Dwarf Wedgemussel

Alasmidonta heterodon

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
New England Field Office
Concord, NH

5-YEAR REVIEW

Species reviewed: Dwarf wedgemussel (*Alasmidonta heterodon*)

TABLE OF CONTENTS

5-YEAR REVIEW
Dwarf wedgemussel / *Alasmidonta heterodon*

1.0 GENERAL INFORMATION

1.1 Reviewers

Technical reviewers:
Barry Wicklow, St. Anselm's College, 603-641-7160, BWicklow@anselm.edu
Dick Neves, Virginia Polytechnic and State University, 540-231-5927, mussel@vt.edu; William Lellis, USGS, WLellis@USGS.gov

Lead Regional or Headquarters Office:
Region 5, Ms. Mary Parkin, (617) 876-6173, Mary_Parkin@fws.gov

Lead Field Office:
New England Field Office, Ms. Susanna von Oettingen, (603) 223-2541, ext. 22, Susi_vonOettingen@fws.gov

Cooperating Field Offices:
New York Field Office, Ms. Robyn Niver, (607) 753-9334, Robyn_Niver@fws.gov
Pennsylvania Field Office, Mr. Robert Anderson, (814) 234-4090, Robert_M_Anderson@fws.gov
New Jersey Field Office, Ms. Annette Scherer, (609) 646-9310, Annette_Scherer@fws.gov
Chesapeake Bay Field Office, Mr. Andy Moser, 410-573-4537, Andy_Moser@fws.gov
Virginia Field Office, Mr. Mike Drummond, (804) 693-6694, Mike_Drummond@fws.gov; Ms. Cindy Kane, (804) 693-6694, Cindy_Kane@fws.gov
Asheville Field Office, Mr. John Fridell, (828) 258-3939, John_Fridell@fws.gov

Cooperating Regional Office: Region 4, Kelly Bibb, 404-679-7132

1.2 Methodology used to complete the review

The dwarf wedgemussel 5-year review was conducted as an individual effort by the recovery lead biologist for the dwarf wedgemussel (DWM). All Service field office and state natural resource agency personnel responsible for the recovery of this species were contacted for up-to-date information on occurrences, threats and recovery activities. USGS biologists and other academics conducting research on the DWM were also contacted. The current recovery plan is 14 years out of date; therefore, the information

that was provided by the state and Service biologists, primarily as reports and other gray literature, is the principal basis for this status review.

1.3 Background

1.3.1 FR Notice citation announcing initiation of this review:

71 FR 20178 (April 21, 2006): Notice of Endangered and Threatened Wildlife and Plants; Initiation of a 5-Year Review of Nine Listed Species: the Purple Bean (*Villosa perpurpurea*), Clubshell (*Pleurobema clava*), Northern Red-bellied Cooter (*Pseudemys rubriventris bangsi*), Roanoke Logperch (*Percina rex*), Swamp Pink (*Helonias bullata*), Northern Riffleshell (*Epioblasma torulosa rangiana*), Flat-spired Threetoothed Land Snail (*Triodopsis platysayoides*), Puritan Tiger Beetle (*Cicindela puritana*), and Dwarf Wedgemussel (*Alasmidonta heterodon*).

1.3.2 Listing history

FR notice: Determination of Endangered Status for the Dwarf Wedge Mussel; 55 FR 9447 9451
Date listed: March 14, 1990
Entity listed: Species
Classification: Endangered

1.3.3 Associated rulemakings: None

1.3.4 Review History:

The DWM was included in a cursory 5-year review conducted for all species listed before 1991 (56 FR 56882). No other 5-year reviews have been conducted for this species.

1.3.5 Species' Recovery Priority Number at start of 5-year review:

The RPN for the dwarf wedgemussel is 5, indicative of a species with a high degree of threat and low recovery potential.

1.3.6 Recovery Plan or Outline

Name of plan: Dwarf wedge mussel (*Alasmidonta heterodon*) recovery plan
Date issued: February 8, 1993

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate? No, the species is an invertebrate; therefore, the DPS policy is not applicable.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria? Yes.

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat? No.

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria? No.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

1993 Recovery Plan Criteria

In order to reclassify the DWM as threatened from endangered, this criterion must be met:

1. The following populations of the DWM must be shown to be viable (a population containing a sufficient number of reproducing adults to maintain genetic variability, and annual recruitment is adequate to maintain a stable population): Mainstem Connecticut River (NH/VT), Ashuelot River (NH), Neversink River (NY), Upper Tar River (NC), Little River (NC), Swift Creek (NC), Turkey Creek (NC), and six other rivers/creeks representative of the species' range.

   This criterion has been partially met.
   Viable populations have been found in the mainstem Connecticut River and Ashuelot River.

In order to remove the DWM from the federal list of threatened and endangered species, the following criteria must be met:

2. At least 10 of the rivers/creeks in Criterion 1 must support a widely dispersed viable population so that a single catastrophic event in a given river will be unlikely to result in the total loss of that river's population.

3. The rivers in Criterion 2 should be distributed throughout the species' current range with at least two in New England (NH,VT,MA,CT), one in New York, and four south of Pennsylvania.

4. All populations referred to in Criteria 1 through 3 must be protected from present and foreseeable anthropogenic and natural threats that could interfere with their survival.

These criteria have not been met, and in some cases have become irrelevant, as discussed below:

Since the Recovery Plan was released, the definition of "site" or "occurrence" is no longer clear. Some of this is due to the discovery of large, contiguous stretches of river hosting scattered occurrences of dwarf wedgemussels that function as one "population". For example, three large (10+ miles), continuous stretches of the main stem of the Connecticut River in New Hampshire should replace the stretch referred to in the Recovery Plan as containing a few "occurrences". Specific sites or stretches of river identified in the Recovery Plan as critical to recovery and essential for maintaining viable populations no longer coincide with new location information. Furthermore, the criteria are vague in quantifying how large or inclusive the viable populations need to be, how separate from other populations (in order to ameliorate catastrophic events), and what constitutes protection of the habitat and populations from present and foreseeable threats. The Tar River watershed appears to be stable; however, the criterion identifying the Upper Tar River as a site for conservation does not specify if this includes the Upper Tar River watershed or merely the single site documented in the Upper Tar River (Appendix 1).

It is likely that the criteria developed for the 1993 Recovery Plan may never be achieved. Criterion 1 will most likely never be met, based on recent development activity within the Neuse River watershed and predicted outcomes of reservoir construction projects on tributaries containing dwarf wedgemussel populations. In 2006, the Swift Creek (part of the Neuse River watershed) was the focus of a biological opinion on the construction of a water treatment facility (USFWS 2006). The already diminishing population of the DWM in this watershed may be further impacted in the future due to increased development pressure as a result of the expanded water treatment facility if protective zoning ordinances are not strictly implemented.

Recent survey data for the Little River (another tributary of the Neuse River) indicate that there are few if any individuals remaining in the one known site. In view of the fact that the DWM populations in these two rivers are declining, it is highly unlikely that Criteria 1, 2 and 3 will be met.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

The DWM is found solely in Atlantic Coast drainage streams and rivers of various sizes and moderate current. It ranges from New Hampshire to North Carolina, in small creeks to deep rivers in stable habitat with substrates ranging from mixed sand, pebble and gravel, to clay and silty sand. In the southern portion of its range, it is often found buried under logs or root mats in shallow water (USFWS 1993), whereas in the northern portion of its range, it may be found in firm substrates of mixed sand, gravel or cobble, or embedded in clay banks in water depths of a few inches to greater than 20 feet (Fichtel and Smith 1995; Gabriel 1995; Gabriel 1996; Nedeau and Werle 2003; Nedeau 2004a, 2004b, 2006a). Its reproductive cycle is typical of other freshwater mussels, requiring a host fish on which its larvae (glochidia) parasitize and metamorphose into juvenile mussels. The DWM is not a long-lived species as compared to other freshwater mussels; life expectancy is estimated at 10 to 12 years (Michaelson and Neves 1995).

2.3.1.1 New information on the species' biology and life history:

Fish host species:
Since the release of the 1993 Recovery Plan, a number of fish species have been positively identified as hosts for the DWM. Michaelson and Neves (1995) confirmed the tessellated darter (*Etheostoma olmstedi*), Johnny darter (*E. nigrum*), and mottled sculpin (*Cottus bairdi*) as host fish for DWM in the southern part of its range. Wicklow (*in* New Hampshire Wildlife Action Plan 2005) confirmed the slimy sculpin (*C. congatus*) and juvenile and parr of the Atlantic salmon (*Salmo salar*) as host fish for DWM in New Hampshire. Currently, there is an ongoing study to evaluate host specificity among geographically distinct populations of DWM on the Delaware River, as well as a few selected sites within its range (White and Ferreri 2005). The study will examine geographic variation in host fish specificity for the tessellated darter and the potential role that acquired immunity to glochidia may play in host specificity, and will identify other fish species either currently or historically present in the Delaware River Basin that are capable of serving as hosts for the DWM.

Reproductive chronology:
The DWM is considered to be a long-term brooder. In general, DWM glochidia may be released between March and June, with peak release times varying from south to north. Michaelson and Neves (1995) documented the reproductive cycle of the DWM from North Carolina and observed that DWM spawn in late summer, become gravid in September, and release glochidia in April. Wicklow (*in* New Hampshire Wildlife Action Plan 2005) observed glochidia release beginning in March and continuing through June in the Ashuelot River in New Hampshire. In a study of DWM reproduction in the Mill River, Massachusetts, McLain and Ross (2005) observed that most glochidia were released in April and May.

Reproductive output appears to be correlated with local population abundance. McLain and Ross (2005) documented that sites with the highest abundance of adult DWM also demonstrated the highest proportion of gravid females, glochidial density, host infection, and density of juvenile mussels.

2.3.1.2 Abundance, population trends, demographic features, or demographic trends:

Because a portion of a DWM population is found below the substrate, population estimates must take into account undetected mussels. Where the DWM is found in low densities, population estimates may have large margins of error due to undetected mussels. Few intensive, statistically viable surveys have been conducted on DWM populations, especially in the southern portion of its range. Strayer *et al.* (1996) conducted a range-wide assessment of the DWM in 1994. Twelve of the largest (at that time) DWM populations were surveyed and density estimates calculated. A number of these populations have been resurveyed primarily using catch-per-unit effort techniques. Populations in the southern part of the DWM range appear to be declining or their status is uncertain (Table 1).

Table 1. Population densities at study streams 1996 and follow-up survey data.[2]

Stream	Number of study reaches	Density Index (no/m^2) 1996 (Strayer *et al.* 1996)	Post 1996 catch-per-unit-efforts and presence/absence
Connecticut River, NH/VT	9	0.03 (0.1-0.05)	Present. Additional populations found, some of which may exceed densities found in 1996
Ashuelot River, NH	7	0.04 (0.02-0.06)	Present. Density estimates of two locations sampled in 2004 and 2006 range from 0.31 to 1.257 (Nedeau 2006c). Sample sites overlapped Strayer *et al.* (1996) sites. Additional subpopulation found downriver of surveyed areas.
Neversink River, NY	6	0.04 (0.02-0.06)	Present, populations affected by 2005 floods. Status uncertain.
McIntosh Run, MD	5	0.03 (0.01-0.05)	Present, no change
Aquia Creek, VA	8	0.007 (0.003-0.01)	No live animals seen since 2003. Population believed to be in decline (Watson B. pers. comm. 2007).
Po River, VA	3	0.01 (0.003-0.03)	Present in very low numbers
Tar River/Shelton Creek,	5	0.03 (0.01-0.05)	Present, no changed to

[2] The survey methods are not comparable, this table merely indicates whether a perceived change in the populations has been observed since the 1994 intensive surveys were undertaken.

NC			population.
Crooked Creek, NC	2	0	Present? 1 live animal found in 2000 survey, status unknown.
Little River, NC	3	0.03 (0-0.06)	Absent, 0 found in 2004
Swift Creek, NC	2	0	Present, 3 animals found in 2002
Turkey Creek, NC	3	0	Absent, 0 found in 2005
Moccasin Creek, NC	3	0	Present? Population viability unknown, presence based only on spent shells

Reproducing DWM populations are often hard to detect when densities are very low or surveys are single-day, catch-per-unit efforts. Evidence of reproduction (young mussels) was found at sites where DWM were documented by Strayer *et al.* (1996) even though some of the populations were considered to have low densities.

Reproduction has been documented for the largest populations in New Hampshire, Massachusetts, Connecticut, and New York (Appendix 1). During translocation of DWM out of a proposed bank stabilization project in the northernmost segment of the Connecticut River population, the highest density of any known DWM population was recorded within the project area as well as the translocation site (Gloria T. and B. Wicklow 2001; Nedeau *et al.* 2003; Nedeau 2004a).

2.3.1.3 Genetics, genetic variation, or trends in genetic variation:

T. King (USGS) and associates have been investigating the genetic structure of DWM with a focus on determining the genetic relatedness of disjunct populations within the Delaware River watershed and among watersheds, including the Connecticut River (NH), the Delaware River (NY and PA), the Potomac River (VA and MD) and the Tar River (NC). Preliminary information suggests that: (1) there are observable population structure differences among the isolated populations in the Delaware River watershed, and (2) rangewide, northern and southern regions are distinguishable, although the level of genetic divergence is limited (King *et al.*, *in litt.*, 2006).

2.3.1.4 Taxonomic classification or changes in nomenclature:

Preliminary research also indicates that there is some question as to the phylogenetics of the *Anodontinae*, the subfamily in which the DWM is found (King *et al.*, *in litt.*, 2006.). Further phylogenetic review of the DWM and other species within the *Anodontinae* will be necessary to confirm the current nomenclature of DWM.

2.3.1.5 Spatial distribution and trends:

Range information:
At one time, this species was recorded from 70 localities in 15 major drainages ranging from North Carolina to New Brunswick, Canada. Since the 1993 Recovery Plan, a number of new locations have been discovered and a number of known locations are possibly no longer extant (Appendix 1).

Based on preliminary information, the dwarf wedgemussel is currently found in 15 major drainages (Table 2), comprising approximately 70 "sites" (one site may have multiple occurrences). At least 45 of these sites are based on less than five individuals or solely on spent shells (see Appendix 1). The only known occurrence in New Brunswick, Canada (Petticodiac River) appears to be historic; no live mussels or spent shells were found during a 1997 survey (Hanson 1998).

Table 2. Dwarf wedgemussel major drainages.[3]

State	Major Drainage	County
NH	Upper Connecticut River	Coos, Grafton, Sullivan, Cheshire
VT	Upper Connecticut River	Essex, Orange, Windsor, Windham
MA	Middle Connecticut River	Hampshire, Hampden
CT	Lower Connecticut River	Hartford
NY	Middle Delaware	Orange, Sullivan, Delaware
NJ	Middle Delaware	Warren, Sussex
PA	Upper Delaware River	Wayne
MD	Choptank River	Queen Anne's, Caroline
MD	Lower Potomac River	St. Mary's, Charles
MD	Upper Chesapeake Bay	Queen Anne's
VA	Middle Potomac River	Stafford
VA	York River	Louisa, Spotsylvania
VA	Chowan River	Sussex, Nottoway, Lunenburg
NC	Upper Tar River	Granville, Vance, Franklin, Nash
NC	Fishing River	Warren, Franklin
NC	Contentnea	Wilson, Nash
NC	Upper Neuse	Johnson, Wake, Orange

The mainstem of the Connecticut River in New Hampshire and Vermont is considered to have the largest remaining DWM population, consisting of three distinct stretches of sporadically occupied habitat segmented by hydroelectric dams. It is estimated that there are hundreds of thousands of DWM scattered within an approximate 75-mile stretch of the Connecticut River. The Ashuelot

[3] The 15 major drainages identified in Table 2 do not necessarily correspond to the original drainages identified in the 1993 Recovery Plan although there is considerable overlap. Watersheds are based on USGS and EPA Cataloguing Units, see http://water.usgs.gov/GIS/huc_name.html and http://cfpub.epa.gov/surf/locate/index.cfm.

River in New Hampshire, the Farmington River in Connecticut, and the Neversink River in New York harbor large populations, but these number in the thousands only. The remaining populations from New Jersey south to North Carolina are estimated at a few individuals to a few hundred individuals.

In summary, it appears that the populations in North Carolina, Virginia, and Maryland are declining as evidenced by low densities, lack of reproduction, or inability to relocate any DWM in follow-up surveys. Populations in New Hampshire, Massachusetts, and Connecticut appear to be stable, while the status of populations in the Delaware River watershed affected by the recent floods of 2005 is uncertain at this time.

2.3.1.6 Habitat or ecosystem conditions:

Very little research has been done on DWM habitat. This is a wide-ranging species that may be found in a variety of habitats and water depths. McLain and Ross (2005) assessed habitat in the Mill River, Massachusetts, and Nedeau (2002, 2005, 2006a, 2006b) provides habitat descriptions for surveyed populations in the Connecticut, Ashuelot, Johns, and Farmington Rivers in New Hampshire and Connecticut. However, there has not been an assessment on the amount, distribution or suitability of existing habitat for this species.

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

The 1993 Recovery Plan identified four primary factors responsible for the decline of the dwarf wedgemussel: impoundments, pollution, riverbank alteration, and siltation (USFWS 1993). All of these factors continue to impact DWM populations. Since the species was listed, one new impoundment (Buckhorn Reservoir, NC) and construction of a water treatment facility and reactivation of an historic impounded water supply (Benton Water Treatment Plant Project) in North Carolina may impact dwarf wedgemussel populations within the Neuse River Basin if protective measures, primarily zoning restrictions, are not strictly implemented. Increased development within the Neuse River Basin is anticipated as a result of the additional water supply availability for the City of Raleigh and surrounding communities. Indirect impacts from construction of the additional water supplies may include water quality degradation from associated upland development in the form of suburban and industrial run-off, river flow alteration, and fragmentation of a small population into two isolated subpopulations (as a result of the Buckhorn Reservoir). Preliminary data from North Carolina indicate a general decline in Neuse River Basin populations due to habitat loss, modification and/or destruction (A. Rodgers, North Carolina Wildlife Resources Commission, email dated 9/7/05).

Strayer *et al.* (1996) speculated that many DWM populations, particularly in the southern portion of the range, may be threatened by low densities, small ranges. and linear structure (i.e., an entire population in one stream with no possibility of refuge from catastrophes or stochastic events). Low-density populations may lead to a loss of productivity due to reproductive impediments (e.g., the distance between mussels being too great) or loss of genetic variability. The Mill River in Hatfield and Whately, Massachusetts is an example of a river with a dwarf wedgemussel population patchily distributed over an approximate 16 mile stretch. The most reproductively robust patch is limited to a small stretch (< 1 mile) making it extremely vulnerable to a catastrophic event (Gabriel, M. pers. comm. 2007). The remainder dwarf wedgemussels are sparsely scattered and may demonstrate a reduced capability to reproduce as indicated by McLain and Ross (2005).

Agricultural run-off has been identified as a significant threat to DWM populations in Massachusetts, Maryland, and North Carolina. In 2001, more than 25 dwarf wedgemussels and hundreds of other mussels (including state-listed species) were killed in the Mill River, Massachusetts, by waste run-off from a small farm (Huckery, P. Mass. Division of Fish and Wildlife, pers. comm. 2001).

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Not applicable.

2.3.2.3 Disease or predation:

There is documented evidence of site-specific predation that could impact small localized populations. However, there is little literature correlating predation or disease to a specific population impact or decline. Currently, disease and predation do not pose an imminent or serious threat to the DWM as a species.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

Overall, the protections provided by the Endangered Species Act of 1973, as amended, are adequate to prevent a rangewide decline of DWM populations, although the ESA allows for incidental take that has resulted in declines of local populations, particularly in the southern portion of the range. Regulations other than the ESA are not adequate to protect the species from decline, but this does not pose a threat as long as the species is listed.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Recently, severe flooding in the Delaware and Neversink Rivers in Pennsylvania and New York, respectively, resulted in the destruction of occupied habitat and

loss of dwarf wedgemussels. Surveys conducted at two sites on the Neversink River below a dam in Cuddebackville, New York, derived abundance estimates ranging from 60 to 500 dwarf wedgemussels per site (Cole *et al.* 2004) prior to 2005. Severe flooding in the spring of 2005 scoured the river channel and deposited cobble in at least one of the sites previously surveyed. Resurveys in 2005 of the two sites conducted after the flood event detected one fresh dead dwarf wedgemussel and no live mussels (Cole and White 2006). Surveys in 2006 indicated that the DWM population in the Neversink River was adversely affected by flood events, although some live mussels were detected (W. Lellis, USGS, email dated 10/25/06).

2.4 Synthesis

Since the dwarf wedgemussel was listed in 1990, new and significantly large populations in the Connecticut and Delaware River watersheds have been discovered. The species should be considered stable in the northern extent of its range in New Hampshire and Connecticut, based on population numbers and extent of occupied habitat. However, little riverine habitat is protected, and the populations remain vulnerable to water quality degradation.

Although a few new sites have been discovered in North Carolina, Virginia, Maryland, and New Jersey, the prognosis for DWM recovery in the southern portion of its range is not as positive. A number of sites in Maryland, Virginia and North Carolina appear to be extirpated or in severe decline. J. McCann (email 5/25/06), in a summary of DWM for Maryland, noted that the number of occurrences has doubled from four to eight since a 2002 recovery meeting. Nonetheless, only four occurrences may be considered viable; one occurrence has declined dramatically for unknown reasons, two occurrences may be extirpated, and two are questionable and, if extant, may comprise very small populations. A 2005 report on the status of the DWM in Virginia states that there are only 14 records for DWM, nine of which were resurveyed. Of the nine surveyed sites, six sites had documented observations of shells or live animals since 1995, although only two sites were reconfirmed during surveys conducted between 2002 and 2004 (Chazal 2005).

Little riverine habitat adjacent to extant populations is protected other than by state shoreline protection regulations or local land use regulations. Development of adjacent uplands continues to be a significant and pervasive threat to southern populations.

Although the U.S. extent of the range remains the same as when the species was listed, the New Brunswick, Canada, population appears to be extirpated. No new populations were discovered during recent surveys of New Brunswick; therefore, Canada may no longer be considered as part of the species' current range.

The DWM should continue to remain listed as *endangered*, as the definition of threatened has not been met, and it continues to be threatened throughout its range, although the threat level is generally more severe in the southern portion of the species' range. Declining populations and loss of viable habitat in the southern portion of its range do not

compensate for the extensive, but geographically-limited populations found in New Hampshire. Without significant recovery activities targeted at southern populations, it is unlikely the species can be downlisted in the near future, since there is a real possibility of range contraction.

3.0 RESULTS

3.1 Recommended Classification: No change is needed. Retain as endangered.

3.2 New Recovery Priority Number:

The RPN of 5 should be retained. The dwarf wedgemussel still faces a high degree of threat throughout its range, and its recovery potential is low given its population status in the southern portion of its range.

3.3 Listing or Reclassification Priority Number: Not applicable.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Recommendation: Revise recovery plan.

A significant amount of life history and population distribution and status information has been collected since the release of the 1993 Recovery Plan for the DWM. Much of the information is unavailable to the general public, since it is found in reports to the Service or state agencies and in other gray literature (presentation abstracts, personal communications). A revised recovery plan will be the nexus for releasing current information, and it may be used to update state fact sheets and assist in developing future pertinent research.

Since additional viable occurrences in Connecticut, New York, Pennsylvania, and New Jersey have been discovered, they should be taken into consideration in revised criteria. Based on preliminary genetic information, revised criteria should center on management units that reflect the genetic relatedness of the populations. Moreover, a consistent definition for "site", "occurrence", and "population" should be developed and applied in order to compare data within a location and between locations.

Recommendations for specific recovery actions:

1. Complete population genetic analyses, determine correct taxonomic nomenclature.

2. Complete ongoing state-wide population surveys in North Carolina and Virginia, assess population status in these states.

3. Identify high priority populations needed for the recovery of the species (if recovery plan revision does not proceed quickly).

4. Develop habitat protection strategies for high priority populations.

5. Encourage and support publication of gray literature in peer-reviewed journals.

6. Develop accurate fact sheets for the DWM (outreach).

7. Resurvey Neversink and Delaware Rivers to assess impacts from severe flooding in 2005 and 2006 and establish new baselines for future comparison.

5.0 REFERENCES

Chazal A. C. 2005. Status of seven Atlantic Slope mussels in the Piedmont and Coastal Plain of Virginia. Natural Heritage Technical Report 05-09. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Richmond, Virginia. 45 pp plus appendices.

Cole, J. C., B. S. White and C. Apse. 2004. A quantitative assessment of freshwater mussels (Bivalvia:Unionidae) in the Neversink River prior to the Cuddebackville Dam removal. Report to The Nature Conservancy, Cuddebackville, New York. 16 pp.

Cole, J. and B. S. White. 2006. An assessment of freshwater mussels in the Neversink River following removal of the dam at Cuddebackville, NY and a severe spring flood event. Report to The Nature Conservancy, Cuddebackville, NY. 12 pp.

Fichtel, C. and D. G. Smith. 1995. The Freshwater Mussels of Vermont. Nongame and Natural Heritage Program, Vermont Fish and Wildlife Department. Technical Report 18. 53 pp.

Gabriel, M. 1995. Freshwater mussel distribution in the rivers and streams of Cheshire, Hillsborough, Merrimack and Rockingham, Counties, New Hampshire. Report submitted to U.S. Fish and Wildlife Service, New England Field Office and New Hampshire Fish and Game Department. 60 pp.

Gabriel, M. 1996. 1996 Monitoring of the dwarf wedgemussel (*Alasmidonta heterodon*) in the Ashuelot and Connecticut Rivers, New Hampshire. Report submitted to The Nature Conservancy, Eastern Regional Office, Boston, Massachusetts. 27 pp.

Gloria, T. and B. Wicklow. 2001. Unpublished report. A third investigation of the survival of dwarf wedgemussels for the relocation project on the Connecticut River, Route 2 stabilization project, Lunenburg, Vermont. Report to the Vermont Agency of Transportation. Montpelier, Vermont. 24 pp.

Hanson, M. J. 1998. March 24. Re: status of dwarf wedgemussel [personal email]. Accessed March 24, 1998.

Huckery, P. 2001. Mill River *Alasmidonta heterodon* (Dwarf Wedgemussel) die-off in Whately, MA. Memorandum to S. von Oettingen, U.S. Fish and Wildlife Service, Concord, NH. 1p.

King, T., K. Shaw, M. Eackles, C. Morrison and S. von Oettingen. 2006. Phylogeographic discontinuity in the endangered dwarf wedgemussel (*Alasmidonta heterodon*). Abstract for 2007 Freshwater Mollusk Conservation Society Symposium. 1 p.

Lellis, W. A. 2006. Email to S. von Oettingen, USFWS New England Field Office, Subject: Dwarf wedgemussel in upper Delaware. Dated 10/25/2006.

McLain, D. and M. R. Ross. 2005. Reproduction based on local patch size of Alasmidonta heterodon and dispersal by its darter host in the Mill River, Massachusetts, USA. Jour. N. Am. Benthol. Soc., 24(1):139-147.

Michaelson, D. L. and R. J. Neves. 1995. Life History and habitat of the endangered dwarf wedgemussel *Alasmidonta heterodon* (Bivalvia:Unionidae). Jour. N. Am. Benthol. Soc. 14:324-340.

Nedeau, E. J. 2002. Dwarf wedgemussel (*Alasmidonta heterodon*) survey near the Fort at No. 4 on the Connecticut River. Unpublished report submitted to the Connecticut River Joint Commission, Charlestown, New Hampshire and the U.S. Fish and Wildlife Service, Concord, New Hampshire. 6 pp.

Nedeau, E. J. 2004a. A Fourth Investigation of the Survival of Dwarf Wedgemussels (*Alasmidonta heterodon*) for the Relocation Project on the Connecticut River, Route 2 Stabilization Project, Lunenburg, Vermont. Unpublished report submitted to the U.S. Fish and Wildlife Service, Concord, New Hampshire. 7 pp.

Nedeau, E. J. 2004b. Quantitative survey of dwarf wedgemussel (Alasmidonta heterodon) populations downstream of the Surry Mountain Flood Control Dam on the Ashuelot River. . Unpublished report submitted to the U.S. Fish and Wildlife Service, Concord, New Hampshire. 12 pp.

Nedeau, E. 2005. Farmington River Freshwater Mussel Survey: Canton to Windsor. Unpublished report submitted to the U.S. Fish and Wildlife Service, Concord, New Hampshire. 26 pp.

Nedeau, E. 2006a. Characterizing the Range and Habitat of Dwarf Wedgemussels in the "Middle Macrosite" of the Upper Connecticut River. Unpublished report submitted to the U.S. Fish and Wildlife Service, Concord, New Hampshire. 6 pp.

Nedeau, E. 2006b. Dwarf Wedgemussels (Alasmidonta heterodon) in the Farmington River. Unpublished report submitted to the U.S. Fish and Wildlife Service, Concord, New Hampshire. 15 pp.

Nedeau, E. 2006c. Quantitative Study of the Freshwater Mussel Community Downstream of the Surry Mountain Flood Control Dam on the Ashuelot River. Unpublished report prepared for U.S. Army Corps of Engineers, Otter Brook/Surry Mountain Lakes, Keene, NH and U.S. Fish and Wildlife Service, New England Field Office, Concord, NH. 19pp.

Nedeau, E.J., M. Ferguson and S. Werle. 2003. Quantitative survey of the dwarf wedgemussel (Alasmidonta heterodon) in the Connecticut River near Lunenburg, Vermont. Report prepared for the Vermont Fish and Wildlife Department and U.S. Fish and Wildlife Service. 16 pp.

Nedeau, E. J. and S. Werle. 2003. Freshwater Mussels of the Ashuelot River: Keene to Hinsdale. Unpublished report submitted to the U.S. Fish and Wildlife Service, Concord, New Hampshire. 50 pp.

Rodgers, A. 2005. Email to D. Suiter, USFWS Raleigh FO, Subject: Dwarf wedgemussel recovery data call. Dated 09/07/2005.

Strayer, D. L., S. J. Sprague and S. Claypool. 1996. A range-wide assessment of populations of the dwarf wedgemussel *Alasmidonta heterodon*. J. N. Am. Benthol. Soc. 15(3):308-317.

U.S. Fish and Wildlife Service. 1993. Dwarf Wedge Mussel *Alasmidonta heterodon* Recovery Plan. Hadley, Massachusetts. 52 pp.

U.S. Fish and Wildlife Service. 2006. U.S. Fish and Wildlife Service Biological Opinion on the proposed Dempsey E. Benton Water Treatment Plant, Wake County, North Carolina. Raleigh Field Office, Raleigh, NC. 38 pp.

White B. S. and C. Paola Ferreri. 2005. Evaluation of fish host suitability for the dwarf wedgemussel Alasmidonta heterodon (Bivalvia:Unionidae) in the upper Delaware River basin. Progress report for the National Park Service, Beach Lake, PA. 6 pp.

Wicklow, B. 2005. *in* New Hampshire Wildlife Action Plan. New Hampshire Fish and Game Department, 11 Hazen Dr., Concord, NH, 03301. pp. A26-A35.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Alasmidonta heterodon* (Dwarf wedgemussel)

Current Classification: Endangered.

Recommendation resulting from the 5-Year Review: No change needed.

Appropriate Listing/Reclassification Priority Number, if applicable: Not applicable.

Review Conducted By: Susi von Oettingen, New England Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date 7/2/07

REGIONAL OFFICE APPROVAL:

Acting

Lead Regional Director, Fish and Wildlife Service

Approve _____ Date 7.26.07

Thomas J. Healy

Cooperating Regional Director, Fish and Wildlife Service

✓ Concur _____ Do Not Concur

Signature _____ Date 6/22/07

Appendix 1

State	County	River	Watershed	Est. River Length	Last Obs.	Last Survey	Number shells at site (live or dead)	Threats
NH/VT	Sullivan/Windsor-Windham,VT	Connecticut River	Connecticut River	18± miles	2002 - 2004 (select sites)	Charlestown surveyed in 2004	50+ observed during bank stabilization project in Charlestown (about 400 m of riverbank), 2 live at Rockingham site	incremental loss due to bank stabilization
NH/VT	Grafton/Windsor and Orange	Connecticut River	Connecticut River	14 mile +/-	2006	2005 - 2006	2005 - 1 live at site 9, 5 live and 2 shells at site 10; short duration snorkel surveys, 2006 - 12 additional sites found. Most sites with >1 ind found	incremental loss due to bank stabilization
NH/VT	Coos/Essex	Connecticut River	Connecticut River	16-18 miles	2001- 2005 (select sites)	1.Lunenburg 2002 and 2004; 2.Northumberland 2004	1. Relocation Project, over 6000 live dwm estimated at site near Lunenberg; (2) a quantitative survey well upstream of stabilization project estimated population size of over 6000 in a small area and extrapolation to large area yielded estimates of 100,00	incremental loss due to bank stabilization
NH	COOS	Johns River	Connecticut River	4 sites	2006	2006	50+ over 4 sites	
VT	Windsor	Black River	Connecticut River	1 mile	1998		3 live, 6 shells	STP and mills impact water quality. Near confluence with Ct. R., part of Ct. R. south population
NH	Cheshire	Ashuelot River	Connecticut River	2 ± miles	2005	Quantitative survey in 2004; qualitative survey in 2005 to find gravid females for research on reproduction	~100, though primary survey was quantitative (systematic random sampling with multiple random starts & double sampling, using 0.25m2 quadrats). Population estimate of 989 and 464 for 2 50-m reaches	Impacts from golf course and urban run-off, development, water quality degredation; flood control dam operations; severe flooding in October 2005
NH	Cheshire	Ashuelot River	Connecticut River	8 ± miles	2001-2004	2004	2001: 13 live at 5 different sites; 2004: 2 live upstream of West Swanzey Dam (none observed prior), and approximately 45 live toward upper end of the impoundment in a ~1 mile reach using adaptive cluster sampling	Keene STP copper loading?, water quality degredation, erosion, upriver contamination (near 101 bridge in Keene), road/development run-off; eventual dam removal
NH	Cheshire	S. Branch Ashuelot River	Connecticut River	0.5 ± miles	2005	1995	6 live dwm, material taken for genetic analysis	Road run-off, agricultural run-off, sedimentation, development

State	County	River	Watershed	Est. River Length	Last Obs.	Last Survey	Number shells at site (live or dead)	Threats
MA	Hampshire	Mill River (Whately & Hatfield)	Connecticut River	18 ± miles	199? - 2001- 2005	2005, 2001, 1 live DWM downstream of dam in portion of Mill River that is essentially the Connecticut River floodplain	2005: first specimen (1) located below Hatfield Dam, 2001: 476 upriver of dam in Hatfield and Whately	Agricultural run-off, localized die-off in 2001 due to ammonia from cattle run-off, bank erosion, water withdrawal from upstream water supply reservoirs, beaver activity, livestock access to river
MA	Hampshire	Running Gutter/Broad Brook (tributaries to Mill R.)	Connecticut River	0.2 miles occurrence; 2.5 miles habitat	1999	1999	13+ individuals	Agiculture upstream
MA	Hampshire	Mill River	Connecticut River	0.2 miles occurrence; 1.2 miles habitat	1998	1998	1998: 1 adult female, 1 old adult shell; 1996 & 1994: shells observed, one ~4 yrs. old; 1973: 4 gravid females, 1adult male.	Upstream dredging of Paradise Pond
MA	Hampden	Fort River	Connecticut River	2.8 miles occurrence; ~8 miles habitat	2002	2002	2002: 1 live; 2001: 2 live; 1988: none found; 1984: 2 live; 1980: 2 males; 1976, '74, & '52: total of 8 found.	
CT	Hartford	Muddy Brook	Connecticut River	1 ± miles	1991		1 live	
CT	Hartford	Podunk River	Connecticut River	Unknown	1997	2000	7 shells, 2 live (1997), 0 dwm in 2000	Development, water quality degredation,
CT	Hartford	Philo Brook	Connecticut River	Unknown	1991		2 shells	
CT	Hartford	Stony Brook	Connecticut River	Unknown	2005	2005	1 live in 3-hour survey near a bridge slated for replacement. 1st record in Stony Brook in 24 years.	bridge replacement; urbanization
CT	Hartford	Farmington	Connecticut River	Unknown	2002, 2005	2005	1 live + 2 shells in 2000; 12 live + 1 shell in 2005, including 11 live in 45 minutes at a site in Avon. 4 sites altogether, separated by several miles	water quality degradation, riparian development; WWTP, bank erosion, rapid urbanization
NY	Orange	Neversink River	Delaware River	5 miles - Cuttybackville Dam to confluence	2006	2005	Surveys done in 2005 at selected sites following flooding in 2005 indicate that at least one to two locations have very few individuals remaining.	Dam removal? Sedimentation, severe flood events
PA / NY	Wayne (PA), Sullivan (NY), Delaware (NY)	Delaware River	Delaware River	21 miles	2006	2000 - snorkel survey of entire stretch; 2002 - quadrat survey of individual sites	2000 - 13 live and 4 shells found at 3 sites during snorkel survey; 2002 - 72 live found at 4 sites during quadrat surveys	Altered hydrology, siltation, nutrient enrichment

State	County	River	Watershed	Est. River Length	Last Obs.	Last Survey	Number shells at site (live or dead)	Threats
PA	Wayne	Delaware River	Delaware River	16 miles (incl. NY)	2001?	2001- 50.6 miles of river surveyed	13 live 4 shells found at 3 sites in 2000, 1 dwm found in 2001	siltation, nutrient enrichment, invasive species, altered hydrology.
NJ	Warren	Pequest River	Delaware River	< 1 mile	2000		2 live, some spent shells	
NJ	Sussex	Paulins Kill River	Delaware River	approx. 6 miles	2000		159 live observed	
NJ	Sussex	Delaware River	Delaware River	Point location	2001	2001	1 live	Sewage treatment plant, urbanization
NJ	Sussex	Flat Brook	Delaware River	11 miles	2006	2001- entire stretch from Peters Valley to Delaware River by snorkel	135 live individuals found in 2001, mostly from upper portion of 11 mile stretch around Wallpack Center. 200 live found in 2006	Recreational fishing, agriculture in lower system.
MD	Queen Anne's/Talbot	Norwich Creek	Tuckahoe River	~0.8 km	1994 - 1997	2002	Severe decline. Possibly extirpated. First reported in 1979 at densities of 0.5-1/m2. During 1984-1999, at least 1 live and/or dead A.h. were found during 11 of 14 surveys; surveys varied greatly in intensity, techniques and extent. Max #live found = 74 b	Chronic agricultural-related sediment and nutrient problems; suburban sprawl; upper part of watershed ditched and channelized.
MD	Queen Anne's/ Caroline	Long Marsh Ditch - (Mason Branch)	Tuckahoe River	~5 km	1992	2002	Severe decline. Possibly extirpated. First reported in 1985 when "several" were found. From 1-8 live and/or dead were found during 7 surveys in 1989-97; surveys varied greatly in intensity, extent and technique. Last live obs = 1992, 5 found. No dead or l	Stream channel ditched and channelized; chronic agricultural-related sediment and nutrient problems; suburban sprawl.
MD	Charles	Nanjemoy Creek	Potomac River	~ 3 km	2005	2005	Among top 3 heterodon streams in Md. First reported in 1991 when 2 live and "several" dead were found. From 2-5 live found during 4 surveys in 1992-97; surveys varied greatly in intensity, extent and technique. Intensive surveys during 2001 detected 106 l	Suburban sprawl, illegal trash dumping
MD	St. Mary's	McIntosh Run	Potomac River	~4 km	2005	2005	Among top 3 heterodon streams in Md. First reported in 1970 when 1 dead indiv was found. From 0-13 live found during 10 surveys in 1983-97; surveys varied greatly in intensity, extent and technique. Population size estimated at 900 in 1994. Intensive survey	Suburban sprawl, livestock grazing in floodplain, sand/gravel mining in watershed.

State	County	River	Watershed	Est. River Length	Last Obs.	Last Survey	Number shells at site (live or dead)	Threats
MD	Queen Anne's	Browns Branch	Southeast Creek	> 4 km	2002	2004	Among top 3 heterodon streams in Md. Best known population on Delmarva Peninsula. Mean of 1.2 live/1.7 dead per 100 m of stream length; mean stream width = 3.8 m.	Suburban sprawl, agricultural runoff, groundwater withdrawal for agric and residential use, lack of watershed forest cover and riparian buffers - 30-35% forest cover.
MD	Queen Anne's	Granny Finley Branch	Southeast Creek	n/a (single specimen)	2002	2003	1 old live specimen found.	Suburban sprawl, agricultural runoff, groundwater withdrawal for agric and residential use, lack of watershed forest cover and riparian buffers - 30-35% forest cover.
MD	Queen Anne's	Unnamed 2nd order trib of Southeast Cr	Southeast Creek	> 0.5 km	2003	2003	1 live/1 dead found.	Suburban sprawl, agricultural runoff, groundwater withdrawal for agric and residential use, lack of watershed forest cover and riparian buffers - 30-35% forest cover.
MD	Queen Anne's	Unnamed 2nd order trib of Three Bridges Branch	Southeast Creek	> 1 km	2005	2005	Total 16 live/10 dead found in two 100-m long sections. Intensive inventory of entire watershed to occur during summer 2006.	Suburban sprawl, agricultural runoff, groundwater withdrawal for agric and residential use, lack of watershed forest cover and riparian buffers - 30-35% forest cover.
VA	Stafford	Aquia Creek	Potomac River	3 miles	2003	2003	2 live/2 shells(1998); 1 dead shell collected, no live spec. obs.(2003)	Development. Spill?
VA	Stafford	Aquia Creek	Potomac River	~0.5 mi NE of Skidmore Corner; Between confluence of Cannon Creek with Aquia Creek	8/27/1992		A total of 69 live specimens were found at this site between 08/26/1992 and 08/27/1992	
VA	Stafford	Aquia Creek	Potomac River	2 mi W of Garrisonville, downstream 400m	10/4/1990		2 live,	
VA	Stafford	Aquia Creek	Potomac River	2 mi W of Garrisonville, upstream to Cannon Creek confluence	10/3/1990	2003	4 live, 12 shells - 1990, 2003 - no mussels	
VA	Stafford	Rappahannock R	Rappahannock	0.20 km	1994		1 fresh dead - Questionable record	

State	County	River	Watershed	Est. River Length	Last Obs.	Last Survey	Number shells at site (live or dead)	Threats
VA	Culpepper/Fauquier	Mountian Run	Rappahannock	37.6 km	1919	1919	Unkn.- questionable record	
VA	Orange	Blue Run	Rappahannock	14.5 km	ND		Questionable record	
VA	Spotsylvania	Ni River	York	6.25 km	1925		Unkn.	
VA	Spotsylvania	Po River	York	0.25 km	2000	2000	3 live/1shell obs. In 36.5 survey hours	
VA	Spotsylvania	Po River	York	1.03	2003	2003	7 live observed (1999); 9 live/3 shells obs. In 15 survey hours	
VA	Spotsylvania	Po River	York	1 km	1995	1995	1 live spec. collected	
VA	Louisa	South Anna River	York	0.22	1972	1972	midden shell	
VA	Louisa	South Anna River	York	0.23	1991	1991	0 live, 1 relict	
VA	Louisa	South Anna River	York	0.14	1972	1972	midden shell	
VA	Sussex	Nottoway River	Chowan	0.11 km	1996	1996	1 live	
VA	Nottoway/Lunenburg	Nottoway River	Chowan	0.21	1995	1995	Aprox. 5 ind. Collected/obs during a construction project survey, 1 collected in 1994	
NC	Granville	Tar River (headwaters)	Tar	Point lcoation	1999	2004	0	beaver activity, silviculture, residential development
NC	granville	Cub Creek	Tar	3 reach surveys, plus (1) 400m reach	2005	2005	10 live and 2 shells total (3 sites in 2004, 8 live, 1 shell); (400m reach in 2005 , 2 live, 1 shell)	small stream, livestock, beaver activity, silviculture
NC	Granville	Shelton Creek	Tar	7 reaches surveyed since 1999	2005	2005	98 total observed since 1999 all in same general reach ;54 live were observed at 2 sites in 2004 ; 44 live observed In 2005 in same reach	(beaver activity, silviculture, residential development); low water, low D.O.(0.38) and thick algae due to possible nutrient enrichment
		Fox Creek (Granville Co, Trib to Shelton Creek)	Tar	4 reaches	2005	2005 at new sites (Last observed at previously surveyed sites was 1995)	3 (DWM found at 2 sites not previously surveyed) but DWM not found at site where they have been found historically	
NC	Vance	Ruin Creek (Trib to Tabbs Creek)	Tar	5km stretch (7 sites), 2 other reach surveys	2005	Point surveys along 5 km stretch	1 live, 2 shells	Degraded habitat, beaver activity, headwaters are urbanizing, 2005 and 2002 extremely low water, Pool where DWM found in 2005 had D.O. of 3.25
NC	Vance	Tabbs Creek	Tar	Reach surveys	2002	2004	2 live	
NC	Warren/Franklin	Shocco Creek	Tar	Reach surveys, 500m	2005	2005	8	beaver activity, silviculture
NC	Warren/Franklin	Little Shocco Creek	Tar	Reach surveys, 800 m	2005	2005	7 live	beaver activity, silviculture?

State	County	River	Watershed	Est. River Length	Last Obs.	Last Survey	Number shells at site (live or dead)	Threats
NC	Warren/Franklin	Isinglass Creek (Formerly Unnamed Trib to Shocco Creek)	Tar	Reach survey	2005	2005	3 live (1 live/2 shells in 1999, 3 live in 2005)	beaver activity, silviculture
NC	Warren	Maple Branch	Tar	Reach survey	2003	2003	6	small stream, beaver activity, silviculture, emergency bridge replacement, gravel road to be paved
NC	Warren	Long Branch	Tar	Reach Survey	2005	2005	1	Low water and D.O. Stream was dry upstream of bridge access point and extremely low downstream of bridge. D.O. in pools was 4.0
NC	Franklin	Red Bud Creek	Tar	Reach Survey	2004	2004	5	?
NC	Franklin	Cedar Creek	Tar	N/A	1993	Last surveyed in 2003 at point sites, four additional sites surveyed	0 - Note The 401 site is the only place whre a live DWM has been recovered	potential bridge replacement/repair impacts
NC	Franklin	Crooked Creek	Tar		2000	2000	1 live -Survey in 2000 was not a mussel survey but a habitat assessment of bridge 3 years after construction. Assesment did yield one live DWM.	Sign. declines, much beaver activity, heavy sediment load, Hurricane Fran damage, much of creek surveyed on foot in 1996
NC	Franklin	Fox Creek (Franklin Co.)	Tar	N/A	2005	2005	3 live found at sites not surveyed before. No DWM found at sites where DWM previously observed.	Much beaver activity, urbanization of stream corridor
NC	Nash	Stony Creek	Tar?	N/A	1992	1995	1 shell; New sites surveyed in 2004 and 0 were observed. Note Sites where shell observed in 1992, have not been surveyed since 1995.	Timber harvest in subbasin; new threats unknown
NC	Halifax	Rocky Swamp Creek	Neuse	N/A	1993	3 survey stations, last surveyed 1997	1 live	Beaver activity,
NC	Halifax	Rocky Swamp Creek	Neuse		2004		100+	
NC	Wilson/Nash	Turkey Creek	Neuse		1997	2005, not all sites where DWM previously found were surveyed	0	
NC	Nash/Wilson/Johnson	Moccasin Creek	Neuse	few miles	2004	Shells found at a site not prevously surveyed. Other sites need to be resurveyed.	2 shells	

State	County	River	Watershed	Est. River Length	Last Obs.	Last Survey	Number shells at site (live or dead)	Threats
NC	Johnson/Wake	Little River	Neuse	1 site	2004	2004	0	Much beaver activity, heavy sediment load, Hurricane Fran damage,
NC	Johnson	Buffalo Creek	Neuse	5 sites	1998	2004 (1998 sites have not been resurveyed), 5 new sites surveyed between 2001-2005)	0	Degraded habitat, beaver activity, headwaters are urbanizing,
NC	Johnson	Swift Creek	Neuse	5 miles	2002	3 live observed in 2002 in a point survey (not surveyed historically)	3	Urban growth in subbasin, regular raw wastewater spills, beaver activity, heavy sediment load, Hurricane Fran damage to riparian habitat, heavy sed. load;
NC		White Oak Creek	Neuse	N/A	1992	2003; two point samples in 2001, ~ 2km surveyed in 2003 in reach where DWM found in 92'	0	Development pressure was just beginning in 2003, beaver dams present
NC	Johnson	Middle Creek	Neuse	N/A	1992	42 sites surveyed in 2003 in Middle Creek Basin; 10 other sites surveyed between 2001-2005	0	Development from Carey, Apex, Holy Springs, and Morrissville; Cumulative and secondary impacts from municpalities to Middle Creek basin
NC	Orange	Eno River	Neuse	Point location	1995	Point surveys, In 2004, 2005, 2006; historic sites resurveyed where shell was found in 1995	0 -A dam was removed within Eno River State Park. Invasion of hydrilla observed in Eno River State Park.	