Project Title: Threats Analysis and Conservation Actions for the Illinois Cave Amphipod: Vulnerability Assessment of Groundwater Quality Land Use and Climate Change Impacts

Job Completion Report

Project Number: T-93-R-1

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Background:

The Illinois Cave Amphipod (*Gammarus acherondytes*) was listed as an endangered species by the U.S. Fish & Wildlife Service (USFWS) more than 15 years ago (USFWS, 1998). Similarly, the state of Illinois lists the species as endangered and considers it a species in greatest conservation need. With these concerns in mind a recovery plan for the ICA was published in 2002 (USFWS, 2002), and more recently a 5-year update was completed (USFWS, 2011). These assessments concluded that a better understanding of the threats facing the ICA is warranted and that best practices for managing these threats should be developed. This study was undertaken with these recommendations in mind. Specifically, in this study, an expert panel was solicited to conduct a threats assessment for the ICA, and to determine specific management practices to address those threats. Experts in cave ecology and ICA ecology and management were convened to address this important topic using a modified Delphi method.

Goals:

1. Convene a panel with expertise in Illinois Cave Amphipod ecology and management
2. Conduct a threats assessment for the Illinois Cave Amphipod, drawing the panel's expertise.
3. Determine the most salient threats facing the Illinois Cave Amphipod, as rated by the expert panel.
4. Determine appropriate management actions associated with each threat.

Using Expert Opinion for Species Conservation:

Identifying threats facing species of conservation concern is a critical component of recovery efforts (Wilcove et al., 1998). However, for some species, significant uncertainty exists

surrounding habitat needs, life history, population status, and threats and vulnerabilities that influence the odds of the species' survival. The capacity to generate knowledge needed to inform endangered species policy is often limited by financial, temporal, and logistical constraints. Policy, however, must be set for species recovery and management. In some cases expert opinion can be instrumental in reducing this uncertainty, identifying salient threats, and building a consensus for appropriate management response (Donlan et al., 2010; Martin et al., 2012; Javeline et al., 2015).

The Delphi Method:

The Delphi Method emerged from the business community as a means to forecast uncertain futures (Dalkey, 1967). It has since been adapted for use in a variety of fields, including natural resource management (Mukherjee et al., 2015; MacMillan & Marshall, 2006), to elicit expert opinion and develop consensus on values-laden topics (Taylor & Ryder, 2003). The technique uses multiple rounds of surveys and feedback of responses to establish a consensus among a panel of experts. Generally, in Delphi studies, experts are asked to provide their attitudes on a given topic, the researcher collates the responses, and presents the results back to the participants in an iterative manner. Participants are then able to adjust their responses in light of the group's beliefs on the issue, until a consensus is reached or minority viewpoints become apparent. Mukherjee et al. (2015), in reference to the Delphi method, state that it "could [also] be used to identify indicators to evaluate and prioritize aspects of biodiversity management." Expert opinion elicited through procedures like the Delphi method are one potential way to rapidly assess threats and identify management strategies in the face of incomplete knowledge regarding species habitat requirements, specific threats driving decline, or

the efficacy of alternative management responses (Mukherjee et al., 2015; Donlan et al., 2010). This is approach was adopted for this study.

Methods:

The study consisted of two rounds of surveys. In the first survey round (n=26), experts were given a description of the study purpose and asked to provided open ended responses regarding threats to the Illinois Cave Amphipod corresponding to the 4 broad categories of identified stressors in the Illinois Wildlife Action Plan; Habitat, Community, Populations, and Direct Human Impacts. Descriptions of these categories were presented to respondents (Table 1). Respondents were also given the option of placing threats in an "other" category in the instance that they did not perceive that the categories captured salient threats to the species. Themes were identified from the panel's open ended responses (Table 1). All data collection occurred through the Qualitrics online platform, and respondents contacted via email.

In the second survey round respondents were presented with the threats that emerged from the first round elicitation process. Roughly two weeks passed between survey 1 and 2. Both surveys were open for a period of one week. Respondents were asked to rate the severity that they perceived from each threat with respect to the Illinois Cave Amphipod (Table 2). Threat severity was rated on a scale from 1=not at all a problem, to 4=a very serious problem, with respect to each threat. Respondents also had the option to state "I don't know." Finally, respondents were asked, for each threat, to identify any management actions that they believed would mitigate the threat, or reduce its impact on the ICA. Open ended responses to potential management actions were subject to analysis, and emergent themes identified.

Finally, threats were categorized in three groups based on the panel's perceived severity. The first group of threats was termed "most salient threats" and consisted of those that the

majority of the panel rated as either “somewhat of a problem” or “a very serious problem.” The second group was dubbed “less salient threats.” This group consisted of those threats that 50% or less of the panel rated as either “somewhat of a problem” or a “very serious problem.” A third group of threats was identified as those that the panel did not possess sufficient knowledge to rate. These threats consisted of those that 50% or more of the panel rated as “I don’t know.” A workflow of these methods is depicted in Figure 1.

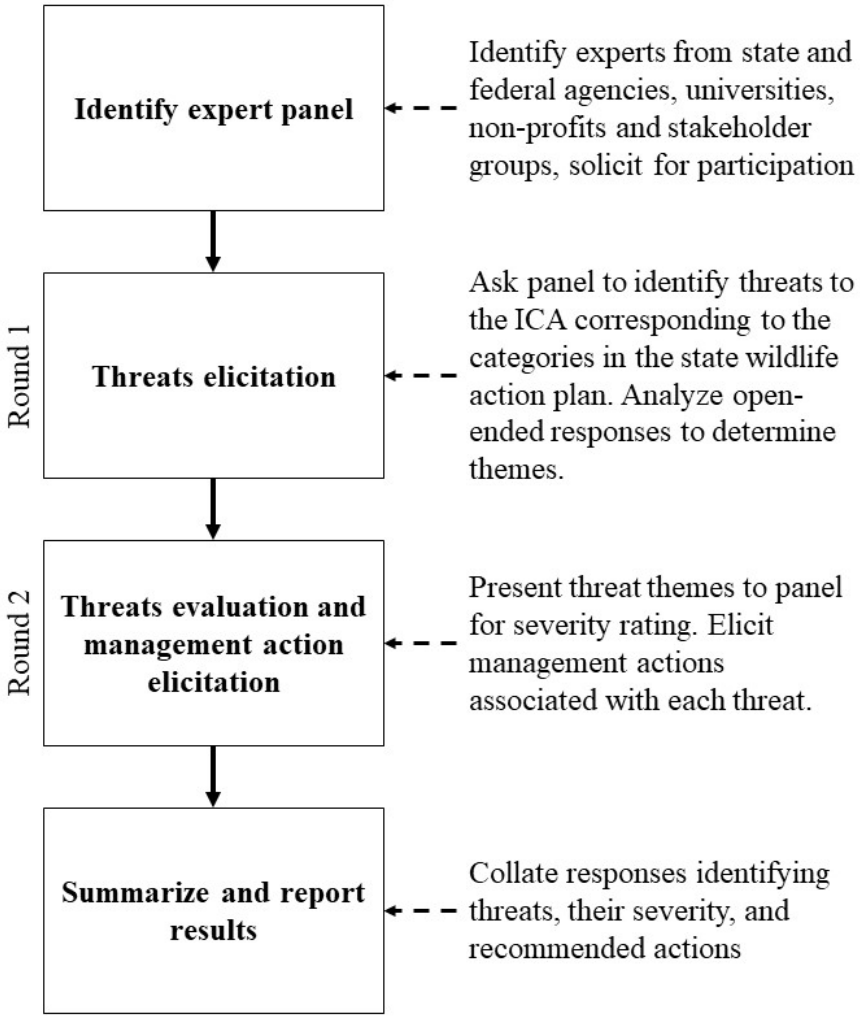

Figure 1. Description of Delphi study workflow to determine expert opinion regarding threats and management responses for the Illinois Cave Amphipod.

Results:

Thirty-one participants were solicited in the first round questionnaire. Of these potential respondents 4 addresses were undeliverable and one respondent asked to opt-out for an adjusted sample frame of 26 individuals. Nine completed questionnaires were obtained for an effective response rate of 35%.

The expert panel identified 21 unique threats facing the ICA (Table 1). Seven threats were associated with Habitat. Among these, water quality was the most common theme. Four of the threats identified were associated with water quality including, nutrients stemming from household septic systems (Threat #1), nutrients and sediment run-off from row crop agriculture (Threat #2), sediments stemming from land management practices near sinkholes/caves (Threat #3) and other contaminants including road salt, pharmaceuticals, and herbicides/pesticides (Threat #4) (Table 1). The panel also indicated that landuse change (Threats #5, 6) and surface activities (Threat #7) pose a threat to the ICA.

Five threats were associated with Community. However, water quality was indirectly implicated by many respondents. Increased populations of competitor species were perceived to negatively influence ICA populations (Threat #8), and changes in competitor numbers are a function of impaired water quality. Similarly, direct mortality (Threat #13), under the category of Population, was perceived to be a function of water quality. Three other threats were identified under the umbrella of Community including predation from other macroinvertabrates (Threat #10), introduced fish (Threat #11), and changes in surface habitat conditions from the proliferation of invasive species (Threat #12), especially bush honeysuckle. Three threats were found to be associated with Direct Human Impact. These included cave visitation (Threat #17),

the disposal of wastes in sinkholes (Threat #18), and groundwater levels and alterations to natural low regimes (Threat #19).

Finally, two threats were offered under the category "Other." Several participants indicated that a lack of monitoring and management of the ICA posed a significant threat to its future status (Threat #20). Climate change was also identified as a potentially significant threat to the ICA (Threat #21).

Table 1. Threat category definitions and threats elicited from expert panel (n=9)

Categories of Threats	Threats Identified by Panel
Habitat includes but is not limited to the extent, physical composition, and spatial distribution/fragmentation of species' range, as well as disturbance regimes, hydrology, and pollutants	**#1 Water Quality** - Increased nutrients leaching from residents' septic systems **#2 Water Quality** – Increased nutrients and siltation from row crop agriculture **#3 Water Quality** – Increased siltation from land management practices near sinkhole and cave entrances **#4 Water Quality** – Increased loading of other contaminants from peri-urban and agricultural sources; herbicides, pesticides, road-salt, pharmaceuticals **#5 Landuse Change** – Increased impervious surface in watershed **#6 Landuse Change** – Deforestation in watershed **#7 Noise pollution** – Changes in bedrock harmonic frequencies from surface activities (e.g., wind turbines, waterlines)

Table 1. Continued.

Community includes but is not limited to inter-specific competition, predation, parasites and disease, food sources, life-stage hosts, competition from invasive/non-native species, and other symbiotic relationships	**#8 Competition** – Competition with increasing populations of other macro-invertebrates (e.g., isopods) in response to declining water quality **#9 Competition** – Toxins released from large numbers of millipedes (*Oxidus gracilis*) in some caves **#10 Predation** – Predation by other macroinvertebrates **#11 Predation** – Predation by introduced fish **#12 Invasive Species** – Bush honeysuckle altering surface habitats
Populations includes but is not limited to genetics, dispersal and recruitment, and mortality rates	**#13 Mortality** – Direct mortality from reduced water quality in the form of sedimentation and contaminants **#14 Dispersal and Recruitment** – Limited, disconnected, high quality cave habitat limits dispersal and refugia that facilitate recolonization following flood events **#15 Inbreeding** – Limited genetic diversity due to isolation and small numbers **#16 Life History** – Low metabolic rate
Direct Human Impacts includes but is not limited to direct killing or removal by humans, harassment, and infrastructure development (e.g., dams, powerlines, and roads)	**#17 Visitation** – Humans using the cave systems for recreation, walking on and disturbing habitat **#18 Sinkhole Dumping** – Humans disposing of trash, manure, animal carcasses directly into caves and sinkholes **#19 Water** – Stream diversion, groundwater pumping
Other any other area of concern for the species	**#20 Management** - Lack of monitoring and management efforts for species recovery **#21 Climate Change** – Changing seasonality of rainfall, surface temperatures

Distribution of threat ratings by participant is presented in Table 2. In total, six experts that completed the first round questionnaire also completed the second. Few threats were rated as a minimal problem, or not a problem.

Table 2. Distribution of threat* ratings by expert panel (n=6)

	Not at all a problem	A minimal problem	Somewhat of a problem	A very serious problem	I don't know
Threat 1	0	0	1	4	1
Threat 2	0	0	2	4	0
Threat 3	0	0	2	2	2
Threat 4	0	0	2	3	1
Threat 5	0	0	4	0	2
Threat 6	0	1	1	2	2
Threat 7	1	1	0	0	4
Threat 8	0	0	2	3	1
Threat 9	0	1	0	1	4
Threat 10	0	2	1	0	3
Threat 11	0	1	1	1	3
Threat 12	0	0	2	1	1
Threat 13	0	1	2	2	1
Threat 14	1	1	2	1	1
Threat 15	1	0	3	0	1
Threat 16	3	1	0	1	1
Threat 17	0	4	2	0	0
Threat 18	0	0	1	4	1
Threat 19	0	2	0	0	4
Threat 20	0	1	1	4	0
Threat 21	0	0	1	2	3

*threat numbers correspond to definitions in table 1

Following the established criteria, 8 threats were identified as "most salient." Seven threats were categorized as "less salient," and the remaining five fell into the "unknown" category with respect to their severity (Table 3). All of the threats associated with water quality (e.g., 1-5, 13) were rated as most salient with respect to their impact on the ICA. Additionally, landuse change, sinkhole dumping, and management were found to pose significant threat.

Table 3. Categorization of threats by panel ratings

Threat Category	Threat
Most salient threats: >50% of panel indicated either "somewhat of a problem" or "a very serious problem"	**#1 Water Quality** - Increased nutrients leaching from residents' septic systems **#2 Water Quality** – Increased nutrients and siltation from row crop agriculture **#3 Water Quality** – Increased siltation from land management practices near sinkhole and cave entrances **#4 Water Quality** – Increased loading of other contaminants from peri-urban and agricultural sources; herbicides, pesticides, road-salt, pharmaceuticals **#5 Landuse Change** – Increased impervious surface in watershed **#13 Mortality** – Direct mortality from reduced water quality in the form of sedimentation and contaminants **#18 Sinkhole Dumping** – Humans disposing of trash, manure, animal carcasses directly into caves and sinkholes **#20 Management** - Lack of monitoring and management efforts for species recovery

Table 3. Continued.

Threat Category	Threat
Less salient threats: ≤50% of the panel indicated either "somewhat of a problem" or "a very serious problem"	**#6 Landuse Change** – Deforestation in watershed **#12 Invasive Species** – Bush honeysuckle altering surface habitats **#14 Dispersal and Recruitment** – Limited, disconnected, high quality cave habitat limits dispersal and refugia that facilitate recolonization following flood events **#15 Inbreeding** – Limited genetic diversity due to isolation and small numbers **#16 Life History** – Low metabolic rate **#17 Visitation** – Humans using the cave systems for recreation, walking on and disturbing habitat **#21 Climate Change** – Changing seasonality of rainfall, surface temperatures
Unknown: ≥50% of the panel indicated "I don't know"	**#7 Noise pollution** – Changes in bedrock harmonic frequencies from surface activities (e.g., wind turbines, waterlines) **#9 Competition** – Toxins released from large numbers of millipedes (Oxidus gracilis) in some caves **#10 Predation** – Predation by other macroinvertebrates **#11 Predation** – Predation by introduced fish **#19 Water** – Stream diversion, groundwater pumping

Management practices were elicited to address each of the threats identified in round 1. Table 4 contains the results of analysis of the options offered by the expert panel as means to address the threats that were rated as most salient. Respondents suggested that in order to address issues associated with nutrient loading from home septic systems (Threat #1), that regulations governing these systems be better enforced, local governments provide incentives to homeowners to upgrade systems, and that options for a centralized sewage treatment system be explored (Table 4).

Several management practices were offered as solutions to nutrient loading and sediment associated with row crop agriculture (Threat #2) including property acquisition around sinks/caves, education programs targeted at landowners, increased monitoring of water quality parameters in caves, encouraging no-till practices in sensitive watershed, increasing the use of buffer strips around sinks/caves and waterways, and increasing the acreage of Conservation Reserve Program in sensitive watershed. To address Threat #3, land management practices near sink/cave openings, the panel suggested greater attention be given by the Illinois Department of Natural resources to the management of the Annbriar property, education programs be developed targeting landowners with sink/cave habitat on their property, and buffer strips be implemented around openings.

Respondents offered several solutions to address the effects of contaminants (Threat #4) including road salt, pharmaceuticals in groundwater, and herbicide/pesticide runoff on the ICA. Again, code enforcement and inspection of septic tanks was recommended, as was increased monitoring. Respondents suggested that studies be undertaken to assess the sensitivity of the ICA to herbicides and pesticides, as well as identify road segments that could be targeted for reductions in road salt application. Additionally, a suggestion was made to switch from salt to a

brine solution in sensitive watersheds to reduce salt application. Finally, the panel suggested an overall reduction in the application of herbicides and pesticides in sensitive watersheds.

To address the impacts of urbanization (Threat #5) the panel suggested exploring mandatory minimums for native land cover in sensitive watersheds including prairie and forest, although the point was raised that these systems likely were not in a forest cover prior to European colonization. Additionally, the panel suggested greater attention be paid to the Annbriar and Pautler properties with respect to the influences of land cover changes.

Recommendations to address effects of direct mortality stemming from reduced water quality (Threat #13) were much the same as for Threats 1-5. However, a recommendation was also made to conduct a study exploring ICA sensitivity to water quality parameters. Sinkhole dumping (Threat #18) was identified as among the most salient threats to the ICA. Respondents suggested greater enforcement of existing code which limits these practices, creation of new protective regulations where absent, and extension programming to educate landowners and youth regarding the potential hazards associated with the practice.

Finally, respondents had several recommendations for Threat #20, the current state of ICA management. A suggestion was made to hire an Illinois cave biologist to assist with monitoring. Similarly, several respondents indicated that more frequent monitoring must be done to assess status of the species. A recommendation of at least an annual survey, in line with USFWS recovery plan, was made. The panel also found that securing external funds to support monitoring efforts for ICA would be prudent.

Table 4. Management practices identified to address each threat

Threat	Management Practices
#1 Water Quality - Increased nutrients leaching from residents' septic systems	*Enforcement of existing code to ensure proper septic system functioning, including provisions for inspection in sensitive watersheds. *Incentives for upgrading and maintenance of private septic systems. *Implementing a regional sewer system to eliminate private septic.
#2 Water Quality – Increased nutrients and siltation from row crop agriculture	*Property acquisition to protect sink habitat above caves *Education programs to leverage buy-in from landowners *Increase monitoring of water quality in caves *Increase the implementation of no-till practices in sensitive watersheds *Provide incentives for farmers to implement buffer strips around sinkholes, and increase enrollment in land-sparing programs in sensitive watersheds (e.g., Conservation Reserve Program). *Reduce application rates of fertilizers to match crop needs based on soil tests.
#3 Water Quality – Increased siltation from land management practices near sinkhole and cave entrances	*Improve management of Annbriar property, including the removal of bush honeysuckle. *Establish vegetative buffers and "dry basins" to capture sediments. *Education and enforcement regarding existing statutes.

Table 4. Continued.

#4 Water Quality – Increased loading of other contaminants from peri-urban and agricultural sources; herbicides, pesticides, road-salt, pharmaceuticals	*Increase monitoring of contaminants in caves. *Research to understand amphipod sensitivity to herbicides/pesticides. Establish recommendations for farmers. *Reduce application rates of herbicides/pesticides in sensitive watersheds. *Identify road segments where salt application should be minimized or eliminated. *Switch to brine solution from road salt to reduce amount applied.
#5 Landuse Change – Increased impervious surface in watershed	*Better manage IDNR properties including Annbriar and Pautler. *Establish minimums for native vegetation cover (e.g., prairie and woodland) within groundwater basins.
#13 Mortality – Direct mortality from reduced water quality in the form of sedimentation and contaminants	See also recommendations outlined under threats 1-4 *Determine amphipod sensitivity to different water quality parameters.
#18 Sinkhole Dumping – Humans disposing of trash, manure, animal carcasses directly into caves and sinkholes	*Enforce existing regulations on sinkhole dumping/create where absent. *Extension programs to engage landowners and school aged kids regarding the potential hazards these practices pose.
#20 Management - Lack of monitoring and management efforts for species recovery	*Hire an Illinois cave biologist. *Secure funds from US Fish and Wildlife to support recovery. *Increase frequency of monitoring. Follow annual recommendation set in recovery plan.

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