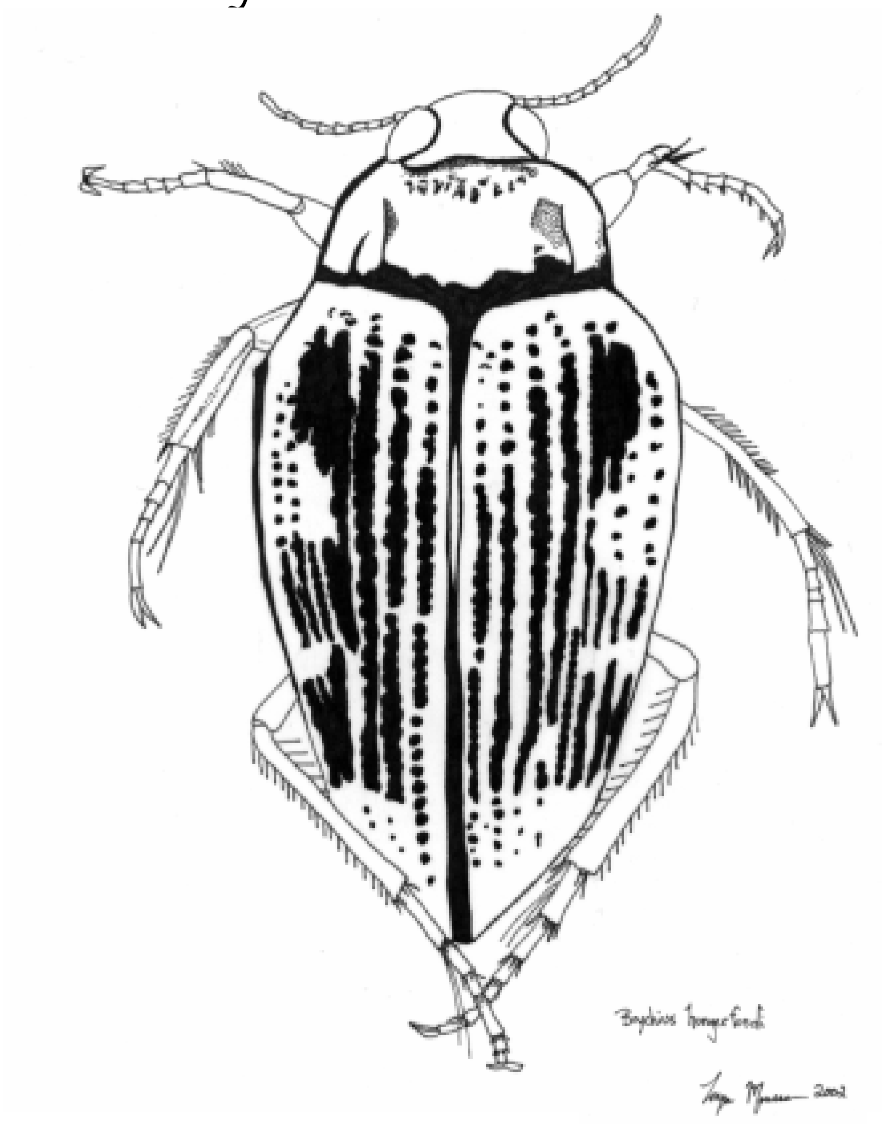
U. S. Fish and Wildlife Service

Hungerford's Crawling Water Beetle (*Brychius hungerfordi*) Draft Recovery Plan



August 2004

Department of the Interior
U.S. Fish and Wildlife Service
Great Lakes-Big Rivers Region
Fort Snelling, MN

Hungerford's crawling water beetle
(Brychius hungerfordi)

Draft Recovery Plan

August 2004

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for

Region 3
U.S. Fish & Wildlife Service
Fort Snelling, Minnesota

Approved: ______________________________
Regional Director, Region 3, U.S. Fish & Wildlife Service

Date: ______________________________

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Recovery plans can be downloaded from FWS website: http://endangered.fws.gov

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EXECUTIVE SUMMARY

<u>Current Species Status</u>: *Brychius hungerfordi* was listed as endangered on March 7, 1994, under the provisions of the U.S. Endangered Species Act. The species is found at four sites in the United States and one site in Canada. Of these sites, only one is considered stable or increasing (i.e., the East Branch of the Maple River). The other sites have low numbers and beetles are not consistently found during surveys; thus, the status of these sites is uncertain.

<u>Habitat Requirements and Limiting Factors</u>: *B. hungerfordi* is found in areas of streams with good stream aeration, moderate to fast stream flow, inorganic substrate, and alkaline water conditions. Specific habitat requirements are not known. The species is often found downstream from culverts, beaver and natural debris dams, and human-made impoundments. It is unknown what factors are limiting the species' distribution. Potential threats to the species include habitat modification, fish management activities, and human disturbance. The small size and limited distribution of *B. hungerfordi* make it vulnerable to chance demographic and environmental events.

<u>Recovery Strategy</u>: Threats to this species are not well understood. At the known sites, threats have been hypothesized and need further examination. Very little is understood about the ecological requirements, life history, and population structure of *B. hungerfordi*. Additional information on these basic parameters will facilitate a better understanding of other factors that may be impacting the species. Therefore, a research program that targets *B. hungerfordi* and its habitat is necessary. Based on these studies, we will seek to maintain multiple populations of *B. hungerfordi* and increase their size to a level at which genetic, demographic, and environmental uncertainty are less threatening. Known sites will continue to be protected and monitored. Our efforts will include reducing, to the extent possible, threats that result in physical habitat destruction and degradation (e.g., from beaver control, stream-side logging, dredging, stream pollution, road work, bank stabilization, impoundment) and threats relating to fish management and human recreation. If research indicates that additional factors are threatening the species, the plan will be revised to include additional recovery criteria.

Recovery Goal: The ultimate goal of the recovery plan is to remove the species from the Federal list of Endangered and Threatened Wildlife (50 CFR 17.11). The intermediate goal of the Plan is reclassification of *B. hungerfordi* to threatened status.

Recovery Objective: The objectives of this recovery plan are as follows: 1) determine and ensure adequate population size, numbers, and distribution for achievement and persistence of viable populations and long-term survival; 2) identify essential habitat for all life stages and ensure adequate habitat protection; and 3) identify additional threats to the species, if they exist. Initially, the objective of the recovery program is to gather sufficient information to revise and refine the recovery criteria.

Interim Recovery Criteria:

Reclassification from endangered to threatened when:

1. Life history, ecology, population biology, and habitat requirements are understood well enough to fully identify threats
2. A minimum of four U.S. populations, in at least two different watersheds, have had stable or increasing populations for at least 10 years.

Delisting when the above criteria are met, plus:

3. Identify and protect habitat necessary for long-term survival and recovery
4. A minimum of four U.S. populations, in at least two different watersheds, are sufficiently secure and adequately managed to assure long-term viability.

Actions Needed:

1. Protect known sites
2. Conduct scientific research to facilitate recovery efforts
3. Conduct additional surveys and monitor existing sites
4. Develop and implement public education and outreach
5. Revise recovery criteria and recovery tasks, as appropriate, based on research and new information
6. Develop a plan to monitor *B. hungerfordi* after it is delisted

Estimated Cost of Recovery for FY 2005 – 2008 (in $1000): Details are found in the Implementation Schedule**.**

Fiscal Year	Task 1	Task 2	Task 3	Task 4	Task 5	TOTAL
2005	16	102	26	1.5	0	**145.5**
2006	11	72	21	1.5	0	**105.5**
2007	11	70	16	1.5	5	**103.5**
TOTAL	**38**	**244**	**63**	**4.5**	**5**	**354.5**

Date of Recovery: Contingent on funding and implementation of recovery actions, full recovery of this species may occur by 2030.

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PART I. BACKGROUND

Status of the Species

Brychius hungerfordi, commonly known as Hungerford's crawling water beetle, was listed as endangered on March 7, 1994, under the provisions of the U.S. Endangered Species Act (ESA) of 1973, as amended (United States Fish and Wildlife Service 1994). *B. hungerfordi* has been assigned a recovery priority of 5, indicating a high degree of threat and low recovery potential. Critical habitat has not been designated for this species.

At the time of its listing, *B. hungerfordi* was known to occur at only three locations in the world. Since then, two additional sites have been discovered. Very little information is known about *B. hungerfordi*. Information on life history, threats and habitat preferences is needed in order to fully recover the species.

Taxonomy and Description

Beetles (Order: Coleoptera) are generally characterized as having hardened forewings (elytra) which, when folded, meet in a straight line over their back and protect and cover the delicate hind wings. Beetles undergo complete metamorphosis and progress through four stages of development: egg, larvae, pupae, and adult.   Appendices A and B define some of the terms used to describe the species and give more detail on beetle morphology.

B. hungerfordi is a member of the Haliplidae family. Members of the Haliplidae family are commonly known as haliplids, or crawling water beetles. They have a distinctive elongated and streamlined body shape, adapted for swimming or crawling in water (Holmen 1987). All members of the Haliplidae family are aquatic, with all active life history stages spent in water (Pennak 1953; Roughley and Larson 1991). Adults have large coxal plates covering the base of their hind legs and abdomen. The elytra almost always have longitudinal rows of dark punctures (Spangler 1954; White et al. 1984). Adult haliplids are small, and range in length from approximately 2-5 mm (Pennak 1953). The family contains five genera (*Algophilus, Apteraliplus, Brychius, Haliplus,* and *Peltodytes)* and about 200 species worldwide (Lawrence and Newton 1995). However, some researchers contend that the generic status of the two monotypic genera, *Apteraliplus* and *Algophilus,* is not appropriate as they are probably closely related with a subgroup of *Haliplus* (Beutel and Ruhnau 1990).

The genus *Brychius* is distinguished from other genera of Haliplidae by the shape of the pronotum in which the basal two-thirds is nearly parallel (Hilsenhoff and Brigham 1978; Leech and Chandler 1956; White et al. 1984). There are currently three species of *Brychius* in North America: *B. hungerfordi, B. hornii,* and *B. pacificus.* The latter two species occur in the western United States and Canada, and are much more common and widely distributed than *B. hungerfordi* (Figure 1).

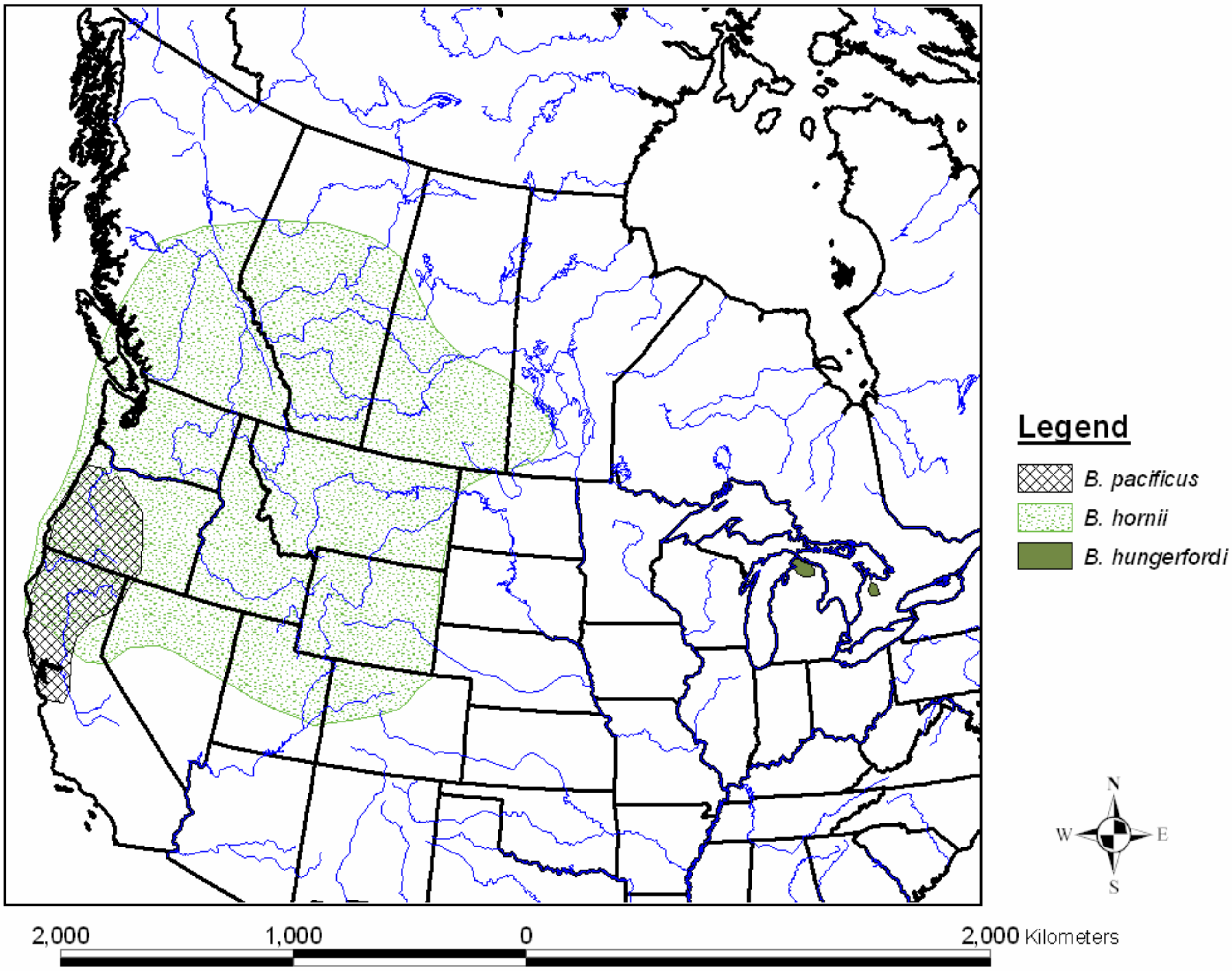


Figure 1. Approximate distribution of the genus *Brychius* in the United States and Canada based on specimens examined. *The ranges shown here are approximate and are for illustrative purposes only.*

B. hungerfordi, first discovered in 1952, was described as a new species by Paul Spangler in 1954 (Spangler 1954). In addition to its geographic distinction, *B. hungerfordi* can be identified from other members of the genus by denser punctation of the head, the presence of a transverse infuscation at the base of the head between the eyes, coarser punctuation on the pronotum (the plate at the base of the head), and larger average size (Spangler 1954). In addition, the male genitalia (i.e., median lobe of the aedeagus) of each *Brychius* species have a unique shape, and can be used for identification (T. Mousseau, University of Manitoba, pers. comm. 2003).

General Description of Adults and Larvae

Adult *B. hungerfordi* are small and torpedo-shaped, with an average body length of 3.8-4.3 mm (0.15-0.17 inches) (Figures 2, 3, and 4). They are yellowish-brown in color with irregular dark markings and longitudinal stripes on the elytra, each of which is comprised of a series of fine, closely spaced and darkly pigmented indentations. Males are characterized by thickened tarsal segments of the front legs with small tufts of hair on the first three segments (Wilsmann and Strand 1990). The females tend to be larger than the males (Spangler 1954; Wilsmann and Strand 1990).

B. hungerfordi larvae are light yellowish brown with cylindrical bodies that taper to a hooked tail (Figure 3). They are stiff-bodied and possess short legs with five-segments and single tarsal hooks (Strand 1989). The larvae of *Brychius* can be distinguished from other described haliplids by having the third antennal segment shorter than the second segment (Leech and Chandler 1956; Strand and Spangler 1994; White et al. 1984). Third instar larvae are approximately 13 mm in length (Strand and Spangler 1994). Strand and Spangler (1994) provide a more thorough description of *B. hungerfordi* larvae.

Population Distribution

B. hungerfordi is found at four sites in northern Michigan and one site in Ontario, Canada (Figure 5). It was discovered in the East Branch of the Maple River in Emmet County, Michigan, in 1952 (Spangler 1954). In 1986, a second population was discovered in the North Saugeen River, Canada (Roughley 1991). Michigan Natural Features Inventory (MNFI) conducted an extensive survey of the Cheboygan River drainage in 1989 which resulted in discovery of a third site, the East Branch of the Black River, in Montmorency County (Strand 1989; Strand and Spangler 1994; Wilsmann and Strand 1990). In 1997, the fourth known site, the Carp Lake River, was discovered in Emmet County (Keller et al. 1998). The fifth site, Van Hetton Creek, was discovered in Montmorency County in 1999 (Grant et al. 2000). Surveys of other streams with similar habitats to known sites have been conducted in other areas of northern Michigan, Ontario, Wisconsin, and Minnesota but have failed to reveal additional populations of *B. hungerfordi* (United States Fish and Wildlife Service 1994).

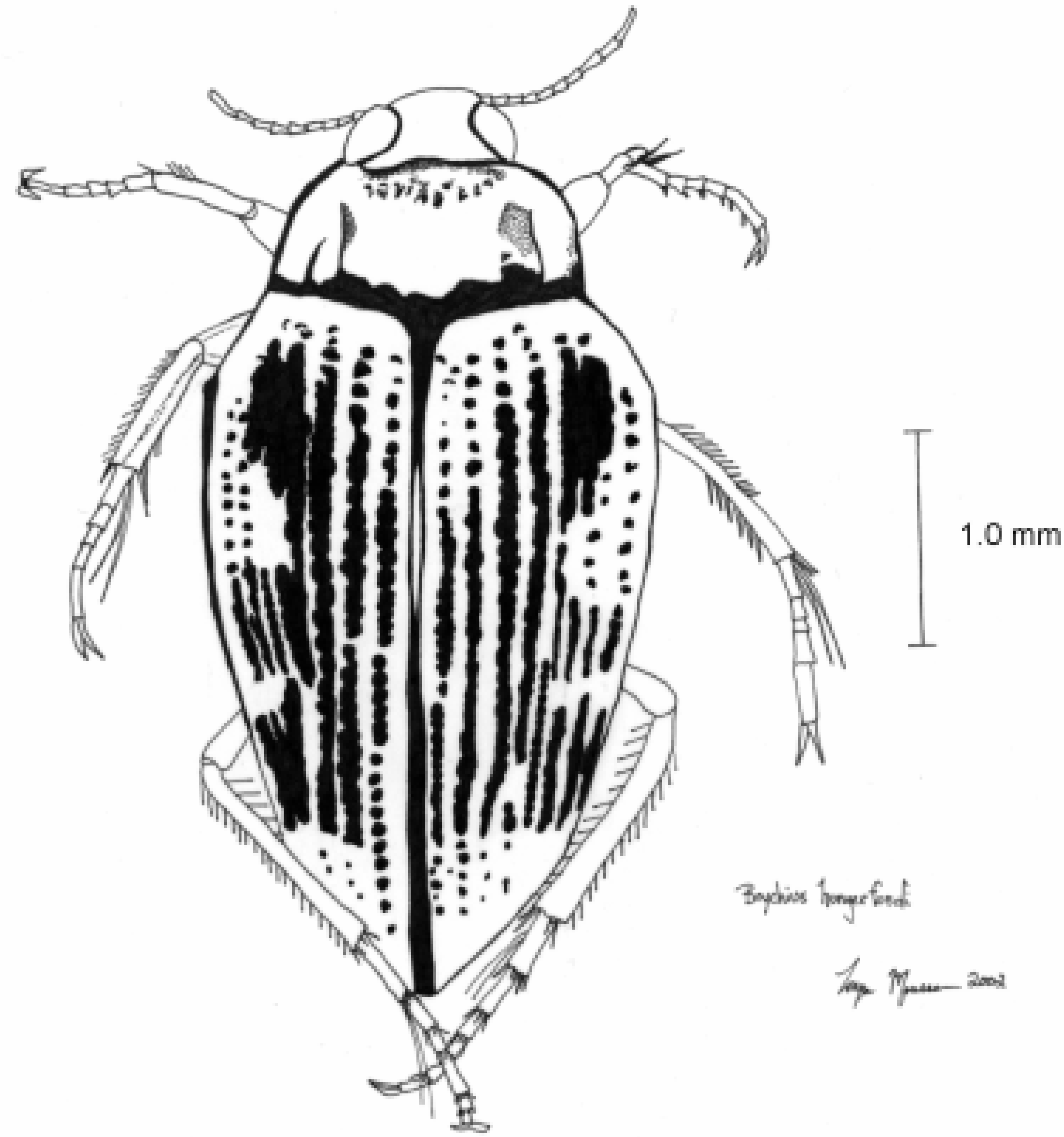


Figure 2. Adult *B. hungerfordi*, dorsal view. Drawing courtesy of Tonya Mousseau, University of Manitoba.

Figure 3. *B. hungerfordi* larva and adults (ventral and dorsal views). Photo from Hinz and Wiley 1999.

Figure 4. *B. hungerfordi* on the tip of a finger. Photo by Mac Strand.

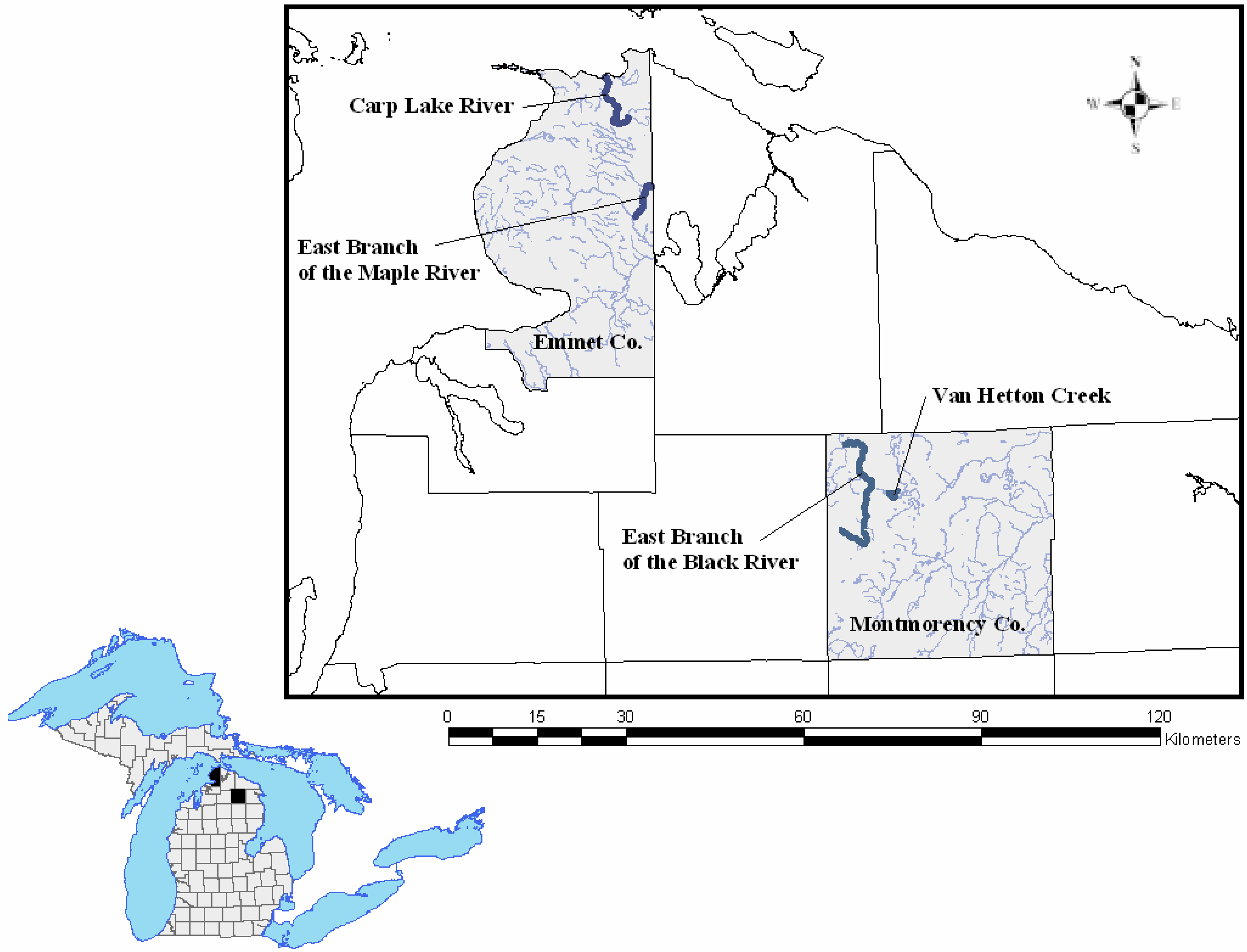


Figure 5. Stream segments in Michigan where Hungerford’s crawling water beetle is known to occur.

Emmet County, Michigan

East Branch of the Maple River

The beetle is found in several areas of the river: from the Douglas Lake Road crossing (T37N, R4W, section 25) downstream for approximately two and a half miles until near the pipeline crossing (T36N, R4W, section 11). This population occurs within the Cheboygan River watershed. The majority of the occupied portions of this stream occur within and along the boundary of the University of Michigan Biological Station (UMBS). The East Branch of the Maple River is the best-studied site and has the largest known population of this species. The results of a mark-recapture study in one pool of the East Branch of the Maple River indicated population numbers near 1000 (Grant et al. 2002). Based on recent studies, populations of *B. hungerfordi* appear to be stable throughout the occupied portions of this stream. At the time of listing, only the site where the beetle was originally discovered and described—the type locality—was known; since then, beetles have been found in additional portions of this stream.

Carp Lake River

B. hungerfordi was first discovered at this site in 1997 when four adults were found under the culvert at the Oliver Road crossing (T39N, R4W, section 32, southwest ¼). The Oliver Road site is on private property surrounded by Mackinaw State Forest, and occurs within the Boardman-Charlevoix watershed. In 1998, the Emmet County Road Commission cleared the road ditches along Oliver Road of vegetation, which resulted in increased erosion and sedimentation of the stream (Vande Kopple and Grant 2004). This led to a loss of some suitable habitat. Surveys conducted in 1998 did not find any *B. hungerfordi*. One adult was found in a survey in 1999 (Hinz, Jr. and Wiley 1999). None were found during surveys conducted in 2003 (Vande Kopple and Grant 2004). Erosion at this road crossing continues to be a problem. Thus, the status of *B. hungerfordi* at this site is unknown.

Montmorency County, Michigan

East Branch of the Black River

This site is approximately 2.5 miles upstream from the Barber Road Bridge (T32N, R1E, section 26) (Strand 1989). It is within the Mackinaw State Forest and the Black River watershed. Only 2 adults were found during surveys in 1989 (Strand 1989). Surveys conducted by MNFI in 1996 found 2 adults at this same location and one adult was found farther downstream, closer to the Barber Road crossing (Legge 1996). The current status of this site is unknown.

Van Hetton Creek

In July 1999, six adult beetles were found along a stretch of Van Hetton Creek (T31N, R2E, section 5). The beetles were found dispersed along a stretch of creek several hundred meters in length (Grant et al. 2000) beginning approximately 30-50 yards downstream of a culvert and county road crossing (Vande Kopple, University of Michigan Biological Station, pers. comm. 1999). This population occurs within the

Mackinaw State Forest and the Black River watershed. The current status of this site is unknown.

<u>Bruce County, Ontario</u>

North Saugeen River

In 1986, forty-two specimens were collected at this site in south central Ontario, Bruce County, near the village of Scone (Roughley 1991). The land surrounding this site is in mixed ownership. This location is downstream from a dam and below an old millrace (Roughley 1991). Surveys in 2002 did not find *B. hungerfordi* in this stream; the last time it was found was in 2001 (R. Roughley, University of Manitoba, pers. comm. 2004). The status of this site is currently unknown.

<u>Historic distribution</u>

The distribution of the species prior to its discovery in 1952 is not known. Recently, however, museum collections throughout North America have been examined in an attempt to find evidence of historic sites (T. Mousseau, University of Manitoba, pers. comm. 2003). This inspection of museum collections led to the discovery of specimens collected in Cheboygan and St. Clair Counties. The Cheboygan County specimens, collected by Stuart Neff in 1953, did not contain specific locality information. It is quite likely that the specimens came from the East Branch of the Maple River, which lies on the border of Emmet and Cheboygan Counties, and were actually collected in Emmet County. The St. Clair County record is that of two larvae which were collected in the St. Clair River in 1983 by Pat Hudson (Hudson et al. 1986). These specimens were identified to the genus level (*Brychius*). This is a very curious record, because the St. Clair River is not similar to known sites and would not be classified as suitable habitat based on our current understanding of the species. Surveys attempts in 2002 were unsuccessful in locating *B. hungerfordi* larvae in the St. Clair River (P. Hudson, Great Lakes Science Center, USGS, pers. comm. 2002).

<u>Biogeography</u>

The disjunct distribution of this species suggests that it is a relict from glacial periods when cool, fast moving streams were more prevalent and the beetle may have been more widespread. Roughley (1989) speculates that “the ancestor of *B. hungerfordi* became isolated in eastern North America during the pre-Pleistocene time. It was probably much more widespread during glacial intervals because peri-glacial streams provided suitable habitat”. As the Wisconsinan glacier retreated, approximately 10,000 years ago, it resulted in natural changes in stream habitat and connectivity. As a result, it is likely that *B. hungerfordi* became increasingly rare and has persisted in very small, suitable pockets of habitat (Roughley 1989). It is possible that this species is naturally rare, and may have always had a very limited distribution during post-Wisconsinan times.

Summary

This species appears to have a very restricted range. Despite several survey attempts, *B. hungerfordi* is only known to occur at five sites. The status of the species is uncertain at four of the known sites. The East Branch of the Maple River has the highest known population and appears to be stable. The historic distribution is unknown, although there are records of *Brychius* in Cheboygan and St. Clair Counties.

Life History and Ecology

Very little is known about the life history of *B. hungerfordi*; however, there are observations and life history information reported for other haliplids. Although there may be differences among species, life history information for closely-related species can give us a reasonable estimate of the likely life history of *B. hungerfordi*. Much of the basic life history of haliplids is taken from Brigham (1982), Hickman (1931), Holmen (1987), Leech and Chandler (1956), Matheson (1912), Pennak (1953) and White et al. (1984).

B. hungerfordi, like all beetle species, undergoes complete metamorphosis with a life cycle that consists of four distinct stages (Figure 6). In general, the period of egg laying for haliplids extends from May through June, although there may be another generation in the fall for some species (Brigham 1982; Hickman 1931). Oviposition (egg-laying) has not been observed for any species of *Brychius*, nor has the egg stage been described. Eggs of the genus *Peltodytes* are approximately 0.415-0.483 mm in length, oval, and yellowish-brown in color (Hickman 1930a). Eggs of the genus *Haliplus* are approximately 0.35-0.45 mm long, elongate or oval in shape, and whitish in color (Hickman 1930a; Holmen 1987). *Peltodytes* eggs are deposited on the leaves and stems of aquatic plants such as *Nitella*, *Elodea*, and *Ceratophyllum*, and upon *Chara* and filamentous algae (Brigham 1982; Hickman 1930a; Hickman 1931). *Haliplus* eggs are inserted within branches of aquatic plants; the female chews a hole in the side of a filament of *Ceratophyllum* or *Nitella* and deposits her eggs within the plant cell (Brigham 1982; Hickman 1930a; White et al. 1984). The form of the gonocoxae in female *B. hornii* indicates endophytic egg-laying behavior (Mousseau and Roughley 2003).

Eggs of haliplids generally hatch 8-14 days after oviposition (Brigham 1982; White et al. 1984). Each egg hatches into a larva which spends most of its time eating and growing. Larvae molt several times as they grow, and each stage preceding a molt is known as an instar. Haliplid larvae pass through three instars and are herbivorous. In *B. hornii*, the first two instars occur in July, and the third instar stage lasts from August to April (Mousseau and Roughley 2003). *B. hungerfordi* larvae have been found in or near direct current in association with algae in the genus *Chara*, which is thought to be a food source (Strand and Spangler 1994). When mature, larvae leave the water in search of a place in damp soil to pupate. In the fall, larvae of *B. hungerfordi* were found away from the current, buried in an island of damp sand and *Chara* up to 15 cm above the water line (Strand and Spangler 1994). Like other haliplids, they likely overwinter in the larval stage in position for spring pupation.

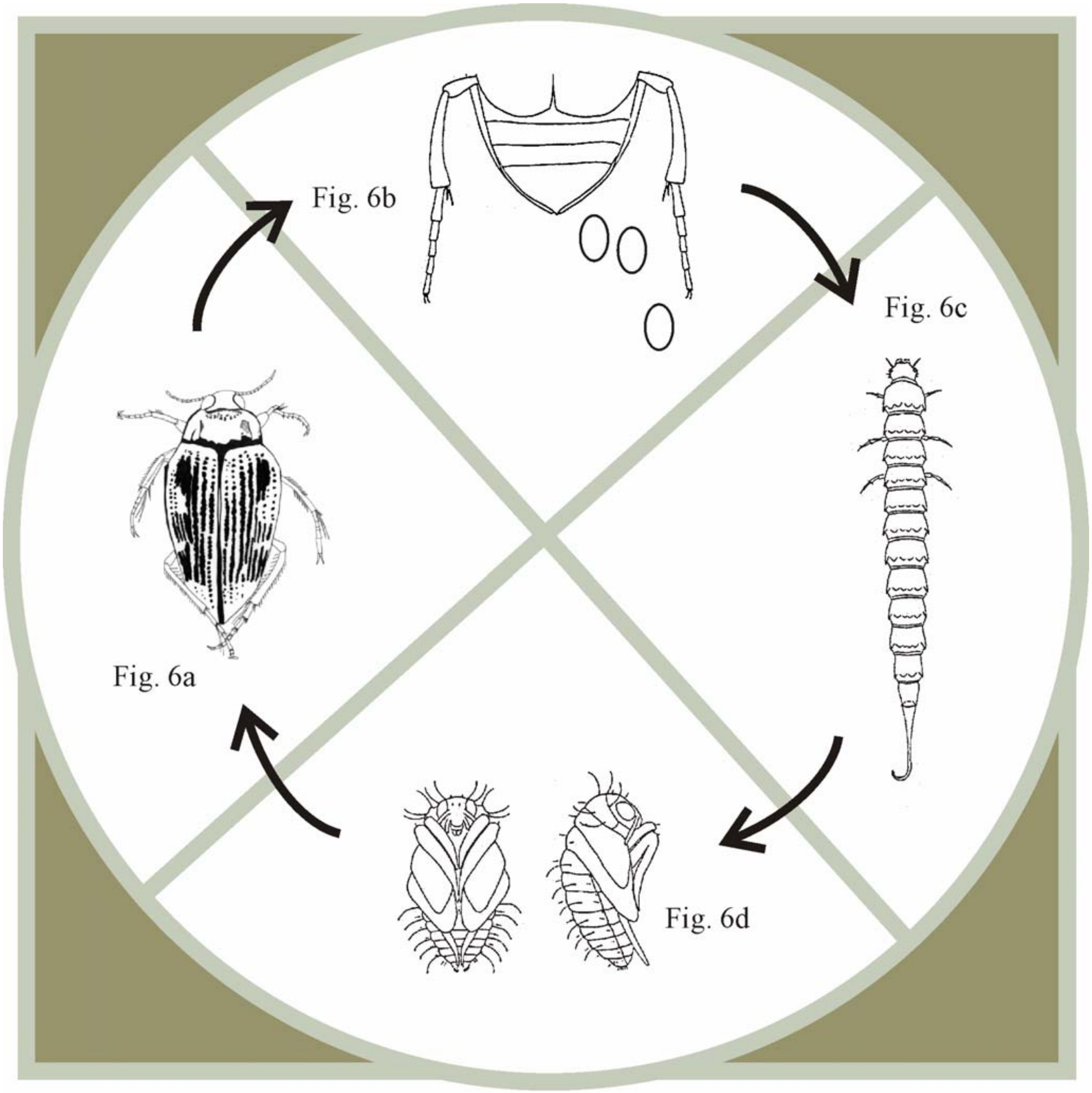


Figure 6. Illustration of life history stages of *B. hungerfordi*. *Fig. 6a*. Adult *B. hungerfordi*. Adult beetles mate in the summer. *Fig. 6b*. Oviposition (egg-laying) stage. The egg stage has not been described for *B. hungerfordi*. It is unknown where the eggs are laid, although it is most likely on or within aquatic vegetation within the stream. *Fig. 6c*. Larval stage. Larvae spend most of their time in the stream, but burrow into the sediment prior to transforming to pupae. *Fig. 6d*. Pupae. This stage has not been described for *B. hungerfordi*. Pupae develop within a protected envelope and emerge as adults.

Figure credits: 6a. Tonya Mousseau, University of Manitoba. 6b. Ventral view of an adult *Haliplus* adapted from Holmen 1987. 6c. Figure of *Haliplus* larva adapted from Holmen 1987. 6d. Figure of *Haliplus* pupae adapted from Hickman 1930a. All images used with permission.

The pupal stage is the only one spent in a terrestrial setting. This stage lasts two to three weeks (Pennak 1953), during which time the transformation to adult takes place. It requires several days before the adult beetle is ready to leave the pupal chamber and re-enter the water (Matheson 1912). The pupal stage of *B. hungerfordi* has not been observed.

The young adults of some haliplids do not reproduce until the following year (Holmen 1987). Reproduction in haliplids usually occurs in the spring and early summer. Mating has been observed in *B. hungerfordi* in June (Scholtens 2002). Mating in *B. hornii* also occurs in June (Mousseau and Roughley 2003). Adults of *B. hungerfordi* have been found year round, suggesting that some adults survive the winter, even beneath ice cover (Grant et al. 2000). Studies have shown that some haliplids can even survive being frozen solid (Hickman 1931). Other species in the Haliplidae family have at least one generation in the summer and likely another in the late summer or fall (Hickman 1931). Observations of *B. hungerfordi* suggest that they may have two generations per year, with a second brood of adults emerging late in the season (Grant et al. 2000).

The life expectancy for *B. hungerfordi* is unknown. Other haliplids have been kept alive in a laboratory culture for as long as 18 months (Hickman 1931). Adult *B. hornii* have been kept alive for over two years in the laboratory (T. Mousseau, University of Manitoba, pers. comm. 2003). The longevity observed in a laboratory setting may not reflect longevity in the natural environment where conditions differ.

Food habits

It has been speculated that *B. hungerfordi* is herbivorous, feeding on algae and periphyton, but the food habits of this species have yet to be confirmed. Beetles of the Haliplidae family are typically herbivorous in both the adult and larval stages (Hickman 1931; Matheson 1912).

Strand (1989) observed adult *B. hungerfordi* crawling from rock to rock, stopping occasionally to grip a rock for varying lengths of time, including rocks too small to be stabilizing in the current. Based on this behavior, it has been speculated that they scrape food material from rocks by grasping the rock with their tarsal claws and scraping the biofilm with their mandibles (Strand 1989; Strand and Spangler 1994; Wilsmann and Strand 1990). White's (1986) observations of adults clinging to and moving throughout *Cladophora* mats on top of rocks led him to speculate that they feed on the algae or on the periphytic diatoms which coat it.

Several preliminary studies have recently been conducted in an attempt to confirm the diet of this species. In one study, five frass (fecal pellet) samples were examined to determine their contents (Scholtens 2002). Adult beetles were collected from the East Branch of the Maple River and placed in vials of filtered river water to obtain the frass. Dr. Rex Lowe, a phycologist from Bowling Green State University, examined each pellet to detect and identify any algal contents. None of the pellets examined had any identifiable filamentous algal or diatom fragments. They did contain some living cells, evidently blue-green bacteria, and small particles that appeared to be bacterial remains (Scholtens 2002). A preliminary feeding study has also been conducted for adult *B. hungerfordi,* where beetles were placed in chambers with various food sources (Scholtens and Latvis 2004). Frass samples were collected from the beetles and examined for possible diet identification. During the study, no direct observation of feeding was observed. Adults placed in a chamber with *Audouinella* and some *Cocconeis* had frass containing algal cell walls, some living algae, and frustules of *Cocconeis*. *Audouinella* is a filamentous red algae, and *Cocconeis* is an epiphytic diatom. Adults placed in a chamber with *Cladophora* did not produce frass with any remnants of the algae, which was unexpected. In addition, beetles placed in a chamber with *Mougeocia*, a filamentous green algae, had frass containing the living algae, algal cell walls, bacilliform bacteria, and empty *Synedra* frustules (Scholtens and Latvis 2004). The results of these studies are not conclusive, and addition research is needed.

Another study attempted to determine feeding habits of *B. hungerfordi* using stable isotope analysis (Grant and Vande Kopple 2003). The isotopic compositions of carbon (C) and nitrogen (N) in an animal reflect the C and N compositions of its diet (DeNiro and Epstein 1978); different food sources have distinct isotopic "signatures" that can be matched to that found in the consumer. This study examined the isotopes of carbon and nitrogen in *B. hungerfordi* and potential food sources in an attempt to determine the diet of *B. hungerfordi*. Algal samples were collected from the East Branch of the Maple River and the Carp Lake River. Samples of *Chara*, *Cladophora*, *Spirogyra*, and *Chaetophora* from both sites were analyzed, as well as *B. hungerfordi* adults and fecal samples. The results indicate two distinct carbon pools. The first is likely a carbon signal indicative of the larval food; emerging adult beetles maintain this highly depleted carbon signature indicative of algae growing in fast flowing water. The second carbon pool, excreted in the fecal samples, had a more enriched signature and is indicative of food consumed while adults. Based on this preliminary study, the most likely food source for adults are *Spirogyra*, lithophilic diatoms or *Cocconeis*. The study also indicated that there may be a seasonal change in diet (Grant and Vande Kopple 2003).

<u>Respiration</u>

Some aquatic insects obtain their oxygen directly from the atmosphere or aquatic plants, while others use dissolved oxygen in the water. Aquatic insects that carry their own air supply can stay submerged longer and can be more active than those that rely on fixed oxygen sources (Eriksen et al. 1984). An air supply may be carried as a bubble or gas film. When an insect with a temporary air supply (i.e., bubble) dives underwater, the bubble can serve not only as an air reserve, but also as a physical gill.

The gas bubble is able serve as a physical gill and to supply more oxygen than it contained originally through the process of diffusion. When the insect fills its temporary air store at the surface, the dissolved gases in the atmosphere, bubble, and water are in equilibrium. As the insect consumes oxygen from the bubble, it is replaced by carbon dioxide, which subsequently diffuses rapidly to the surrounding water where the concentration of carbon dioxide is generally low. As the oxygen is consumed from the bubble, oxygen from the water diffuses into the bubble. In this manner, the bubble can continue to extract oxygen from the water, supplying much more oxygen than was in the original air store (Eriksen et al. 1984). The length of time the temporary air store can function as a physical gill depends on the ratio of oxygen consumption to the surface area of the exposed gill surface—the smaller the ratio, the longer the lifetime of the gill (i.e., for insects that use a relatively small amount of oxygen and have a relatively large gill surface, the gill is long lived). Other factors affect the rate of diffusion into the gill (and thus the effectiveness of the physical gill), including depth, oxygen concentration in surrounding water, and water temperatures (Eriksen et al. 1984).

Members of the Haliplidae family have uniquely expanded hind coxal plates which create chambers that can hold stored air. Falkenström (1926) reported that haliplids generally receive enough oxygen from the water by diffusion, but under certain conditions they can take in air much like members of the Dytiscidae (who surface to replenish their air stores) (as cited in Hickman 1930b). He determined that the surface of the bubble which is present in the posterior coxal cavity serves as a diffusion membrane (i.e., a physical gill) through which oxygen and carbon dioxide gas are exchanged between the coxal air store and the water. He arrived at this conclusion when he failed to see the beetles, under normal conditions, come to the surface of the water to renew the air supply (as cited in Hickman 1930b).

Hickman (1930b) found that haliplid beetles (*Haliplus sp*. and *Peltodytes sp*.) did not receive enough oxygen from the water to support life, even at low temperatures. He conducted an experiment to determine whether beetles given only dissolved oxygen could survive by not allowing them to surface. All of the submerged beetles died, so he concluded that beetles must need to surface for oxygen. Hickman (1930b) also examined the following: the mechanism by which haliplid beetles replenish their air stores, the hydrostatic and respiratory functions of the air stores, and the frequency of surfacing. He found that the air store is indeed used for respiration while the beetle is underwater. It also serves a hydrostatic function by allowing the beetle to more easily surface and by orienting their body so that the tip of the abdomen can properly break the surface film. Finally, he found that the length of time between surfacing events was dependent on the nature of their activity. As expected, increased activity required more oxygen and required more frequent trips to the surface. Thus, disturbed beetles surface more frequently, from 2-3 seconds to several minutes. He determined that normally they use little oxygen and therefore frequent trips are not necessary to supply their needs.

The studies conducted thus far have looked at respiration in other haliplids (i.e., *Haliplus* and *Peltodytes*), but none have looked specifically at the breathing requirements of *B. hungerfordi*. It is not clear at what frequency these beetles surface, if at all. It is likely that they do surface for breathing purposes, at least occasionally, but probably not frequently. White (1986) observed *B. hungerfordi* surfacing for air while watching the behavior of two adult beetles in the East Branch of the Maple River. He noted adult beetles surfaced every 5 to 7 minutes, with each trip through the water column to the surface and back lasting no more than 3 to 4 seconds (White 1986). However, recent observations in the East Branch of the Maple River failed to observe beetles surfacing for air, despite lengthy observation of beetles in their natural environment within the stream, and continuous observation of beetles held in vials for more than 2 hours (Scholtens 2002). More recent studies have been inconclusive (Scholtens and Tamaska 2004).

If these beetles use a temporary air store, or bubble, that functions as a physical gill, then the frequency of surfacing to replenish the air store would depend on environmental conditions (i.e., temperature, oxygen content, depth) of their surroundings. In some habitats, they would need to surface frequently, whereas in other environments they may be able to remain submerged for long periods of time. Recently adult *B. hungerfordi* beetles have been found to survive under thick ice cover, where they are unable to surface. During this time, their oxygen demand is less and the available dissolved oxygen is greater, so perhaps they may be able to rely solely on diffusion. It is also possible that they utilize a gas film, or plastron, that acts as a permanent physical gill, although this has not been examined in *B. hungerfordi*. Beetles may also utilize oxygen generated by submerged aquatic plants (Hickman 1931). They are often found in areas rich with algae where much oxygen is produced. Also, adult beetles have been observed "grabbing" air bubbles given off from aquatic plants (M. Grant, UMBS, pers. comm. 2004). More research is needed to confirm the breathing mechanism of adults of this species.

Larvae can breathe continually underwater and do not take in air at the surface. They obtain oxygen by cutaneous respiration and through microtracheal gills (Eriksen et al. 1984; Holmen 1987; Strand and Spangler 1994).

<u>Locomotion and dispersal</u>

Adult haliplids are generally not fast or strong swimmers, and spend the majority of their time crawling on the bottom among the cobbles and aquatic vegetation (Matheson 1912). Aside from long hairs on the tarsi, the legs are unmodified for swimming (Pennak 1953). White (1986), however, described *B. hungerfordi* as a strong swimmer, based on his observations of beetles surfacing in swift current (>50 cm/sec) with only minimal downstream displacement (15-20 cm). It is unknown how *B. hungerfordi* beetles disperse within the stream. Drift, the passive downstream transport of aquatic organisms in current, is a possible mechanism of dispersal. They may also be able to crawl upstream to colonize new sites. It is not known to what extent these beetles use drift or what distances they can crawl upstream.

Another potential mechanism of dispersal is flight. Adults of most aquatic Coleopteran species leave the water on dispersal flights (White et al. 1984). Hickman (1931) reported adult haliplids coming to lights in the laboratory, but others report attraction to light to be very rare (Matheson 1912). Holmen (1987) reports that although many species of Haliplidae are capable of flight, the majority of species do so only rarely. Jackson (1952; 1956) found that the development of muscles necessary for flight varies among species, and may also vary through the life span of some specimens. Several beetle species are capable of flight for only short periods of time (e.g., some elmid species only fly immediately after emergence from the pupal chamber). Specimens of *Brychius* do have fully developed flight wings (Roughley 1989); however, it is unknown whether they are capable of flight during any period of development. *B. hungerfordi* has never been observed to fly or been found at blacklight stations. If flight were possible in this species, it would be a means of dispersal to distant suitable habitats.

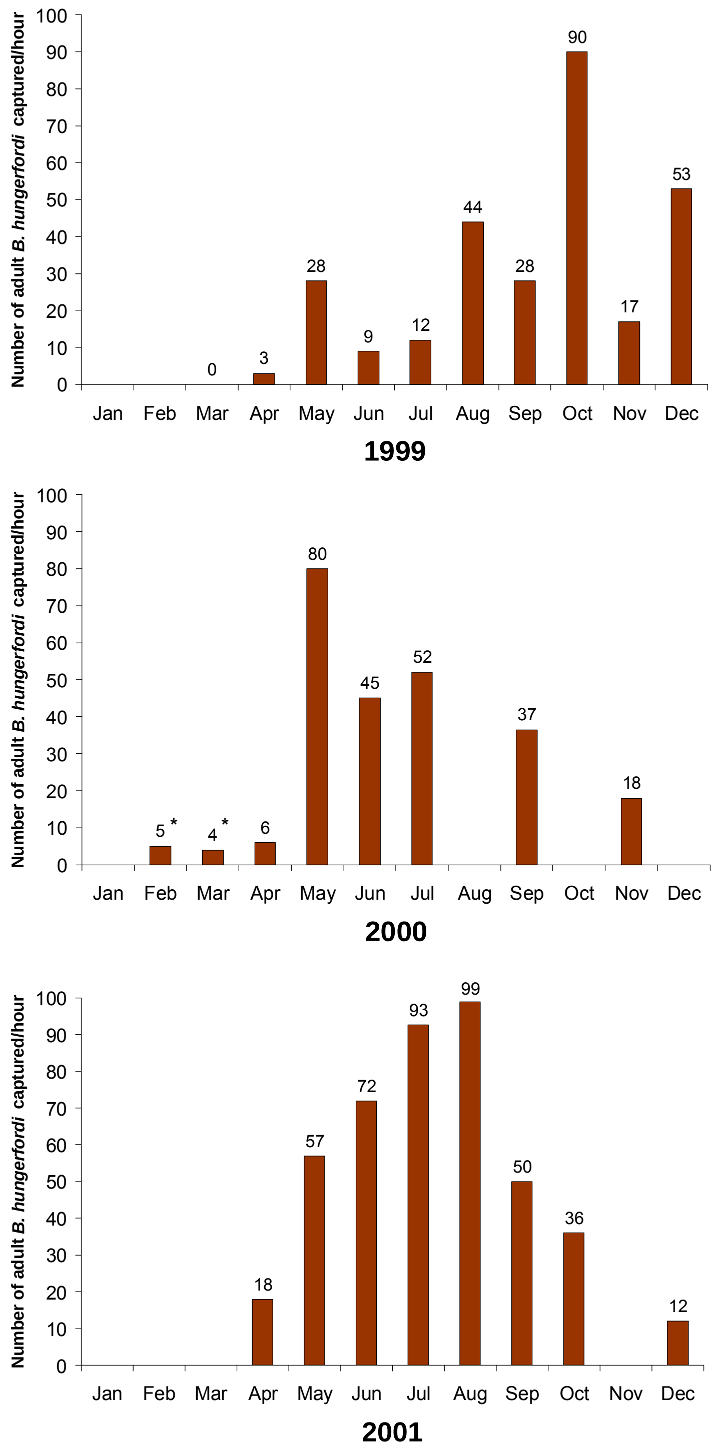
Legs of haliplid larvae are short and adapted for crawling on vegetation or along the substrate (Holmen 1987). Larvae of *Brychius* are sluggish (Holmen 1987), and are not adapted for swimming.

<u>Population studies, surveys, and observations</u>

Seasonal abundance has been examined in the largest known population of *B. hungerfordi* in one pool of the East Branch of the Maple River (Grant et al. 2000; Grant et al. 2002). This pool was sampled monthly over a three year period, and the number of adult *B. hungerfordi* captured per hour was recorded (Figure 7). During the three years of the study, the population peaked during different seasons and showed no obvious trend. In July 2001, a three day mark-release-recapture (MRR) study was conducted on the same population. Beetles were marked with a small dot of paint on their elytra and released back at the site of capture. Calculations estimated this population at approximately 1,052 beetles (Grant et al. 2002). Population and seasonal abundance estimates are not available for the other occupied *B. hungerfordi* sites.

Surveys for adults are typically conducted by creating a rapid current over the site to dislodge the beetles from their substrate (Hinz, Jr. and Wiley 1999; Scholtens 2002; Vande Kopple and Grant 2004). Surveyors use an aquatic D-net to vigorously sweep the water just above the bottom. This motion creates a temporary whirlpool effect which pulls beetles up into the current where they are captured in the net. The contents of the net are then emptied into a white enamel pan filled with stream water for identification and examination of the beetles. This technique of disturbing the water and not disrupting the substrate is preferred, as it is less destructive to the habitat and has a lesser risk of crushing the beetles.

Species of *Brychius* tend to be highly localized and very difficult to collect (T. Mousseau, University of Manitoba, pers. comm. 2003). The adults are very small and inconspicuous, and tend to hide under cobbles and vegetation along the bottom. Because they can be difficult to find, it is possible that some surveys may not detect the species when it is, in fact, present. This is particularly true for sites that have small numbers of beetles. Thus, negative survey data of known sites should be interpreted cautiously and should be considered in concert with other factors (e.g., presence of suitable habitat, length of time since last known positive survey, acute threats at the site or recent stochastic events, etc.). In addition, it is possible that populations of *B. hungerfordi* may be found at additional sites. More survey work is needed to determine if other sites exist. Moreover, research into the ecology and habitat requirements of the species may enable surveyors to conduct more targeted surveys, which may result in an improved survey strategy.



* Number of beetles captured in less than one hour (5-7 minutes)

Figure 7. Seasonal abundance of adult *B. hungerfordi* beetles in one pool of the East Branch of the Maple River, from 1999-2001. Results are the number of beetles captured in one hour (unless otherwise noted). Adapted from Grant et al. 2000 and Grant et al. 2002.

Surveys for *B. hungerfordi* larvae have been attempted by several researchers, although only a few have been successful in locating them. Wilsmann and Strand (1990) located larvae in the East Branch of the Maple River by dislodging them from the substrate with a kick and catching them downstream with a net. They also were able to collect larvae by scooping up *Chara* and the underlying substrate with a small spade (Strand and Spangler 1994; Wilsmann and Strand 1990). Intensive surveys for larval specimens (or other early life stages) may result in destruction of suitable habitat and should be conducted with caution.

Observation of adult *B. hungerfordi* is possible at some sites by using a diving mask or a glass bottom bucket. At some sites, adults can be seen crawling among cobbles and algae on the stream bed. At other sites, beetles occur under the cobbles and are not visible from above without moving the cobbles. Observations of beetles in the East Branch of the Maple River found that individuals stay very close to the bottom and seemed to require a tarsal hold to continue movement (Scholtens 2002). If dislodged by a current change, they quickly dove to the bottom and grabbed onto the nearest foothold, then continued their slow and deliberate movement along the bottom. Beetles found under cobble would immediately seek another cobble to hide under when disturbed.

Population demography (e.g., birth rate, rates of dispersal, and survivorship) of *B. hungerfordi* populations has not been examined at any site. These factors are essential to understanding how *B. hungerfordi* may persist over time, and how it may respond to changes in its habitat. Thus, these factors are important to recovery of the species and should be the subject of future research. Only small numbers of adult beetles have been found at three of the four Michigan sites; no larvae or other early life stages have been found at these sites. For some of these locations, it is unknown if the individuals represent a reproducing population or if they are dispersing individuals. It may be that *B. hungerfordi* is successful in producing offspring at some sites, but may suffer poor reproductive success at other sites. Poor habitats may represent population sinks—areas where local mortality is greater than local reproductive success. It is possible that beetles dispersed to these areas from a nearby source population; however, dispersal is still not understood for *B. hungerfordi*. Without immigration, sink populations will eventually be extirpated. Once dispersal is understood, research should examine whether any sites function as a metapopulation. Viability of a population depends not only on the quality of local habitat, but also on the number and distribution of suitable habitat patches, and the amount of movement between them. Research is needed to examine the population demography and dynamics of this species.

Habitat Characteristics

Populations of *B. hungerfordi* are found downstream from culverts, beaver and natural debris dams, and human-made impoundments. They are often found in plunge pools created below these structures, as well as in riffles and other well-aerated sections of the stream. In general, *B. hungerfordi* is found in areas of streams characterized by moderate to fast stream flow, good stream aeration, inorganic substrate, and alkaline water conditions (Wilsmann and Strand 1990). The adult beetles are generally found at depths of a few inches to a few feet in streams that are relatively cool (15º C to 25º C) (Wilsmann and Strand 1990). Table 1 gives the chemical characteristics of water collected from some of the sites where *B. hungerfordi* occurs, and from sites where no beetles are found (Keller et al. 1998). Ammonia, nitrate and nitrite, alkalinity and pH were similar among all sites and appeared to be typical of lotic ecosystems in northern Michigan, but occupied *B. hungerfordi* sites appeared to have low levels of phosphorous (Keller et al. 1998).

B. hungerfordi is found in first, second, and third order streams (Table 2). The hydrology of a site appears to be important for this species. *B. hungerfordi* seems to prefer seasonal streams that have some groundwater input. These streams do not dry up completely, but the water level can drop considerably (e.g., several feet in the East Branch of the Maple River) (Vande Kopple and Grant 2004). As the water levels drop, damp river edge sand becomes exposed in the summer and fall (Vande Kopple and Grant 2004). This microhabitat may be important for the pupation stage of the beetle's life cycle. The types of streams inhabited by this species do not appear to be rare. In fact, streams similar to those in which the species is found appear to be common in northern Michigan and other surrounding states. In the East Branch of the Maple River, the beetles can be found in two different microhabitats—in cobble near the edge of pools, or in association with filamentous algae in riffles (Scholtens 2002). The first microhabitat is characterized by low flows, with filamentous green algae growing on the cobbles in low mats. Most individuals in the East Branch of the Maple River occur in this type of microhabitat. Beetles occur under the cobbles and are not visible from above without moving the cobbles. In second microhabitat, beetles occur in algal beds that are found on sandy areas just behind larger rocks. Algae found in these areas include *Chara*, *Cladophora* and *Dichotomosiphon*. Beetles at these sites apparently live in and on the algal beds, rather than under the cobbles, and can be observed from above on the algae or sand surface. Observers using a diving mask or glass-bottomed bucket can occasionally view beetles in this type of habitat. Relatively few individuals are seen in this type of microhabitat, and numbers at these microsites are generally low (Scholtens 2002).

Presence of algae appears to be important in determining suitable habitat for the species. Both adults and larvae are commonly found in association with several species of algae. Not only is it a possible source of food, but it may also be important for other reasons (e.g. cover, oxygen source, etc.). For example, vegetation with a dense growth form (e.g., *Chara* or *Nitella*), rather than the plant species itself, may be an important factor for *B. hungerfordi* habitat (W. Brigham, pers. comm. as cited in Wilsmann and Strand 1990). *B. hungerfordi* has a similar body shape as *Apteraliplus* from California,

Table 1. Chemical composition of water collected from sites where *B. hungerfordi* adults have been reported and from sites where no beetles have been found. Taken from Keller et al. 1998.

Locations	**Alkalinity ($mgCaCO_3$/L)**	**pH**	**Nitrates + Nitrites (mg/L)**	**Ammonia (mg/L)**	**Soluble Reactive Phosphorous (µg/L)**	**Silica (mg/L)**	**Chloride (mg/L)**	**Specific Conductance (µS)**	**Temp (ºC)**
B. hungerfordi reported									
Carp River[a]	194	8.2	0.23	0.021	1.6	7.6	4.5	356	15
East Branch Maple River[a]	143	7.97	<0.010	0.035	1.4	6.9	2.3	261	14
East Branch Black River[b]	197	7.95	0.098	0.013	1.8	10.4	2.0	353	13
No B. hungerfordi found									
West Branch Maple River[c]	176	7.9	<0.010	0.021	12.4[e]	7.5	1.3		16
Black River[d]	226	7.8	0.041	0.027	10.0[e]	8.6	1.7		22
Pigeon River[c]	213	7.3	0.12	0.031	26.4[e]	5.7	5.9		23

[a] Water samples collected 11 September 1997
[b] Water samples collected 13 September 1997
[c] Water samples collected 9 August 1996, samples frozen before analysis
[d] Sampled 6 August 1996, samples frozen before analysis
[e] Data not corrected for silica interference

Table 2. Stream order of known *B. hungerfordi* sites in Michigan

***B. hungerfordi* sites**	**County**	**Stream Order**
Van Hetton Creek	Montmorency	1st
East Branch of the Maple River (several sites throughout stream)	Emmet	2nd
Carp Lake River	Emmet	2nd
East Branch of the Black River	Montmorency	3rd

which is found in dense aquatic vegetation (W. Brigham, pers. comm. as cited in Wilsmann and Strand 1990).

Based on his analysis of habitats of known *Brychiu*s locations, Roughley identified that all known sites had mineral substrates which are heavily eroded on at least an annual basis (Roughley 1989). At the East Branch of the Maple River site, this “erosion” occurs due to the water coming through the culvert, which creates a scour of the substrate in the pool below. At Scone (North Saugeen River), this erosion activity could have been due to bridge construction. Thus, he hypothesizes that *B. hungerfordi* is a species of naturally disturbed stream habitats, but that it can also do well in artificially disturbed habitats (Roughley 1989).

Historically, natural debris dams and beaver activity likely created and maintained habitat for this species. Prior to intervention by humans, early beaver populations would have created a mosaic of dams and ponds in varying conditions which was certainly a significant factor in determining the ecology of stream ecosystems (Wilsmann and Strand 1990). Beaver numbers were greatly reduced in Michigan during the 1800s due to extensive land clearing and fur trapping (Baker 1983; Kurta 1995). Regulation of the fur trade and planned reintroductions have allowed many populations to recover, and the species has returned to most areas (Baker 1983; Kurta 1995). The East Branch of the Maple River currently has a healthy beaver population. The backwater of beaver dams stabilizes water levels, and the downstream sides often provide well-aerated riffle areas preferred by the beetle (Wilsmann and Strand 1990). Beaver impoundments also retain sediments and organic material, raise water temperatures, and modify nutrient cycling, decomposition dynamics, and riparian zone structure and composition. Human-made structures that create similar conditions, such as dams and culverts, may also be important by mimicking natural processing and thereby creating habitat for the species.

Hinz, Jr. and Wiley (1999) used an ecological classification system to characterize the river valley segments in which *B. hungerfordi* was known to occur. At the time of this study, three of the four Michigan sites had been discovered. These stream segments were characterized using the Michigan River Valley Segment Ecological Classification System (MI-VSEC) which identifies, describes, and classifies valley segments based on their physical and biological characteristics (Hinz, Jr. and Wiley 1999; Seelbach et al. 1997). The valley segments in which *B. hungerfordi* occurred were found to have hardwater oligotrophic chemistries, fair to high base flows with low to moderate peak flows, cold to cool July temperatures with low to moderate daily temperature fluctuation, low valley slope, and to occur in alternating or sporadically confined alluvial valleys (Hinz, Jr. and Wiley 1999). Using the five corresponding MI-VSEC codes (i.e., chemistry, hydrology, temperature, valley slope, and valley shape), a similarity index was developed (Hinz, Jr. and Wiley 1999). The known locations of the East Branch of the Maple River and the Carp Lake River were highly similar (4 out of 5 MI-VSEC codes matched). The East Branch of the Black River, however, had a low similarity (only 2 out of 5 matched) to the other two sites. The similarity index was then used to predict other streams in which the species is likely to occur based on similarity to the three known Michigan sites. None of the other 775 classified valley segments in Lower Michigan were found to be identical (all five codes matching), but several were found to be highly similar to the known sites. Based on this data, high ranking streams were targeted for field surveys. Twenty four sites were sampled from 15 valley segments. No additional populations were found during these surveys. It is interesting to note that Van Hetton Creek was determined to be highly similar using this classification system. *B. hungerfordi* was not found in Van Hetton Creek during these surveys, but it was discovered in this stream several months later (Grant et al. 2000). This ecological classification system may be useful in focusing future survey efforts to areas with similar characteristics as known sites, although other factors may also be important when determining potential habitat.

Although there are a number of similarities among the occupied sites, many have unique habitat characteristics. In fact, it is uncertain as to what characteristics are important in terms of suitable habitat for this species, as some sites are markedly different. Roughley (1991) describes the North Saugeen River habitat as being very different than the type locality. The Scone site is just downstream from an impoundment dam with an epilimnion outlet. Warm water from the impoundment passes through an old millrace and under a county road. Prior to discovery of *B. hungerfordi* at this site, the stream had been dredged and disturbed by bridge construction. The habitat is characterized by heavy deposits of a marl-like substance on stones and rocks. Beetles were collected from gravel and algae along a narrow zone parallel to the stream margin among gravel and cobble (Roughley 1991). This site had none of the cool, stenothermic species of water beetles listed by Spangler (1954) as being found at the type locality along with *B. hungerfordi*. Van Hetton Creek is described as being different from previously known locations in that the creek channel is composed of sand overlain with a thin layer of detritus (Grant et al. 2000). Finally, the East Branch of the Black River site is the most atypical of all of the Michigan sites. It is the only known site in a third order stream, and is much deeper, faster and wider than the other sites (M. Strand, Northern Michigan University, pers. comm. 2003). In addition, the two larval specimens collected from the St. Clair River further confuse the issue of “suitable” habitat. If these larval specimens were indicative of a local population of *B. hungerfordi* in the St. Clair River, then there is much to be learned about the range of habitats this species may occupy. The species may be more of a generalist in terms of habitat (and therefore, habitat may not be limiting its distribution), but more work is needed to confirm the habitat requirements for the species.

Despite some research examining habitat and microhabitat components, the habitat requirements of the species are not fully understood. The species may be limited to pool and riffle environments downstream of beaver dams and culverts. However, the species may also have a broader range of suitable habitat. In this case, their distribution may be limited by dispersal or another factor. Alternatively, the species may be a glacial relict that has been rare since the last glaciation. More research is needed to examine the factors that create suitable *B. hungerfordi* habitat.

Critical Habitat

"Critical habitat" is defined by the ESA; thus, it is a legal definition of the areas considered essential to a species' conservation. Section 3 of the ESA defines critical habitat as: (i) the specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the ESA, on which are found those physical or biological features (I) essential to the conservation of the species and (II) that may require special management considerations or protection; and (ii) specific areas outside the geographic area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species. "Conservation" means the use of all methods and procedures needed to bring the species to the point at which listing under the ESA is no longer necessary. At the time of listing, the designation of critical habitat for *B. hungerfordi* was not determinable. The USFWS regulations (50 CFR 424.12(a)(2)) state that critical habitat is not determinable when one or both of the following situations exist: (i) Information sufficient to perform required analyses of the impacts of the designation is lacking; or (ii) The biological needs of the species are not sufficiently well known to permit identification of an area as critical habitat.

If, following completion of this plan, we find that it is prudent and determinable to designate critical habitat for the species, the USFWS will prepare a critical habitat proposal in the future, at such time as our available resources and other listing priorities under the ESA allow. This proposal will be based on the essential habitat features needed to ensure the conservation and recovery of the species. Currently, more research is needed to determine the physical and biological habitat features required by the species, as described in the Habitat Characteristics section.

Reasons for Listing and Existing Threats

At the time of listing in 1994 (59 FR 10580), *B. hungerfordi* was known to occur in only 3 isolated locations, despite extensive surveys in Michigan, Wisconsin, Minnesota, and Ontario. The listing rule cites the research results of Wilsmann and Strand (1990), which indicated the rarity of the species and its geographic isolation. The Service analyzed the status survey, as well as other information, and determined that the beetle is facing serious threats and should be protected as an endangered species (United States Fish and Wildlife Service 1994). Specific threats were unknown, but it was speculated in the listing rule that human activities such as fish management, logging, beaver control management, dredging, stream pollution, and general stream degradation have contributed to the reduction of *B. hungerfordi* habitat (Wilsmann and Strand 1990). In general, it can be assumed that threats to the species include any activities that degrade water quality or remove or disrupt the pools and riffle environment of streams in which this species lives.

Habitat Destruction and Modification

Although this species' habitat requirements are not completely understood, it is likely that habitat protection is important for this species. Stream modification is thought to be the primary threat to the species and may include physical destruction of the stream habitat and degradation of water quality. Specific threats may include beaver control, dredging, stream pollution, stream-side logging, channelization, bank stabilization, and impoundment (Hyde and Smar 2000).

Beaver impoundments appear to be important to maintaining the habitat of *B. hungerfordi* (Wilsmann and Strand 1990). If so, removal of beaver dams upstream from current *B. hungerfordi* populations is a threat to the beetle. The upstream side of a beaver dam (i.e., the impoundment) is not suitable habitat, however, so it is also important to monitor new beaver activity, as new flooding could eliminate known suitable habitat.

Many known *B. hungerfordi* sites occur below road-stream crossings, where the culvert provides similar conditions to those found downstream of a beaver dam. Excessive erosion and subsequent sedimentation into the stream is a possible threat at these sites. This may be caused by a poorly designed or deteriorating road crossing and increased by clearing ditches of vegetation near occupied sites. The cleaning out of ditches and culverts should be approached cautiously near these occupied streams as it could pose a serious threat to the beetle if not done properly (Hyde and Smar 2000). In areas where degraded road crossings result in heavy erosion and sedimentation into the stream, suitable habitat may be lost. In addition, culverts can serve as an entry point of pollutants (e.g., road salt, silt) that accumulate from water that runs off roads and into roadside ditches. The effects of this pollution on *B. hungerfordi* are not known. Accidental spills on the roadway (such as gasoline or chemical spills) may also pose a threat. Culverts may also serve as a barrier to upstream dispersal within the stream (Vaughan 2002).

Logging in the riparian zone is another possible threat to this species; it can cause significant modification of habitat and increase erosion and the sediment load into the stream (Strand 1989). Other alterations of stream habitat that may result in destruction of suitable *B. hungerfordi* habitat include dredging for stream bed modification, channelization, and bank stabilization.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Research efforts have involved mostly capture and release rather than collecting, and the few collections that have been made are housed in appropriate museums.

Because rare insects are often considered valuable to amateur collectors, there is the possibility that illegal collections could occur. The collection threat for haliplid beetles, however, is probably minimal.

<u>Disease or Predation</u>

The listing rule points out that although little is known about disease and predation, there are no indications that they may be contributing to the decline of *B. hungerfordi* (USFWS 1994). Predation by fish has been speculated but never confirmed as a threat. Brown trout (*Salmo trutta*), introduced into Michigan in the mid-1800s, may be a predator (Wilsmann and Strand 1990). Other water column and surface feeders such as the common shiner, dace, and white sucker, as well as bottom feeders such as darters and sculpins could also be predators (Strand 1989; White 1986; Wilsmann and Strand 1990). *B. hungerfordi* may be more vulnerable during time spent in the water column (e.g., when surfacing for air, drifting), although adults likely do not spend much time traveling in the water column.

B. hungerfordi is typically found crawling among cobble or in association with vegetation in shallow, high velocity areas that are not accessible to many mid-water or bottom-dwelling fish (White 1986; Wilsmann and Strand 1990). Their habitat distribution may be due to active habitat selection for shallow areas or may be the result of fish predation eliminating them from deeper and slower-moving parts of the stream (Wilsmann and Strand 1990). The largest population of *B. hungerfordi* (in the East Branch of the Maple River) is inaccessible to brown trout, and the entire stream provides only marginal habitat for brown trout (White 1986; Wilsmann and Strand 1990). No research has been conducted to indicate the degree to which predation is a threat. This should be examined in the future to help guide management efforts.

<u>Inadequacy of Existing Regulatory Mechanisms</u>

Prior to listing under the ESA, *B. hungerfordi* was listed as endangered under Michigan's Endangered Species Act (Public Act 203 of 1974, as amended) which provided for some protection of the species. The State's endangered species statute, implemented by the Michigan Department of Natural Resources, includes a take prohibition; thus, any taking of this species, including harassment, is unlawful without a state permit. The Michigan Department of Environmental Quality implements section 404 of the Clean Water Act. This section allows Michigan to regulate placement of fill material in waters of the United States.

Listing under the ESA offers additional protection to this species, primarily through the recovery and consultation processes. The federal protections offered by the ESA are described in the Conservation Measures section.

Other Natural or Manmade Factors

Certain types of fish management activities may pose a threat to the species (United States Fish and Wildlife Service 1994), although some forms of fish management may also be beneficial. Fish management activities that result in creation, maintenance, or enhancement of suitable *B. hungerfordi* habitat may be beneficial to the species. Likewise, activities that result in the elimination of suitable *B. hungerfordi* habitat may pose a threat. For example, removal of a dam or culvert (e.g., to allow fish passage) immediately upstream of a known site may eliminate suitable *B. hungerfordi* habitat. As discussed above, some researchers have speculated that insectivorous fish predate *B. hungerfordi*. If certain fish are found to eat *B. hungerfordi*, then managing fish populations to increase in the abundance of those predators may be harmful to the beetle. More information is needed to determine the degree to which predation is a threat.

The effects, if any, of lampricide treatment on *B. hungerfordi* are not known. The Carp Lake River and unoccupied portions of the Maple River have been treated with the lampricides 3-trifluoromethyl-4-nitrophenol (TFM) and 2'5-dichloro-4'-nitrosalicylanilide (niclosamide). Researchers are currently conducting a study that will examine the relative toxicity of the lampricides TFM and niclosamide on a closely-related surrogate species (*Haliplus sp*.). Preliminary results did not demonstrate an adverse effect of lampricide to the surrogate species (pers. comm. John Weisser, USFWS, 2004). In addition, the effects of electrofishing on *B. hungerfordi* are not known. Some studies have indicated an increase in drift of other stream insects due to electricity (Bisson 1976; Mesick and Tash 1980); however, this has not been examined for *B. hungerfordi*. Further research is needed to examine the extent of use of this technique in occupied streams, and the potential for harm to the beetle.

Human disturbance within the stream may be a threat to *B. hungerfordi*. Areas of a stream where there are high levels of disturbance caused by fishing and recreation are not likely to be suitable for *B. hungerfordi*. Human disturbance could result in disruption of habitat as one walks through the stream, or inadvertent crushing of individuals by stepping on them. Although this is a potential threat, there are no known occupied sites with excessive human disturbance due to fishing or recreation.

The existence of only five small, geographically isolated populations of *B. hungerfordi* increases the potential for extinction from stochastic events. Small isolated populations are more likely to be destroyed by chance environmental and demographic events than larger widespread populations (Shaffer 1981). Stochastic events include human-caused or natural environmental disturbance and could destroy an entire population and, in some cases, a significant percentage of the known individuals of the species. Small population size and restricted range also makes *B. hungerfordi* vulnerable to genetic isolation. The limited gene pool may lead to decreased fitness. There have been no studies examining population viability or genetic diversity of this species.

At this time, the greatest threat to recovery of this species is the lack of information on its ecology and natural history. Specifically, additional information is needed on resource requirements and microhabitat preferences, life history (e.g., location, timing, and duration of larval, pupal, and adult stages, oviposition location and timing; diet), and population dynamics. Information needs are further discussed in Appendix C, "Research Needs".

Conservation Measures

Conservation measures underway to protect *B. hungerfordi* include recognition, State and Federal regulatory protection, and prohibitions against certain practices. Listing encourages and results in increased conservation actions by Federal, state and private agencies, groups, and individuals. The ESA provides for possible voluntary land acquisition and cooperation with the State and requires that recovery plans be developed for all listed species. The protection required of Federal and State agencies and the prohibition against certain activities involving listed animals are discussed, in part, below.

<u>Federal Regulatory Protection</u>

The ESA contains several sections that provide regulatory protections for *B. hungerfordi*:

Section 9 – Prohibition against Take

Section 9 of the ESA prohibits any person subject to the jurisdiction of the United States from "taking" federally listed threatened and endangered species. The term "take" is defined to include harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting these species. It is also unlawful to attempt such acts, solicit another to commit such acts, or cause such acts to be committed. Regulations implementing the ESA (50 CFR 17.21) define "harm" to mean an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation that results in the killing or injury to wildlife by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering. "Harass" means an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. These restrictions apply to all listed species not covered by a special rule. No special rule has been published for *B. hungerfordi*. There are several sections of the ESA that provide for exemptions from the take prohibition through the consultation and permitting processes.

Section 7 – Interagency Cooperation with Federal Agencies

Regulations implementing interagency cooperation provisions of the ESA are codified at 50 CFR Part 402. Section 7(a)(2) of the ESA requires Federal agencies to consult with the USFWS when federally permitted, authorized, or funded actions may affect listed species, including *B. hungerfordi*. This consultation process promotes interagency cooperation in finding ways to avoid or minimize adverse effects to listed species. If a Federal action is likely to adversely affect any listed species, the Federal action agency must enter into formal consultation with the USFWS. The consultation process is intended to ensure that the action is not likely to jeopardize the continued existence of listed species, nor destroy or adversely modify critical habitat. Critical habitat has not been designated for this species. Section 7(a)(1) requires all Federal agencies to use their authorities to further the conservation of federally listed species.

Since its listing, only a few section 7 consultations have been completed for *B. hungerfordi*. These consultations have been conducted with the USFWS (i.e., Intra-Service consultation), and the U.S. Army Corps of Engineers (COE).

Section 10 – Permits for Scientific Research and Conservation Actions, and Incidental Take Permits

Section 10(a)(1)(A) of the ESA provides for permits to authorize activities otherwise prohibited under section 9 for scientific purposes or to enhance the propagation or survival of a listed species. Several of these permits have been issued for *B. hungerfordi* research activities, including studies in the field and in the lab. Research will be a key component of recovery of this species, as identified in the Recovery section of this plan. Section 10(a)(1)(A) permits will continue to permit activities that contribute to the conservation and recovery of the species. Section 10(a)(1)(A) permits are also issued to participants in the Safe Harbor Program. The Safe Harbor Policy encourages private landowners to voluntarily conserve threatened and endangered species. Under a Safe Harbor Agreement, a private landowner would agree to create, restore or maintain habitats for the benefit of a listed species. In return, the Service would provide assurances that future landowner activities will not be subject to restriction from the ESA above those applicable to the property at the time of enrollment in the agreement. There are currently no Safe Harbor agreements in place for *B. hungerfordi*.

Section 10 (a)(1)(B) permits can also provide for take that is incidental to an otherwise lawful activity, provided certain conditions have been met. In order to obtain an incidental take permit, an applicant must prepare a Habitat Conservation Plan (HCP). The HCP is designed to offset any harmful effects that the proposed activity may have on the species by minimizing and mitigating the effects of the authorized incidental take. No HCPs have been developed for *B. hungerfordi*.

Section 6 – Cooperation with States

State conservation agencies and their designated agents have certain take authority for species listed as threatened or endangered if the state agency has a section 6 Cooperative Agreement with the USFWS. In addition, section 6 of the ESA allows the USFWS to grant money to states for the conservation of listed and candidate species.

State Protection

B. hungerfordi was listed as endangered by the Michigan Department of Natural Resources in 1987. It was listed pursuant to Michigan's Endangered Species Act (Public Act 203 of 1974), now Part 365 of the Natural Resources and Environmental Protection Act of 1994 (Public Act 451). State law also prohibits take of the beetle.

Canadian Protection

B. hungerfordi is not currently protected in Canada. Although the Scone site is discussed throughout this Recovery Plan, it is not included in the recovery goals for the species.

Research and Outreach

Since listing, surveys and research have been conducted in an effort to learn more about the species. For many years, researchers from UMBS have been studying *B. hungerfordi* in an attempt to answer important questions about the life history and ecology of the species. The East Branch of the Maple River sites occur within close proximity of UMBS, and it is the best studied and largest population of the known sites. UMBS researchers have been able to observe *B. hungerfordi* in both their natural environment and in a laboratory setting. The field studies have taken place in several pools of the East Branch of the Maple River. Laboratory studies have been conducted at the UMBS Stream Research Facility (SRF), which is an outdoor artificial stream laboratory, as well as in a traditional laboratory setting. The SRF was designed to conduct experimental studies on aquatic organisms and stream processes by simulating the natural stream habitat while allowing for experimental manipulation and observation. Water from the East Branch of the Maple River is pumped and distributed throughout the experimental area, which is comprised of various channels where environmental conditions can be manipulated. This gives researchers an opportunity to examine *B. hungerfordi* in a semi-controlled environment. Research is also being conducted at the University of Manitoba to determine the morphology, biology, and life history of species in the genus *Brychius* (pers. comm. T. Mousseau, University of Manitoba, 2002).

Outreach efforts have also been initiated to gain support and awareness of the species. Biologists at the East Lansing Field Office are currently developing a fact sheet for distribution to landowners and other stakeholders in the areas surrounding known *B. hungerfordi* sites. Outreach and education will be important components of the recovery effort.

Biological Constraints and Needs

With the exception of general habitat characteristics, little is known about the ecological requirements of *B. hungerfordi*. Habitat characteristics of current sites suggest that riffle and pool habitat below beaver dams or other impoundment structures is suitable for *B. hungerfordi*; however, we do not know if it is limited to this habitat. Research is needed to gather more information on the species' life history, habitat requirements, distribution, and ecology in order to determine if this species has inherent biological constraints. In addition, threats to the species need to be confirmed and evaluated. Research needs have been outlined in Appendix C.

PART II. RECOVERY

Recovery Strategy

B. hungerfordi has a very limited range. This species occurs in five streams within Michigan and Ontario. Of these sites, only one is considered stable or increasing (i.e., the East Branch of the Maple River). The other sites have low numbers and beetles are not consistently found during surveys; thus, site status remains uncertain. The historic distribution of the species is unclear. Other information on the species also is lacking. The key habitat components include riffles and pools created below beaver dams or other impoundment structures. It is uncertain as to what characteristics are important in terms of suitable habitat for all life stages of this species. In general, the types of streams inhabited by this species do not appear to be rare.

In addition, the threats to this species are not completely understood. Because historic distribution remains unclear, threats that may limit the species to currently known sites are difficult to determine. At the known sites, threats have been hypothesized and need further examination. Very little is understood about the ecological requirements, life history, and population structure of *B. hungerfordi*. Additional information on these basic parameters will facilitate a better understanding of other factors that may be impacting the species.

Therefore, a research program that targets *B. hungerfordi* and its habitat is necessary. Scientific data are required to develop and implement protection and management activities to ensure the long-term survival of the species. Thus, the initial recovery strategy will focus on systematically answering crucial questions about the species' ecology. Based on these studies, we will seek to maintain multiple populations of *B. hungerfordi* and increase their size to a level at which genetic, demographic, and environmental uncertainty are less threatening. A better understanding of its ecological requirements will allow identification of appropriate population goals for the species and development of threat reduction strategies. In the interim, the current sites will require continued protection and monitoring. Our efforts will include reducing, to the extent possible, threats that result in physical habitat destruction and degradation (e.g., from beaver control, stream-side logging, dredging, stream pollution, road work, bank stabilization, impoundment) and threats relating to fish management and human recreation. If results of research indicate that additional factors are threatening the species, the plan will be revised to include additional recovery criteria.

Boersma et al. (2001) examined effectiveness of recovery plans, and found that it "can be improved through incorporation of dynamic, explicit science in the recovery process, such as strongly linking species' biology to recovery criteria". Recovery success is limited in recovery plans that do not make the connection between recovery criteria and species biology (Clark et al. 2002; Gerber and Hatch 2002). Because the knowledge of basic biology of this species is lacking, ultimate recovery criteria are dependent on specific information needs; it follows that the criteria for this species will be refined and revised as information becomes available.

Recovery Goals and Objectives

The recovery program is intended to bring *B. hungerfordi* to the point at which protections under the ESA are no longer necessary. Therefore, the ultimate goal of the recovery program is to remove the species from the Federal list of Endangered and Threatened Wildlife (50 CFR 17.11). The intermediate goal of this Recovery Plan is reclassification of *B. hungerfordi* to threatened status.

The objectives of this recovery plan are as follows: 1) determine and ensure adequate population size, numbers, and distribution for achievement and persistence of viable populations and long-term survival; 2) identify essential habitat for all life stages and ensure adequate habitat protection; and 3) identify additional threats to the species, if they exist. Initially, the recovery program will focus on obtaining sufficient information to revise and refine the recovery criteria.

These objectives will rely heavily on researching the species' biology and habitat requirements so that we may more adequately assess and alleviate threats and develop measurable and objective recovery criteria.

Interim Recovery Criteria

The criteria for meeting the recovery goals are interim because further research is necessary to make them fully measurable. The tasks that are necessary to make the criteria fully measurable are identified in Appendix D and are included in the Narrative for Recovery Activities and Implementation Table.

<u>Reclassification criteria</u>

Criterion 1. Life history, ecology, population biology, and habitat requirements are understood well-enough to fully identify threats

As discussed throughout this draft recovery plan, little is known about important components of the species' life history, ecology, population biology and habitat requirements. Recovery of this species will require a better understanding of these parameters so that we may gain a better understanding of current threats and develop strategies to minimize threats.

To meet this recovery criterion, we must understand the biology of and threats to the species well enough to allow for a current threats assessment. In order to adequately assess threats to the species, further research is necessary (as outlined in Action 2 of the Stepdown Outline and Narrative). Ultimately, threats must be reduced or eliminated such that the majority of sites have a "low"[1] degree of threat, and no site has a "high" degree of threat.

Based on the results of the new information on life history, ecology, population biology, and habitat requirements, and the resulting outcome of a complete threats assessment, we will determine if additional threats-related recovery criteria are necessary for reclassification or delisting. The recovery criteria will be revised as needed.

Criterion 2. A minimum of four U.S. populations, in at least two different watersheds, have had stable or increasing populations for at least 10 years

We will consider populations to be stable when a linear regression analysis of population numbers reveals no significant decline in numbers. The four populations must be in at least two different watersheds—hydrologically distinct areas of the Great Lakes basin—in order to ensure preservation of the species in the event of a catastrophic event in one watershed.

B. hungerfordi will be considered for delisting when all of the above criteria (1-2) are achieved, plus:

<u>Delisting criteria</u>

Criterion 3. Identify and protect habitat necessary for long-term survival and recovery

Research is needed to fully understand the habitat requirements of the species. For example, we must understand the various microhabitat needs of each stage of the species' life cycle. Once we understand the habitat requirements of the species, we can identify areas necessary for long-term survival and recovery. Those areas of habitat will be protected by minimizing physical disturbances. Physical disturbances include, but are not limited to, beaver control, dredging, stream pollution, stream-side logging, channelization, road projects, bank stabilization, and impoundment, and recreation pressure.

This criteria will be met when land adjacent to populations identified for recovery has been protected from disturbances through long-term voluntary landowner agreements such as stewardship plans, easements, and memorandums of agreement that promote best management practices. It is also prudent to protect areas upstream from these sites, as sedimentation may also be a threat. In addition to areas adjacent to populations identified

[1] A high degree of threat is one that is likely to occur and will seriously degrade the habitat. A moderate degree of threat is one that is likely to occur and may moderately degrade the habitat. A low degree of threat is one that is unlikely to occur or would only slightly degrade the habitat.

for recovery, riparian zones up to 0.25 miles upstream of these areas should be similarly protected.

Criterion 4. A minimum of four U.S. populations, in at least two different watersheds, are sufficiently secure and adequately managed to assure long-term viability

More information is needed to determine what constitutes long-term viability. For example, the four populations must be of sufficient size to persist despite demographic, environmental, and genetic uncertainty. However, at this time we can not identify a minimum population number and distribution necessary for recovery; this criterion will be revised based on the results of research.

If additional populations or threats are discovered, and as new information about the species becomes available, recovery criteria will be revised and finalized.

Step-down Outline

The step-down outline lists actions required to meet the recovery objectives of this Recovery Plan. The step-down outline and narrative are presented in order of task category; priority level of each sub-task is indicated at the end of the task description in parentheses. Implementation of all actions with Priority **(1)** is essential to prevent *B. hungerfordi* from becoming extinct in the foreseeable future. Implementation of all actions with Priority level **(2)** is necessary to prevent a decline in population numbers or habitat quality and quantity. Actions assigned Priority **(3)** are necessary to create an increasing trend toward recovery of *B. hungerfordi*.

1. Protect known sites

    1.1. Define and protect areas of essential habitat (1)

    1.2. Develop and implement site conservation plans for each site to address threats (1)

    1.3. Review Federal, state, and private actions (1)

        1.3.1. Section 7 review and conservation

        1.3.2. Section 10 permits

            1.3.2.1. Section 10 (a)(1)(A) – Enhancement of survival permits

            1.3.2.2. Section 10 (a)(1)(B) – Incidental take permits

    1.4. Land acquisition and protection (2)

    1.5. Encourage watershed-level conservation (2)

    1.6. Coordinate with Canadian officials regarding the North Saugeen River site (3)

2. Conduct scientific research to facilitate recovery efforts

    2.1. Conduct studies to examine life history and ecology of *B. hungerfordi* (2)

    2.2. Conduct studies to examine population dynamics and demography (2)

    2.3. Examine habitat requirements (2)

    2.4. Investigate genetic heterogeneity and population viability (2)

    2.5. Confirm threats to the species (2)

    2.6. Investigate utility of captive propagation (2)

3. Conduct additional surveys and monitor existing sites

3.1. Develop standard survey and monitoring protocols (2)

3.2. Continue to survey new locations to identify new populations or areas of suitable habitat (2)

3.3. Develop and implement a monitoring plan for all known sites (2)

4. Develop and implement public education and outreach

4.1. Conduct landowner contact and educational programs to increase awareness of *B. hungerfordi* (3)

4.2. Design educational materials and presentations for the public (3)

4.3. Contact local organizations to inform them of the beetle (3)

5. Revise recovery criteria and recovery tasks, as appropriate, based on research and new information (3)

6. Develop a plan to monitor *B. hungerfordi* after it is delisted (3)

Narrative for Recovery Actions

1. Protect known sites

The known distribution of this species is limited to only four sites in the United States. Habitat essential to recovery must be defined and protected. Review of Federal, state, and private actions at these sites will continue. Land acquisition from willing sellers by Federal and State agencies and private conservation organizations will be encouraged.

1.1. Define and protect areas of essential habitat (1)

Areas of essential habitat throughout the range of the species should be identified. Essential habitat will include all areas that are biologically essential to the species. Essential habitat includes areas needed for all aspects of the species' life cycle and survival, including areas for shelter, feeding, reproduction, and overwintering. Before essential habitat can be determined, it will be crucial to better understand the population dynamics, habitat needs, and biology of the species (discussed in more detail in task 2). Thus, research will be very important prior to completing this task. Both quality and quantity of habitat will be considered when defining essential habitat. Areas of essential habitat may include areas in addition to currently occupied sites.

1.2. Develop and implement site conservation plans for each site to address threats (1)

Site conservation plans will be developed for each of the four known sites. These plans should determine the threats at each site and ways to minimize those threats. In some cases, management activities may be necessary in order to maintain suitable habitat. However, in order to effectively manage for suitable habitat, we must understand the species' habitat needs. Key components of *B. hungerfordi*'s habitat needs (e.g., food source, oviposition site, pupation site) will be investigated in order to support habitat management. Thus, this task will rely heavily on the results of research (discussed in more detail in task 2). Site conservation plans should be updated as new information becomes available.

1.3. Review Federal, state, and private actions (1)

Federal, state and private activities that may affect the habitat or result in harm to *B. hungerfordi* will be reviewed to the extent possible under Federal and state law.

1.3.1. Section 7 review and conservation

Under section 7(a)(1) of the ESA, Federal agencies are directed to utilize their programs to conserve threatened and endangered species. Section 7(a)(2) requires Federal agencies to consult with the Service to insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of listed species, nor destroy or adversely modify critical habitat (no critical habitat has been designated for *B. hungerfordi*). Federal programs and consultations with the Service should strive to implement recovery goals for *B. hungerfordi* to the maximum extent possible. Consultations are expected to continue with Federal agencies whose projects occur within the range of *B. hungerfordi*. Refer to the Conservation Measures section of this Recovery Plan for more information on the section 7 process.

1.3.2. Section 10 permits

1.3.2.1. Section 10 (a)(1)(A) – Enhancement of survival permits

Enhancement of survival permits under section 10(a)(1)(A) of the ESA are issued by the USFWS to researchers for scientific purposes or to private individuals who wish to enhance the propagation or survival of the listed species through a Safe Harbor Agreement (SHA). Research permits are initiated with an application accompanied by a study or management proposal. Permits are conditioned to minimize harm to the species. Several research permits have already been issued, and future permits are anticipated to address research needs related to management and recovery questions.

1.3.2.2. Section 10 (a)(1)(B) – Incidental take permits

Section 10(a)(1)(B) of the ESA provides for the issuance of "incidental take" permits (ITP) for the take of federally-listed animals, such as *B. hungerfordi*, for non-Federal actions. Applicants for an incidental take permit must develop a Habitat Conservation Plan (HCP). There have been no 10(a)(1)(B) permits issued for *B. hungerfordi*.

1.4. Land acquisition and protection (2)

Two of the five known sites occur on public lands. Land acquisition from willing sellers by Federal, state, or private conservation organizations may be important for site protection.

1.5. Encourage watershed-level conservation (2)

Conservation of the watersheds in which *B. hungerfordi* is found is an important component of the recovery program. Recovery partners should work together to encourage protection of water resources at the watershed level. This task will involve working with local conservation organizations to increase community awareness and involvement in watershed conservation. This may involve activities such as promoting best management practices to reduce pollution and sedimentation into the watershed.

1.6. Coordinate with Canadian officials regarding the North Saugeen River site (3)

Members of the Ontario government will be contacted and encouraged to monitor and protect the known *B. hungerfordi* site near Scone. Although this site is not included in the recovery goals of this Recovery Plan, it is still important for conservation of the species.

2. Conduct scientific research to facilitate recovery efforts

Research is vital to successful implementation of this recovery program. Many of the recovery actions identified in this Recovery Plan require more information in order to be effectively implemented. In addition, the recovery criteria will be revised and updated based on the results of these studies.

2.1. Conduct studies to examine life history and ecology of *B. hungerfordi* (2)

Knowledge of the life history and ecology of this species is critical to adequate and long-term protection. Researchers should conduct studies to describe the life history of this species and investigate unknown aspects of its reproduction, food habits, and behavior. These studies will likely include both laboratory and field work.

2.2. Conduct studies to examine population dynamics and demography (2)

The population dynamics and demography of the known sites should be examined. Dispersal mechanisms are unknown and must be determined. Rates of birth, immigration, emigration, and death should be investigated.

2.3. Examine habitat requirements (2)

Habitat protection for this species depends on an understanding of its habitat requirements. This research will rely on the results of other studies; it will be necessary to understand certain basic aspects of the species' ecology (e.g., oviposition site selection, dispersal mechanisms) in order to fully identify necessary habitat components.

Suitable habitat should be defined once the habitat needs of the species have been identified. Suitable habitat will include all habitat features necessary for survival and reproduction of *B. hungerfordi*. Surveys should be conducted to find areas of existing suitable habitat, or areas with potential suitable habitat. This research topic directly supports Task 1.1.

2.4. Investigate genetic heterogeneity and population viability (2)

Genetic information on *B. hungerfordi* can provide guidance for management and recovery of the species. No information on genetic variation is currently available for *B. hungerfordi*. Genetic variation may be examined within individuals, within populations, and among populations. Loss of variation may have a negative effect on fitness and can occur in small populations through founder effects, genetic drift, and inbreeding. Research should examine the genetic diversity of *B. hungerfordi* to determine if loss of genetic variation is a threat to the species. Information on genetic diversity should be considered in a population viability analysis (PVA) for the species. Population viability analyses (PVAs) can be used to examine the degree to which a population is indefinitely self-sustaining. Data obtained from a PVA can help guide future recovery criteria revision.

2.5. Confirm threats to the species (2)

Research is needed to examine potential threats to the species. Currently, the majority of threats are speculative. This task will require determination of the effects of stream and watershed management activities on *B. hungerfordi* (e.g., fish management, beaver control, dredging, stream-side logging, channelization, bank stabilization, impoundment, road-crossing improvement projects). The effects of other factors must also be considered, including road and road-side projects, recreation and human disturbance, disease and predation, point and non-point source pollution, and risks associated with small isolated populations.

2.6. Investigate utility of captive propagation (2)

The potential use of captive rearing of *B. hungerfordi* for research and population supplementation purposes should be investigated. A facility for rearing *B. hungerfordi* could provide a genetically diverse stock for research purposes, establishing new wild populations or enhancing existing wild populations. However, research will be important in determining whether captive propagation is necessary for recovery and the extent to which it should be used, if at all. Prior to implementation of a captive propagation program, protocols should be developed to guide use of this technique for recovery purposes.

3. Conduct additional surveys and monitor existing sites

Because this species is difficult to detect during surveys, it is possible that there are additional, undiscovered populations of *B. hungerfordi*. Surveys should be conducted in an attempt to locate unknown populations of the species. In addition, known sites should continue to be monitored to determine population status and identify possible management efforts. Protocols should be developed to standardize survey and monitoring efforts.

3.1. Develop standard survey and monitoring protocols (2)

A standardized monitoring scheme should be developed such that data generated can be compared between years for a given site, if possible. The protocol should describe survey techniques and a structured monitoring program. It should provide information on frequency of surveys and interpretation of negative survey data. Careful evaluation of survey results at known sites may assist in development of adequate techniques for new locations. Monitoring protocols should include parameters of a population that may be important to research programs, including data for PVAs if possible.

3.2. Continue to survey new locations to identify new populations or areas of suitable habitat (2)

Once the habitat requirements of the species are better understood, surveys should target areas containing the necessary habitat components. Surveys at likely unoccupied sites should include a repetitive element as indicated in Task 3.1. If additional populations are discovered, the recovery criteria may be revised as appropriate.

3.3. Develop and implement a monitoring plan for all known sites (2)

Each of the known sites should be regularly monitored to determine whether the status of the site is increasing, stable, or decreasing. A monitoring plan should be developed to ensure that each site is routinely visited such that population trends may be determined.

4. Develop and implement public education and outreach

4.1. Conduct landowner contact and educational programs to increase awareness of *B. hungerfordi* (3)

Landowners of properties near known *B. hungerfordi* sites should be notified of presence of the species. Information should be provided to landowners who are interested in conservation of the species. An information kit should be developed to explain the biological needs of the species, threats, and its connection to healthy stream management.

4.2. Design educational materials and presentations for the public (3)

News releases, brochures, presentation, and displays should be used to educate the general public about *B. hungerfordi*. These efforts should address the value of preserving biological diversity and the importance of endangered species and watershed conservation.

4.3. Contact local organizations to inform them of the beetle (3)

Universities, government agencies, and other groups that may conduct invertebrate surveys in northern Michigan should be contacted and informed of the beetle so that they can look for *B. hungerfordi* during other surveys. In addition, local road commissions, fire departments, and conservation groups, should be informed of the beetle and potential threats to the species.

5. Revise recovery criteria and recovery tasks, as appropriate, based on research and new information (3)

These recovery criteria will be revised based on scientific data and results of research in order to make them fully measurable. If additional sites are discovered, recovery criteria may also be revised.

6. Develop a plan to monitor *B. hungerfordi* after it is delisted (3)

The ESA (4)(g)(1) requires the Service to "…implement a system in cooperation with the States to monitor effectively for not less than five years the status of all species which have recovered to the point at which the measures provided pursuant to this Act are no longer necessary." The Service should begin working on this plan when it determines that the species has met its recovery criteria and its protection under the ESA is no longer required, and should consider monitoring for at least ten years.

PART III. IMPLEMENTATION

The following Implementation Schedule outlines actions and estimated costs for the recovery program in the United States portion of *B. hungerfordi's* range for the next three years. It is a guide for meeting the objectives discussed in the RECOVERY section. The Implementation Schedule lists and ranks recovery tasks, provides task descriptions and duration, identifies partner agencies, and provides estimated costs. The listing of a partner in the Implementation Schedule does not require, nor imply requirement, that the identified partner has agreed to implement the action(s) or to secure funding for implementing the action(s). However, partners willing to participate may benefit by being able to show that their funding request is for a recovery action identified in an approved recovery plan and is therefore considered a necessary action for the overall coordinated effort to recover *B. hungerfordi*. Also, section 7(a)(1) of the ESA directs all federal agencies to utilize their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of threatened and endangered species. This schedule will be reviewed periodically until the recovery objective is met, and priorities and tasks will be subject to revision. Tasks are presented in order of priority.

Key to Implementation Schedule

Column 1: Task Priority

Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to meet the recovery objectives.

Column 2: Task Description

A short description of the recovery task which coincides with the STEPDOWN RECOVERY OUTLINE (PART II)

Column 3: Task Number

The number from the STEPDOWN RECOVERY OUTLINE (PART II).

Column 4: Task Duration

The number of years that it is expected to take before the task is completed. The letter "O" indicates that the task is currently ongoing. The letter "C" indicates that the task will be continuous throughout the recovery period. Tasks may be both ongoing and continuous.

Column 5 and 6: Recovery Partner

This designates the USFWS programs and other organizations that may be involved in carrying out the task. A key to the acronyms is provided here.

ES	USFWS Division of Ecological Services
LCO	Local Conservation Organizations (e.g., The Nature Conservancy, Tip of the Mitt Watershed Council, Conservation Resource Alliance, and others)
LG	Local Government (e.g., County Road Commissions)
MDNR	Michigan Department of Natural Resources
MNFI	Michigan Natural Features Inventory
OTHERS	Other individuals or groups willing to participate (e.g. landowners)
RSCH	Universities and Research Institutions
RWG	Recovery Working Group for *B. Hungerfordi*
USFWS	U.S. Fish and Wildlife Service

Columns 7-9: FY05, FY06, and FY07

This column gives the estimated cost for carrying out the task during fiscal year 2005 (FY 05), fiscal year 2006 (FY 06), and fiscal year 2007 (FY 07). Costs are listed in thousands of dollars. TBD means costs are yet to be determined.

Column 10: Comments

Explanatory comments. For more detailed information, refer to the RECOVERY section. TBD = To be determined.

Table 3. Implementation Schedule for *B. hungerfordi*

				Recovery Partner		Est. Cost ($1,000)			
Priority	Description	Task number	Task duration	USFWS	Other	FY05	FY06	FY07	Comments
1	Define and protect areas of essential habitat	1.1	3	R3 ES	MDNR, RWG, RSCH	TBD			Completion of this task is contingent upon results of research on habitat requirements.
1	Develop and implement site conservation plans for each site to address threats	1.2	4	R3 ES	MDNR, RWG, RSCH, LCO, LG, OTHERS	10	5	5	This task should be conducted in concert with task 2.5.
1	Review Federal, state, and private actions	1.3	C, O	R3 ES	MDNR, MNFI	5	5	5	
2	Land acquisition and protection	1.4	C	R3 ES	MDNR, LCO	TBD	TBD	TBD	
2	Encourage watershed-level conservation	1.5	O	R3 ES	MDNR, LCO, LG	1	1	1	This task will involve education and outreach (see also task 4).
2	Conduct studies to examine life history and ecology of *B. hungerfordi*	2.1	3	R3 ES	RSCH, MDNR, RWG	20	10	10	

				Recovery Partner		Est. Cost ($1,000)			
Priority	Description	Task number	Task duration	USFWS	Other	FY05	FY06	FY07	Comments
2	Conduct studies to examine population dynamics and demography	2.2	3	R3 ES	RSCH, MDNR, RWG	20	10	10	
2	Examine habitat requirements and define suitable habitat	2.3	3	R3 ES	RSCH, MDNR, RWG	20	20	20	
2	Investigate genetic heterogeneity and population viability	2.4	4	R3 ES	RSCH, MDNR, RWG	20	20	20	
2	Confirm threats to the species	2.5	3	R3 ES	RSCH, MDNR, RWG	20	10	10	
2	Investigate utility of captive propagation	2.6	2	R3 ES	RSCH, MDNR, RWG, OTHERS	2	2	0	

Priority	Description	Task number	Task duration	Recovery Partner USFWS	 Other	Est. Cost ($1,000) FY05	 FY06	 FY07	Comments
2	Develop standard survey and monitoring protocols	3.1	3	R3 ES	RSCH, MDNR, RWG, MNFI	1	1	1	
2	Continue to survey new locations to identify new populations or areas of suitable habitat	3.2	5	R3 ES	RSCH, MDNR, RWG, MNFI	20	15	10	
2	Develop and implement a monitoring plan for all known sites	3.3	3	R3 ES	RSCH, MDNR, RWG, LCO, MNFI	5	5	5	
3	Coordinate with Canadian officials regarding the North Saugeen River site	1.6	C	R3 ES	RWG, MDNR, RSCH	0	0	0	

Priority	Description	Task number	Task duration	Recovery Partner USFWS	Recovery Partner Other	Est. Cost ($1,000) FY05	Est. Cost ($1,000) FY06	Est. Cost ($1,000) FY07	Comments
3	Conduct landowner contact and educational programs to increase awareness of *B. hungerfordi*	4.1	C	R3 ES	MDNR, LCO, MNFI	0.5	0.5	0.5	
3	Design educational materials and presentations for the public	4.2	C, O	R3 ES	MDNR, MNFI, LCO	1	1	1	
3	Contact local organizations to inform them of the beetle	4.3	O	R3 ES	MDNR, MNFI, LCO	0	0	0	
3	Revise recovery criteria and recovery tasks, as appropriate, based on research and new information	5	1	R3 ES	MDNR, RSCH, RWG, MNFI	0	0	5	

				Recovery Partner		Est. Cost ($1,000)			
Priority	Description	Task number	Task duration	USFWS	Other	FY05	FY06	FY07	Comments
3	Develop a plan to monitor *B. hungerfordi* after it is delisted	6	2	R3 ES	MDNR	0	0	0	No costs anticipated in years 1-3.

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APPENDICES

Appendix A. Glossary of terms and list of acronyms

1. GLOSSARY OF TERMS

Basal: At or towards the base or the main body, or closer to point of attachment

Coxa (*pl*. coxae): The first or basal segment of the leg of insects

Elytron (*pl*. elytra): Hardened forewing that forms a protective covering for the rear wings

Endophytic: Within plant tissues

Epiphytic: A plant that grows on another plant upon which it depends for mechanical support but not nutrients

Gonocoxae: Part of the egg-laying apparatus in females; genital valves

Infuscation: The state of being dark; darkness

Lithophilic: Associated with a stony substrate

Oviposition: Egg laying in insects

Pronotum: The plate at the base of the head

Punctation: Marked with points or dots; having minute spots or depressions

Tarsus (*pl*. tarsi): Leg segments distal to the tibia.

2. LIST OF ACRONYMS

ESA	Endangered Species Act of 1973, as amended
MNFI	Michigan Natural Features Inventory
MDNR	Michigan Department of Natural Resources
UMBS	University of Michigan Biological Station
USGS	United States Geological Survey
MI-VSEC	Michigan River Valley Segment Ecological Classification System
USFWS	United States Fish and Wildlife Service
CFR	Code of Federal Regulations
TFM	3-trifluromethyl-4-nitrophenol
COE	United States Army Corps of Engineers
HCP	Habitat Conservation Plan
SRF	Stream Research Facility (University of Michigan)
ITP	Incidental Take Permit

Appendix B. General beetle anatomy

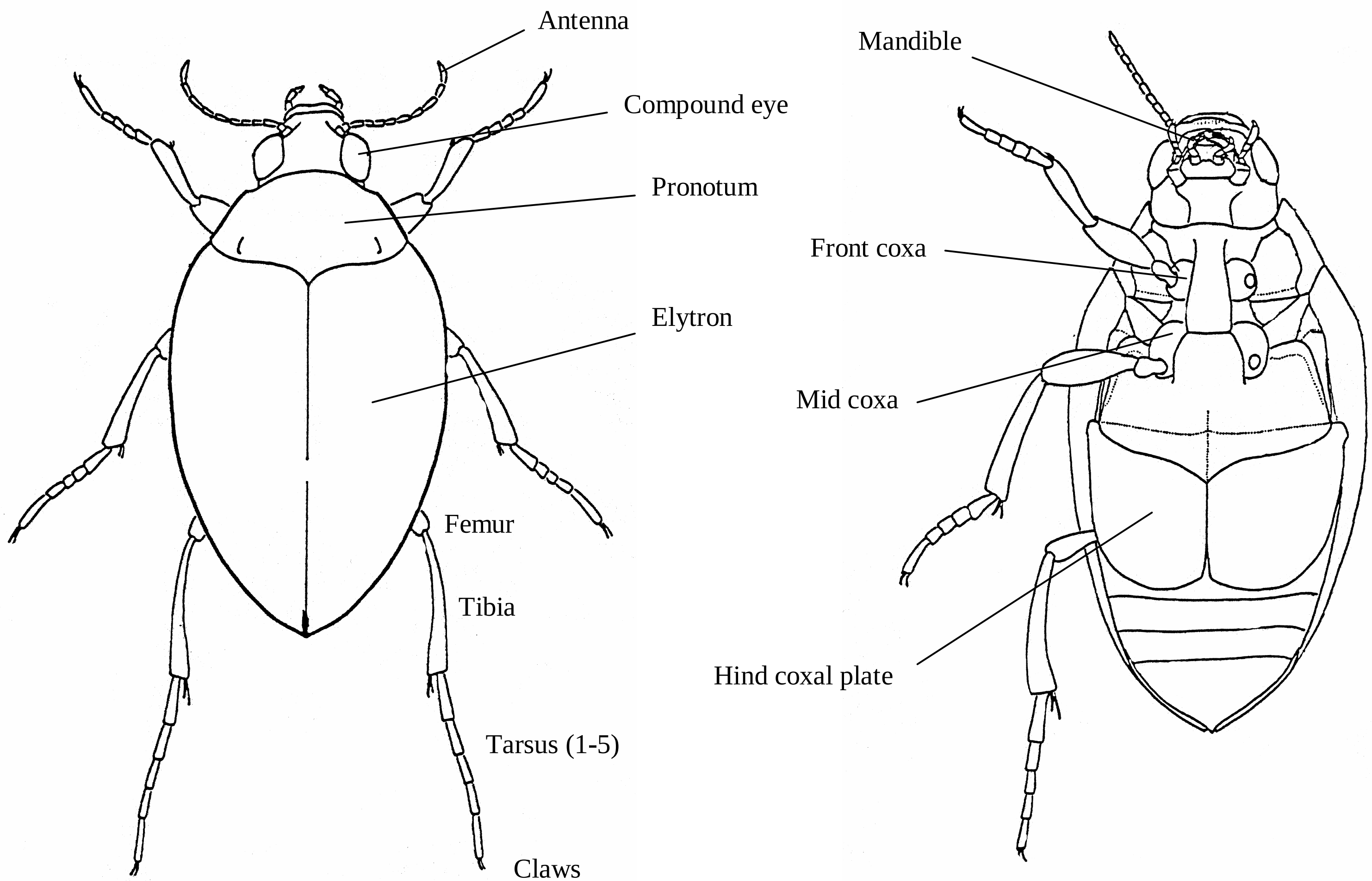

Figure B1. General beetle anatomy
Left - *Haliplus ruficollis* (De Geer), dorsal view. Right - *Haliplus flavicollis* (Sturm), ventral view. Figures adapted from Holmen 1987; used with permission.

Appendix C. Research Needs

Range and population dynamics

- *Conduct surveys for additional populations of B. hungerfordi*

  Because the species is difficult to detect during surveys, this may include areas that have previously been surveyed with negative results. Areas considered optimal habitat should be targeted, but other areas should also be surveyed since we do not fully understand the species habitat requirements (e.g., St. Clair River).

- *Confirm the St. Clair River larval specimens, and continue efforts to identify a historic range for this species*

  There is very little historic information for this species, as it was only discovered by the scientific community in the 1950s.   Museum collections have been examined for *Brychius* specimens (T. Mousseau, University of Manitoba, pers. comm., 2003). If additional specimens are available, they should be examined. The historic record of two larval specimens collected in St. Clair County should be confirmed and the habitat should be surveyed.

- *Study population biology*

  Population demographics, growth rate, and dynamics need to be examined. Dispersal mechanisms should be confirmed. If populations are isolated with no genetic interchange, the consequences of loss of genetic variation should be examined. Population viability should be examined once there is enough information on biology and demographics to conduct such an analysis.

Habitat

- *Determine the habitat requirements of the species*

  Habitat needs must be understood in order to adequately protect habitat for the species.   Habitat necessary for survival and completion of its life cycle should be identified. Oviposition and pupation sites, as well as the appropriate larval and adult food sources, should be identified.

- Develop list of other areas of potential suitable habitat for the beetle

  Once the habitat requirements of the species are understood, areas of suitable habitat within the region should be identified. These areas should be targeted for surveys, and may also serve as future sites for introduction of the species.

- Identify areas important for habitat protection or enhancement

Areas of suitable habitat should be further examined to determine potential threats. Sites that may be important for recovery should be identified so that they may be considered for protection. In addition, there may be areas where suitable habitat can be enhanced by management. These areas should also be identified and applicable management techniques described.

Life history and ecology

- Confirm the life history of this species

  Much of the life history information presented in this Recovery Plan is based on an assumption that *B. hungerfordi* has a similar life history to other haliplids. The egg and pupal stage of any *Brychius* species have yet to be described. The life history, including timing of the four stages of development, number of generations per year, age at first breeding, and fecundity is not known. Research is also needed to examine these factors, as well as survival rates and mortality (see also discussion on population biology). In addition, breathing mechanisms should be confirmed.

- Confirm the food habits of larvae and adults

Threats

- Confirm threats to the species and develop methods to minimize them

  Currently, threats are not well understood. Potential threats at each site should be examined, including habitat alteration, fisheries management (e.g., use of lampricide), and predation.

Appendix D. Summary of threats and recommended recovery actions for *B. hungerfordi*

Listing Factor	Threat	Recovery Criteria	Tasks
A	**Stream modification and management** *This includes physical destruction of the stream habitat and degradation of water quality (e.g., dredging, stream pollution, logging, channelization, bank stabilization, beaver control, and impoundment)*	1, 2, 3, 4	Protect known sites (Tasks 1.1, 1.2, 1.3, 1.4, 1.5, 1.6); Conduct research to investigate habitat requirements and determine effect of stream management activities (Tasks 2.3, 2.5)
A	**Road crossing projects** *Road crossing deterioration, road and road-side maintenance, and road crossing alteration (e.g. construction, removal of culverts) are potential threats*	1, 2, 3, 4	Protect known sites (Tasks 1.1, 1.2, 1.3, 1.4, 1.5); Conduct research to investigate habitat requirements and determine effect of road crossing projects (Tasks 2.3, 2.5)
A,E	**Fish management activities** *These may include activities that modify or destroy habitat (e.g., removal of a dam or culvert to allow fish passage) and other activities (e.g., use of lampricide).*	1, 2, 3, 4	Protect known sites (Tasks 1.1, 1.2, 1.3); Conduct research to answer questions about the effects of fish management activities (Task 2.5)
C	**Disease and predation**	1	Conduct research to determine if disease or predation is threatening this species; if so, examine ways to minimize the threat (Tasks 1.2, 2.5)
E	**Lack of information**	1	Define areas of essential habitat (Task 1.1); Conduct research to examine the species' life history and ecology, population dynamics and demography, habitat requirements and threats (Tasks 2.1, 2.2, 2.3, 2.4, 2.5, 2.6); Conduct surveys and monitor existing sites (Tasks 3.1, 3.2, 3.3); Revise recovery criteria based on new information (Task 5)

Listing Factor	Threat	Recovery Criteria	Tasks
E	**Risks associated with small isolated populations (e.g., stochastic events)**	1, 2, 3, 4	Protect known sites (Tasks 1.1, 1.2, 1.3, 1.4, 1.5, 1.6); Conduct research to better understand biology of the species (Tasks 2.1, 2.2, 2.3, 2.4, 2.5, 2.6); Continue to look for new sites and monitor existing sites (Tasks 3.1, 3.2, 3.3)
E	**Human disturbance**	1, 2, 3, 4	Protect known sites (Tasks 1.2, 1.4); Implement monitoring program (Task 3.3); Conduct outreach to make the public aware of the species (Tasks 4.1, 4.2, 4.3)

Listing Factors:
A. The Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range
B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes (Not applicable)
C. Disease or Predation
D. The Inadequacy of Existing Regulatory Mechanisms (Not applicable)
E. Other Natural or Manmade Factors Affecting its Continued Existence

Recovery Criteria:
<u>Reclassification criteria</u>
1. Life history, ecology, population biology, and habitat requirements are understood well enough to fully identify threats
2. A minimum of four U.S. populations, in at least two different watersheds, have had stable or increasing populations for at least 10 years
<u>Delisting criteria</u>
3. Identify and protect habitat necessary for long-term survival and recovery
4. A minimum of four U.S. populations, in at least two different watersheds, are sufficiently secure and adequately managed to assure long-term viability

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