes, reducing pollution and riparian disturbance

Primary Threat Addressed: Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Specific Threat (IUCN Threat Levels): Natural system modifications

Objective:
Restoration of fragmented rivers will allow increased dispersal, increasing the overall potential for persistence of mussels. As mussels are established in new habitat, linear range, re-colonization, and population size increase.

General Strategy:
Stream fragmentation, and attendant gene flow restrictions, will be reduced by removing barriers such as nonfunctional dams, where feasible, by operating dams at “run of the river” flow regimes, and by rehabilitating degraded river reaches. These measures will increase dispersal and recolonization of mussels into rehabilitated river reaches. Mussel populations and habitats must be assessed prior to implementation. Mussels found below a dam removal site or rehabilitated river reach may appear within 3 to 5 years, but 10 to 20 years or more may be necessary to establish a viable population. Riparian protection and restoration will be a long-term effort. As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. Pollution may render stream reaches uninhabitable. Destruction and transformation of riparian corridors accelerates erosion, bank sloughing, and runoff leading to increased levels of stream toxins, sediment, and higher stream temperatures. Education should be provided to adjacent landowners about practices that contribute pollutants into nearby rivers, streams, and ponds. Protection of riparian corridors through fee simple land acquisition, conservation easements, and private landowner cooperation will reduce pollution runoff and sedimentation. Properly sized culverts will reduce sedimentation and mass mortality of mussel beds. Surveys are needed to choose long-term, quantitative monitoring sites in occupied rivers and streams to assess patterns of disturbance and pollution. Following riparian disturbance mitigation or efforts to decrease pollution, the initial response of mussel populations should be monitored with qualitative surveying. As mussel populations increase in size, quantitative methods will be used (Strayer and Smith 2003). As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. The number of reproducing

subpopulations of mussels will indicate the success of the program.

Political Location:
Belknap County, Hillsborough County, Merrimack County, Rockingham County, Strafford County, Sullivan County

Watershed Location:
Lower CT Watershed, Merrimack Watershed, Coastal Watershed

Monitor mussel populations

Objective:
Conduct surveys to detect mussel populations and collect additional land use data in mussel-occupied habitats is needed to better inform management decisions and create conservation plans for the species.

General Strategy:
General distribution surveys should be focused on historic sites and areas where data is lacking. Data on population structure, age class distribution, sex ratio, recruitment, growth rates, and migration is needed, as well as distribution and abundance data on host fish. Studies may also examine the effects of predation and competition. Research is needed to determine the biological response of mussels to artificial flow regimes. Response variables include displacement of juveniles, interference of spawning success, larval release patterns, and host fish attachment success. Villella et al. used mark-recapture techniques to estimate survival, recruitment, and population growth of freshwater mussels (Villella et al. 2004), and this technique could provide valuable demographic information. Currently, much of the information on the condition of mussel populations and habitat is qualitative. Needed are quantitative studies to assess the physical habitat, including sediment type and hydrology, particularly shear, and water quality. As actions are initiated and populations potentially enlarge, mussel sites should be monitored using quantitative, statistically valid methods. Water quality monitoring stations upstream of mussel populations must be established.

Political Location:
Belknap County, Hillsborough County, Merrimack County, Rockingham County, Strafford County, Sullivan County

Watershed Location:
Lower CT Watershed, Merrimack Watershed, Coastal Watershed

References, Data Sources and Authors

Data Sources

Information on the life history, habitat, and distribution of brook floaters was obtained from the scientific literature, unpublished reports, databases, expert consultation, and unpublished research results.

Distribution data were obtained from the New Hampshire Natural Heritage Bureau Element Occurrence Database, unpublished reports, scientific literature, and consultation with experts. Several targeted brook floater surveys were initiated by NHFG in the previous 10 years (Nedeau 2006, Nedeau 2009, Nedeau 2011, Wicklow 2008). B. Wicklow summarized the status of NH brook floater population in a draft report for a regional status assessment funded by the Regional Conservation Need grant program (State Wildlife Grants). The threat assessment was conducted by Michael Marchand (NHFG), Barry Wicklow (St. Anselms), and Susi von Oettingen (USFWS).

Data Quality

Most information on brook floater populations is qualitative and was acquired in the mid-1990s or earlier. Early surveys efforts employed Catch Per Unit Effort (CPUE) methods, and while helpful in determining presence of absence, these methods are not statistically valid and therefore cannot be reliably used to determine population changes or trends. In 1996, Wicklow began a 10-year quantitative study of the brook floater population in the main stem of the Piscataquog River in Goffstown. The population was monitored in 1996, 1997, 1999, 2004, and will be monitored again in 2005 and 2006 (Wicklow, Saint Anselm College, unpublished).

2015 Authors:

Michael Marchand, NHFG

2005 Authors:

Barry J. Wicklow, Saint Anselm College

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Alewife Floater

Anodonta implicata

Photo by Ethan Nedeau

Federal Listing	N/A
State Listing	SGCN
Global Rank	G5
State Rank	S3
Regional Status	High

Justification (Reason for Concern in NH)

Freshwater mussels have declined dramatically in diversity, abundance, and distribution within the last 200 years and are considered the most imperiled fauna in North America (Richter et al. 1997, Lydeard et al. 2004). Because this species is of high regional concern and high regional responsibility, it was deemed a regional species of greatest conservation need. Because their populations are so closely linked to their species of anadromous host fish (Alewife, blueback herring, and American shad, which are also Species of Greatest Conservation Need in NH), their vulnerability is increased. The decline and loss of alewife in streams likely puts pressure on the alewife floater population, especially in habitats too small to support the American shad, which is typically a more common fish (Nedeau 2008). The prevalence of dams restricts anadromous fish distributions, thus restricting alewife floater distribution, and this has resulted in local extirpations historically (Nedeau et al 2000).

Distribution

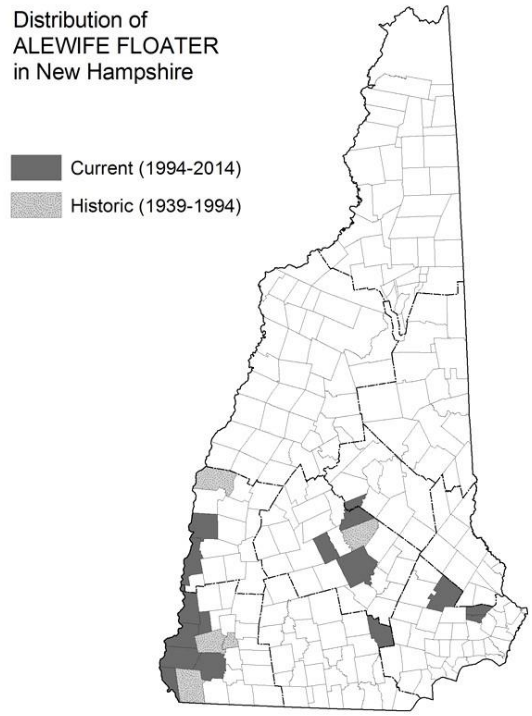
Its range stretches from Maryland up to Nova Scotia and New Brunswick (Nedeau 2008). In New Hampshire, alewife floaters are found in the southern half of the state where it has been observed in most major tributaries of the Connecticut River, the Ashuelot watershed, and scattered through the Merrimack River and Great Bay tributaries. The alewife floater was historically extirpated from many of these areas due to dams that blocked host fish passage, but installation of fish passageways has restored populations to many of these areas (Nedeau 2008). To accommodate for dam fragmentation, fisheries biologists distribute fish species throughout a watershed, and so it’s possible that the moving of individual host fish has also moved alewife floaters. Since alewife floaters are attached to a host fish as juveniles, they could easily be moved along with the fish.

Habitat

Alewife floaters can be found in rivers, streams, ponds, and lakes. They seem to tolerate a variety of flow rates and substrate types within these waterbodies, ranging from cobble to silty or sandy. As part of its life cycle, all mussel species must attach to the fins or gills of a fish in order to grow and reach their next life stage, where they sink to the bottom of the waterbody and spend the rest of their lives. The alewife floater is only known to attach to alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and American shad (*Alosa sapidissima*) (Nedeau 2008). Thus, alewife floaters will occur only in waterbodies that support populations of these host fish.

NH Wildlife Action Plan Habitats

- Large Warmwater Rivers
- Warmwater Rivers and Streams
- Warmwater Lakes and Ponds



Distribution Map

Current Species and Habitat Condition in New Hampshire

Alewife floater populations in NH have apparently benefited from the construction of fish passageways. However, populations remain limited in the state. In the sites where alewife floaters are found, they seem to be abundant in these areas. In areas where alewife, American shad, and blueback herring are plentiful and their populations stable, alewife floater populations are likely the most robust. Researchers encountered a portion of dead alewife floaters during surveys, although cause of death is undetermined.

Population Management Status

There is little management particularly for alewife floaters in New Hampshire. NHFG works to restore fish passage in rivers and streams throughout the state, which greatly benefits the alewife floater by supporting its host fish.

Regulatory Protection (for explanations, see Appendix I)

- Fill and Dredge in Wetlands - NHDES
- Rivers Management and Protection Program - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Clean Water Act-Section 404

Quality of Habitat

The quality of alewife floater habitat patches in NH is unknown.

Habitat Protection Status

Habitat protection is variable among stream reaches and regions of the state. Some protection of riparian areas is provided by the NH Comprehensive Shoreland Protection Act (NHDES).

Habitat Management Status

Currently there are no management or restoration efforts targeting alewife floater habitat in the state. However, the Nature Conservancy, the Monadnock Conservancy, the Society for the Protection of New Hampshire Forests, and the Southwestern Regional Planning Commission have developed a conservation plan for the Ashuelot River Watershed (Zankel 2004). The Connecticut River Joint Commission published a Connecticut River Management Plan in 2008 (http://crjc.org/pdffiles/WATER.final.pdf).

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat degradation and mortality from dams that alter hydrology upstream and downstream (Threat Rank: High)

The conversion of free-flowing rivers to highly regulated rivers has seriously affected freshwater mussels (Locke et al. 2003, Watters 1996, Watters 1999). Barriers cause direct mortality, prevent dispersal, block gene flow, prohibit re-colonization of rehabilitated habitat, and prevent host fish migration (Layzer et al. 1993, Parmalee and Hughes 1993, Vaughn and Taylor 1999, Watters 1996). Cycles of extreme flooding and dewatering cause direct adult mortality by scouring. Extreme fluctuations in flow disrupt mussels by exposing young mussels to flood-induced damage, mortality, or displacement to unfavorable habitat downstream (Layzer et al. 1993, Layzer and Madison 1995, Hardison and Layzer 2000). Dewatering exposes mussels to heat, desiccation, and opportunistic predators. Predator foraging efficiency increases with decreasing depth.

The Connecticut River watershed has an extraordinary number of dams (Nedeau 2008). Multiple dams within a watershed leads to mussel populations that are isolated and therefore at a higher risk of extirpation (Nedeau 2008). Evidence of the impact on alewife floaters in New Hampshire has not been studied or documented. However, more studied mussel populations, such as the Dwarf Wedge mussel which has similar habitat preferences, have been separated in every river system they inhabit.

During a period of low water in 1997, 163 brook floaters (another similar freshwater mussel) downstream from the Gregg Falls Hydroelectric Dam on the Piscataquog River were lost to predation (Wicklow, Saint Anselm College, unpublished data). In addition, over 100 dwarf wedgemussel valves were collected from muskrat middens in a 15-meter segment of the Ashuelot River during a period of extremely low water (von Oettingen, USFWS and Wicklow, Saint Anselm College, unpublished).

Habitat impacts (fragmentation) from dams that cause inhospitable stream conditions (Threat Rank: High)

Fragmentation from dams or undersized stream crossings causes many issues for mussel populations. This impacts how water flows and transports sediment through the system (Nedeau 2008). Dams can produce low flow conditions which reduce availability of mussel habitat and can increase vulnerability to other threats.

The Connecticut River watershed has an extraordinary number of dams (Nedeau 2008). Multiple dams within a watershed lead to mussel populations that are isolated and therefore more susceptible to other threats such as pollution and habitat degradation (Nedeau 2008, Strayer et al. 1996). Dams can alter stream temperatures in impoundments and downstream areas (Nedeau 2008), which can have direct impacts on mussel species and/or their host fish species.

Any combination of increased water temperature, lack of water, low dissolved oxygen levels, and concentrated pollutants can create inhospitable stream conditions for freshwater mussels (Nedeau 2008). Dams and culverts constrict channels and can cause these poor stream conditions. More common mussel species have shown a decline in abundance downstream of a road crossing (Levine et al. 2003), although this hasn't been specifically studied for alewife floaters.

Habitat degradation and mortality from increased flooding that destroys mussel beds (Threat Rank: High)

Cycles of extreme episodic flooding and dewatering use cause direct adult mortality by scouring. Extreme fluctuations in flow disrupt mussel life cycles by exposing young mussels to flood-induced damage, mortality, or displacement to potentially unfavorable habitat downstream (Layzer et al. 1993, Richter et al. 1997). Dewatering exposes mussels to heat, desiccation, and opportunistic predators. Predator foraging efficiency increases with decreasing depth.

Road stream crossings are extremely common and can impact habitat conditions and have negative impacts on aquatic life. Undersized culverts can be problematic in times of high flow or storm conditions, where flooding may result. In addition, dam maintenance often requires periodic de-watering and flooding that changes the habitat conditions, which has direct impacts on aquatic species (Nedeau 2008). Flooding typically leads to sedimentation, which can cause mass mortality of mussel beds.

Species impacts from reduction or loss of host fish from degraded habitat and species composition changes (Threat Rank: High)

Freshwater mussels may be threatened by changes in fish species composition. Freshwater mussels spend their initial stage of life (called glochidia) attached to the gills, fins and scales of certain fishes. When the mussel drops off the fish as a juvenile, it lives the rest of its life as a suspension feeder on bacteria and organic matter. If host fish are removed from the environment, it's likely that the dependent mussel species will be extirpated.

The alewife floater was historically extirpated from much of its range due to dams that blocked host fish passage, but installation of fish passageways has restored populations to many of these areas (Nedeau 2008). The three main host fish for alewife floater are the Alewife, blueback herring, and American shad, which are all Species of Greatest Conservation Need in New Hampshire.

Mortality from drawdowns for plant control and waterbody management (Threat Rank: Medium)

Drawdowns and the associated dewatering expose mussels to heat, desiccation, and opportunistic predators. Cycles of extreme dewatering can cause direct adult mortality by scouring. Extreme fluctuations in flow disrupt mussel life cycles by exposing young mussels to flood-induced damage, mortality, or displacement to potentially unfavorable habitat downstream (Layzer et al. 1993, Richter et al. 1997). Predator foraging efficiency increases with decreasing depth.

In New Hampshire, drawdowns typically occur in winter months for maintenance and flood control purposes, and occasionally for aquatic plant control. Drawdowns conducted under certain conditions allow drying and freezing of the sediments that become exposed, causing damage or death to certain aquatic weed species. Following a drawdown event, aquatic vegetation and organisms may exhibit changes in species composition and density by causing direct mortality to species and changes to habitat suitability.

List of Lower Ranking Threats:

Habitat degradation and mortality from streambank stabilization

Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins

Mortality from recreational activities within a stream that can crush mussels

Mortality from the introduction and spread of problematic diseases and parasites

Species impacts from introduced or invasive animals that result in competition, predation, and reduced habitat quality

Habitat impacts from introduced or invasive plants

Habitat impacts and disturbance from development of riparian habitats that increases stream temperature

Habitat degradation and mortality from development of shorelines

Mortality from chemical treatments for nuisance plant control in waterbodies

Actions to benefit this Species or Habitat in NH

Direct swimming and fishing access points away from mussel beds

Primary Threat Addressed: Mortality from recreational activities within a stream that can crush mussels

Specific Threat (IUCN Threat Levels): Human intrusions & disturbance

Objective:
Reduce mortality of mussels from recreational activities within a stream, river or pond.

General Strategy:
As additional information on mussel occurrences is collected and mapped, managers should consider ways to direct recreational activities away from sensitive mussel beds. This can include strategically placing docks, boat launches, parking areas, beaches, and trails away from documented mussel beds.

This will help reduce disturbance to mussels, reduce the potential for direct mortality, and help reduce pollution and sedimentation into mussel habitat. Targeted outreach to fishermen may occur coinciding with this effort, advising that mussels not be cracked open and used for bait. This has been commonly observed during mussel surveys.

Political Location:
Belknap County, Cheshire County, Hillsborough County, Merrimack County, Rockingham County, Sullivan County

Watershed Location:
Lower CT Watershed, Merrimack Watershed, Coastal Watershed

Research and monitoring to evaluate current mussel populations and distribution, and to detect new mussel populations

Objective:
Surveys to detect mussel populations and collect additional land use data in mussel-occupied habitats is needed to better inform management decisions and create conservation plans for the species.

General Strategy:
General distribution surveys should be focused on historic sites and areas where data is lacking. Data on population structure, age class distribution, sex ratio, recruitment, growth rates, and migration is needed, as well as distribution and abundance data on host fish. Studies may also examine the effects of predation and competition. Research is needed to determine the biological response of mussels to artificial flow regimes. Response variables include displacement of juveniles, interference of spawning success, larval release patterns, and host fish attachment success. Villella et al. (2004) used mark-recapture techniques to estimate survival, recruitment, and population growth of freshwater mussels, and this technique could provide valuable demographic information. Currently, much of the information on the condition of mussel populations and habitat is qualitative. Needed are quantitative studies to assess the physical habitat, including sediment type and hydrology, particularly shear, and water quality. As actions are initiated and populations potentially enlarge, mussel sites should be monitored using quantitative, statistically valid methods. Water quality monitoring stations upstream of mussel populations must be established.

Political Location:
Belknap County, Cheshire County, Hillsborough County, Merrimack County, Rockingham County, Sullivan County

Watershed Location:
Lower CT Watershed, Merrimack Watershed, Coastal Watershed

Restoration and management of streams and rivers, with an emphasis on reducing stream fragmentation and restoring natural flow regimes, reducing pollution and riparian disturbance

Primary Threat Addressed: Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Specific Threat (IUCN Threat Levels): Natural system modifications

Objective:

Restoration of fragmented rivers will allow increased dispersal, increasing the overall potential for persistence of mussels. As mussels are established in new habitat, linear range, recolonization, and population size increase.

General Strategy:

Stream fragmentation, and attendant gene flow restrictions, will be reduced by removing barriers such as nonfunctional dams, where feasible, by operating dams at “run of the river” flow regimes, and by rehabilitating degraded river reaches. These measures will increase dispersal and re-colonization of mussels into rehabilitated river reaches. Mussel populations and habitats must be assessed prior to implementation. Mussels found below a dam removal site or rehabilitated river reach may appear within 3 to 5 years, but 10 to 20 years or more may be necessary to establish a viable population. Riparian protection and restoration will be a long-term effort. As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. Pollution may render stream reaches uninhabitable. Destruction and transformation of riparian corridors accelerates erosion, bank sloughing, and runoff leading to increased levels of stream toxins, sediment, and higher stream temperatures. Education should be provided to adjacent landowners about practices that contribute pollutants into nearby rivers, streams, and ponds. Protection of riparian corridors through fee simple land acquisition, conservation easements, and private landowner cooperation will reduce pollution runoff and sedimentation. Properly sized culverts will reduce sedimentation and mass mortality of mussel beds. Surveys are needed to choose long-term, quantitative monitoring sites in occupied rivers and streams to assess patterns of disturbance and pollution. Following riparian disturbance mitigation or efforts to decrease pollution, the initial response of mussel populations should be monitored with qualitative surveying. As mussel populations increase in size, quantitative methods will be used (Strayer and Smith 2003). As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. The number of reproducing subpopulations of mussels will indicate the success of the program.

Political Location:

Belknap County, Cheshire County, Hillsborough County, Merrimack County, Rockingham County, Sullivan County

Watershed Location:

Lower CT Watershed, Merrimack Watershed, Coastal Watershed

References, Data Sources and Authors

Data Sources

Literature review, expert review and consultation, and NH mussel survey data (NH Mussel database 2015, Gabriel 1995).

Distribution data was obtained from unpublished reports, scientific literature, and consultation with experts. The threat assessment was conducted by Michael Marchand (NHFG), Barry Wicklow (St Anselm College), and Susi von Oettingen (USFWS).

Data Quality

NHFG has kept records of all mussel occurrences reported from surveys. NHFG also maintains records of mussel species submitted through the NH Wildlife Sightings online reporting website (http://nhwildlifesightings.unh.edu). Many mussel surveys occurring in New Hampshire were monitoring projects in response to hydroelectric projects or dam impact studies.

The Connecticut River main stem has been surveyed and intermittently monitored for mussels since 1988. Early surveys were conducted by canoe and snorkeling in shallow water, usually within 15 meters of the bank, and later SCUBA surveys were used to survey depths greater than 1.5 meters. The Ashuelot River population downstream of the Surry Mountain flood control dam has been periodically monitored since 1991 (Gabriel and Strayer 1995). In 2004, Nedeau conducted a quantitative survey of dwarf wedgemussels in the Ashuelot River downstream of the Surry Mountain dam, and recorded alewife floater occurrences.
Condition information for alewife floater in New Hampshire is lacking and needs further study.

2015 Authors:
Loren Valliere, NHFG

2005 Authors:
N/A - Species was not listed as SGCN during 2005 WAP

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Eastern Pondmussel

Ligumia nasuta

Photo by Ethan Nedeau

Federal Listing	N/A
State Listing	SC
Global Rank	
State Rank	S1
Regional Status	Very High

Justification (Reason for Concern in NH)

Freshwater mussels are the most imperiled fauna in North America, having suffered steep declines in diversity, abundance, and distribution within the last 200 years (Richter et al. 1997, Master et al. 2000, Lydeard et al. 2004). The Eastern pondmussel is distributed from Ontario, Canada, along the Atlantic coast to Virginia and west into Pennsylvania and New York. It is stable and abundant in many locations and is expanding its range into the Allegheny basin in New York (Strayer and Jirka 1997). Nevertheless, the Freshwater Mussel Subcommittee of the American Fisheries Society's Endangered Species Committee listed it as a species of special concern (Williams et al. 1992), and the Northeast Endangered Species and Wildlife Diversity Technical Committee listed it as a species of regional conservation concern (Therres 1999). It is listed as threatened in New Jersey and endangered in Delaware. In Maine, Massachusetts, and Connecticut it is listed as Special Concern (Nedeau et al. 2000, Nedeau and Victoria 2002). The Eastern pondmussel was ranked as a priority candidate for status under the Committee on the Status of Endangered Wildlife in Canada, COSEWIC (Metcalfe-Smith 1998). In New Hampshire, Eastern pondmussels are found in only 6-7 ponds and rivers in the southeast part of the state, only one of which had high eastern pond mussel numbers detected during recent surveys (Nedeau 2011).

Distribution

The only extant populations of Eastern pondmussels occur in 7 locations in the coastal watershed: Golden Brook near the outflow of Simpson Pond in Windham, Cobbetts Pond in Winhdam, Country Pond in Kingston/Newton, Little Island Pond in Pelham, Wash Pond in Hampstead, Great Pond in Kingston, and Powwow Pond in East Kingston (Clench and Russell 1938, Master 1990, Cutko and Johnson 1992, Nedeau 2009, Nedeau 2011). There is 1 historic record for Keene in the Connecticut River watershed (Clench and Turner 1938). Eastern pondmussels were not found during surveys of the Ashuelot River from Keene to Hinsdale between 2001 and 2004 (Nedeau and Werle 2003) or more recently. However, it is found in the Connecticut River watershed in Massachusetts and Connecticut, and recently in a Connecticut River tributary as far north as Whately, Massachusetts (von Oettingen, USFWS, personal communication).

Habitat

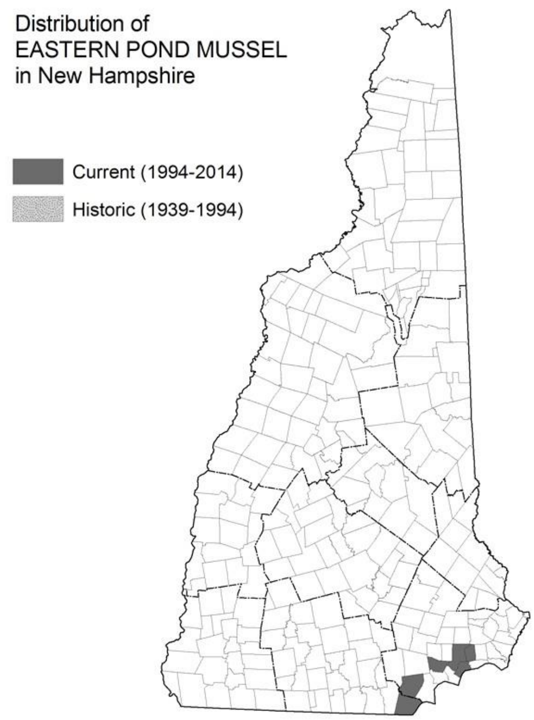
Eastern pondmussels inhabit ponds, lakes, and the low velocity segments of streams and rivers. They are often found in fine sands and other soft sediments (Strayer and Jirka 1997). Mussels are suspension feeders, subsisting on phytoplankton, bacteria, fine particulate matter, and dissolved organic matter (Strayer 2004).

Unionid mussels have complex life cycles. Larvae called glochidia must attach and encyst on a host species – usually a fish – to complete development disperse. Little is known about the reproductive biology of the Eastern pondmussel, and host fish species for glochidia have not been determined. They are long-term brooders, spawning in summer, then releasing glochidia the following spring or summer.

Mantle displays in eastern pondmussel function to attract hosts; papillae line the mantle edge, rhythmic movements of which elicit attacks by potential host fish (Corey 2003). Glochidia are discharged during the attack.

NH Wildlife Action Plan Habitats

- Warmwater Lakes and Ponds
- Warmwater Rivers and Streams



Distribution Map

Current Species and Habitat Condition in New Hampshire

Information that is needed to assess relative abundance, size, density, or recruitment of Eastern pondmussel populations is limited. During surveys targeting eastern pond mussels in southeastern New Hampshire, eastern pond mussels were detected in 6 of 18 waterbodies surveyed, despite apparently suitable habitat being present at some undocumented sites (Nedeau 2011). Wash Pond in Hampstead had the largest number of individual mussels during quantitative surveys, including evidence of recruitment (Nedeau 2011). The species was also documented in lower densities at Cobbetts Pond, Country Pond, Little Island Pond, Great Pond, and Powwow pond. Eastern pond mussels appear to be at low densities in Powwow pond as the species was found in only 2 of 10 plots surveyed (Nedeau 2009, Nedeau 2011). The species was not detected in Golden Brook during 2 recent qualitative surveys sites, despite having been documented there previously (Nedeau 2011).

Population Management Status

There is no population management of the Eastern pondmussel. Additional survey information is needed in order to identify potential conservation opportunities. Asian clams have been documented in Wash pond and Cobbetts Pond and it isn't known what impact the Asian clams or the associated management of Asian clams will have on eastern pond mussels.

Regulatory Protection (for explanations, see Appendix I)

- Fill and Dredge in Wetlands - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Clean Water Act-Section 404

Quality of Habitat

Very little habitat information exists. Some ecological attributes have been measured for occupied sites (Nedeau 2011) but additional monitoring and research is needed to determine population size, density, and recruitment and to assess habitat. Mussel populations in Powwow pond may have been adversely influenced by previous pond management (e.g., drawdowns) as all mussel species had particularly low densities in areas of shallow water (Nedeau 2009). A similar observation was noted for several other ponds (Nedeau 2011). In Wash pond, the most robust eastern pond mussel population known, eastern pond mussels were more common in shallow plots than in deep plots which is consistent with some of the healthiest lake populations of eastern pond mussels in Massachusetts (Nedeau 2011). In all other ponds where eastern pond mussels were detected, mussel densities (all species) were more abundant in deeper water. At Island Pond where eastern pondmussels were not detected, only 1 of 962 mussels occurred in shallow plots suggesting lake drawdowns may be having an impact on mussel populations (Nedeau 2011). The Department of Environmental Service Limnology Bureau monitors water quality at all occurrence locations.

Habitat Protection Status

Sites occupied by eastern pond mussels are public waterbodies. Land conservation of shorelines vary.

Habitat Management Status

There are no habitat management efforts for Eastern pondmussel populations. Asian clams have been documented in Wash Pond and Cobbetts Pond and it isn't known what impact the Asian clams or the associated management of Asian clams will have on eastern pond mussels.

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Mortality from drawdowns for plant control and waterbody management (Threat Rank: High)

Freshwater mussels have variable and generally limited ability to move from rapid drawdowns. Drawdowns during the spring-fall can leave animals vulnerable to desiccation and predation. Drawdowns during the winter can leave animals exposed to freezing conditions resulting in mortality to individuals exposed.

Appendix A: Freshwater Mussels

Mussel populations in Powwow pond may have been adversely influenced by previous pond management (e.g., drawdowns) as all mussel species had particularly low densities in areas of shallow water (Nedeau 2009). A similar observation was noted for several other ponds in southern NH (Nedeau 2011). In Wash Pond, the most robust eastern pond mussel population known, eastern pond mussels were more common in shallow plots than in deep plots which is consistent with some of the healthiest lake populations of eastern pond mussels in Massachusetts (Nedeau 2011). In all other ponds where eastern pondmussels were detected, mussel densities (all species) were more abundant in deeper water. At Island Pond where eastern pondmussels were not detected, only 1 of 962 mussels occurred in shallow plots suggesting lake drawdowns may be having an impact on mussel populations (Nedeau 2011).

Habitat degradation and mortality from development of shorelines (Threat Rank: Medium)

Riparian corridors and adjacent lands are being rapidly developed in New Hampshire. Lakeshores are highly valued for the recreation potential they offer, and lakeside development, docks, and motorized boat traffic degrade habitat, lower water quality, and increase pollution.

Habitat destruction, pollution, and water degradation are considered the most likely causes for the decline of freshwater mussels (Neves 1997, Strayer et al. 2004). The east and south shores of Great Pond are developed, and development continues on the southwest shore of Powwow Pond and around most of Wash Pond. Additional on-site threat evidence needs to be gathered.

Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins (Threat Rank: Medium)

Runoff from municipalities, industrial waste, sewage outfalls, golf courses, and poorly managed agricultural and silvicultural lands degrades water and leads to sedimentation and organic pollution. As rapid development increases, impervious surfaces increase the volume and velocity of runoff, causing erosion, sedimentation, and toxic pollution in streams and rivers. Riparian vegetation is critical in retarding these effects.

Mussels are sensitive to chronic and acute exposure to heavy metals introduced through runoff and atmospheric deposition as well as to toxins, such as chlorine and ammonia (Naimo 1995, Augsburger et al. 2003). Glochidia and juveniles are considered the life stages most sensitive to pollutants. Juveniles burrow into and feed within the sediments; adult mussels may also deposit feed. Low sediment pore-water oxygen and high sediment levels of toxins put infaunal juveniles at risk. Hence, sediments may represent a major contamination pathway for mussels (Newton et al. 2003, Poole and Downing 2004).

The effect of acute pollution on freshwater mussels is well-documented (Neves et al. 1997), and chemical and agricultural waste spills cause direct mussel mortality. For instance, hundreds of mussels, some state and federally listed, were killed by waste runoff from a small farm in the Connecticut River watershed (USFWS 2002). The most widely reported sources of pollution are poor land use practices (Neves et al. 1997, Poole and Downing 2004). The effect of sediment toxicity is not well understood. However, recent toxicity tests for total residual chlorine showed that juvenile mussels are much more sensitive to toxins than glochidia (Cherry et al. 2005).

List of Lower Ranking Threats:

Habitat degradation and mortality from streambank stabilization

Species impacts from reduction or loss of host fish from degraded habitat and species composition changes

Mortality from recreational activities within a stream that can crush mussels

Mortality from the introduction and spread of problematic diseases and parasites

Species impacts from introduced or invasive animals that result in competition, predation, and reduced habitat quality

Habitat impacts from introduced or invasive plants

Habitat degradation and mortality from increased flooding that destroys mussel beds

Habitat impacts (fragmentation) from dams that cause inhospitable stream conditions

Habitat impacts and disturbance from development of riparian habitats that increases stream temperature

Mortality from chemical treatments for nuisance plant control in waterbodies

Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Actions to benefit this Species or Habitat in NH

Monitor mussel populations

Objective:
Monitor the distribution, condition, and threats to eastern pond mussel populations.

General Strategy:
Eastern pond mussels have a limited distribution in New Hampshire. The distribution and condition of populations needs to be assessed periodically to determine species status. Potential threats to the species such as water drawdowns, aquatic herbicide treatments, invasive species, and shoreline development should be monitored for impacts to populations.

Political Location:
Hillsborough County, Rockingham County

Watershed Location:
Merrimack Watershed

Review projects that have potential to harm eastern pondmussel populations

Primary Threat Addressed: Habitat degradation and mortality from development of shorelines

Specific Threat (IUCN Threat Levels): Residential & commercial development

Objective:
Review projects that have potential to harm eastern pondmussel populations and develop guidelines for minimizing impacts.

General Strategy:
Eastern pond mussels are listed as special concern in New Hampshire and the species warrants consideration as endangered or threatened. As such, NHFG will review any proposed activities (residential, commercial, water level management, dam maintenance, lake management, recreation, herbicide applications, dam licensing) that has the potential to harm eastern pond mussels. NHFG will work with applicants and permitting staff from other state and federal agencies, primarily Department of Environmental Services (Wetlands Bureau) and U.S. Army Corps of Engineers, to

identify avoidance and minimization conditions for permit applicants. NHFG will develop guidelines for consistent and effective review of projects potentially impacting eastern pond mussels. Guidelines will consider scenarios where impacts should be avoided and scenarios where impact minimization of mitigation may be appropriate. Pre- and post- construction monitoring of eastern pond mussels and associated habitat should be considered as a component of project review.

Political Location:
Hillsborough County, Rockingham County

Watershed Location:
Merrimack Watershed

References, Data Sources and Authors

Data Sources
Information on the life history, habitat requirements, and distribution of Eastern pondmussel was obtained from the scientific literature, unpublished reports, databases, and expert consultation. Two targeted surveys in New Hampshire (Nedeau 2009, Nedeau 2011) provided all distribution and condition information for the previous 10 years.
The threat assessment was conducted by Michael Marchand, Barry Wicklow, and Susi von Oettingen.

Data Quality
Information of the Eastern pondmussel in New Hampshire is sparse, and data are limited to occurrence locations: Wash pond Hampstead, 9 living individuals, 1992; Golden Brook near the outflow of Simpson Pond, Windham, 1 individual, 1990; Powwow Pond, East Kingston, 1 individual, 2004; Great pond, Kingston, 1 live individual in 2 hours of searching on the southwestern shore, 1992. In 2000, on the eastern shore of Great Pond several dozen individuals were observed embedded in fine sand (von Oettingen, USFWS, personal observations).
Quantitiatve data on the condition of Eastern pondmussel populations is limited.

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Eastern Pearlshell

Margaritifera margaritifera

Federal Listing	N/A
State Listing	SGCN
Global Rank	G4
State Rank	S3
Regional Status	High

Photo by Ethan Nedeau

Justification (Reason for Concern in NH)

Freshwater mussels are the most imperiled fauna in North America, having suffered steep declines in diversity, abundance, and distribution within the last 200 years (Richter et al. 1997, Master et al. 2000, Lydeard et al. 2004). Eastern pearlshell populations are vulnerable to extirpation or extinction in New Hampshire. They are listed as a Regional Species of Greatest Conservation Need and are of high regional concern. Because their populations are closely linked to their host fish, coupled with dependability on clean, coldwater habitats, their vulnerability is increased. Where these conditions exist in New Hampshire, Vermont, and elsewhere in the northeast, eastern pearlshell populations are still rare and often absent (Nadeau 2008). This mussel species also has shown high intolerance of eutrophication and acidification (Nadeau 2008), where pH near or below 5.5 was found capable of decimating an eastern pearlshell population. The existence of dams, forest cutting and land clearing in northern upland habitats has probably restricted eastern pearlshell distribution (Nadeau 2008), and likely resulted in local extirpations historically.

Distribution

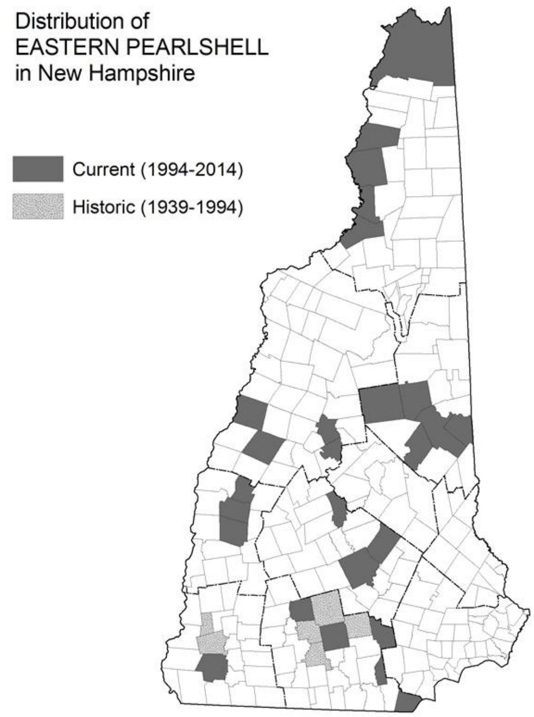
The Eastern pearlshell range stretches from Pennsylvania and New York up into Canada, and is the only North American mussel species that can be found on another continent, extending to Scandinavia and northern Europe (Nadeau 2008). In New Hampshire, Eastern pearlshell is found mainly in the Connecticut and Merrimack River watersheds. Populations appear to be very scattered throughout New Hampshire.

Habitat

Eastern pearshell is found in cold streams or rivers that support salmon or trout populations. It prefers sand, gravel, and cobble substrates. As part of its life cycle, all mussel species must attach to the fins or gills of a fish in order to grow and reach their next life stage, where they sink to the bottom of the waterbody and spend the rest of their lives. The eastern pearshell is only known to attach to Atlantic salmon (*Salmo salar*), and brook (*Salvelinus fontinalis*), rainbow (*Oncorhynchus mykiss*), and brown (*Salmo trutta*) trout.

NH Wildlife Action Plan Habitats

- Coldwater Rivers and Streams



Distribution Map

Current Species and Habitat Condition in New Hampshire

Because eastern pearlshell is a long-lived species (over 100 years), it is difficult to detect trends in populations without an established long-term monitoring program, which does not currently exist (Nedeau et al 2000). In other northeast states, there has been little evidence of reproductive success in recent years (Nedeau et al 2000). It's believed that eutrophication, acidity, sedimentation, and warmer water temperatures limit populations of pearlshell (Nedeau 2008). The most robust populations, with densities exceeding 200 animals per square meter, exist in just a few areas of Massachusetts and Connecticut (Nadeau 2008). Populations numbering over 50 individuals have been documented between Ossipee Lake and Lake Winnipesaukee. New Hampshire-specific data is lacking.

Population Management Status

There is little management particularly for eastern pearlshell in New Hampshire. NHFG works to restore fish passage in rivers and streams throughout the state, which greatly benefits the pearlshell by supporting its host fish. Historically, surveys have focused on mussel species that are more endangered, and thus have not adequately described the habitat, distribution and abundance of pearlshell in the state (Nedeau 2008).

Regulatory Protection (for explanations, see Appendix I)

- Fill and Dredge in Wetlands - NHDES

- Rivers Management and Protection Program - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Clean Water Act-Section 404

Quality of Habitat

Very little habitat information exists. Most pearlshell populations or site occurrences have not been assessed in many years. Ecological attributes have not been measured, and research is needed to determine population size, density, and recruitment and to assess habitat. NH DES conducted a new assessment of water quality in the Connecticut River mainstem in 2004. Of particular importance to mussel species, the assessment suggested that sedimentation and turbidity may be the greatest threat to water quality, particularly in the northern part of the state (Headwater CRJC 2009). In Cheshire county, sudden water releases from the Ball Mountain and Townsend Dams for whitewater recreation contribute to sedimentation and greatly affect the natural communities downstream (Wantastiquet CRJC 2009).

Habitat Protection Status

Habitat protection is variable among stream reaches and regions of the state. Some protection of riparian areas is provided by the NH Comprehensive Shoreland Protection Act (NHDES).

Habitat Management Status

Currently there are no management or restoration efforts targeting pearlshell habitat in the state. However, the Nature Conservancy, the Monadnock Conservancy, the Society for the Protection of New Hampshire Forests, and the Southwestern Regional Planning Commission have developed a conservation plan for the Ashuelot River Watershed (Zankel 2004). The Connecticut River Joint Commission published a Connecticut River Management Plan in 2008 (http://crjc.org/pdffiles/WATER.final.pdf).

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat degradation and mortality from increased flooding that destroys mussel beds (Threat Rank: High)

Cycles of extreme episodic flooding and dewatering can cause direct adult mortality by scouring. Extreme fluctuations in flow disrupt mussel life cycles by exposing young mussels to flood-induced damage, mortality, or displacement to potentially unfavorable habitat downstream (Layzer et al. 1993, Richter et al. 1997). Dewatering exposes mussels to heat, desiccation, and opportunistic predators. Predator foraging efficiency increases with decreasing depth.

Undersized culverts placed at road stream crossings can be problematic in times of high flow or storm conditions, where flooding may result. Road stream crossings are extremely common and can alter habitat conditions, and thus have negative impacts on aquatic life. In addition, dam maintenance often requires periodic de-watering and flooding that changes the habitat conditions, which has direct impacts on aquatic species (Nedeau 2008). Flooding typically leads to sedimentation, which can cause mass mortality of mussel beds.

Habitat impacts and disturbance from development of riparian habitats that increases stream temperature (Threat Rank: Medium)

Riparian corridors and adjacent lands are being rapidly developed in New Hampshire. Shorelines are highly valued for the recreation potential they offer, and associated structures (such as docks) and motorized boat traffic degrade habitat, lower water quality, and increase pollution.

As development increases and riparian vegetation buffers decrease, the effects of pollution on the biota in rivers and tributaries will increase. Runoff from municipalities, industrial waste, sewage outfalls, golf courses, poor agricultural and silviculture land contributes to sedimentation, organic pollution, and general water quality degradation (Poole and Downing 2004). The introduction of sediment and removal of shoreline plants that is often a remnant of riparian development can decrease oxygen levels, increase turbidity and change temperature levels in surface waters (NH DES 2005). Young mussels are the most sensitive to pollutants because they burrow into and feed within the sediments. Thus sediment, particularly when low in pore-water oxygen and high in toxins, may be a major contamination pathway for mussels (Newton et al. 2003, Poole and Downing 2004).

The effect of acute pollution on freshwater mussels is well documented (Neves et al. 1997), including negative impacts from thermal pollution. Habitat destruction, pollution, and water degradation are considered the most likely causes for the decline of freshwater mussels (Neves 1997, Strayer et al. 2004).

Dams can alter stream temperatures in impoundments and downstream areas (Nedeau 2008), which can have direct impacts on mussel species and/or their host fish species. The most widely reported sources of pollution are poor agriculture practices (Neves et al. 1997, Poole and Downing 2004). Run-off from these sites and similar sites can add large amounts of warm water into an aquatic system, causing problematic low oxygen levels and bringing with it other pollutants. Although pearlshell-specific evidence has not been documented in New Hampshire, similar freshwater mussel species have been better studied. For example, 20 dwarf wedgemussels and hundreds of other mussel species were killed by waste runoff from a small farm in the Connecticut River Watershed (USFWS 2002).

List of Lower Ranking Threats:

Habitat degradation and mortality from streambank stabilization

Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins

Species impacts from reduction or loss of host fish from degraded habitat and species composition changes

Mortality from recreational activities within a stream that can crush mussels

Mortality from the introduction and spread of problematic diseases and parasites

Species impacts from introduced or invasive animals that result in competition, predation, and reduced habitat quality

Habitat impacts from introduced or invasive plants

Habitat impacts (fragmentation) from dams that cause inhospitable stream conditions

Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Actions to benefit this Species or Habitat in NH

Restoration and management of streams and rivers, with an emphasis on reducing stream fragmentation and restoring natural flow regimes, reducing pollution and riparian disturbance.

Primary Threat Addressed: Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Specific Threat (IUCN Threat Levels): Natural system modifications

Objective:
Restoration of fragmented rivers will allow increased dispersal, increasing the overall potential for persistence of mussels. As mussels are established in new habitat, linear range, re-colonization, and population size increase.

General Strategy:
Stream fragmentation, and attendant gene flow restrictions, will be reduced by removing barriers such as nonfunctional dams, where feasible, by operating dams at "run of the river" flow regimes, and by rehabilitating degraded river reaches. These measures will increase dispersal and re-colonization of mussels into rehabilitated river reaches. Mussel populations and habitats must be assessed prior to implementation. Mussels found below a dam removal site or rehabilitated river reach may appear within 3 to 5 years, but 10 to 20 years or more may be necessary to establish a viable population. Riparian protection and restoration will be a long-term effort. As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. Pollution may render stream reaches uninhabitable. Destruction and transformation of riparian corridors accelerates erosion, bank sloughing, and runoff leading to increased levels of stream toxins, sediment, and higher stream temperatures. Education should be provided to adjacent landowners about practices that contribute pollutants into nearby rivers, streams, and ponds. Protection of riparian corridors through fee simple land acquisition, conservation easements, and private landowner cooperation will reduce pollution runoff and sedimentation. Properly sized culverts will reduce sedimentation and mass mortality of mussel beds. Surveys are needed to choose long-term, quantitative monitoring sites in occupied rivers and streams to assess patterns of disturbance and pollution. Following riparian disturbance mitigation or efforts to decrease pollution, the initial response of mussel populations should be monitored with qualitative surveying. As mussel populations increase in size, quantitative methods will be used (Strayer and Smith 2003). As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. The number of reproducing subpopulations of mussels will indicate the success of the program.

Political Location:
Carroll County, Cheshire County, Coos County, Grafton County, Hillsborough County, Merrimack County, Sullivan County

Watershed Location:
Androscoggin-Saco Watershed, Upper CT Watershed, Middle CT Watershed, Lower CT Watershed, Merrimack Watershed

Direct swimming and fishing access points away from mussel beds

Primary Threat Addressed: Mortality from recreational activities within a stream that can crush mussels

Specific Threat (IUCN Threat Levels): Human intrusions & disturbance

Objective:
Reduce mortality of mussels from recreational activities within a stream or river.

General Strategy:
As additional information on mussel occurrences is collected and mapped, managers should consider ways to direct recreational activities away from sensitive mussel beds. This can include strategically placing docks, boat launches, parking areas, beaches, and trails away from documented mussel beds. This will help reduce disturbance to mussels, reduce the potential for direct mortality, and help reduce pollution and sedimentation into mussel habitat. Targeted outreach to fishermen may occur coinciding with this effort, advising that mussels not be cracked open and used for bait. This has been commonly observed during mussel surveys.

Political Location:
Carroll County, Cheshire County, Coos County, Grafton County, Hillsborough County, Merrimack County, Sullivan County

Watershed Location:
Androscoggin-Saco Watershed, Upper CT Watershed, Middle CT Watershed, Lower CT Watershed, Merrimack Watershed

Monitor mussel populations

Objective:
Conduct surveys to detect mussel populations and collect additional land use data in mussel-occupied habitats is needed to better inform management decisions and create conservation plans for the species.

General Strategy:
General distribution surveys should be focused on historic sites and areas where data is lacking. Data on population structure, age class distribution, sex ratio, recruitment, growth rates, and migration is needed, as well as distribution and abundance data on host fish. Studies may also examine the effects of predation and competition. Research is needed to determine the biological response of mussels to artificial flow regimes. Response variables include displacement of juveniles, interference of spawning success, larval release patterns, and host fish attachment success. Villella et al. used mark-recapture techniques to estimate survival, recruitment, and population growth of freshwater mussels (Villella et al. 2004), and this technique could provide valuable demographic information. Currently, much of the information on the condition of mussel populations and habitat is qualitative. Needed are quantitative studies to assess the physical habitat, including sediment type and hydrology, particularly shear, and water quality. As actions are initiated and populations potentially enlarge, mussel sites should be monitored using quantitative, statistically valid methods. Water quality monitoring stations upstream of mussel populations must be established.

Political Location:
Carroll County, Cheshire County, Coos County, Grafton County, Hillsborough County, Merrimack County, Sullivan County

Watershed Location:
Androscoggin-Saco Watershed, Upper CT Watershed, Middle CT Watershed, Lower CT Watershed, Merrimack Watershed

References, Data Sources and Authors

Data Sources

Literature review, expert review and consultation, and NH database information (Gabriel 1995). Distribution data was obtained from unpublished reports, scientific literature, and consultation with experts. Threat assessment was conducted by Mike Marchand (NHFG), Barry Wicklow (St Anselm College), and Susi von Oettingen (USFWS).

Data Quality

NHFG has kept records of all mussel occurrences reported from surveys. NHFG also maintains records of mussel species submitted through the NH Wildlife Sightings online reporting website (http://nhwildlifesightings.unh.edu). Many mussel surveys occurring in New Hampshire were monitoring projects in response to hydroelectric projects or dam impact studies. Most mussel studies are focused on endangered mussel species, but typically record all mussel species observed. New Hampshire has over 180 documented sites of eastern pearlshell in the state.

The Connecticut River main stem has been surveyed and intermittently monitored for mussels since 1988. Early surveys were conducted by canoe and snorkeling in shallow water, usually within 15 meters of the bank, and later SCUBA surveys were used to survey depths greater than 1.5 meters. The Ashuelot River downstream of the Surry Mountain flood control dam has been periodically monitored since 1991 (Gabriel and Strayer 1995).
Much of the information on the condition of eastern pearlshell populations and habitat is qualitative.

2015 Authors:
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2005 Authors:
N/A - Species was not listed as SGCN during 2005 WAP

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Creeper

Strophitus undulatus

Federal Listing	N/A
State Listing	SGCN
Global Rank	N/A
State Rank	S3
Regional Status	

Photo by Ethan Nedeau

Justification (Reason for Concern in NH)

Freshwater mussels are the most imperiled fauna in North America, having suffered steep declines in diversity, abundance, and distribution within the last 200 years (Richter et al. 1997, Master et al. 2000, Lydeard et al. 2004). Creeper populations are vulnerable to extirpation or extinction in New Hampshire, and are a species of special concern in Maine and Massachusetts. Although they occur where their habitat requirements are met throughout the region, they occur at a low abundance throughout their range. Mussel species are especially sensitive to pollutants, oxygen levels and temperature levels, making them important indicators of waterbody health.

Distribution

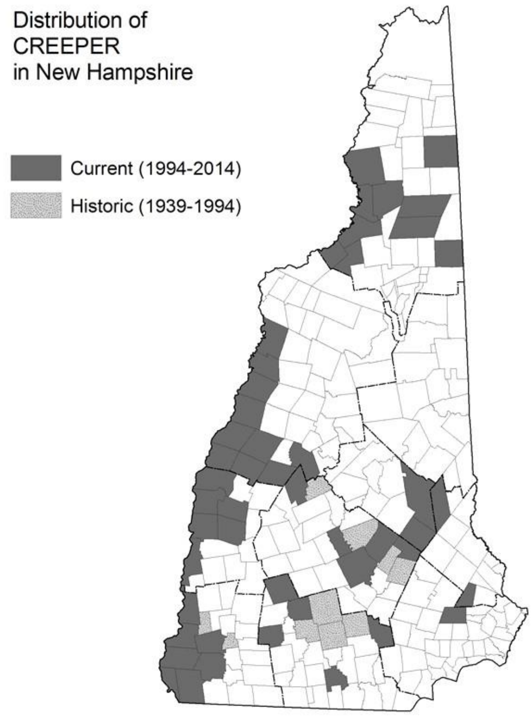
Creepers can be found in most major watersheds in the northeast, although are never common (Nedeau et al. 2000). The creeper can use a broad range of host fish to complete its life cycle, and is the only mussel species known to also use amphibians for this purpose (Nedeau 2008), allowing it to persist in a broader range of watersheds than other more host-specific species. The species has been documented from the Massachusetts border to as far north as Stratford and Errol. Creepers are found in stream and river habitats throughout New Hampshire. New Hampshire has over 197 documented sites where creepers occur. Documented occupied watersheds include the Connecticut River and tributaries, Upper Ammonoosuc and Androscoggin rivers in the north, and Lakes Region rivers in central NH. There are few documented records in the Great Bay area and the Contoocook, Merrimack, and Souhegan river stretches.

Habitat

Creepers are a freshwater mussel that can be found in small streams and rivers with sand, cobble, or gravel substrates. It seems to prefer low to moderate velocity river stretches, and may occur in small impoundments that retain at least some flow (Nedeau 2008). As part of its life cycle, all mussel species must attach to the fins or gills of a fish in order to grow and reach their next life stage, where they sink to the bottom of the waterbody and spend the rest of their lives. The creeper is known to attach to largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), fathead minnow (*Pimephales promelas*), fallfish (*Semotilus corporalis*), golden shiner (*Notemigonus crysoleucas*), and bluegill (*Lepomis macrochirus*), and thus will occur in habitats where these fish are commonly found.

NH Wildlife Action Plan Habitats

- Large Warmwater Rivers
- Warmwater Rivers and Streams
- Coldwater Rivers and Streams
- Lakes and Ponds with Coldwater Habitat
- Warmwater Lakes and Ponds



Distribution Map

Current Species and Habitat Condition in New Hampshire

Although the creeper is widely distributed in the state, it seems to be rarely abundant. In Maine, fewer than ten individuals were typically found at any given site, and long-term viability of these small populations is of concern (Nedeau et al. 2000). In other parts of the northeast, large watersheds that support robust populations of many other mussel species have documented very few live creepers, suggesting increased rarity of creeper populations throughout their range (Nedeau 2008). The most abundant populations in New Hampshire seem to be in the Ashuelot River, with many sites documenting over 10 individuals, and a few sites with over 100 individuals (NH Survey Data).

Population Management Status

There is little to no management particularly for creeper populations in New Hampshire. Historically, surveys have focused on mussel species that are more endangered, and thus have not adequately described the habitat, distribution and abundance of creepers in the state (Nedeau 2008).

Regulatory Protection (for explanations, see Appendix I)

- Fill and Dredge in Wetlands - NHDES
- Rivers Management and Protection Program - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Clean Water Act-Section 404

Quality of Habitat

Very little habitat information exists. Most creeper populations or site occurrences have not been assessed in many years. Ecological attributes have not been measured, and research is needed to determine population size, density, and recruitment and to assess habitat. NH DES conducted a new assessment of water quality in the Connecticut River mainstem in 2004. Of particular importance to mussel species, the assessment suggested that sedimentation and turbidity may be the greatest threat to water quality, particularly in the northern part of the state (Headwater CRJC 2009). In Cheshire county, where creeper densities appear highest, sudden water releases from the Ball Mountain and Townsend Dams for whitewater recreation contribute to sedimentation and greatly affect the natural communities downstream (Wantastiquet CRJC 2009).

Habitat Protection Status

Habitat protection is variable among stream reaches and regions of the state. Some protection of riparian areas is provided by the NH Shoreland Protection Act (NHDES).

Habitat Management Status

Currently there are no management or restoration efforts targeting creeper habitat in the state. However, the Nature Conservancy, the Monadnock Conservancy, the Society for the Protection of New Hampshire Forests, and the Southwestern Regional Planning Commission have developed a conservation plan for the Ashuelot River Watershed (Zankel 2004). The Connecticut River Joint Commission published a Connecticut River Management Plan in 2008 (http://crjc.org/pdffiles/WATER.final.pdf).

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat impacts (fragmentation) from dams that cause inhospitable stream conditions (Threat Rank: Medium)

Fragmentation from dams or undersized stream crossings causes many issues for mussel populations. The presence of dams changes how water flows and transports sediment through an aquatic system (Nedeau 2008). Dams can produce low flow conditions which reduce the availability of mussel habitat and can increase vulnerability to other threats.

The Connecticut River watershed has an extraordinary number of dams (Nedeau 2008). Multiple dams within a watershed lead to mussel populations that are isolated and therefore more susceptible to other threats such as pollution and habitat degradation (Nedeau 2008, Strayer et al. 1996). Dams can alter stream temperatures in impoundments and downstream areas (Nedeau 2008), which can have direct impacts on mussel species and/or their host fish species.

Any combination of increased water temperature, lack of water, low dissolved oxygen levels, and concentrated pollutants can create inhospitable stream conditions for freshwater mussels (Nedeau

2008). Dams and culverts constrict channels and can cause these poor stream conditions. Some mussel species have shown a decline in abundance downstream of a road crossing (Levine et al. 2003), although this hasn't been specifically studied for creepers.

Habitat degradation and mortality from increased flooding that destroys mussel beds (Threat Rank: Medium)

Cycles of extreme episodic flooding and dewatering can cause direct adult mortality by scouring. Extreme fluctuations in flow disrupt mussel life cycles by exposing young mussels to flood-induced damage, mortality, or displacement to potentially unfavorable habitat downstream (Layzer et al. 1993, Richter et al. 1997). Dewatering exposes mussels to heat, desiccation, and opportunistic predators. Predator foraging efficiency increases with decreasing depth.

Undersized culverts placed at road stream crossings can be problematic in times of high flow or storm conditions, where flooding may result. Road stream crossings are extremely common and can alter habitat conditions, and thus have negative impacts on aquatic life. In addition, dam maintenance often requires periodic de-watering and flooding that changes the habitat conditions, which has direct impacts on aquatic species (Nedeau 2008). Flooding typically leads to sedimentation, which can cause mass mortality of mussel beds.

List of Lower Ranking Threats:

Habitat degradation and mortality from streambank stabilization

Habitat degradation and mortality from impervious surface run-off that contains excess nutrients, sediment and toxins

Species impacts from reduction or loss of host fish from degraded habitat and species composition changes

Mortality from recreational activities within a stream that can crush mussels

Mortality from the introduction and spread of problematic diseases and parasites

Species impacts from introduced or invasive animals that result in competition, predation, and reduced habitat quality

Habitat impacts from introduced or invasive plants

Habitat impacts and disturbance from development of riparian habitats that increases stream temperature

Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Actions to benefit this Species or Habitat in NH

Restoration and management of streams and rivers, with an emphasis on reducing stream fragmentation and restoring natural flow regimes, reducing pollution and riparian disturbance.

Primary Threat Addressed: Habitat degradation and mortality from dams that alter hydrology upstream and downstream

Specific Threat (IUCN Threat Levels): Natural system modifications

Appendix A: Freshwater Mussels

Objective:

Restoration of fragmented rivers will allow increased dispersal, increasing the overall potential for persistence of mussels. As mussels are established in new habitat, linear range, recolonization, and population size increase.

General Strategy:

Stream fragmentation, and attendant gene flow restrictions, will be reduced by removing barriers such as nonfunctional dams, where feasible, by operating dams at "run of the river" flow regimes, and by rehabilitating degraded river reaches. These measures will increase dispersal and recolonization of mussels into rehabilitated river reaches. Mussel populations and habitats must be assessed prior to implementation. Mussels found below a dam removal site or rehabilitated river reach may appear within 3 to 5 years, but 10 to 20 years or more may be necessary to establish a viable population. Riparian protection and restoration will be a long-term effort. As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. Pollution may render stream reaches uninhabitable. Destruction and transformation of riparian corridors accelerates erosion, bank sloughing, and runoff leading to increased levels of stream toxins, sediment, and higher stream temperatures. Education should be provided to adjacent landowners about practices that contribute pollutants into nearby rivers, streams, and ponds. Protection of riparian corridors through fee simple land acquisition, conservation easements, and private landowner cooperation will reduce pollution runoff and sedimentation. Properly sized culverts will reduce sedimentation and mass mortality of mussel beds. Surveys are needed to choose long-term, quantitative monitoring sites in occupied rivers and streams to assess patterns of disturbance and pollution. Following riparian disturbance mitigation or efforts to decrease pollution, the initial response of mussel populations should be monitored with qualitative surveying. As mussel populations increase in size, quantitative methods will be used (Strayer and Smith 2003). As additional water quality and habitat assessment information is collected, efforts can be redirected or expanded. The number of reproducing subpopulations of mussels will indicate the success of the program.

Political Location:

Statewide

Watershed Location:

Statewide

Direct swimming and fishing access points away from mussel beds

Primary Threat Addressed: Mortality from recreational activities within a stream that can crush mussels

Specific Threat (IUCN Threat Levels): Human intrusions & disturbance

Objective:

Reduce mortality of mussels from recreational activities within a stream or river.

General Strategy:

As additional information on mussel occurrences is collected and mapped, managers should consider ways to direct recreational activities away from sensitive mussel beds. This can include strategically placing docks, boat launches, parking areas, beaches, and trails away from documented mussel beds. This will help reduce disturbance to mussels, reduce the potential for direct mortality, and help reduce pollution and sedimentation into mussel habitat. Targeted outreach to fishermen may occur coinciding with this effort, advising that mussels not be cracked open and used for bait. This has been commonly observed during mussel surveys.

Political Location:
Statewide

Watershed Location:
Statewide

Monitor status of mussel populations

Objective:
Conduct surveys to detect mussel populations and collect additional land use data in mussel-occupied habitats is needed to better inform management decisions and create conservation plans for the species.

General Strategy:
General distribution surveys should be focused on historic sites and areas where data is lacking. Data on population structure, age class distribution, sex ratio, recruitment, growth rates, and migration is needed, as well as distribution and abundance data on host fish. Studies may also examine the effects of predation and competition. Research is needed to determine the biological response of mussels to artificial flow regimes. Response variables include displacement of juveniles, interference of spawning success, larval release patterns, and host fish attachment success. Villella et al. used mark-recapture techniques to estimate survival, recruitment, and population growth of freshwater mussels (Villella et al. 2004), and this technique could provide valuable demographic information. Currently, much of the information on the condition of mussel populations and habitat is qualitative. Needed are quantitative studies to assess the physical habitat, including sediment type and hydrology, particularly shear, and water quality. As actions are initiated and populations potentially enlarge, mussel sites should be monitored using quantitative, statistically valid methods. Water quality monitoring stations upstream of mussel populations must be established.

Political Location:
Belknap County, Cheshire County, Coos County, Grafton County, Hillsborough County, Merrimack County, Rockingham County, Strafford County, Sullivan County

Watershed Location:
Statewide

References, Data Sources and Authors

Data Sources
Literature review, expert review and consultation, and NH mussel survey data (Gabriel 1995). Distribution data was obtained from unpublished reports, scientific literature, and consultation with experts. The threat assessment was conducted by Michael Marchand (NHFG), Barry Wicklow (St Anselm College), and Susi von Oettingen (USFWS).

Data Quality
NHFG has kept records of all mussel occurrences reported from surveys. NHFG also maintains records of mussel species submitted through the NH Wildlife Sightings online reporting website (http://nhwildlifesightings.unh.edu). Many mussel surveys occurring in New Hampshire are monitoring efforts in response to hydroelectric projects or dam impact studies. Most mussel studies

are focused on endangered mussel species, but usually record and report all mussel species observed. The Connecticut River main stem has been surveyed and intermittently monitored for mussels since 1988. Early surveys were conducted by canoe and snorkeling in shallow water, usually within 15 meters of the bank, and later SCUBA surveys were used to survey depths greater than 1.5 meters. Condition information for creeper in New Hampshire is lacking and needs further study.

2015 Authors:
Loren Valliere, NHFG

2005 Authors:
N/A. Species was not listed as SGCN during 2005 WAP.

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