Batrachochytrium salamandrivorans (*Bsal*) in Appalachia: Using Scenario Building to Proactively Prepare for a Wildlife Disease Outbreak Caused by an Invasive Amphibian Chytrid Fungus

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Cover. Eastern red-spotted newt (*Notophthalmus viridescens*), New River Gorge National River. This species is susceptible to *Bsal*. Photograph by the National Park Service.

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Abstract

Batrachochytrium salamandrivorans (*Bsal*), a pathogenic chytrid fungus, is nonnative to the United States and poses a disease threat to vulnerable amphibian hosts. The *Bsal* fungus may lead to increases in threatened, endangered, and sensitive status listings at State, Tribal, and Federal levels, resulting in financial costs associated with implementing the Endangered Species Act of 1973. The United States is a global biodiversity hotspot for salamanders, an order of amphibians that is particularly vulnerable to developing a disease called chytridiomycosis when exposed to *Bsal*. Published *Bsal* risk assessments for North America have suggested that salamanders within the Appalachian region of the United States are at a high risk. In May 2017, a workshop was facilitated by the Department of the Interior's Strategic Sciences Group. During the workshop, a discussion-based incident-response exercise focused on a hypothetical *Bsal* disease outbreak in Appalachia was led by U.S. Geological Survey staff members. Participants included representatives of the Eastern Band of the Cherokee Indians, U.S. Fish and Wildlife Service, National Park Service, Appalachian Landscape Conservation Cooperative, Tennessee Wildlife Resources Agency, and U.S. Department of Agriculture's U.S. Forest Service. Scenario building was used to brainstorm cascading consequences (social, economic, and ecological) of a *Bsal* disease outbreak in the Appalachian region. This report highlights the management and science actions that could be undertaken to ensure an effective, rapid response to a *Bsal* introduction into the United States.

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Introduction

Chytridiomycosis, the fungal disease previously thought to only be caused by *Batrachochytrium dendrobatidis* (*Bd*), is considered the greatest threat to biodiversity of any wildlife disease due to the large number of amphibian species it affects and its unique ability to drive species and populations to extinction (Wake and Vredenburg, 2008). A close relative of *Bd, Batrachochytrium salamandrivorans* (*Bsal*) was described in 2013 (Martel and others, 2013) when die-offs in fire salamander (*Salamandra salamandra*) populations were reported in Europe. *Bsal* is not known to occur in North America, but during preliminary laboratory trials some U.S. species were infected and found to be susceptible to *Bsal*-associated disease (Martel and others, 2014). Our knowledge of amphibian species that are vulnerable to *Bsal* currently is incomplete (Martel and others, 2013), with knowledge of anuran infections only coming to light in 2017 (Nguyen and others, 2017; Stegen and others, 2017). Laboratory findings show that U.S. amphibians can be affected by *Bsal*, and because the United States has the highest salamander diversity in the world (Petranka, 1998), this fungal pathogen is a major threat (Gray and others, 2015; Yap and others, 2015; Richgels and others, 2016). *Bsal* has the potential to exacerbate already severe amphibian declines and lead to major increases in threatened, endangered, and sensitive status listings for these animals at State, Tribal, and Federal levels, with corresponding increases in costs associated with the Endangered Species Act of 1973.

Bsal is thought to have an Asian origin with amphibians in international trade markets serving as reservoirs for spreading the disease to Europe (Martel and others, 2014; Laking and others, 2017; Nguyen and others, 2017) and potentially elsewhere. *Bsal* has been detected in captive amphibians in Europe (Cunningham and others, 2015; Sabino-Pinto and others, 2015), but not yet in the United States (Klocke and others, 2017). Millions of amphibians, however, have been imported into the United States annually (Schloegel and others, 2009). More than

3.5 million small-webbed, fire-bellied toads (*Bombina orientalis*; Nguyen and others, 2017) that are susceptible to *Bsal* were imported to the United States between 2001 and 2009 (Herrel and van der Meijden, 2014), and *Bsal*-susceptible Asian salamanders accounted for more than 90 percent of the salamanders imported to the United States from 2004 to 2014 (Gray and others, 2015). Thus, there is concern that this disease-causing pathogen may be introduced into the United States if it is not already present. The U.S. Fish and Wildlife Service proactively published an interim rule in 2016, listing 20 genera (201 salamander species) as injurious under the Lacey Act (18 U.S.C. § 42) and banning them from import to reduce the chance of introduction by way of the pet trade (U.S. Fish and Wildlife Service, 2016). Smithsonian Conservation Biology Institute research suggests that this rule has been effective (Klocke and others, 2017). The Government of Canada also implemented a 1-year import restriction on all salamanders in 2017 (Government of Canada, 2018). Internationally, *Bsal* has been recognized by the World Organization for Animal Health as a notifiable amphibian pathogen (World Organization for Animal Health, 2018).

Emerging infectious diseases typically have been addressed reactively when they become a crisis (Grant and others, 2017). Having prior knowledge of a wildlife disease threat before its occurrence in the United States is unprecedented and offers a unique chance to develop and implement a coordinated response in a timely manner before significant effects are realized. This proactive response could be particularly helpful for amphibians, which are often cryptic in nature and receive less attention than other animal groups. Mortality events in wild amphibian populations may escape notice, allowing further disease transmission among individuals, species, and sites before detection is confirmed.

Executive Order 13751, Safeguarding the Nation From the Impacts of Invasive Species (Executive Office of the President, 2016), describes the Federal policy to prevent the introduction of invasive species as well as to eradicate and control established populations. This order also applies to causative agents of disease like *Bsal*. If *Bsal* were discovered in the United States, Federal departments and agencies, in coordination with State and Tribal agencies, would be tasked with detecting and rapidly responding to this pathogen, thus reducing harm to U.S. amphibians. To this end, the USGS Amphibian Research and Monitoring Initiative (ARMI) organized an international workshop that led to the formation of the *Bsal* Task Force (*Bsal* Task Force, 2016; Grant and others, 2016). The Task Force comprises a Technical Advisory Committee and seven working groups that address and coordinate efforts for diagnostics, response, decision support, research, surveillance, outreach, and data sharing. The *Bsal* Task Force has developed a customizable response template for agencies dealing with a *Bsal* detection in various contexts, such as in captivity versus the wild and with or without a mortality event (*Bsal* Task Force, 2016). USGS ARMI also proactively partnered with the USGS National Wildlife Health Center (NWHC) to conduct national-level *Bsal* surveillance with a focus on areas identified as high risk (Richgels and others, 2016). Through the *Bsal* Task Force, a beta version of a repository for *Bsal* surveillance results, including USGS data, has been set up through AmphibiaWeb and is available at https://amphibiandisease.org. Although *Bsal* has not yet been discovered in the United States, surveillance and response planning efforts continue.

To better understand the immediate consequences and actions that might accompany the discovery of *Bsal* in the United States, the USGS engaged the DOI Strategic Sciences Group (SSG, https://www.doi.gov/strategicsciences) to lead a workshop that explored social, economic, and ecological chains of consequences with a small group of resource managers representing an array of State, Tribal, and Federal agencies within the Appalachian region, a global hotspot for salamander diversity (Milanovich and others, 2010). Using methods developed for response to the Deepwater Horizon oil spill and Hurricane Sandy (U.S. Department of the Interior, 2010, 2012, 2013; Machlis and McNutt, 2010), the SSG approach presented predetermined scenarios (see below) to a group of experts who were then asked to brainstorm the cascading consequences of the scenarios presented. After developing numerous chains of consequences for each scenario, the group identified possible interventions that could alter or interrupt each chain. For this exercise, the group was also asked to consider barriers to an effective response that might be addressed in advance of a *Bsal* outbreak.

Scenario-Building Process

The scenario-building methodology used for the *Bsal* workshop was based on methods previously published by the DOI SSG for response to the Deepwater Horizon oil spill (U.S. Department of the Interior, 2010, 2012; Machlis and McNutt, 2010) and Hurricane Sandy (U.S. Department of the Interior, 2013). These methods include defining terminology as well as establishing assumptions and the scope of the scenarios. The SSG approach uses the conceptual framework of a coupled human-natural ecosystem model, allowing land managers and natural resource specialists to consider the effects of a *Bsal* detection not only on the ecosystem but also on society, including visitors to affected lands (regional economic impact), employees, and nearby communities. Participants developed chains of consequences to visualize the depth and breadth of the impact of detecting this invasive animal pathogen in Appalachia. Qualitative levels of uncertainty (for example, 5 = certain, 1 = not likely) were assigned to each element in each chain of consequences, providing a first-order assessment. After initial discussion of scenarios, assumptions, and definitions, the process generally began by brainstorming chains of consequences of the scenarios (workshop agenda, appendix 1). These chains of consequences include automatic occurrences given the scenario and consequences that often lead to other consequences. After developing these chains of consequences, the group brainstormed possible interventions. Implied is that the interventions are meant to alter the chains of consequences and therefore alter the outcome of the scenario; however, for simplicity, this exercise was done without discussing the objectives of the interventions. A more formal decision-making process would seek to link possible interventions with desired outcomes. Although we adhered to the general process of first focusing on consequences and then moving to interventions, it quickly became apparent that it was difficult to clearly distinguish between the two. We did not attempt to enforce any distinction or definition but used this structure for the workshop to promote brainstorming. In other words, many of the "consequences" we envisioned were actions by responsible agencies that could be viewed as "interventions." We also added the step of identifying barriers that might get in the way of an effective response. The goal of the scenario-building process was to thoroughly consider courses of action that could happen under different *Bsal* outbreak scenarios so that we can improve our preparation for the expected arrival of this invasive pathogen. The exercise was not meant to guide decisions to achieve specified outcomes but, rather, to explore the initial consequence of and reactions to *Bsal* discovery. Structured decision making would be a useful next step for some needs we identified and would help link potential actions to specified objectives.

Scenario Scope

The workshop attendees created chains of consequences and interventions for two scenarios. The scenarios are described in appendix 2, and maps of the geographic settings of the scenarios are included in appendix 3. These scenarios were designed to investigate the potential effects and response pathways of *Bsal* discovery on lands managed by different agencies, test the capacity and readiness of the *Bsal* Task Force and other entities in responding to an event, consider the effectiveness of the draft *Bsal* response plan in the scenarios, and introduce the challenge of communicating a *Bsal* discovery to the public.

Scenario 1

The first scenario the group considered involved the discovery of *Bsal* in the Great Smoky Mountains National Park (GSMNP). GSMNP is the most-visited U.S. National Park, hosting more than 11 million visitors in 2016 (https://irma.nps.gov/Stats/), and is situated in a region with the highest salamander diversity in the world. Park visitation is a major component of the local economy (Cullinane Thomas and others, 2014) and would be a factor in managing the consequences of *Bsal* detection. In Scenario 1, visitors reported to GSMNP biologists that a large die-off of Eastern red-spotted newts (*Notophthalmus viridescens*) was observed at Methodist Church Pond, GSMNP, in Tennessee. The pond is in a region of the park called Cades Cove, which is one of the park's most popular areas. In this scenario, swab samples of newts from Methodist Church Pond were collected by GSMNP biologists and submitted to the USGS NWHC where deoxyribonucleic acid (DNA) was extracted and a *Bsal* polymerase chain reaction (PCR) technique was employed to test for the presence of *Bsal* genetic material (Blooi and others, 2013). *Bsal* was detected in the swab samples. Previous sampling by USGS ARMI had not detected *Bsal* here or anywhere else in the United States. Several other amphibian species are found at Methodist Church Pond. Two days after finding the newt die-off, a park ranger found a visitor releasing a Chinese fire belly newt (*Cynops orientalis*) in another region of the park called the Sinks (about 10 miles direct line from Methodist Church Pond). It was determined that this person had previously released salamanders in the park. *Cynops* species are common in the pet trade and are known carriers of *Bsal* (Martel and others, 2014).

After a brief discussion of the scenario, the group agreed on the following assumptions: (1) no other pathogens were detected; (2) a second laboratory analysis confirmed the PCR result of *Bsal* detection; (3) the skin lesions on the wild-caught salamanders from the pond were consistent with *Bsal*; (4) visitors were aware of the die-off; and (5) the Chinese fire belly newt was confiscated by park staff.

Scenario 2

The second scenario the group considered involved the discovery of *Bsal* at Scott-Booher Pond in the Cherokee National Forest, Tennessee. The forest adjoins GSMNP and national forests in four other States. Scott-Booher Pond is in a less-visited part of Tennessee, compared to GSMNP, but the Appalachian Trail passes within 65 feet of Scott-Booher Pond and is traversed by more than 1,500 hikers per year (Zarnoch and others, 2011). The scenario was that a die-off of Eastern red-spotted newts was reported at Scott-Booher Pond. Simultaneously, a local hunter reported seeing more than 20 dead salamanders on the Eastern Band of the Cherokee Indians (EBCI) Tribal land, about 112 miles from Scott-Booher Pond on the other side of the GSMNP. Administratively, the lands directly affected by Scenario 2 differ from Scenario 1. Scenario 1 occurred within the jurisdiction of the U.S. Department of the Interior, which manages national parks, and the State of Tennessee. The first die-off event in Scenario 2 took place on lands managed by the U.S. Department of Agriculture's Forest Service and the State of Tennessee. The second die-off event in Scenario 2 occurred on sovereign trust lands of the EBCI, where there is no State or Federal jurisdiction to legally act. If a disease is found on Tribal lands, however, the DOI Bureau of Indian Affairs and the U.S. Department of Agriculture Office of Tribal Relations would likely be tasked to promote Federal cooperation and collaboration with local Tribal liaisons.

After a brief discussion, the group agreed to the following assumptions: (1) this scenario is an extension of the first scenario (the first scenario had occurred a few days prior); (2) the U.S. Forest Service contacted the Tennessee Wildlife Office and State Biological Division who contacted a disease specialist at the University of Tennessee to initiate testing; (3) *Bsal* was detected by PCR analyses from swab samples collected at Scott-Booher Pond, and the detection was confirmed by tests at a second laboratory; (4) the cause and exact location of the die-off on the EBCI lands were unknown at the time of the reported die-off; and (5) the hunter reported the die-off to a GSMNP ranger.

Highlights of Interventions

The participants envisioned extensive cascading consequences, which are too cumbersome to present here in their entirety; however, examples of subsections of the cascading consequences from the built scenarios are described in appendix 4. We did not enforce any definition of "consequences" or "intervention" during the workshop, but instead used the initial consequences discussion to envision what could happen even if those consequences were to be considered interventions. We then revised the chains of consequences by focusing on interventions that might be used to change outcomes. In this report, we present items that came up in both steps and loosely refer to them as interventions. We then divided the interventions into three categories: (1) interventions that would need to be initiated *before* an outbreak, (2) interventions that would need to be initiated as soon as an outbreak is suspected, and (3) interventions that may or may not be used depending on a manager's assessment of the effectiveness, risk, and uncertainty of the intervention. The third category of interventions indicates areas where a structured decision-making process would be particularly useful. Finally, *Bsal* research needs relevant to interventions were also determined.

Interventions that would need to be initiated as soon as possible *before* an outbreak:

- Establish interagency agreements and an incident command structure to respond quickly and efficiently to an identified outbreak that may occur across multiple jurisdictional boundaries (Federal, State, Tribal, private).
- Establish channels of communication with stakeholders (law enforcement personnel, pet owners, pet store owners, natural history educators, land and natural resource managers, recreation groups, and others who may encounter an ill amphibian or potential vector through their jobs or activities) to provide information about amphibian diseases and what they can do if they encounter amphibians that are dead or appear to be infected.
- Educate stakeholders and the public about *Bsal* and how authorities might respond if it is found in the United States so that interventions are not a surprise. Education may include development of a *Bsal*-free campaign for owners of pets and pet stores.
- Develop amphibian disease, including *Bsal*, educational and outreach programs for the National Park Service and U.S. Forest Service.
- Prepare a *Bsal* outbreak communication plan to inform the public and stakeholders about the outbreak and how it is being addressed. The plan would include template messaging for key points after the *Bsal* outbreak has been confirmed.
- Identify laboratories across the United States that are prepared to test samples for *Bsal* by multiple techniques to confirm infections. Preparedness should include the possibility that there could be a sudden overabundance of samples or specimens as attempts are made to identify the extent of an outbreak (surge capacity testing).
- Improve our knowledge of the fine-scale distribution of key amphibian species (State and Federal threatened and endangered [T&E] species; *Bsal*-susceptible species) and develop an interorganizational online data visualization tool so that we can quickly know what species of interest may be at risk for a given outbreak.
- Create a decision model for all potential treatment methods and keep it updated to reflect research on the efficacy and constraints of each method.
- Conduct research on key questions that will help with response and decision making (described below under "*Bsal* research needs relevant to interventions").

Interventions that would need to be initiated as soon as an outbreak is suspected:

- Initiate an interagency incident command structure on site (described above as a task to prepare before an outbreak occurs).
- Identify, contain, and isolate areas potentially exposed to *Bsal*. Containment options include the following:
    - Preventing human access or requesting biosecurity measures, such as chemical decontamination of footwear, when moving through peripheral regions of the outbreak.

- Installing drift fences around the area of the outbreak to prevent movement of amphibians in and out of infected sites.
- Deploying netting over ponds to prevent birds from visiting the site and possibly picking up *Bsal* from water or soil and dispersing it further (Stegen and others 2017).
- Installing fencing or wildlife hazing gear to discourage terrestrial wildlife from visiting the site and potentially dispersing *Bsal*.

- Conduct *Bsal* surveys in ever-widening radii to detect the extent of contamination in the amphibian population. Sample amphibians and habitat as possible. Expand the containment area as needed.
- Make a definitive diagnosis to support or refute the initial *Bsal* detection from the analysis of a single laboratory.
- Initiate the *Bsal* outbreak communication plan (described above as a task to prepare before an outbreak occurs).

Interventions that may or may not be used depending on a manager's assessment of the effectiveness, risk, and uncertainty of the intervention:

- Once a fungicide is identified for effective field decontamination, initiate consultation with the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture Animal and Plant Health Inspection Service, and potential agency landholders to prepare for a Section 18 emergency exemption (Federal Insecticide, Fungicide, and Rodenticide Act), which allows States to use a pesticide for an unregistered use for a limited time should an outbreak be detected and if EPA determines that emergency conditions exist.
- Prepare a preliminary National Environmental Policy Act (NEPA) compliance review to cover anticipated interventions, such as deployment of fencing, use of fungicides, and possible draining of ponds. On private lands, an NEPA review may be needed if Federal assistance in interventions is anticipated.
- After a *Bsal* outbreak is confirmed, treat the site of the outbreak in a circumferential area beyond which *Bsal* is no longer detected. Treatment might include (1) site isolation while waiting for natural conditions, such as extreme temperatures, to kill the fungus and spores; (2) draining a water body; treating the siphoned water; and containing, treating, or euthanizing potentially affected animals; and (or) (3) spreading appropriate fungicide over the area.
    - If an appropriate antifungal treatment for live amphibians is identified, remove some of the population of any threatened, endangered, or special interest amphibian species for treatment and hold the sample population in captivity until the site has been decontaminated.
    - If bait species can serve as *Bsal* carriers or are susceptible to disease from *Bsal*, develop a plan to educate bait shop owners and fishermen about the risk of *Bsal* and how to take actions to prevent *Bsal* spread by this pathway.

Bsal research needs relevant to interventions:

- Describe the nature of *Bsal* in a lotic environment, specifically, how far downstream the fungus could spread and remain infective, how long it could remain infective in such conditions, and how one would create a barrier to its movement downstream, such as the application of a chemical treatment.
- Describe, under natural conditions, what temperature would be necessary and how long that temperature would be required to kill *Bsal* in an ephemeral pond that dries with warm summer conditions.
- Identify fungicides that are effective for treating ponds, wetlands, and streams for *Bsal* elimination.
- Identify and (or) confirm efficacy of antifungal medications that might be effective for treating infected amphibians so that T&E species in a contaminated zone can be captured and held until the site is declared *Bsal* free (Blooi and others, 2015a, b).
- Identify effective techniques for testing for the presence of *Bsal* in the physical environment (terrestrial and aquatic), especially for determining the scope of infection and if decontamination interventions have been successful.
- Determine if salamander fish bait species (for example, *Desmognathus fuscus* and *D. conanti*), which may be harvested for use as bait by licensed anglers in Tennessee (Tennessee Wildlife Resources Agency, 2017), are susceptible to *Bsal* or can serve as carriers.
- Determine if American bullfrogs (*Lithobates catesbeianus*) and other ranids are susceptible to *Bsal* or can serve as carriers.
- Determine the abilities of susceptible and carrier species to disperse *Bsal* (spatiotemporal).
- Determine how environmental conditions influence disease outcomes when *Bsal* is present.

Highlights of Potential Barriers to Action

Multiple projects and crises compete for finite resources and attention from managers; the most fundamental barrier to the implementation of the interventions highlighted previously could be the challenge to maintain sufficient focus on the threat of *Bsal* in addressing the interventions that ideally would be in place before an outbreak is detected in North America. One strategy for addressing this barrier could be to find complementary uses for the resources that might be more compelling than trying to fund readiness against an unrealized threat. For example, one could develop memoranda of understanding for the general conservation of amphibian resources between different agencies with jurisdiction across a watershed, where preparation for a *Bsal* outbreak would be just one trigger for action items. Initiating an education campaign about the potential of a *Bsal* outbreak could also improve public readiness to support interventions.

Unless mathematical modeling is used or an inactive fungus is tested, many of the research needs might best be addressed in Europe or Asia where *Bsal* occurs in the wild and has been detected in captive animals. Outside of a high-containment aquatic laboratory (biosafety level three), testing alternative methods for treating wetlands, streams, and ponds infected with *Bsal* is currently not possible in North America. Until efficient response protocols are established, North America cannot be fully prepared for a quick response to an outbreak. Even if a preferred or provisional (experimental) course of action were to be identified, it may not be possible to have compliance approval in place before an outbreak. Agencies may not approve emergency use of chemical treatments against a pathogen that is still hypothetical within their jurisdiction.

Barriers to communication with the public could be many. Although it might be beneficial to make the public aware of this threat and prepare for possible closures of areas being quarantined, there is the concern that the public would quickly lose attention for a threat that is not yet realized, thus making the education ineffective. Including information about existing amphibian and reptile pathogens, such as ranavirus and snake fungal disease, could improve the general receptivity of the information, leading to behaviors and attitudes that could also help with *Bsal* control and prevention. In this regard, informing the public about the recently launched Herpetofauna Disease Alert System (http://wildlife.org/new-herp-disease-alert-system-relies-on-info-from-public/), where individuals can report observations of dead and dying amphibians and reptiles to local authorities, could be one step toward an interactive educational program to keep public interest piqued and awareness enhanced for the consequences of emerging infectious herptile diseases.

If stakeholders (for example, protected area law enforcement officials, wildlife biologists, naturalists, educators, and pet shop personnel) are not familiar with *Bsal*, they may not report observations of sick or dying animals, thus possibly leading to delays in recognizing and responding to an outbreak. This barrier would need a multipronged informational campaign aimed at these different stakeholders.

Once a *Bsal* disease outbreak is detected, it is unclear when in the process it would be most appropriate to alert the public and local land managers (Adams and others, 2018). If scientists or management agencies announce the first detection of *Bsal* immediately, we run the risk that it could turn out to be a false positive after more definitive testing (Iwanowicz and others, 2017). If we wait, however, there could be a delay in mobilizing partners, which may lead to greater transmission of the pathogen or damaging rumors about the reasons behind containment interventions. Resources to dedicate on-site educators to an outbreak area could prevent some individuals from ignoring signage and barriers surrounding the outbreak site.

Interventions with an eye to cultural sensitivity are important. Private landowners may be more receptive to interventions that could affect their property if approached respectfully. Some sites may have cultural or religious importance that could require customized interventions. Implementation of interventions that may conflict with other land-use priorities, such as recreation, farming, worship, and (or) transportation, could necessitate analysis by managers to evaluate whether the containment of *Bsal* is worth the loss of the alternative uses. In Scenario 2, hikers along the Appalachian Trail may have been planning an exit or entrance at a connecting trail near the affected pond, hence planning may be needed to route them to another area or to help them exit or enter by way of another path.

At some point during an outbreak, it may be necessary to shift the response focus from containment and eradication to triage for T&E species and local genetic diversity. Barriers to this strategy may include not knowing when the tipping point is reached, not having the capacity to hold and care for rescue animals, not having a technique for clearing rescue animals of a *Bsal* infection, and not knowing what T&E species may be within an outbreak area. Modeling the distributional probability of T&E species and potential vector species may provide some guidance as to what species are likely to be present at an outbreak site (https://science.nature.nps.gov/parks/grsm/species/).

Lastly, it is important to have a designated local coordinator for the *Bsal* response with sufficient time allotted to maintain contact information for partners and to update action plans as new information becomes available. As a start, the Herpetofauna Disease Alert System has assembled herpetological disease contacts for all U.S. States, Canadian provinces, and Mexico as a nation (Olson, 2017). All plans and memorandums of understanding must be living documents, constantly updated as personnel change and new research findings become available.

Conclusions

The SSG workshop helped us envision the strategic processes and possible decisions that could be made for two scenarios involving the discovery of *Bsal* in the United States. Although many scenarios are possible, many of the same consequences and interventions likely would occur. Exploring these scenarios gives us a more detailed and multidisciplinary understanding of situations we could be faced with and highlights areas where additional advanced planning could be useful. The results of the workshop also highlighted areas where managers could be faced with difficult decisions in which they would need to balance risk, reward, and uncertainty. Such areas could benefit from a formal decision analysis.

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Appendixes

1. Workshop Agenda
2. Scenario Handouts
3. Scenario Maps
4. Built Scenarios

Appendix 1. Workshop Agenda

***Batrachochytrium salamandrivorans* (*Bsal*) Workshop**
May 11-12, 2017
National Conservation Training Center
Instructional East Building, Conference room #205
AGENDA

<u>Workshop Goals</u>

- Identify barriers that might slow the response to a *Bsal* detection
- Explore options for containment and communication in the event of a *Bsal* detection
- Determine pre-*Bsal* detection actions that could be taken to ensure a rapid response
- Identify scientific data gaps that need to be filled to support decisions in the event of a *Bsal* detection
- Identify tools or capacities needed to inform decision-making about *Bsal*

<u>Arrival: May 10, 2017</u>

7:00-9:00pm **Mixer (NCTC Lounge) (optional)**
Please join us for a meet and greet mixer at the NCTC lounge if you are available.

<u>Day 1: May 11, 2017</u>

7:45-8:00 **Coffee**

8:00-8:15 **Welcome & Introductions**

8:15-8:45 ***Bsal* Overview Presentation**

8:45-9:15 **Introducing the SSG Process/Ground Rules**

9:15-9:40 **Day 1 Scenario Overview and Discussion**

9:40-10:00 *Break*

10:00-11:30 **Develop chain of consequences: *Bsal* discovery in Great Smoky Mountain National Park**

11:30-12:30 *Lunch*

12:30-2:00 **Continue to develop chain of consequences: *Bsal* discovery in GRSM**

2:00-2:20 *Break*

2:20-4:00 Develop interventions for Day 1 scenario

4:00-4:20 *Break*

4:20-4:40 Day 2 Scenario Overview and Discussion

4:40-5:00 Check Out/Wrap Up

5:30-7:00 *Dinner*

Day 2: May 12, 2017

7:45-8:00 Coffee

8:00-8:15 Check-In/Review results from Day 1

8:15-10:00 Develop cascading consequences for *Bsal* discovery in Cherokee National Forest

10:00-10:15 *Break*

10:15-11:30 Identify Interventions for *Bsal* discovery in Cherokee National Forest

11:30-12:00 Next Steps and Closing Thoughts

12:00 Adjourn

Appendix 2. Scenario Handouts

EXERCISE EXERCISE EXERCISE

Bsal Tabletop Exercise: DAY 1

Map of GRSM locations: **http://tinyurl.com/GRSMlocations**

Geographic/Ecological Setting:

Great Smoky Mountain National Park (GRSM): Tennessee & North Carolina. The park is 522,427 acres. GRSM is the most visited national park, having recorded more than 11.3 million recreational visits in 2016. This figure does not include the approximately 11 million people who use the park as a transit corridor from Gatlinburg to Pigeon Forge Spur. The park is estimated to generate over $734 million and 10,734 jobs in surrounding communities.

Methodist Church Pond at Cades Cove (within GRSM): Ranked #3 in "things to do" in GRSM. It is a popular spot for photography, historical and nature tourism. It is close to the intersection of two roads and is a 40 minute drive from Townsend, the closest town, population 244. There is some fishing in Abrams Creek which flows through Cades Cove and at other ponds in Cades Cove. People sometimes use salamanders as bait in this region.

Previous USGS ARMI surveys at Cades Cove have identified the following amphibian species at this site: Spotted Salamanders, Northern Green Frogs, Pickerel Frogs, and Eastern Red-spotted Newts.

The Sinks (within GRSM): A very popular destination among tourists and locals during warmer months for swimming, sunbathing, and wading (ranked # 10 in "things to do" in GRSM). There is a parking lot and a road directly adjacent to this area. It is known for dangerous currents and fast-moving water. It is a 20 minute drive from Townsend. It might be possible that people catch salamanders here to use as fishing bait elsewhere.

Previous USGS ARMI surveys have identified the following amphibian species at the Sinks: Spotted Salamander, Spotted Dusky Salamander, Dusky Salamander, Seal Salamander, Black-bellied Salamander, Long-tailed Salamander, Blue Ridge Two-lined Salamander, Spring Salamander, Four-toed Salamander, Mud Salamander, Black-chinned Red Salamander, Cope's Gray Treefrog, Spring Peeper, and Wood Frog. Additionally, Hellbenders (*Cryptobranchus alleganiensis*), an endangered salamander species, are known to occur at multiple locations in streams draining GRSM including the Little River.

Date of Event	Event
Thursday May 4	Visitors to the Methodist Church pond at Cades Cove discovered a mass die-off of Eastern Red-spotted Newts (*Notophthalmus viridescens viridescens*) on Thursday May 4. *Bsal* has been detected in samples submitted to the National Wildlife Health Center (NWHC) from the salamander die-off at GRSM. NWHC notes that *Bsal* is known to be lethal to this species (Martel *et.al.* 2014). Previous *Bsal* sampling by Amphibian Research and Monitoring Initiative (ARMI) scientists at this location was negative. **This is the first reported detection of *Bsal* in the United States.**
Monday, May 8	A park ranger has reported that a visitor was caught trying to release a pet salamander in the vicinity of the Sinks. It was determined that the same visitor had previously released a pet salamander from the same cohort to this site in early April. A GRSM biologist determined that the pet the visitor tried to release on May 8 was a Chinese fire belly newt (*Cynops orientalis*). This species has previously been identified as a potential carrier of *Bsal*(Martel *et al.* 2014). [https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=286]. The biologist notes that the Sinks drains to the Little River and *Bsal* is known to persist in water (Stegen *et al.* 2017).

EXERCISE EXERCISE EXERCISE

Bsal Tabletop Exercise: DAY 2

Map of GRSM locations: **http://tinyurl.com/GRSMlocations**

Geographic Setting

Cherokee National Forest: The forest is 650,000 acres and is the largest tract of public land in Tennessee. It adjoins GRSM and other national forests in Virginia, North Carolina and Georgia. The forest is the second most visited tourist attraction in TN and is a popular destination for hunters, hikers, campers, fishermen, and road-tourists.

Scott-Booher Pond: A popular stop along highway 421. It is located on the site for an 1800s era homestead and is managed for bluegill and bass.

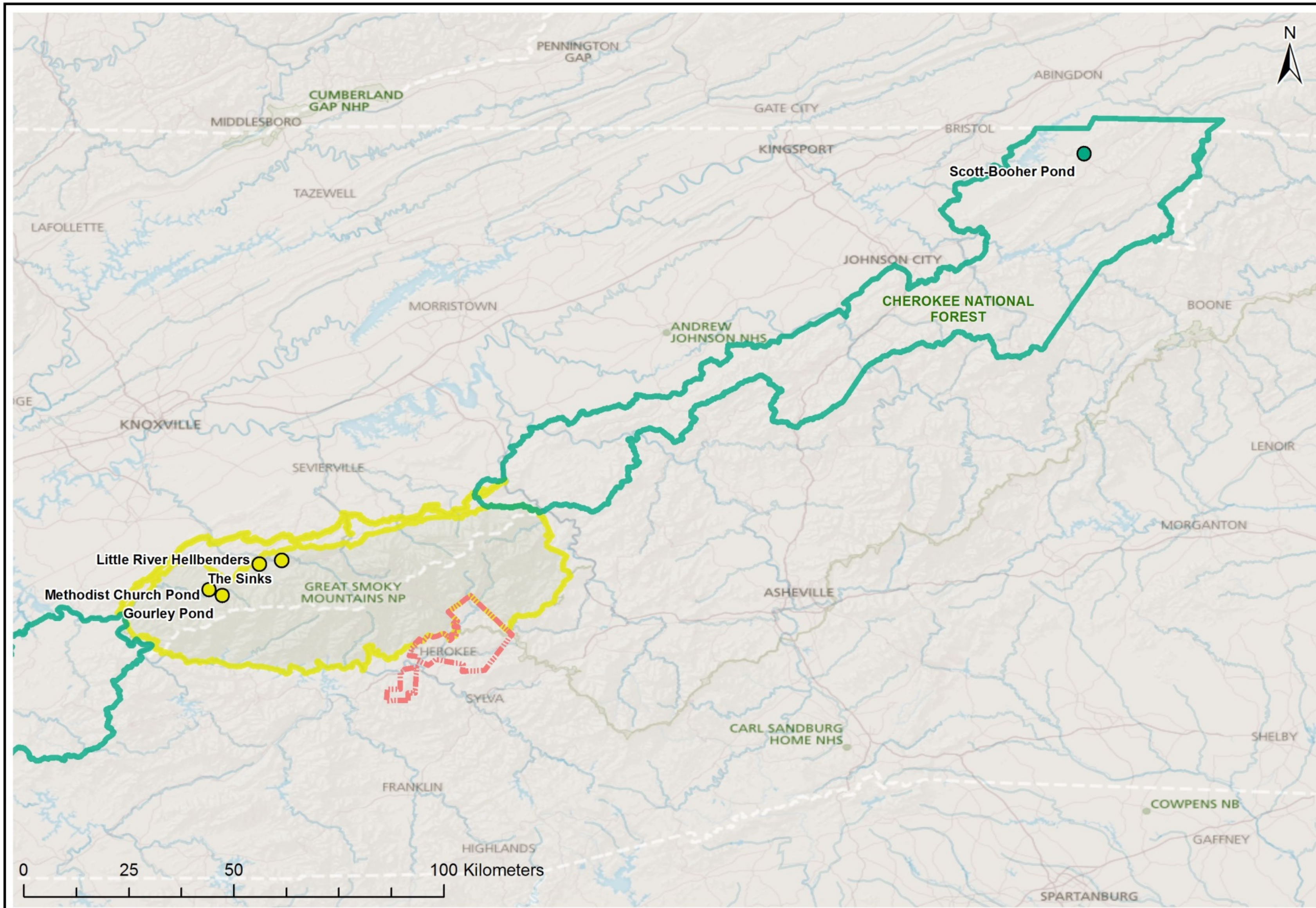
Cherokee Reservation: Home to the Eastern Band of Cherokee Indians, this reservation is located at the main North Carolina entrance to the GRSM National Park. Most of the 15,300 members of this federally-recognized Cherokee Tribe live on the reservation. The reservation is 56,000 acres held in trust by the Federal Government. The reservation attracts tourists with a large casino, as well as with its natural and cultural resources.

Date of Event	Event
Wednesday May 10	USFS/Cherokee National Forest biologist reports that they are investigating a die-off of newts at Scott-Booher pond. This pond is about 120 miles from Cades Code, directly off the Blue Ridge Parkway, and well-visited by tourists. Testing is pending. Around the same time, a local hunter reported seeing a group of more than twenty dead salamanders on Cherokee Reservation land near the border of the National Forest.

Appendix 3 – Bsal SSG Workshop Scenario Maps

Developed by Jennifer Rowe

All Sites



PENNINGTON GAP
ABINGDON
CUMBERLAND GAP NHP
MIDDLESBORO
GATE CITY
BRISTOL
KINGSPORT
Scott-Booher Pond
TAZEWELL
LAFOLLETTE
JOHNSON CITY
CHEROKEE NATIONAL FOREST
MORRISTOWN
BOONE
ANDREW JOHNSON NHS
KNOXVILLE
LENOIR
SEVIERVILLE
MORGANTON
Little River Hellbenders
The Sinks
Methodist Church Pond
Gourley Pond
GREAT SMOKY MOUNTAINS NP
ASHEVILLE
SYLVA
CARL SANDBURG HOME NHS
SHELBY
FRANKLIN
COWPENS NB
GAFFNEY
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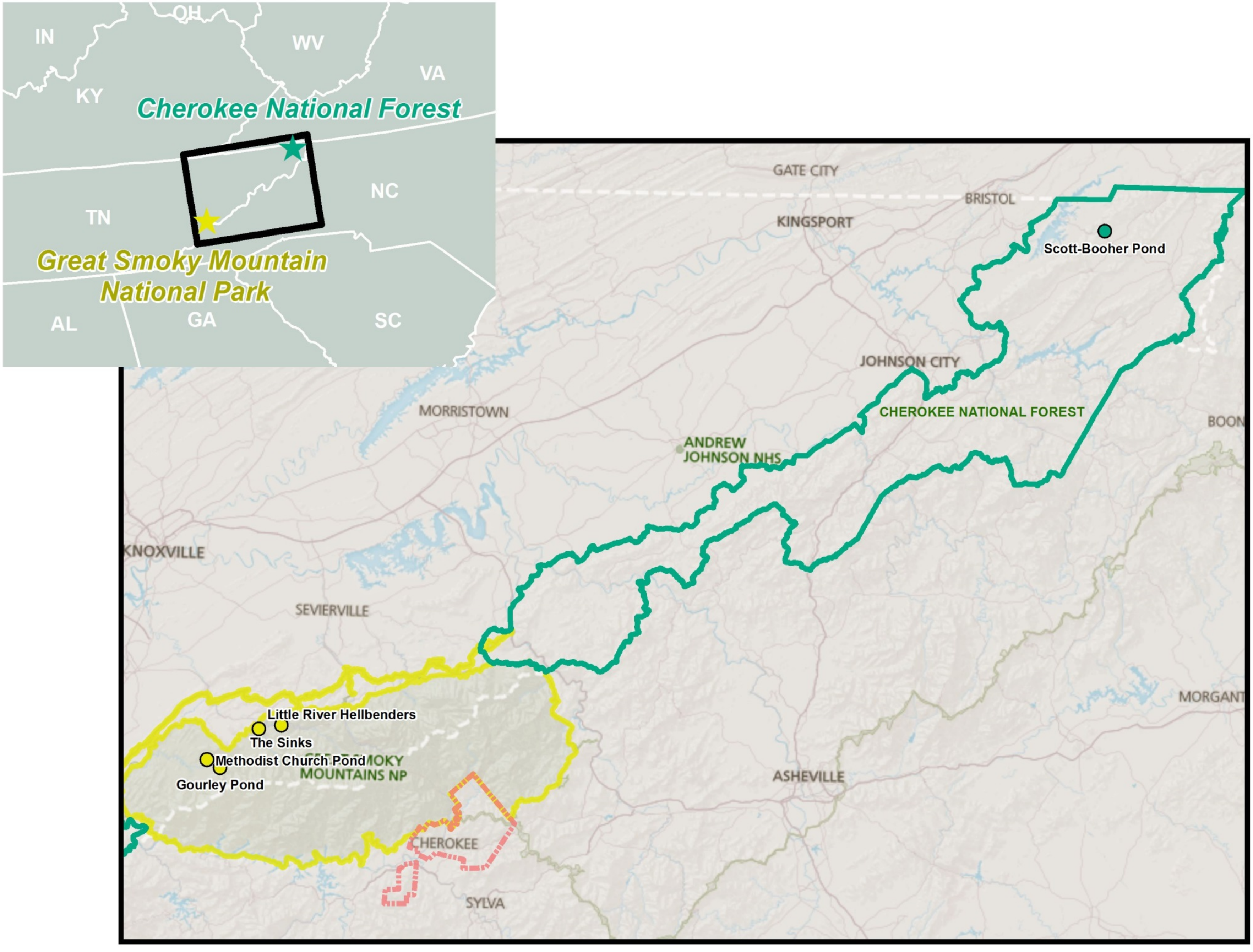
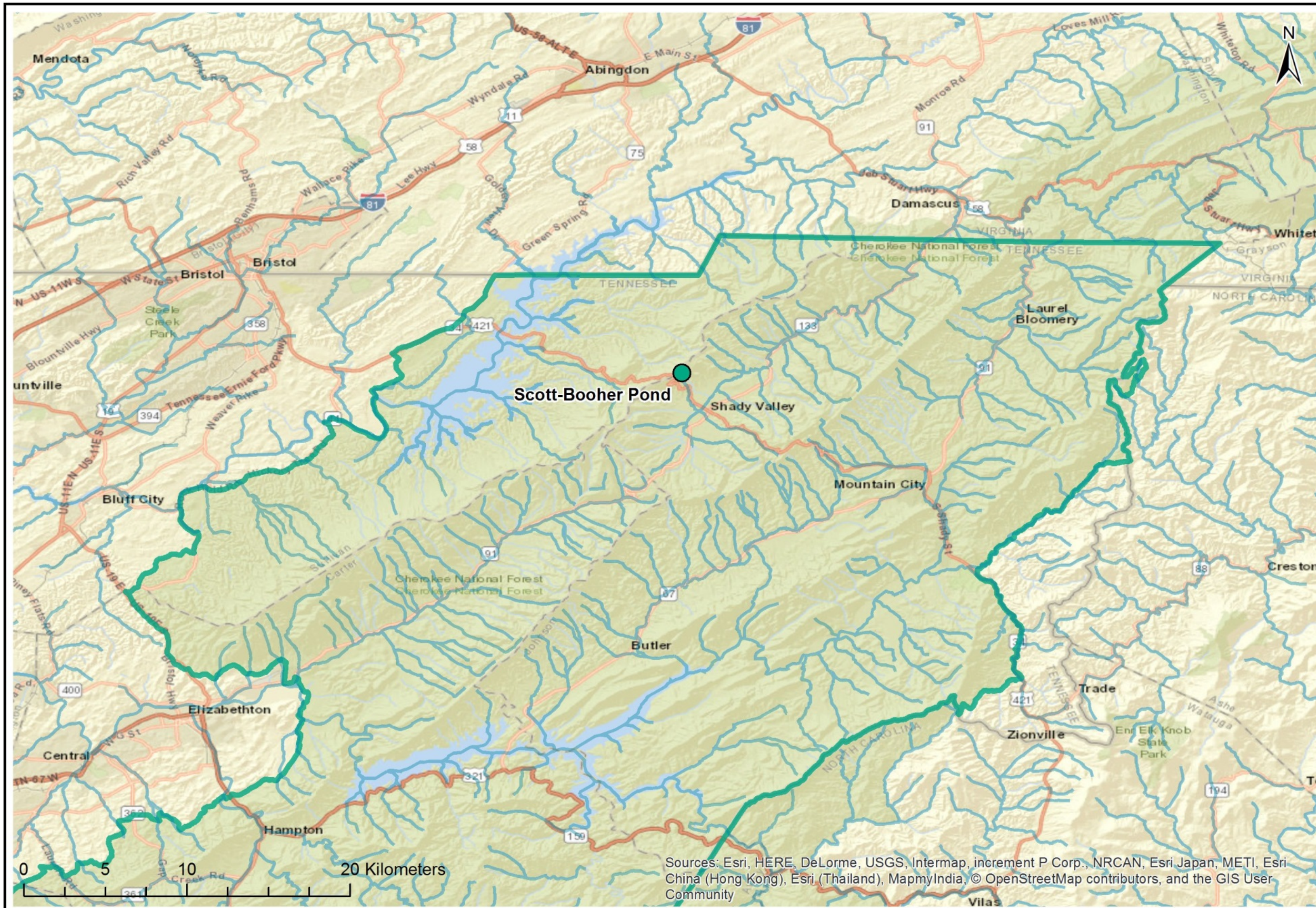
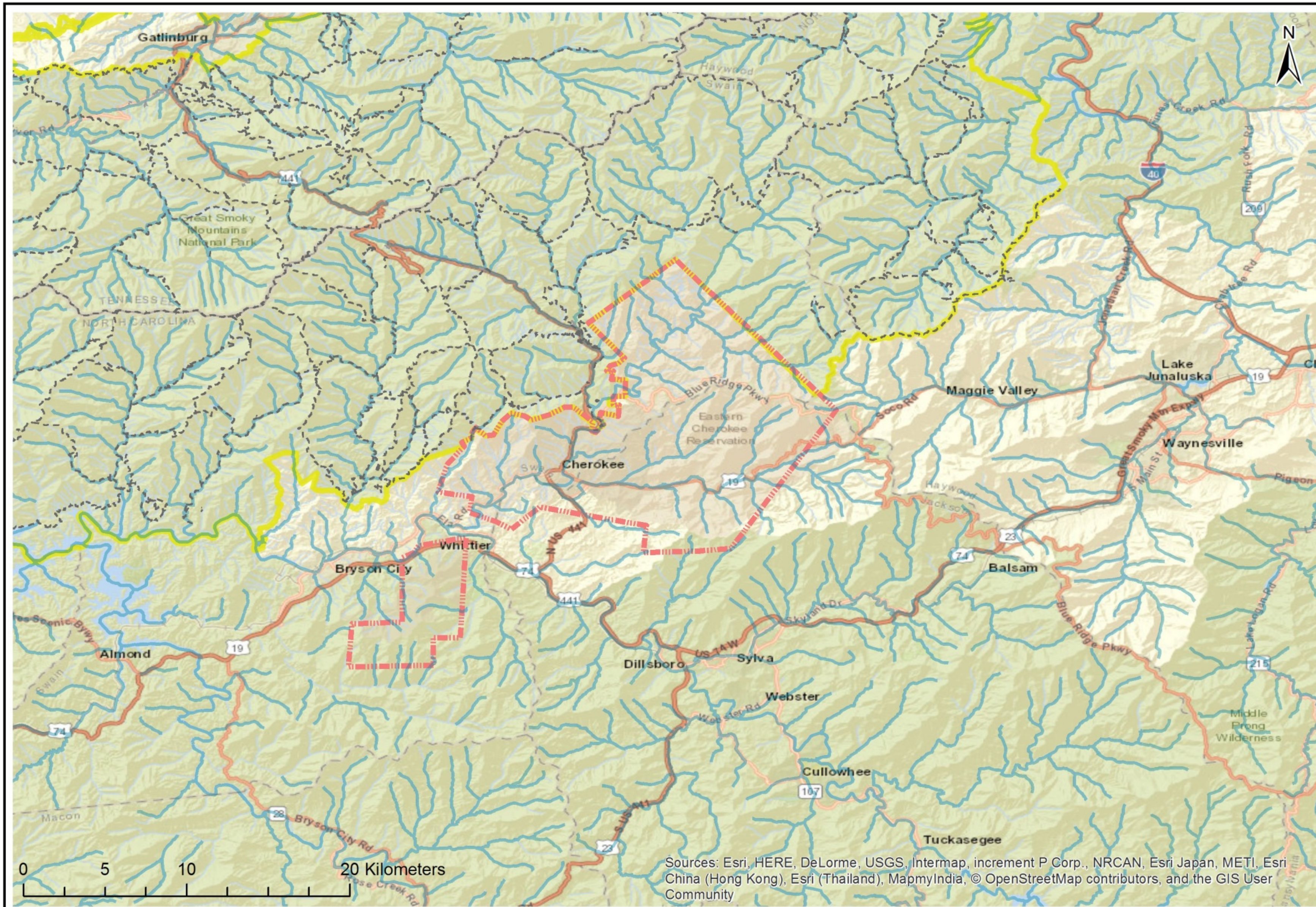


IN
OH
WV
VA
KY
Cherokee National Forest
TN
NC
Great Smoky Mountain National Park
AL
GA
SC
GATE CITY
BRISTOL
KINGSPORT
Scott-Booher Pond
JOHNSON CITY
CHEROKEE NATIONAL FOREST
MORRISTOWN
ANDREW JOHNSON NHS
BOON
KNOXVILLE
SEVIERVILLE
Little River Hellbenders
The Sinks
Methodist Church Pond
GREAT SMOKY MOUNTAINS NP
Gourley Pond
MORGANT
ASHEVILLE
CHEROKEE
SYLVA

Cherokee National Forest - Scott-Booher Pond

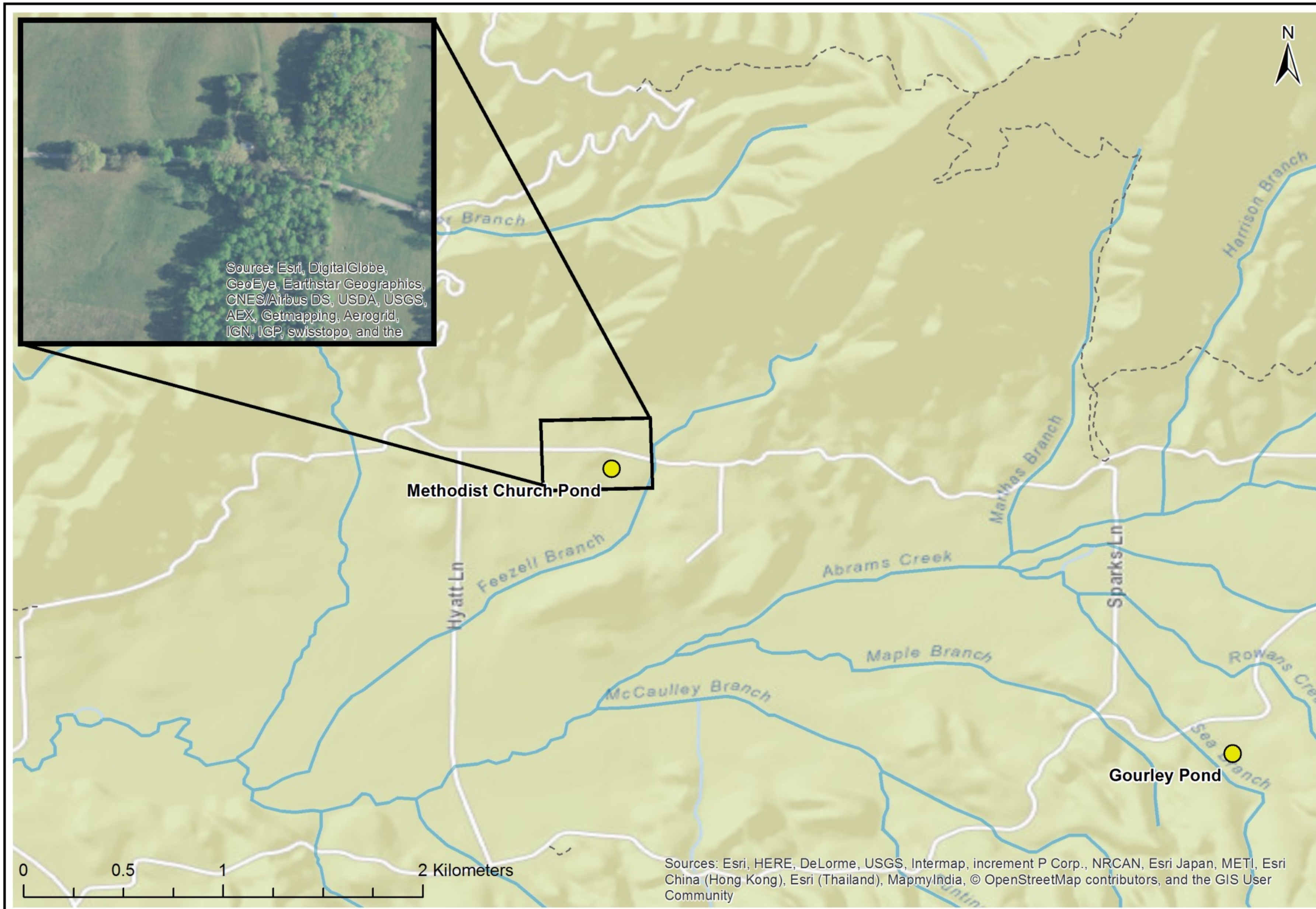


Eastern Cherokee Reservation

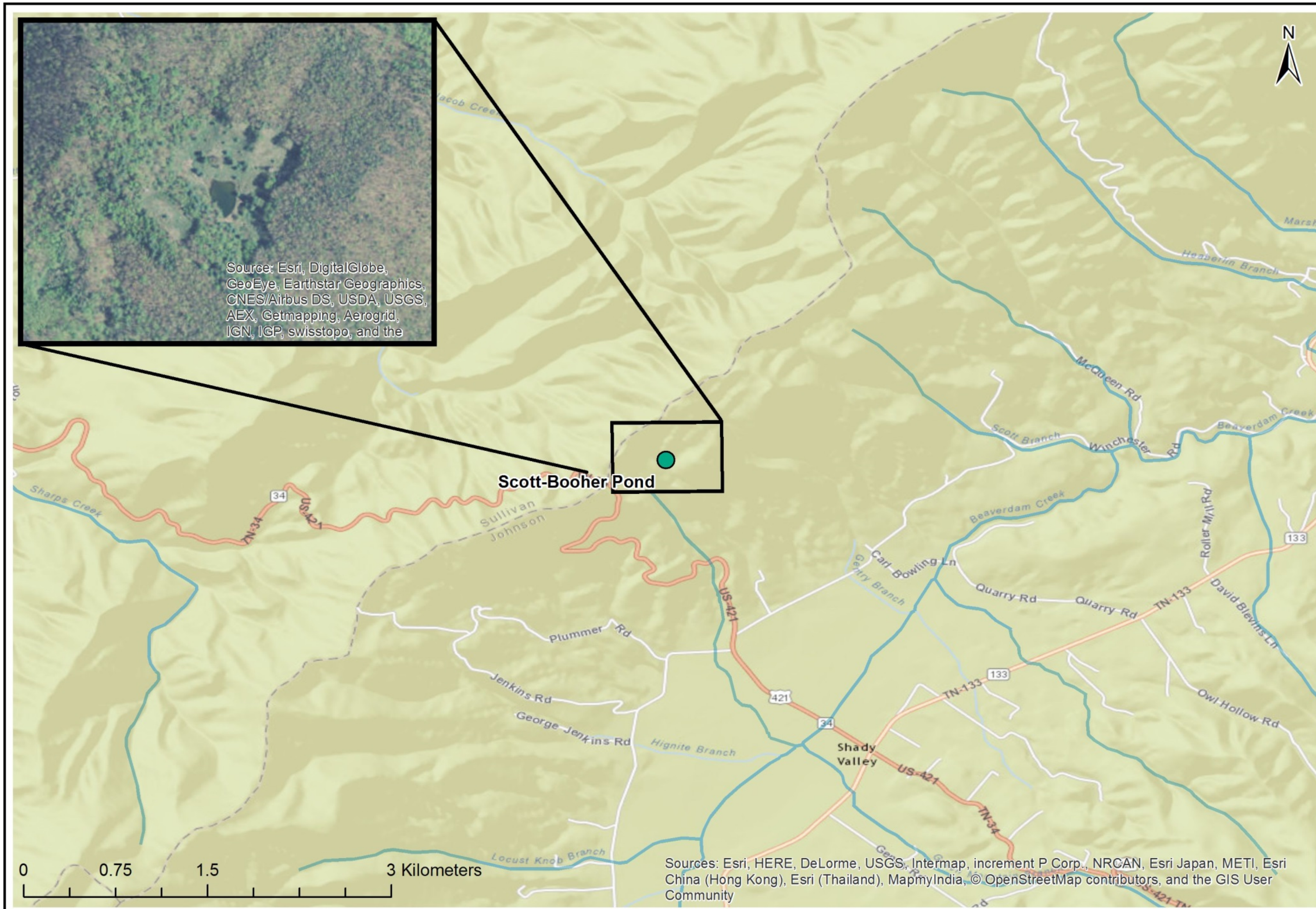


Great Smoky Mountain National Park Sites

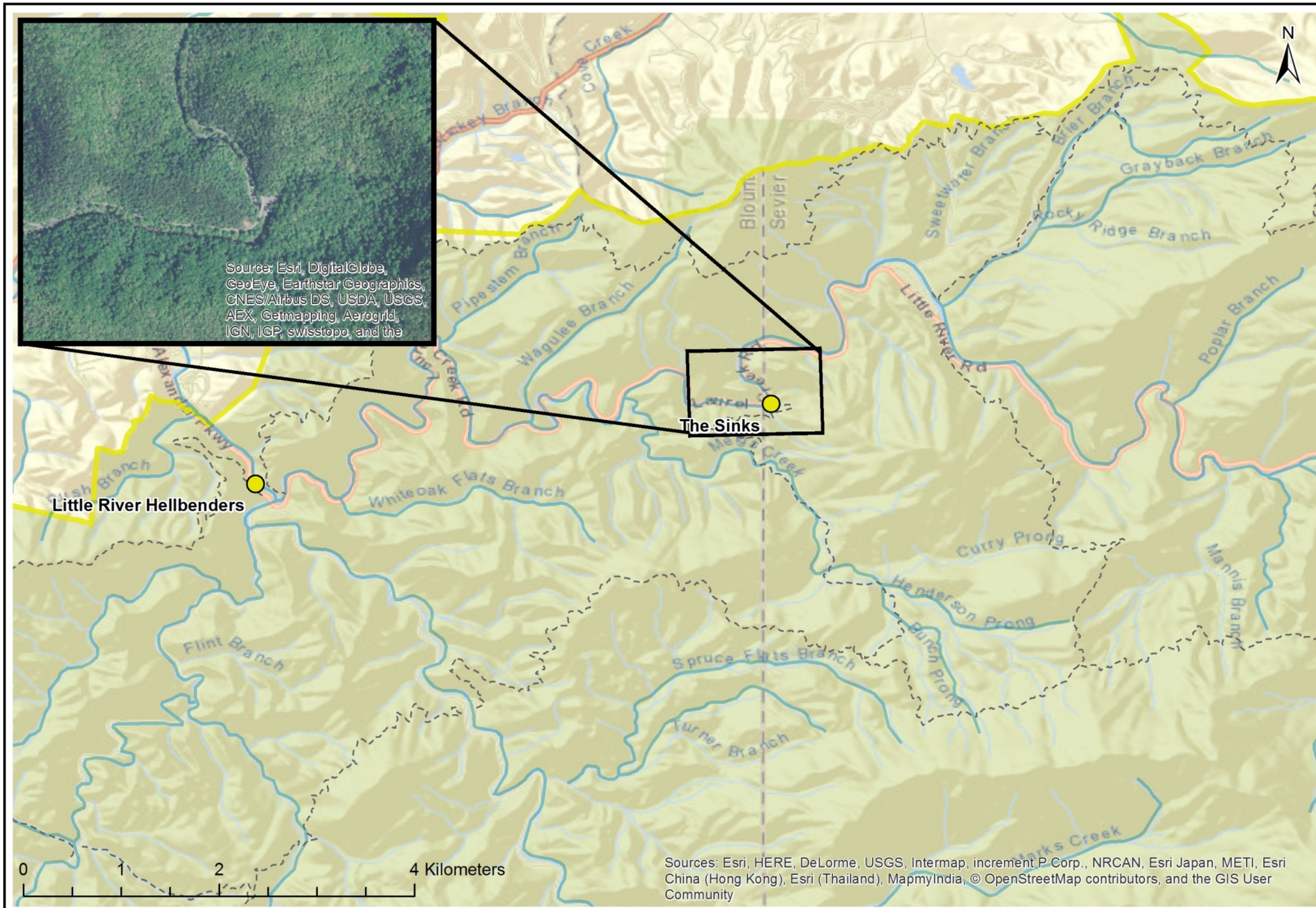
Methodist Church Pond



Scott-Booher Pond



The Sinks


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the
N
The Sinks
Little River Hellbenders
Cove Creek
Blount
Sevier
Sweetwater Branch
Brier Branch
Grayback Branch
Rocky Ridge Branch
Pipestem Branch
Waguiee Branch
Little River Rd
Poplar Branch
Laurel Creek
Meigs Creek
Whiteoak Flats Branch
Curry Prong
Henderson Prong
Mannis Branch
Bunch Prong
Flint Branch
Spruce Flats Branch
Turner Branch
Marks Creek
0
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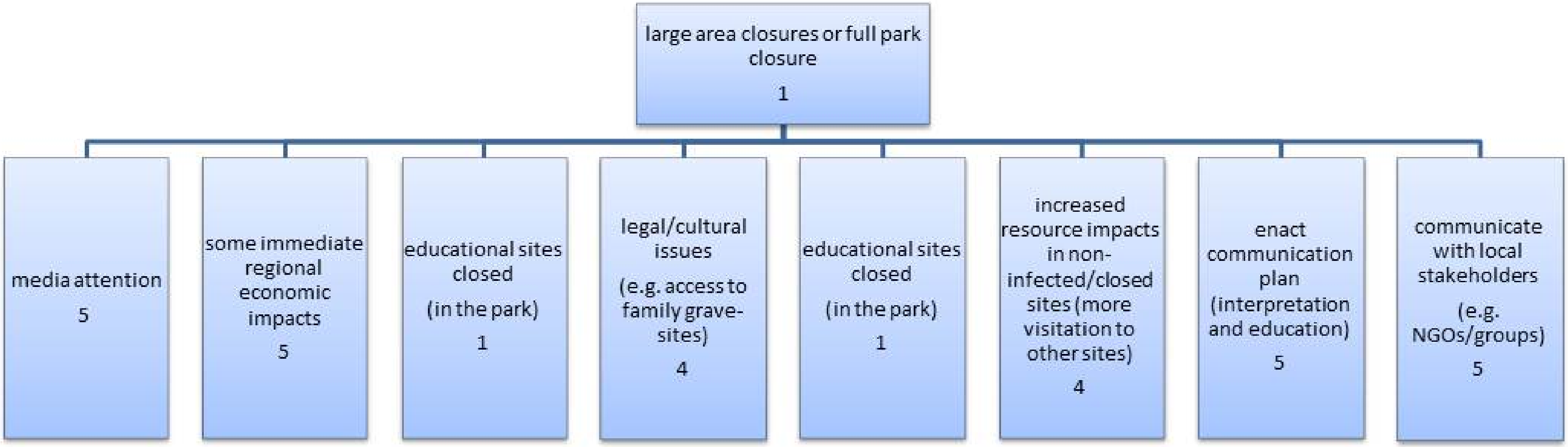
4 Kilometers
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

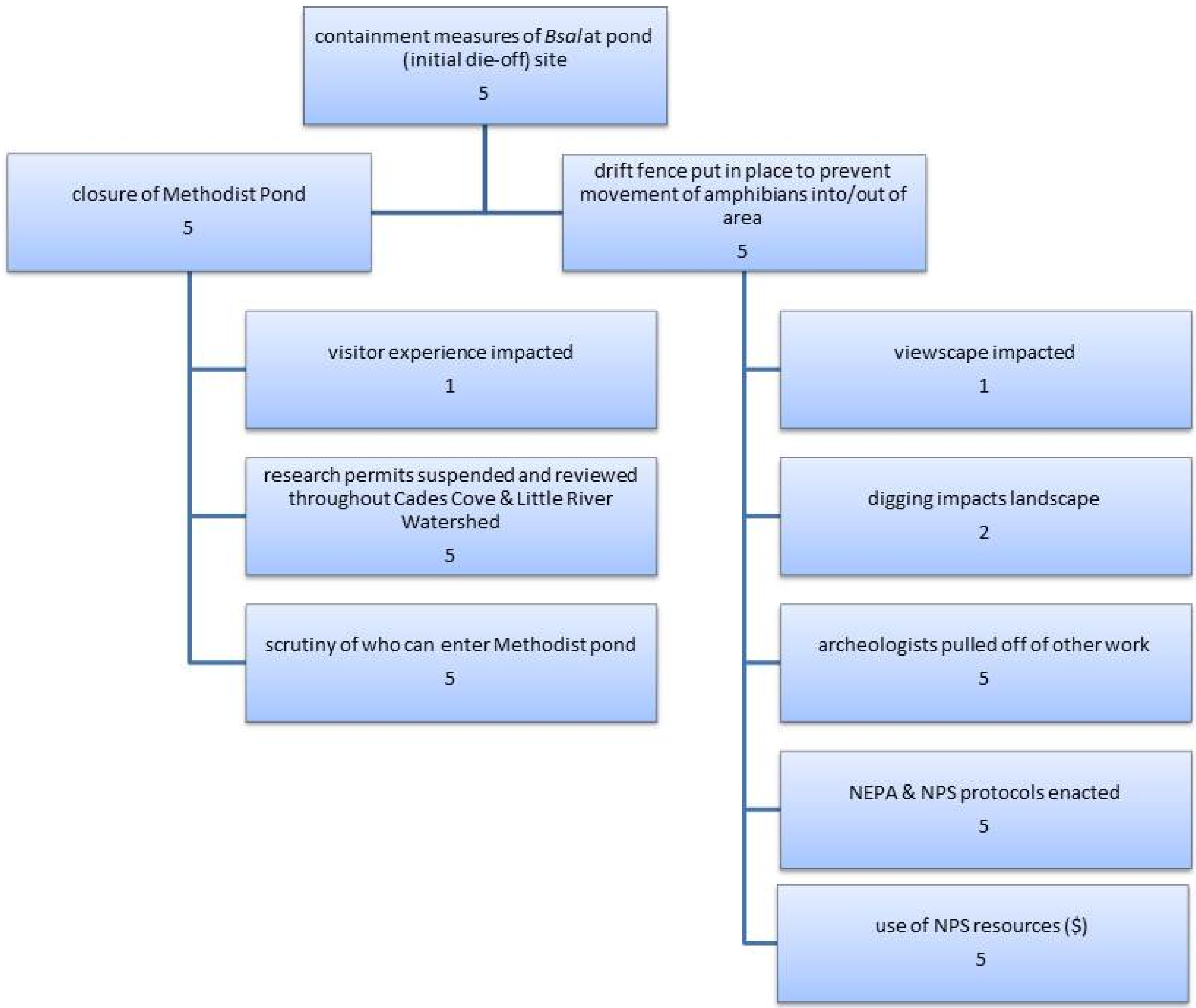
Appendix 4 – Built Scenarios

Developed by Alice Pennaz

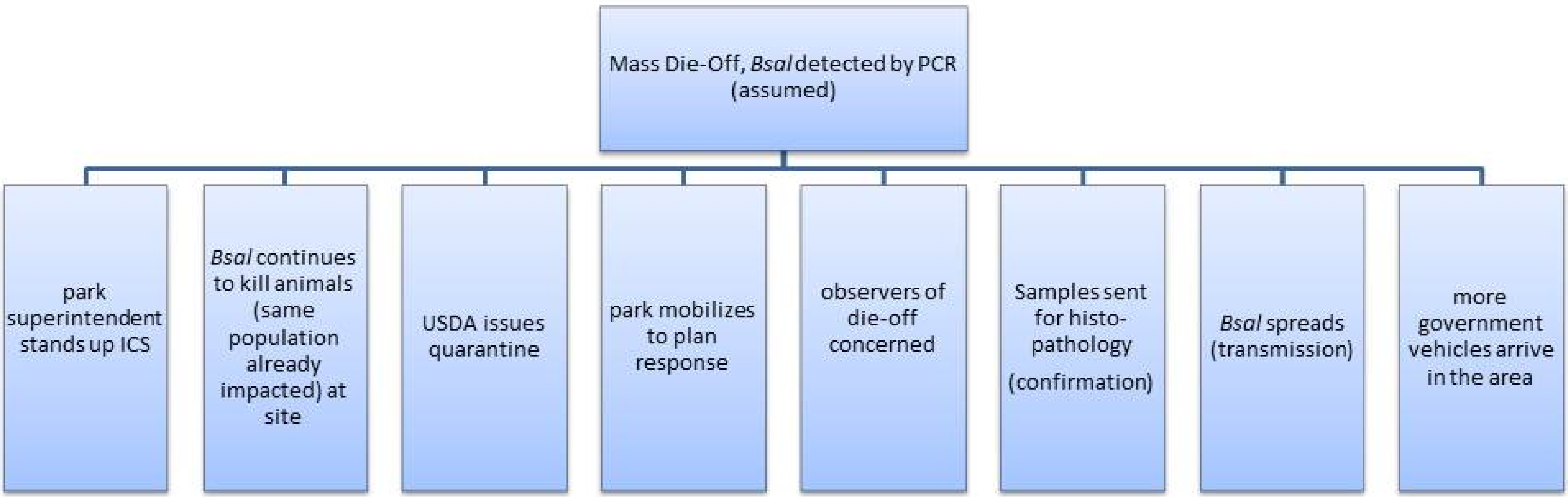
Day 1, Figure 1



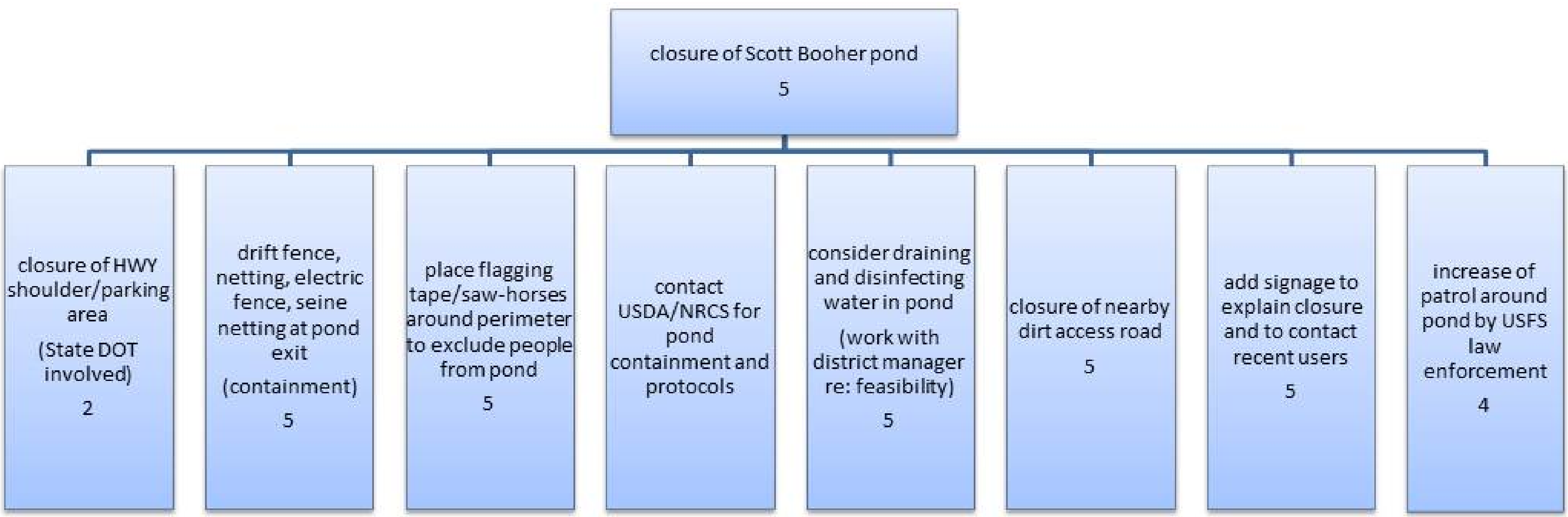
Day 1, Figure 2



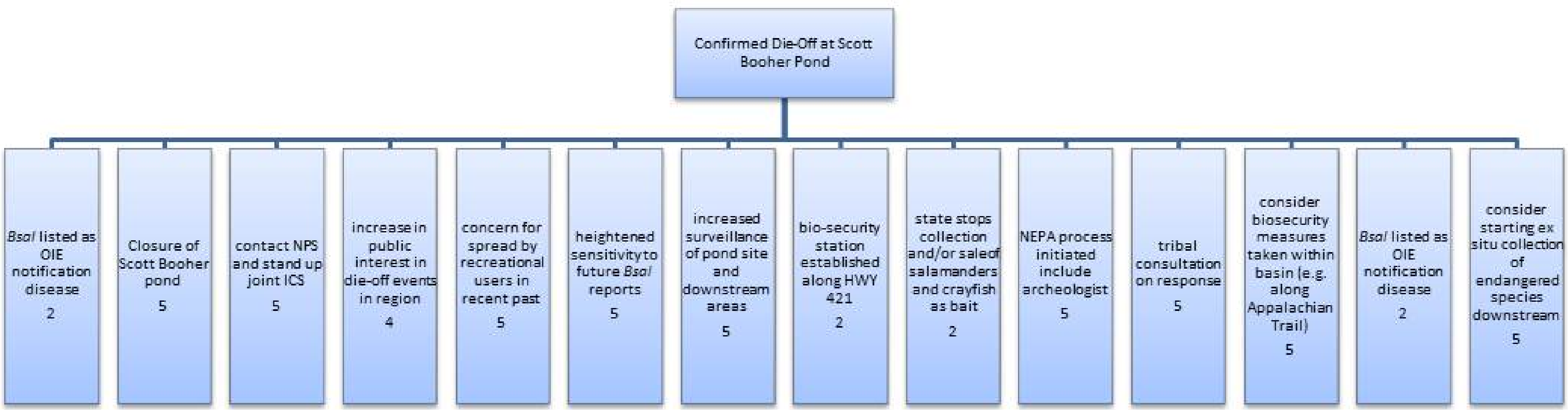
Day 1, Figure 3



Day 2, Figure 1



Day 2, Figure 2



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