Recovery Outline for the Ozark Hellbender

Common Name: Ozark Hellbender

Scientific Name: *Cryptobranchus alleganiensis bishopi*

Classification: Endangered

Effective Listing Date: November 7, 2011

Recovery Priority Number: 3

Lead Region: Region 3

Cooperating Regions: Region 4

Lead Office: Columbia Missouri Field Office
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Photo courtesy of Jeff Briggler

Purpose of the Recovery Outline

In the interim between listing and recovery plan approval, a recovery outline provides preliminary strategies for conservation that conform to the mandates of the Endangered Species Act (ESA), as amended. It organizes near-term recovery actions, provides a range-wide conservation context for U.S. Fish and Wildlife Service (USFWS) decisions, and sets the stage for recovery planning and stakeholder involvement.

Information Sources and Treatment of Uncertainties

This recovery outline is based on the best available data, including the Hellbender Conservation Strategy (Briggler *et al.* 2010), the Spotlight Species Action Plan (USFWS 2009), the listing decision (USFWS 2011, 76 FR 61959), and recent information from species experts. Research needed to address information gaps is described in this document and will be part of the implementation table in the recovery plan. For issues in which there is uncertainty associated with the conservation needs, caution will be exercised until such uncertainty can be resolved.

I. RECOVERY STATUS ASSESSMENT

A. Species Description and Life History

The Ozark Hellbender is a large, strictly aquatic salamander endemic to streams of the Ozark Highlands in southern Missouri and northern Arkansas. They have a large, keeled tail; small eyes; and a dorso-ventrally flattened body that enables movements in the fast-flowing streams it inhabits (Nickerson and Mays 1973). Numerous fleshy folds along the sides of the body provide surface area for respiration, and adults may attain lengths of 29-57 centimeters (Dundee and Dundee 1965, Johnson 2000). Hellbenders are long-lived and capable of living 25 to 30 years in the wild (Peterson *et al*. 1983). Females reportedly reach sexual maturity in 6 to 8 years (Nickerson and Mays 1973; Peterson *et al*. 1983; Taber *et al*. 1975) and males in approximately 5 years (Taber *et al*. 1975).

The Ozark Hellbender is a habitat specialist that depends on consistent levels of dissolved oxygen, temperature, and flow (Williams *et al.* 1981). Ozark Hellbender adults are typically found beneath large rocks in rocky, fast-flowing streams (Johnson 2000; Fobes and Wilkinson 1995); while larvae and juveniles hide beneath small stones in gravel beds or under large rocks, similar to those occupied by adults (Nickerson and Mays 1973, LaClaire 1993).

Ozark Hellbender breeding generally occurs in early to mid-October, with the exception of Spring River populations that breed in the winter (Peterson *et al.* 1989). Males prepare nests beneath large flat rocks, within bedrock, or beneath submerged logs. Ozark Hellbenders mate via external fertilization, and males guard the fertilized eggs against predation by fish and other Ozark Hellbenders (Nickerson and Mays 1973). Clutch sizes vary from 138 to 450 eggs per nest (Dundee and Dundee 1965), and eggs hatch after approximately 80 days (Bishop 1941).

B. Distribution and Population Status

The Ozark Hellbender historically occurred in portions of the Spring, White, Black, Eleven Point, and Current rivers and their tributaries (North Fork of the White River, Bryant Creek, and Jacks Fork) (LaClaire 1993). Currently, Ozark Hellbender populations are known to occur in Bryant Creek, North Fork of the White River, Eleven Point River, and Current River, with some individuals possibly still present in the White River, Spring River, and Jacks Fork (Fig. 1).

Surveys of historic sites indicate that populations in each river have declined by at least 70 percent (Trauth *et al*. 1992, Wheeler *et al*. 2003), and no population is considered stable. In 2006, the total number of Ozark Hellbender individuals in the wild was estimated to be approximately 590 individuals (Briggler *et al*. 2007). In addition, it appears that there has been a shift in age class structure to older individuals and a reduction in recruitment (Wheeler *et al*. 2003).

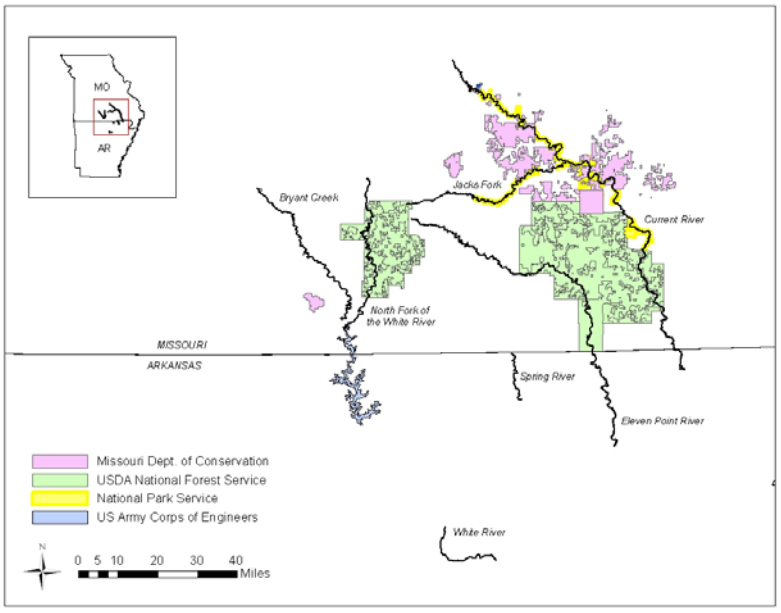

Figure 1. Rangewide distribution of the Ozark Hellbender and surrounding public lands. Occupied streams include Bryant Creek (MO), North Fork of the White River (MO), mainstem of the White River (AR), Spring River (AR), Eleven Point River (AR, MO), Jacks Fork (MO), and Current River (AR, MO).

C. Landownership

Federal – Major Federal lands within the current distribution of the Ozark Hellbender include the Mark Twain National Forest (U.S. Forest Service), Ozark National Scenic Riverways (National Park Service), and Norfork Reservoir (U.S. Army Corps of Engineers) (Fig. 1).

State – Major State lands within the current distribution of the Ozark Hellbender include Montauk Fish Hatchery and several Conservation Areas (Angeline, Caney Mountain, Cedar Gap, Cedar Grove, Clearwater, Current River, Gist Ranch, Logan Creek, Peck Ranch, Rippee, Rocky Creek, and Sunklands) managed by the Missouri Department of Conservation (MDC) and Montauk State Park managed by the Missouri Department of Natural Resources (Fig. 1).

Other – Non-governmental organizations within the Ozark Hellbender distribution include The Nature Conservancy, LAD Foundation, and Ozark Regional Land Trust. Most of the remaining area is in other private ownership and managed primarily for crop production, livestock operations, or timber harvest.

D. Threats to the Species

The primary threats to the Ozark Hellbender are habitat loss and degradation, over collection, disease, severe physical abnormalities resulting from unknown causes, and potential predation by non-native fish. Presented below is a brief description of the threats, classified according to the five listing/delisting factors identified in section 4 of the Endangered Species Act ("Act"; 16 USC 1531 *et seq*.). Additional information, including a description of all potential threats, may be found in the in the final rule (76 FR 61959).

(a) The present or threatened destruction, modification, or curtailment of its habitat or range (Factor A) - The construction of several impoundments in the 1940s and 1950s in the upper White River destroyed potential Ozark Hellbender habitat within inundated river reaches and downstream of the impoundments, effectively isolating Ozark Hellbender populations. Ongoing adverse effects from impoundments include: isolation of the Bryant Creek Ozark Hellbender population from the North Fork of the White River, increased sediment and gravel deposition upstream of reservoirs, and increased exposure to predatory fish immediately upstream of impoundments.

Habitat degradation from sedimentation and reduced water quality, is caused by multiple factors (human and livestock wastes, agricultural runoff, mine waste, unpaved roads, activities related to timber harvest, riparian forest clearing, etc.) and poses a significant threat to the Ozark Hellbender. Increased siltation can affect Ozark Hellbenders by potentially suffocating eggs, eliminating suitable habitat for all life stages, reducing dissolved oxygen levels, and reducing prey populations. Increased nitrate levels, along with other contaminants from agricultural runoff and increased urbanization, have been detected in Ozark Hellbender streams and may be negatively affecting survivorship and/or reproduction.

(b) Overutilization for commercial, recreational, scientific, or educational purposes (Factor B) - Anecdotal reports and published information indicate that Ozark Hellbenders have been extensively collected for commercial and scientific purposes (Trauth *et al.* 1992, Nickerson and Briggler 2007). Measures to reduce the threat of collection have been implemented by State agencies, but the unauthorized collection of Ozark Hellbenders for commercial sale in the pet trade continues to be a significant threat, especially with declining numbers.

(c) Disease or predation (Factor C) - Chytridiomycosis is a highly infectious amphibian disease caused by the pathogen *Batrachochytrium dendrobatidis* (*Bd*, or amphibian chytrid fungus), and has been demonstrated to infect and kill all life stages of an increasing number of amphibian species worldwide (Berger *et al.* 1998). With the exception of Bryant Creek and Spring River, the fungus has been detected in all currently occupied Ozark Hellbender rivers (Briggler *et al*. 2008).

Non-native trout (*e.g.*, rainbow and brown trout) are stocked in several of the rivers that historically and currently contain Ozark Hellbenders. Predation of Ozark Hellbender larvae by non-native trout and other piscivorous fish possibly contributes to the decline of Ozark Hellbender populations (Gall and Mathis 2010a; Gall and Mathis 2010b). Stocking of predatory fish is an ongoing threat, particularly if stocking numbers increase in Ozark Hellbender streams.

The presence of physical abnormalities is becoming increasingly common and includes abnormal limb structures (missing toes, feet, and limbs), epidermal lesions, blindness, missing eyes, and bifurcated limbs. The exact cause of these abnormalities remains unclear, but the current belief among Ozark Hellbender experts is that secondary bacterial or fungal infections may be causing the abnormalities (Nickerson *et al*. 2011).

(d) The inadequacy of existing regulatory mechanisms (Factor D) - Several factors contributing to degradation of water quality remain outside government regulatory authority. Ongoing gravel mining in Ozark Hellbender streams is no longer regulated by the U.S. Army Corps of Engineers under section 404 of the Clean Water Act unless there is placement of fill back into the streams; while State agencies only regulate commercial gravel mining and not mining for personal use or for county or municipal governments. Gravel mining can cause stream instability when the scouring process leads to degradation or when excessive sediment deposition results in aggradation (the process of building up a streambed grade or level by deposition of sediment). These modifications to the stream channel can alter habitat conditions that provide space, cover, shelter, and sites for breeding, reproduction, and growth of offspring for the Ozark Hellbender.

Best Management Practices (BMPs) have been developed for timber harvest activities and address the construction of logging decks, increased use of unpaved roads, improperly designed and maintained roads, skid trails, riparian areas, and

fire breaks. BMPs help reduce impacts to aquatic resources from erosion and sedimentation; however, implementation is not mandatory. There are also no laws or regulations that preclude the wholesale removal of riparian forest buffers, livestock from grazing in riparian corridors, or livestock from directly accessing streams and rivers, which increases sedimentation and nitrification of streams.

(e) Other natural or manmade factors affecting its continued existence (Factor E) - The small size and isolation of Ozark Hellbender populations, potential loss of genetic diversity, reduced recruitment, and potential effects from climate change could exacerbate other factors negatively affecting the subspecies and increase the risk of extinction. Effects from some threats also may interact synergistically to enhance effects from other factors (*e.g*., compromised health from water quality or increased predation risks from exposure to various pathogens).

E. Past and Current Conservation Efforts

The Ozark Hellbender Working Group (Briggler *et al.* 2010) was formed in 2001 and is composed of individuals from Federal and State agencies, academia, zoos, nonprofit organizations, and other individuals interested in the conservation of the subspecies. The group has played a significant role in identifying information needs and guiding conservation efforts for Ozark Hellbenders, which includes the development of a comprehensive conservation strategy (Briggler *et al.* 2010). Below is a brief summary of conservation measures which have been undertaken to date; for a comprehensive list of measures, see the Hellbender Conservation Strategy (Briggler *et al.* 2010).

Population monitoring (*ongoing*) – The severe decline in Ozark Hellbender populations was first recognized in the late 1990s (Trauth *et al*. 1992, Wheeler *et al.* 2003). Subsequently, the Arkansas Game and Fish Commission (AGFC) and Missouri Department of Conservation (MDC) began conducting regular surveys to monitor populations and assess the overall health of animals. AGFC conducts biennial surveys on the Arkansas portion of the Eleven Point River; while MDC surveys each Ozark Hellbender river in Missouri on a three year rotation. The survey protocol implemented by MDC allows for calculating detection rates, estimating population sizes, and projecting population trends. In addition, suitable habitat has been mapped throughout all occupied steams. Involved partners include AGFC, MDC, National Park Service (NPS), and USFWS.

Captive propagation (*ongoing*) – The captive propagation program was initiated in 2002, and in 2004 Ozark Hellbender adults were collected from the North Fork of the White River and transferred to indoor raceways at the Saint Louis Zoo. In 2009 - 2011, adults also were collected from the Current and Eleven Point rivers and eventually released into outdoor raceways at the zoo in 2011. Until 2011, breeding attempts were unsuccessful despite the deposition of eggs in multiple years by females in the indoor raceway. However, in 2011, fertilized eggs were found in the outdoor raceway containing individuals from the Eleven Point River. The eggs were successfully hatched and are being reared for eventual release. In addition to captive breeding, egg clutches also have been collected from the wild for hatching and head-

starting. To date, eggs have been collected from the North Fork of the White, Current, and Eleven Point rivers and approximately 1,500 larvae and juveniles are currently being reared at the Saint Louis Zoo and Shepherd of the Hills Hatchery, MDC for future release. Collecting eggs from the wild and head-starting will help bolster populations by maintaining genetic diversity, significantly increasing survivorship rates of young, and by effectively augmenting more individuals into the population than would have otherwise normally survived. Propagation of Ozark Hellbenders has been a collaborative effort among various partners and includes the Saint Louis Zoo, MDC, AGFC, USFWS, NPS, and U.S. Forest Service (USFS).

Protecting populations and habitat (*ongoing*) – Both State agencies and USFWS review projects potentially affecting Ozark Hellbenders and make recommendations to minimize or mitigate for adverse effects. USFWS reviews proposed projects having a federal nexus (*i.e*., authorized, funded, or carried out by a Federal agency) under Section 7 of the ESA; while States often review projects with no federal nexus. Best Management Practices (BMPs) were developed by MDC and include specific recommendations for activities occurring in or near Ozark Hellbender streams. To protect populations from illegal collection, disclosure of specific locations of Ozark Hellbender sites is limited and law enforcement and private landowners monitor sites for suspicious activity. Involved partners include AGFC, MDC, USFWS, NPS, USFS, and U.S. Army Corps of Engineers (USACE).

Disease Assessment and Treatment (*ongoing*) – Due to the prevalence and severity of physical abnormalities found in Ozark Hellbender populations (except for Bryant Creek which has a low sample size), considerable effort has been focused on understanding the cause of these abnormalities as well as other diseases that may be compromising animal health. External microorganisms associated with injured or necrotic tissue have been identified (Nickerson *et al.* 2010), and extensive necropsies and screenings have been performed on affected individuals. Recent and ongoing monitoring surveys incorporate sampling protocols for testing of fungal, bacterial, and viral pathogens; while museum specimens have been histologically examined to determine when the fungus first occurred in the populations (Bodinof *et al*. 2011). Additionally, methods to treat captive individuals infected with amphibian chytrid fungus have been explored, with heat treatment methods proving most successful. Involved partners include MDC, AGFG, Saint Louis Zoo, USFWS, and University of Tennessee.

Other Efforts – Numerous other measures have focused on understanding the causes underlying Ozark Hellbender declines or addressing potential threats. These measures include: investigating predation by non-native fish; assessing the sperm quality of wild and captive individuals; monitoring survivorship, hematology, and movement patterns of released captive-reared individuals; examining reproductive hormones and heavy metal levels; adding both Ozark and Eastern subspecies of hellbenders to the Appendix III list for the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), preparing outreach materials, developing a Population and Habitat Viability Analysis, and multiple genetic studies

investigating genetic variability and population structure among rivers. Involved partners include various individuals from Federal and State agencies, academia, zoos, and nonprofit organizations.

F. Recovery Status Assessment Summary

Ozark Hellbender populations have declined over 70 percent since the 1980s, and roughly 590 individuals are estimated to remain in the wild. In addition, little recruitment is observed in wild populations and a large proportion of individuals exhibit severe physical abnormalities. Although extensive work has been done to help conserve the Ozark Hellbender and better understand potential threats, population declines continue and the exact cause(s) of the declines remains unclear. The captive propagation program however, is helping to stabilize the populations until threats are more definitively identified and managed.

G. Recovery Needs

Initial recovery efforts should focus on further investigating potential causes of declines while continuing to stabilize populations using the captive propagation and head-starting program. Long-term recovery efforts should focus on improving water quality, reducing sediment and gravel input, and addressing any other threats found to contribute to declines. Impacts to avoid are those that could 1) result in mortality or injury to Ozark Hellbenders, 2) reduce reproduction or recruitment of young into populations, 3) increase stress to remaining individuals in the wild, or 4) alter habitat such that survival or reproduction is reduced. Especially critical is the protection of Ozark Hellbender sites where reproduction is known to still occur or which contain larger numbers of hellbenders.

II. PRELIMINARY RECOVERY STRATEGY

A. Recovery Priority Number

The Ozark Hellbender is assigned a recovery priority number of 3 on a scale of 1C (highest) to 18 (lowest; the "C" indicates the potential for conflict with human economic activities). The ranking is based on a high degree of threat, high potential for recovery, and taxonomic status as a subspecies (USFWS 1983a, b).

The magnitude of threat is currently high given continued population declines, spread of amphibian chytrid fungus, potential predation by non-native fish, reduced recruitment in the wild, and severe physical abnormalities observed in a significant portion of wild-caught Ozark Hellbenders.

Recovery potential is considered high because most of the potential threats can ultimately be managed or abated. These threats include: habitat degradation from sedimentation, degraded water quality; unauthorized collection; and potential predation by non-native predators. Threats which may not be possible to manage include amphibian chytrid fungus, because there is currently no known method to control the fungus in the wild; and physical abnormalities, because their cause remains unknown. Recovery potential is also considered high because approximately 1,500 Ozark Hellbenders larvae/juveniles are

currently being reared in captivity. These individuals will be used to augment wild populations and investigate potential threats contributing to population declines.

We do not presently anticipate implementation of recovery actions to conflict with construction or other forms of economic activity.

B. Recovery Goals

The ultimate goal of the recovery effort is to ensure the long-term survival of the Ozark Hellbender by controlling or reducing threats to the extent that populations are self-sustaining and protections afforded by the Endangered Species Act are no longer required. The interim goal is to secure the subspecies to the point that we may consider down-listing from endangered to threatened status. The identification of appropriate recovery objectives will likely involve substantial discussion; therefore, objectives will be identified in the recovery plan rather than in this recovery outline. The recovery plan also will identify specific, measureable criteria that will describe the precise standards for measurement to determine that the species has achieved its recovery objectives for down-listing and delisting.

C. Initial Action Plan

Below are the primary actions which are anticipated, including ongoing conservation measures outlined under Past and Current Conservation Efforts.

1. Captive propagation
    a. Develop a captive propagation, augmentation, and reintroduction plan and coordinate Section 10(a)(1)(a) recovery permits with State agencies and the Saint Louis Zoo.
    b. Maintain adult brood stock at the Saint Louis Zoo for captive breeding.
    c. Continue to collect eggs from the wild and head-start at propagation facilities (Saint Louis Zoo and Shepherd of the Hills Hatchery, MDC) as needed.
    d. Temporarily remove males (and possibly females) from the wild for captive breeding or artificial fertilization.
    e. Continue investigating sperm cryopreservation methods.
    f. Continue to address and monitor health related concerns of captive animals.
2. Monitor population status
    a. Continue conducting regular surveys to monitor population status, including pathogens (*e.g.*, viral, bacterial, fungal, etc.).
    b. Record morphometric measurements of captured individuals and document the presence of abnormalities, external parasites, and indicators of reproductive condition.
    c. Further investigate the life history of Ozark Hellbender larvae and juveniles in the wild.

3. Protect populations and habitat
    a. Through Section 7(a)(2) of the Act, insure that any activities authorized, funded, or carried out by a Federal agency are not likely to jeopardize the continued existence of the species.
    b. Continue to protect Ozark Hellbender sites from illegal collection by limiting disclosure of site localities and encouraging law enforcement and private landowners to monitor sites for suspicious activity.
    c. Utilize landowner incentive programs to implement conservation practices on private property that will protect riparian habitat adjacent to Ozark Hellbender streams and reduce non-point sources of pollution into streams (also outlined under Section 7. *Reduce sediment and gravel input into rivers*).
    d. Coordinate with Arkansas Department of Environmental Quality, Missouri Department of Natural Resources, and the U.S. Environmental Protection Agency to ensure water quality criteria and standards are suitable for all life stages (also outlined under Section 6. *Investigate potential water quality issues*).
4. Investigate physical abnormalities
    a. Continue to collect information on abnormalities of wild individuals.
    b. Continue to investigate potential causes, including immunosuppression (also addressed under Section 8. *Other research*).
5. Investigate diseases
    a. Continue to screen for amphibian chytrid fungus, *Ranavirus*, and other pathogens in wild populations and captive individuals.
    b. Infect larval hellbenders with amphibian chytrid fungus to determine effects and assess effectiveness of treatment techniques.
6. Investigate potential water quality issues
    a. Collect and summarize existing water and habitat quality data from Ozark Hellbender streams.
    b. Determine acute and chronic toxicity of water and sediment quality parameters (*i.e.*, heavy metals, ammonia, etc.) for all life stages and compare to parameters in hellbender streams.
    c. Investigate changes over time in reproductive hormones and heavy metals of telemetered, released individuals (assessments underway).
    d. Continue to collect blood samples from previously telemetered and examined animals to document changes of blood profiles, reproductive hormones, and heavy metals over time.
    e. Determine extent to which sedimentation may contribute to population declines.
7. Reduce sediment and gravel input into rivers
    a. Identify sources of excessive sediment transport into streams.
    b. Utilize Federal and State landowner incentive programs to protect riparian habitat and reduce sedimentation.

8. Other research –The following are areas of important research needed for effective management of Ozark Hellbenders and not outlined under other conservation measures:
    a. Determine the effect of electrofishing on all life stages of Ozark Hellbenders.
    b. Continue to investigate the potential role of non-native trout in population declines.
    c. Continue to assess sperm quality of males in wild populations and captive stock as needed.

III. PREPLANNING DECISIONS

A. Recovery Plan Development

A recovery plan for the Ozark Hellbender will be prepared pursuant to section 4(f) of the Endangered Species Act. The USFWS anticipates convening a formal recovery team to oversee development of the plan. Members of the team have yet to be identified, but will include representatives from appropriate State and Federal agencies and species experts.

B. Stakeholder Involvement

Other potential stakeholders in Ozark Hellbender recovery efforts, including members of the Ozark Hellbender Working Group, will have opportunity for involvement through the recovery planning process. As the recovery team finds appropriate, this process may include coordination with consulting experts and meetings with interested parties to facilitate information exchange. A public comment period will open when a notice announcing the availability of the draft Recovery Plan is published in the *Federal Register*. In addition, we will seek peer review from at least three independent species (hellbender) experts during the public comment period.

C. Recovery Plan Timeframe

Draft Recovery Plan anticipated: April 2013
Final Recovery Plan anticipated: April 2014

D. Information Management

All information relevant to the recovery of the Ozark Hellbender will be housed in the Columbia Missouri Field Office's administrative files. The lead biologist will be responsible for maintaining a full administrative record for the recovery planning and implementation process for the species.

Approved:

Thomas O. Melius

Regional Director, Region 3
U.S. Fish and Wildlife Service

May 18, 2012
Date

Citation

U.S. Fish and Wildlife Service. 2012. Recovery Outline for the Ozark Hellbender. Columbia, Missouri. 13 pp.

References

Berger, L., R. Speare, P. Daszak, D.E Green, A.A. Cunningham, C.L. Goggin, R. Slocombe, M.A. Ragan, A.D. Hyatt, K.R. McDonald, H.B. Hines, K.R. Lips, G. Marantelli, and H. Parkes. 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. Proceedings of the National Academy of Sciences 95:9031−9036.

Bishop, S.C. 1941. Salamanders of New York. New York State Museum Bulletin 324:1−365.

C.M. Bodinof, J.T. Briggler, M.C. Duncan, J. Beringer, and J.J. Millspaugh. 2011. Historic occurrence of the amphibian chytrid fungus *Batrachochytrium dendrobatidis* in hellbender *Cryptobranchus alleganiensis* populations from Missouri. Disease of Aquatic Organisms 96:1-7.

Briggler, J.T., T. Crabill, K. J. Irwin, C. Davidson, J. Utrup, and A. Salveter (editors). 2010. Hellbender Conservation Strategy: An action plan for the recovery of the Ozark and Eastern Hellbender in the Ozark Highlands of Missouri and Arkansas. Ozark Hellbender Working Group, Jefferson City, Missouri. 59 pp.

Briggler, J., J. Utrup, C. Davidson, J. Humphries, J. Groves, T. Johnson, J. Ettling, M. Wanner, K. Traylor−Holzer, D. Reed, V. Lindgren, and O. Byers (eds.). 2007. Hellbender Population and Habitat Viability Assessment: Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN. 118 pp.

Briggler, J.T., K.A. Larson, and K.J. Irwin. 2008. Presence of the Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*) on hellbenders (*Cryptobranchus alleganiensis*) in the Ozark Highlands. Herpetological Review 39(4):443-444.

Dundee, H.A., and D.S. Dundee. 1965. Observations on the systematics and ecology of Cryptobranchus from the Ozark plateaus of Missouri and Arkansas. Copeia 1965:369−370.

Fobes, T. M., and R. F. Wilkinson. 1995. Summer, diurnal habitat analysis of the Ozark hellbender, *Cryptobranchus alleganiensis bishopi*, in Missouri. Final Report, Southwest Missouri State University.

Gall, B.G., and A. Mathis. 2010a. Innate predator recognition and the problem of introduced trout. Ethology 116:47-58.

Gall, B.G., and A. Mathis. 2010b. Response of native and introduced fishes to presumed antipredator secretions of Ozark hellbenders (*Cryptobranchus alleganiensis bishopi*). Behaviour 147:1769-1789.

Johnson, T.R. 2000. The amphibians and reptiles of Missouri. Missouri Department of Conservation, Jefferson City, Missouri. 400 pp.

LaClaire, L. V. 1993. Status review of Ozark hellbender (*Cryptobranchus bishopi*). U.S. Fish and Wildlife Service status review. Jackson, Mississippi.

Nickerson, M.A., and J.T. Briggler. 2007. Harvesting as a factor in population decline of a long−lived salamander; the Ozark hellbender, *Cryptobranchus alleganiensis bishopi* Grobman. Applied Herpetology 4:207−216.

Nickerson, M.A., and C.E. Mays. 1973. The hellbenders: North American giant salamanders. Milwaukee Public Museum Publications in Biology and Geology 1:1−106.

Nickerson, C.A., C.M. Ott, S.L. Castro, V.M. Garcia, T.C. Molina, J.T. Briggler, A.L. Pitt, J.J. Tavano, J.K. Byram, and M.A. Nickerson. 2011. Microbiome profiling of injured and repressed tissue regeneration sites from endangered giant aquatic Ozark hellbender salamanders. PLoS ONE 6:1-10.

Peterson, C.L., Ingersol, C.A., and R.F. Wilkinson. 1989. Winter breeding of *Cryptobranchus alleganiensis bishopi* in Arkansas. Copeia 1989:1031-1035.

Peterson, C.L., R.F. Wilkinson, Jr., M.S. Topping, and D.E. Metter. 1983. Age and growth of the Ozark hellbender (*Cryptobranchus alleganiensis bishopi*). Copeia 1983:225−231.

Taber, C.A., R.F. Wilkinson, Jr., and M.S. Topping. 1975. Age and growth of hellbenders in the Niangua River, Missouri. Copeia 1975:633−639.

Trauth, S.E., J.D. Wilhide, and P. Daniel. 1992. Status of the Ozark hellbender, *Cryptobranchus bishopi*, (Urodela: Cryptobranchidae), in the Spring River, Fulton County, Arkansas. Proceedings of the Arkansas Academy of Science 46:83−86.

[USFWS] U.S. Fish and Wildlife Service. 1983a. Endangered and threatened species listing and recovery priority guidance. Federal Register 48:43098-43105.

[USFWS] U.S. Fish and Wildlife Service. 1983b. Endangered and threatened species listing and recovery priority guidelines correction. Federal Register 48:51985.

[USFWS] U.S. Fish and Wildlife Service. 2009. Spotlight species action plan for the Ozark Hellbender. Columbia, Missouri. 7 pp.

[USFWS] U.S. Fish and Wildlife Service. 2011. Endangered and threatened wildlife and plants; endangered status for the Ozark Hellbender Salamander. Federal Register 76: 61956.

Wheeler, B.A., E. Prosen, A. Mathis, and R.F. Wilkinson. 2003. Population declines of a long− lived salamander: a 20+ year study of hellbenders, *Cryptobranchus alleganiensis*. Biological Conservation 109:151−156.

Williams, R.D., J.E. Gates, C.H. Hocutt, and G.J. Taylor. 1981. The hellbender: a non-game species in need of management. Wildlife Society Bulletin 9:94−100.