Hellbender
Population and Habitat Viability Assessment

Final Report

7-10 August 2006
St. Louis, Missouri

Saint Louis Zoo WildCare Institute®

SAINT LOUIS ZOO
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CONSERVATION BREEDING SPECIALIST GROUP

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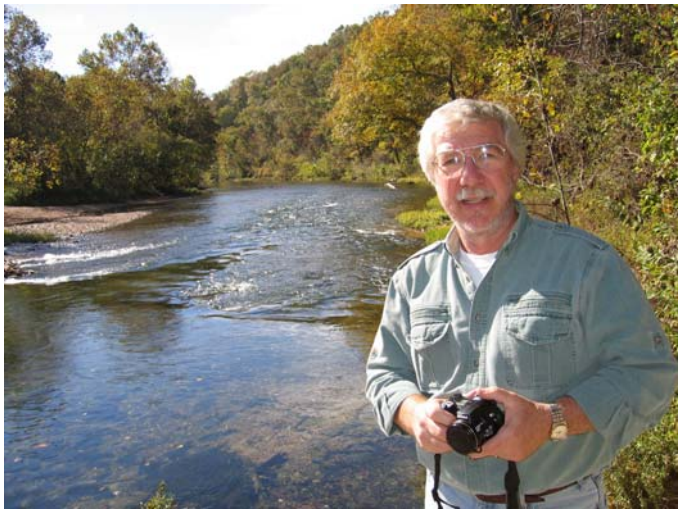
A contribution of the IUCN/SSC Conservation Breeding Specialist Group.

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

Additional copies of the *Hellbender Population and Habitat Viability Assessment: Final Report* can be ordered through the IUCN/SSC Conservation Breeding Specialist Group, 12101 Johnny Cake Ridge Road, Apple Valley, MN 55124, USA www.cbsg.org.

Dedication



Ron Goellner, Director of Animal Collections at the Saint Louis Zoo, passed away on 26 February 2006 after a year-long battle with cancer. His career at the Saint Louis Zoo spanned 35 years, starting as a reptile keeper in 1970. Within a few years he was promoted to Curator of Reptiles, a position he held until 1995. For the past 10 years Ron served as Director of Animal Collections for the Zoo, where he oversaw a collection of 11,400 animals, ranging from American burying beetles to Asian elephants. Throughout his career, Ron never strayed far from his true love: reptiles and amphibians.

In 2004 Ron founded the Saint Louis Zoo's Center for Hellbender Conservation, to address the alarming decline of Missouri's largest and most endangered salamander. It was the culmination of a career spent studying this fascinating creature and trying to raise awareness about its plight. Ron established valuable links with the Missouri Department of Conservation, universities, and field biologists to forge ahead with cooperative *in situ* initiatives for the hellbender in Missouri. As a tribute to Ron's distinguished career and his commitment to conservation, in 2006 the Saint Louis Zoo formally dedicated the Center in his name, the Ron Goellner Center for Hellbender Conservation, to ensure the continuation of his life's work with one of Missouri's most endangered amphibians.

Above all else, Ron is remembered for his way with people. He made everyone around him feel special, always putting their needs and interests first. Ron's sense of humor and caring manner put everyone around him at ease. He was able to take the most difficult tasks and find fun in them for everyone involved. He led with a gentle hand and a compassionate heart and earned the respect and admiration of all who knew him.

In honor of Ron's passion for conservation and, in particular, his dedicated efforts to ensure the survival of the hellbenders, we dedicate this document to him.

Hellbender

Population and Habitat Viability Assessment Workshop

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HELLBENDER
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FINAL REPORT

Section I
Executive Summary

Introduction

The hellbender is a giant, long-lived salamander native to cool, fast-flowing streams of central and eastern U.S. Once common, hellbender populations in some areas have declined by 77% since the 1970s, likely due to a combination of factors such as declining water quality, siltation from human activities, direct collecting, persecution, etc. In addition, emerging diseases, such as chytrid fungus, (*Batrachochytrium dendrobatidis*), has recently been observed in parts of the species' range that may also be contributing to the decline. In some areas, juvenile recruitment appears to be low, resulting in populations composed primarily of adults. At the request of the Saint Louis Zoo's Wildcare Institute, the Conservation Breeding Specialist Group (CBSG) facilitated a PHVA for the Ozark (*Cryptobranchus alleganiensis bishopi*) and Eastern hellbender (*C. a. alleganiensis*) on 7-10 August 2006. Thirty workshop participants worked to explore threats to hellbender populations and develop management actions aimed at understanding and halting this precipitous decline.

The Workshop Process

The workshop was opened by Jeffrey Bonner, Saint Louis Zoo's president and CEO, and Eric Miller, Director of the Wild Care Institute, who dedicated the gathering to the memory of Ron Goellner, Director of Animal Collections at the Saint Louis Zoo and founder of their Center for Hellbender Conservation. Participants stood for a moment of silence in his honor. It was Ron who originally envisioned this meeting, and he was deeply missed by all the dedicated hellbender biologists in the room. The Saint Louis Zoo raised nearly $40,000 in Ron's memorial fund, and a high point of the workshop was the announcement that these funds would be allocated to support the highest priority projects resulting from this workshop.

The opening ceremony was followed by an introduction to CBSG and the process designed for this workshop. As mentioned above, this workshop was to evaluate two subspecies of hellbender. The Eastern subspecies (*Cryptobranchus alleganiensis alleganiensis*) is found throughout the Eastern Mountain region of the US, from New York to Georgia, with an isolated population in Missouri. The other subspecies being evaluated in the workshop, the Ozark subspecies (*C. a. bishopi*), is found only in the Midwestern states of Missouri and Arkansas. Therefore, this meeting was designed to respond to the complex nature of this geographic distribution. In addition, only three of the 30 participants represented the Eastern region of the country, so this lack of balance with respect to subspecies and geographic expertise was also factored into the process design.

The CBSG team prepared and presented a baseline model for hellbender populations, and worked through the input parameters with the participants to optimize the model. The model development was extremely detailed and productive, with the group examining several subpopulations individually. Participants then identified a goal of doubling the population size of hellbenders in 15 years, with increased recruitment in the early age classes, as the population viability goals for the model. Once discussions were completed, the modelers began running the preliminary models.

While the modelers were working, the rest of the group focused on the next task, which was a structured brainstorming exercise to identify the key issues affecting the long-term survival of the species. The results of this exercise were themed into three threat-based working groups:

1) Biological/human-induced threats (exotic species, predation, over collecting, disease, and management/research techniques);

2) Land use (land use, siltation, agricultural runoff, and water quality); and

3) Public use (public use and recreation).

Two additional groups were formed as the workshop progressed. One group focused on the role captive breeding can play toward species survival, and the other was devoted to identifying management and research recommendations specifically for the hellbender populations in the Eastern U.S.

Each of the three threat-based groups was then asked to develop causal flow charts for each threat (see Sections II, Working Groups Reports). This was an extremely demanding set of tasks but worth the effort. The majority of participants have been working together on these issues for some time and were looking for consensus around priority management and research efforts. This exercise helped them to identify the pressure points in the system and where their efforts have the potential to make a measurable improvement.

Each group was asked to:

1) Review their threat categories and add any that are missing.

2) Discuss each threat in terms of its root causes and its ultimate impact in the population(s).

3) Illustrate the system from root cause to ultimate outcome as a causal flow chart.

4) Note on chart:
   a) The relationships and information that are considered facts (F) and those that are considered assumptions (A).

   b) Points in the system that can be quantified (Q) and modeled (*Note: this information was provided to the modelers as soon as possible so it could be incorporated into the model and the results could then inform the development of recommendations*).

   c) Points in the system that we can influence (I).

   d) Points in the system where research is needed (R).

The causal flow charts were presented in plenary and, after incorporating the comments received, a text description was prepared for each. This description included the information captured on the charts regarding facts and assumptions, quantifiable points in the system, things that can be influenced and areas where research is needed.

At each plenary session, a presentation was made of the preliminary modeling results. Projections of population viability for both hellbender subspecies in the Midwest are poor; both metapopulations are projected to decline by more than 50% in 12-16 years, viability of all

individual populations is low after 20-25 years (N<100, gene diversity < 90%), and risk of metapopulation extinction is high within 40-50 years. Participants recognized that the projected viability of hellbender populations would be improved if the agreed upon population goals were achieved. Model results suggested ways in which population viability could be improved – for instance, by reducing or eliminating the risk of intensive collecting events or promoting positive population growth.

Limited data are available for the Eastern hellbender populations outside of Missouri. Best guess estimates of these fragmented populations were made during the workshop, leading to an estimate of over 300 populations ranging from 50 to 5000 individuals each. Model projections for Eastern populations differed substantially for these populations depending upon estimated demographic rates that are not well known. Better demographic and population status data, especially for the main Eastern populations, was identified as a vital need for accurately projecting the future viability of Eastern hellbender populations and the potential impact of management actions.

Each group listed and prioritized the items they identified as things that can be influenced (I); and for the areas where research is needed (R). Prioritization was done based on the item's potential impact (if addressed) on hellbender survival. After the plenary presentations, the working groups brainstormed potential recommendations to address each I and R on their causal flow charts.

All potential solutions were discussed, considered, and ultimately prioritized (based in part on scenario testing results) to identify those most promising, and then recommendations and detailed actions were developed for implementation of top priority solutions.

Outcomes

Workshop participants used the best available information and their expertise to develop recommendations addressing the key issues facing the survival of hellbenders. All recommendations were presented in plenary session so all participants had an opportunity to offer input into the final report of each group. These recommendations are listed below. More detailed recommendations, including specific action steps, timelines and responsible parties, can be found in Section II of this report.

Group 1 Recommendations (Biological/human-induced threats)

1) Build a baseline of diseases found in wild hellbender populations.
2) Develop a post-mortem/protocol/pathology network.
3) Standardize and unify monitoring/research efforts/methods.
4) Upgrade the protection status of hellbenders and prevent illegal collecting.
5) Determine possible impacts of predation by native and non-native fishes and native mammals.

Group 2 Recommendations (Land Use)

1) Initiate intensive water quality analysis and monitoring program on all prioritized hellbender streams.
2) Conduct a comprehensive threat analysis incorporating stakeholder involvement/comments, GIS analysis, modeling and, where needed, field measurements.
3) Standardize survey methodology for conducting meta-population studies and long-term monitoring of life history and population demography, and conduct baseline studies.
4) Measure and correlate sediment deposition rates to hellbender demographics from a wide range of streams (impacted to pristine).
5) Using surrogate species, determine acute and chronic toxicity of heavy metals, organophosphates, ammonia, etc. to various life stages (eggs, larvae, and adults) of hellbenders.
6) Determine the effects of endocrine disrupters on hellbender eggs, larvae, and adults.
7) Develop reintroduction and augmentation and captive husbandry protocols and techniques.
8) Develop comprehensive watershed conservation plans and agreements.
9) Identify stakeholders within priority watersheds and develop a comprehensive outreach program.
10) Develop a comprehensive, consensus-based, best management practices manual for hellbenders.
11) Federally list the Ozark hellbender and petition for listing the Eastern hellbender as a federally threatened or endangered species.

Group 3 Recommendations (Public Use)

1) Educate recreational users regarding effects of habitat disturbance.
2) Formulate guidelines for river access construction and bridge placement.
3) Inspire local landowners and river users to value and protect the hellbender.
4) Lobby for new environmental laws to improve water quality.
5) Inform anglers about impacts on hellbenders from releasing bait (disease transmission, habitat and prey competition).
6) Seek legislation in each state regarding issues such as collecting hellbenders and dumping bait. Some states in the eastern part of the range have live bait regulation that allow hellbenders to be collected legally. Hellbenders need to be removed from the list for bait collection.
7) Support ongoing and new research on the effects of introduced hormones on the health and immune systems of hellbenders in streams.
8) Support research into other potential threats related to public use and recreation such as disease in the bait industry, competition/predation from released bait, and effects of noise from recreational vehicles.

Group 4 Recommendations (Captive Breeding)

1) Collect eggs from Eastern populations of hellbenders for research and from Midwest hellbender populations (Ozark and Eastern Hellbenders) to head-start for release.
2) Produce animals for captive assurance colonies to maintain genetic diversity, for experimental release and reintroduction where appropriate, and for research purposes.
3) Investigate possibility of establishing "semi-natural" outdoor breeding facilities for hellbenders within their range.
4) Conduct research to determine:
    a. The effect of rain and lowered light levels on the initiation of breeding activity;
    b. How water quality affects propagation efforts at hatcheries and other facilities that use potentially contaminated water from rivers;
    c. What is a nutritionally healthy vs. unhealthy hellbender;
    d. The types of nest sites that should be provided in a captive situation to encourage breeding; and
    e. The feasibility of applying artificial insemination techniques to hellbenders.

Group 5 Recommendations (Management and Research for Hellbenders in Eastern Part of Range)

1) Establish an Appalachian Hellbender Assessment Project to determine the current status and distributions of Eastern populations of hellbenders as well as provide baseline data (weights, lengths, etc.). Information about Eastern populations is needed to address questions concerning Federal listing at the species level (including Ozark subspecies).
2) Develop a monitoring program to augment baseline data with monitoring data from multiple populations in the eastern United States.
3) Provide education/information on the importance of hellbenders to the public.
4) Welcome support and partnership with Ozark Hellbender Working Group.

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Section II
Working Group Reports

Group 1: Biological Threats, Management, and Research (exotic species, predation, over collecting, disease, and management/research techniques)

Participants: *John Ackerson, George Cline, Rich Collister, Jeff Ettling, Karen Goellner, Victoria Grant, Brian Greene, John Groves, Yue-wern Huang, Tom Johnson, Alicia Mathis, Max Nickerson, Richard Shelton, Zack Walker, Ben Wheeler*

Initial Discussion

Our working group was tasked with discussing the following threats to the survival of hellbender populations: 1) exotic species, 2) predation, 3) over collecting, 4) disease, 5) research techniques, and 6) management issues. We decided as a group that all causal chains would lead to decreases in either reproduction or survival of hellbenders (or both), and terminate in a decrease in hellbender population size (increase in extinction risk).

Effects of Exotic Species

In the past decade, numerous publications have indicated the negative impacts of exotic species on native species [see websites for ISSG (The Invasive Species Specialist Group), SSC (Species Survival Commission), and IUCN (World Conservation Union)]. Due to the potential threat of many exotic species, this working group determined that trout (brown trout and rainbow trout), non-native crayfish, mussels, escaped/released bait species and aquatic vegetation pose a potential threat to hellbenders.

The importance of each of these taxonomic groups will need to be determined at a species specific level through further monitoring and research. For example, brown and rainbow trout have different life histories, and thus might have different impacts to hellbender populations. Likewise, there can be differential impacts on the stages of hellbender development (eggs, larvae, sub-adults, adults). Numerous publications over the past 10 yrs have shown the negative impacts that non-native trout have on different life history stages of amphibian species [e.g., Yellow-legged frogs (*Rana muscosa),* Pacific giant salamanders (*Dicamptodon tenebrosus*), Long-toed salamanders (*Ambystoma macrodactylum*), Northwestern salamanders (*Ambystoma gracile*) to name a few]. Investigations of behavioral responses of hellbender larvae by Missouri State Univ., Springfield indicated that hellbender recruitment might be adversely affected by non-native trout and numerous states identified non-native trout as a potential threat to hellbenders in the Eastern Hellbender Status Assessment Report. It is likely that most exotic introductions will affect smaller hellbenders more than adult hellbenders, but more information is warranted to determine the impacts of non-native trout on hellbenders in overlapping cold water habitats.

Most exotic species are thought to be present directly or indirectly as the result of recreational activities, such as fish stocking, catch and release, etc. These introductions can cause direct and indirect impacts to hellbender populations. For example, the introduction of a predator species can directly reduce a population through predation of hellbenders or indirectly through competition for resources. The introduction of a seemingly harmless species, such as a non-native crayfish may also cause problems. An introduced crayfish species that is not palatable to hellbenders may out-compete native crayfish, causing a reduction in available prey. A second threat is the introduction of a disease that may also devastate the prey base. In addition, the

introduction of an exotic species that replaces a native species may have a different life history, and thus may negatively influence the environment (e.g., a native crayfish that feeds primarily on detritus is replaced with a non-native crayfish that feeds primarily on live fish). The habitat also may be impacted by in-stream process level interactions, for example exotic vegetation may cause increased siltation rates, which in turn cause changes in the benthic structure of the habitat. All of these interactions can directly affect hellbender survivorship, and breeding sites availability, and thus lead to decreased population sizes of hellbenders.

The group discussed whether the relationships mentioned above are fact and which are assumptions or hypotheses. Although many of the relationships are known to be true for some systems, few have been examined in relation to hellbenders. We recommended that research be focused on determining the specific impacts of these species on hellbenders.

Effects of Native Predators

Predation by native predators can influence decline of hellbenders through two basic processes. First, predation can increase due to introductions of hellbender predators for conservation (e.g., river otters) or management (e.g., sport fishes) or if predation becomes more important because of other issues (e.g., stress leads to increased vulnerability to predators). Potential native predators include:

1) River otters (re-introduced into hellbender habitat)
2) Fishes: walleye, sauger, rock bass, smallmouth bass, sculpin, suckers, and green sunfish
3) Snapping turtles (common and alligator)
4) Mink and raccoons
5) Water snakes

Predation can differentially effect: eggs, larvae, sub-adults, and adults. We addressed these three potential impacts separately.

Predation on eggs

We assume that eggs are consumed by fishes (sculpins and suckers) and water snakes, leading to decreased recruitment and decreased population size. We know of no reason to suspect that populations of these predators have increased during the period of hellbender decline.

Predation on larvae/ sub-adults

We assume that larvae and sub-adults are consumed by fish (smallmouth bass, catfish, walleye), river otters, mink, raccoons, wading birds, and snapping turtles, leading to decreased recruitment and decreased population size. Both river otter and walleye have been introduced into streams containing hellbenders.

Predation on adults

We assume that adult hellbenders are consumed by river otters, wading birds, and snapping turtles. River otters have been introduced into streams containing hellbenders. Predation by river otters, mink, and raccoons is suspected to be particularly intense during periods of drought when water levels are low.

Illegal Collecting

What are the major issues?

1. Mass collecting of hellbenders for the commercial pet trade (primarily overseas).
2. Hobbyist collecting of small numbers of hellbenders for personal pets.
3. Incidental/accidental take of hellbenders by anglers.

Commercial collectors can cause substantial damage to hellbender populations through mass removal of specimens from a given locality. These unscrupulous collectors utilize the scientific literature to locate the sites where hellbenders are known to occur or where they occurred formerly. This illegal collecting results in the removal of large numbers of adults and sub-adults from these populations. There are two documented illegal collections of hellbenders on the North Fork of the White River which resulted in the removal of 281 individuals. These animals were being shipped to Japan for the pet trade. Only eight specimens were recovered from this collecting event.

Herpetological hobbyists are known to impact hellbender populations through the removal of small numbers of specimens for personal use. Although the collection of these small numbers may not seem of importance, when multiple individuals engage in this behavior it can ultimately have a significant impact. In many instances these specimens do not survive and/or are released in locations other than where they were captured.

Anglers can also impact hellbender populations through the accidental/incidental take of specimens on hook and line or by gigging for rough fish in some states. In some instances the angler may cut the line and release the hellbender, but in many cases the animal is killed out of fear.

The combination of these illegal collecting activities can have a substantial impact on the survival of hellbender populations in many river systems.

Disease

The working group recognized that disease was a very serious potential problem in hellbender populations. Disease epidemics can lead to catastrophic population declines and often limits the geographic distribution of species. Amphibians as a whole are suffering greatly from disease, and it is likely that hellbenders are no exception. There are a large number of diseases that potentially effect hellbenders, but very little is known about which are actually present in populations. This working group was particularly interested in the potential for increased stress levels (e.g., due to rising water temperatures) to decrease the immune response, making individuals more susceptible to disease. This is a particular worry because of the body of literature suggesting a link between stress and disease resistance, a recent paper (Pounds et al. 2006) demonstrating and interaction between global warming and chytrid fungus infections in amphibians, and an anecdotal account from the Saint Louis Zoo of captive animals stressed during a power outage that subsequently developed a chytrid infection. Thus, this working group suspects that pre-existing opportunistic diseases are a more likely threat than a new zoonotic.

Research Techniques
Research techniques identified that were potentially harmful to hellbenders were the use of MS222, disturbance of habitat, frequency of surveys, cross-contamination between individuals and populations, and techniques used to manage sport fisheries, such as supplementation and electro-shocking. We determined that these and other techniques can cause stress to individual hellbenders, potentially making all life stages more susceptible to disease and predation.

Management
This working group determined that the management/protection of the hellbender is weak in several aspects, which causes confusion/problems across the range of the hellbender. The lack of protection is largely due to the high level of public interest (monetary) in sport fishing, and thus there is little political support for protection. Many states have few laws to protect hellbenders, while other states have laws that allow the removal of hellbenders for bait. The lack of or insufficient protection of hellbenders is also present in states with laws protecting the hellbender due to a lack of judicial enforcement. This leads to the removal of hellbenders from the wild and an overall decrease in population size. We suggest that because states have inconsistent laws regarding protection of hellbenders, facilitating illegal poaching and smuggling across state lines (and eventually overseas), that a potential solution for the problem would be federally listing them as endangered. Most group members agreed that the best chance of federal listing would be for the Ozark subspecies and that the two subspecies should be split for purposes of listing.

Research Recommendations
We recommend that research be focused on the impacts of exotic species on hellbender populations, especially those that might be considered predators on smaller individuals. Research efforts should also be directed towards the effects of native predators such as river otter and native fish on hellbender populations. Additionally, the presence and effects of algal blooms and algal toxins should be investigated. Disease is also an important area for research. Specifically, baseline studies of existing diseases within the populations need to be formulated. The results of the studies should be compared across healthy and unhealthy populations. Any individuals with infections should be biopsied or even necropsied if deemed necessary. Managers need to be educated on the effects of various techniques, such as MS-222, electro-shocking and other collecting techniques.

Prioritizing of Recommendations
In order to prioritize issues generated during brainstorming for more discussion and specific recommendations, each group member was supplied with six sticky dots. The dots represented 'votes' for the specific issues next to which they were placed. The voting was as follows (the number in parentheses is the number of votes the topic garnered):

Develop baseline data on the distribution and relative abundance of existing exotic species. (2)
Impact of trout on various sizes classes of hellbenders. (1)
Palatability of hellbender larvae by trout. (3)
Microhabitat overlap between trout and hellbenders. (1)
Hellbender behavior in streams with/without trout (1)

River otters as competitors/predators. (3)

Impact of native fish on specific age classes of hellbender. (1)
Palatability of hellbender eggs. (1)

Develop a post-mortem protocol & network of disease specialist. (11)
Distribution of diseases. (1)
Lack of regeneration of limbs. (1)
Sanitation techniques. (2)
Standardize survey techniques. (1)
Effects of handling techniques on hellbenders. (3)
Establishment of long-term monitoring sites. (2)
Improve communication among researchers. (2)
Develop semi-natural breeding facilities. (3)
Nutrition. (2)

Prioritization

The specific issues listed above were organized and collapsed into broader categories and votes for the broader categories were calculated by counting the votes of their component issues.

1) Develop a baseline for diseases already present in hellbender populations. (16)
2) Standardize and unify research efforts/methods (15)
3) Develop a postmortem/pathology network (13)
4) Investigate predation by trout and native fishes on hellbenders (13)
5) Upgrade the protection status of hellbenders (7)
6) Continue the development of captive propagation programs (5)
7) Investigate predation by native mammals on hellbenders (3)

Disease

1. Chytrid
2. Saprolegnia
3. Numerous Bacteria (secondary)
4. Multixenobiotic Resistance
5. Viruses
6. Unknown Diseases (abnormalities, immunosuppressants, etc.)
   —At current time, abnormalities have only been noted in Missouri/Arkansas hellbenders. This might be due to either the lack of attention by researchers to report abnormalities in other states or abnormalities are currently not present in other states.

Figure 1. Flow diagram showing the potential influence on disease on hellbenders.

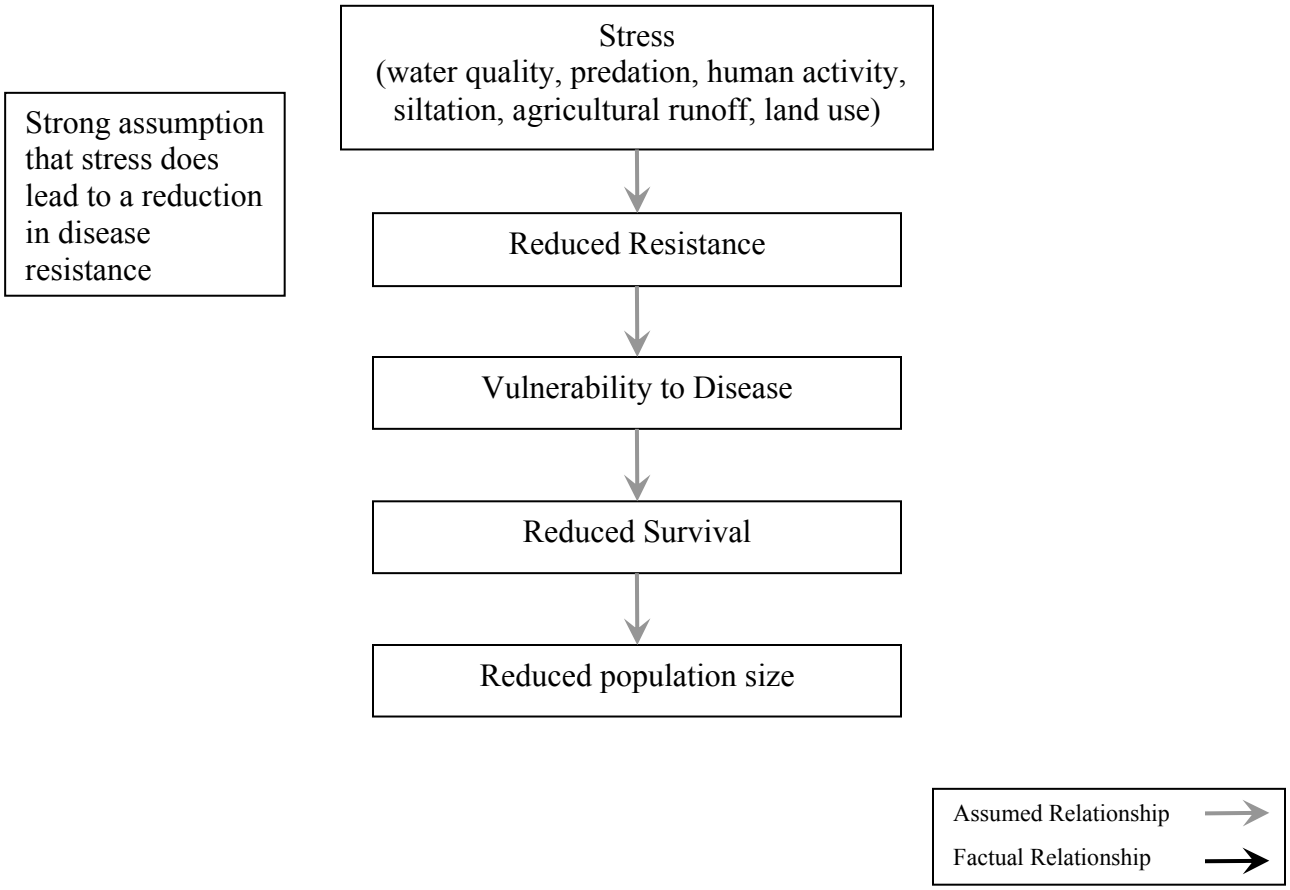
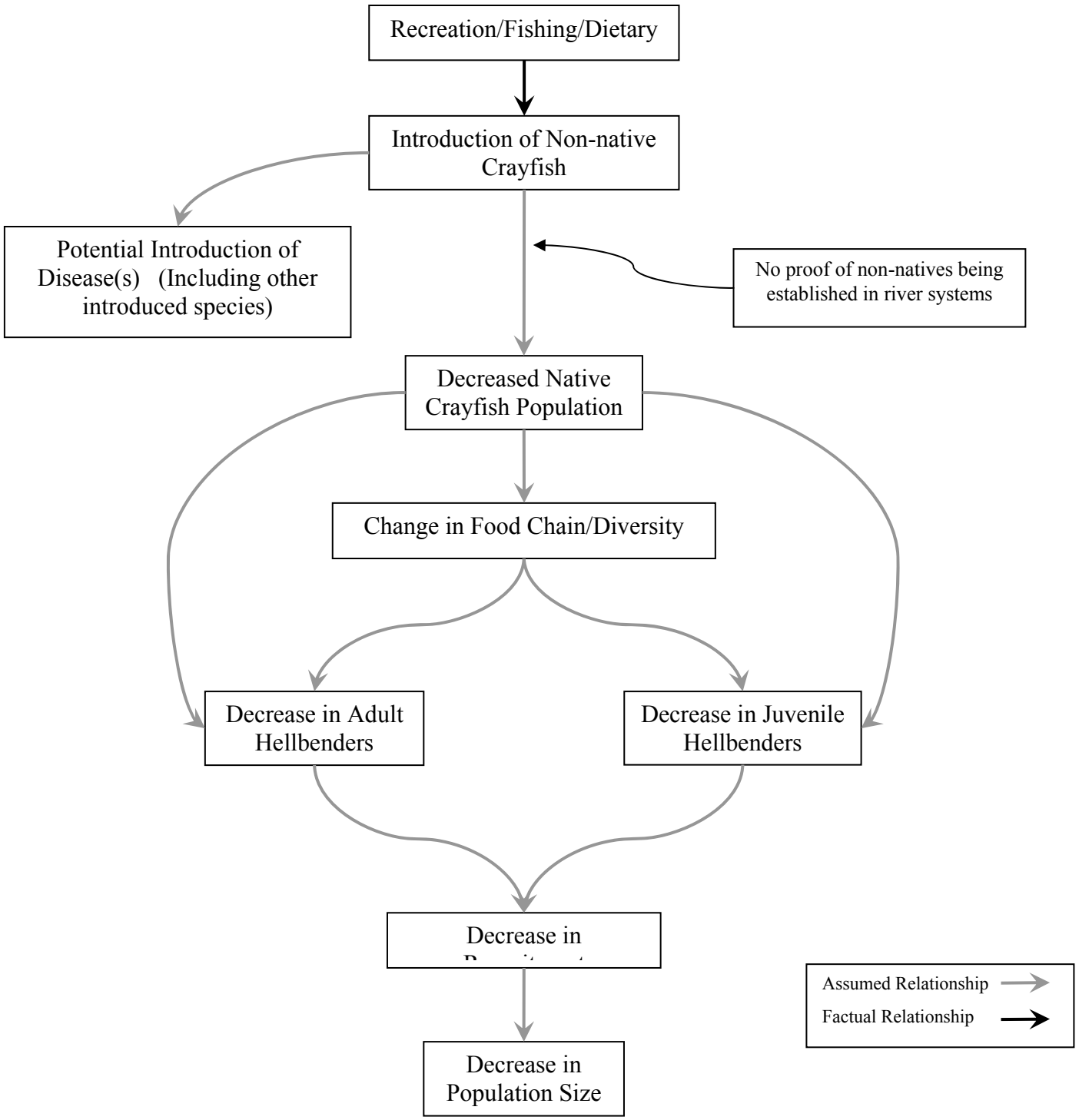


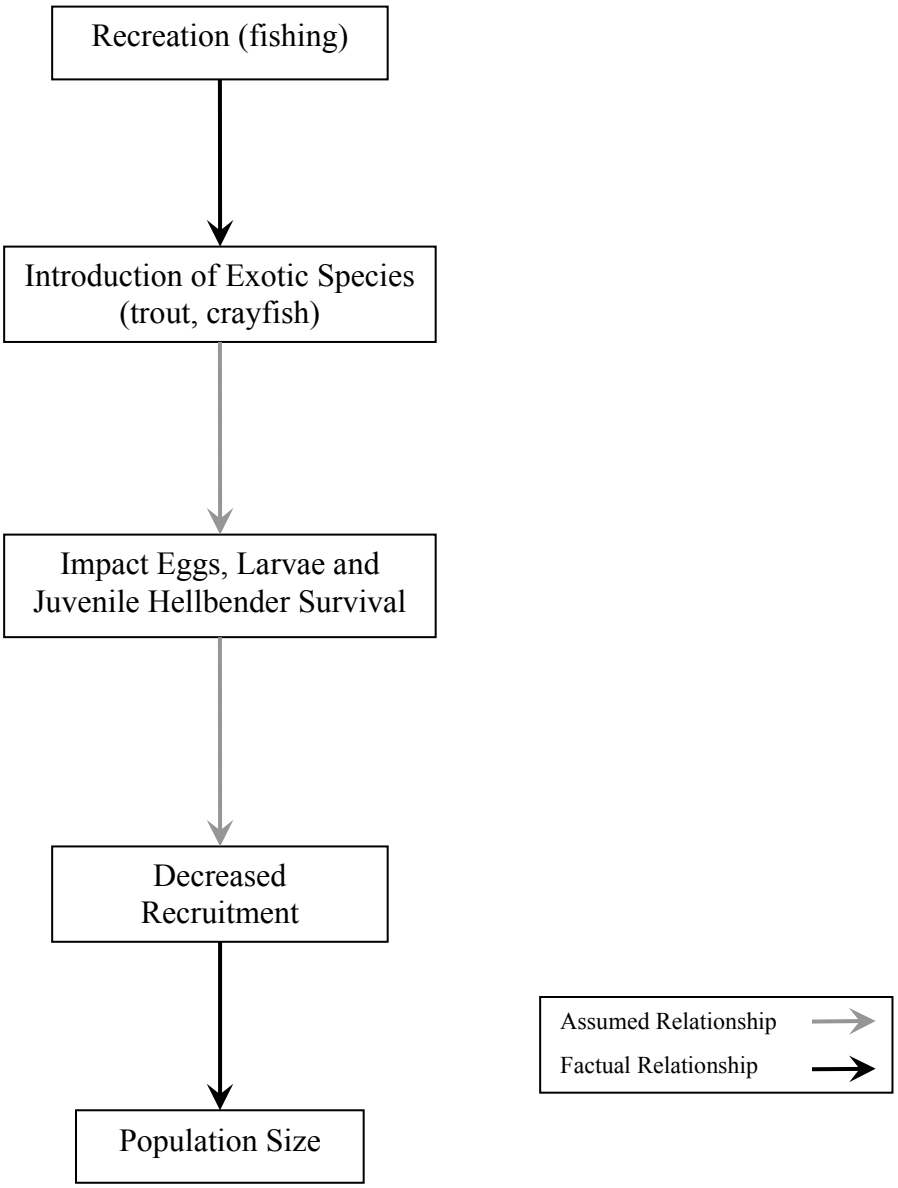
Figure 2. Flow diagram showing the potential influence of non-native species on hellbender population size.



Exotic Species—Definition

1. Trout (Rainbow, Brown) ⟶ Change in Native Fish Species
2. Crayfish (Louisiana Red)
3. Mussels
4. Escaped/Released Bait Species
5. Aquatic Vegetation

Figure 3. Flow diagram showing the potential influence of recreational fishing on hellbender population size.



Management/Research 1

1. MS222 use
2. Electroshocking
3. Cross-contamination
4. Fisheries Management (introductions, supplementation, survey techniques, electroshocking)
5. Hellbender Survey Techniques (mechanical equipment use, rock flipping, frequency)
6. Lack of protection (inconsistent by state and federal)

Impact

Figure 4. Flow diagram showing the effect of stress on hellbender population size.

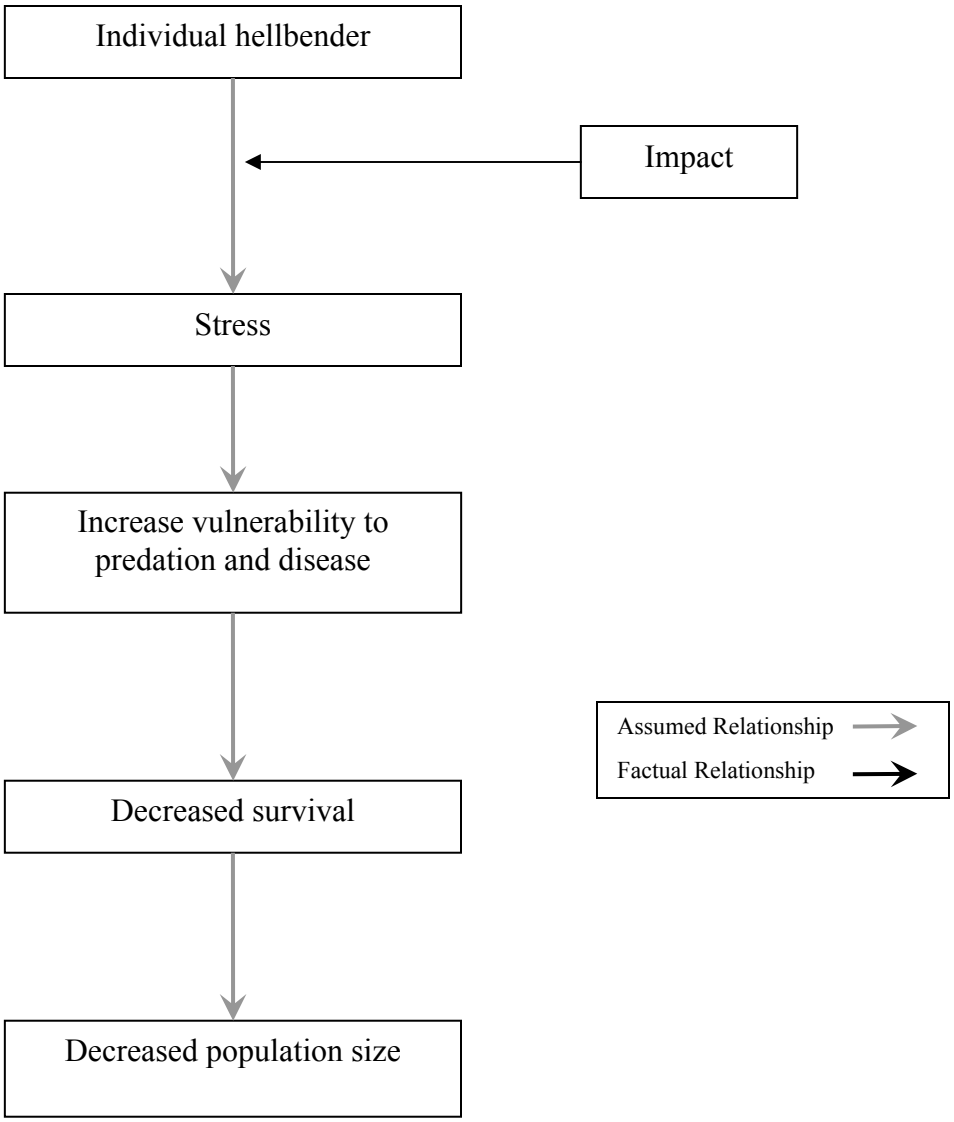


Figure 5. Flow diagram showing the effects of lack of protection of hellbenders on hellbender population size.

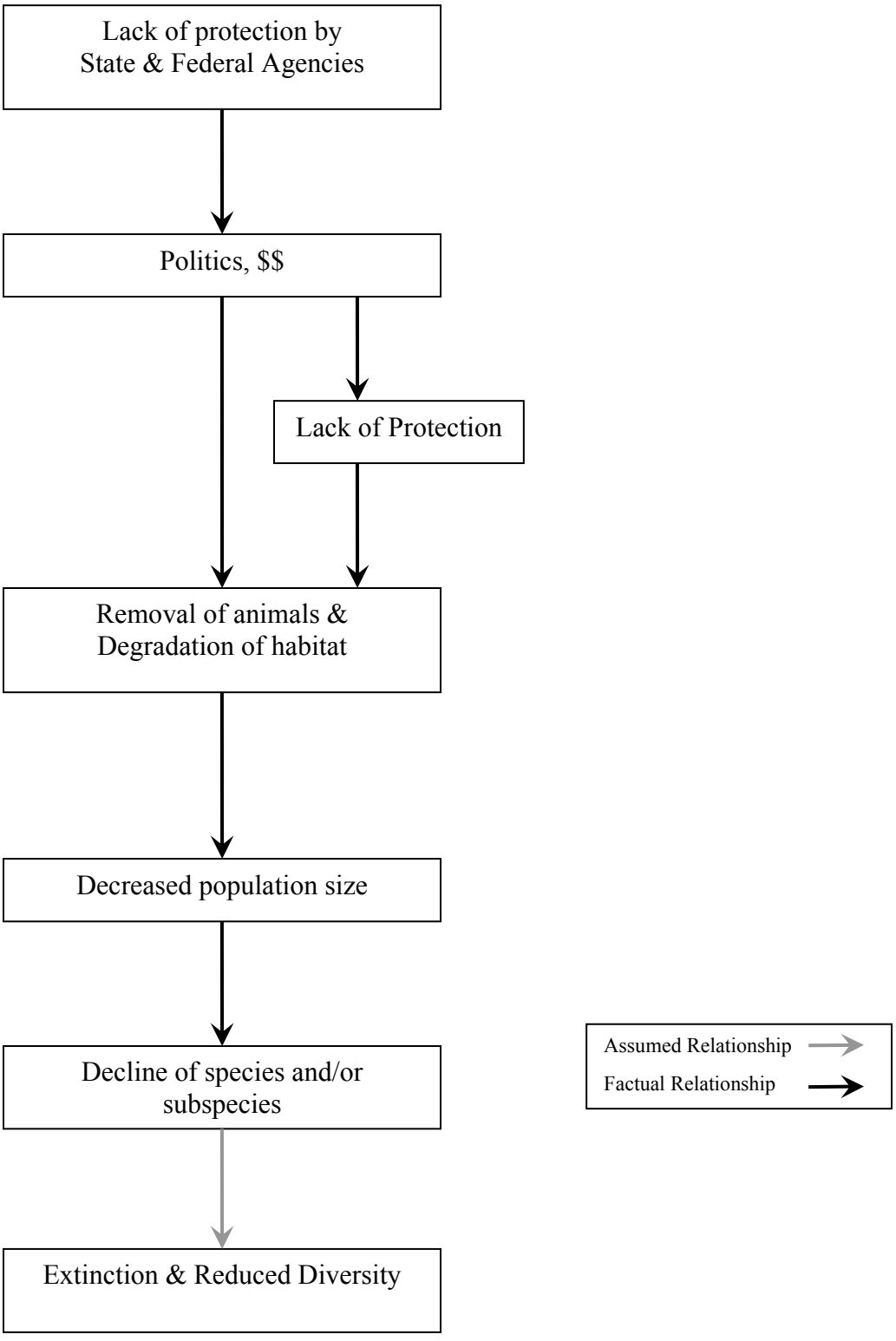
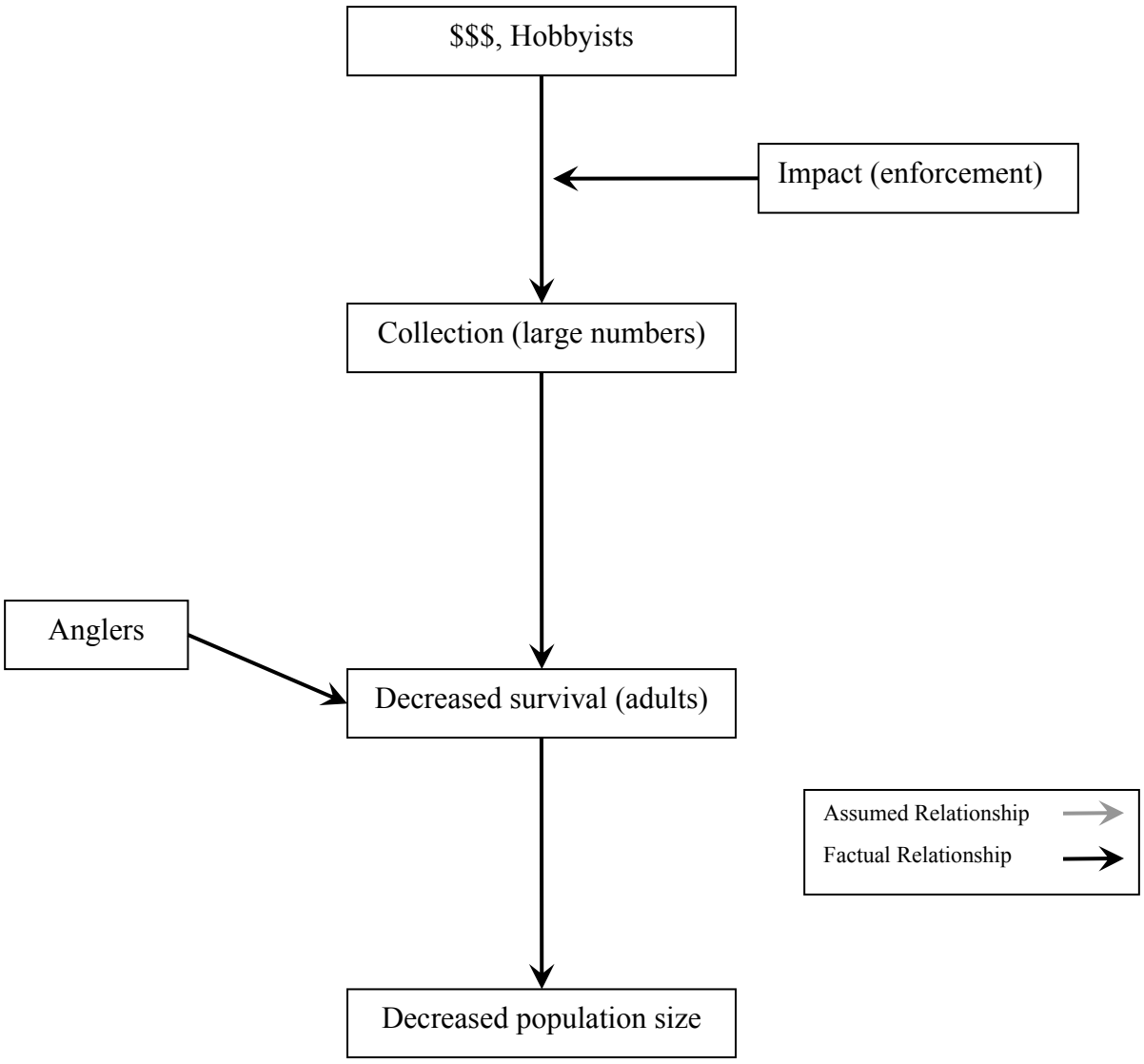


Figure 6. Flow diagram showing the potential influence of over collecting (refers to illegal collecting) on hellbender population size.

1. Pet trade (commercial)
2. Hobbyists
3. Anglers (accidental take)

Adult and subadult hellbenders



Predation

1. Re-introduction of native species (e.g. river otter)
2. Increase in population size of native fish species (walleye, sauger, rock bass, small mouth bass, sculpin, suckers, green sunfish)
3. Snapping turtles (common and alligator)
4. Mink and raccoons
5. Water snakes

Figure 7. Flow diagram showing the effects of predation on hellbender population size.

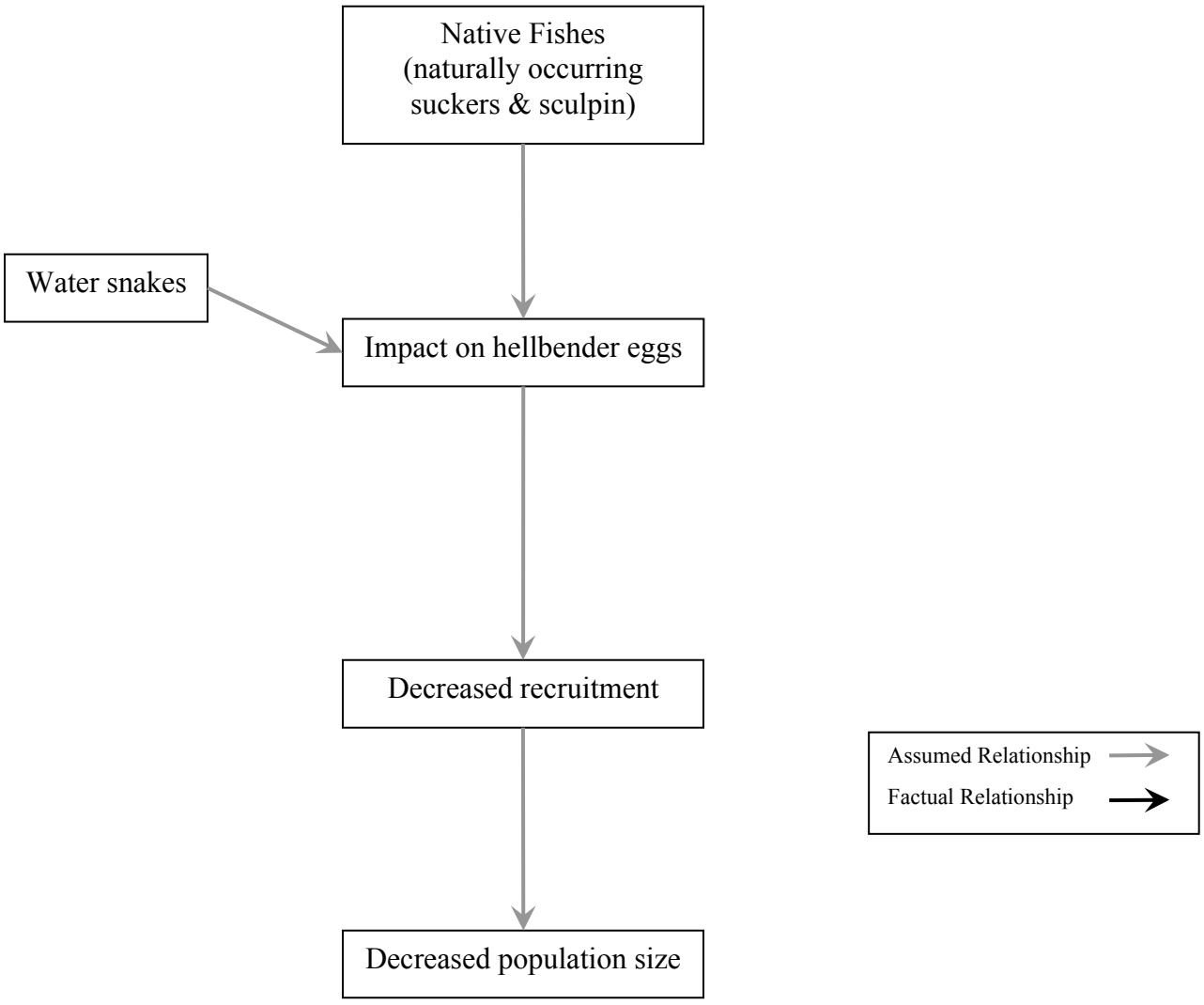
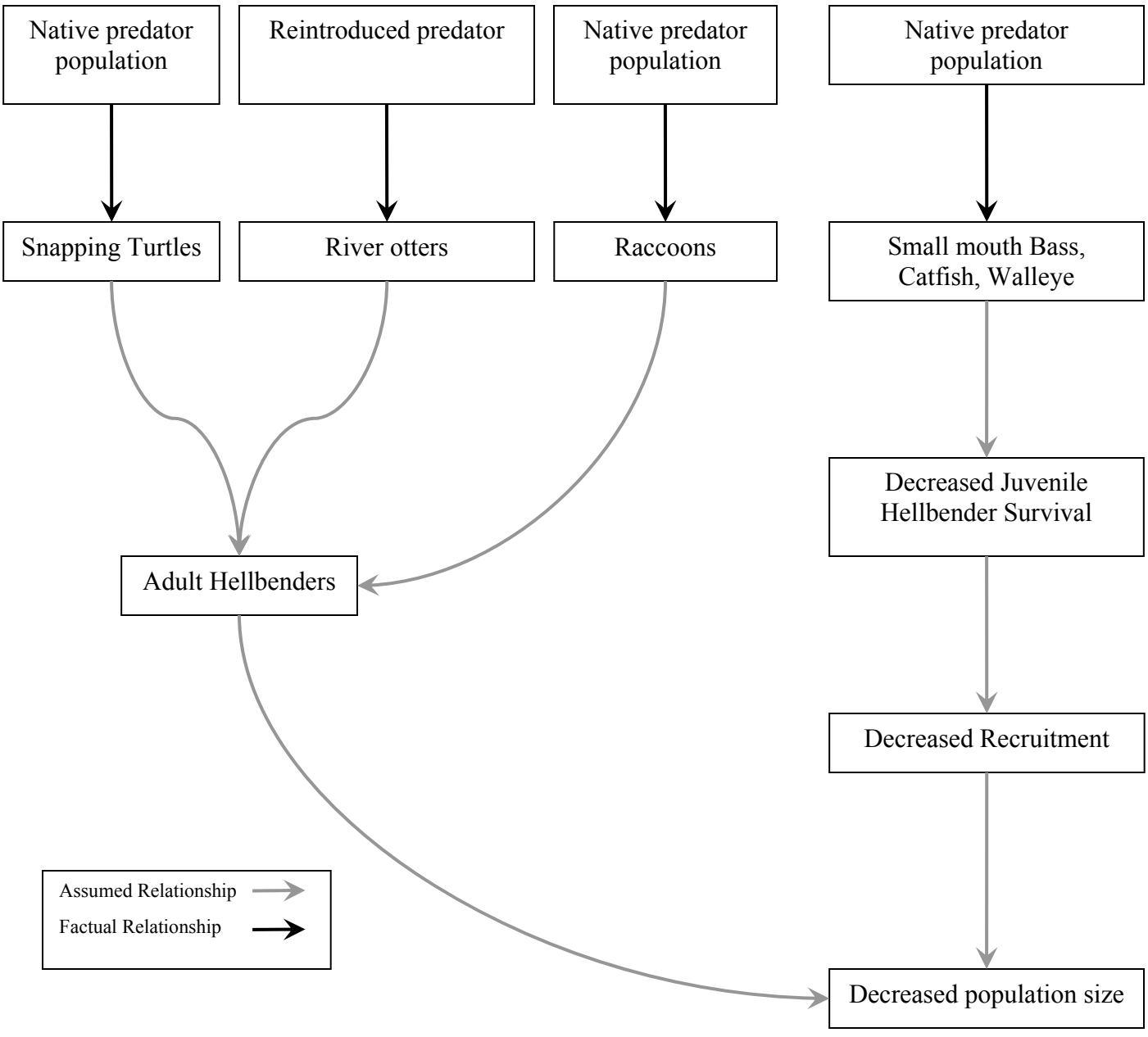


Figure 8. Flow diagram showing the effects of predation on sub-adult hellbender (12 inches or less) populations



Recommendations

1) Recommendation: Build a baseline of diseases found in wild hellbender populations

Why:

1. Determining the potential disease threats that are present in hellbender populations will aid in detecting and treating them in the future.
2. The ability to separate novel pathogens from pre-existing pathogens that have become symptomatic due to environmental stressors allows for the root causes of disease to be identified and ameliorated more efficiently.
3. Threats cannot be prioritized accurately without quantifying the impact diseases are having on hellbender populations.

Action Steps:

1. Compare healthy (stable) populations with unhealthy (declining) populations (geographic considerations: Ozark ecoregions vs Eastern population ecoregions). This may identify candidate diseases that impact populations differentially.
2. Collect size-specific data on abnormalities and external parasite loads of hellbenders.
3. Collect blood samples for disease analysis and future DNA analysis.
4. Collect sample from skin swabs for chytrid testing.
5. Examine preserved specimens for presence/absence of abnormalities (has been done for preserved specimens for Spring River) and chytrid fungus.

Who: Missouri Department of Conservation (MDC), Arkansas Game and Fish Commission (AGFC), University of Missouri-Rolla (UM-R), Arkansas State University-Jonesboro (ASU), and Saint Louis Zoo, St. Louis, MO.

How: Collect samples from hellbenders in river systems across the USA.

Funding Possibilities: Saint Louis Zoo, MDC, and UM-R.

Timeline: Present and on-going, estimated sample collection will be done by October 2006 for Missouri

Responsible: J. Briggler (MDC), K. Irwin (AGFC)

Evaluation techniques: All rivers tested for presence/absence of chytrid and selected heavy metals.

2) Recommendation: Develop a post-mortem/protocol/pathology network

Why:

1. Standardization of data collection techniques and a central repository for samples/specimens will make data more useful to researchers and easier to access.
2. Allows insight into causes of mortality.

Action Steps

1. Establish a pathology network for carrying out pathology studies on hellbenders.

2. Hold a meeting of selected veterinarians and field biologists to develop protocols for data collection.
3. Create a central depository for samples. (Research need)
4. Samples should not only include tissue, but environmental samples as well. Other data should include location and details of site. (Research need)
5. Annual report of processed hellbenders will be written and distributed to appropriate individuals. (Research need)

Who: Saint Louis Zoo (Mary Duncan) contact for network establishment, addition people as needed, NC State University, Alan Pessier with San Diego Zoo

How: Have a pathologist draft a protocol for data collection, perhaps based on pre-existing protocols used for other amphibians (e.g. frogs). Completed protocol distributed through state conservation department.

Funding Possibilities: In kind match, Saint Louis Zoo, UMR, MDC

Timeline: Development of protocol within 6 months (April 2007)
On-going data collection.

Evaluation techniques: Protocol written by April 2007, samples collected according to protocol.

3) Recommendation: Standardize and unify monitoring/research efforts/methods

Why:

1. To prevent habitat degradation evident from some of the more destructive sampling methods.
2. Reduce mortality and injuries to sampled hellbenders.
3. Facilitate comparisons between studies.
4. Reduce redundancy of effort through improved communication.

Action:

1. Evaluate the use of MS-222 and other anesthesia on hellbenders.
2. Determine effects of electroshocking on hellbenders.
3. Evaluate and standardize collection methods.
4. Establish a protocol on handling techniques.
5. Establish a protocol for sanitation of equipment.
6. Establish standardized PIT tag use by field researchers.

Who: Jeff Briggler and Kelly Irwin for Midwest; experts on eastern US hellbender populations

How: Collaboration of interested parties (e.g.. Regional/ Ozark Hellbender Working Groups)

Funding possibilities: State and federal agencies, universities, zoos

Timeline: Draft protocols will be developed by April 2007, ASAP
Evaluation: Protocols accepted and implemented

4) Recommendation: Upgrade the protection status and prevent illegal collecting

Why:

1. Impede the illegal collecting of hellbenders for the pet-trade.
2. Increase enforcement and judicial support.
3. Protect sensitive populations from poaching and habitat disturbance.
4. Increase public awareness/sensitivity.
5. Increase consistency in state-by-state protection.
6. Prevent habitat destruction and hellbender harassment/stress through general public use of the habitat.
7. Prevent the export of hellbenders.

Actions:

1. Lobby politicians and environmental groups (federal and state)
2. Initiate/develop "River Teams" to watch for illegal collection activities
3. Do not publish localities where hellbenders occur
4. Focus efforts on getting the Ozark hellbender listed federally
5. Contact IUCN representative to encourage the upgrading of the species from "near threatened" (see notes from OHWG)
6. CITES listed

Who: Jill Utrup (FWS), Chris Davidson, (FWS), Jeff Briggler (MDC)
Conservation International – S. Stuart
Ozark Hellbender Working Group
CITES – M. Maltese, J. Groves
Webster Grove Nature Study Society
Saint Louis Zoo – personal Washington lobbyist

How: Lobby local judicial systems where there is a lack of support
Go through the local records for environmental cases
Present a positive presentation regarding the importance of environmental legislation to the State Bar Association

Funding Possibilities: Time donation by participation, draw from educational efforts

Timeline: Lobby Senator K. Bond to support Federal listing of the hellbender (Spring 2007), Actions to coincide with local elections, Contact outreach and education offices to establish volunteer patrols in official garments to float rivers (April 2007). Federal Listing (Currently in progress).

Evaluation: Evaluate trends in environmental judicial cases prosecuted.

5) Recommendation: Determine possible impacts of predation by native and non-native fishes, and native mammals.

Why: Determine the possible impacts on hellbender populations.

Actions:

1. Conduct a palatability study to verify whether fish and/or river otters etc. feed on hellbender eggs, larva, and adults. (Research need)
2. Determine population levels of potential predators. (Research need)
3. Survey of fish stomach contents (eastern rivers) to determine whether they are feeding on hellbenders. (Research need)
4. Create artificial stream to examine whether trout etc. will feed on larvae hellbender when they are moving and foraging. (Research need)
5. Modify existing fisheries management actions if the previously mentioned actions indicate that fish are having an impact on hellbender populations. (Point in the system that we can influence)

Who: Palatability (MDC, Missouri State University-Springfield (MSU), Saint Louis Zoo, Wonder of Wildlife, Springfield, MO, NC Zoo)

Artificial stream study (MDC, Wonders of Wildlife)

Modification of Fisheries Techniques if necessary (MDC, AGFC)

VA Tech – trout stomach survey???

How: See specific actions listed above.

Funding Possibilities: MDC, universities, zoo grants, federal and state agencies,

Timeline: Depends on acquisition of fertilized eggs, stomach surveys summer 2007

Evaluation: Completion of projects

Group 2: Land use (land use, siltation, agricultural runoff, and water quality)

Participants: *Alan Christian, Chris Davidson, Adam Davis, Jody Eberly, Jeff Humphries, Amber Pitt, Stan Trauth and Jill Utrup*

Siltation/Sedimentation

Major issues:

1. Increased homogeneity of stream channels resulting in reduction of available hellbender and prey habitat.

Discussion:
All causes of siltation and sedimentation ultimately can be traced back to human population growth. An increasing demand for goods and services is one result of human population growth and expansion. Our group did not go into great detail discussing every possible cause of siltation and sedimentation. The group focused primarily on:

1. urban/rural development ("sprawl") which increases impervious surfaces, road (asphalt and gravel) density, and maintenance activities;

2. agriculture (row crops) which removes or substantially reduces/alters native vegetation from/in riparian areas and flood plains;

3. confined animal operations (chickens, horses, pigs, dairy cattle etc.) which may remove or substantially reduce/alter native vegetation from/in riparian areas and flood plains;

4. pasture land (cattle, etc) which may remove or substantially reduce/alter native vegetation from/in riparian areas and flood plains; and

5. silviculture (forestry) which may remove or substantially reduce/alter forest from/in riparian areas and flood plains.

The buffering capacity of riparian areas and flood plains is well documented in the literature. Likewise, the effects on streams (*i.e.*, increased siltation/sedimentation, erosion of stream banks, channel aggradation/degradation) resulting from removal or alteration of native vegetation structure, density, and composition is well documented in the literature.

The effects of increase siltation and sedimentation include:

1. Silt covering cobble and boulders and subsequently filling interstitial spaces, leading to:
    a. increases in aquatic macrophytes;
    b. reduction of hellbender habitat availability/quality; and
    c. smothering hellbender egg masses.

2. Increase homogeneity of stream channels, leading to:
    a. reduction in prey abundance;
    b. changes in prey composition; and

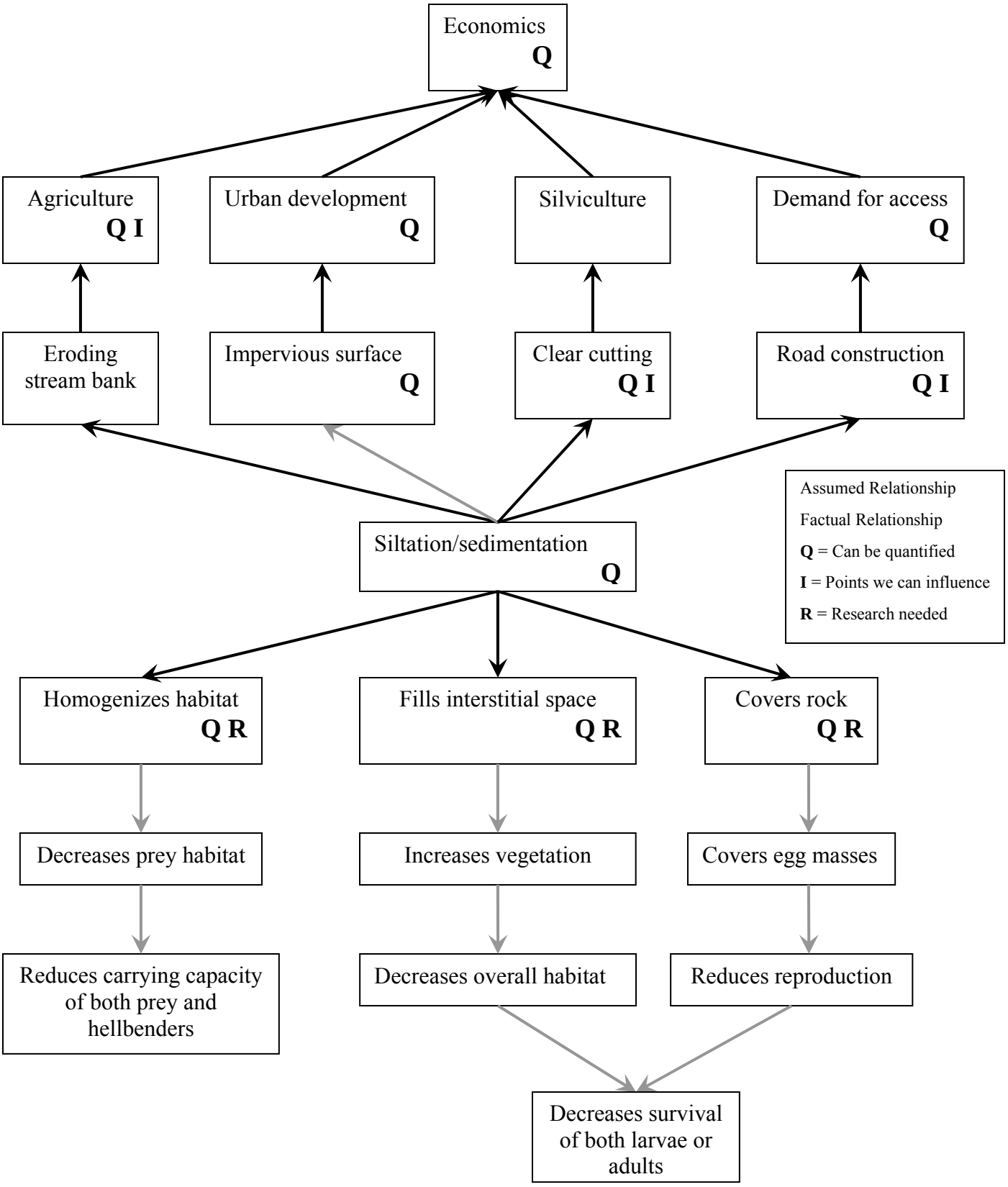
c. changes in prey quality.

3. Reduction in hellbender and prey carrying capacity, leading to:
    a. reduction in hellbender and prey survival;
    b. reduction in hellbender and prey fitness; and
    c. reduction in hellbender and prey reproduction.

The group acknowledges that several assumptions have been made in regards to effects of siltation and sedimentation on hellbenders and their prey. Specifically, research is needed to further identify and quantify effects of siltation and sedimentation on egg masses, aquatic macrophyte abundance, and thresholds where hellbender and prey habitat availability/quality is reduced. We also recognize that no knowledge exists regarding natural and current carrying capacity of hellbender streams. Therefore, we assumed, based on current knowledge regarding effects of siltation and sedimentation on other aquatic species; that hellbender survival, fitness, and reproduction most likely will decrease with increasing siltation and sedimentation.

There is no possible way for biologists working to recover hellbender populations to reduce or stop human population growth and expansion. However, we believe that by establishing a working relationship and public outreach program with communities, counties, and private landowners, we can influence how land use activities are designed, implemented, and maintained. For example, proper implementation of best management practices (BMPs) to reduce erosion of sediments is well documented and proven effective. Location and design of road networks can greatly reduce sediment loads to streams. Riparian buffer areas or "green areas", retention ponds, and natural and artificial wetlands in urban settings can help absorb storm water runoff, reduce peak flow, and ultimately trap sediments before they reach stream channels.

Figure 9. Flow diagram showing the potential effects of siltation/sedimentation on hellbender populations



Water Quality

Major Issues:

1. Prey abundance
2. Physicochemical parameters
3. Heavy metals/inorganics
4. Organic compounds
5. Nutrients/eutrophication

Discussion:

Similar to causes of siltation and sedimentation discussed above, we considered humans (and associated domestic animals) the ultimate cause of water quality degradation. There is a causal relationship between inadequacy of regulations and water quality degradation, although we are not sure whether this is fact or assumption. The group specifically discussed the following causes of water quality degradation/impairment:

1. mining activities (i.e., acid mine drainage in the eastern portion of the hellbender range, lead mining in the Ozark ecoregion);

2. urban/rural development (i.e., municipal and industrial effluents, septic leakage/runoff, pesticides, inorganic and organic compounds, etc);

3. land clearing (i.e., agricultural and confined animal operation runoff, increased turbidity, etc);

4. air pollution (i.e., atmospheric deposition of volatile organics, mercury, nitrates, etc); and

5. public use (we defer to the Public Use/Recreation Working Group).

6. livestock in streams (i.e., increased nitrogen and phosphates levels in streams)

The effect of water quality degradation on hellbender prey abundance, composition, and quality is not fully understood, but there are well documented impacts on macroinvertebrate (aquatic insects and mussels) populations associated with water quality impairment. Therefore, we made inference to water quality impacts on hellbender prey populations. We also recognized the need for more toxicological data. Acute and chronic toxicity to hellbender prey is known to impact hellbender populations through bioaccumulation of compounds.

Physicochemical parameters include numerous physical and chemical water quality parameters. We specifically discussed the effects of the following on hellbender populations:

1. temperature (increases to 70 – 72° Fahrenheit) has been documented to increase hellbender movement and energy expenditure, particularly towards habitats with higher dissolved oxygen concentrations (i.e. riffles). Temperature increases beyond 72° Fahrenheit increases stress and eventually leads to reductions in fitness, reproduction, and survival;

2. nutrient increases have been documented to decrease respiration (attributed to nitrates/nitrites) and increase macrophyte growth which increases CO_2 and decomposition rates subsequently decrease dissolved oxygen concentrations eventually leading to reductions in fitness, reproduction, and survival;

3. turbidity increases can be attributed to both biotic (plankton) and abiotic (suspended solids) factors and are natural occurrences. However excessive (greater than historic levels under similar environmental conditions) turbidity values may be an indication of excessive erosion (abiotic) or nutrients (biotic) associated with land use activities eventually leading to reductions in fitness, reproduction, and survival;

4. heavy metals/inorganic compounds compromise reproductive functions resulting in infertility or decreased sperm motility subsequently leading to decreased genetic diversity which eventually leads to reductions in fitness, reproduction, and survival; and

5. organic compounds such as endocrine disrupters reduce fecundity, and embryo development, cause changes in morphology (deformity), and skew sex ratio. This eventually leads to reductions in fitness, reproduction, and survival.

We assume that ultimately all these effects associated with water quality degradation/impairment result in decreased hellbender (and prey) reproduction, fitness, and survival. More experimental research is needed to quantify and determine the effects of various water quality parameters on hellbender fitness, reproduction, and survival.

Figure 10. Flow diagram showing the potential effects of water quality on hellbender populations

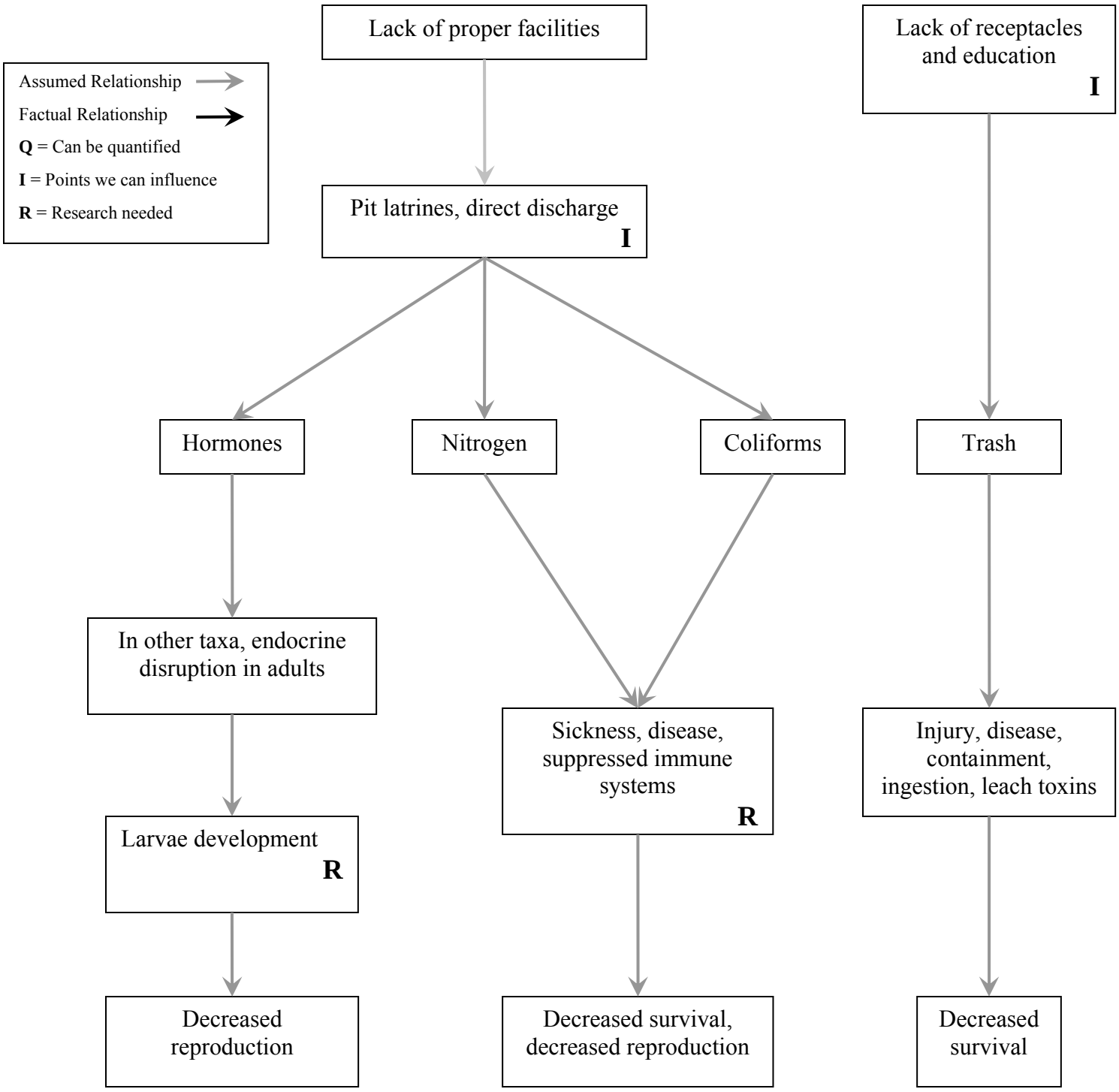
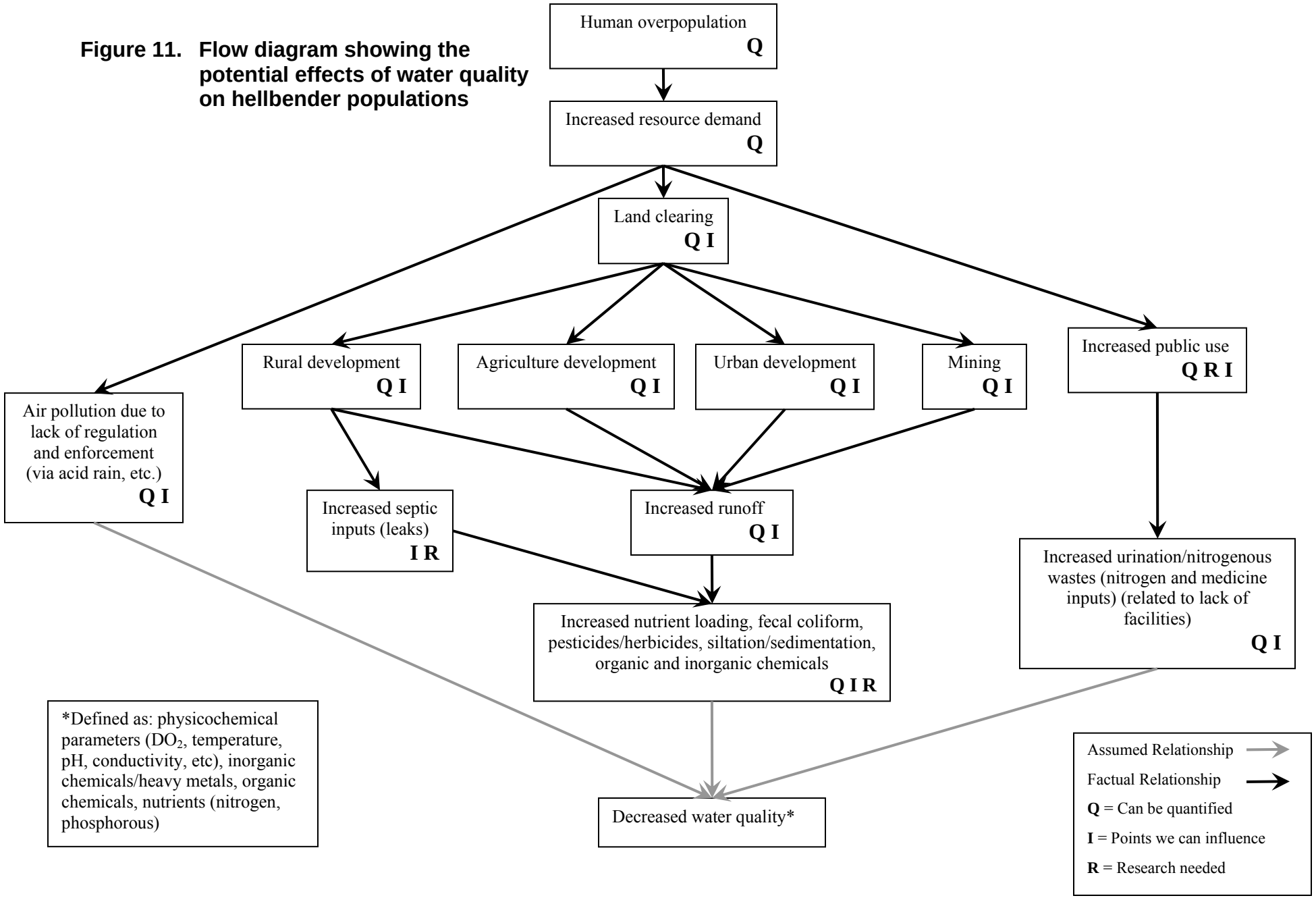
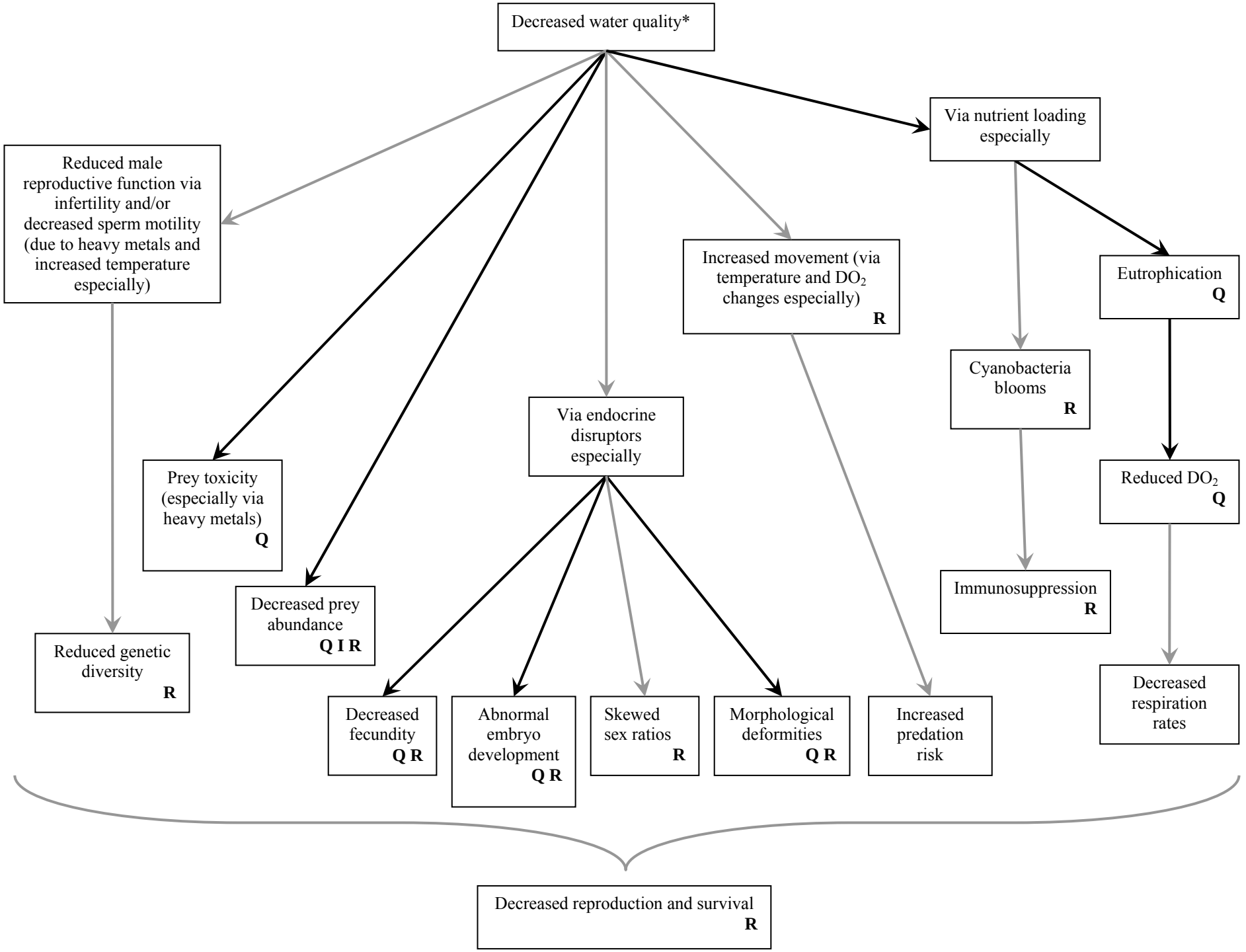


Figure 11. Flow diagram showing the potential effects of water quality on hellbender populations




Decreased water quality*
Reduced male reproductive function via infertility and/or decreased sperm motility (due to heavy metals and increased temperature especially)
Via nutrient loading especially
Increased movement (via temperature and DO_2 changes especially) R
Eutrophication Q
Cyanobacteria blooms R
Via endocrine disruptors especially
Prey toxicity (especially via heavy metals) Q
Reduced DO_2 Q
Decreased prey abundance Q I R
Immunosuppression R
Reduced genetic diversity R
Decreased fecundity Q R
Abnormal embryo development Q R
Skewed sex ratios R
Morphological deformities Q R
Increased predation risk
Decreased respiration rates
Decreased reproduction and survival R

Habitat Fragmentation

Major Issues:

1. Channel alteration (e.g. sand, gravel, rock mining; channelization)
2. Ecologically sustainable flows (dams; road crossing)
3. Natural stochastic events (i.e. flooding/drought)
4. Water removal
5. Watershed "health" and function

Discussion:

As previously discussed, human population growth and expansion is the ultimate cause of hellbender declines. Socioeconomics are the main force driving causes associated with habitat fragmentation. The only cause associated with socioeconomics that the group discussed was public demand, which includes:

1. recreation;
2. energy;
3. drinking water;
4. public access;
5. flood control; and
6. human "living space".

The group discussed several effects that lead to stream habitat fragmentation that are discussed above. These include siltation and sedimentation, water and air pollution, acid mine drainage, and stream bank erosion.

Habitat fragmentation associated with dam construction is well documented for aquatic species. Dam construction exacerbates drought, reduces minimum flow, change physicochemical parameters and fluvial geomorphology.

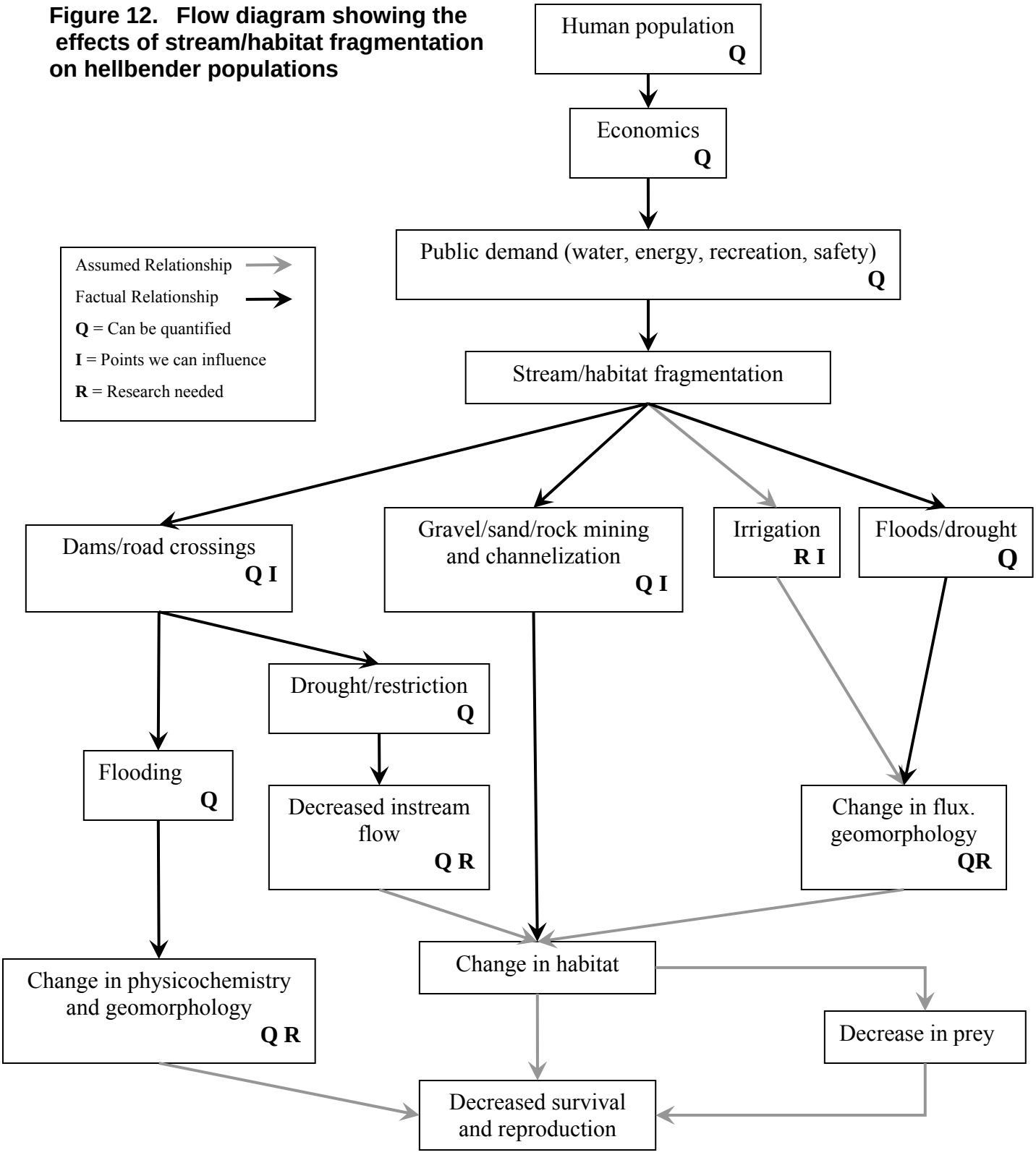
Considerable literature is available to support how improperly designed road crossings (bridges) fragment fish populations. Improperly designed bridges have been documented to change stream geomorphology, reduce gene flow, prevent longitudinal movement (passage), increase channel scour (channel aggradation/degradation), destabilize stream banks, and alter nearby instream habitat. All of these stream alterations were assumed by this group to impact hellbender populations.

Gravel mining/rock removal and channelization have similar effects as improperly designed stream crossing on streams. These activities also cause changes in physicochemical parameters and remove suitable habitat.

Three effects associated with instream water quantity were discussed by this group. These include floods/droughts, irrigation (water withdrawal), and ecologically sustainable flow. Increased water withdrawal exacerbates drought, reduces habitat availability and locations, changes physicochemical parameters, and changes fluvial geomorphology.

We assume that ultimately all these effects associated with water quality degradation/impairment result in decreased hellbender (and prey) reproduction, fitness, and survival.

Figure 12. Flow diagram showing the effects of stream/habitat fragmentation on hellbender populations



Areas over which we have influence (ranked highest to lowest):

1. **Prioritize watersheds**
   Why: Prioritizing watersheds will allow a focused effort, determined by the stakeholders and based on stakeholder criteria (e.g. best populations/habitats, best potential for conserving, etc), thus allowing for maximizing the potential and for efficiency in attaining goals. Our group can influence this because we have the researchers, NGOs, and agency personnel to initiate this process and to network with other stakeholders.

2. **Develop comprehensive watershed conservation plans and agreements**
   Why: The development of comprehensive watershed conservation plans and agreements forms a consolidated effort to conserve habitat and populations with the stakeholders and provides stakeholders opportunities to form agreements. These plans and agreements are designed to reduce impacts to stream organisms and stream ecosystems. Our group can influence this because we have the researchers, NGOs, and agency personnel to initiate this process and to network with other stakeholders.

3. **Stakeholder outreach**
   Why: Outreach is designed to inform stakeholders, develop and strengthen a stakeholder network, and form a consensus for the development and implementation of conservation plans within a region. Our group can influence this because we have the researchers, NGOs, and agency personnel to initiate this process and to network with other stakeholders.

4. **Management implementation (landowner incentives, best management practices)**
   Why: Incentives such as conservation easements or the implementation of best management practices have been shown to reduce impacts versus the possible alternatives. The use of landowner incentives for using best management practices offsets the cost a landowner may incur for using the practice or offset the difference a landowner may get for enrolling in the program versus a market value. Our group can influence this because we have the researchers, NGOs, and agency personnel to initiate this process and to network with other stakeholders.

5. **Establish networks**
   Why: Networks form a consolidated effort and communication system to make a conservation effort more efficient and effective, allowing the group to respond to needs and demands quickly and uniformly. Our group can influence this because we have the researchers, NGOs, and agency personnel to initiate this process and to network with other stakeholders.

6. **Petition for development of adequate laws**
   Why: Current state laws and regulation are not standardized in management and enforcement. These inconsistencies make it difficult to conserve the resource uniformly across the hellbender's geographic range, thus making enforcement and planning difficult. Our group can influence this because we have the researchers, NGOs, and agency personnel to initiate this process and to network with other state regulators.

7. **Balance public demand with conservation**
   Why: With increased human population size and greater accessibility to natural resources, the public demand for the use of natural resources (such as canoeing, tubing, and whitewater rafting) is increasing but potentially harmful to the resource. This increased demand for the resource may be at odds of the conservation goals of the resource. Our group can influence this because we have the researchers, NGOs, and agency personnel to initiate this process and to network.

Areas in Need of Research (ranked highest to lowest):

1. **Water quality analyses/monitoring (baseline data and trends).**
   a. Collect existing historic water quality data from hellbender streams and compile in central database.

   Why: Prioritizing water quality analysis and monitoring water quality, including looking at historical data, could provide researchers with correlative data on changes in hellbender abundances. Once a correlative is identified, it can be systematically investigated Currently, little water quality data is available.

2. **Comprehensive threats analysis that incorporates stakeholder involvement and land use changes at the watershed level.**

   Why: Because watersheds are often not only impacted by one threat, conducting a comprehensive threat analysis will allow the identification of most impacted watersheds and the threat(s) that are most likely to impact the watershed. This will then be used in comprehensive conservation planning and incorporation of best management practices.

3. **Life history (metapopulation dynamics).**
   a. Genetic studies
   b. Telemetry studies
   c. Demography studies

   Why: Basic metapopulation dynamics data are still needed for both subspecies. Genetic studies identifying phylogeographic relations, population genetics, and taxonomic entities are needed range wide to help in the management of this species, especially for guidance in translocation/reintroduction/propagation. Telemetry studies on juvenile and adult hellbenders are needed to identify movement patterns for reproduction and feeding. Demographic studies are needed for both subspecies to investigate and monitor cohorts. Long term monitoring data are needed to better predict / manage / model the population. Some of the data needed to model extinction probability in both subspecies is either lacking or weak. Thus, demographic studies can increase confidence in these parameters such as mortality, birth, survivorship etc.

4. **Determine how habitat alteration/degradation and water quality impairment affects hellbender demography.**

   Why: Data showing that habitat alteration/degradation and water quality impairment affects hellbender demography at this point is correlative. Thus, controlled experiments investigating these correlative impacts and the mechanism(s) of these impacts are needed to better manage the threat.

5. **Effects of specific compounds on health (experimental approaches).**
   a. Endocrine disruptors

   Why: Endocrine disruptors compounds have been shown to cause reproductive deformities and reduce fitness and survival in amphibians. Thus monitoring and surveillance of these compounds in hellbenders and the environment are needed to assess this potential effect. Identification of threshold levels for specific compounds at the egg, juvenile, and adult stages is needed as well.
   b. Toxicity testing

   Why: Toxic compounds (e.g. heavy metals, pesticides, ammonia) have been shown to reduce fitness and survival in aquatic organism. Thus determining the threshold concentrations of these compounds via a controlled and designed manner in egg, juvenile, and adult stages of hellbenders and the environment are needed. Threshold levels then can be used in developing regulations on these compounds.

6. **Relocation/reintroduction into suboptimal habitats (assumes captive breeding research).**
   a. Sanctuaries for experimental studies

   Why: Experiments in the relocation / reintroduction into previously occupied hellbender habitat is needed to determine the feasibility of this management option prior to the wide scale reintroduction and relocation.

7. **Ecologically sustainable flow studies in streams as needed (not required at this time within the hellbender range, but may be at some point in the future).**

   Why: Because streams may be dammed or mined for water for irrigation, determination of ecological sustainable flows for hellbenders is warranted for management of hellbender habitat and their potential prey.

8. **Identify hellbender experts in each geopolitical region.**

   Why: Identification of hellbender experts in each geopolitical region will first form a network and secondarily allow stakeholders to respond to issues and dissemination of information in a timely and efficient manner.

9. **Use of captive husbandry and of individuals for reintroductions into prioritized streams (restored, threats abated).**

   Why: While ranked here at 9 because of the groups concern about addressing environmental problems before reintroduction, the group feels that captive husbandry and its technology needs to be prioritized in order to counteract demographic stochastisity and to enhance populations thus reducing the potential for extinction.

Research Priority 1: Water Quality Analysis/Monitoring

Action 1: Identify and prioritize hellbender watersheds and, if necessary, streams.

Purpose: to identify and prioritize hellbender populations and/or habitat in greatest need of conservation. This will enable resource managers and researchers to focus conservation efforts and projects while working towards a common goal of preservation of the hellbender and its habitat.

Location: to be determined following location and prioritization process.

Time Frame: May 2007

Responsible Party: AR/MO hellbender populations – Ozark Hellbender Working Group; Eastern U.S. hellbender populations – Jeff Humphries/Max Nickerson

Action 2: Initiate intensive water quality analysis and monitoring program for 100 percent of prioritized hellbender streams.

Purpose: determine differences in hellbender abundance based on water quality differences by collecting baseline and current water quality conditions (i.e., physicochemical, inorganic and organic compounds, nutrient loads, *E. coli* and fecal coliform) to identify potential problems affecting hellbender populations and compare water quality parameters between hellbender populations.

Location: a minimum of three sites in prioritized streams (as determined in Research Priority 1, Action 1).

Time Frame: monthly for physicochemical parameters and bacteria (*E. coli* and fecal coliform); seasonal testing of pesticides and endocrine disrupters; implement in 2007 for a minimum three-year period.

Responsible Party: U.S. Geological Survey, state water regulatory agencies, Arkansas State University-Jonesboro, University of Missouri - Rolla, Missouri State University-Springfield, Ohio State University-City. Arkansas Department of Environmental Quality, Missouri DNR

Action 3: Collect and summarize existing water quality data from prioritized hellbender streams.

Purpose: establish baseline data (i.e., physicochemical, inorganic and organic compounds, pesticides, nutrient loads etc.), where available, for prioritized hellbender streams; determine existing historic versus current water quality trends; identify prioritized
hellbender streams with declining water quality trends, thereby focusing conservation efforts.

Location: all prioritized hellbender streams with water quality data

Time frame: January 2008

Responsible Party: Arkansas – Chris Davidson (FWS); Missouri – Jeff Briggler (MDC) and Jill Utrup (FWS); Eastern U. S. – Jeff Humphries will coordinate effort; Arkansas Department of Environmental Quality, Missouri DNR

Action 4: Compile water quality collected in Research Priority 1, Actions 2 and 3 in a centralized water quality database for hellbender conservation

Purpose: ensure water quality data are readily available to hellbender managers and researchers.

Location: store in a centralized Microsoft Excel or Access file available on the hellbender web page; updates will be posted as data becomes available, but no less than six month intervals; protect from unauthorized use.

Time frame: June 2008

Responsible Party: web page – Jeff Humphries; Ben Wheeler (University of Arkansas – Batesville).

Research Priority 2: Watershed Threats Analysis

Action 1: Conduct a comprehensive threats analysis for priority hellbender watersheds; the analysis should incorporate stakeholder involvement/comments, GIS analysis, modeling, and where needed field measurements.

Purpose: determine historic and current land use trends, sources of erosion (i.e., roads, agriculture, silviculture, eroding stream banks), recreational uses, public access, road density, stream crossings, and stream bed scour.

Location: prioritized hellbender watersheds as funding becomes available; impaired streams, as determined by section 303(d) of the Clean Water Act, may be funded through EPA grants and may be prioritized by availability of funds.

Time frame: initiate all impaired streams/watersheds by January 2009; completion for each threats analysis may take two to three years after initiation. Responsible Party: to be determined; The Nature Conservancy has extensive experience and established protocols for conducting threat assessments; universities such as Arkansas State University also have experience conducting threat assessments. Each state herpetologist and FWS lead should help coordinate efforts to secure funding.

Research Priority 3: Life History

Action 1: Standardize survey methodology for conducting meta-population studies and long-term monitoring.

Purpose: ensure range-wide consistency to ensure that data is comparable.

Location: range wide

Time frame: August 2007

Responsible Party: Jeff Briggler (MDC), Kelly Irwin (AGFC), Stan Trauth (ASU), Max Nickerson (UF), Jeff Humphries; Chris Phillips is developing a plan for Current River, MO

Action 2: Conduct baseline meta-population studies, which should include population structure, age classes, sex ratios, fecundity, recruitment, and survivorship data.

Purpose: determine species status, provide population dynamic data for modeling and better understand factors affecting species decline, aid in future monitoring efforts.

Location: prioritized hellbender watersheds/streams, particularly within the eastern U.S. portion of the hellbender range.

Time frame: initiate studies in 2007 and continue until all prioritized streams have baseline meta-population data; semi-annual progress reports.

Responsible Party: to be determined, but should include qualified hellbender biologists in state and federal agencies, non-governmental organizations, and universities.

Action 3: Establish and continue long-term monitoring of population demography.

Purpose: determine population trends.

Location: one to three stream reaches per prioritized hellbender stream.

Time frame: initiate within one year of conducting baseline meta-population studies and continue at a three-year interval.

Responsible Party: state herpetologists and researchers

Action 4: Conduct genetic studies investigating phylogeography, meta-population dynamics, and taxonomic entities.

Purpose: determine genetic variation range wide using various mitochondrial and microsatellite techniques

Location: range-wide

Time frame: initiate studies in 2007; progress reports upon data availability and request.

Responsible Party: to be determined, but will include qualified population geneticist. UM – Columbia and Jeff Briggler are conducting MO mitochondrial and microsatellite research. Eric Routman is reanalyzing species range wide analysis; Michael Freake is conducting southeast DNA work; Tim King of USGS – Leetown is developing microsatellite primers and analysis.

Action 5: Conduct telemetry studies investigating hellbender movement patterns.

Purpose: determine hellbender nest locations, immigration, and emigration.

Location: range-wide

Time frame: initiate investigation by 2008

Responsible Party: University of Missouri – Columbia and Jeff Briggler initiating a study; others to be determined, but will include qualified hellbender biologists

Action 6: Determine larval microhabitat in Midwest hellbender populations.

Purpose: better understand larval microhabitat in Midwest hellbender populations; is currently not well understood; to quantify habitat types; to determine larval movement from nesting sites; to determine hellbender recruitment.

Location: Arkansas/Missouri hellbender populations.

Time frame: initiate investigations by 2008

Responsible Party: to be determined, but will be conducted by qualified hellbender biologists

Research Priority 4: Sedimentation/Siltation Effects on Hellbender Demography

Action 1: Measure and correlate sediment deposition rates to hellbender demographics from a wide range of streams (impacted to pristine).

Purpose: determine extent to which sedimentation contributes to hellbender declines; to determine how various deposition rates effect egg survival.

Location: range-wide

Time frame: initiate by 2009

Responsible Party: to be determined, but will be conducted by qualified hellbender biologists.

Research Priority 5: Toxicity Testing

Action 1: Using surrogate species, determine acute and chronic toxicity of heavy metals, organophosphates and ammonia to hellbenders (eggs, larvae, and adults)

Purpose: determine thresholds to suspected compounds and how these affect fitness and survival of eggs, larvae, and adults.

Location: range-wide analysis, but priority on Ozark hellbender populations; use Eastern hellbenders in the Eastern ecoregion as surrogates due to availability of individuals.

Time frame: initiate by 2009

Responsible Party: Missouri State University, Arkansas State University; University of Missouri-Rolla and (Dr. Huang) and other qualified laboratories.

Research Priority 6: Endocrine Disruptors

Action 1: Determine the effects of endocrine disruptors on hellbender eggs, larvae, and adults.

Purpose: determine whether endocrine disruptors cause hellbender infertility or reduced fecundity.

Location: priority on Arkansas and Missouri hellbender populations using Eastern ecoregion as controls.

Time frame: on-going

Responsible Party: University of Missouri- Rolla, Dr. Huang

Research Priority 7: Translocation and Reintroduction

Action 1: Develop reintroduction and augmentation protocols

Purpose: ensure consistent approaches, monitoring requirements, and adherence to FWS policy (if federally listed).

Location: range-wide (one document).

Time frame: one year prior to the first reintroduction/translocation effort.

Responsible Party: all hellbender biologists; FWS lead.

Action 2: Develop captive husbandry protocols and techniques

Purpose: provide hellbenders for reintroduction and augmentation efforts in order to perpetuate the species.

Location: Saint Louis Zoo, Detroit Zoo, Fort Worth Zoo, Omaha's Henry Doorly Zoo, North Carolina Zoo, Tennessee Aquarium, Oklahoma City Zoo, Louisville Zoo, Como Zoo (St. Paul, MN), Rosamond Gifford Zoo (Syracuse), Toledo Zoo, Denver Zoo, Nashville Zoo, Oglebay Good Children's Zoo (Wheeling, WV), New York State Zoo (Watertown, NY), Wonders of Wildlife (Springfield, MO), The Virginia Living Museum, Shepherd of the Hills State Fish Hatchery (Branson, MO), Mammoth Spring National Fish Hatchery (Mammoth Spring, AR), The WILDS (Columbus, OH).

Time frame: current knowledge by January 2008 and annually thereafter as techniques are perfected.

Responsible Party: see location.

Action 3: Establish an experimental sanctuary in suboptimal hellbender habitat (streams that have experienced dramatic hellbender population declines or extirpated stream populations).

Purpose: determine the probability of successful reintroduction into previously impaired/impacted hellbender streams.

Location: any extirpated stream population (e.g. Spring River) or streams with dramatic population declines.

Time frame: to be determined based on availability of specimens and threat abatement.

Responsible Party: state and federal hellbender biologists; hellbender researchers to be determined.

Research Priority 8: Ecologically Sustainable Flow

Action 1: There currently are no known water quantity issues in extant hellbender populations. However, we recognize that such issues may arise in the future with human population growth and expansion. State and federal regulatory agencies will recommend/require ecologically sustainable flow studies prior to authorizing projects that will remove significant quantities of water in hellbender streams/watersheds.

Purpose: determine minimum flow required to maintain biological diversity and hydrologic function.

Location: to be determined.

Time frame: prior to authorizing permits/projects that will result in significant removal of water from hellbender streams.

Responsible Party: to be determined

Influence Priority 1: Develop Comprehensive Watershed Conservation Plans and Agreements

Action 1: Standardize criteria to characterize watershed, and where necessary stream, "health" and function and hellbender population status to focus conservation efforts.

Purpose: develop a working model to ensure consistency when characterizing and prioritizing conservation efforts for hellbender populations.

Location: range-wide

Time frame: 2007

Responsible Party: Jill Utrup (FWS) and Jeremy Applegate (FWS) will develop a committee

Action 2: Develop and implement programmatic Candidate Conservation Agreements with Assurances for priority watersheds.

Purpose: encourage landowners to implement conservation measures on private lands by offering incentives and ESA assurances; alleviate threats associated with undesirable land use practices; stream line the enrollment process for individual landowners.

Location: priority watersheds, but specifically Eleven Point River watershed (AR/MO), lower Current River watershed (MO) and North Fork White River watershed (MO).

Time frame: initiate agreement development in 2007; agreement implementation will begin 1-2 years following agreement submission to FWS; agreement duration should be a minimum of 30 years.

Responsible Party: state/federal agencies, and non-governmental organizations should administer agreement by enrolling landowners and implementing conservation measures with landowner assistance.

Action 3: Identify, prioritize, and target individual conservation projects

Purpose: alleviate threats

Location: range-wide, but will be determined by landowner willingness to participate in conservation programs.

Time frame: ongoing

Responsible Party: state/federal agencies and non-governmental organizations

Action 4: Balance public demand with conservation of hellbenders by limiting public access and restricting boat motor size and types.

Purpose: decrease adverse impacts on hellbender and their habitat from recreational use.

Location: range-wide in recreation hot spots.

Time frame: 2007 and ongoing thereafter.

Responsible Party: agency responsible for managing river.

Influence Priority 2: Stakeholder Outreach

Action 1: Identify stakeholders within priority watersheds

Purpose: ensure that agencies and non-governmental organizations are working towards a common goal with a common message; to ensure stakeholder involvement in decision-making.

Location: range-wide

Time frame: 2007

Responsible Party: Cryptobranchid Interest Group, Ozark Hellbender Working Group

Action 2: Develop a comprehensive outreach program

Purpose: disseminate information that will increase awareness about hellbender conservation.

Location: range-wide

Time frame: 2008

Responsible Party: Cryptobranchid Interest Group, Ozark Hellbender Working Group, zoos, state and federal agencies.

Influence Priority 3: Management Implementation

Action 1: Identify existing programs to help implement conservation measures/practices

Purpose: ensure stakeholder awareness of available funding sources to implement conservation programs/practices.

Location: range-wide

Time frame: 2007

Responsible Party: Ozark Hellbender Working Group and Jeff Humphries

Action 2: Develop a comprehensive, consensus-based best management practices manual for hellbenders

Purpose: ensure consistency between different agencies and what they are promoting (e.g. conservation/management practices) to landowners and industry.

Location: range-wide

Time frame: 2008

Responsible Party: state and federal agencies

Influence Priority 4: Petition for Development of Adequate Laws

Action 1: Form a committee to review laws and regulations and the efficacy as it relates to providing hellbender conservation

Purpose: provide the maximum protection for conservation of hellbender.

Location: range-wide

Time frame: 2007

Responsible Party: Jeff Humphries

Action 2: Federally list the Ozark hellbender as endangered and petition for listing the Eastern hellbender as a federally threatened or endangered species.

Purpose: provide the maximum protection for conservation of hellbender by perusing Full Species Listing (both Eastern and Ozark subspecies) first, alternatively, encourage Emergency Listing of Ozark subspecies first then use resemblance for listing the Eastern sub species.

Location: range-wide

Time frame: 2006 begin taking actions for listing Ozark hellbender; to be determined for Eastern hellbender as southeast U.S. surveys are completed.

Responsible Party: Ozark hellbender listing – Jill Utrup (FWS-Columbia Field Office); Eastern hellbender to be determined.

Group 3: Public use (public use and recreation)

Participants: *Jeff Briggler, Kevin Zippel, Diane Barber, James Civiello, Mark Wanner, Andy Snider, Jessi Krebs, Joe Tavano*

Major threats that fall under this category:

Bait fishing

What are the major issues?

1. Over collecting of larvae (more in eastern populations)
2. Dumping unused bait

Discussion:
Over collecting of larvae is a potential problem in some eastern populations. Some regulations allow up to 150 eastern hellbenders to be collected per day. This can quickly decrease populations and skew age classes. Collecting of hellbender for bait is less of an issue in the Midwest.

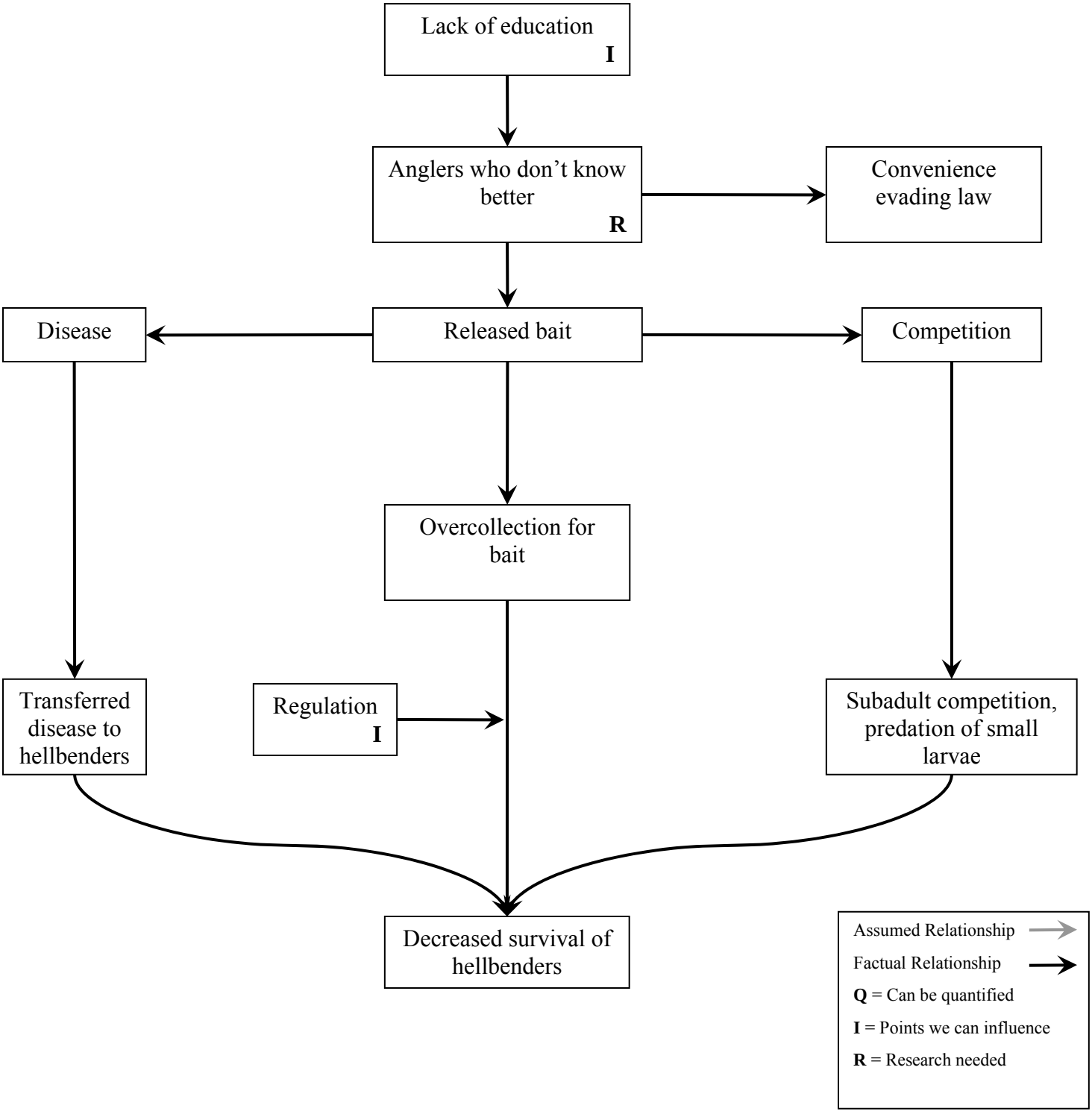
Dumping bait that may be native or non-native into streams could compete with hellbenders for habitat usage. Depending upon the type of bait species introduced, direct predation of hellbenders may occur. Indirectly, non-native crayfish could out-compete native crayfish (food source for hellbenders). Also, using live bait on trotlines (Midwest) and hook/line will increase the potential of hellbenders being captured.

Diseases can also be spread from released bait. People are misinformed on the potential problem of dumping native or non-natives into the stream that were purchased from bait shops. (They may do this for convenience.) There may be a need to inform anglers when they purchase their fishing permits. Disease transferred from bait could lead to decreased survival of hellbenders. Known example of bait dumping is tiger salamanders in Arizona: Competition with sub-adults and possible predation of larvae of other species.

There is no quantifiable information under this disease category. We potentially have bait disease issues with hellbenders. However, by using other amphibians, we may be able to obtain quantifiable data for comparisons (e.g. Arizona native amphibians and tiger salamander larvae used for bait).

What type of information is needed to address the potential diseases that might occur on live bait? Surveys and sampling bait should be conducted in local shops to see if there are potential disease issues. Some mail-in surveys regarding the type of baits being sold needs to be conducted in states that currently do not collect such information. Non-native crayfish are commonly sold in bait shops and African clawed frogs are commonly sold in the pet trade. It is known that African clawed frogs do carry chytrid fungus. However, unknowingly some educators released African clawed frogs into streams believing it is safe for native species. Release of tiger salamander larvae may not be an issue in Ozark ecoregion. It might be hard to change bait regulations due to long standing tradition, and individuals, especially the older generation, would most likely resist change. Younger generations may be more open to change. There is a need to create prohibitive bait species lists. This is being done in several states already.

Figure 13. Flow diagram showing the effects of bait fishing on hellbender populations.



Water quality

What are the major issues?

1. Hormones being released into the water through urine.
2. Nitrogenous waste and coliform introduction into the water from urination/defecation.
3. Trash/pollution

Discussion:

Estrogen is more than likely affecting the reproduction of male and female hellbenders. Trash and nitrogenous waste from urine and feces by livestock and humans may contribute to increased estrogen and high levels of coliform bacteria in streams. Raw sewage often travels directly into the river. A lot of people use the stream as a restroom; directly urinating in the water when boating, canoeing and/or tubing. Traditionally livestock, especially cattle and horses, are allowed to use the stream as a water source and directly urinate and defecate in the stream. In some situations, fencing livestock from the river and providing alternative water sources has been successful, but in most cases there is resistance to such practices. Sewage from houses and livestock use along the river is more of a land usage issue, not a recreational one. Therefore, these two topics should be addressed in detail in the land use section.

Hormones may come from boaters, canoeists, tubers, and livestock urinating directly in the water. Nitrogen/coliform is also introduced from canoeists, tubers, rafters, campers, and livestock urinating and defecating directly in the water. Pit latrines are also potential contributors. Some suggest educating people to use restroom located at least 100 yards from the river. Hormones are creating endocrine disruption in many aquatic species, particularly males. Does this affect larval hellbender development? Feminization of male hellbenders will lead to decreased reproduction. Nitrogen/coliform is potentially toxifying aquatic organisms. This could lead to death, suppressed immune systems (allowing other pathogens to attack, i.e., chytrid), or decreased reproduction in populations.

Trash thrown in the rivers can lead to accidental ingestion, injury, and potential containment or entrapment of hellbenders. Injury could cause avenues for the disease process. Leaching toxins from plastics, rubbers, sunscreen, mosquito spray, and nicotine from cigarettes could also be a problem leading to decreased survival.

In some areas, there are gasoline powered boats that might contribute to pollution of the river and destruction of hellbender habitat (boat smashing rocks). In Spring Creek, which feeds into North Fork of the White River, MO, there are ATV's that drive into the water. ATVs could also be contributing to pollution and habitat destruction (gravel substrate for larvae). At a small scale, boats and ATVs might have minimal impact, but heavy use could potentially contribute pollution of the river and destruction of adult and larvae hellbender habitat.

Potential research needs identified: 1) effect of hormones, 2) impact of trash, and 3) coliform/nitrogen were determined to be the most important topics of further discussion. The impacts of hormones, nitrogen/coliform, and trash on hellbenders need to be investigated. It is a fact that several types of artificial hormones have been detected in the water in the Ozark ecoregion. However, it is an assumption that these hormones impact hellbenders. There is nothing quantifiable under this category. Basic research needs to be completed - especially concerning the effects of hormones.

Persecution

What are the major issues?

1. Intentional killing (gigging Midwest ecoregion and rock smashing).
2. Accidental take through hook and line fishing and trot lines (Midwest ecoregion).
3. Incidental take/collecting by recreational users.

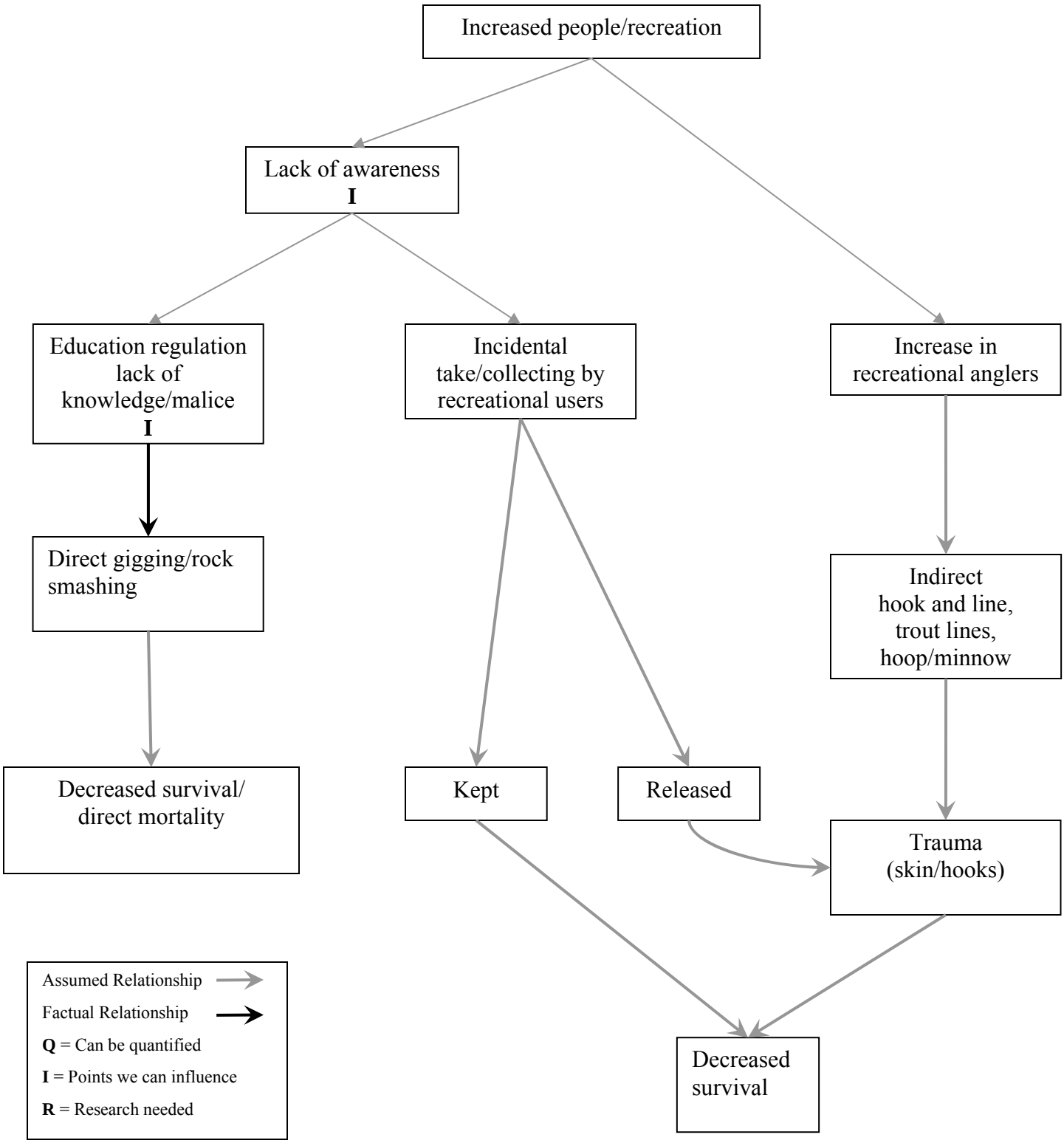
Discussion:

Gigging is intentional killing resulting from misinformed or malicious behavior (fact). The extent of gigging activity can probably be influenced through education and regulation. It might be possible to shorten or change gigging season regulations to better address the incidental removal of hellbenders, especially during the breeding season. This issue is definitely a Midwest ecoregion problem.

Rock smashing is a common method of killing hellbenders, based on lack of knowledge of individuals and fear of the hellbender. The majority of malicious behavior using rocks can probably be reduced through education.

Accidental take by hook and line fishing does directly lead to some deaths of hellbenders, but some of these animals may survive. However, the chance of survival is decreased due to damages to skin, or swallowed hooks, etc. Jeff Briggler states that hellbenders heal relatively quickly if they are healthy and they can also rid themselves of hooks. There is little chance of changing the way anglers fish, but there is an opportunity to teach them how to properly remove hooks and safely release hellbenders when captured. Anglers often report hellbenders to MDC (J. Briggler, pers. comm.) that they catch on trotlines or on hook-and line while fishing. Fishing licenses have been declining slowly over time in some states, and there is a slight decrease in fishing in some particular areas. Incidental take occurs by recreational users who think the hellbender is novel and takes it home to place in an aquarium. Many individuals do not even know what a hellbender is when encountered. Incidental take can probably be influenced by education efforts. Recreational use (boating, rafting, canoeing, tubing, etc.) of the streams is increasing (minus fishing), which increases the chances of people encountering hellbenders. There is a need for increase law enforcement to reduce incidental take. At this time, nothing in this category is quantifiable.

Figure 14. Flow diagram showing the effects of increased recreational use on hellbender populations



Enforcement regulation

What are the major issues? (See other categories.)

Discussion:
We have been identifying this issue under most of the other categories. Amber Pitt and Joe Tavano say that in the three years they have been working on a Missouri stream, they have never been stopped or questioned by government officials. Jeff Briggler says land owners will often report suspicious activity on the river to him or the conservation agent. There is an obvious need to increase enforcement, but there are limited personnel to cover the field.

Habitat disturbance

What are the major issues?

1. Crayfish hunting
2. Hellbender hobbyists/ independent researchers
3. Recreational water vehicles
4. Rock removal/alteration

Discussion:
Crayfish hunting for human consumption is influenced by culture, especially in the Midwest ecoregion. Some children collect crayfish for fun and place in buckets (Missouri) and then release them in different areas. Searching for crayfish probably disturbs refugia/nesting sites of hellbenders and removes a potential hellbender food source (crayfish). Eggs may flush out from underneath rocks when lifted, and there may be a decreased health of hellbenders, particularly females (lack of food), resulting in low egg production and possible deaths (smashed by rocks). Education can resolve most of these problems. However, some adults may be reluctant to stop catching crayfish for food since it is part of their culture and tradition.

Independent public researchers can be a problem. Hellbender hobbyists casually looking for animals are also a problem, incorrectly flipping stones, ruining habitat and potentially smashing hellbenders. "Killing with kindness" is sometimes hard to correct through education. The more you teach hobbyist, the more they want to see and handle hellbenders. Some of Jeff Briggler's "help" survey teams are so over zealous that they all want to get into the field to help look for hellbenders. Hobbyists do not link finding hellbenders with disturbing and destroying hellbender habitat. Unfortunately, some of these hobbyists are conservation stalkers!

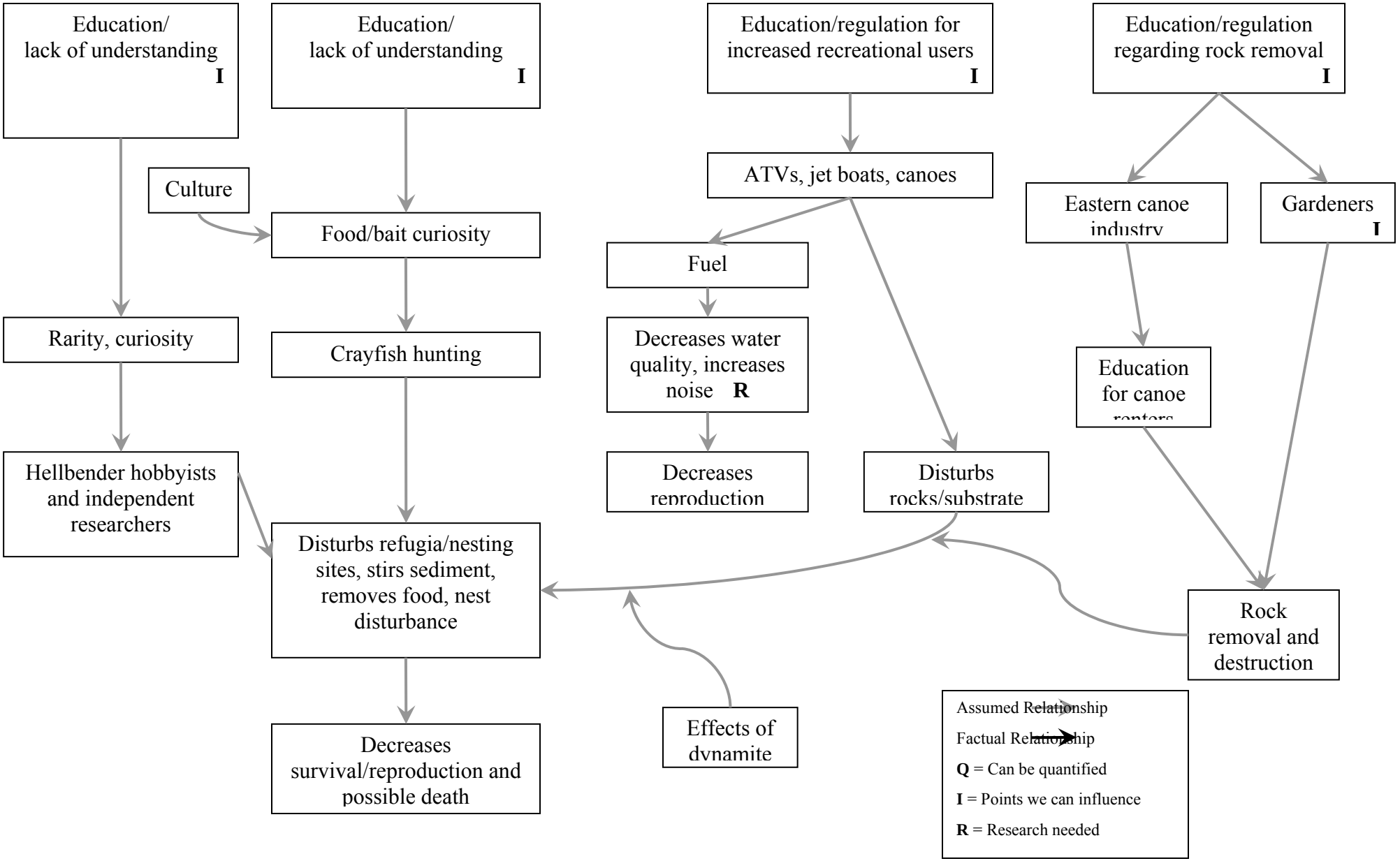
ATVs and jet boats (a Midwest ecoregion issue) are potential sources of toxic leaks into the water. Boaters not only unknowingly destroy hellbender habitat with boats, but also purposely destroy or move large rocks so that they don't hit them with their boats. Disturbance of the stream substrate can affect egg, larvae and adult survivorship. Noise pollution provided by boat motors may be disruptive to hellbenders during the breeding season. Increased turbidity caused by wave action from boats is also a potential problem. Increased erosion and siltation is created due to wave action along the stream banks.

Education/regulation can potentially influence these problems if individuals have respect for habitat. However it appears that most individuals have little concern, and they continue to do whatever they want to habitat even though they might get caught and fined. There are cameras

used to watch illegal drug transactions, cave trespassers, etc., but the offenders/destructors seem to return time and time again.

Moving rocks to create swift flow for canoes or to create dams for swimming holes causes a change in geomorphology within rivers. Canoeist operations have dynamited big rocks in the past (during M. Nickerson's initial studies in the Ozark ecoregion), but this practice is not allowed anymore (in the Ozarks ecoregion; uncertainty exists regarding Eastern streams). Some people may collect large rocks or gravel for home landscaping projects. This appears to be a problem in both the Ozark ecoregion and Eastern ecoregion. Removing rocks decreases habitat for hellbenders resulting in fewer refugia and nesting sites; thus leading to decreased recruitment. Stopping the removal of large rocks can probably be influenced through education efforts and regulation. Regulations protecting hellbender habitat from removal already exist in some areas.

Figure 15. Flow diagram showing the effects of habitat disturbance on hellbender reproduction and survival



River Access

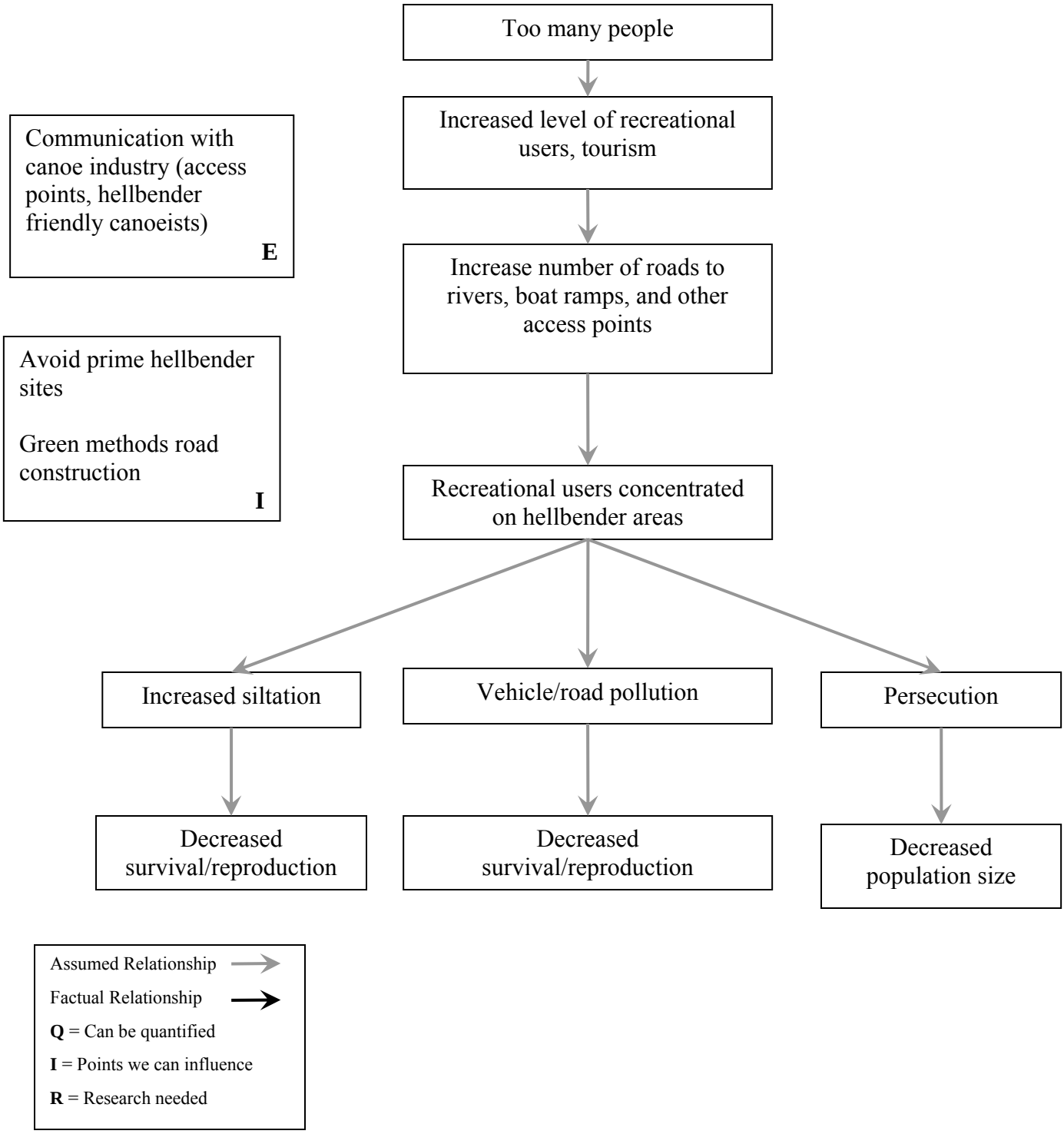
What are the major issues?

1. Roads, boat ramps, and other river access points

Discussion:

There is an increase in roads and boat ramps and other access points (particularly in the Midwest ecoregion) built near or on rivers since more people are utilizing this resource (i.e., increased tourism, canoeists, etc.). Both roads and boat ramps increase erosion, siltation and access to the river, which increases the number of visitors and increases disturbance in particular areas throughout the river. Random placement of boat ramps and other access points could have a large detrimental effect if placed in prime hellbender riffle areas. Canoeists and tubers like the same type of habitat as hellbenders (fast flowing areas). Some hellbenders are being displaced from boat ramp/access areas (i.e. illegal collecting, potentially animals move out of area if possible etc.) and some are killed outright (i.e. by gigging, hook-and-line, rock smashing etc.). Increased amounts of oils, salts, other toxins and trash mainly obtained from run-off from roads during rain events) are potential dangers for hellbenders. Boat ramps and roads can be influenced by strategic planning of such access points to avoid prime hellbender locations. J. Briggler recommends at least a river mile from prime hellbender habitat. It may be possible to provide environmental and hellbender-friendly educational materials to canoe rental companies and government agencies regarding access locations on rivers with hellbenders. J. Tavano and A. Pitt have been working with a local canoe company in their study site, on the North Fork of White River, and this company seems to be willing to help educate others. We can also educate the canoe rental owners about proper land management (i.e., not clearcutting trees from banks, moving or removing of rocks, etc.).

Figure 16. Flow diagram showing the effects of river access on hellbender populations.



List of things we can influence: (in order of priority)

Outreach and Education:

1. Habitat disturbance (education of recreational users)
   A. Rock turning
      1) Crayfish hunters (especially in the Midwest ecoreion) and other recreational users:
         - Flipping rocks while searching for crayfish
         - Removing rocks to make small dams for swimming (growing problem in the eastern populations)

      Action Items: Teach about consequences of turning rocks/disturbing habitat, and educate people about need for culture change (not harvesting large numbers of crayfish for food or pets).

      Tasks: Visible signs, media, informational boards, flyers in bait shops, general stores, canoe rental shops, fishing regulation books. There should be at least one sign at the major point of river access. This information should be general and to the point so that it is easily understood.

      Time Frame: Summer 2007

      Responsible Party: Mark Wanner and Jeff Briggler will coordinate.

      2) Hellbender hobbyists and independent researchers:
         - Teach about consequences of turning rocks/disturbing habitat.

      Action Items: Target of specific audiences on the internet (Herp Field Forum, kingsnake.com, caudate.org, CIG, local herpetological societies, Center for North America Herpetology, hellbender.org., etc.)

      Tasks: Create an information hyperlink. This information can be more biology based and technical. Joe Travano will complete by 01 Dec 2006.

      Time Frame: Summer 2007

      Responsible Party: Joe Travano will coordinate.

   B. Rock removal
      1) Gardeners:
         - People visiting the river specifically to collect large rocks for their gardens.

      Action Items: Target local garden societies, nurseries, botanical gardens, landscapers. Also, educate nursery owners who may collect rocks to sale.

Tasks: Create a flyer aimed at a moderate intellectual level (regarding biology).

Time Frame: Summer 2007

Responsible Party: Andy Snider will coordinate.

2) Recreational Users:

A. Rock removal
    - Rocks are moved by boaters so that they don't damage their boats (Midwest ecoregion).
    - Canoeists/rafters remove rocks to create better high flow spots.

Action Items: Target specific media outlets, bait shops and canoe/rafting companies.

Tasks: Visible signs, media, informational boards, flyers in bait shops, general stores, canoe/rafting rental shops, and fishing regulation books. There should be at least one sign at the major point of river access. This information should be general and to the point so that it is easily understood.

Time Frame: Summer 2007

Person Responsible: Mark Wanner will coordinate.

B. Urinating, defecating and trash disposal
    - Unfortunately, many individuals do not understand the connection between these practices and water quality.

Action Items: Educate recreational users about the consequences of urinating and defecating in the water.

Tasks: Visible signs, media, informational boards, flyers in bait shops, general stores, canoe and raft rental shops, and fishing regulation books. There should be at least one sign at the major point of river access. This information should be general and to the point so that it is easily understood.

Time Frame: Summer 2007

Person Responsible: Mark Wanner will coordinate.

C. Vehicle use (ATVs)
    - Lack of knowledge by vehicle users of impacts on hellbenders and water quality.

Action Items: Educate at vehicle use sites.

Task: Visible signs, media, informational boards, flyers in bait shops, general stores, canoe rental shops, and fishing regulation books. There should be at least one sign at the major point of river access. This information should be general and to the point so that it is easily understood.

Time Frame: Summer 2007

Person Responsible: Mark Wanner will coordinate.

Materials that need to be created relating to habitat disturbance:

1. General Documents:

   A. Document: General "Help the Hellbender" posters, car decals, fishing regulation booklet and flyers. (Already exist for Missouri)

   Responsible Parties: J. Briggler and M. Wanner and other interested individuals can modify the material for the next printing to include all of the issues listed above. They will share this information with other state agencies and interested parties so they can tailor it to their needs.

   Distribution: Stream team, River Keepers, zoo volunteer groups, and state and federal agencies can help distribute the material.

   B. Document: Targeted towards gardeners- include very generic information, gear more towards habitat destruction rather than just hellbenders so they have more of an interest.

   Responsible Parties: Andy Snider.

   Distribution: Stream Team, River Keepers, zoo volunteer groups, and state and federal agencies can help distribute the material.

2. River Access:

   - New boat ramps/river access points ideally should be placed at least one river mile from prime hellbender habitat (riffles). This would also help to deter collectors since they are unlikely to travel one mile for collecting.

   - Remove old ramps once new ones are constructed. Areas where bridges are constructed across the river often become river access areas. Things can be done during the construction process to address these issues. However, this is more of a policy driven issue and many different agencies would need to be involved. Corp of Engineers generally is the permit issuer, but this will vary on a state-by-state basis.

Action Item: Formulate guidelines for access construction and bridge placement.

Tasks: Create a guide sheet with participation of federal and state agencies that would assist in BMPs for hellbender related activities. The target audience would mainly include, but not be limited to, federal and state agencies (i.e. ACE, FWS, FS, DOT, DNRs, etc.)

Time Frame: Summer 2007

Responsible Party: Jeff Briggler will coordinate.

3. Persecution:
   - Lack of knowledge and understanding of this animal has led to persecution

   Action Items: Produce education materials and target media audience to decrease persecution

   Tasks: Visible signs, media, informational boards, flyers in bait shops, general stores, canoe rental shops, fishing regulation books. There should be at least one sign at the major point of river access. This information should be general and to the point so that it is easily understood.

   Target landowners for help distributing educational materials. Inspire them to value and protect the hellbender. J. Briggler suggests biologists spend time/ talk with giggers when they are out- especially on opening night of gigging season. Radio campaigns prior to opening of the season also help to spread the word (primarily a Midwest ecoregion issue).

   Time Frame: Summer 2007

   Responsible Party: Mark Wanner will coordinate.

4. Water Quality:

   - Human waste and trash disposal
   - Link this issue to Land Use Groups.

   Action Items: Target specific audiences to improve water quality

   Tasks: Lobby for new environmental laws, requesting assistance from other agencies (e.g., EPA, Water Shed Protection Agencies, etc.) Vault or contained tanks (not open pit) and trash receptacles should be installed at all major river access areas. 'Port a Potties' could be problematic as a long term solution since they can be knocked over and easily damaged. Stream Team members regularly patrol the water and remove trash. The Stream Team approach in Missouri and Arkansas should be used as a model and shared with other agencies who oversee hellbender habitat. (River Keepers may also be a good

group to target.) Master Naturalist's Program exists in Missouri and would also be a good group to target. This program exists in other states, but more information is needed as to the status. Post all material on canoe rental place websites.

Responsible Party: This action item is being passed on to the Land Use Group.

5. Bait Fishing:

   - It is unclear if anglers are as naive to the laws/regulations as they appear. Current habits of anglers: bait fishing, collecting, release, etc. Inform anglers about release of bait (disease transmission, habitat competition).

   Action Items: Inform Anglers about release of bait (disease transmission, habitat competition).

   Tasks: Recommendations to seek legislation in each state regarding issues such as collecting larvae (more of a problem in the Eastern ecoregion) and dumping bait into the wild. Pursue bait species problems on a state-by-state basis. Create prohibitive species lists if they don't already exist. Use previously mentioned educational materials and add that it is illegal to dump bait species into the wild. A suggestion was made to require some sort of treatment for all bait fish prior to being sold. Information should be given to bait shop owners, explaining how it would benefit them (i.e. healthy bait lives longer) in order to provide an incentive.

   Time Frame: Summer 2007

   Responsible Party: Rich Collister will coordinate.

Research Needs in Order of Importance: (After prioritized by dots)

1. Recommendations for research on the effects of hormones introduced into streams on hellbenders:

   Dr. Huang and Jeff Briggler are currently conducting this via bloodwork on adults in Missouri. To further evaluate hormones, imported larvae are needed. Unless there happens to be a surplus of larval hellbenders from the Ozark ecoregion, larvae from the Eastern part of the range may be necessary. Recommendation would be to collect egg masses to bring into captivity.

   Action: SW Missouri State University-Springfield could possibly help with future projects. Numerous zoos (particularly Fort Worth, Omaha, Dallas as well as others) could assist with this research if aid is given during the initial permitting process (e.g., a letter of support from MO government agencies, as a cooperative project as needed). We could also possibly contact ASA Zoos in Japan to see if they could do similar research.

   Timeframe: Summer 2007

   Responsible Parties: Kevin Zippel and Jessi Krebs will coordinate
   Funding possibly available from Saint Louis Zoo.

   *Impacts of human waste on health or immune systems of hellbenders would also fall into this category

2. Disease in the Bait Industry:

   PCR/Swabs: Bait would need to be purchased from bait shops and other retailers and then tested for potential diseases. There is a concern that openly entering shops to test could cause resistance to the project.

   Action: It is suggested that we target graduate students from interested universities to conduct this work. We can also consult with Amphibian Specialist Group to see if they have individuals that would be interested in conducting this study throughout the hellbender range. Potentially, this project may take a lot of time and investment; therefore a pilot study with involvement of graduate students could be initiated first in Midwestern populations. Iiridovirus and ranavirus should also be tested for, as well as other potential diseases to be named later.

   Timeframe: Summer 2007

   Responsible Party: Kevin Zippel will coordinate.
   Funding possibly from ASG, NFS grant, the hellbender state agencies

3. Effects of noise on hellbenders from recreational vehicles and other mechanical devices:

Large boats and jets skis are heavily used in some hellbender streams, particularly in Missouri waters. At this time, we are unsure that noise pollution produced by watercrafts is a major concern for hellbenders in the wild. However, noise produced by pumps, generators and filter systems seems to be more of a concern for biologists working with captive animals used for propagation.

Action: We could measure noise levels, vary the levels, and record behavioral observations of hellbenders. There is some research being conducted on this on fish in the Caribbean.

Timeframe: Summer 2008

Responsible Party: Jeff Briggler will discuss with Alicia Mathis regarding the specifics of such a project by summer 2007.

4. Current Habits of Anglers:

Action: Generate a three question survey for anglers using live bait: 1) what bait do they collect**,** 2) what bait do they purchase, 3) what happens to the bait when they are finished fishing? Distribute survey questions with fishing license application via state agencies. Make surveys anonymous so that anglers are more likely to answer questions honestly. It was also suggested to have a separate card that they can fill out to enter a drawing for a gift certificate or new fishing pole. Point persons for each state would be responsible.

Timeframe: Summer 2008

Responsible Parties: Jeff Briggler will contact Tim Turpin-MO DNR to see if he is willing to coordinate. Also, point persons for each state should be involved.

5. Competition/predation from released bait:

Action: Research the effects of tiger salamander larvae or other potential release bait predators when placed in the same environment as hellbenders. Sources: cross reference with the water quality section. Possible researchers - Dr. Mathis, zoos or other universities using Eastern hellbender larvae.

Responsible Party: Kevin Zippel or Jessi Krebs once larvae are available.

Group 4: Role of Captive Breeding

Participants: *Jeff Briggler, Kevin Zippel, Diane Barber, James Civiello, Mark Wanner, Andy Snider, Jessi Krebs, Joe Tavano*

Three Populations:
Ozark hellbenders (Cryptobranchus a. bishopi)
Eastern hellbenders (Cryptobranchus a. alleganiensis) - Midwest Ecoregion
Eastern hellbenders (Cryptobranchus a. alleganiensis) - Eastern Ecoregion

Rearing

1. collecting eggs for eastern hellbender populations from eastern ecoregion and rear for research
2. collecting eggs from Midwest ecoregion (Ozarks and eastern hellbenders) to head-start for future release.

Action 1: Collecting eggs from eastern ecoregion populations of eastern hellbenders: Requests should go out to researchers that are currently in the field (i.e., Jeff Humphries, John Groves, Mike Freake, Gregg Lipps, Millers at Middle TN Univ., etc.) to collect egg masses with appropriate permits for captive research.

Timeframe: As needed for specific projects
Responsible Parties: John Groves/Jeff Humphries

Action 2: Collecting eggs from the Midwest ecoregion populations (Ozark and eastern hellbenders) to be conducted mainly by MDC staff and approved permitted biologists.

Timeframe: Annual searches September through early November.
Responsible Party: Jeff Briggler

Propagation

1. producing animals for captive assurance colonies (all three populations defined above)
2. producing animals for experimental release and reintroduction (all three populations defined above)
3. producing animals for research (Eastern part of range)

It is noted that any reintroductions should be kept river specific and that all efforts are made to complete genetic work. It is also suggested that zoos obtain hellbenders through captive produced specimens for exhibit if they are available rather than collecting animals from the wild.

See “Rearing (above)” and “Eastern Hellbenders (below)” action items.

Eastern hellbenders

1. Easterns already in captivity: 5.1.18 individuals at 15 institutions. This number does not include Saint Louis Zoo or Wonders of Wildlife-Springfield animals.
2. Establish two or three "breeding" facilities: (Fort Worth, Wonders of Wildlife, Tennessee Aquarium, Nashville, Milwaukee, North Carolina are interested and have animals) The Wilds, Omaha, Dallas MDC, Sheppard of the Hills Hatchery-Branson, MO (rearing eggs facility), Mammoth Springs (Rearing eggs AR) don't have animals yet, but are interested if the need arises. Saint Louis Zoo can assist in rearing/head start program.
3. Sex individuals that are currently in captivity and move into genetic groups if possible for propagation, If enough animals exist for particular locations(genetically similar), it is suggested that these animals be pooled and used for propagation stock and subsequent release of propagative offspring. If enough animals do not exist from a particular known locality, these animals could be used to provide a breeding source for exhibits and research opportunities.
4. Determine genetic diversity throughout the range in order to determine how many breeding centers are necessary.

Action: Contact all facilities currently housing eastern hellbenders and determine locality data and current numbers, take tissue or blood samples for genetic analysis, laparoscope to determine sex, and see if these facilities are willing to loan adult animals into captive group for propagation efforts

Timeframe: Summer 2007
Responsible Party: Diane Barber will contact facilities to coordinate logistics, Eric Routman agreed to conduct the genetic analysis as necessary, and Jeff Briggler will assist with coordination of tissue or blood samples to provide to Eric Routman.

Action: Review Saint Louis Zoo records to determine if any Missouri hellbenders were sent out to other facilities in the U.S. and see if any living animals might be Eastern hellbenders from Missouri.

Timeframe: Summer 2007

Responsible Party: Mark Wanner.

Research Possibilities

1. Effect of rain and lowered light levels on the initiation of breeding activity.
2. Investigate possibility of establishing "semi-natural" outdoor breeding facilities within the range of hellbender.
3. Water quality issues at hatcheries and other facilities utilizing water directly from the rivers that may have contamination problems. How does this affect propagation efforts?
4. Nutrition: determine what is a healthy vs. unhealthy hellbender?
5. Investigation of what types of nest sites should be provided in a captive situation to encourage breeding.

6. Determine whether artificial insemination may be effective (Oglebay's Good Zoo and MDC Shepherd of the Hills Hatchery, Branson, MO are currently investigating the feasibility of such a project.).

Action: Majority of these items are currently being addressed at the Ron Goellner Center for Hellbender Conservation, Saint Louis Zoo. Other institutions will need to assist with efforts as soon as animals can be obtained.

Husbandry Challenges

1. Mimicking natural conditions (determine acceptable parameters).
2. What is the appropriate social structure of hellbenders needed for propagation?
3. Should male and female hellbenders be separated during part of the year?
4. What is the appropriate diet for hellbenders used for propagation?
5. Need to sex current unknown hellbenders held in captivity.
6. Need to determine hormone profiles of male and female hellbenders on a yearly cycle, with particular emphases during reproductive cycle.
7. Determine suitable nesting sites (natural [rocks] vs. artificial [pvc pipes, concrete, etc.]; cavity size and location to flow, etc) used by hellbenders in propagation centers.
8. Determine animal health issues and appropriate treatments.
9. Determine micro-habitat use of raceways (flow, cover, etc.).

Action: Saint Louis Zoo is currently working on mimicking natural cues and defining some parameters. The zoo staff continues to learn about hellbender social structure, nesting site selection, and microhabitat use through in situ research work/communication and will try to mimic natural conditions in captivity as necessary. Saint Louis Zoo will experiment with separating some of their animals next year if no reproduction occurs this year. The Saint Louis Zoo, along with J. Briggler and Y. Huang, are also looking into hormonal changes over time. One preliminary analysis has been conducted on nutritional value of crayfish purchased from vendors vs. wild species by Dr. Ellen Dierenfeld, Saint Louis Zoo Nutrition Department. They are also examining fat soluble vitamin contents and minerals in blood of Midwestern hellbenders. Dr. Barbara Wolfe at The Wilds is also working on nutritional analysis of Eastern hellbenders. Animal health issues will be addressed as they occur. To date, there are no major reoccurring known health problems, with the exception of foot ulcerations and chytrid fungus related losses at Saint Louis Zoo. Little information is currently available on hellbender health related issues.

Action: Saint Louis Zoo is working on a husbandry manual. A taxon management account has already been written by Bill Flanagan and is available for distribution to institutions that house hellbenders. Rich Collister has nutrition information as well as documented growth rates in captive hellbenders. It has been suggested that these documents be included in the husbandry manual as well.

Group 5: Eastern hellbenders

Participants: *Max Nickerson, John Groves, Jeff Humphries*

Projects to tackle in eastern (Appalachian) populations:

1. **Appalachian Hellbender Assessment**

   Purpose: Determine status of Eastern hellbender populations as well as provide baseline status data. Baseline data on hellbender population size, density, size structure, and distribution throughout stream systems is completely lacking for large areas of the eastern United States. Information about eastern populations is needed to address questions concerning Federal listing of the entire species (including Ozark subspecies).

   Methods:

   - Intensive mark-recapture survey of 14 entire watersheds in eastern states.
   - Two watersheds in 7 states (GA, NC, TN, NC, VA, WV, MD, PA).
   - Watersheds include both "pristine" and "degraded" watersheds in each state (1 of each per state).
   - Couple hellbender surveys with other at-risk aquatic species monitoring efforts (e.g., fish, mussels, native crayfish, snails, aquatic macroinvertebrates).

   Product:

   Besides information about population parameters (demographics, population estimates, etc.), this study will answer critical questions regarding:
   - "whole watershed" abundance of hellbenders in watersheds of varying quality;
   - data about survivorship, growth rates, nesting attributes (how many nesting sites per population), and other variables completely lacking in the literature and "guesstimated" at the CBSG Hellbender Vortex Meeting in 2006; and
   - more accurate assessment of baseline status of a large portion of the hellbender's range; this information that will aid in determining needed protection of listing levels.

2. **Develop Monitoring Program**

   Purpose: Augment baseline data with monitoring data from multiple populations in the eastern United States.

   - Train teams of students / volunteers to "adopt" streams / hellbender populations.
   - Supply materials and equipment for hellbender research.
   - Collect data in a central place.
   - Need support from agencies, NGOs, environmental groups, etc.

3. **Provide Education / Information**
    - Amber Pitt already developed for both subspecies.

4. **Welcome support and partnership with Ozark Hellbender Working Group.**

HELLBENDER
Population and Habitat Viability Assessment

FINAL REPORT

Section III
Population Modeling Report

Simulation Modeling of Hellbender Populations

Introduction to Stochastic Models

Computer modeling is a valuable and versatile tool for assessing risk of decline and extinction of wildlife populations. Complex and interacting factors that influence population persistence and health can be explored, including natural and anthropogenic causes. Models also can be used to evaluate the effects of alternative management strategies to identify the most effective conservation actions for a population or species and to identify research needs to gather critical data. Such an evaluation of population persistence under current and varying conditions is commonly referred to as a population viability analysis (PVA).

The simulation software program *Vortex* (v9.61) was used to examine the viability of Eastern (*Cryptobranchus alleganiensis alleganiensis*) and Ozark (*C. a. bishopi*) hellbender populations. *Vortex* is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. *Vortex* models population dynamics as discrete sequential events that occur according to defined probabilities. The program begins by creating individuals to form the starting population and stepping through life cycle events (e.g., births, deaths, dispersal, catastrophic events), typically on an annual basis. Events such as breeding success, litter size, sex at birth, and survival are determined based upon designated probabilities. Consequently, each run (iteration) of the model gives a different result. By running the model hundreds of times, it is possible to examine the probable outcome and range of possibilities. For a more detailed explanation of *Vortex* and its use in population viability analysis, see Lacy (1993, 2000) and Miller and Lacy (2003).

Development of the Baseline Hellbender Model

A preliminary baseline model for hellbenders was developed prior to the PHVA workshop based upon life history data for *C. a. bishopi* populations in Missouri provided by workshop participants as well as from published literature. Information from other amphibian species was used to estimate values for parameters for which hellbender data were not available. Model inputs then were reviewed and revised by workshop participants to determine the final values for the baseline model described below. The same input values were used for all populations of both subspecies except where otherwise indicated.

Reproductive/Genetic Input Parameters

Inbreeding depression: *Included*

Inbreeding is thought to have major effects on reproduction and survival, especially in small populations. There is little information available for inbreeding depression in amphibians. Historic information suggests a low level of genetic variation in hellbenders. Inbreeding depression was included in the model (as reduced survival of inbred offspring through their first year). The impact of inbreeding was modeled as 5.00 lethal equivalents as a conservative estimate based on estimates from wild avian and mammalian species (Reed *et al*. 2003; O'Grady *et al*. 2006), with 100% of the effect of inbreeding due to recessive lethal alleles.

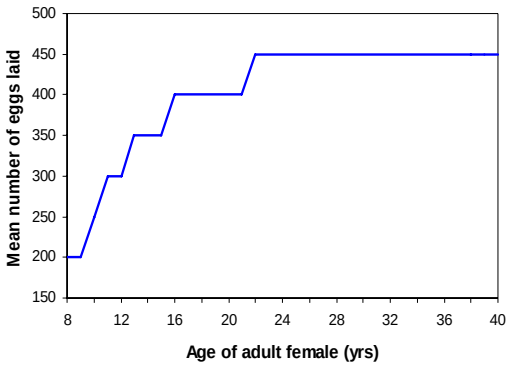
Mating system: *Polygynous*
Several females may lay eggs under the same nesting rock, to be fertilized and defended by the same male. No pair bonds are formed.

Age of first reproduction: *8 years (females); 6 years (males)*
Vortex defines reproduction onset as the time at which offspring are born, not the age of sexual maturity. Age of first reproduction was estimated at 8 years for females and 6 years for males (Nickerson and Mays 1973; Peterson *et al*. 1983; Peterson *et al*. 1988).

Maximum age of reproduction: *40 years*
Vortex assumes that animals can reproduce throughout their adult life and does not model reproductive senescence. Individuals are culled from the population once they surpass this maximum age. This model set maximum age at 40 years based on captive and field data (Taber *et al.* 1975; Peterson *et al*. 1983), with very few individuals surviving past 25-30 years.

Percent adult females breeding**:** *30% (stable); 16.5% (declining)*
Little information is available regarding the percent of females reproducing each year. Topping and Ingersoll (1981) found all 18 adult female hellbenders captured in September 1979 to be gravid; 8 of 27 (30%) collected from November 1979 to February 1980 were gravid. Workshop participants stated that Ingersoll observed 7 males and 6 females under one rock, with only one female laying eggs (no ref). Values of 30% (stable) and 16.5% (declining) females breeding were chosen to produce realistic growth rates for stable and declining populations, respectively. No information is available on environmental variation (EV); based on other species, year-to-year variation in percent of females breeding may not be highly variable and was set at 20% of the mean (20% coefficient of variation). Reproduction was assumed to be density-independent.

Number of offspring per female per year: *Age-specific*
Age (size)-specific fecundity has been observed in hellbenders. Data defining the relationship between size and age (Peterson *et al*. 1983) and size- (Topping and Ingersol 1981) and age-specific (Peterson *et al*. 1988) fecundity were used to model annual production of offspring as a stepwise-function (see graph). This function results in a mean of 325 eggs laid per reproducing female given a stable age distribution (SD set at 32.5). Sex ratio was assumed to be equal at birth.



Percent males in breeding pool: *72%*
Little information is available; 72% represents an estimate of those males holding territories.

Environmental variation (EV) concordance of reproduction and survival: *Included*
Certain streams may be significantly affected by annual environmental variation. Adult hellbenders are highly dependent on consistent water temperatures, so temperature changes during dry years may have an impact on both reproduction and survival. The inclusion of EV concordance in the model means that years that are good for survival tend to also be good for reproduction and vice versa.

Mortality Rates

Little data are available, particularly for stable hellbender populations, so mortality rates were chosen based on rates for other amphibian species and in an effort to produce a reasonable growth rate for a stable population of hellbenders (main population of Eastern hellbenders) and a declining population in the presence of threats (representing Ozark and Midwestern Eastern populations) (Table 1). Juvenile mortality rates and percent of females breeding were adjusted to simulate the historical decline of the Missouri hellbender population and to mimic the current age (size) distribution of the population (Nickerson and Mays 1973; Peterson and Wilkinson 1996; Wheeler *et al*. 2003). This assumes that the population is in decline primarily due to a lack of juvenile recruitment, which is the consensus of the literature (Wheeler *et al*. 2003).

Table 1. Age- and sex-specific mortality rates used in the *Vortex* hellbender model for populations that were estimated to be declining or stable. Data for early age classes were drawn from general amphibian demography; mortality rates after age 5 were based in part on Peterson *et al.* (1983, 1985, 1988).

	Declining		**Stable**	
	Females	**Males**	**Females**	**Males**
Age class (yrs)	*Mean (EV)*	*Mean (EV)*	*Mean (EV)*	*Mean (EV)*
0 – 1	90 (1)	90 (1)	90 (1)	90 (1)
1 – 2	67 (5)	67 (5)	60 (5)	60 (5)
2 – 3	67 (5)	67 (5)	50 (5)	50 (5)
3 – 4	33 (3)	33 (3)	33 (3)	33 (3)
4 – 5	33 (3)	33 (3)	33 (3)	33 (3)
5 – 6	33 (3)	33 (3)	33 (3)	33 (3)
6 – 7	15 (1.5)	15 (1.5)	15 (1.5)	15 (1.5)
7 – 8	15 (1.5)	15 (1.5)	15 (1.5)	15 (1.5)
8+	12 (1)	15 (1)	12 (1)	15 (1)

Population Size and Carrying Capacity

Metapopulation models were developed for three large regional populations of hellbenders:

1. Ozark hellbenders (*C. a. bishopi*) in the Midwest (MO and AR)
2. Eastern hellbenders (*C. a. alleganiensis*) in the Midwest (MO)
3. Eastern hellbenders (*C. a. alleganiensis*) in the eastern U.S. (NY to GA)

Workshop participants discussed each of these regional metapopulations in plenary to determine the number of primary populations and the current estimated population size and carrying capacity of the habitat for each. Gene flow among rivers is minimal, so all populations were considered to be isolated from each other (Routman 1993; Routman *et al*. 1994). It should be noted that these population size estimates may be inflated since these numbers were often based on recent numbers of hellbenders caught and then extrapolated to the rest of the available habitat for each stream (population) (J. Briggler, pers. comm.). The estimates were based on the "best case scenario" for each population. Population estimates represent only individuals one year or older, as this is the input needed for the *Vortex* model and because it may be more difficult to estimate the first larval age class with any level of accuracy.

Ozark Hellbender (C. a. bishopi) Metapopulation

This regional metapopulation consists primarily of four populations: North Fork/Bryant Creek; Eleven Point; Current River/Jack's Fork; and Spring River. Details surrounding the plenary discussion of current population size and carrying capacity estimates are given below where available (see Table 3); otherwise, estimates were based on the consensus of the workshop participants. These populations are thought to be declining; thus, reproductive and mortality rates developed for declining populations were used to model Ozark hellbender populations.

North Fork/Bryant Creek (MO)

Population size (age classes over 1 yr): 200

Fifty-seven were caught, none of which were tagged, but tags are often lost. Although there is little scientific evidence, participants were comfortable with an estimate of 200 individuals.

Carrying capacity (K): 5000

On the basis of data from good quality habitat in North Carolina where carrying capacity is 625 hellbenders per mile, the estimate for K for North Fork could be as high as 15,000. A conservative estimate of 5,000 was chosen for the model.

Eleven Point (AR and MO)

Population size (age classes over 1 yr): 300

A thorough search of 36 river miles in MO revealed 33 individuals, which may represent as little as 10% of the population. Monthly surveys in MO caught 14 individuals in a 0.7-mile stretch from May to September, 21.4% of which were recaptured. Based on this information, participants estimated the population at 100 in MO. In AR, 70 individuals have been marked in two good sites; in other locations, typically only a couple of individuals are found. The AR population was estimated at 200.

Carrying capacity (K): 5000

Based on about twice the river miles and one-half of the density of the North Fork population.

Current River/Jack's Fork (MO)

Population size (age classes over 1 yr): 80; Carrying capacity (K): 1000

There is a lot of habitat and potential sites, but few with many individuals. The river appears capable of supporting more hellbenders than have ever been found there in the past. Habitat, native crayfish populations and water temperatures are very good for hellbenders. The population may have been in decline by the time that the first surveys were done in the early 1980s, or there may be something unsuitable about the habitat that has not been detected.

Spring River (AR)

Population size (age classes over 1 yr): 10; Carrying capacity (K): 400

There are only 2-3 sites on this river. Peterson's surveys found over 100 hellbenders in two sites, but much of this habitat has been destroyed by siltation. Above dam site No. 3 there is still good habitat that might be able to support about 100 individuals; the other site is mostly destroyed and could support a maximum of 50. There is also a southern site that might support 250.

Eastern Hellbender (C. a. alleganiensis) Metapopulation in Missouri

This regional metapopulation consists primarily of four populations: Niangua River; Gasconade River; Big Piney River; and Meramec/Big River. Details surrounding the discussion of current population size and carrying capacity estimates are given below and in Table 4. These populations are thought to be declining; thus, reproductive and mortality rates developed for declining populations were used to model Eastern hellbender populations in MO.

Niangua River

Population size (age classes over 1 yr): 400; Carrying capacity (K): 5000

Very good habitat; about two good sites per river mile compared to one site per river mile in other Missouri rivers. Thorough surveys of this river (~25 river miles) in 2006 yielded 104 hellbenders, 64 of which were found at one location (34% recapture rate). Based upon this data, participants believed that the river supported at least 300 hellbenders, and estimated the population at 400 due to good habitat, especially bedrock. Illegal collecting could be more significant on this river due to large number of hellbenders at few locations with easy access.

Gasconade River

Population size (age classes over 1 yr): 100; Carrying capacity (K): 500

In the two best sites, only 7 individuals were found; total population estimate is about 100 individuals. Habitat is very degraded. The middle section of the river lacks good riparian protection, has many erosion problems, wandering livestock, and relatively warm water temperatures (> 80° F). Drought impacts may be more significant here due to existing high water temperatures. Illegal collecting was most likely prevalent on this river at 2 well known sites with easy access (common knowledge among collectors).

Big Piney River

Population size (age classes over 1 yr): 50; Carrying capacity (K): 1000

It is suspected that collectors hit the upper part of the river and took the majority of hellbenders at a few well known sites. This river can definitely support more hellbenders than the Gasconade River based upon the habitat and improved watershed protection.

Meramec/Big River

Population size (age classes over 1 yr): 50; Carrying capacity (K): 1500

The upper 20 river miles of the Meramec River contain the best habitat for hellbenders; habitat becomes degraded as you travel downstream. In this 20 river mile reach, only six hellbenders were observed with repeated surveys in the 2006 field season, so this may be a high estimate. Surveys from 1986 – 1994 captured and marked 525 hellbenders in this 20 river mile reach.

Eastern Hellbender (C. a. alleganiensis) Metapopulation in Eastern U.S.

This regional metapopulation consists of a large number of isolated river populations extending from New York to Georgia and encompassing 95% of the species' range. Four relatively well known populations were identified during plenary discussions to provide a representative sample of the main Eastern hellbender population for comparative purposes: Little River (Great Smoky Mountains National Park – GSM); Greenbrier River (WV), Davidson River (NC), and Coosa Creek (GA) (see Table 5 for population estimates). These four populations represent only a fraction of the entire metapopulation of Eastern hellbenders in the eastern U.S.

Accurate current population estimates do not exist for the entire Eastern hellbender metapopulation. A small working group was established at the PHVA workshop (members: J. Humphries, M. Nickerson, J. Groves, K. Traylor-Holzer) to discuss and estimate approximate numbers of populations of various size across the range as well as their perceived status. There was general consensus that populations in the southern regions were generally healthy (stable), while populations in the north were declining. Land use issues were cited as occurring everywhere, but being more of a problem for hellbenders in the north.

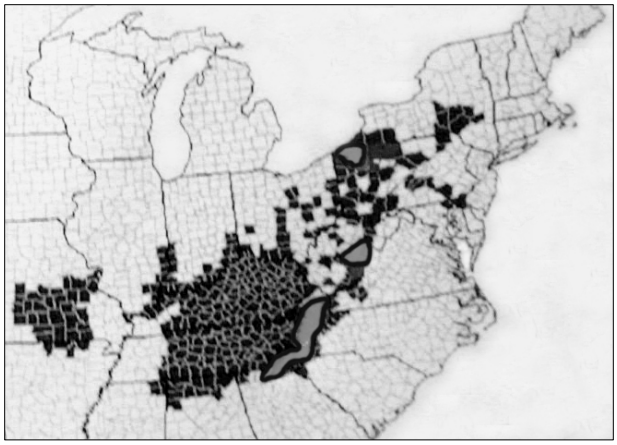


Figure 1. Approximate hellbender distribution (in black) and three core areas of remaining large populations (in gray) indicated by workshop participants. These match Forest Service and high elevation areas.

Based on their collective knowledge and available data, working group members estimated the current number of hellbender populations of various size (about 50, 100, 250, 500, 1000, 2500 or 5000 hellbenders) and whether these populations are healthy/stable or declining. This resulted in the estimation of over 300 populations across the eastern U.S., representing about 350,000 hellbenders (Table 2). Three core areas were identified (Figure 1) thought to represent the remaining large healthy Eastern hellbender populations, the largest being in Great Smoky Mountains National Park. Additional hellbenders may exist outside of these estimated populations. These rough estimates are not intended to accurately reflect the current total Eastern hellbender population; rather, they give an approximation of the estimated range of hellbender population sizes, status and relative distribution. This information provided a basis from which to project the relative viability of individual Eastern hellbender populations of varying size and status.

Table 2. Estimates of Eastern hellbender populations (sites) in the eastern U.S by region and state.

Region	State	Status	# sites	N/site	Total N
NY/PA	NY	Severe decline	Several	50	400
	PA	Declining	10	500	5,000
	PA	Good	10	500	5,000
IL/IN/OH	IL	Extirpated	0	--	0
	IN	Declining	1	500	500
	IN	Declining	2-3	50	150
	OH	Declining	10	100	1,000
WV/MD	WV	Healthy	8	5,000	40,000
	WV	Declining	17	250	4,250
	MD	Declining	2	200	400
VA/NC/east TN	Good sites	Stable	100	2,500	250,000
	Poor sites	Declining?	70+	250	17,500
West TN/KY	West TN	Declining?	20	250	5,000
	KY	Marginal	35	100	3,500
MS/AL	AL	Severe decline	9	50	450
	MS	Severe decline	1	50	50
GA	GA	Healthy	9	1,000	9,000
	GA	Declining?	10	500	5,000
Total					*347,200*

Catastrophes

Number of catastrophes: *3 (Midwest); 1 (Eastern U.S.)*

Catastrophes represent events of significant impact that occur outside of estimates of normal annual environmental variation. Potential catastrophes discussed were flooding events, disease (chytrid fungus), drought, climate change, stream capture, chemical spills, and large collecting events; however, little information is available regarding the frequency and impact of these events on hellbender populations. Participants chose to include three catastrophes in the model – drought, flooding, and large-scale collecting. The occurrence of these catastrophes is probabilistic in any given year (e.g., 5% = occurring on average once every 20 years). Drought and flooding occur regionally (i.e., occur during the same year for all populations in the subspecies metapopulation in the region), while collecting events were modeled to occur independently for each population. When a catastrophe occurs, it affects reproduction and/or survival across all age and sex classes during that year unless otherwise indicated. Probability of occurrence and impacts vary among populations and subspecies as outlined below and in Tables 3-5.

Drought: Drought results in high water temperatures, which can significantly impact reproduction. During recent drought conditions, no males were observed leaking milt. In general, significant drought was estimated to occur on average once every 20 years (5%) in the Midwest, reducing reproduction by 80% and survival by 5%. Drought was estimated to be less of an issue in the eastern U.S. and was only included in the Greenbrier River population model.

Flooding: Floods deposit gravel on and around nest rocks, potentially filling interstitial spaces; but also may expose previously buried rocks, thus creating new (nesting) habitat. If flooding occurs during reproductive season, there could be a significant effect on reproduction. Eggs may wash away, but this impact is estimated to be minimal. Survival generally is not affected by flood events, but may be decreased if water velocity increases near the river bottom, resulting in injury due to rolling rocks. In general, significant flooding was estimated to occur on average once every 100 years (1%), reducing reproduction by 25% and survival by 14%.

Large Collecting Events: Workshop participants felt that there is some risk of collectors removing a large number of hellbenders from one site and significantly reducing the population. The risk of this anthropogenic threat varies among populations depending upon location, accessibility, and other factors. Only hellbenders at least 13 cm ($\geq$ 2 years of age) are expected to be harvested. Large-scale collecting was modeled only for the Midwest metapopulations, as a reduction in survival (i.e., removal) of individuals 2 years and older in the affected population.

Model Parameters

Number of iterations: *1000*

1000 independent iterations were run for each scenario.

Number of years: *75 years*

Each scenario was run for 75 years to evaluate the long-term population trends (about 6 generations). Results also can be viewed for shorter time periods, as management plans generally span 15-20 years.

Extinction definition: *Only one sex remaining.*

Table 3. Estimates of population size (N), carrying capacity (K), and catastrophe frequency and impacts for populations of Ozark hellbenders.

Ozark hellbender (C. a. bishopi)			Drought (global)			Flooding (global)			Collection (2+ yrs) (local)		
Population	*N*	*K*	*Prob.*	*Repro.*	*Surv.*	*Prob.*	*Repro.*	*Surv.*	*Prob.*	*Repro.*	*Surv.*
North Fork/ Bryant Creek	200	5000	5%	0.20	0.95	1%	0.75	0.86	20%	1.00	0.80
Eleven Point	300	5000	5%	0.20	0.95	1%	0.75	0.86	10%	1.00	0.90
Current River/ Jack's Fork	80	1000	5%	0.20	0.95	1%	0.75	0.86	5%	1.00	0.95
Spring River	10	400	5%	0.20	0.95	1%	0.75	0.86	1%	1.00	0.50
TOTAL	*590*	*11400*									

Table 4. Estimates of population size (N), carrying capacity (K), and catastrophe frequency and impacts for populations of Eastern hellbenders in Missouri.

Eastern hellbender (C. a. alleganiensis)			Drought (global)			Flooding (global)			Collection (2+ yrs) (local)		
Population	*N*	*K*	*Prob.*	*Repro.*	*Surv.*	*Prob.*	*Repro.*	*Surv.*	*Prob.*	*Repro.*	*Surv.*
Niangua River	400	5000	5%	0.20	0.95	1%	0.75	0.86	20%	1.00	0.80
Gasconade River	100	500	10%	0.05	0.90	1%	0.75	0.86	10%	1.00	0.80
Big Piney River	50	1000	5%	0.20	0.95	1%	0.75	0.86	10%	1.00	0.90
Meramec/ Big River	50	1500	5%	0.20	0.95	1%	0.75	0.86	1%	1.00	0.95
TOTAL	*600*	*8000*									

Table 5. Estimates of population size (N), carrying capacity (K), and catastrophe frequency and impacts for four sample populations of Eastern hellbenders in the eastern U.S.

Eastern hellbender (C. a. alleganiensis)			Drought (global)			Flooding (global)			Collection (2+ yrs) (local)		
Population	*N*	*K*	*Prob.*	*Repro.*	*Surv.*	*Prob.*	*Repro.*	*Surv.*	*Prob.*	*Repro.*	*Surv.*
Little River (GSM)	600	600	--	--	--	3%	0.75	0.68	--	--	--
Greenbrier River (WV)	2188	3000	3%	0.20	0.90	1%	0.75	0.86	--	--	--
Davidson River (NC)	3125	3125	--	--	--	1%	0.75	0.86	--	--	--
Coosa Creek (GA)	250	2000	--	--	--	1%	0.75	0.86	--	--	--
TOTAL	*6163*	*8725*									

Discussion of Population Goals

Workshop participants recognized the critical situation for hellbender populations in the Midwest evidenced by the observed population declines and skewed age structure suggestive of low juvenile recruitment. A plenary discussion addressed the various options for setting and measuring population goals that would target increased viability for these populations. Ultimately the group set the following goals for each river population of Ozark hellbenders and for Eastern hellbenders in the Midwest:

Goal 1: Population size should double within 15 years.
Goal 2: Individuals 12" and smaller in total length should account for at least 25% of sampled hellbenders (comparable to survey records from the 1970s).

These goals address not only population growth/decline by setting target population numbers but also consider increased juvenile recruitment and more balanced age structure.

Deterministic Results and Model Validation

Deterministic model results were examined to consider population characteristics in the absence of stochastic processes to help assess how well the model represents estimated hellbender population biology. The baseline model describes a population that shows positive deterministic growth under simulated stable conditions ($r = 0.028$; $\lambda = 1.028$; $Ro = 1.42$) and shows moderate population decline under higher juvenile mortality/decreased recruitment conditions ($r = -0.062$; $\lambda = 0.940$; $Ro = 0.43$). These estimates represent the average population growth expected based on mean fecundity and mortality rates in the absence of inbreeding, environmental variation and other stochastic processes (e.g., shortage of mates, skewed sex ratio). Stochastic growth rates are expected to be lower, particularly for small populations, which are most impacted by stochastic processes. Generation time is 13.08 years, and adult male/female ratio is 0.43.

These results seem biologically plausible for a long-lived amphibian species such as the hellbender. The rate of decline in the declining population model matches the decline in hellbender populations reported by Wheeler *et al*. (2003) of 77% over 20+ years. A lambda of 0.940 observed in the model leads to a 77% decline in about 24 years. In summary, the model input values appear reasonable given the limited knowledge of hellbender demographic rates.

Population Simulation Projections

Ozark Hellbender Metapopulation

Projections over the next 75 years were made for individual Ozark hellbender populations as well as the subspecies metapopulation based upon the best available life history and population status information as described above. These projections assume mortality and fecundity rates that lead to population decline of about 6% annually in the absence of stochastic effects and are designed to mimic current threats to these populations with no further habitat loss or degradation.

As expected, all populations show negative growth, with faster rates of decline in smaller populations and those with greater risk of mass collecting events (Table 6). All populations are

at high risk of extinction [probability of extinction in 75 years (PE) > 0.96], with a mean time to extinction for most populations of about 35 years. In those few iterations in which the population did not go extinct (i.e., extant populations), mean population size is very small and gene diversity is low. Hellbenders are projected to be quickly lost from Spring River (current estimate of N = 10). Other hellbender populations are expected to decline and become at risk of extinction (PE > 0.05) in 15 to 30 years (see Figures 2 & 3). The Eleven Point population has the highest projected viability due to its larger population size and relatively low vulnerability to collecting; however, it is still projected to decline by 50% in about 13 years and has a 96.4% risk of extinction within 75 years.

The potential occurrence and impact of large collecting events was speculated during the PHVA but was difficult to quantify accurately. Removal of this threat from the model results in some improvement in population viability, bringing the probability of subspecies extinction from 95% to 64% (Table 6). Even without these large collecting events, however, long-term viability is extremely poor for Ozark hellbenders under current estimated conditions.

Cautionary note: Detailed accurate information is not available for current age structure, population size, demographic rates, and the impact of threats on hellbender populations. Field surveys suggest significant declines in hellbender populations and reduced juvenile recruitment. An attempt has been made to incorporate this into the hellbender simulation model, as reduced percent of breeding females and increased juvenile mortality. The actual mechanism for reduced recruitment potentially could involve any aspect of reproduction or survival to breeding age, such as reduced fertility, lack of suitable nesting rocks/habitat, reduced clutch size, or reduced hatch rate. The collection and analysis of demographic data will be necessary to accurately project population viability, assess the relative impact of various threats, and develop management strategies to address these threats most effectively.

Table 6. Projected viability of Ozark hellbender populations over 75 years (stochastic r; PE = probability of extinction; N_{ext} = mean population size of extant populations; SD = standard deviation of N_{ext}; GD = proportion of gene diversity remaining; Mean TE = mean time to extinction, in years).

Population	Initial N	Stoch. r	PE	N_{ext}	SD(N)	GD	Mean TE
Current Projection							
North Fork/Bryant Creek	200	-0.122	0.997	5.3	2.3	0.58	34
Eleven Point	300	-0.092	0.964	13.2	14.9	0.60	47
Current River/Jack's Fork	80	-0.094	0.991	10.2	10.1	0.56	33
Spring River	10	-0.232	1.000	--	--	--	5
Metapopulation	*590*	*-0.099*	*0.952*	*12.3*	*13.7*	*0.60*	*51*
Without Collecting Events							
North Fork/Bryant Creek	200	-0.073	0.891	13.5	15.3	0.67	50
Eleven Point	300	-0.066	0.754	23.2	25.6	0.70	57
Current River/Jack's Fork	80	-0.082	0.970	14.7	18.7	0.64	36
Spring River	10	-0.129	1.000	--	--	--	10
Metapopulation	*590*	*-0.070*	*0.643*	*21.7*	*25.1*	*0.71*	*62*

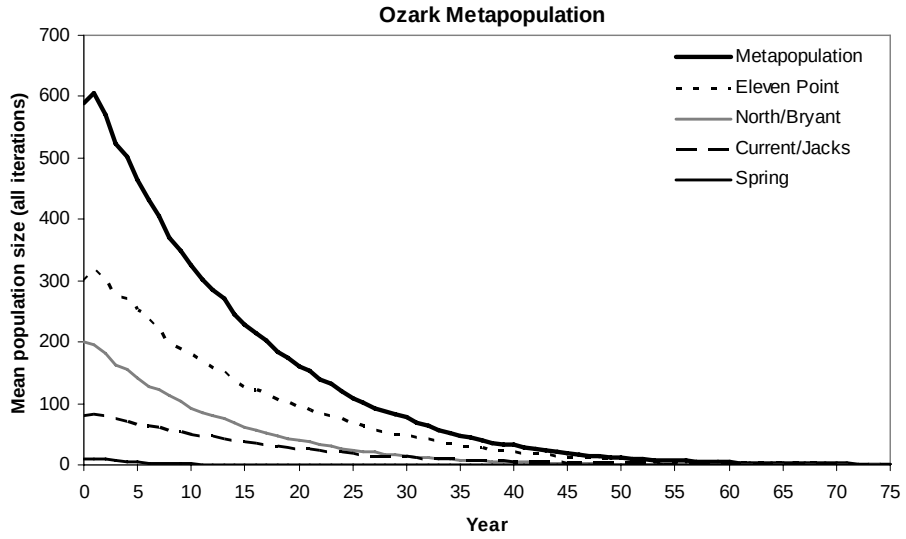


Figure 2. Projected mean population size for Ozark hellbender populations over the next 75 years.

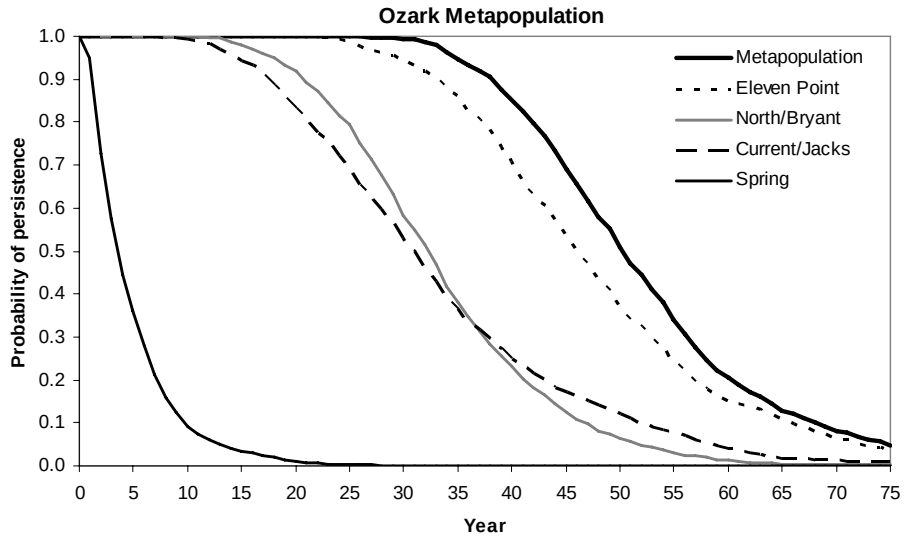


Figure 3. Probability of persistence for Ozark hellbender populations over the next 75 years.

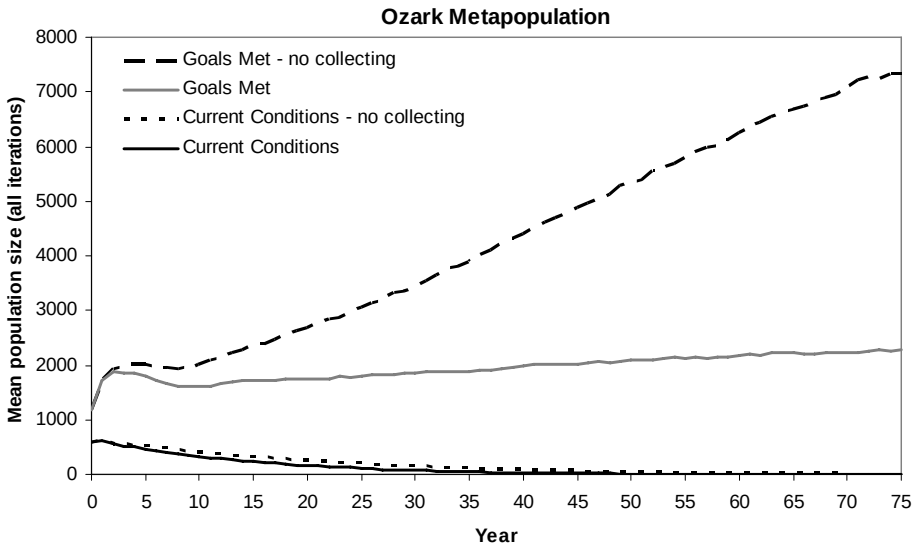


Figure 4. Projected mean population size for the Ozark hellbender metapopulation over the next 75 years, under current conditions and if population goals were achieved (stable population), with and without risk of large collecting events.

Population Goals for Ozark Hellbenders

As mentioned earlier, at the beginning of the PHVA, workshop participants recommended the following population goals for Ozark hellbenders: 1) double population size within 15 years; and 2) improve juvenile recruitment such that at least 25% of hellbenders surveyed are 12" or smaller. An attempt was made to roughly model Ozark hellbender populations that met these population goals by doubling current population estimates and adjusting the percent of females breeding, juvenile mortality rates, and age structure to those values used for stable hellbender populations. This represents conditions in which populations are larger (and therefore less vulnerable to stochastic processes) and has the potential to grow in the absence of stochastic threats.

Table 7 illustrates the long-term impact of these conditions on hellbender population viability. Viability is good (low PE, large N, GD $\geq$ 0.90) for all populations except the small Spring River population, although North Fork/Bryant Creek is still at risk due to collecting events. Removal of the risk of large collecting events further improves viability of all populations.

Under these projected conditions of doubling population size in concert with improving demographic rates, the metapopulation is able to grow and stabilize at about double the initial N (Figure 4). Further growth appears to be counteracted by collecting events; if large-scale collecting is removed from the model, the population continues to grow toward carrying capacity. Under both conditions the risk of subspecies extinction within 75 years is zero, but final mean population size is over three times larger without periodic large collecting events.

Although it is difficult to model the exact impact of achieving these population goals, and how population parameters may be altered to accomplish this, the model results highlight the significant potential risk of extinction for this hellbender subspecies, the importance of addressing those factors that are leading to population decline, and the need for additional information to be able to act in a timely and effective manner to prevent further population decline.

Table 7. Projected viability of Ozark hellbender populations over 75 years under stable conditions (population goals met) (stochastic r; PE = probability of extinction; N_{ext} = mean population size of extant populations; SD = standard deviation of N_{ext}; GD = proportion of gene diversity remaining; Mean TE = mean time to extinction, in years).

Population	Initial N	Stoch. r	PE	N_{ext}	SD(N)	GD	Mean TE
Goals Met (stable)							
North Fork/Bryant Creek	400	-0.016	0.081	281.4	304.2	0.91	62
Eleven Point	600	0.009	0	1486.6	1019.7	0.97	--
Current River/Jack's Fork	160	0.016	0.011	551.4	264.3	0.95	51
Spring River	20	-0.147	0.998	34.0	43.8	0.68	12
Metapopulation	*1180*	*0.008*	*0*	*2290.7*	*1202.4*	*0.98*	--
Without Collecting Events							
North Fork/Bryant Creek	400	0.027	0	2957.0	1296.7	0.98	--
Eleven Point	600	0.027	0	3594.1	1077.6	0.99	--
Current River/Jack's Fork	160	0.027	0.002	710.9	233.8	0.97	77
Spring River	20	-0.001	0.587	184.4	121.9	0.87	24
Metapopulation	*1180*	*0.028*	*0*	*7336.7*	*2067.0*	*0.99*	--

Eastern Hellbender Metapopulation (Missouri)

The Eastern hellbender (*C. a. alleganiensis*) occurs in two disjunct geographic distributions: an extensive range throughout the eastern U.S. from New York to Georgia, and a small region in Missouri consisting of four primary populations. As with the Ozark hellbender subspecies, relatively little current information is available on the life history and population status of these hellbender populations. Model projections for the Missouri metapopulation assume demographic rates that lead to an annual 6% population decline in the absence of stochastic effects and are designed to mimic current threats to these populations with no further habitat loss or degradation.

Simulation model results are similar to those for Ozark hellbender populations (Figures 5 & 6). All populations show strong population decline (9-11%) and very high risk of extinction (PE > 0.99), with mean extinction occurring in about 30 years (Table 8). The largest population, Niangua River, is likely to persist the longest, but is still projected to decline by 50% in about 9 years and has a 99% risk of extinction within 75 years. Mean time to extinction for the Missouri metapopulation is 47 years. The elimination of large collecting events from the model improves viability of the Niangua River population and decreases the probability of metapopulation extinction from 98% to 65%. Even without large collecting events, however, long-term viability is very poor for Eastern hellbenders in Missouri under current estimated conditions.

As noted for Ozark hellbenders, accurate data are lacking on the status of hellbender populations in Missouri and the factors leading to population decline. Better data are needed to accurately project population viability, assess the relative impact of various threats, and develop management strategies to address these threats most effectively.

Table 8. Projected viability of Eastern hellbender populations in Missouri over 75 years (stochastic r; PE = probability of extinction; N_{ext} = mean population size of extant populations; SD = standard deviation of N_{ext}; GD = proportion of gene diversity remaining; Mean TE = mean time to extinction, in years).

Population	Initial N	Stoch. r	PE	N_{ext}	SD(N)	GD	Mean TE
Current Projection							
Niangua River	400	-0.114	0.991	16.6	23.9	0.66	42
Gasconade River	100	-0.118	0.999	13.0	0.0	0.50	29
Big Piney River	50	-0.108	0.995	31.8	34.8	0.57	24
Meramec/ Big River	50	-0.092	0.991	15.3	26.0	0.41	28
Metapopulation	*600*	*-0.109*	*0.978*	*20.9*	*27.3*	*0.56*	*47*
Without Collecting Events							
Niangua River	400	-0.066	0.681	23.5	27.4	0.70	59
Gasconade River	100	-0.092	0.984	17.0	22.1	0.64	36
Big Piney River	50	-0.093	0.990	13.5	16.1	0.69	28
Meramec/ Big River	50	-0.096	0.993	20.7	22.8	0.65	28
Metapopulation	*600*	*-0.071*	*0.654*	*23.4*	*27.6*	*0.71*	*61*

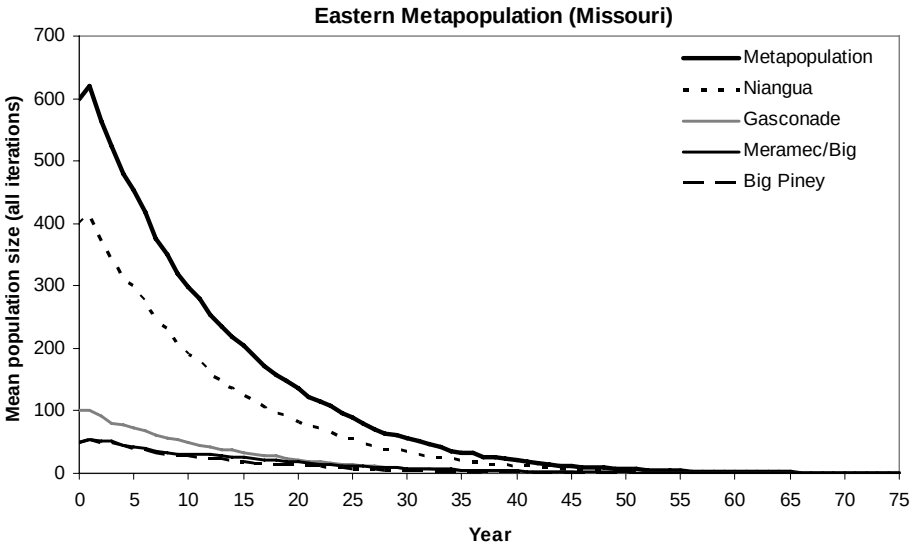


Figure 5. Projected mean population size for Eastern hellbender populations in Missouri over the next 75 years.

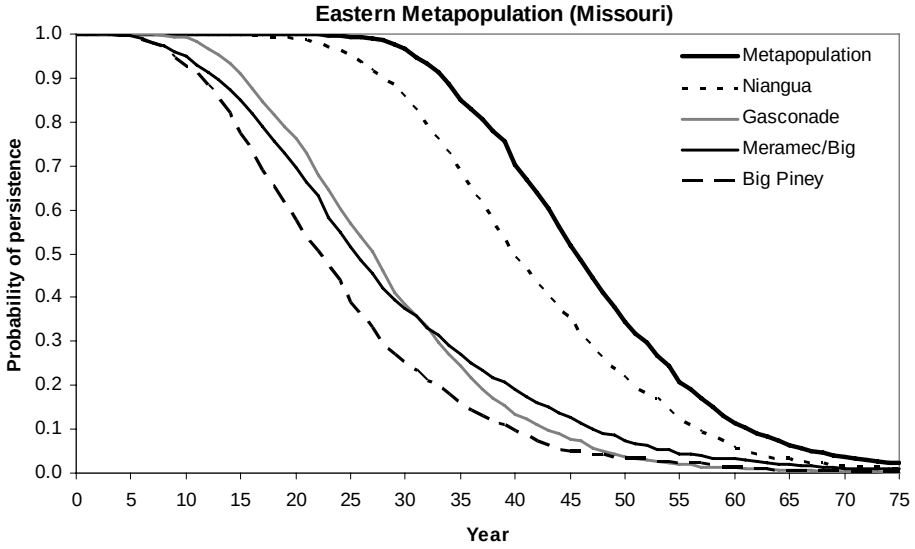


Figure 6. Probability of persistence for Eastern hellbender populations in Missouri over the next 75 years.

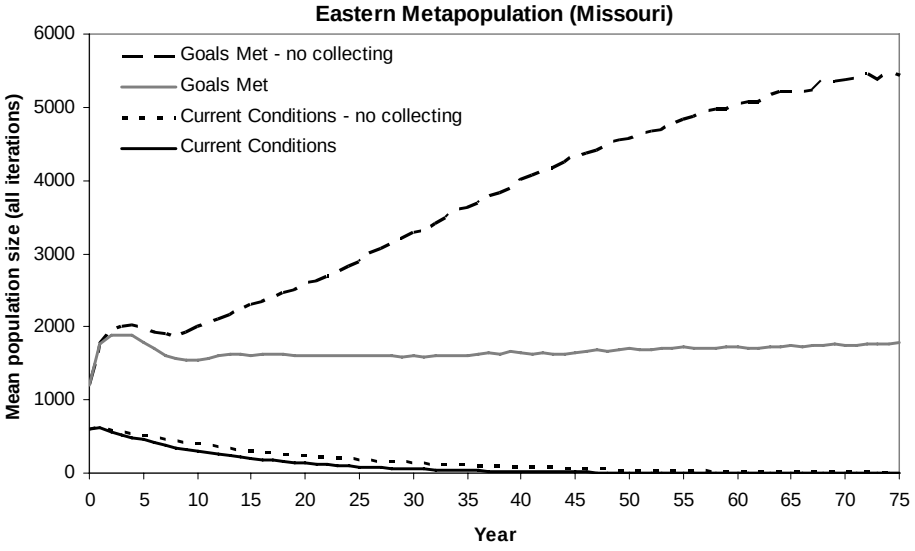


Figure 7. Projected mean population size for Eastern hellbender populations in Missouri over the next 75 years, under current conditions and if population goals were achieved (stable population), with and without risk of large collection events.

Population Goals for Eastern Hellbenders in Missouri

As stated previously, at the beginning of the PHVA, workshop participants recommended the following population goals for Eastern hellbenders in Missouri: 1) double population size within 15 years; and 2) improve juvenile recruitment such that at least 25% of hellbenders surveyed are 12" or smaller. An attempt was made to roughly model Eastern hellbender populations in Missouri that met these population goals by doubling current population estimates and adjusting the percent of females breeding, juvenile mortality rates, and age structure to those values used for stable hellbender populations. This represents conditions in which populations are larger (and therefore less vulnerable to stochastic processes) and has the potential to grow in the absence of stochastic threats.

Table 9 illustrates the long-term impact of these conditions on hellbender population viability. Viability is good (low PE, large N, GD $\geq$ 0.90) for all populations except for Gasconade River. Removal of the risk of large collecting events further improves viability.

Under these projected conditions of doubling population size in concert with improving demographic rates, the metapopulation is able to grow and stabilize at about 1.5x initial N (Figure 7). Further growth appears to be counteracted by collecting events; if large-scale collecting is removed from the model, the population continues to grow toward carrying capacity. Under both conditions the risk of subspecies extinction within 75 years is zero, but final mean population size is three times larger without periodic large collecting events.

It is not surprising that results for Ozark and Eastern hellbender populations in the Midwest are so similar, given the similarity in number of populations, size, status, threats and use of the same baseline model and demographic rates. As more detailed information becomes available, differences in biology, status and/or threats between these two subspecies can be modeled to better project future trends. Although there is substantial uncertainty surrounding many model parameters, simulation results highlight the significant potential risk of extinction for both hellbender subspecies in Missouri, the importance of addressing those factors that are leading to population decline, and the need for additional information to be able to act in a timely and effective manner to prevent further population decline.

Table 9. Projected viability of Eastern hellbender populations in Missouri over 75 years under stable conditions (population goals met) (stochastic r; PE = probability of extinction; N_{ext} = mean population size of extant populations; SD = standard deviation of N_{ext}; GD = gene diversity remaining; Mean TE = mean time to extinction, in years).

Population	Initial N	Stoch. r	PE	N_{ext}	SD(N)	GD	Mean TE
Goals Met (stable)							
Niangua River	800	-0.011	0.018	593.5	614.1	0.94	67
Gasconade River	200	-0.012	0.157	159.5	120.3	0.89	59
Big Piney River	100	0.012	0.062	408.8	271.3	0.92	50
Meramec/Big River	100	0.022	0.023	706.5	417.9	0.94	49
Metapopulation	*1200*	*0.005*	*0*	*1791.1*	*938.4*	*0.97*	--
Without Collecting Events							
Niangua River	800	0.028	0	3856.2	961.7	0.99	--
Gasconade River	200	0.013	0.010	279.9	130.9	0.94	59
Big Piney River	100	0.024	0.022	589.5	283.4	0.95	48
Meramec/Big River	100	0.023	0.024	747.2	430.7	0.95	52
Metapopulation	*1200*	*0.029*	*0*	*5439.0*	*1290.3*	*0.99*	--

Eastern Hellbender Metapopulation (Eastern U.S. Population)

The primary distribution of the Eastern hellbender is across the eastern United States. Workshop participants identified four specific hellbender populations within this distribution (Little River, Greenbrier River, Davidson River, and Coosa Creek) for specific population modeling as well as a general assessment of isolated populations across the entire geographic range.

The four identified populations differ from the hellbender populations in Missouri and Arkansas in several ways, which impact both how they were modeled and the potential viability of these populations. In general, these populations are estimated to be larger than those in the Midwest, making them less vulnerable to stochastic effects. Secondly, these populations are believed to be stable rather than declining, and so demographic rates and age distribution were used to reflect this. Finally, these populations were not thought to be at risk for drought (except for Greenbrier River) or large collecting events. All of these differences act to improve population viability.

Under these conditions, all four populations show a positive stochastic growth rate, remain relatively large, retain a high level of gene diversity, and have essentially no risk of extinction in 75 years (Table 10). If these conditions reflect the true situation for this subspecies, then long-term viability is good for these hellbender populations in the eastern U.S. If, however, these assumptions are inaccurate, or if conditions change that result in population decline or habitat loss/degradation, the prognosis could be quite different. Results from an alternative model scenario using reproductive and mortality rates based on a declining population indicate high risk of extinction for the two smaller populations (Little River and Coosa Creek), and 96% decline in the larger populations in Greenbrier and Davidson Rivers, suggesting extinction in subsequent years if a longer time period were modeled (Figure 8).

These divergent results underscore the importance of accurate estimates of current demographic rates for hellbender populations. Prior to the PHVA workshop, biologists assumed that hellbender populations in the east were stable. If, however, these populations are becoming more heavily impacted by human activities, they may become or may already be vulnerable to those processes causing population declines in hellbenders in the Midwest.

Table 10. Projected viability of Eastern hellbender populations in the eastern U.S. over 75 years (stochastic r; PE = probability of extinction; N_{ext} = mean population size of extant populations; SD = standard deviation of N_{ext}; GD = proportion of gene diversity remaining; Mean TE = mean time to extinction, in years).

Population	Initial N	Stoch. r	PE	N_{ext}	SD(N)	GD	Mean TE
Current Projection (Stable)							
Little River (GSM)	600	0.020	0.003	404.9	143.3	0.96	57
Greenbrier River (WV)	2188	0.028	0	2407.7	515.8	0.99	--
Davidson River (NC)	3125	0.033	0	2644.7	457.6	0.99	--
Coosa Creek (GA)	250	0.033	0	1594.4	362.2	0.99	--
Metapopulation	*6163*	*0.035*	*0*	*7050.5*	*938.0*	*0.99*	--
Under Population Decline							
Little River (GSM)	600	-0.075	0.719	26.4	33.0	0.75	57
Greenbrier River (WV)	2188	-0.054	0.058	72.2	66.4	0.87	70
Davidson River (NC)	3125	-0.046	0.002	132.5	99.6	0.91	72
Coosa Creek (GA)	250	-0.058	0.637	32.1	36.5	0.78	56
Metapopulation	*6163*	*-0.047*	*0*	*219.8*	*137.2*	*0.94*	--

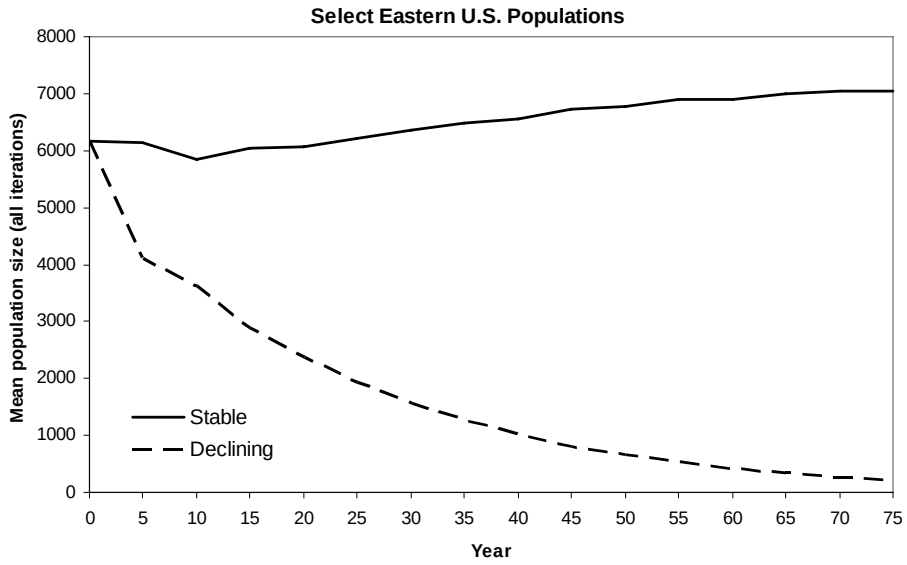


Figure 8. Projected mean population size for select Eastern hellbender populations in the eastern U.S. over the next 75 years, under current conditions and using demographic rates associated with population decline.

The Eastern hellbender metapopulation consists of hundreds of populations in isolated river systems. These river systems are becoming increasingly impacted by land use, especially in the northern portion of the range. The Eastern hellbender working group discussed all available information at the PHVA to estimate the number, size and status (stable vs. declining) of hellbender populations in each drainage system and state as shown in Table 2. The viability of these populations was evaluated by modeling single populations of each size and status, with no drought or large collecting events and assuming K = 2x initial N. Model results are presented in Table 11.

Predictably, declining populations (all of which were estimated at $N \leq 500$) show negative growth rates, high risk of extinction, and small population size and significant loss of gene diversity in extant populations. Larger, stable populations (which were estimated at $N \geq 500$) show positive growth of about 3% annually, high retention of gene diversity, and essentially no risk of extinction within 75 years. If these estimates are reflective of the current status of the subspecies, it is likely that small hellbender populations ($N < 500$) will be lost, but that larger, stable populations are viable.

Table 11. Model results for estimated Eastern hellbender populations in the eastern U.S according to population size and status (declining vs stable) (stochastic r; PE = probability of extinction; N_{ext} = mean population size of extant populations; SD = standard deviation of N_{ext}; GD = proportion of gene diversity remaining; Mean TE = mean time to extinction, in years).

Estimated N	Declining	Stable	Stoch. r	PE	N_{ext}	SD(N)	GD	Mean TE
50	20	--	-0.086	0.993	25.7	25.7	0.40	28
100	45	--	-0.080	0.966	17.2	19.3	0.55	40
250	110	--	-0.064	0.762	21.0	20.7	0.68	56
500	21	--	-0.060	0.504	29.9	30.5	0.74	63
500	--	10	0.031	0	805.5	168.3	0.95	--
1000	--	9	0.032	0	1652.7	306.5	0.98	--
2500		100	0.034	0	4254.8	694.4	0.99	--
5000	--	8	0.034	0	8604.3	1356.0	1.00	--
Total # pops	*196*	*127*						
Total N	*43,500*	*304,000*						

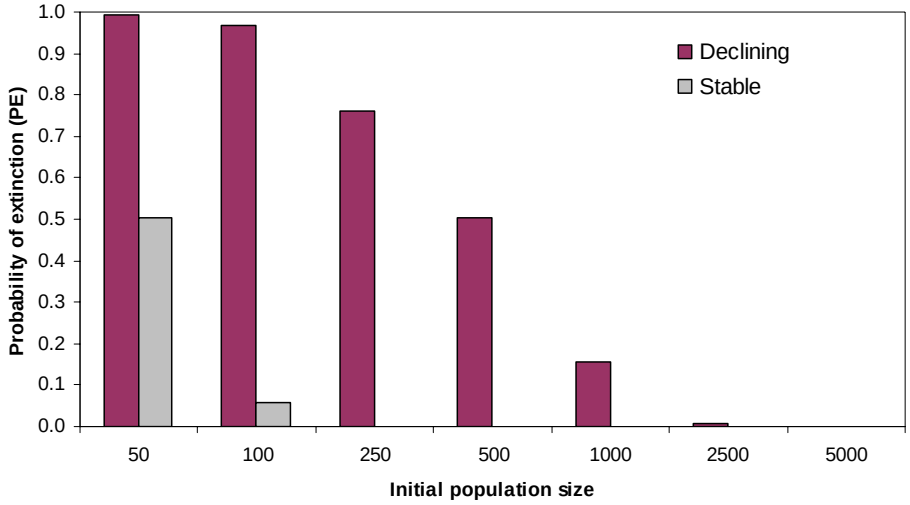


Figure 9. Probability of extinction in 75 years for hellbender populations based on population size and status.

Figure 9 illustrates the effects of population size and demographic rates on hellbender population viability. By definition, declining populations will eventually go extinct, no matter how large; however, interbreeding populations of at least 2500 individuals have little risk of extinction within 75 years. On the other hand, small populations (e.g., 50 individuals) are vulnerable to stochastic processes and have a significant risk of extinction even under stable conditions with no large-scale collecting events. Populations of at least 250 individuals show no risk of extinction in 75 years under stable conditions.

Summary of Model Projections

The best available estimates of hellbender and general amphibian biology and population status were used to develop a hellbender stochastic population model using *Vortex*. Hellbender population and habitat estimates across the geographic range of both subspecies were developed by PHVA workshop participants and used to estimate population viability over the next 75 years. Populations of both subspecies in the Midwest (Missouri and Arkansas) are generally thought to be relatively small and experiencing long-term population decline. Low juvenile recruitment is suspected, but the population mechanisms and factors responsible for low recruitment have not been confirmed. The best guess projections for these metapopulations suggest high probability of extinction for both hellbender subspecies in the Midwest within the 75-year timeframe used for the model, even with no further loss of habitat. Both metapopulations are projected to decline by more than 50% in 12-16 years, viability of all individual populations is low after 20-25 years ($N<100$, gene diversity < 90%), and risk of metapopulation extinction is high within 40-50 years. These projections may be optimistic, as they are based on best case density estimates and assume that hellbender populations within each river system are continuous. However, hellbenders do not travel great distances, and subpopulations within each river system may be separated by miles (in some cases) of unsuitable habitat and represent fragmented populations.

Population estimates and status for the Eastern hellbender in the eastern U.S. are less well known. These populations are generally believed to be larger and more stable, particularly in the southern portion of the range. Best guess projections suggest that small populations are likely to be lost in the next 75 years, but that large, stable populations centered primarily near northwestern Pennsylvania, eastern West Virginia, and the Great Smoky Mountains National

Park are viable. Changing conditions or an increase in threats to these populations that reduce population growth may jeopardize the long-term viability of even large populations.

The ability to make future projections for hellbender populations is compromised by the paucity of detailed information regarding current demographic rates, age structure, population size, and the impact of threats on hellbender populations. Sensitivity testing demonstrates how changes in demographic rates (population growth) impact population viability projections. A thorough understanding of the mechanisms resulting in population decline and factors affecting hellbender biology are critical for developing effective management strategies to reverse this trend.

Assessment of Eastern hellbender populations during the workshop helped participating biologists to realize the uncertainty and assumptions regarding the status of this subspecies and how divergent possible futures may be for these populations. This prompted the Eastern Hellbender working group participants to begin development of a grant proposal to survey 14 watersheds (two per state) to more accurately assess hellbender density, demography, age (size) structure, and population size using mark-recapture data. Such research efforts could provide current estimates for critical targeted information across the geographic range of this subspecies in order to better estimate the long-term viability of these populations and guide management actions for the conservation of this subspecies.

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Section IV
Participant List and Introduction Questions

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PARTICIPANT INTRODUCTION QUESTIONS

What do you hope will be accomplished during this 3½ day workshop?

1. An exposure of the broad areas and specific areas of research needed to more fully understand hellbender biology and thus conservation; to provide a more in depth understanding of what we know about hellbenders.
2. That the attendees will gain a clear sense of direction and planning for successful conservation of the hellbenders
3. Continued cooperation among all agencies and institutions getting *C. a. alleganiensis* and *C. a. bishopi* on the endangered species list quickly; identify threats to *C. a. alleganiensis* and *C. a. bishopi* in habitat and identify means of curbing effects of these threats.
4. Advance the conservation of hellbenders, particularly the Ozark hellbender, by focusing our knowledge and efforts to prioritize conservation goals and objectives.
5. Since I just took over the lead for the hellbender in our office, I hope to learn as much as possible within the next 31/2 days of the current research with regard to the hellbender and come away with some idea of the current status of the species as a whole and the 2 subspecies.
6. That a nice clear picture of the hellbenders status overall - be it in wild and in captivity – can be agreed with focus on next steps.
7. A robust model of life history needs which may highlight mechanisms of decline
8. Identify information gaps that can be filled through focused research.
9. Identify data gaps that are needed to guide hellbender conservation.
10. Model/plan to start and identification of data gaps/data priority.
11. I would like to witness the experts present “state of the art” knowledge about conservation of hellbenders. I wish to understand the “priority needs” for this species throughout its range.
12. I would like to learn enough here about hellbenders and their habitat to put to use in artificial stream system
13. Prioritize research topics, integrate resources and share data
14. Create an open dialogue that does not get hindered by personal agendas; create a model that highlights areas of research that are lacking and come up with a plan that will allow us to efficiently fill in as many of these gaps as possible.
15. Develop a national conservation plan for the hellbender - both in situ and ex situ; gather information to use to develop a North Carolina state-wide survey; need more hellbender workers
16. I hope that some priorities will be set as to where future research is needed.
17. Identify recovery goals that allow researchers, government agencies, universities, and zoos to work together for the conservation of the hellbender.
18. I hope that we will come to some conclusions as to how we can best preserve the hellbender through a cooperative sharing of knowledge and expertise.
19. I hope that we are able to prioritize the areas in need of further research and/or those that need immediate conservation action.
20. Networking opportunities between field and zoo researchers and a framework for the continuing conservation of the hellbender.
21. Design some sort of action plan with all parties involved to determine what needs to be done (and how)to guarantee hellbender survival.
22. Develop means to reverse the major decline of hellbenders in Missouri stimulate state and federal agendas to protect the hellbender streams and rivers; encourage all parties (agencies, counties and private landowners) to greatly reduce water pollution, siltation,

agricultural run off, etc., so streams will improve as habitat for this species and all aquatic animals.
23. Appears to be so many factors impacting hellbenders. I hope we can obtain a shorter list for directing research to save the hellbender.
24. Concentrate on emphasis areas to learn and be able to further educate others about hellbenders.
25. A strengthening of the established partnership between field and captive components.
26. I'd like to have a better understanding of the relative importance of threats to hellbenders in Missouri and of management actions hat could be harming or helping hellbender survival.

What do you hope to contribute?

1. Any information that would help us understand hellbender biology/conservation.
2. An ability to research and find various funding sources for conservation of the hellbender.
3. My love and support to each of you.
4. My knowledge and expertise working to recover imperiled aquatic species including stabilizing/improving increasing populations and the habitat they depend on.
5. Since I don't have any data to present, my contribution will most likely be future efforts in terms maintaining partnerships and developing new ones for the hellbenders
6. Hellbender husbandry experience in captivity and how that can contribute to a realistic and recognized opportunity to breed them in captivity.
7. A linkage to public and NPS activities within the Current and Jacks Fork rivers which may encourage in situ continuation and enhancement of the Ozark hellbender in these waters
8. Some information from the captive aspect
9. Knowledge gained through field experience that may not be in published literature.
10. Info about Eastern hellbender life history (ways they differ from Ozarks and Midwestern Eastern group), since most people here are from the Midwest.
11. Information on aquatic ecology, macrohabitat and land use patterns.
12. I will provide any information that I can toward advancing the conservation status of this species.
13. Physiological and health aspects, i.e., establish health/physiological/reproductive databank to assist monitoring of release animals; water quality monitoring
14. Field data/knowledge of Tennessee and Missouri hellbenders; my enthusiasm
15. Knowledge and experience on natural history and distribution of hellbender in the east.
16. I hope to offer insight and observation from the field.
17. Help strengthen our role in improving a captive program and education program for the species.
18. I hope to contribute my knowledge of the hellbender, (specifically as I've come to know them in captivity) and apply it to our purposes toward captive propagation, conservation in the wild, and education through cooperative efforts of the rest of the PHVA conference invitees.
19. I hope to contribute my knowledge of working with hellbenders in captivity towards ex situ conservation efforts.
20. I want to contribute an open mind. I hope to perhaps provide some insight into the roles zoos and aquariums can possibly play in the conservation of the hellbender.
21. Trials, errors and successes of hellbender husbandry in captivity.
22. Stimulate discussion on what can be done on the ground – in the field- on streams to get things done for *Cryptobranchus* to survive.
23. I hope to contribute my vast knowledge of this species in Missouri from research, surveys, planning, coordination and education.

24. Educate myself in order to provide accurate information to the public about the recovery effort in place. I can contribute some public and private landowner information and perhaps some stream habitat information.
25. A clear understanding of the potential benefits zoos, aquariums and museums can be to this species.
26. I hope to contribute a management perspective that will help everyone understand the challenges (logistical, political and financial) involved in management of habitat for an aquatic endangered species.

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Section V
Invitation List

Invitation List

Kelly Abercrombie	Saint Louis University
John Ackerson	Missouri Department of Conservation
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Alvin Breisch	New York State Department of Environmental Conservation
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James Civiello	Missouri Department of Conservation
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Rich Collister	Wonders of Wildlife Zooquarium
Chris Davidson	U.S. Fish & Wildlife Service
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Karen Goellner	Saint Louis Zoo
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Brian Green	Missouri State University
John Groves	North Carolina Zoological Park
Charlie Hoessle	Saint Louis Zoo
Peggy Horner	Missouri Department of Conservation
Yue-wern Huang	Huang University of Missouri-Rolla
Kelly Irwin	Arkansas Game & Fish Commission
Lisa Irwin	Independent biologist
John Jensen	Georgia Department of Natural Resources
Tom Johnson	Missouri Department of Conservation - retired
John Kleopfer	Virginia Department of Game & Inland Fisheries
Jessi Krebs	Omaha's Henry Doorly Zoo
Bob Legler	Missouri Department of Conservation
Greg Lipps	Midwest PARC, Co-chair
Dale Madison	State University of New York-Binghamton
Alicia Mathis	Missouri State University
Max Nickerson	University of Florida
Christopher Phillips	Illinois Natural History Survey
Amber Pitt	University of Florida
Eric Routman	San Francisco State University
Erica Shelby	State of Arkansas Department of Environmental Quality
Andy Snider	Detroit Zoo
Richard Shelton	U.S. Fish & Wildlife Service
Joe Tavano	University of Florida
Stanley Trauth	Arkansas State University
Tim Turpin	Missouri Department of Natural Resources
Jill Utrup	U.S. Fish & Wildlife Service
Mark Wanner	Saint Louis Zoo
Zack Walker	Indiana Department of Natural Resources
Doug Warmolts	Columbus Zoo & Aquarium
Ben Wheeler	Arkansas State University

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Section VI
Working Group Notes

Working Group Notes

Group 1

Points of Influence

The working group recognized three major areas where significant impacts could be made towards improving the viability of hellbender populations: (1) illegal collecting, (2) research techniques, and (3) lack of protection due to status by state and federal governments. We have the following recommendations:

1. Take steps to decrease illegal collecting
    a. Insure that appropriate laws are in place in every state with hellbenders.
    b. Encourage wildlife/conservation agencies to enforce laws.
    c. Encourage/support effort to obtain money to fund enforcement activities.
    d. Make recommendations regarding timing and location of enforcement activities.
    e. Encourage judicial enforcement of laws.

2. Up-grade the protection status of hellbenders by state, federal, and international regulatory agencies.
3. Immediately implement maintenance of captive populations for possible reintroduction in natural habitats

Brainstorming

Exotic Species

Need baseline studies to determine presence/absence of exotic species currently in hellbender habitat.

- Survey fishes, crayfish, and algal communities.
- Perform literature search to help determine already established exotics and potential exotics.
- Need to involve specialists from taxonomic groups that potentially impact hellbender populations.
- List the known exotics river by river.

Determine the predatory impacts of the exotic species already established in hellbender habitat.

- Are all hellbender age groups available as prey?
- Are hellbenders palatable to potential predators sharing their habitat? Will such predators attack hellbenders the second or third time they are offered them as prey?
- Are there evolutionary differences in behavior of the various hellbender populations to exotic predators?

Determine the niche (spatiotemporal activity patterns) overlap between known exotic species and hellbenders (i.e., do they potentially come in contact with each other or act as competitors).

- Location of larvae compared to exotic species. If larvae spend much of their time in the interstitial matrix, are they available as prey?

Determine the source of exotic fish stocking.

- Brown trout - Current, North Fork, and Eleven Point Rivers.
- Rainbow trout - Eleven Point and Current Rivers.

Determine methods to mitigate the effects of exotics (especially trout).

- Compare the effects of different species of trout on hellbenders.
- Potential to decrease interaction of trout and hellbenders by manipulating the timing of stocking.
- Potential to decrease interaction of trout and hellbenders by altering the location of stocking.

Determine the age-specific effects of known exotic species.

- Competition effects of exotic species directly on hellbenders or indirectly via lowering the abundances of potential hellbender prey.

Predation

Is there an interaction between stress and predation?

Effect of reintroductions of native species (e.g., river otters)

- Density of river otters.
- Density of river otters increasing or decreasing.
- Predation rate on hellbenders.
- Competition for hellbender prey (e.g., native crayfish)
- Behavior of river otters.
- Alteration of habitat by river otters.

Determine the impacts of native predators (e.g., raccoons, mink, muskrats, water snakes, snapping turtles, water birds)

- Learned behavior of hellbender predators (e.g., flipping behavior to get at underside of belly).
- Determine if populations of potential predators have increased during hellbender decline.
- Determine if habitat changes (shallowing and widening) affect predator impacts

Determine the effects of cannibalism.

Palatability of hellbenders at different life stages (e.g., eggs of some amphibian species are toxic).

Effects of human predation

Disease

Interaction between stress and disease.

- Which stressors make hellbenders most vulnerable to disease?
- Are there age- or size-specific disease effects?
- Are certain age- or size-classes most vulnerable to having their immune system suppressed through stress?

Literature review is needed.

Potential diseases.

Treatment methodologies.

Involve amphibian disease experts to determine protocols to screen for a variety of diseases (field, veterinary, DATF, epidemiologist, and zoos)

- Centralize pathology so that methodology and record keeping is consistent.
- Biopsy/necropsy as deemed necessary.
- Develop post-mortem protocol.

- Preserve specimens/tissue for potential assays at a future time.
- Accumulate knowledge of successful disease treatments.

Investigate known diseases throughout geographic range of hellbenders (Chytrid, iridiovirus).
- Determine geographic distribution of diseases.
- Compare disease profiles of healthy (stable) and unhealthy (declining) populations.
- Stage (age) - specific effects of diseases.
- Determine the protective qualities of skin secretions.

Investigate abnormalities commonly found in some populations of hellbenders in Missouri.
- Cause of abnormalities (e.g, disease, injury, genetic problems, or some combination of these).
- Treatment for the abnormalities.

Do hellbenders in some populations have compromised immune systems (reduced xenobiotic resistance)? If so, why?
- Determine why limbs are not regenerating in some populations.
- Investigate potential for cross-species disease transfer

Develop protocol for investigating disease.
- Complete data collection at infected habitat.
- Send samples to appropriate authorities.
- Deposit specimen in museum.

Research/Management Techniques

Trophy areas
- Slot limits

Multiple agency use of populations
- Stream Teams, schools, government

Impact of teaching/using volunteers for hellbender work

Standardizing survey techniques
- Habitat protection
- Prevention of destructive techniques

Determine where enforcement is needed

Fund-raising for enforcement
- Volunteer basis

Appearance of enforcement
- Dummy cameras
- Fake signage
- Uniformed volunteers

Lack of Judicial enforcement
- Networks to influence prosecution

Effects of specific techniques
- MS-222
- Electro-shocking

Get hellbender officially listed

- Give this group a name to officially attach to these proceedings
- Newspaper-local effects, grass roots efforts

Remote survey techniques
Timing of management techniques for fisheries
Horsepower limits for river
Specific Site monitoring

Captive Propagation / Headstarting / Captive Assurance Populations

Compare to Chinese and Japanese methodologies
Dark day with rain to initiate breeding
Assurance populations for disease prevention
Numbers of institutions
Locality of institutions
In situ captive breeding
Location of funding
Water quality of institutions
Minimum parameters for participating institutions
Collaboration with field researchers

Ecology

Changes in community composition

Group 2

Areas over which we have influence:

Siltation/Sedimentation (top priorities)

1. Best management practices (inform and proper implementation). *Priority 4*
2. Public outreach. *Priority 3*
    a. Establish a hellbender network
    b. Agency/NGO outreach
    c. Identify groups/personnel to work with stakeholders
    d. Establish good working relationships with stakeholders (private landowners, state and federal agencies, NGOs, local watershed groups, etc.).
3. Landowner incentives
4. Identify critical watersheds. *Priority 1*
    a. Identify and conserve important habitat/stream reaches
5. Promote conservation of healthy forest ecosystems (i.e. Farm Bill, Healthy Forest Reserve Program, Private Stewardship Grants, etc)
6. Develop comprehensive watershed conservation plans and agreements. *Priority 2*
7. Balance public access with conservation of species. *Priority 5*
8. Limit horsepower of motors in rivers with boat access

Habitat Fragmentation (top priorities)

1. Public outreach (i.e. county judges/commissioners). *Priority 1*
    a. Use social diffusion.
    b. Use media (Newspapers, TV, magazines, etc)
    c. Use outdoor retailers (Bass Pro Shops, Gander Mountain, etc.)
    d. Focus public outreach on things that the public can connect with (good water quality, sport fish such as smallmouth bass).
    e. Politician education/support.
2. Identify accepted road crossing designs for hellbender conservation. *Priority 3*
    a. Reclamation of poorly designed bridges.
    b. Limit road crossings/density
3. Petition for development of adequate protections/laws. *Priority 2*

Water Quality (top priorities)

1. Increase public facilities (U.S. Forest Service, National Park Service). *Priority 4*
    a. Landowner incentives to increase facilities, trash cans.
2. Visitor limitations on rivers.
3. Inform DNR/EPA. *Priority 3*
4. Prioritize watersheds to focus water quality efforts. *Priority 1*
    a. High elevation WV
    b. Southwest VA, western NC, east TN
    c. North GA
    d. Northwest PA
    e. AR/MO
5. Develop community pride/social diffusion. *Priority 2*
6. Informational materials (coozys, kiosks)

Group 3

General list of things we can influence (no prioritization):

Education:

1. Educate anglers
2. Over collecting of hellbender larvae
3. Educate recreational users about the consequences of urinating and defecating in the water
4. Educate individuals about the basic biology of hellbenders and their value (Inform individuals that hellbenders are becoming more rare in the wild)
5. Educate anglers about the proper handling/release from hooks
6. Teach individuals about consequences of turning rocks/disturbing habitat
7. Educate younger people about the need for culture changes (not harvesting large numbers of crayfish to eat or play with) (Midwest ecoregion)
8. Habitat disturbance: educate recreational users about affects of habitat disturbances from rock turning, removal vehicles use in streams and canoe and rafting rental places
9. River access (select locations away from hellbender sites): educate canoe and rafting industry (green methods, road construction- avoid prime habitat)

Regulation/Enforcement:

1. Create regulation to provide proper toilets and waste disposal
2. Require business owners to provide proper trash containers
3. Fine people if they litter
4. Fine people for gigging and enforce laws (Midwest ecoregion)
5. Regulate habitat disturbance by ATVs, boats, canoes, etc. as well as rock removal and dynamiting rocks. Dynamiting is also an issue in the eastern areas with respect to mining and urban development.

Research Needs:

1. Are anglers mis-informed to the laws/regulations as they appear? Current habits of anglers: bait fishing, collecting, release, etc.
2. What diseases are prevalent on species sold in bait shops?
3. Is there competition/predation from released bait species?
4. Effects of hormones introduced through urination into streams on hellbenders
5. Physical/chemical risks of "trash"
6. Impacts of human waste on health or immune systems of hellbenders
7. Effects of noise on hellbenders from recreational vehicles. (There is some research being conducted on this on fish in the Caribbean.)