1 CANDIDATE ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Villosa fabalis*

COMMON NAME: Rayed bean

LEAD REGION: 3

INFORMATION CURRENT AS OF: December 2002

STATUS/ACTION (Check all that apply):
_X New candidate
___ Continuing candidate
___ Non-petitioned
___ Petitioned - Date petition received: _____
____ 90-day positive - FR date: _____
____ 12-month warranted but precluded - FR date: _____
____ Is the petition requesting a reclassification of a listed species?
___ Listing priority change
Former LP: ___
New LP: ___
Latest Date species became a Candidate: _____
___ Candidate removal: Former LP: ___ (Check only one reason)
___ A - Taxon more abundant or widespread than previously believed or not subject to a degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.
___ F - Range is no longer a U.S. territory.
___ I - Insufficient information on biological vulnerability and threats to support listing.
___ M - Taxon mistakenly included in past notice of review.
___ N - Taxon may not meet the Act's definition of "species."
___ X - Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY:
Phylum Mollusca, Class Bivalvia, Order Unionoida, Family Unionidae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: Illinois, Indiana, Kentucky, Michigan, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, Alabama, and Ontario

CURRENT STATES/ COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE:
Indiana, Michigan, New York, Ohio, Pennsylvania, and Ontario

LEAD REGION CONTACT (Name, phone number): Leslie Tewinkel, 612/713-5164

LEAD FIELD OFFICE CONTACT (Office, name, phone number): Reynoldsburg, Ohio Field

Office, Angela L. Boyer, 614/469-6923 x 22

BIOLOGICAL INFORMATION (Briefly describe habitat, historic vs. current range, historic vs. current population estimates (# populations, #individuals/population), etc.):

The following information on description, biology, life history, distribution, threats, and other subsequent information included in this form on the rayed bean is taken from Butler (2002) and others cited in his status review, unless otherwise stated.

Species Description:

The following description of the rayed bean is generally summarized from Cummings and Mayer (1992), Parmalee and Bogan (1998), and West et al. (2000). The rayed bean is a small mussel usually less than 1.8 inches in length. Shell outline is elongate or ovate in males and elliptical in females, and moderately inflated in both sexes, but more so in females. The valves are thick and solid. The anterior end is rounded in females and bluntly pointed in males. Females apparently are generally smaller than males. Dorsally, the shell margin is straight, while the ventral margin is straight to slightly curved. The beaks are slightly elevated above the hingeline, with sculpture consisting of double loops with some nodules. No posterior ridge is evident. Surface texture is smooth and sub-shiny, and green, yellowish-green, or brown in color, with numerous wavy dark-green rays of various widths (sometimes obscure in older, blackened specimens). Internally, the left valve has two pseudocardinal teeth that are triangular, relatively heavy, and large, and two short heavy lateral teeth. The right valve has a low triangular pseudocardinal tooth, with possibly smaller secondary teeth anteriorly and posteriorly, and a short, heavy, and somewhat elevated lateral tooth. The color of the nacre (mother-of-pearl) is silvery white or bluish and iridescent posteriorly. Key characters useful for distinguishing the rayed bean from other mussels is its small size, thick valves, unusually heavy teeth for a small mussel, and color pattern.

Taxonomy:

The rayed bean is a member of the mussel family Unionidae and was originally described as *Unio fabalis* Lea, 1831. The type locality is the Ohio River, probably in the vicinity of Cincinnati, Ohio. Parmalee and Bogan (1998) summarized the synonomy of the rayed bean. The rayed bean was ultimately placed in the genus *Villosa* by Stein (1963), where it remains today (Turgeon et al. 1998). The Service recognizes *Unio capillus, U. lapillus,* and *U. donacopsis* as synonyms of *Villosa fabalis.*

Habitat:

The following habitat requirements are generally summarized from Watters (1988), Parmalee and Bogan (1998), and West et al. (2000). The rayed bean is generally known from smaller headwater creeks, but records exist in larger rivers. They are usually found in or near shoal or riffle areas, and in the shallow wave-washed areas of glacial lakes, including Lake Erie. In Lake Erie, it is generally associated with islands in the western portion of the lake. Substrates

typically include gravel and sand. It is oftentimes associated with vegetation (e.g., water willow, *Justicia americana*; water milfoil, *Myriophyllum* sp.) in and adjacent to riffles and shoals. Specimens are typically buried among the roots of the vegetation. Strayer (1999a) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that displayed little movement of particles during flood events. Flow refuges conceivably allow relatively immobile mussels to remain in the same general location throughout their entire lives. Adult and juvenile specimens appear to produce byssal threads (Woolnough 2002), apparently to attach themselves to substrate particles.

Historical Range/Distribution:

The rayed bean was historically known from 106 streams, lakes, and some man-made canals in 10 states and 3 Service regions. The mussel occurred in parts of the upper (i.e., Lake Michigan drainage), lower Great Lakes system, and throughout most of the Ohio and Tennessee River systems. Historical locations include the following stream systems (with tributaries): upper Great Lakes system (Pigeon River); lower Great Lakes system (Black [Mill Creek], Pine, Belle, Clinton [North Fork Clinton River], Sydenham, South Branch Thames, Detroit, Rouge, Huron, Raisin [Macon Creek], Maumee [St. Joseph River (West Branch St. Joseph; Fish, Cedar Creeks; Feeder Canal to St. Joseph River), Auglaize (Ottawa, Blanchard Rivers)], Sandusky [Tymochtee, Wolf Creeks] Rivers; Lake Erie); Ohio River system (Ohio River [Allegheny River (Chautauqua Lake outlet; Chautauqua Lake; Olean, Cassadaga, Conewango, Oil, French [Cussewago Creek], Crooked Creeks), West Fork, Beaver (Shenango, Mahoning Rivers; Pymatuning Creek) Rivers; Middle Island Creek; Muskingum (Walhonding, Mohican Rivers), Elk, Scioto (Olentangy River; Mill, Alum, Whetstone, Big Walnut [Walnut Creek], Big Darby [Little Darby Creek], Deer, Sugar, Scioto Brush, Cedar Creeks; Buckeye Lake; Ohio and Erie Canal), Little Miami (East Fork Little Miami River), Stillwater, South Fork Licking, North Fork Elkhorn Creek, Eagle Creek, Brashears Creek, Green (Nolin, Barren Rivers), Wabash (Salamonie, Mississinewa, Tippecanoe Rivers [Tippecanoe, Winona Lakes; Lake Maxinkuckee], Vermilion [Salt Fork Vermilion, Middle Fork Vermilion, North Fork Vermilion Rivers], Embarras, Sugar Creek, White [West, East Forks White; Big Blue Rivers; Walnut, Mill, Fall, Sugar Creeks])] Rivers); and Tennessee River system [Tennessee River (Holston [North, South Forks Holston River], Nolichucky [Lick Creek], Clinch [North Fork Clinch, Powell Rivers], Elk [Richland Creek], Duck Rivers)].

Current Range/Distribution:

Populations of the rayed bean are generally considered extant if live or fresh dead specimens have been collected since the mid-1980s. Currently, this species is limited to ten streams in the lower Great Lakes system: (Black [Mill Creek], Pine, Belle, Clinton, Sydenham, St. Joseph [Fish Creek], Blanchard Rivers; Tymochtee Creek); and twelve streams and one lake in the Ohio River system: (Allegheny [Olean, Cassadaga, French, Cussewago Creeks], Walhonding, Scioto Brush Creek, Little Miami [East Fork Little Miami River], Stillwater, Tippecanoe [Lake Maxinkuckee] Rivers; Sugar Creek]).

Population Status:

The rayed bean has been eliminated from 78% of the total number of streams and other water bodies from which it was historically known (22 streams and a lake currently compared to 106 water bodies historically). This species has also been eliminated from long reaches of former habitat in hundreds of miles of the Maumee, Ohio, Wabash, and Tennessee Rivers and from numerous stream reaches in their tributaries. In addition, the species is no longer known from the States of Illinois, Kentucky, Tennessee, Virginia, West Virginia, and Alabama, representing over half of the states from which it was formerly known.

Relatively few streams are thought to harbor long-term viable populations (e.g., Sydenham, Blanchard, Allegheny Rivers; French Creek). The best remaining populations are found in the far northern portions of its range. The rayed bean appears to be extirpated from the southern unglaciated portion of its range.

THREATS (Describe threats in terms of the five factors in section 4 of the ESA providing specific, substantive information. If this is a removal of a species from candidate status or a change in listing priority, explain reasons for change):

A. <u>The present or threatened destruction, modification, or curtailment of its habitat or range</u>.

The decline of the rayed bean in the Great Lakes drainages and the Ohio and Tennessee River systems and other mussel species in the eastern United States is primarily the result of habitat loss and degradation (Neves 1991). These losses have been well documented since the mid-19th century (Higgins 1858). Chief among the causes of decline are impoundments, channelization, chemical contaminants, mining, and sedimentation (Williams et al. 1993; Neves 1991, 1993; Neves et al. 1997; Watters 2000).

<u>Impoundments</u>

Impoundments result in the dramatic modification of riffle and shoal habitats and the resulting loss of mussel resources, especially in larger rivers. Neves et al. (1997) and Watters (2000) reviewed the specific effects of impoundments on freshwater mollusks. Dams interrupt most of a river's ecological processes by modifying flood pulses; controlling impounded water elevations; altering water flow, sediments, nutrients, and energy inputs and outputs; increasing depth; decreasing habitat heterogeneity; decreasing stability due to subsequent sedimentation; blocking host fish passage; and isolating mussel populations from fish hosts. Even small low-head dams can have some of these effects on mussels. The reproductive process of riverine mussels is generally disrupted by impoundments making the rayed bean unable to successfully reproduce and recruit under reservoir conditions. The rayed bean historically occurred in the wave-washed shallows of several glacial lakes, an environment very different from that found in impoundments.

In addition, dams can also seriously alter downstream water quality and riverine habitat and negatively impact tailwater mussel populations (Allan and Flecker 1993, Layzer et al. 1993, Neves et al. 1997, Watters 2000). These changes include thermal alterations immediately below

dams; changes in channel characteristics, habitat availability, and flow regime; daily discharge fluctuations; increased sediment loads from bank sloughing; and altered host fish communities. Coldwater releases from large non-navigational dams and scouring of the river bed from highly fluctuating, turbulent tailwater flows have also been implicated in the demise of mussel faunas (Layzer et al. 1993). There is no evidence that the rayed bean may persist in hypolimnetic tailwater conditions. Cold tailwaters below Tims Ford Dam on the Elk River and Norris Dam on the Clinch River, Tennessee, may have helped eliminate the rayed bean in those streams.

Population losses due to impoundments have probably contributed more to the decline and imperilment of the rayed bean and other Ohio River system mussels than has any other single factor. Stream habitat throughout significant portions of the range of the rayed bean has been impounded. The majority of the Tennessee River main stem and many of its largest tributaries are now impounded. For example, over 2,300 river miles (about 20 percent) of the Tennessee River and its tributaries with drainage areas of 25 square miles or greater were impounded by Tennessee Valley Authority (TVA) by 1971 (Tennessee Valley Authority 1971). A total of 36 major dams are located in the Tennessee River system. Watters (2000) summarizes the tremendous loss of mussel species from various portions of the Tennessee River system. The rayed bean has been eliminated from the Tennessee River system. This impoundment scenario is all to familiar in many other parts of its range, and include numerous navigational locks and dams (e.g., Ohio, Allegheny, Muskingum, Green Rivers), some high-wall dams (e.g., Walhonding, Tippecanoe Rivers), and many low-head dams (e.g., Duck River) that have contributed to the loss of rayed bean habitat. Sediment accumulations behind dams of all sizes generally preclude the occurrence of the rayed bean.

Channelization

Dredging and channelization activities have profoundly altered riverine habitats nationwide. Hartfield (1993), Neves et al. (1997), and Watters (2000) reviewed the specific effects of channelization on freshwater mollusks. Channelization impacts a stream=s physical (e.g., accelerated erosion, reduced depth, decreased habitat diversity, geomorphic instability, riparian canopy loss) and biological (e.g., decreased fish and mussel diversity, changed species composition and abundance, decreased biomass, and reduced growth rates) characteristics (Hartfield 1993, Hubbard et al. 1993). Channel construction for navigation has been shown to increase flood heights (Belt 1975). This increase in flood heights is partially attributed to a decrease in stream length and increase in gradient (Hubbard et al. 1993). Flood events may thus be exacerbated, conveying into streams large quantities of sediment, potentially with adsorbed contaminants. Channel maintenance may result in profound impacts downstream (Stansbery 1970), such as increases in turbidity and sedimentation, which may smother benthic organisms. The only known rayed bean populations that remain in navigation channels are in the upper two navigation pools of the Allegheny River. These activities may have contributed to the elimination of the rayed bean from the Ohio, lower Allegheny, and Muskingum Rivers, and potentially others.

Chemical Contaminants

Contaminants contained in point and non-point discharges can degrade water and substrate quality and adversely impact, if not destroy, mussel populations. Although chemical spills and other point sources of contaminants may directly result in mussel mortality, widespread decreases in density and diversity may result in part from the subtle pervasive effects of chronic low-level contamination (Naimo 1995).
The effects of contaminants are especially profound on juvenile mussels (Robison et al. 1996), which can readily ingest contaminants adsorbed to sediment particles while feeding, and on the glochidia, which appear to be very sensitive to toxicants (Goudreau et al. 1993, Jacobson et al. 1997) (both of these studies were conducted in the Clinch River). Mussels are very intolerant of heavy metals (Havlik and Marking 1987, Keller and Zam 1991), and even at low levels, certain heavy metals may inhibit glochidial attachment to fish hosts (Huebner and Pynnönen 1992). Cadmium appears to be the heavy metal most toxic to mussels (Havlik and Marking 1987), although chromium, copper, mercury, and zinc also negatively affect biological processes (Keller and Zam 1991, Naimo 1995, Jacobson et al. 1997, Keller and Lydy 1997).

Among pollutants, ammonia has been shown to be lethal to mussels at concentrations of 5.0 ppm (Havlik and Marking 1987). Ammonia is oftentimes associated with animal feedlots, nitrogenous fertilizers, and the effluents of out-dated municipal wastewater treatment plants (Goodreau et al. 1993). In stream systems, ammonia is most prevalent at the substrate/water interface (Frazier et al. 1996). Due to its high level of toxicity and the fact that the highest concentrations occur in the microhabitat where mussels live, ammonia should be considered among the factors potentially limiting survival and recovery of mussels at some locations (Augspurger et al. in prep.). A congener of the rayed bean, the rainbow (*Villosa iris*), is very sensitive to common toxicants, such as ammonia and monochloramine (Goodreau et al. 1993) and copper (Jacobson et al. 1997). If the rayed bean is also sensitive to pollution, this data suggests that contaminants are at least partially responsible for the demise of the rayed bean rangewide (West et al. 2000).

Contaminants associated with households and urban areas, particularly those from industrial and municipal effluents, may include heavy metals, chlorine, phosphorus, and numerous organic compounds. Wastewater is discharged through National Pollution Discharge Elimination System (NPDES) permitted (and some non-permitted) sites throughout the country. Elimination sites are ubiquitous in watersheds with rayed bean populations, providing ample opportunities for some pollutants to enter streams.

Agricultural sources of chemical contaminants are considerable and include two broad categories: nutrient enrichment (e.g., runoff from livestock farms and feedlots, fertilizers from row crops) and pesticides (e.g., from row crops) (Frick et al. 1998). Nitrate concentrations are particularly high in surface waters downstream of agricultural areas (Mueller et al. 1995).

Stream ecosystems are impacted when nutrients are added at concentrations that cannot be assimilated, resulting in over-enrichment, a condition exacerbated by low-flow conditions. Juvenile mussels utilizing interstitial habitats are particularly affected by depleted dissolved oxygen levels resulting from over-enrichment (Sparks and Strayer 1998). Because interstitial habitats are also the typical habitat of adult rayed beans, oxygen reductions may also negatively

affect them. Increased risks from bacterial and protozoan infections to eggs and glochidia may also pose a threat (Fuller 1974). Pesticide runoff commonly ends up in streams. The effects of pesticides on laboratory-tested mussels may be particularly profound (Fuller 1974, Havlik and Marking 1987), and commonly used pesticides have been directly implicated in a North Carolina mussel die-off (Fleming et al. 1995). Once widely used in parts of the Midwest and Southeast, organochlorine pesticides are still detected in streams and aquatic organisms decades after their use has been banned and may still be found at levels in streams that often exceed chronic-exposure criteria for the protection of aquatic life (Buell and Couch 1995, Frick et al. 1998). Fertilizers and pesticides are also commonly used in developed areas. These contaminants have the potential to impact all extant populations of the rayed bean.

Numerous streams throughout the range of the rayed bean have experienced mussel and fish kills from toxic chemical spills (Sparks et al. 1999), particularly in the upper Tennessee River system in Virginia where several major spills have been documented (Neves 1986, 1991). Catastrophic pollution events, coupled with pervasive sources of contaminants (e.g. municipal and industrial pollution, coal-processing wastes), probably contributed to the elimination of the rayed bean in the Clinch River several decades ago (Neves 1991). An alkaline fly ash pond spill in 1967 and a sulfuric acid spill in 1970 on the Clinch at Carbo, Virginia, caused a massive mussel kill for up to 12 miles downstream from a power plant site (Cairns et al. 1971). Natural recolonization has not occurred in the impacted river reach (Ahlstedt 1991). The timing of this single event roughly coincides with the demise of the rayed bean in the Clinch River. A major diesel fuel spill from a ruptured pipeline in Fish Creek, DeKalb County, Indiana, in 1993 resulted in a mussel kill in the lower portion of the stream (Sparks et al. 1999). Chemical spills will invariably continue to occur and have the potential to completely eliminate rayed bean populations from restricted stream reaches and possibly entire streams.

Mining

Heavy metal-rich drainage from coal mining and associated sedimentation has adversely impacted portions of historical rayed bean habitat in the Allegheny River system in western Pennsylvania (Ortmann 1909) and the upper Tennessee River system, Virginia (Kitchel et al. 1981). The low pH commonly associated with mine runoff can reduce glochidial encystment rates (Huebner and Pynnönen 1992). Residual acid mine runoff may thus impact mussel recruitment. No rayed bean populations are thought to remain in drainages with current coal mining activities. However, if coal mining activities are reinitiated in western Pennsylvania, they could become a threat to populations in lower French Creek and the Allegheny River. Oil and gas exploration is accelerating in western Pennsylvania. Pollutants from these activities include brines and organics. These activities are also a threat to rayed bean populations in these streams.

Instream gravel mining has been implicated in the destruction of mussel populations (Hartfield 1993). Negative impacts associated with gravel mining include stream channel modifications (e.g., altered habitat, disrupted flow patterns, sediment transport), water quality modifications (e.g., increased turbidity, reduced light penetration, increased temperature), macroinvertebrate population changes (e.g., elimination, habitat disruption, increased sedimentation), and changes

in fish populations (e.g., impacts to spawning and nursery habitat, food web disruptions) (Kanehl and Lyons 1992, Roell 1999). Gravel mining activities may be a localized threat in some streams with extant rayed bean populations. Gravel mining has been a long-term problem in the Elk River, Tennessee, and may have contributed to the demise of its rayed bean population.

Sedimentation

Siltation and general sedimentation runoff is a pervasive problem in streams and has been implicated in the decline of stream mussel populations (Ellis 1936, Marking and Bills 1979, Vannote and Minshall 1982, Dennis 1985, Brim Box 1999, Fraley and Ahlstedt 2000). Specific biological impacts on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity, and physical smothering (Ellis 1936, Stansbery 1971, Marking and Bills 1979, Vannote and Minshall 1982, Waters 1995). Studies tend to indicate that the primary impacts of excess sediment on mussels are sublethal, with detrimental effects not immediately apparent (Brim Box and Mossa 1999). The physical effects of sediment on mussels appear to be multifold and include changes in suspended and bed material load; bed sediment composition associated with increased sediment production and run-off in the watershed; channel changes in form, position, and degree of stability; changes in depth or the width/depth ratio, which affects light penetration and flow regime; actively aggrading (filling) or degrading (scouring) channels; and changes in channel position that may leave them high and dry (Vannote and Minshall 1982, Kanehl and Lyons 1992, Brim Box and Mossa 1999).

Interstitial spaces in the substrate provide crucial habitat for juvenile mussels. When clogged, interstitial flow rates and spaces may become reduced (Brim Box and Mossa 1999), thus reducing juvenile habitat. The habit of the rayed bean in burrowing deep into interstitial substrates makes it more susceptible to degradation of this habitat. Sediment may act as a vector for delivering contaminants such as nutrients and pesticides to streams. Juveniles can readily ingest contaminants adsorbed to silt particles during normal feeding activities. These factors may help explain, in part, why so many mussel populations, including potentially those of the rayed bean, appear to be experiencing recruitment failures. Many Midwestern, Northeastern, and Southeastern streams have increased turbidity levels due to siltation. Mussels may be indirectly affected when turbidity levels significantly reduce the amount of light available for photosynthesis and the production of unionid food items (Kanehl and Lyons 1992).

Agricultural activities produce the most significant amount of sediment that enters streams (Waters 1995). Neves et al. (1997) stated that agriculture (including both sediment and chemical run-off) affects 72 % of the impaired river miles in the country. Unrestricted access by livestock is a significant threat to many streams and their mussel populations (Fraley and Ahlstedt 2000). Grazing may reduce infiltration rates and increase run-off and trampling increases the probability of erosion (Armour et al. 1991, Trimble and Mendel 1995, Brim Box and Mossa 1999).

Other Activities Affecting Mussels

Silvicultural and developmental activities may also impact streams where adequate buffers are not maintained and erosion of impacted lands is allowed to freely enter streams. Due to its proximity to the Greater Metropolitan Columbus area, the once substantial population in the middle Scioto River system has been decimated. Extant populations still occur in the Greater Metropolitan Detroit and Fort Wayne areas, but are probably declining. Developmental activities may threaten isolated rayed bean populations in some other regions (e.g., western New York, northwestern Pennsylvania). Droughts may also be a threat, exacerbated by global warming and water withdrawals for agricultural irrigation, municipal, and industrial water supplies. These anthropogenic activities act insidiously to lower water tables, thus making rayed bean and other mussel populations susceptible to depressed stream levels.

B. Overutilization for commercial, recreational, scientific, or educational purposes.

The rayed bean is not a commercially valuable species. An increasingly rare species like the rayed bean may increasingly be sought by lay and experienced collectors. Most stream reaches inhabited by this species are restricted, and its populations are generally small. Although scientific collecting is not thought to represent a significant threat, localized populations could become impacted and possibly extirpated by over-collecting, particularly if this activity is unregulated.

C. Disease or predation.

The occurrence of disease in mussels is virtually unknown. Several mussel dieoffs have been documented during the past 20 years (Neves 1986). Although the ultimate cause is unknown, some researchers believe that disease may be a factor.

Muskrats are a perceived localized threat to mussel populations, according to Neves and Odum (1989). They concluded that this activity could limit the recovery potential of endangered mussel species or contribute to the local extirpation of already depleted mussel populations. However, muskrats were not thought to be a threat to the rayed bean by West et al. (2000), due to their general selection of mussels larger than 1.4-1.6 inches long (Convey et al. 1989, Hanson et al. 1989). Neves and Odum (1989) also noted that muskrats did not select for small unionids (e.g., moccasinshell, *Medionidus conradicus*). Nevertheless, some muskrat predation on the rayed bean has recently been documented, but is generally considered insignificant.

D. The inadequacy of existing regulatory mechanisms.

Most states with extant rayed bean populations prohibit the taking of mussels for scientific purposes without a State collecting permit. However, enforcement of this permit requirement is difficult. Furthermore, State regulations do not generally protect mussels from other threats.

Existing authorities available to protect riverine ecosystems may not have been fully utilized, such as the Clean Water Act (CWA), administered by the Environmental Protection Agency and the U.S. Army Corps of Engineers. This may have contributed to the general habitat degradation apparent in riverine ecosystems and loss of populations of aquatic species in the Southeast,

Midwest, and Northeast. Although the rayed bean coexists with other federally listed mussels and fishes throughout a portion of its range, listing under the Endangered Species Act (Act) would provide additional layers of protection. Federal permits would be required to take the species, and Federal agencies would be required to consult with the Service when activities they fund, authorize, or carry out may adversely affect the species.

E. Other natural or manmade factors affecting its continued existence.

The majority of the remaining populations of the rayed bean are generally small and geographically isolated. The patchy distributional pattern of populations in short river reaches makes them much more susceptible to extirpation from single catastrophic events, such as toxic chemical spills (Watters and Dunn 1993-94). Furthermore, this level of isolation makes natural repopulation of any extirpated population impossible without human intervention. Population isolation prohibits the natural interchange of genetic material between populations, and small population size reduces the reservoir of genetic diversity within populations, which can lead to inbreeding depression (Avise and Hambrick 1996).

The likelihood is high that some populations of the rayed bean are below the effective population size (Soulé 1980) required to maintain long-term genetic and population viability. Recruitment reduction or failure is a potential problem for many small rayed bean populations rangewide, a potential condition exacerbated by its reduced range and increasingly isolated populations. If these trends continue, further significant declines in total rayed bean population size and consequent reduction in long-term viability may soon become apparent. The present distribution and status of the rayed bean may be indicative of the detrimental bottleneck effect resulting when the effective population size is not attained. A once diffuse population of this species occurred throughout much of the Great Lakes drainages and the Ohio and Tennessee River systems. Historically, there were presumably no absolute barriers preventing genetic interchange among its tributary sub-populations that occurred in various streams and lakes. With the completion of numerous dams, some main stem rayed bean populations were lost, and tributary populations became isolated.

Whereas small isolated tributary populations of imperiled short-lived species (e.g., most fishes) would have theoretically died out within a decade or so after impoundment, the rayed bean would potentially take many years to expire post-impoundment. Without the level of genetic interchange the species experienced historically (i.e., without barriers such as reservoirs), small isolated populations that may now be comprised predominantly of adult specimens could be slowly dying out. Even given the improbable absence of the impacts addressed in AFactors A through D@ above, we may lose smaller isolated populations of this species to the devastating consequences of below-threshold effective population size.

Various alien or nonnative species of aquatic organisms are firmly established in the range of the rayed bean. The alien species that poses the most significant threat to the rayed bean is the zebra mussel (*Dreissena polymorpha*). The invasion of the zebra mussel poses a threat to mussel faunas in many regions, and species extinctions are expected as a result of its continued spread in the eastern United States (Ricciardi et al. 1998). Strayer (1999b) reviewed in detail the

mechanisms in which zebra mussels impact native mussels. The primary means of impact is direct fouling of the shells of live native mussels. Zebra mussels have attached in large numbers to the shells of live native mussels and have been implicated in the loss of mussel beds. Fouling impacts include impeding locomotion (both laterally and vertically), interfering normal valve movements, deforming valve margins, and locally depleting food resources and increasing waste products. Heavy infestations of zebra mussels on mussels may overly stress the animals by reducing their energy stores. They may also reduce food concentrations to levels too low to support reproduction or even survival in extreme cases. Other ways in which zebras may impact native mussels is potentially through filtering their sperm and possibly even their tiny glochidia from the water column. Habitat for native mussels may also be degraded by large deposits of zebra mussel pseudofeces (Vaughan 1997).

Overlapping much of the current range of the rayed bean, zebra mussels are thoroughly established in the Great Lakes drainages and much of the Ohio River system. Populations of the rayed bean have been eliminated by the zebra mussel in Lakes Erie and Tippecanoe and the Detroit River. The greatest current potential for present zebra mussel impacts to the rayed bean appears to be in the Lake St. Clair drainages, Allegheny and Tippecanoe Rivers, French Creek, and Lake Maxinkuckee. In addition, there is long-term potential for zebra mussel invasions into other systems that currently harbor rayed bean populations.

The Asian clam (*Corbicula fluminea*) has spread throughout the range of the rayed bean since its introduction in the mid-1900s. This species has been implicated as a competitor with native mussels for resources such as food, nutrients, and space, particularly as juveniles (Neves and Widlak 1987). According to Strayer (1999b), dense populations of Asian clams may ingest large numbers of unionid sperm, glochidia, and newly-metamorphosed juveniles. He also thought they actively disturb sediments, so dense populations may reduce habitable space for juvenile native mussels. Periodic dieoffs may produce enough ammonia and consume enough oxygen to kill native mussels (Strayer 1999b). However, specific impacts upon native mussels remain largely unresolved (Leff et al. 1990, Strayer 1999b). Yeager et al. (2000) determined that high densities of Asian clams negatively impacted the survival and growth of newly metamorphosed juvenile mussels and thus reduced recruitment. They proved from laboratory experiments that Asian clams readily ingested glochidia, clam density and juvenile mussel mortality were positively correlated, growth rates were reduced with the presence of clams, and juvenile mussels were displaced in greater numbers downstream in laboratory tests with clams (Yeager et al. 2000).

BRIEF SUMMARY OF REASONS FOR ADDITION, REMOVAL OR LISTING PRIORITY CHANGE:

The rayed bean appears to be declining rangewide (Strayer and Jirka 1997, West et al. 2000). The species has been eliminated from 78% of the total number of streams and other water bodies from which it was historically known (22 streams and a lake currently compared to 106 water bodies historically). This species has also been eliminated from long reaches of former habitat in hundreds of miles of the Maumee, Ohio, Wabash, and Tennessee Rivers and from numerous stream reaches in their tributaries. In addition, the species is no longer known from the States of Illinois, Kentucky, Tennessee, Virginia, Alabama, and West Virginia, representing over half of

the states from which it was formerly known. Relatively few streams are thought to harbor long-term viable populations (e.g., Sydenham, Blanchard, Allegheny Rivers; French Creek).

The factors that have caused this decline are ongoing including the loss and degradation of habitat, the effects of small and geographically isolated populations, and the impact of zebra mussels. The decline of the rayed bean is primarily the result of habitat loss and degradation (Neves 1991). Bourgeoning human populations will invariably increase the likelihood that habitat-related threats will continue to impact extant rayed bean populations. Population losses due to impoundments have probably contributed more to the decline and imperilment of the rayed bean than has any other single factor; significant portions of this species' range have been impounded. The majority of the remaining populations of the rayed bean are small and geographically isolated. The resulting patchy distributional pattern of populations in short river reaches makes them much more susceptible to extirpation from single catastrophic events, such as toxic chemical spills (Watters and Dunn 1993-94). Furthermore, this level of isolation makes natural repopulation and genetic interchange impossible without human intervention. Some populations of the rayed bean are likely so small that they are below the effective population size (Soulé 1980) required to maintain long-term genetic and population viability. Last, zebra mussels are thoroughly established throughout much of the current range of the rayed bean and will potentially invade the remaining systems. Populations of the rayed bean have been eliminated by the zebra mussel in Lakes Erie and Tippecanoe and the Detroit River.

FOR RECYCLED PETITIONS:

a. Is listing still warranted? ___

b. To date, has publication of a proposal to list been precluded by other higher priority listing actions? ___

c. Is a proposal to list the species as threatened or endangered in preparation? ___

d. If the answer to c. above is no, provide an explanation of why the action is still precluded.

LAND OWNERSHIP (Estimate proportion Federal/state/local government/private, identify non-private owners):

Numerous parcels of public land (e.g., state parks, state forests, wildlife management areas) occur along historical and extant streams of occurrence for the rayed bean or in their respective watersheds. However, over 90% of the lands draining the watersheds populated by the rayed bean are privately owned. The prevalence of privately held riparian lands in streams with extant populations somewhat diminishes the level of importance afforded by public lands that may implement various land-use restrictions. Riparian activities that occur outside or upstream of public lands may be pervasive and have a profound impact on their populations. Habitat protection benefits on public lands may therefore easily be negated by detrimental activities upstream in the watershed. Following are some of the more significant public lands associated with important rayed bean populations.

In the lower Great Lakes basin, the Port Huron State Game Area is located on the Black River and lower Mill Creek. Johnny Appleseed Memorial Park is located on the lower St. Joseph River and is thought to harbor an extant rayed bean population. TNC has a few inholdings in Fish Creek and French Creek watersheds where they have established bioreserves. In the Ohio River system, Clear Creek State Forest and State Game Lands No. 86 are located on the Allegheny River. Parcels of Allegheny National Forest occur in some small tributaries of the Allegheny. The Miami Conservancy District owns lands associated with the rayed bean population in the Stillwater River.

Several parcels of public lands are known in the Wabash River system. Along the Tippecanoe River these include Winamac City Park (which harbors an extant rayed bean population), Potawatomi Wildlife Park, Winnamac Fish and Wildlife Area, Tippecanoe River State Park, and Tippecanoe River and Sandhill Nature Preserves. The lower main stem of Sugar Creek, Indiana, occurs in Camp Atterbury Maneuver Training Center and Atterbury Fish and Wildlife Area.

PRELISTING (Describe status of conservation agreements or other conservation activities):

The Service=s Partners for Fish and Wildlife program has funded millions of dollars in projects in Service Regions 3, 4, and 5. Funding in this program has been provided to landowners to enhance riparian habitat in streams with rayed bean populations. Other funding sources play significant roles in the Service=s riparian habitat protection program. These include CWA Section 319, Natural Resource Conservation Service programs (e.g., Environmental Quality Incentives Program, Wildlife Habitat Improvement Program, Conservation Reserve Enhancement Program), Landowners Incentives Program, National Fish and Wildlife Foundation (NFWF) habitat programs, and numerous other Federal programs are potential sources of money for rayed bean habitat restoration and conservation.

Settlements from large chemical spills have been negotiated and restoration plans written to help mitigate for spill impacts. Sparks et al. (1999) outlined the Fish Creek Restoration Plan, which was written for a diesel fuel spill in northeastern Indiana in 1993. The plan focused on five primary objectives: 1) enhancing mussel recovery, 2) improving water quality, 3) protecting the

riparian corridor, 4) conducting public outreach efforts, and 5) monitoring restoration plan success. Approximately $2.5 million of settlement money is going towards these goals in Fish Creek. Similarly, money from an illegal harvest case was used to establish a Mussel Mitigation Trust Fund (MMTF). This trust is used to fund imperiled mussel recovery work.

Some of the Service ecosystems in the range of the rayed bean have made imperiled mussels a high priority resource for conservation. The Ohio River Valley Ecosystem (ORVE), Mollusk Subgroup determined the need for this status review. Ecosystem teams will be a source for identifying future funding needs for the rayed bean.

Most Service field offices now have public outreach/environmental education staff. These staff members are involved in various efforts to educate the general public as to the benefits of habitat preservation and water quality. For instance, in the Southern Appalachian Ecosystem, comprising the headwaters of the Tennessee River system (among other drainages), aquatic issues form a major part of the outreach efforts in the ecosystem among Service representatives and partners. Representative projects have included posters and videos highlighting aquatic faunal groups, a riparian restoration and conservation video for streamside landowners, endangered species pamphlets, and mussel trunks (outreach/education kits) for educators.

The spread of the zebra mussel threatens many populations of rayed bean. Public outreach efforts to stem the spread of this invader, such as signs at boat ramps, are in place in many areas (e.g., Sydenham River; D.A. Woolnough, ISU, pers. comm., 2002). A web site (www.sydenhamriver.on.ca) provides a recovery strategy for rare mussels in the Sydenham while outlining perceived threats to native mussel species in that stream.

Survey work continues in many portions of the range of the rayed bean. For instance, intensive sampling is currently planned for portions of the lower Allegheny River (R. Villella Bumgardner, USGS, pers. comm., 2002) and southeastern Michigan streams (P. Badra, MNFI, pers. comm., 2001). Information gathered from these surveys will help determine its population status and generates other data useful for conservation management and recovery efforts.

TNC has made at least two streams harboring extant populations of the rayed bean bioreserves: Fish Creek, Indiana and Ohio; and French Creek, Pennsylvania and New York. Although TNC has few riparian inholdings in these watersheds, they have carried out aggressive and innovative community-based projects in both watersheds that address aquatic species and instream habitat conservation on multiple scales. They have worked with scores of riparian landowners to help them restore and protect streambanks and riparian zones and partner with various other stakeholders in conserving aquatic resources.

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LISTING PRIORITY (place * after number)

THREAT

Magnitude	Immediacy	Taxonomy	Priority
High	Imminent	Monotypic genus	1
		Species	2*
		Subspecies/population	3
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/population	6
Moderate to Low	Imminent	Monotypic genus	7
		Species	8
		Subspecies/population	9
	Non-imminent	Monotypic genus	10
		Species	11
		Subspecies/population	12

Rationale for listing priority number:

Magnitude:
The threats to the rayed bean are significant and present throughout the species range, and thus are high in magnitude. Threats associated with habitat loss and degradation occur throughout the range of the rayed bean, including impoundments, channelization, chemical contaminants, mining, and sedimentation. Significant portions of this species' range have been impounded; population losses due to impoundments have probably contributed more to the decline and imperilment of the rayed bean than any other single factor. Zebra mussels have become established throughout the majority of the rayed bean's range and have the long-term potential of spreading throughout additional portions of the range. Remaining rayed bean populations are small and geographically isolated making them susceptible to a single catastrophic event and making natural repopulation and genetic interchange impossible.

Imminence:
Once a common mussel species, the rayed bean has disappeared from a large portion of its range including the entire Tennessee River system and the rest of its range south of the Ohio River. Threats to the remaining populations are imminent are occurring now and will likely not lessen in the future. These threats include the ongoing effects of impoundments, channelization, sedimentation, chemical contamination, and mining. Bourgeoning human populations will increase the likelihood that many of these habitat-related factors will continue to impact extant rayed bean populations. The zebra mussel has already eliminated the rayed bean from Lakes Erie and Tippecanoe and the Detroit River and is posing an immediate threat to the rayed bean populations in the Lake St. Clair drainages, Allegheny and Tippecanoe Rivers, French Creek,

and Lake Maxinkuckee. The resulting range restrictions and disjunct nature of the remaining populations continue to impact the species through reduced genetic diversity and limited natural reproduction. Relatively few streams across the species' former range are thought to harbor long-term viable populations.

APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes to the candidate list, including listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all additions of species to the candidate list, removal of candidates, and listing priority changes.

Approve: Marvin Moriarty 03/13/2003
Acting Regional Director, Fish and Wildlife Service Date

Concur: Steve Williams April 5, 2004
Director, Fish and Wildlife Service Date

Do not concur:_____ _____
Director, Fish and Wildlife Service Date

Director's Remarks: _____

_____

_____

Date of annual review:
Conducted by:

Comments: _____

_____

_____

(rev. 8/02)