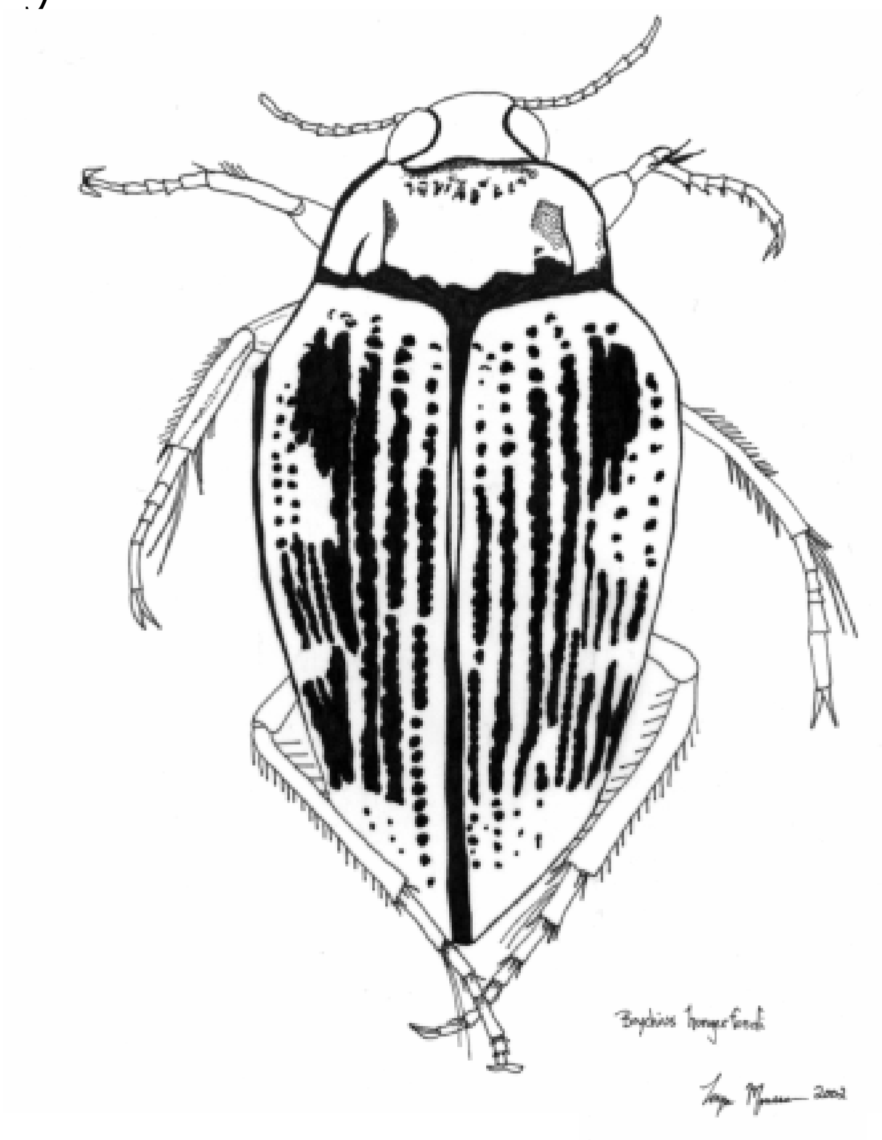
U. S. Fish and Wildlife Service

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



September 2006

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)

Recovery Plan

September 2006

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

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Recovery plans delineate reasonable actions which the best available science indicates are required to recover and/or conserve listed species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be obtained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views or the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the Fish and Wildlife Service only after they have been signed by the Regional Director. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

LITERATURE CITATION

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AVAILABILITY

Recovery plans can be downloaded from FWS website, http://endangered.fws.gov, or you may send a request to:

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ACKNOWLEDGEMENTS

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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 in five streams in the United States and one stream in Canada. Of these occupied streams, only the East Branch of the Maple River has consistently large numbers of beetles. At the other sites, only relatively small numbers of individuals have been found.

<u>Habitat Requirements and Limiting Factors</u>: *Brychius hungerfordi* is found in clear cool streams with well-aerated riffle segments, a cobble bottom, an underlying sand 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 remains unknown what factors may limit the species' distribution. Potential threats to the species may include habitat modification, certain 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. In general, it can be assumed that threats to the species include any activities that modify or disrupt the pool and riffle environments of streams in which this species lives. 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 factors that may be impacting the species. Therefore, recovery efforts would benefit from a research program that targets *B. hungerfordi* and its habitat. Based on the results of necessary research, 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 conserved and monitored. Our efforts will include reducing, to the extent possible, threats that result in physical habitat destruction and degradation (e.g., stream-side logging, stream pollution) and threats relating to certain fish management activities and human recreation. If research indicates that additional factors are threatening the species, we will revise the plan 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 habitat essential for all life stages and ensure adequate habitat conservation; and 3) identify whether additional threats exist. Initially, the objective of the recovery program is to gather sufficient information to revise and refine the interim 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 evaluate threats, and
2. A minimum of five U.S. populations, in at least three different watersheds, have had stable or increasing populations for at least 10 years, and at least one population is considered viable.

Delisting when the above criteria are met, plus:

3. Habitat necessary for long-term survival and recovery has been identified and conserved, and
4. A minimum of five U.S. populations, in at least three different watersheds, are sufficiently secure and adequately managed to assure long-term viability.

Actions Needed:

1. Conserve 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 actions, 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 Years 1, 2, and 3 and 4-20 (in $1000): Details are found in the Implementation Schedule (page 52).

Year(s)	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6	TOTAL
1	1	70	20	3	0	0	94
2	1	90	25	3	0	0	119
3	0	110	30	3	0	0	143
4-20	40	281	45	15	5	0	386
TOTAL	42	551	120	24	5	0	742

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 (USFWS 1994). *Brychius 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, three 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, larva, pupa, and adult. Appendices A and B define some of the terms used to describe the species and give more detail on beetle morphology.

Brychius hungerfordi is a member of the family Haliplidae. Members of the Haliplidae are commonly known as haliplids, or crawling water beetles. They have various body shapes from globular to elongated and streamlined, with many adaptations for swimming or crawling in water (Holmen 1987). All members of the Haliplidae are aquatic, with all active life history stages spent in water (Pennak 1953, Roughley and Larson 1991). Adults have large hind coxal plates covering the base of their hind legs and much of the abdomen (see Appendix B, ventral view). 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 to 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 (Leech and Chandler 1956, Hilsenhoff and Brigham 1978, White et al. 1984). There are currently three recognized species of *Brychius* in North America: *B. hungerfordi, Brychius hornii,* and *Brychius pacificus.* The latter two species occur in the western United States and Canada (Figure 1). *Brychius hornii* is by far the most widespread and common species of

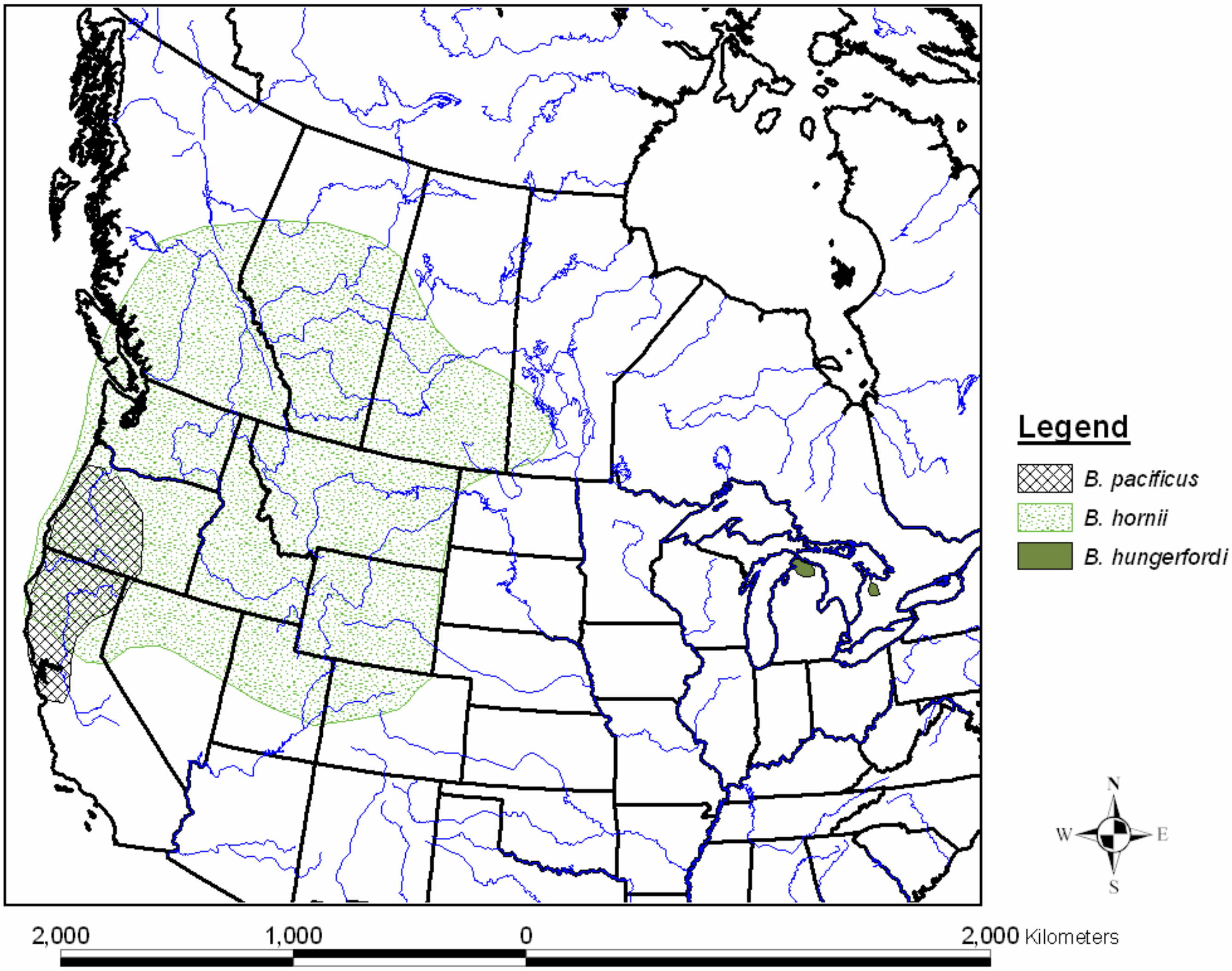


Figure 1. Approximate distribution of the genus *Brychius* in the United States and Canada based on specimens examined. *The ranges shown here are approximate and are for illustrative purposes only.*

Brychius in North America (Mousseau 2004). There are two additional *Brychius* species that occur in Europe.

Brychius 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, median lobe of the aedeagus (part of the male genitalia) of each *Brychius* species has a unique shape, and can be used for identification (T. Mousseau, University of Manitoba, pers. comm., 2003).

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).

Brychius 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). *Brychius* larvae have modified forelegs which could be an adaptation for feeding on filamentous algae (Hickman 1931, Mousseau 2004). 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, White et al. 1984, Strand and Spangler 1994). Final 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

Brychius hungerfordi is found in five streams in northern Michigan (Figure 5) and one stream in Ontario, Canada. 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 in the East Branch of the Black River, in Montmorency County (Strand 1989, Wilsmann and Strand 1990, Strand and Spangler 1994). In 1997, the fourth known occurrence, in the Carp Lake River, was discovered in Emmet County (Keller et al. 1998). The fifth occurrence, in Van Hetton Creek, was discovered in Montmorency County in 1999 (Grant et al. 2000). The most recently discovered site, in Canada Creek, was discovered in Presque Isle County in 2005 (B. Walker, Michigan Department of Environmental Quality, pers. comm., 2005). Surveys of other streams with similar habitats to known sites have been conducted in other areas of northern Michigan, Ontario, Wisconsin, and Minnesota but

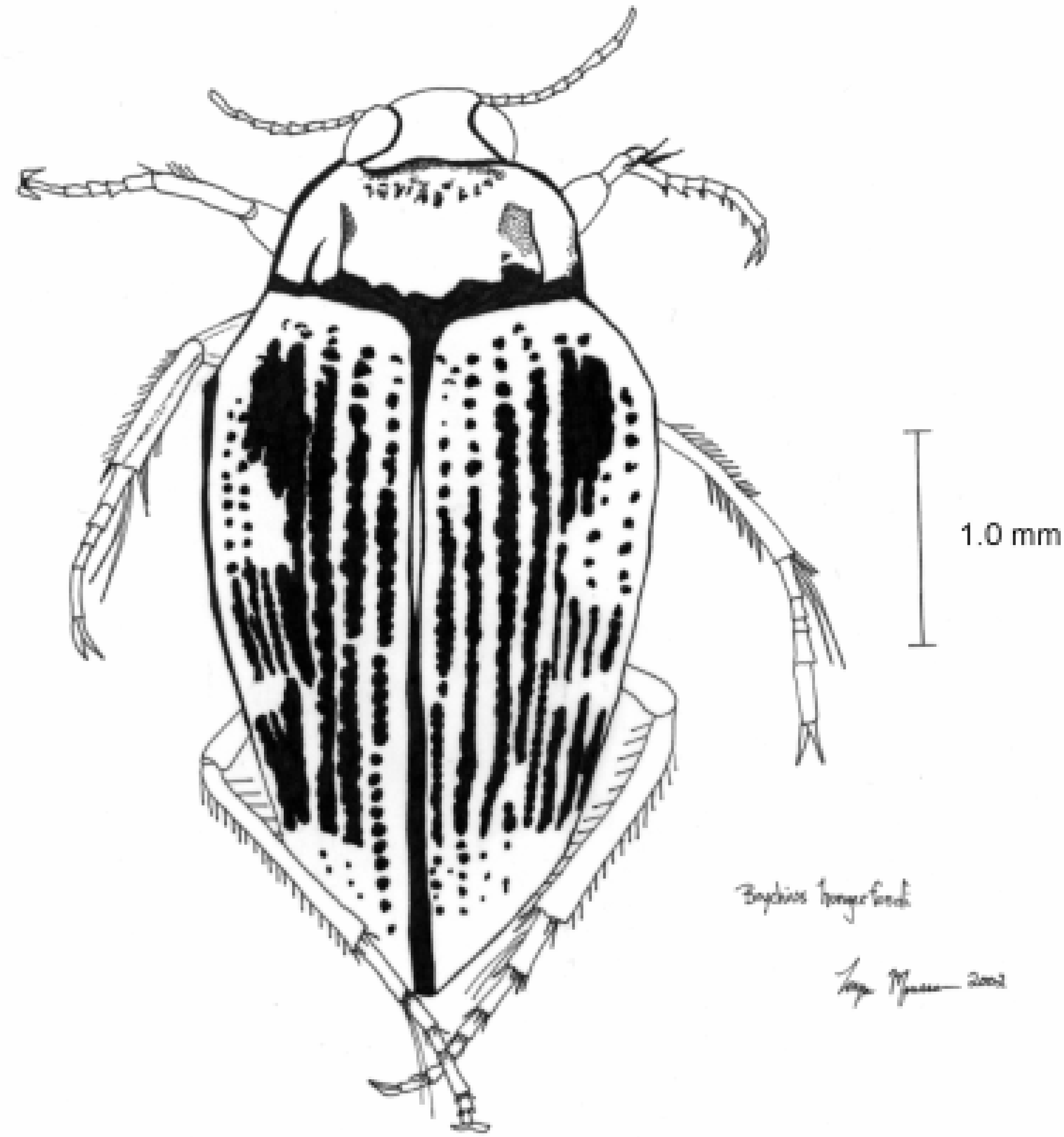


Figure 2. Adult *B. hungerfordi*, dorsal view. Drawing courtesy of Tonya Mousseau, University of Manitoba.

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.

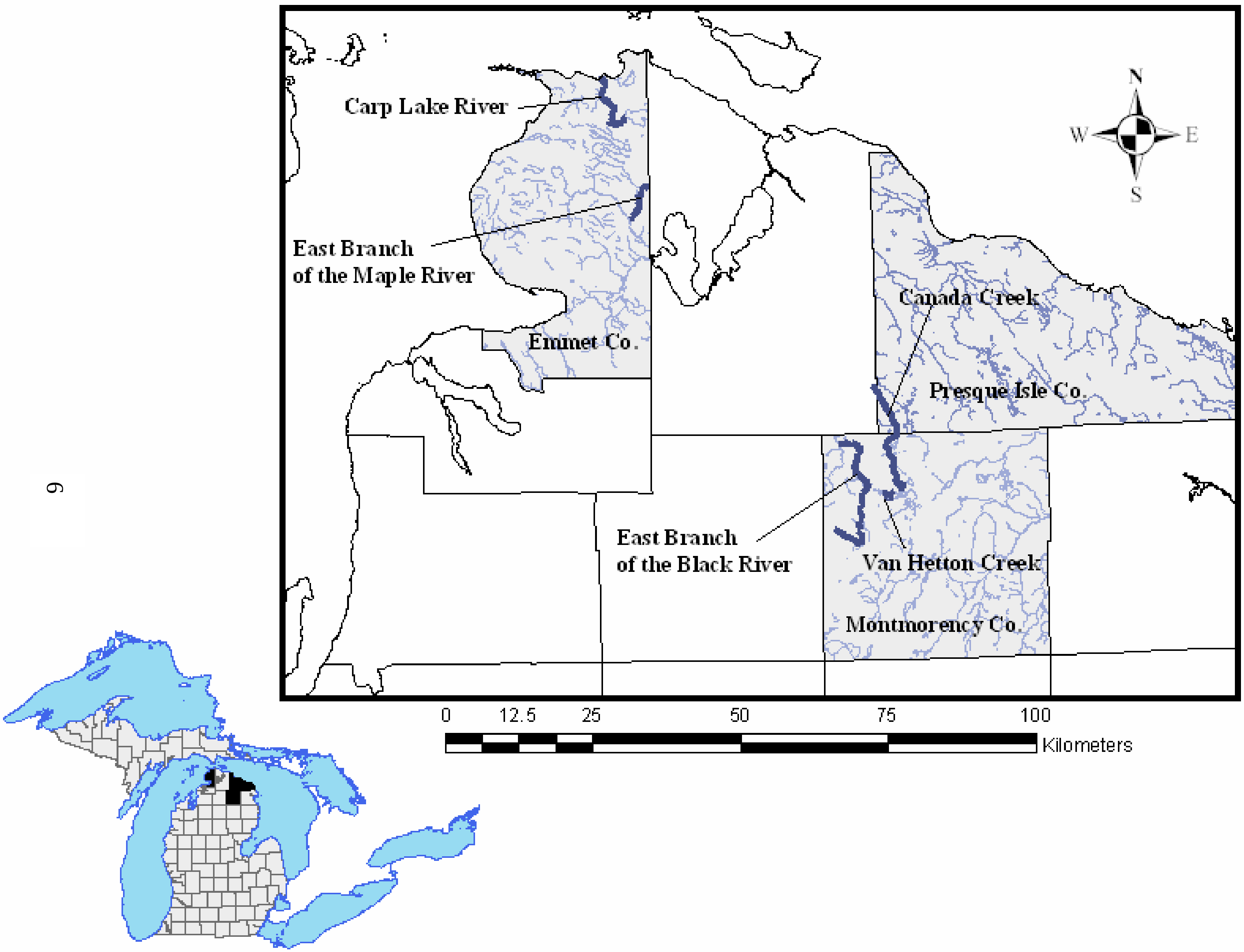


Figure 5. Streams in Michigan where *B. hungerfordi* is known to occur.

have failed to reveal additional populations of *B. hungerfordi* (USFWS 1994).

Current distribution (by County)

Emmet County, Michigan

East Branch of the Maple River

The East Branch of the Maple River represents the best-studied and largest known population of this species. 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), including at least a dozen occupied sites. Wilsmann and Strand (1990) reported finding over 100 adults and 20 larvae in this stream in 1989. White (*in litt.* 1987) estimated the population at the type locality (Robinson Road) to be between 200 and 500 individuals. The results of a mark-recapture study in 2001 indicated population numbers over 1000 individuals in one pool (Grant et al. 2002).

The majority of the occupied portions of this stream occur within and along the boundary of the University of Michigan Biological Station (UMBS). This population occurs within the Cheboygan River watershed. There are relatively large numbers of *B. hungerfordi,* and its status appears to be stable throughout occupied portions of this stream.

Carp Lake River

Brychius hungerfordi was first discovered in the Carp Lake River in 1997 when four adults were found under the culvert at the Oliver Road crossing (T39N, R4W, section 32, southwest ¼). 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). 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). In 2004, one adult *B. hungerfordi* was found at the Oliver Road crossing in August and again in September during 13 hours of total survey effort (Ebbers 2005). Twenty eight beetles were found during an intensive targeted search at this site in August 2006 (Ebbers 2006). The Emmet County Road Commission plans to remove the existing culverts at this site and replace them with a timber bridge. For additional information on this project, refer to the Conservation Measures section (Section 7, Interagency Cooperation with Federal Agencies). The Oliver Road site occurs on private property surrounded by Mackinaw State Forest.

In addition, five beetles were found at the Gill Road crossing, approximately 3 miles upstream of Oliver Road (B. Ebbers, Great Lakes Ecosystem Consulting, pers. comm., September 2004). The five adult beetles were found at the Gill Road site in approximately 10 minutes, and there are likely greater numbers in this pool (B. Ebbers, pers. comm., 2004). Currently, the habitat at Gill Road site is better overall and appears to support the greatest number of beetles (B. Ebbers, pers. comm., 2004). The Gill Road site is surrounded by a mix of private property and public land.

The Carp Lake River is in the Lake Michigan watershed. The overall numbers of beetles in this stream, although small, appear to be stable.

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) and occurs within the Mackinaw State Forest and the Black River watershed. Only two adults were found during surveys in 1989 (Strand 1989). Surveys conducted by MNFI in 1996 found two adults at this same location, and one adult was found farther downstream, closer to the Barber Road crossing (Legge 1996). This stream has not been surveyed in recent years, and its status 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 to 50 yards downstream of a culvert and county road crossing (B. Vande Kopple, University of Michigan Biological Station, pers. comm., 1999). This population occurs within the Mackinaw State Forest and the Black River watershed. Three beetles were found at this site in 2004 (C. Tansy, U.S. Fish and Wildlife Service, pers. comm., 2004), and one was found during a brief survey effort in 2005 (B. Walker, pers. comm., 2005). The population at this site appears to be stable.

Presque Isle County, Michigan

Canada Creek

In June 2005, a new site was discovered that expanded the previously known range for this species. One adult beetle was discovered in Canada Creek, just upstream from the road crossing of Bear Den Road (T33N R2E SE 1/4 of sec. 29) (B. Walker, pers. comm., 2005; B. VandeKopple, pers. comm., 2005). It is possible that the beetle was washed from an area upstream to the location in which it was discovered, as the beetle was found following a significant rain storm event (B. VandeKopple, pers. comm., 2005). Canada Creek is in the Black River watershed. The site is approximately 10 stream-miles downstream from the known occurrence in Van Hetton Creek. Canada Creek has not been extensively surveyed, and the status of the species in this stream is unknown.

Bruce County, Ontario

North Saugeen River

In 1986, forty-two specimens were collected at this site in south-central Ontario near the village of Scone in Bruce County (Roughley 1991). The land surrounding this site has mixed ownership and occurs 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.

Historic distribution

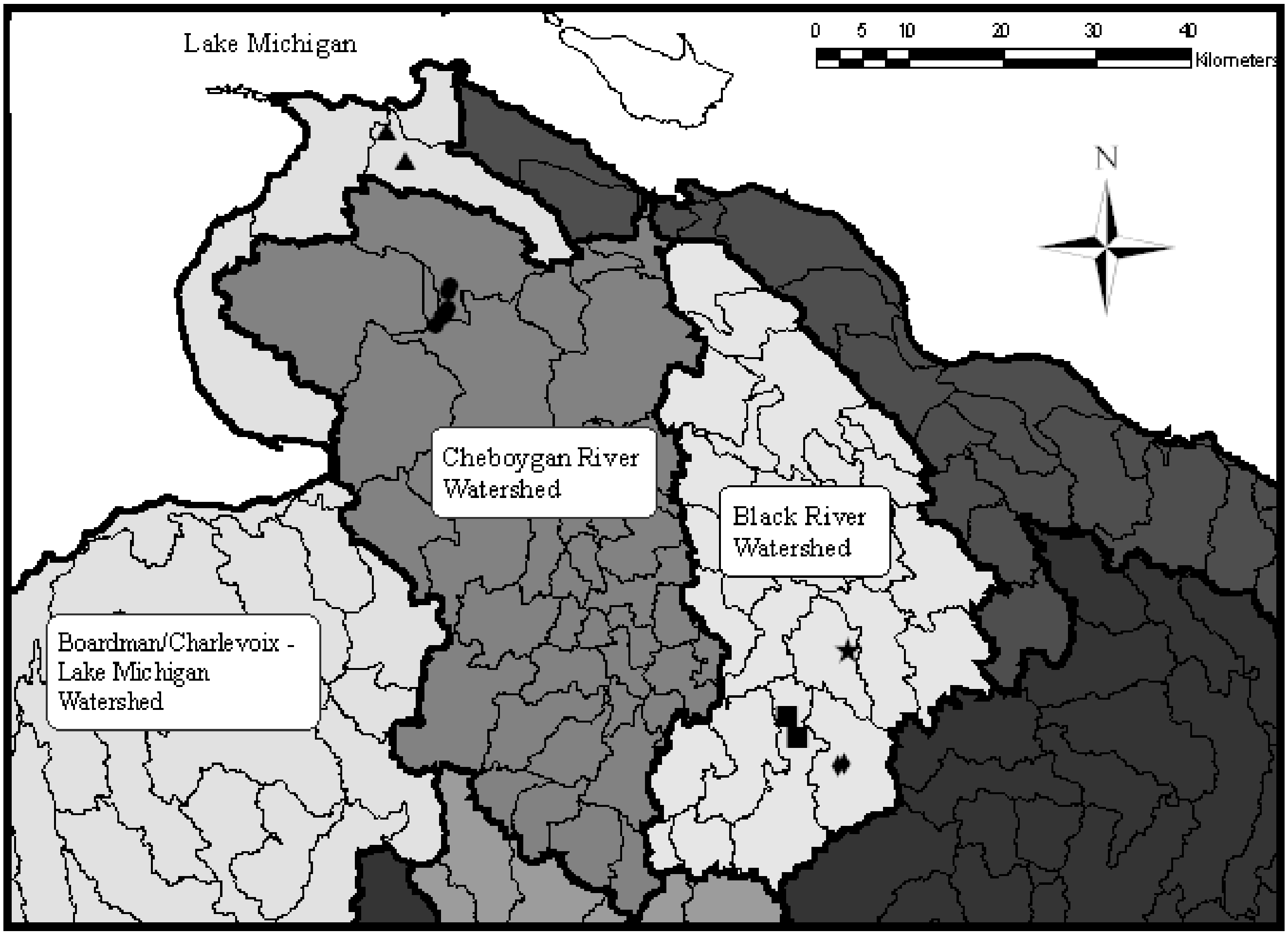
The distribution of the species prior to its discovery in 1952 is not known. Recently, however, museum collections throughout North America have been examined for *Brychius* specimens (Mousseau 2004). This inspection of museum collections led to the discovery of *B. hungerfordi* specimens collected in 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 *Brychius* larvae which were collected in the St. Clair River in 1983 by Pat Hudson (Hudson et al. 1986) and were confirmed as *B. hungerfordi* (R. Roughley, pers. comm., 2004). This record is curious because the St. Clair River is dissimilar 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, U.S. Geological Survey, pers. comm., 2002).

Biogeography

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, *B. hungerfordi* likely became increasingly rare but 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 limited distribution during post-Wisconsinan times. Additional discussion on the biogeography of *Brychius* can be found in Mousseau (2004).

Summary

This species appears to have a restricted range. Despite several survey attempts, *B. hungerfordi* is only known to occur within six streams in three watersheds (Figure 6). The status of the species is uncertain for several of the known streams. The East Branch of the Maple River has the highest known population and appears stable. The historic distribution remains unknown, although there are records of *Brychius* in Cheboygan and St. Clair Counties.



Legend

***B. hungerfordi* Locations**

- ★ Canada Creek
- ▲ Carp Lake River
- ■ East Branch of the Black River
- ● East Branch of the Maple River
- ♦ Van Hetton Creek

- Watersheds (8-digit HUC)
- Watersheds (14-digit HUC)

Figure 6. Northern Michigan watersheds where *B. hungerfordi* is known to occur. The watershed boundaries referred to in this Recovery Plan are based on the 8-digit hydrologic unit code (HUC), as labeled above. Smaller scale watershed boundaries are also shown on this map, based on the 14-digit HUC. Each *B. hungerfordi* population, sometimes represented by multiple locations within a stream, occurs within a distinct watershed based on the 14-digit HUC.

Life History and Ecology

<u>Life history</u>

Very little is known about the life history of *B. hungerfordi*; however, there are observations and life history information reported for other haliplids, including *B. hornii*. Although differences occur among species, life history information for closely related species may give us a reasonable estimate of the likely life history of *B. hungerfordi*. Much of the basic life history of haliplids is taken from Matheson (1912), Hickman (1931), Pennak (1953), Leech and Chandler (1956), Brigham (1982), White et al. (1984), Holmen (1987), and Mousseau (2004).

Brychius hungerfordi, like all beetle species, undergoes complete metamorphosis with a life cycle that consists of four distinct stages (Figure 7). In general, the period of egg laying for haliplids extends from May through July, although this may extend later in the summer in *B. hungerfordi*, and there may be another generation in the fall for some species (Hickman 1931, Brigham 1982). 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 to 0.483 mm in length, oval, and yellowish-brown in color (Hickman 1930a). Eggs of the genus *Haliplus* are approximately 0.35 to 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 (Hickman 1930a, Hickman 1931, Brigham 1982). *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 (Hickman 1930a, Brigham 1982, White et al. 1984).

Eggs of haliplids generally hatch 8 to14 days after oviposition (Brigham 1982, White et al. 1984). Each egg hatches into a larva. 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). *Brychius hungerfordi* larvae have been found in or near direct current in association with algae in the genus *Chara*, which is thought to be a possible food source (Strand and Spangler 1994). When mature, larvae leave the water in search of a place in damp soil to pupate. In the lab, larvae of *B. hornii* emerged from the water in November and remained throughout the winter months half-buried in moist earth and sand (Mousseau 2004). 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.

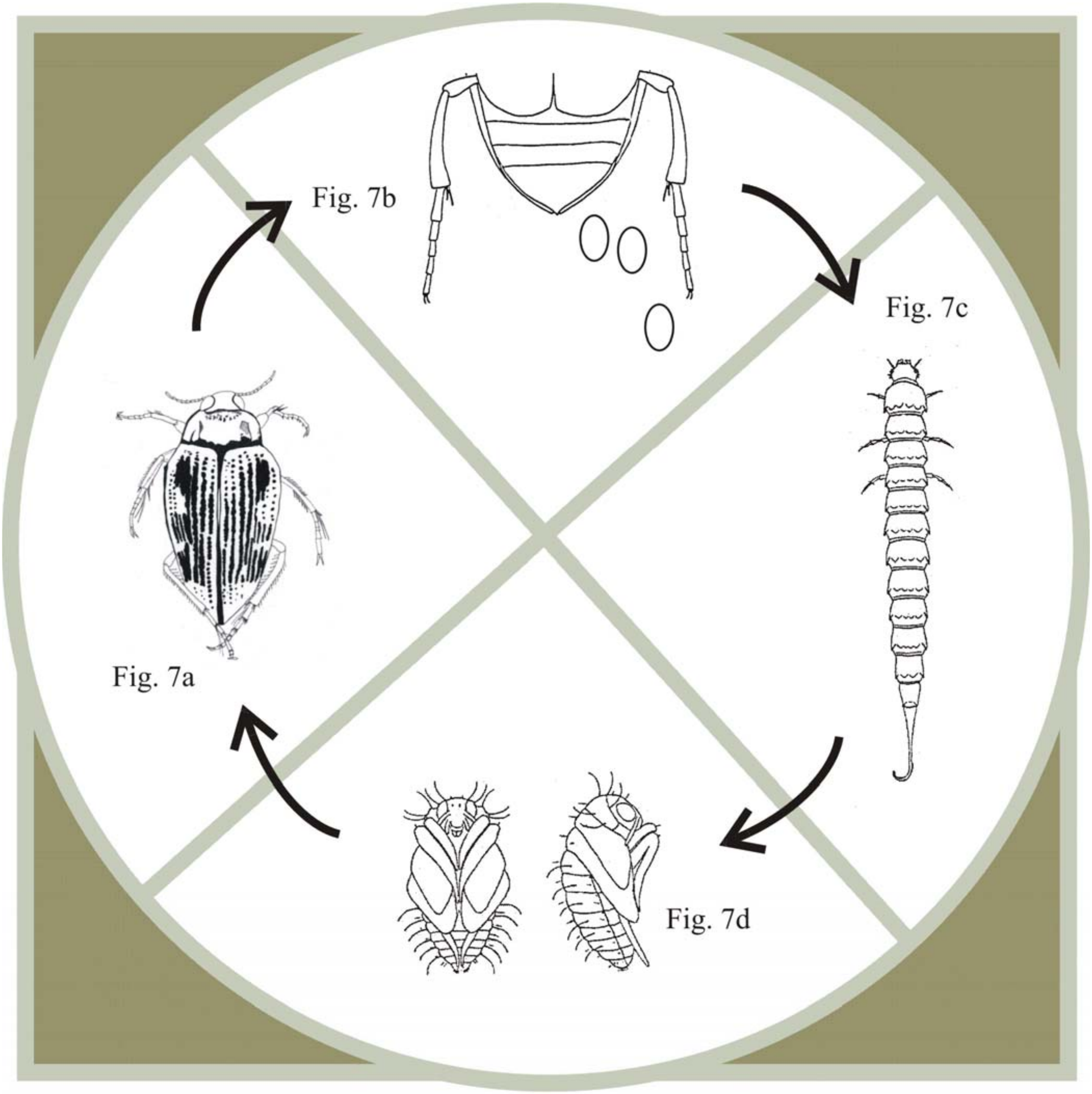


Figure 7. Illustration of life history stages of *B. hungerfordi*. *Fig. 7a*. Adult *B. hungerfordi*. Adult beetles mate in the summer (Scholtens 2002). *Fig. 7b*. Oviposition (egg-laying) stage. The egg stage has not been described for *B. hungerfordi*. It is unknown where eggs are laid, although it is most likely on or within aquatic vegetation within the stream (Hickman 1930a, 1931). *Fig. 7c*. Larval stage. Larvae spend most of their time in the stream, but likely burrow into the sediment to overwinter (Mousseau 2004). *Fig. 7d*. Pupae. This stage has not been described for *B. hungerfordi*. Pupae develop within a chamber constructed in the soil and emerge as adults in the spring (Brigham 1982).

Figure credits: 7a. Tonya Mousseau, University of Manitoba. 7b. Ventral view of an adult *Haliplus* adapted from Holmen 1987. 7c. Figure of *Haliplus* larva adapted from Holmen 1987. 7d. 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 family Haliplidae 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, pers. comm., 2003). The longevity observed in a laboratory setting may not reflect longevity in the natural environment.

Further study is needed to confirm certain aspects of the life cycle of *B. hungerfordi*, including timing of the four stages of development and location of oviposition and pupation sites. This information will help researchers more fully understand potential threats to the species and how to minimize or avoid them.

<u>Food habits</u>

Brychius hungerfordi is herbivorous, likely feeding on algae and periphyton, but the food habits of this species have yet to be confirmed. Beetles of the Haliplidae are typically herbivorous in both the adult and larval stages (Matheson 1912, Hickman 1931).

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, Wilsmann and Strand 1990, Strand and Spangler 1994). 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 attempted 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. In addition, beetles placed in a chamber with *Mougeotia*, 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 but suggest a diet that includes red and green filamentous algae and epiphytic diatoms.

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, larvae, and fecal samples. Based on the preliminary data, the most likely food source for adults is *Cladophora* spp. (Grant and Vande Kopple 2005). Larvae most likely feed primarily on *Vaucheria* spp. (Grant and Vande Kopple 2005). The study also indicated that their diet may have seasonal changes (Grant and Vande Kopple 2003). Because of the endangered status of *B. hungerfordi*, only a small number of individuals could be used for this study. Additional research is needed to confirm food sources for both adults and larvae.

<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 and active longer than those that rely strictly on atmosphere or aquatic plants (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 to serve as a physical gill because the bubble supplies 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, oxygen 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 family Haliplidae have uniquely expanded hind coxal plates which create chambers that hold stored air. Falkenström (1926) reported that haliplids generally receive enough oxygen from the water by diffusion, but under certain conditions they take in air much like members of the Dytiscidae (which 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 to 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*. The species likely surfaces to renew its air supply, but questions remain regarding frequency. 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 are inconclusive as well (Scholtens and Tamaska 2004).

If *B. hungerfordi* 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 (e.g., temperature, oxygen content, depth) of their surroundings. In some habitats, they would surface frequently, whereas in other environments they may remain submerged for long periods of time. Recently, adult *B. hungerfordi* beetles were 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 can rely solely on diffusion during winter months. Among groups related to haliplids (e.g., dytiscids), it is not uncommon for adults to replenish their air store from bubbles trapped under ice (R. Roughley, pers. comm., 2004). 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* (B. Scholtens, College of Charleston, pers. comm. 2004). 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).

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>General behavior</u>

Adults are often found in water less than 25 cm deep (Strand and Spangler 1994), allowing for observation through a diving mask or glass bottom bucket. At some sites, adults are observed 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 seem 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.

During laboratory observations of *B. hornii*, adult beetles spent the majority of their time: 1) crawling on the surface of rocks and gravel near the bottom of the aquarium; 2) clustering in crevices on the underside of rocks (when disturbed from this position, they would hook themselves together using their tarsal claws and legs and form a tangled "*Brychius* ball" with up to six individuals); 3) digging at the gravel at the bottom of the tank; and 4) swimming to the surface to replenish their air supply (Mousseau 2004).

When removed from the water, adult haliplids may exhibit thanatosis (feigning death) for up to several minutes (Hickman 1931, Mousseau 2004).

Hickman (1931) reported adult haliplids coming to lights in the laboratory, but others report attraction to light to be very rare (Matheson 1912). *Brychius hornii* seemed to be attracted to light in the laboratory (Mousseau 2004). In this case, adults were placed in a white sorting tray filled with water, gravel, and larger rocks. The light of a desk lamp was shone on one corner of the tray. Within minutes, adults had aggregated towards the light (Mousseau 2004).

<u>Locomotion and dispersal</u>

Adult haliplids are generally not fast or strong swimmers (Hickman 1931), 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). The adults of *B. hornii* are also described as excellent swimmers (Mousseau 2004). Haliplids are also fairly good at walking on land (Hickman 1931); *Brychius hornii* can walk with considerable ease and agility out of the water (Mousseau 2004).

It remains unknown how *B. hungerfordi* beetles disperse within the stream. Drift, the passive downstream transport of aquatic organisms in current, represents a possible mechanism of dispersal. They may also be able to swim or crawl upstream to colonize new sites. It is not known to what extent these beetles use drift or what distances they can swim or crawl upstream.

Adult *B. hungerfordi* beetles may be good dispersers at certain times of their life, or under certain environmental conditions through flight. Adults of most aquatic coleopteran species leave the water on dispersal flights (White et al. 1984). 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. Adults of *B. hungerfordi* seemed unusually reluctant to fly when deprived of water (Wilsmann and Strand 1990), although they can fly. Despite many hours of observations on this species, there exists only one report of flight in *B. hungerfordi*; an adult *B. hungerfordi* in the East Branch of the Maple River flew from a researcher's hand (B. Scholtens, pers. comm., 2005). *Brychius hungerfordi* may be similar to other aquatic beetles in that they may be capable of flight for only discrete periods of time (e.g., some elmid species only fly immediately after emergence from the pupal chamber), or under certain environmental conditions (e.g., warm, humid spring nights). This would make dispersal of more significant distances possible, including potential genetic exchange among watersheds. The timing, extent, and distances of dispersal flights in *B. hungerfordi* are unknown.

Legs of haliplid larvae are short and adapted for crawling on vegetation or along the substrate (Holmen 1987). Larvae of *B. hungerfordi* are sluggish (R. Strand, Northern Michigan University, pers. comm., 2005) and are not adapted for swimming.

Population studies and surveys

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 8). 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 (Mousseau 2004). The adults are very small and inconspicuous, and tend to hide under cobbles and vegetation along the bottom. Because they are difficult to find, 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 occur at additional sites. More survey work would assist in determining if other populations 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.

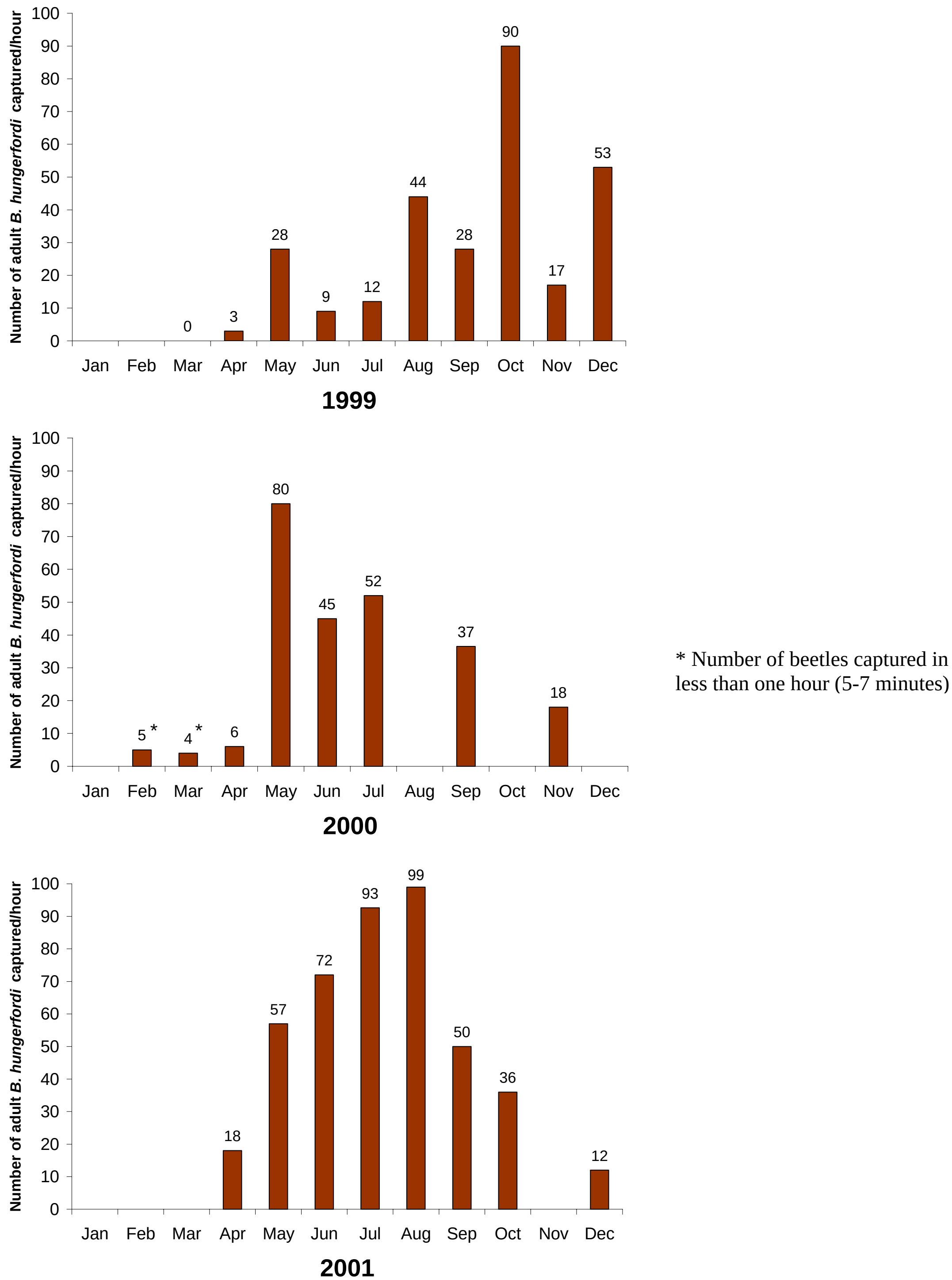


Figure 8. Seasonal abundance of adult *B. hungerfordi* beetles in one pool of the East Branch of the Maple River, from 1999-2001. Results are the number of beetles captured in one hour (unless otherwise noted). Adapted from Grant et al. 2000 and Grant et al. 2002.

Several researchers have attempted surveys for *B. hungerfordi* larvae, although only a few have successfully located them. Strand and Spangler (1994) 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 1989, Strand and Spangler 1994). Intensive surveys for larval specimens (or other early life stages) may result in destruction of suitable habitat and should be conducted with caution.

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 four of the five 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* occurs 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).

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

Brychius hungerfordi occurs in first, second, and third order streams (Table 2). The hydrology of a site appears to be important for this species. *Brychius 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) (Figures 9 and 10). 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 immediately downstream of 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).

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

B. hungerfordi sites	County	Stream Order[1]
Canada Creek	Presque Isle	2nd
Carp Lake River	Emmet	2nd
East Branch of the Black River	Montmorency	3rd
East Branch of the Maple River	Emmet	2nd
Van Hetton Creek	Montmorency	1st

[1] Based on U.S. Geological Survey 7.5 Minute Series Topographic Quadrangle Maps

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.).

Figure 9. *Brychius hungerfordi* is often found in pools below culverts at road crossings. Photo by Carrie Tansy, USFWS.

Figure 10. One example of *B. hungerfordi* microhabitat (swift moving water with cobble bottom and underlying sand substrate. Photo by Carrie Tansy, USFWS.

It has been suggested that beaver activity may be important in maintaining the habitat of *B. hungerfordi* (Wilsmann and Strand 1990). The first larval collection site for this species was found below a beaver dam (R. Strand, pers. comm., 2004) and adult beetles have also been found downstream of beaver dams. However, new beaver activity may change the flow dynamics and potentially threaten existing *B. hungerfordi* occurrences elsewhere in the stream. Although a beaver dam may create good habitat immediately below the structure, it often eliminates suitable habitat for many miles upstream and can result in considerable siltation downstream. In some cases, beaver dams may be spaced close enough together that the ponded water from one dam reaches to the base of the next one upstream, leaving no suitable *B. hungerfordi* habitat between the two (B. Ebbers, pers. comm., 2004). Beaver dams may also impede dispersal of *B. hungerfordi*. Consequently, many scientists familiar with *B. hungerfordi* and its habitat needs have recently begun to question the role of beaver in creating or maintaining suitable habitat (B. Ebbers, pers. comm., 2004; B. VandeKopple, pers. comm., 2004).

Many *B. hungerfordi* occurrences are found immediately downstream of culverts at road/stream crossings. Based on the best available information, this species prefers well-aerated riffle segments, a cobble bottom, an underlying sand substrate, alkaline water, algae for a food source, and suitable larval and pupation sites. Areas below culverts and beaver dams appear to provide this type of habitat, but areas with these habitat conditions are likely available in undisturbed streams without culverts or beaver activity. Additional research is needed to determine the preferred habitat of this species, and the role culverts and beaver play in creating or maintaining that habitat.

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 five 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 (Seelbach et al. 1997, Hinz, Jr. and Wiley 1999). 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 identical (all five codes matching), but several were highly similar to the known sites. Based on these data, high ranking streams were targeted for field surveys (Hinz, Jr. and Wiley 1999). Twenty four sites were sampled from 15 valley segments. No additional populations were found during these surveys. Interestingly, Van Hetton Creek was determined to be highly similar using this classification system. *Brychius 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 help in focusing future survey efforts to areas with characteristics similar to known sites, although other factors may also be important when determining potential habitat.

Although there are a number of similarities among occupied sites, many have unique habitat characteristics. In fact, it remains uncertain what characteristics are important to determine 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 (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). 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 (R. Strand, pers. comm., 2003). The two larval specimens collected from the St. Clair River further illustrate our lack of understanding of the species' habitat requirements. 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.

In summary, despite some research examining habitat and microhabitat components, the habitat requirements of the species are not fully understood. It is uncertain what habitat characteristics are important for all life stages of this species. In general, the types of streams inhabited by this species do not appear to be rare. The species appears to prefer environmental conditions found downstream of culverts, beaver dams, and similar structures. 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 (e.g., appropriate food, pupation sites). Alternatively, the species may be a glacial relict that has been rare since the last glaciation. Future research should examine factors that create and maintain suitable *B. hungerfordi* habitat and determine microhabitat requirements for each life stage, including overwintering sites (e.g., whether buried in the soil, among root hairs, or within the water column).

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. We will base this proposal 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 was facing serious threats and should be protected as an endangered species (USFWS 1994). Specific threats were unknown, but the listing rule hypothesized that human activities such as fish management, logging, beaver control management, dredging, stream pollution, and general stream degradation had contributed to the reduction of *B. hungerfordi* habitat (Wilsmann and Strand 1990, USFWS 1994). In general, it is likely 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 we do not completely understand the habitat requirements of this species, conservation of occupied *B. hungerfordi* habitat is important for recovery. Disturbance to areas where this species occurs may result in loss or degradation of habitat and may disrupt normal behavior patterns such as breeding, feeding, or sheltering. Although the impacts of many of the following threats on *B. hungerfordi* may not be documented, their impacts on water quality or on other invertebrates have been. Thus, in the absence of data on threats to *B. hungerfordi*, we are proposing these possible threats through inference based on information available on impacts to the habitat in which the species is found or impacts to other aquatic invertebrates. Research is outlined in the Recovery Actions and Appendix C that will provide the information necessary to determine the magnitude of these threats.

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, beaver activity, stream pollution, stream-side logging, channelization, bank stabilization, dredging, and impoundment (Wilsmann and Strand 1990, USFWS 1994, Hyde and Smar 2000).

The significance of beaver in creating and maintaining *B. hungerfordi* habitat is not known. At some sites, beaver impoundments may 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 (B. VandeKopple, pers. comm., 2004; B. Ebbers., pers. comm., 2004). In fact, beaver may create more harm than good in some areas (see pages 24 and 71 for additional discussion).

Many known *B. hungerfordi* sites occur below culverts at road-stream crossings, which may result in multiple threats. Poorly designed or deteriorating road crossings may result in excessive erosion and subsequent sedimentation into the stream. Clearing or cleaning of ditches or culverts may also affect water quality and habitat, if not done properly (Hyde and Smar 2000). Culverts may also serve as a barrier to upstream dispersal within the stream (Vaughan 2002). In addition, culverts can serve as an entry point of pollutants that accumulate from water that runs off roads and into roadside ditches. The effect of pollution on *B. hungerfordi* is not known. Accidental spills on the roadway (such as gasoline or chemical spills) may also pose a threat.

Road work and culvert removal or bridge construction may impact *B. hungerfordi*. In-stream projects, such as culvert removal projects, may result in considerable disturbance downstream. In some cases these projects may have short-term adverse effects but may have overall benefits through reduction of erosion and sedimentation in the stream. For example, at the Oliver Road site in the Carp Lake River, the undersized twin culverts are proposed for removal in late summer of 2006 and will be replaced with a timber bridge (USFWS 2006) as described in the Conservation Measures section. Following the construction stage of the project, the indirect effects are expected to include an overall benefit to the habitat by decreasing the amount of sediment entering the stream. Thus, the suitable habitat currently at the site may be enhanced by reducing the threats associated with sedimentation. In general, projects that reduce erosion at road crossings are likely to have overall benefits to this species. At some occupied sites where greater numbers of beetles occur (e.g., certain locations within the East Branch of the Maple River), the overall habitat benefits of some stream-crossing improvement projects may not outweigh the effects of the disturbance to *B. hungerfordi* during culvert removal and construction activities. Each project must be evaluated on a case-by-case basis to evaluate the potential risks and benefits to *B. hungerfordi*.

Similarly, other projects within the stream may have contemporaneous benefits and potential adverse impacts which should be weighed very carefully. Bank stabilization is likely to result in overall improvement to the stream and may reduce the threat of sedimentation. However, if an artificial impervious cover is used, it may eliminate potential pupation habitat (through covering the moist soil above the water line that late instar larvae likely use during overwintering); this effect may be temporary depending on the nature of the material used. Activities that occur within occupied habitat that disturb the stream bed may also have adverse impacts through trampling of individuals or other disturbance. Most bank stabilization projects within the watershed are likely to have overall benefits to *B. hungerfordi.*

Logging in the riparian zone represents another possible threat to habitat; 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 and channelization.

<u>Overutilization for Commercial, Recreational, Scientific, or Educational Purposes</u>

Research efforts have used mostly capture and release methodologies rather than collection. The few collections that exist 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 states 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). Other haliplids are preyed upon by fish, waterfowl, amphibians, and other aquatic insects (Hickman 1931). The greatest predators of all species of *Brychius* are most likely fish (Hickman 1931). Water column and surface feeders such as brown trout, common shiner, dace, and white sucker, as well as bottom feeders such as darters and sculpins may feed on *B. hungerfordi* (White 1986, Strand 1989, Wilsmann and Strand 1990).

There is no information available on the impacts of predation on *B. hungerfordi;* thus, the significance of this threat is unknown. However, other haliplids are preyed upon by insectivorous fish, and it seems likely that adult or larval *B. hungerfordi* would also be a potential food source to certain fish species. Thus, stocking of those insectivorous fish species in occupied streams may result in increased predation of *B. hungerfordi*. Under its current fish production and stocking program, the State of Michigan does not stock insectivorous fish in habitats known to be occupied by *B. hungerfordi* (T. Hogrefe, Michigan Department of Natural Resources, pers. comm., 2006). Future research should examine the extent to which predation occurs and is a threat to this species.

Inadequacy of Existing Regulatory Mechanisms

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 (MDNR), 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. Streams in Michigan are also protected by the Natural Resources and Environmental Protection Act (Inland Lakes and Streams, Part 301 of Act 451 of 1994).

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 (USFWS 1994), although other forms of fish management may be beneficial. Specifically, fish management activities that result in creation, maintenance, or enhancement of suitable *B. hungerfordi* habitat may be beneficial to the species. Conversely, 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, in some cases, eliminate suitable *B. hungerfordi* habitat (as discussed above). Some actions may have contemporaneous positive and negative impacts that must be weighed very carefully.

As discussed above, some insectivorous fish may predate *B. hungerfordi,* but the degree to which predation is a threat is unknown. If certain fish are found to eat *B. hungerfordi,* then managing for an increase of those predators may be harmful to the beetle. More information is needed to determine the extent of predation on *B. hungerfordi* and if fish management activities contribute to this potential threat. The MDNR does not stock insectivorous fish in areas where *B. hungerfordi* may be present (T. Hogrefe, pers. comm., 2006).

The use of lampricides for the control of sea lamprey is a potential concern for *B. hungerfordi*. Sea lamprey larvae live in certain Great Lakes tributaries before transforming to parasitic adults that migrate to the Great Lakes. Lampricides are chemicals used to reduce populations of sea lamprey to levels that lessen the impact to Great Lakes fish (Great Lakes Fishery Commission 2000). 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) (J. Weisser, U.S. Fish and Wildlife Service, pers. comm., 2004). In order to evaluate potential effects of lampricide to *B. hungerfordi,* the U.S. Fish and Wildlife Service's Marquette Biological Station contracted with U.S. Geological Survey Upper Midwest Environmental Sciences Center in LaCrosse, Wisconsin, to examine the toxicity of TFM to *B. hungerfordi* using a surrogate species (Boogaard and Kolar 2004). Results of tests done on *Haliplus* spp. provide the best available information on potential effects to *B. hungerfordi*. Results of the initial phase of this study indicate that it is unlikely that TFM would cause mortality *of B. hungerfordi* adults or larvae. However, it remains possible that some *B. hungerfordi* adults may attempt to avoid TFM by drifting downstream or leaving the water (Boogaard and Kolar 2004). The U.S. Army Corps of Engineers recently replaced a deteriorating lamprey weir in the Carp Lake River with a new structure that will block spawning adult sea lampreys (VandeKopple and Grant 2004). The weir should reduce, but may not entirely eliminate, the need for future TFM treatments in the Carp Lake River.

The effects of electrofishing on *B. hungerfordi* are not known. Electrofishing is used to assess fish populations in streams. Some studies have indicated an increase in drift of aquatic insects due to electricity (Elliott and Bagenal 1972, Bisson 1976, Mesick and Tash 1980, Taylor et al. 2001); however, this has not been examined for *B. hungerfordi*. Further investigation 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 activity could result in habitat disturbance 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 such as human caused or natural environmental disturbances. Small isolated populations are more likely to be destroyed by chance environmental and demographic events than larger widespread populations (Shaffer 1981). For this species, stochastic events could destroy an entire population and, in some cases, a significant percentage of the known individuals. Small population size and restricted range also makes *B. hungerfordi* vulnerable to genetic isolation (Meffe and Carroll 1997). The limited gene pool may lead to decreased fitness (Meffe and Carroll 1997). There have been no studies examining population viability or genetic diversity of this species.

At this time, the greatest threat to advancing recovery of this species may be 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; and diet), and population dynamics. Information needs are further discussed in Appendix C, "Research Needs."

Conservation Measures

Conservation measures underway for *B. hungerfordi* include State and Federal regulatory protection and prohibitions against certain practices. Listing encourages and results in increased voluntary conservation actions by Federal, State and private agencies, groups, and individuals. 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 kills or injures listed 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, discussed below.

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, several informal consultations and two formal consultations have been conducted for *B. hungerfordi*. The informal consultations have been conducted with the USFWS (i.e., Intra-Service consultation) and the U.S. Army Corps of Engineers (COE). The two formal consultations are briefly described below:

- <u>Sea Lamprey Control in the Carp Lake River</u>

  In October 2004, the USFWS conducted formal Intra-Service consultation on sea lamprey control in Carp Lake River. The proposed action was treatment of the Carp Lake River with the lampricide TFM (Lamprecid®) at concentration of 1 to1.5 times the minimum lethal concentration (MLC) required to kill 99.9% of larval sea lampreys in 9 hours. The geographical area for this consultation was the stretch of the Carp Lake River from approximately 1/3 mile downstream of Gill Road to the mouth at Lake Michigan (approximately 5 miles of stream). Based on the best available information, it was determined that the lampricide was not likely to result in mortality of *B. hungerfordi*, but that it was likely that some of the beetles may exhibit some form of behavioral avoidance (possibly an increase in drift) (Boogaard and Kolar 2004). Through the formal consultation process, the initial proposed treatment of the entire stream was modified and reduced to the areas below Gill Road, in order to minimize adverse effects to *B. hungerfordi*. The USFWS also agreed to monitor and achieve the lowest possible concentrations (MLC or lesser) at the Oliver road crossings and downstream for 200 feet. In addition, wading in the stream was minimized near known sites in order to reduce potential disturbance to *B. hungerfordi*. The Biological Opinion anticipated that no more than ten Hungerford's crawling water beetles would be incidentally taken as a result of the proposed action, provided the terms and conditions were implemented. The incidental take was expected in the form of harassment. Incidental take in the form of harm or mortality was expected to occur for no more than three individuals by actions incidental to the proposed action, based on information available for a surrogate species (USFWS 2004).

- Oliver Road Timber Bridge Project, Carp Lake River

  In June 2006, the Service issued a Biological Opinion that considered the effects of removal of the existing twin culverts at the Oliver Road crossing of the Carp Lake River and installation of a free-span timber bridge (USFWS 2006). The action is being funded in part with Federal funding from the U.S. Forest Service's Wood In Transportation Program and the U.S. Fish and Wildlife Service's Fish Passage program (administered by the Green Bay Fisheries Resource Office). The applicant for this project is the Conservation Resource Alliance, a private conservation organization that is working closely with the Emmet County Road Commission in this effort. The action is expected to have overall benefits to the species by improving habitat at the Oliver Road site through elimination or reduction of ongoing sedimentation off of the roadway and roadside ditches. The project engineers worked with species experts to design a structure that would maintain the existing suitable *B. hungerfordi* habitat. During culvert removal, however, it was expected that the disturbance would result in harm or mortality of individuals in the action area.

  Prior to commencement of construction, the action agencies agreed to contract with qualified biologists to locate as many *B. hungerfordi* in the action area as possible. All individuals found at the Oliver Road site were to be captured, transported to a site upstream of Oliver Road, and permanently released. The survey team consisted of Bert Ebbers, Bob VandeKopple, and Michael Grant, species experts with the most experience surveying and conducting research on this species since its listing in 1994. Previous surveys at this site found no more than one beetle found in the past seven years; since 1994, the highest number recorded was four adults. Based on these data and considering the best available information on estimating population size, it was expected that the survey team would find only a few individuals. The team spent a total of two hours each, for a cumulative six hours of searching, and found a total of 28 adult *B. hungerfordi* (Ebbers 2006). The 28 individuals were moved to Gill Road, which has higher quality habitat and supports greater numbers of *B. hungerfordi* compared to the Oliver Road site (Ebbers 2005). Because the Biological Opinion anticipated only a few individuals would be found at the Oliver Road site, the formal consultation was reinitiated in August 2006.

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.

<u>State Protection</u>

Brychius hungerfordi was listed as endangered by the MDNR 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). This state law also prohibits take of the beetle.

<u>Canadian Protection</u>

Brychius hungerfordi is not currently protected in Canada. Although the North Saugeen River site (near Scone, Ontario) is discussed throughout this Recovery Plan, it is not included in the recovery goals for the species.

<u>Research and Outreach</u>

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 occurs within close proximity of UMBS and contains the best studied and largest known population of the species. 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 occurred 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 has recently been conducted at the University of Manitoba to determine the morphology, biology, and life history of species in the genus *Brychius* (Mousseau 2004).

Biologists at the East Lansing Field Office have conducted outreach efforts to increase support and awareness of the species, including development of 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*. The species is often found downstream from culverts, beaver and natural debris dams, and human-made impoundments; 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

Brychius hungerfordi has a very limited range. The species is only known to occur in six streams within Michigan and Ontario. Of these occupied streams, only one has relatively large numbers of beetles (i.e., the East Branch of the Maple River). At the other sites, only small numbers of individuals have been found. We lack information on the historical distribution of this species and specific habitat needs for all life stages.

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 known sites, threats have been hypothesized but 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, recovery efforts would benefit from a research program that targets *B. hungerfordi* and its habitat. Scientific data are required to develop and implement conservation 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 the species' 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 conservation and monitoring. Our efforts will include reducing, to the extent possible, threats that result in physical habitat destruction and degradation (e.g., from stream-side logging, dredging, stream pollution, road work, impoundment) and threats relating to certain fish management activities 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 they "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 this species' basic biology is lacking, interim Recovery Criteria are used in this Plan; 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 habitat essential for all life stages and ensure adequate habitat conservation; and 3) identify whether additional threats 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 Actions and Implementation Table.

<u>Reclassification criteria</u>

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

As discussed throughout this 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 Recovery Action 2 of the Stepdown Outline and Narrative). Based on the additional information on life history, ecology, population biology, genetic variability, and habitat requirements, and the resulting outcome of a complete threats assessment, we will determine if additional Recovery Criteria are necessary for reclassification or delisting. The interim Recovery Criteria will be revised as needed.

Criterion 2. A minimum of five U.S. populations, in at least three different watersheds, have had stable or increasing populations for at least 10 years, and at least one population is considered viable

We will consider population numbers as stable or increasing when regression analysis or other appropriate statistical tests reveal a positive trend (e.g., slope greater than 0 for a linear trend) with 95% confidence, or alternatively, sufficient data are available to use population viability analysis. At least three populations must occur in 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.

The specific characteristics of a viable *B. hungerfordi* population are unknown and will be the focus of future research. It is likely that "viability" will require consistently large numbers of beetles widely distributed within a stream or watershed, evidence of reproduction, and relatively extensive suitable habitat. Currently, the East Branch of the Maple River is the only stream that appears to support a viable population of *B. hungerfordi*. Thus, conservation of this stream is critical to recovery of the species.

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

<u>Delisting criteria</u>

Criterion 3. Habitat necessary for long-term survival and recovery has been identified and conserved

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 conserved by minimizing physical disturbances.

This criterion 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 conserve areas upstream from these sites, as sedimentation may also be a threat. In addition to areas adjacent to populations identified for recovery, riparian zones up to 0.25 miles upstream of these areas should be similarly conserved.

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

More information is needed to determine what constitutes long-term viability. Each of the five populations must be of sufficient size to persist despite demographic, environmental, and genetic uncertainty and there must be evidence of reproduction, within each, sufficient to maintain a self-sustaining population. At this time we can not identify a minimum population size, nor can we quantify what constitutes reproduction sufficient for a self-sustaining population. This criterion will be revised based on the results of research as appropriate.

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. Conserve known sites

    1.1. Define and conserve 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

        1.3.1. Section 7 review and conservation (2)

        1.3.2. Section 10 permits

            1.3.2.1. Section 10 (a)(1)(A) – Enhancement of survival permits (2)

            1.3.2.2. Section 10 (a)(1)(B) – Incidental take permits (2)

    1.4. Land acquisition and conservation (2)

    1.5. Encourage watershed-level conservation

        1.5.1. Conserve riparian buffers (2)

        1.5.2. Conduct restoration activities that result in overall benefits to the watershed after ensuring benefits to *B. hungerfordi* outweigh risks

            1.5.2.1. Implement erosion control BMPs for road/stream crossings to minimize sedimentation, as appropriate (2)

            1.5.2.2. Conduct in-stream projects such as bank stabilization projects, as appropriate (2)

            1.5.2.3. Conduct other stream and watershed restoration activities that result in benefits to occupied watersheds, as appropriate (2)

        1.5.3. Investigate the potential for transportation of hazardous materials (e.g., oil and other chemicals) on roads within occupied watersheds and potential for spills (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* (1)

   2.2. Examine habitat requirements (1)

   2.3. Confirm threats to the species (1)

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

   2.5. Investigate genetic heterogeneity and population viability (2)

   2.6. Investigate utility of captive propagation and translocation (2)

   2.7. Investigate the hydrological needs of the species (2)

   2.8. Convene scientific meeting/conference to share information (3)

3. Conduct additional surveys and monitor existing sites

   3.1. Develop standard survey and monitoring protocols (3)

   3.2. Continue to survey new locations to identify new populations or areas of suitable habitat (3)

   3.3. Develop and implement a monitoring plan for all known sites (3)

4. Develop and implement public education and outreach

   4.1. Design educational materials and presentations for the public

      4.1.1. Develop informational materials on *B. hungerfordi* and endangered species conservation (3)

      4.1.2. Develop informational materials on the importance of local and watershed level conservation (3)

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

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

5. Revise Recovery Criteria and recovery actions, 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. Conserve known sites

The known distribution of this species is limited to only five streams in the United States. Habitat essential to recovery must be defined and conserved. 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 conserve 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. Completion of this task is contingent upon surveys of populations of *B. hungerfordi*. Furthermore, 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 Recovery Action 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 five known streams. These plans should determine the threats at the local and watershed levels, and identify 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 Recovery Action 2). Site conservation plans should be updated as new information becomes available.

1.3. Review Federal, State, and private actions

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

1.3.1. Section 7 review and conservation (2)

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 (2)

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. 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 (2)

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 HCP. There have been no 10(a)(1)(B) permits issued for *B. hungerfordi*.

1.4. Land acquisition and conservation (2)

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

1.5. Encourage watershed-level conservation

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 conservation at the watershed level. This task will involve working with local conservation organizations to increase community awareness and involvement in watershed conservation. Many groups and programs already exist, providing a network of partners that can encourage community-based conservation and completion of this recovery action.

This task will also involve the following activities and any additional activities that reduce habitat alteration, pollution, and sedimentation into the watershed.

1.5.1. Conserve riparian buffers (2)

Riparian areas are the vegetated areas adjacent to the stream. Riparian buffers are important for water quality, and act as natural "biofilters", protecting aquatic environments from excessive sedimentation, polluted surface runoff, and erosion. They can provide shade that reduces water temperature and also help stabilize stream banks. Existing native vegetation should be retained to the extent possible, and efforts should be undertaken to restore the natural plant community composition and distribution when possible.

1.5.2. Conduct restoration activities that result in overall benefits to the watershed after ensuring benefits to *B. hungerfordi* outweigh risks

Projects that occur in or immediately upstream of occupied habitat may result in adverse impacts during project activities. In some cases, the disturbance may be temporary and the adverse impacts may be short-term, while providing long-term overall benefits to the species. The risks of these projects should be carefully weighed against the benefits for *B. hungerfordi*. Organizations that conduct these activities in areas where *B. hungerfordi* may occur should contact the Fish and Wildlife Service to determine when adverse impacts are reasonably certain to occur. The Service will work with those organizations to minimize or avoid adverse impacts and ensure activities do not jeopardize the continued existence of *B. hungerfordi*.

1.5.2.1. Implement erosion control BMPs for road/stream crossings and other projects to minimize sedimentation, as appropriate (2)

Many secondary roads are unpaved, and at certain road/stream crossings large amounts of road-gravel and sand can be deposited into the streams during precipitation events. Excessive amounts of sediment entering tributary streams can result in a wider and shallower river channel, destruction of fish and aquatic insect habitat, and elevated water temperatures.

Best Management Practices (BMPs) are guidelines used to ensure that projects are conducted in such a way as to have minimal impact on natural resources. BMPs should be implemented for construction, removal, and maintenance of road/stream crossings, as appropriate based on the nature of the project and characteristics of the site.

Potential projects in the vicinity of occupied habitat must be evaluated on a case-by-case basis to evaluate the potential risks and benefits to *B. hungerfordi*.

1.5.2.2. Conduct in-stream projects such as bank stabilization projects as appropriate (2)

In addition to poorly designed or failing road/stream crossings, other activities also result in increased sedimentation in streams (e.g., logging, removal of riparian buffers, beaver dams). In some cases, it may be prudent to stabilize stream banks to reduce sedimentation (after identifying and reversing the cause of excessive erosion when possible). BMPs should be applied during in-stream restoration activities.

Potential projects in the vicinity of occupied habitat must be evaluated on a case-by-case basis to evaluate the potential risks and benefits to *B. hungerfordi*.

1.5.2.3. Conduct other stream and watershed restoration activities that result in benefits to occupied watersheds, as appropriate (2)

Other activities may include programs for general watershed health. These may include preventing polluted runoff from pesticides, fertilizers, or animal waste and preventing the introduction of invasive exotic species. In the watersheds where *B. hungerfordi* is known to occur, these projects can have benefits through increased water quality and reduction of threats.

1.5.3. Investigate the potential for transportation of hazardous materials (e.g., oil and other chemicals) on roads within occupied watersheds and potential for spills (2)

Coordination with the appropriate highway and county road departments should occur to determine the potential for transportation of hazardous materials on roads within occupied watersheds and the potential for a spill of gasoline, solvents, or other chemicals. If there is a significant risk, the possibility of restrictions on transport of dangerous goods in high priority areas should be evaluated.

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 conserve 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 additional information for effective implementation. 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* (1)

Knowledge of the life history and ecology of this species is critical to adequate and long-term conservation. 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 (i.e., lab rearing) and field work.

2.2. Examine habitat requirements (1)

Habitat conservation 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 Recovery Action 1.1.

2.3. Confirm threats to the species (1)

Research is needed to examine and confirm the extent and magnitude of potential threats to the species. This task will require determination of the effects of stream and watershed management activities on *B. hungerfordi* (e.g., fish management, beaver control, beaver activity, dredging, stream-side logging and related erosion, etc). 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.

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

The population dynamics and demography of the known sites should be examined, including dispersal capabilities, rates of birth, immigration, emigration, and death.

2.5. 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, along with all other relevant data collected on the species, should be considered in a population viability analysis (PVA). 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.

2.6. Investigate utility of captive propagation and translocation (2)

The potential use of captive rearing of *B. hungerfordi* for research and population supplementation purposes should be investigated. *B. hungerfordi* has never been reared from egg to adult in the laboratory, so researchers will need to develop appropriate methods. 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.

2.7. Investigate the hydrological needs of the species (2)

Hydrology appears to be important for *B. hungerfordi*. Investigation is needed to further study the hydrological needs of the species, which will allow us to better assess the potential hydrological threats at occupied sites. These assessments will likely include groundwater monitoring, land use, and watershed-level modeling and will help to direct watershed-scale needs (e.g., wetland conservation, logging practices).

2.8. Convene scientific meeting/conference to share information (3)

Future conferences for interested researchers and members of the public should be planned. At these meetings, the results of research tasks identified above can be shared and discussed.

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 (3)

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.

As we develop standard survey and monitoring protocols, care should be taken to ensure all areas of available habitat are surveyed equally to reduce the likelihood of sampling bias.

3.2. Continue to survey new locations to identify new populations or areas of suitable habitat (3)

Understanding the distribution and abundance of *B. hungerfordi* is necessary to understand the status of the species and its risk of extinction. 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 Recovery Action 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 (3)

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. Design educational materials and presentations for the public

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.

4.1.1. Develop informational materials on *B. hungerfordi* and endangered species conservation (3)

4.1.2. Develop informational materials on the importance of local and watershed-level conservation (3)

4.2. 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 to explain the biological needs of the species, threats, and the benefits of stream conservation and watershed management.

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 actions, 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 actions, 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 action 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
FRO	USFWS Division of Fisheries
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, Conservation Districts)
MDNR	Michigan Department of Natural Resources
MNFI	Michigan Natural Features Inventory
NRCS	Natural Resource Conservation Service
OTHERS	Other individuals or groups willing to participate (e.g. landowners)
PFW	USFWS Partners for Fish and Wildlife Program
RSCH	Universities and Research Institutions
RWG	Recovery Working Group for *B. hungerfordi*
USFWS	U.S. Fish and Wildlife Service

Columns 7-10: Cost estimates for Years 1, 2, and 3 and 4-20

This column gives the estimated cost for carrying out the task during the next three years and for years four through twenty. 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.

Table 3. Implementation Schedule for *B. hungerfordi*

				Recovery Partner		Est. Cost ($1,000)				
Priority	Description	Task number	Task duration	R3 USFWS	Other	Year 1	Year 2	Year 3	Years 4-20	Comments
1	Define and conserve areas of essential habitat	1.1	C	ES	MDNR, RWG, RSCH	TBD	TBD	TBD	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	C	ES	MDNR, RWG, RSCH, LCO, LG, OTHERS	0	0	0	40	No costs are expected in years 1-3. Completion of this task is contingent upon results of research on habitat requirements, threats, and life history.
1	Conduct studies to examine life history and ecology of *B. hungerfordi*	2.1	3	ES	RSCH, MDNR, RWG	20	30	40	TBD	Additional research may be necessary in years 4-20.
1	Examine habitat requirements	2.2	3	ES	RSCH, MDNR, RWG	30	30	30	TBD	Additional research may be necessary in years 4-20.
1	Confirm threats to the species	2.3	3	ES	RSCH, MDNR, RWG	20	30	40	TBD	Additional research may be necessary in years 4-20.
2	Review Federal, State, and private actions	1.3	C, O	ES	MDNR, MNFI	TBD	TBD	TBD	TBD	Cost will depend on the number and complexity of Federal, State, and private actions during a given year.

				Recovery Partner		Est. Cost ($1,000)				
Priority	Description	Task number	Task duration	R3 USFWS	Other	Year 1	Year 2	Year 3	Years 4-20	Comments
2	Land acquisition and conservation	1.4	C	ES	MDNR, LCO	TBD	TBD	TBD	TBD	
2	Conserve riparian buffers	1.5.1	O, C	ES FRO PFW	MDNR, LCO, LG, NRCS	TBD	TBD	TBD	TBD	Cost will vary depending on the area and its existing conditions.
2	Implement erosion control BMPs for road/stream crossings to minimize sedimentation, as appropriate	1.5.2.1	O, C	ES FRO PFW	MDNR, LCO, LG, NRCS	TBD	TBD	TBD	TBD	Cost will depend on the number and nature of road/stream crossing projects.
2	Conduct in-stream projects such as bank stabilization projects, as appropriate	1.5.2.2	O, C	ES FRO PFW	MDNR, LCO, LG, NRCS	TBD	TBD	TBD	TBD	Cost will depend on the number and nature of in-stream projects.

				Recovery Partner		Est. Cost ($1,000)				
Priority	Description	Task number	Task duration	R3 USFWS	Other	Year 1	Year 2	Year 3	Years 4-20	Comments
2	Conduct other stream and watershed restoration activities that result in benefits to occupied watersheds, as appropriate	1.5.2.3	O, C	ES FRO PFW	MDNR, LCO, LG, NRCS	TBD	TBD	TBD	TBD	Cost will depend on the number and nature of in-stream projects.
2	Investigate the potential for transportation of hazardous materials (e.g., oil and other chemicals) on roads within occupied watersheds and potential for spills	1.5.3	2	ES	LG, LCO	1	1	0	0	
2	Conduct studies to examine population dynamics and demography	2.4	3	ES	RSCH, MDNR, RWG	0	0	0	90	No costs are expected for years 1-3.
2	Investigate genetic heterogeneity and population viability	2.5	3	ES	RSCH, MDNR, RWG	0	0	0	90	No costs are expected for years 1-3.

				Recovery Partner		Est. Cost ($1,000)				
Priority	Description	Task number	Task duration	R3 USFWS	Other	Year 1	Year 2	Year 3	Years 4-20	Comments
2	Investigate utility of captive propagation and translocation	2.6	2	ES	RSCH, MDNR, RWG, OTHERS	0	0	0	40	No costs are expected for years 1-3.
2	Investigate hydrological needs of species	2.7	3	ES	RSCH, MDNR, RWG, LCO	0	0	0	60	No costs are expected for years 1-3.
3	Coordinate with Canadian officials regarding the North Saugeen River site	1.6	C	ES	RWG, MDNR, RSCH	0	0	0	0	
3	Convene scientific meeting to share information	2.8	1, C	ES	RSCH, MNFI, RWG	0	0	0	1	
3	Develop standard survey and monitoring protocols	3.1	3	ES	RSCH, MDNR, RWG, MNFI	0	0	0	15	No costs are expected in years 1-3.

				Recovery Partner		Est. Cost ($1,000)				
Priority	Description	Task number	Task duration	R3 USFWS	Other	Year 1	Year 2	Year 3	Years 4-20	Comments
3	Continue to survey new locations to identify new populations or areas of suitable habitat	3.2	5	ES	RSCH, MDNR, RWG, MNFI	20	25	30	TBD	Additional surveys may be necessary in years 4-20.
3	Develop and implement a monitoring plan for all known sites	3.3	3, C	ES	RSCH, MDNR, RWG, LCO, MNFI	0	0	0	30	No costs are expected in years 4-20.
3	Develop informational materials on *B. hungerfordi* and endangered species conservation	4.1.1	C, O	ES	MDNR, MNFI, LCO	1	1	1	5	
3	Develop informational materials on the importance of local and watershed level conservation	4.1.2	C, O	ES	MDNR, MNFI, LCO	1	1	1	5	

				Recovery Partner		Est. Cost ($1,000)				
Priority	Description	Task number	Task duration	R3 USFWS	Other	Year 1	Year 2	Year 3	Years 4-20	Comments
3	Conduct landowner contact and educational programs to increase awareness of *B. hungerfordi*	4.2	C	ES	MDNR, LCO, MNFI	1	1	1	5	
3	Contact local organizations to inform them of the beetle	4.3	O	ES	MDNR, MNFI, LCO	0	0	0	0	
3	Revise Recovery Criteria and recovery actions, as appropriate, based on research and new information	5	1	ES	MDNR, RSCH, RWG, MNFI	0	0	0	5	
3	Develop a plan to monitor *B. hungerfordi* after it is delisted	6	2	ES	MDNR	0	0	0	0	

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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

Stenothermic: Indicating the ability to tolerate only a limited range of temperatures.

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

2. LIST OF ACRONYMS

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

Appendix B. General beetle anatomy

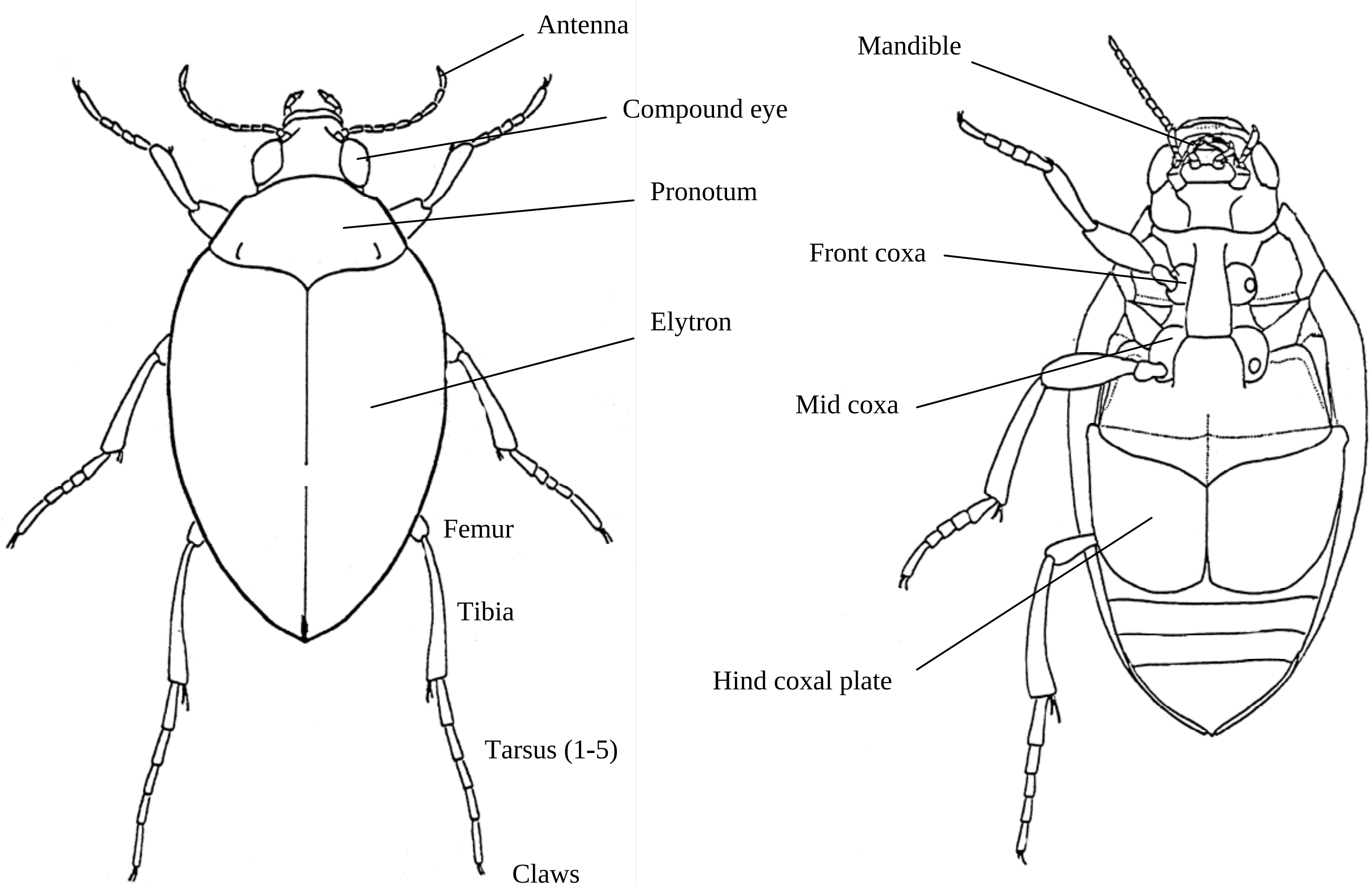

Figure credits: Left - *Haliplus ruficollis* (De Geer), dorsal view. Right - *Haliplus flavicollis* (Sturm), ventral view. Figures adapted from Holmen 1987; used with permission.

Appendix C. Research Needs

Range and population dynamics

- *Conduct surveys for additional populations of B. hungerfordi and monitor existing populations*

  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 because we do not fully understand the species habitat requirements (e.g., St. Clair River).

- *Investigate 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 (Mousseau 2004). If additional specimens are available, they should be examined. The habitat of two larval specimens collected in St. Clair County 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. The hydrological needs of the species should also be evaluated.

- *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 potential 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, certain fisheries management (e.g., electrofishing), and predation.

Research needs are also outlined in the Recovery Plan, Recovery Action 2 (pages 46-47).

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

Listing Factor	**Threat**	**Recovery Criteria**	**Action**
A	**Stream modification and management** *This includes physical destruction of the stream habitat and degradation of water quality or habitat structure (e.g., due to dredging, stream pollution, logging, channelization, and impoundment)*	1, 2, 3, 4	Protect known sites (Actions 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 (Actions 2.1, 2.2, 2.3, 2.7)
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 and implement BMPs as appropriate (Actions 1.1, 1.2, 1.3, 1.4, 1.5, 1.6); Conduct research to investigate habitat requirements and determine effect of road crossing projects (Actions 2.1, 2.2, 2.3)
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, electrofishing, etc).*	1, 2, 3, 4	Protect known sites (Actions 1.1, 1.2, 1.3, 1.5); Conduct research to answer questions about the effects of fish management activities (Action 2.3)
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 (Actions 1.2, 2.3)
E	**Lack of information**	1	Define areas of essential habitat (Action 1.1); Conduct research to examine the species' life history and ecology, population dynamics and demography, habitat requirements and threats (Actions 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8); Conduct surveys and monitor existing sites (Actions 3.1, 3.2, 3.3); Revise recovery criteria based on new information (Action 5)

Listing Factor	Threat	Recovery Criteria	Actions
E	**Risks associated with small isolated populations (e.g., stochastic events)**	1, 2, 3, 4	Protect known sites (Actions 1.1, 1.2, 1.3, 1.4, 1.5, 1.6); Conduct research to better understand biology of the species (Actions 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8); Continue to look for new sites and monitor existing sites (Actions 3.1, 3.2, 3.3)
E	**Human disturbance**	1, 2, 3, 4	Protect known sites (Actions 1.2, 1.4, 1.5); Implement monitoring program (Action 3.3); Conduct outreach to make the public aware of the species (Actions 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:
Reclassification criteria
1. Life history, ecology, population biology, and habitat requirements are understood well enough to fully evaluate threats
2. A minimum of five U.S. populations, in at least three different watersheds, have had stable or increasing populations for at least 10 years, and at least one population is considered viable
Delisting criteria
3. Habitat necessary for long-term survival and recovery has been identified and conserved
4. A minimum of five U.S. populations, in at least three different watersheds, are sufficiently secure and adequately managed to assure long-term viability

Appendix E. Summary of comments on Draft Recovery Plan and U.S. Fish and Wildlife Service responses

On August 6, 2004, the U.S. Fish and Wildlife Service (Service) released the Hungerford's Crawling Water Beetle (*Brychius hungerfordi*) Draft Recovery Plan (Draft Plan), for a 30-day review and comment period ending on September 7, 2004. Availability of the Draft Plan was announced in the Federal Register (FR 69 47950) and via a news release to media contacts throughout the species' U.S. range.

In accordance with Service policy, requests for peer review of the Draft Plan were sent to experts outside the Service. Requests for peer review were sent to the following individuals:

Dr. Brian Scholtens, College of Charleston, Charleston, South Carolina
Dr. Robert Roughley, University of Manitoba, Winnepeg, Manitoba, Canada
Dr. Roger Strand, Northern Michigan University, Marquette, Michigan
Mr. Robert VandeKopple, University of Michigan Biological Station, Pellston, Michigan

During the comment period, 43 copies of the Draft Plan were distributed to interested government agencies, organizations, and private individuals. A notice of the draft's availability and information on how to obtain a copy of the draft was sent to an additional 41 organizations and individuals.

The Service received thirteen comment letters during the official comment period. Affiliations of the originators of these 13 comment letters are tabulated below:

Peer reviews	3 letters
Federal agencies	4 letters
State governments	3 letters
Environmental/non-government organizations	2 letters
Individuals/Private citizens	1 letter

Each letter contained one or more comments or questions, and some letters raised similar issues. Most letters requested explanation or clarification of points made in the plan and included suggestions for changes. Many commenters expressed strong support for the conservation of this species and commented on the thoroughness and importance of the plan. Most comments were incorporated into the approved recovery plan. Information and comments not incorporated into the approved plan were considered and noted. The majority of comments received are summarized below, including significant comments that were not incorporated or that required further clarification.

All of the comment letters that the Service received on the Draft Plan are on file at the U.S. Fish and Wildlife Service, 2651 Coolidge Road, Suite 101, East Lansing, Michigan, 48823.

Comments from Peer Reviewers with Service Responses

- **Comment:** One reviewer questioned our emphasis on lack of information on Hungerford's crawling water beetle (HCWB) and pointed out that we know very little about most insects in general. The reviewer stated that although we still have much to learn, the basic life history has been worked out. Another reviewer noted that the emphasis on additional information is appropriate and the identified research needs are thorough.

  Response: We acknowledge that we have some basic information about HCWB, although much of our understanding of life history is based on information reported for closely related species. The emphasis on lack of information throughout the recovery plan is meant to draw attention to areas where we need to focus future efforts, and to provide support for making certain assumptions when necessary.

- **Comment:** Several reviewers and commenters questioned the role of beaver in maintaining HCWB habitat. One reviewer suggested that there is little evidence that beaver are important in maintaining habitat of HCWB (as suggested in the listing rule). Another reviewer questioned whether beaver have any positive effects on the beetle. The reviewer stated that the pools created by beaver dams are not good for HCWB, and erosion and silt deposition occur for years afterward. When a dam is broken, it does create some good pools and riffles, but those habitats are available regardless of beaver activity in seasonal streams like those HCWB is found. One commenter indicated that beavers may be more of a problem for long-term survival of Hungerford's crawling water beetle than an asset. This commenter provided anecdotal evidence that beaver are much more common now than 20 years ago, and beaver activity has dramatically altered the habitat in the East Branch of the Maple River. In another stream, the high level of beaver activity has eliminated HCWB habitat in all but a handful of pools and riffles. The commenter suggested further consideration of beaver removal as a step in recovery of HCWB.

  Response: We added discussion to the recovery plan regarding the potential effects of beaver activity to HCWB. Although beaver dams may create suitable habitat immediately below the structure, erosion and siltation probably lessen the quality. Further, suitable habitat upstream is eliminated by impoundment created by the beaver dam. Thus, increased beaver activity in some streams may eliminate suitable habitat for HCWB. However, removal of existing beaver dams upstream from current populations may also impact HCWB. Clearly, much can be learned about habitat requirements for this species.

- **Comment:** One reviewer thought that the Recovery Criteria were realistic and that a "stable" population is an appropriate goal since we have no way of knowing whether we had more populations or individuals in the past. The reviewer expressed support of revision of Recovery Criteria as new information becomes available. Another reviewer questioned interim Recovery Criterion 2, because insect population sizes naturally fluctuate up and down, especially within a ten year period. Similarly, a commenter questioned whether using linear regression analysis was an appropriate technique to determine when a population is stable or increasing (Criterion 2).

Response: Criterion 2 was revised based on the comments received. The appropriate statistical test will be used, based on the available data and whether it meets the necessary assumptions, to ensure the overall trend over 10 years is stable or increasing.

- **Comment:** Two reviewers suggested revision of the section on respiration. One reviewer indicated that HCWB periodically surface to renew air supply, and that the Draft Plan offers no support or definition for the phrase “probably not frequently.” The reviewer also provided comments on HCWB surviving under ice cover, and gives an example of other beetles that use bubbles trapped under ice for respiration.

  Response: The respiration section was revised accordingly to reflect the reviewers' comments.

- **Comment:** One reviewer asked for clarification on how some activities identified as threats in the Draft Plan can have both positive and negative effects on HCWB which must be weighed very carefully. The reviewer gave an example that installing culverts may create habitat for this species even though it may temporarily cause siltation. Likewise, the reviewer indicated that although replacing a culvert may be beneficial to the stream overall, the activity could be detrimental to HCWB.

  Response: We agree that action agencies must carefully weigh the risks and benefits associated with removing a culvert or other structure immediately upstream of a known HCWB site. In general, activities that result in decreased sediment load into the stream are beneficial, but in some cases the resulting disturbance may result in harm to HCWB. Each project must be evaluated on a case-by-case basis to evaluate the potential risks and benefits to HCWB. We added discussion in the recovery plan on the potential threat of road work and culvert removal (see Reasons for Listing and Existing Threats section) and emphasized the importance of evaluating the risks and benefits of all projects in the vicinity of occupied HCWB habitat.

- **Comment:** One reviewer had several comments on metapopulations and population dynamics. The reviewer stated that some streams (e.g., the East Branch of the Maple River) may function as a source subpopulation for the HCWB metapopulation (i.e., a population divided into subpopulations with periodic gene flow). The reviewer suggested a working model of a HCWB metapopulation with one obvious source subpopulation (e.g., East Branch of the Maple River) and a handful of sink subpopulations. Because these sink subpopulations would require “rescuing” through movement of individuals from the major source population, one could argue that protection of the East Branch of the Maple River is critical to keep the sink subpopulations from permanent extinction. The reviewer also questioned the use of the terms population and watershed in the Recovery Criteria. The reviewer stated that there is only one population in the Maple River watershed, and it is certainly the largest population. Based on Criterion 4, it would appear that at least three more populations in one more watershed are required. The reviewer was concerned that this would be very difficult to establish and recommends drawing population boundaries at the watershed level.

Response: The dispersal capabilities of this species are not well understood and the degree to which individuals from distinct geographic areas interact is unknown. As a result, determination of actual boundaries between populations and/or subpopulations is not currently possible. In order to consider HCWB in Michigan to be a metapopulation, there must be some level of dispersal among subpopulations; as a metapopulation is a group of isolated subpopulations with some, albeit limited, gene flow. Due to the limited understanding of the dispersal capabilities of this species, it is unknown if gene flow occurs among watersheds or even between groups of individuals geographically separated within a watershed. Therefore, we are not able to determine if there are several distinct populations, or perhaps several subpopulations of one metapopulation. What we currently refer to as a "population" may, in fact, be subpopulations of one metapopulation if genetic exchange occurs among them. Genetic exchange is much more likely to occur between some populations due to proximity to other sites within the same watershed (e.g., Van Hetton Creek and East Branch of the Black River) or an adjacent watershed (e.g., Carp Lake River and East Branch of the Maple River).

Until we have additional information on the population dynamics and dispersal of this species, we are assuming that each stream contains reproducing individuals that constitute a distinct population because it is most likely that genetic exchange is occurring within a given stream. We acknowledge the possibility that genetic exchange may be occurring between streams within close proximity to one another, even within separate watersheds, through dispersal flight, but do not want to make conservation recommendations based on this assumption until additional data has been gathered. We have identified several Recovery Actions that will help us to better understand the population boundaries for this species. Recovery Action 2.5 (Investigate genetic heterogeneity and population viability) will allow us to understand the genetic relatedness of HCWB throughout its range. Recovery Action 2.4 (Conduct studies to examine population dynamics and demography) will further help us to determine population boundaries. As we gather this information on genetic relatedness and population dynamics of HCWB, the recovery plan and interim Recovery Criteria will be updated and revised.

Regardless of the terminology, we agree that protection of the East Branch of the Maple River is likely critical to conservation of this species. Therefore, we have revised Criterion 2 to include at least one viable population. Currently, the East Branch of the Maple River is the only stream that appears to support a viable population of HCWB. Thus, conservation of this stream will be critical to achieving recovery of the species.

- **Comment:** One peer reviewer emphasized the potential threat of fish management, such as the introduction of fish to the watershed. He suggested inventorying HCWB streams for fish and recommended excluding the introduction of additional fish species. One commenter questioned our lack of emphasis on predation from non-native brown trout and other potential stocked fishes. Conversely, one commenter recommended downplaying or completely removing discussion of the natural relationship (predator and prey). The commenter stated that all of the fish species mentioned in the plan, with the exception of brown trout, have evolved naturally alongside the beetle.

Response: Insectivorous fish, including native species, may be a threat to HCWB. Although the relationship between native predators and prey may have evolved naturally, the relative impact of the predator on the prey may be greater if the prey species has been impacted by other threats. In this way, predation even by a native species can be a threat. As the Recovery Plan states, it is unknown to what extent predation occurs. No *Brychius* species has been found in fish stomach contents to our knowledge. Other haliplids, however, are known to be consumed by fish, predatory insect larvae, birds, and amphibians. The plan was revised to include a more thorough discussion about the issue of fish predation as a threat to the species.

- **Comment:** One reviewer indicated that introduction of individuals from healthy populations into new appropriate streams or other suitable habitat would be beneficial (once genetic heterogeneity has been investigated). Because these beetles are likely poor dispersers, introduction may be a good way to expand the current range of the species. Research on a surrogate species, possibly *B. hornii*, could be conducted to see if this is likely to work for HCWB.

  Response: We agree that it may be necessary to create additional populations of the species, or augment existing populations, in order to reach recovery. Introduction of the species into new areas could occur through translocation of individuals from healthy populations from individuals reared in captivity for that purpose. We added a brief discussion of the potential benefit of translocation of individuals from healthy populations into new areas of suitable habitat in Recovery Action 2.6.

- **Comment:** One reviewer asked for clarification on the phrase “sufficiently secure and adequately managed” in Criterion 4 and how that might be achieved.

  Response: More information is needed to clarify what constitutes long-term viability, as discussed in Criterion 4 and elsewhere in the recovery plan. Once we understand what we need to assure long-term viability of the species, we will be able to make the interim Recovery Criteria fully measurable. In order to be assured long-term viability, there must be populations of sufficient size and distribution to persist despite demographic, environmental, and genetic uncertainty. We used the phrase “sufficiently secure and adequately managed to assure long-term viability” to indicate conditions that will be clarified through the research discussed in the step-down outline and narrative. The interim Criteria will be revised accordingly, and the specific measures needed to assure long-term viability will be identified.

Other Significant Comments and Service Responses

Recovery criteria comments:

- **Comment:** One commenter suggested an increase in the number of populations necessary to reclassify or delist the species. The commenter expressed concern that only four populations is not sufficient to warrant reclassification or delisting, and suggested adding at least two populations to the Recovery Criteria.

  Response: Currently, there are as many as five populations known in the U.S., including the newly discovered adult beetle in Canada Creek in June 2005. The status of many of these populations is unknown. In fact, some known occurrences are represented by only one or a few adults, and it is not clear if all of these occurrences represent reproducing populations. Furthermore, we have no data on important considerations such as genetic variation, survival, and reproduction. The lack of population data is further exacerbated by our lack of understanding of dispersal mechanisms for this species. As discussed above, these may be subpopulations of one metapopulation (if at least some genetic exchange is occurring).

  Without additional information on the species, we determined Recovery Criteria based on our current perception of threats to the species. Criteria 2 and 4 are intended to ensure population resiliency and redundancy. Population resiliency involves ensuring that each population is sufficiently large to withstand stochastic events. Population redundancy involves ensuring a sufficient number of populations to provide a margin of safety for the species to withstand catastrophic events. Thus, if something occurs to eliminate one population, at least one other population of the species will still exist, in sufficient numbers, and the species will not become extinct. We revised the interim recovery criterion for delisting Hungerford's crawling water beetle to require there are at least five U.S. populations, in at least three different watersheds, that are sufficiently secure and adequately managed to assure long term viability. Five viable populations in at least three different watersheds offer redundancy to insure against catastrophic events wiping out the species.

  The criteria for meeting the recovery goals are interim because further research is necessary to make them fully measurable. Interim Recovery Criteria are used for the short-term until better delisting objectives and criteria can be determined. The implementation schedule of this plan includes research activities that, when completed, will enable us to revise the Recovery Criteria as needed. We fully intend to revise this recovery plan when we have sufficient information on the life history, ecology, population biology, and habitat requirements of the species to enable us to more confidently determine when the species has reached recovery.

- **Comment:** One commenter recommended the inclusion of some aspect of minimum size in addition to "stable or increasing populations" for Criterion 2. Size could be expressed as a number or as a minimum length of stream within which the beetle is found. The commenter explained that a stable but small population would be more susceptible to destruction by a stochastic event than one that is more widely distributed in a watershed.

Response: We agree that some aspect of minimum population size would make this criterion fully measurable. However, at this time we do not have sufficient information to determine an appropriate minimum population size. As discussed above, we will revise these interim Recovery Criteria based on scientific data. The research needs and recovery tasks necessary to gather this data are discussed in the recovery plan.

- **Comment:** One commenter questioned the approach of “low” and “high” degree of threat used in Criterion 1 (pages 31 and 32 in the Draft Plan), and explained that an unlikely threat that would seriously degrade the habitat (e.g., chemical spill) might fall into the low category, and may not be acceptable.

  Response: The statement regarding “low” and “high” degree of threats was removed from the final recovery plan. Clearly, the capability of a species to survive such an event depends on its initial population size and distribution, the degree to which the event depresses population growth and survival, and the duration and extent of the event. At this time, we do not fully understand the species’ ability to persist against unlikely but catastrophic events, such as a chemical spill. Furthermore, it is unknown what level of risk is acceptable or what level of perturbation these sites can withstand. Criterion 1 requires that a threats assessment be completed based on the results of new information regarding the species’ life history, ecology, population biology, genetic variability, and habitat requirements. When the interim Recovery Criteria are revised, they will include a discussion on specific threats and how these threats must be managed in order to reach recovery.

- **Comment:** One commenter suggested using a modeling approach to assess population viability.

  Response: We agree that a modeling approach may be a useful tool in assessing population viability. This concept is captured in Recovery Action 2.5, “Investigate genetic heterogeneity and population viability.” We also added a discussion of PVA in Criterion 2 and Criterion 4.

- **Comment:** One commenter requested clarification on the scale of watersheds represented in the Recovery Criteria. The commenter recommended ensuring that the scale used is sufficiently geographically and hydrologically distinct to ensure that catastrophic events do not eliminate out all populations.

  Response: Populations of Hungerford’s crawling water beetle occur in two sub-basins of the Great Lakes—Lake Michigan and Lake Huron. Furthermore, there are separate watersheds within the Lake Huron sub-basin to provide additional separation. For example, if a catastrophic event were to occur in the Black River watershed, it would not effect population of Hungerford’s crawling water beetle in the Cheboygan River watershed or the Lake Michigan watershed.

The level of watershed for the Recovery Criteria is based on the 8-digit hydrologic unit code (HUC). We added a figure (Figure 6) with a map of the watersheds in northern Michigan at both the 8-digit HUC level and at a finer scale (using the 14-digit HUC) to show the hydrological distinction of each of the five populations.

Fish management comments

- **Comment:** Several commenters asked for clarification on the potential threat of fisheries management activities. One stated that it "is hard to support the suggestion that restoring or improving habitat in watersheds could be detrimental to anything native or routinely considered part of a natural environment." Several commenters discussed their concern that this recovery plan will have negative impacts to fish habitat restoration programs and other efforts to improve the health of watersheds. Specifically, one commenter questioned the mention of fish passage and restoration of insectivorous fish as threats and indicates that this is very problematic for ecosystem management and [fish] habitat restoration efforts and may create more problems than the protection is intended to provide.

- **Response:** Some fisheries management activities may be a threat to HCWB, as described in the "Reasons for Listing and Existing Threats" section. For example, the use of lampricide to control sea lamprey in occupied streams is likely to result in harm or harassment of HCWB. Stocking of insectivorous fish in occupied streams may result in increased predation of HCWB. Electroshocking is likely to result in harm or harassment of HCWB when conducted in occupied habitat. Habitat alterations in the vicinity of occupied habitat (i.e., through culvert removal) may result in disturbance to HCWB, through trampling, increased sedimentation, and temporary depletion of available food sources.

  The purpose of this recovery plan is to direct activities to recover HCWB with the goal of removing the species from the Federal list of Endangered and Threatened Wildlife (50 CFR 17.11). Presence of HCWB may have implications for certain fish habitat restoration programs when those activities may adversely affect HCWB. The intent of the recovery program is to recover the species, and to encourage, rather than impede, watershed restoration activities. If restoration activities can not avoid adverse impacts to HCWB, the Service will work with those programs, through the Section 7 or Section 10 processes, to minimize incidental take and ensure their activities do not jeopardize the continued existence of the species. We expect that the Recovery Plan will have overall benefits to occupied watersheds through implementation of Recovery Actions.

- **Comment:** One commenter questioned the threat of electrofishing and stated that "the potential for harm seems too small to mention." The commenter also mentioned the benefits of electrofishing to fisheries managers in acquiring quality data for stream game fish.

Response: We recognize the benefits of electrofishing activities to fish management; however, electrofishing in occupied HCWB habitat is likely to result in take. A review of the literature provides evidence that electrofishing may result in an increase in drift of aquatic invertebrates. The ESA defines "take" to include harm and harassment. If electrofishing causes an increase in drift in HCWB, then it would likely result in take (at the very least, harassment, and possibly lead to indirect mortality due to an increased likelihood of predation). Without additional information, it is reasonable to conclude that even small amounts of electrical current can lead to take of HCWB when conducted in occupied habitat. Additional references have been added to the "Reasons for Listing and Existing Threats" section to provide additional documentation and support regarding the potential for harm due to electrofishing.

- **Comment:** Two commenters requested an update on recent studies of the effects of TFM on a surrogate species.

  Response: The final plan was revised to include additional discussion on sea lamprey control and includes a brief discussion of the results of a recent study on the relative toxicity of the lampricide TFM to larval and adult *Haliplus* spp.

Watershed and habitat restoration projects and Best management Practices (BMPs)

- **Comment:** One commenter noted that we should promote BMPs well beyond the land adjacent to populations and should include areas potentially well upstream from a population and well beyond riparian areas (Criterion 3). Another commenter called for BMPs for road-stream crossings.

  Response: We agree that promotion of BMPs should extend throughout the watershed, including areas well upstream of occupied sites and beyond riparian areas. In order to reach recovery, riparian areas must be conserved through landowner agreements, easements, and other tools to protect habitat (Criterion 3). Conservation at the watershed scale and promotion of BMPs (including for management of road-crossings) throughout the watershed is also necessary to prevent a decline in HCWB and recover the species. Additional discussion and specific tasks were added to Recovery Action 1.5.

- **Comment:** Several commenters asked for clarification on the threat of bank stabilization, since it is intended to reduce sedimentation which is also a threat to the species.

  Response: Bank stabilization is likely to result in overall improvement to the stream and may reduce the threat of sedimentation. If artificial impervious cover is used, it may eliminate potential pupation habitat through covering the moist soil above the water line that late instar larvae likely use during overwintering. Most bank stabilization projects, however, are likely to have overall benefits to HCWB as long as they do not result in disturbance to the stream bed (which may result in trampling of individuals). Additional discussion was added to the recovery plan.

- **Comment:** One commenter suggested that the species may be found below culverts and road crossings because these areas are more easily accessible to surveyors. The commenter asked for evidence that other areas in remote stretches of the stream have had comparable survey efforts. The commenter noted that cold water clean riffles are more often found in areas undisturbed by roads and other anthropogenic effects and may be more likely to support HCWB populations.

  Response: Areas near road crossings are more accessible and easier to get to than other more remote areas of streams. However, other areas of occupied streams have been surveyed for HCWB. For example, during recent surveys in the Carp Lake River, 30 hours were spent surveying for HCWB; this included seventeen hours of surveying in portions of the stream that were not known to be occupied and included areas of the stream not associated with road crossings (Ebbers 2005). Despite many hours of searching, the species has been found in only two areas of the stream–below the culvert at Gill Road, and below the culverts at Oliver Road. Many other areas within the stream do not appear to be suitable, in part because of diminished stream velocity due to active and inactive beaver dams and a thick layer of gray silt that covers the stream bottom (Ebbers 2005). HCWB is found in areas of other streams not associated with culverts (e.g., portions of the East Branch of the Maple River, the East Branch of the Black River, and Canada Creek).

  We added discussion of possible sampling bias to Recovery Action 3.1. As we develop standard survey and monitoring protocols, care should be taken to ensure all areas of available habitat are surveyed equally to reduce the likelihood of sampling bias.

  Comment: One commenter asked for clarification on activities that may be undertaken to benefit the beetle, and additional discussion on programs that can benefit watersheds. The commenter also sought clarification on determining when HCWB may be present and when certain restrictions apply when an action is to occur in the vicinity of occupied habitat.

  Response: Activities that may benefit the beetle are identified in the step-down outline and narrative for recovery actions sections. Additional discussion was added to Recovery Action 1.5 to describe programs that can benefit watersheds.

  The species is known to occur in five streams in the U.S., often in several discrete locations within each stream. Because the species can be difficult to detect, it is likely that the species occurs in additional areas of occupied streams and possibly within other streams within the known range. This possibility is supported by recent discoveries of new occurrences within an occupied stream and in a new stream within an occupied watershed. If a project is to occur in one of the occupied streams, then the habitat within the area should be evaluated for suitability for HCWB and possibly surveyed to determine if the species may be present. Activities that occur upstream or in the immediate vicinity of an occupied site are more likely to have impacts to HCWB. If any activity that occurs within the stream or in the vicinity of occupied habitat may result in adverse impacts to HCWB (either directly or indirectly), then the FWS should be contacted to determine whether a permit or other incidental take exemption is needed. Through the Section 7 or Section 10 processes, the FWS will work with the applicant to ensure the project will not jeopardize the continued existence of the species, and may require certain restrictions to minimize take.

Other comments:

- **Comment:** One commenter stated that several statements in the draft plan imply that we know more than we do about the species or are using the limited information we have to identify habitat requirements. This commenter asked that the final plan eliminate these "leaps of faith" and promote survey work essential to development of a realistic recovery plan. The commenter went on to say that statements are based on extremely limited data assumptions could create impediments to certain programs intended to enhance and restore fish habitat.

  Response: Throughout the recovery plan, we identify information needs and emphasize the lack of information on HCWB. In order to recover HCWB so that it can be removed from the Federal list of Endangered and Threatened Wildlife (50 CFR 17.11), we must assess threats to this species and determine how to ameliorate those threats. Because data are lacking, we must make certain assumptions in order to evaluate the reasons for listing and existing threats. We base our understanding of the species' natural history in part on what we know of the natural history of closely related species; we make an assumption that because they are closely related the natural history will be similar or the same. In terms of habitat requirements, we mention many times throughout the plan that habitat requirements are not fully understood. We present in this recovery plan the best available information on the species. We believe we have clearly identified when we are making assumptions and explain the best available information on which we base those assumptions. A key component of this recovery plan is implementation of a research program, which will help us evaluate the validity of our assumptions.

- **Comment:** One commenter questioned the validity of man-made barriers and culverts creating habitat for the species because they feel these are often detrimental to the natural condition of the stream. Another commenter stated that the fact that culverts appear to be important in maintaining habitat and that they serve as barriers to dispersal is contradictory.

  Response: Within three of the five known HCWB streams in the U.S. (i.e., Carp Lake River, Van Hetton Creek, and the East Branch of the Maple River), the species is found areas of the stream directly below culverts. In fact, the best known occurrence of this species range-wide occurs in a plunge pool below a culvert and road crossing in the East Branch of the Maple River. The sixth occurrence in Canada occurs below a man-made dam.

  Because we find the majority of sites below culverts, we deduce that areas below culverts provide suitable habitat conditions for HCWB. This is not to say that this species requires culverts. Rather, this species appears to require clean gravel or cobble bottom streams with a sand substrate, algae for a food source, and suitable larval and pupation sites. Apparently, culverts and similar structures support these habitat conditions. This type of habitat is likely available in undisturbed streams without culverts or beaver. We added additional discussion to the recovery plan on the role of culverts and beaver in creating HCWB habitat.

- **Comment:** One commenter suggested that altered hydrology should be addressed as a major threat to the species. The commenter stated that larger-scale landscape forces are as important as beaver activity in determining streamflow dynamics. The commenter suggested that an understanding of historic watershed-scale changes in hydrology may assist in elucidating the historic distribution for the species. In addition, the commenter recommended Research Actions related to the study of hydrologic needs of the species and potential hydrologic threats at occupied sites.

  Response: We agree that hydrology is an important factor and have added a Recovery Action (Action 2.7) to investigate the hydrological needs of the species and potential hydrological threats to HCWB.

- **Comment:** One commenter recommended that the recovery plan be revised to emphasize protection of critical habitat for the species. The commenter stated that the Service is required to designate critical habitat for the species as soon as possible, without regard to its funding or listing priorities. The commenter stated that critical habitat provides recovery benefits for listed species, and urges the Service to immediately designate critical habitat for Hungerford's crawling water beetle based on the best available science.

  Response: Critical habitat is a legal term defined within Section 3 of the ESA. As the plan indicates, critical habitat is not currently designated for HCWB. A future critical habitat proposal would be based on essential habitat.

  Essential habitat is defined as the areas necessary for all aspects of the species' life cycle including shelter, feeding, reproduction, and over-wintering. Essential habitat for this species is described in part in this plan, but for the most part is largely unknown. The recovery plan places a significant emphasis on the need to protect and further describe essential habitat.

- **Comment:** One commenter disagreed with the wording of recovery plan's goal (i.e., "to remove the species from the Federal list of Endangered and Threatened Species)." The commenter asked that the recovery plan goal be re-written to emphasize the recovery of the species, not the elimination of regulatory protections. The commenter expressed concern that making delisting the goal of the recovery plan "puts the cart before the horse" and gives the impression that if the Service attempts to complete the objectives in the recovery plan, then delisting will automatically be appropriate, irrespective of what new information is received after the recovery plan is finalized.

Response: The goal of the recovery process is to restore listed species to a point where they are secure, self-sustaining components of their ecosystems, so that the protections of the Endangered Species Act are no longer necessary. The goal of a recovery plan is to create conditions that allow the species to be reclassified and delisted.

The Recovery Criteria in the HCWB Recovery Plan are interim; the recovery plan will require revision when new information becomes available that allows the criteria to be made fully measurable. Delisting will only occur if the species meets the definition of recovered, and this analysis will consider all available information.

- **Comment:** One commenter recommended that several Research Actions be given the highest priority (i.e., priority rank of '1'), since additional research is critical for the ongoing development and implementation of the recovery program.

  Response: We agree that several research activities should be Priority 1, and we revised the recovery plan accordingly. Recovery Actions with a Priority 1 rank are those actions that are considered essential to prevent Hungerford's crawling water beetle from becoming extinct in the foreseeable future. Although a research activity in and of itself can not prevent extinction, the *application* of some research tasks may be necessary to prevent extinction. Because the bulk of the recovery program is dependant upon the researched outlined in the recovery plan, including revision of the interim Recovery Criteria, we revised the recovery priority ranks for several research actions to Priority 1.

- **Comment:** Several commenters suggested increasing the cost of recovery in the implementation schedule, particularly for research tasks.

  Response: We revised the cost of several Recovery Actions in the implementation schedule based on the comments we received and added a column extending the timeframe covered from three years to twenty years.

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