**Manuscript 1: Expert elicitation of salamanders**

**Authors:**

Rachel A. Katz1,2,3,4, Daniel J. Hocking2, Evan H. Campbell Grant3

1Department of Environmental Conservation, University of Massachusetts-Amherst

2U.S. Geological Survey, SO Conte Anadromous Fish Research Branch

3U.S. Geological Survey, Patuxent Wildlife Research Center

Michael C. Runge, U.S. Geological Survey, Patuxent Wildlife Research Center

Allison H. Roy, U.S. Geological Survey, Massachusetts Cooperative Fish and Wildlife Research Unit and Department of Environmental Conservation, University of Massachusetts-Amherst

Benjamin H. Letcher, U.S. Geological Survey, Leetown Science Center, SO Conte Anadromous Fish Research Branch

**Title:**

* Predicting salamander occurrence when data is lacking using expert opinion

**Journal:**

* Conservation Evidence (see Meredith et al. 2016)
* Conservation Biology (see Martin et al. 2012, Addison et al. 2015)
* Diversity and Distributions (see Adams-Hosking 2016)

**Overview:** Elicit parameter values and model beliefs from experts for predicting effects of climate, land use, and brook-trout presence on catchment-level occupancy of three stream-salamander species occurring throughout the northeastern US. Use this model to forecast current distributions of salamanders under difference climate scenarios and compare to existing published distributions.

**\* Step 1: build the catchment-level salamander occupancy model**

**\* Step 2: create expert elicitation survey for model parameters and beliefs (means only, use 20+ experts to get variance in mean expected values instead of eliciting confidence)**

**\* Step 3: identify salamander experts based on snow-ball or publication criteria**

**\* Step 4: provide a list of literature for experts to consult prior to elicitation**

**\* Step 5: compare expert opinions and host webinar/call if large discrepancies suggesting lack of understanding of the questions (repeat elicitation if needed)**

**\* Step 6: forecast salamander occupancy based on expert elicitation**

**\* Step 7: conduct sensitively analysis for major uncertainties (hold all constant at the mean and vary one parameter at a time)**

**Abstract:**

**Introduction**

**Why has expert knowledge been in conservation – what’s the problem?**

* Expert knowledge is widely used in conservation b/c of the complexity of problems, relative lack of empirical data and imminent nature of decisions.
* This knowledge typically takes the form of mental models without explicit consideration of biases (i.e., experts are called on to express opinions in a qualitative and non-transparent way). In fields where there is extensive expert knowledge, yet little published data, the use of expert information as priors for ecological models is a cost-effective way of making more confident predictions about the effect of management on biodiversity.
* Use of expert elicitation to consolidate the current state of knowledge is valuable when the status of a species is uncertain, yet there is general recognition that the species is subject to multiple, often synergistic, threats to its persistence in the wild.

**This is well-accepted method and increasing in use:**

* Increasing use of expert elicitation methods to help inform conservation decisions (identify important hypothesis and parameter uncertainties to resolve). Probabilistic framework that accounts for uncertainty (confidence) of multiple experts.
* The use of expert knowledge is growing as a tool for synthesizing diverse sources of information into a reliable representation of the current state of scientific knowledge, including its uncertainties when elicited with the same level of rigour pro- vided in the collection and use of empirical data.
* When empirical measures are required for evaluating alternative actions, but are not available, expert judgment can help develop plausible estimates that most effectively inform decisions (Speirs-Bridge et al. 2010; Martin et al. 2012). Expert opinions are valuable in the management of threatened species, where the need to make urgent decisions leaves little time for the collection of further information (?).
* Expert elicitation can be conducted within a probabilistic framework, which accounts for uncertainty (confidence) of multiple experts. Also used to parameterize models in the absence of data and as Bayesian priors to supplement sparse data and improve confidence in predictions (Yamada et al., 2003; Martin et al., 2005; Denham and Mengersen, 2007; Griffiths et al., 2007; Mac Nally, 2007; O’Neill et al., 2008; Low Choy et al., 2009; O’Leary et al., 2009; Murray et al., 2009; James et al., 2010)
* Some chance that expert opinions alone (w/ no data) may not be as useful? Yet, when lacking data, expert opinion does not necessarily offer an improvement (Cox, 2000; Pearce et al., 2001; Seoane et al., 2005).
* Examples of expert elicitation used to parameterize models that inform management decisions (from Martin et al. 2012):
  + Johnson et al. 2010 – use to parameterize Bayesian network to evaluate population viability of cheetahs (X experts)
  + Runge et al. 2011 – use to identify alternative hypotheses and uncertainties affecting mgt of whooping cranes (X experts)
  + O’Neill et al. 2008 – used to quantify trends and range of effects of climate change on polar bears (10 experts)
  + Martin et al. 2005 and Kuhnert et al. 2005 – used to evaluate effects of livestock grazing intensity on austrialian woodland birds in Bayesian GLM (20 experts)
  + Smith et al. 2011 – Bayesian networks
* Examples from Charney 2012:
  + Expert opinion is increasingly used to parameterize models in the absence of data and as Bayesian priors to supplement sparse data (Yamada et al., 2003; Martin et al., 2005; Denham and Mengersen, 2007; Griffiths et al., 2007; Mac Nally, 2007; O’Neill et al., 2008; Low Choy et al., 2009; O’Leary et al., 2009; Murray et al., 2009; James et al., 2010). Yet, when lacking data, expert opin- ion does not necessarily offer an improvement (Cox, 2000; Pearce et al., 2001; Seoane et al., 2005).
* Canessa: Where empirical measures of the required parameters for a situation of interest are not available, expert judgment can help develop plausible estimates that most effectively inform decisions (Speirs-Bridge et al. 2010; Martin et al. 2012). Such methods can prove especially valuable in the management of threatened species, where the need to make urgent decisions leaves little time for the collection of further information.

**What do we mean by "expert" - who are the experts?**

* An expert is someone who has substantial information on a particular topic that is not widely known by others and who is offered deferred to for their knowledge and interpretation.
* Expert knowledge can be defined as substantive information on a particular topic that is not widely known by others (Martin et al., 2012).
* Experts are distinguished from non-experts by having training or experience with respect to a topic of interest (Fazey et al., 2006).

**What are the steps for expert elicitation?**

* Expert-elicitation (in general) is composed of 5 steps:
  + Deciding how information will be used (purpose and motivation)
  + Determining what to elicit (and identifying experts; creating a statistical model)
  + Designing elicitation process
  + Performing elicitation
  + Translating elicited information into quantitative statements that be used in ecological models (to ultimately help make decisions).
* Additional important steps:
  + How to work with multiple experts
  + How to combine multiple judgments (treat as equal or weights, average or ranges)
  + Minimizing bias in elicited information
  + Verifying accuracy of expert information

**Why conduct expert elicitation for predicting/forecasting stream salamander occupancy?**

* Limited information about amphibians (salamanders) region-wide and are in decline – call for experts to aid in identifying parameters to be used in both predictive and decision models to evaluate range of outcomes of conservation actions.
* Do predictions from experts vary from publications? (maybe compare in analysis or compare in discussion)
* Publications have to make lots of assumptions, we hope experts are considering these assumptions and relaxing them, thus providing a more realistic understanding of drivers of occurrence.
* Three common stream salamander species occur across the northeastern streams (i.e., relevant for NECSC) and are known to co-occur in streams with fishes (brook trout; cite), an important predictor/competitor affecting salamander populations, and are sensitive to buffer and upland forest cover, stream temperature and discharge (and network structure).
* Current data availability:
* Direct threats include:
* Indirect threats include:
* Potentially competing hypotheses?
* Management-relevance (land-protection near buffer or upland?)
  + riparian vs. upland land protection is better for instream biota (downstream). Evidence that upland land protection can influence downstream habitat and species occurrence, yet conservation efforts are largely focused on riparian mgt first, then upland (we'll explore this in decision paper)
  + fish-interaction is strong or weak (brook trout-salamander interactions)
  + species-specific responses (how much do species vary?)
  + stream-network impacts on species-responses? some watersheds are more vulnerable than others (i.e., network structure, buffer vs. upland effects?)
* Increasing threat of climate change (temp and flow alterations)
* Range-wide assessments are lacking (studies are patchy in mostly forested landscapes with low forest loss, flow-impacts).
* Knowledge of that status and potential declines is needed to identify mangagement actions that can be implemented to reduce population declines in the future (act now to mitigate climate/land use threats)
* Current data on these species is patchy?
* No consistent monitoring method or field-studies across their range
* Thus they have high levels of uncertainty when extrapolating to even huc 10 (lowest level of mgt), state, or regional scales.
* Significant geographical gaps in estimates and trend in occupancy (need to come up with a list of current studies).
* Need address occupancy, trends, threats and effects of potential land-potection (buffer vs. upland) so that headwater stream mgt actions can be confidently employed to impact local and minimize species declines.
* Also, there are diverse experts opinions on occupancy/threats in various regions.

**Objectives of this elicitation/study:**

* Overall Motivation: To use a structured, expert elicitation methods for species in which empirical data are limited and expert opinions may vary (conflict among experts?), such that effectiveness of alternative mgt strategies may vary.
* Conduct expert elicitation for Plethedontide (stream obligate for at least some stage of life-history?): Desmognathus, Gyrinophilus, and Eurycea
* Specifically, G. porphyriticus; spring salamander, D. fuscus; dusky salamander, and E. bislineata; two-lined salamander
* These species occur across the northeastern streams (i.e., relevant for NECSC) and are known to co-occur in streams with fishes (brook trout; cite), an important predictor/competitor affecting salamander populations.
* Use insights from experts to build predictive co-occurrence models under climate change (Hocking et al. forecasting paper), and evaluate land-protections strategies (Kate et al. optimization paper).
* Questions:
  + How much do expert opinions agree with field-observations (do we have any? – see publication list that we’ll be sending to experts)
  + How variable are expert opinions (mean and confidence)? Where is the disagreement?
  + Which uncertainties are driving forecasts of occurrence (sensitivity analysis; tornado diagram)?
  + Does expert knowledge agree with recent field-observations / occupancy / distribution estimates? (why or why not? do we have any? – see publication list that we’ll be sending to experts for potential comparisons).
* Compare across experts
* Use for predictions

**Methods:**

*Expert Elicitation (overview)*

We used a structured elicitation process (i.e., Delphi method and four-point elicitation; Speirs-Bridge et al., 2010; McBride et al., 2012) to question experts (Table 2 and Table 3), which improves the accuracy of estimates (Burgman et al., 2011), promotes the pooling of individual knowledge, and reduces overconfidence (Speirs-Bridge et al., 2010; McBride et al., 2012).

(selection of experts)

Stream salamander experts were identified based on their level of regional knowledge of the focal species. We used the snowball method to identify additional experts. Experts had to have local knowledge of at least one species in at least one region (southern, mid-atlantic, northern; Figure 1), with primary focus on field ecology, natural history, or field experiments (not phylogenetics, physiology, etc). Experts were self-selected in comparison to the broader community of stream salamander ecologists (survey – q1 and q9).

(first survey)

We used an indirect elicitation method, with requires experts to answer questions that relate to their experiences (instead of direct elicitation of parameters distributions; Kuhnert et al. 2010). Responses are then encoded into the parameters of interest for the analysis (i.e., question: what is the expected site occupancy under specific habitat conditions? parameter: the effect (mean and variance) of one unit change in habitat conditions on the probability of occupancy within a site). In this study, we asked experts “under the abiotic and biotic conditions specified, how many 500-reaches (site-level) out of 100 randomly, but evenly, selected from across a specific region (northeast, mid-atlantic, or southeast), would contain a population of stream salamanders for each focal species?” We conducted region-specific elicitation because of well-established understanding of interspecies interactions on the occurrence of our focal species (cite), and that the number and identify of other salamanders present varies across regions (i.e., total northeast = 0 to 4 species, mid-atlantic = 0 to 6 species, and southeast = 0 to 10 species within a given 500-m reach). We conducted an initial survey based on our assessment of major factors (Table 1) expected to influence stream salamander occupancy. We matched scale of actions (catchment-level) with scale of salamander response (occupancy of a 500-m reach within the catchment). In the first round of elicitation, participants provided their best estimates for all questions and optimistic and pessimistic estimates with their confidence for a subset of questions using an emailed survey (Table 2; Appendix A; four-point elicitation approach; Speirs-Bridge et al. 2010).

Martin et al. 2005 (Eco Apps) only elicited the mean, and calculated the mean and precision using mean values across experts (did not elicit lowest, highest and confidence).

(webinar and second-survey) (from Adams-Hosking)

4-hr webinar led by a facilitator (RK) with assistance of (EHG, DJH). Each expert’s first-round answers from the email questionnaire were displayed anonymously to the group by the facilitator. During webinar, the first round of elicited answers was discussed in detail within the group, with experts sharing knowledge from their respective regions of expertise. All experts were given the opportunity to participate in the discussion of each region and, in particular, to query experts with local knowledge. The experts agreed that this information was influential in guiding their revisions of their estimates in cases where they did not possess knowledge.

Identify new factors or hypotheses? Change baseline conditions?

After the webinar and the survey questions were added/changed, experts were asked to reconsider their previous assessments in the light of the group discussions. They were given the opportunity to anonymously revise their first-round answers and all questions additionally included optimistic and pessimistic estimates, and their confidence (four-point elicitation approach for all questions?). These revised estimates were used in the estimation of the probability of occupancy for each focal stream salamander across regions (Figure 2).

Table 1. List of abiotic and biotic factors hypothesized to influence stream salamander occupancy in a 500-m stream reach.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Description | Unit | Interpretation |
| Regional occupancy (RO) | Mean probability of occupancy within a region | 0-1 | Mean occupancy varies among regions (northeast, mid-atlantic, southern) (due to variation in the occurrence of other stream-salamanders) |
| Stream size (SS) | Upstream drainage area (km2) | Mean = 28 sq-km  Range = 0.75–200 sq-km  Baseline = 2 sq-km | Occupancy declines with increasing stream size (drainage area = stream size) |
| Stream temperature (ST) | Summer mean monthly temperature (C) | Mean = 18O C  Range = 10O–26O C  Baseline = 14 O C | Occupancy declines with increasing stream temperatures |
| Upland forest (UF) | Percent forested land in the local catchment (non-riparian) | Mean = 50  Range = 0–100%  Baseline = 100% | Occupancy declines with decreasing upland forest cover |
| Riparian forest (RF) | Percent forested land in riparian zone (30-m) | Mean = 50  Range = 0–100%  Baseline = 100% | Occupancy declines with decreasing upland forest cover |
| Upland (UF) x Riparian (RF) |  |  | The effect of increasing forest cover in the riparian decreases the effect of upland forest cover on occupancy. |
| Streamflow (SF) | Summer mean monthly precipitation x drainage area = streamflow index / average summer flow conditions | Percent of long-term (X-year) average flow,Mean = 100  Range = 10-190%  Baseline = 100 | Occupancy declines within increasing frequency of exceedingly dry years. |
| Streamflow (SF) x stream size (SS) |  | Small = 2 km2 | Effect of exceedingly dry years is larger in smaller streams compared to medium (and large) |
| Flow frequency (FF) |  |  | Occupancy declines with increasing frequency of exceedingly dry years. |
| Fish Presence (FP) | Presence of a brook trout population | 0 or 1  Baseline = not present (0) | Occupancy is high if a brook trout population is absent |
| Salamander Presence (SP) | Presence of other focal-salamander species | 0 (absent) or 1 (present) | Occupancy of DFUS is not influenced by EBIS or GPOR presence.  Occupancy of EBIS increases when DFUS or GPOR are absent.  Occupancy of GPOR increases when DFUS is present, but decreases with GPOR is present? |
| Network Position (NP) | Stream network structured (get metrics from evan/will) | ? | Stream network structure influence occupancy, but the effect varies by species (what metrics/directions?) |

Table 2. The structured elicitation procedure (after Adams-Hosking et al. 2016 and McBride et al., 2012).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Pre-elicitation** | **Elicitation** | | | **Post-elicitation** |
| **Estimate** | **Feedback** | **Estimate** |
| Occupancy model framework outlined with NEARMI co-authors | All experts individually answer email survey | All experts shown anonymous answers and discuss over webinar | All experts individual make second and final anonymous estimates | Mean and median of all experts’ final estimates are calculated. |
| Covariates for each catchment calculated (CONTE/NEARMI) |  |  |  | Experts review individual and group estimates via email, provide feedback, and make individual estimates, sign off on final results |

Table 3 (from Adams-Hosking). Parameters elicited for each focal salamander species. Experts provided assessments for the number of reaches, based on 100 evenly and randomly selected 500-m reaches across each region, that contain a population of stream salamanders under various combinations of factors (see Appendix B).

|  |  |
| --- | --- |
| **Elicitation question** | **Value** |
| What is your best estimate (the most likely value)? | between 0 and 100 |
| Realistically, what is the lowest value it could be? | between 0 and 100 |
| Realistically, what is the highest value it could be? | between 0 and 100 |
| How confident are you that the interval you provided contains the truth? | between 50 and 100% |

*Data analysis*

Estimate betas:

Combine the data from all experts into a single data set.

Estimate betas (without confidence intervals)

Estimate betas (with confidence intervals – see Adams-Hosking: Uncertainty = (Upper – Lower) / Upper \* 100

definitions:

s = species [1:3] # one model for each species (should we just use a single model with species-specific intercept *and* slopes?)

r = region [1:3] # one model for each region? (intercept or model for each region?)

i = 500-m stream reach

model 1 (use names in table1):

logit (poccsi)) = ROsr + log(SSsi\*β1sr) + STsi\*β2sr + UFsi\*β3sr + RFsi\*β4sr + UFsi\*RFsi\*β5sr + SFsi\*β6sr + FFsi\*β7sr + SFsi\*FFsi\*β8sr + (SF\*FF\*SS? +) FPsi\*β9sr + SP1si\*β10sr + SP2si\*β11sr + NPsi\*β12sr

Functional relationships (mostly linear) will be determined by expert data (i.e., exponential decline with stream size = log(SS), or quadratic relation with stream temp (ST2), etc)?

Comparisons across experts (second round; Adams-Hosking): Coefficients of variation were higher for estimates of upper and lower bounds than for best estimates, and higher for the first- round estimates than for second- round estimates, indicating a shift towards agreement among experts (von der Gracht, 2012).

*Salamander predictions*

Calculate catchment covariates (cite SHEDS)

**Results**

(Overview): Number of experts (n = 28; Appendix A)

Comparisons across experts (similar, different)

Betas

* Comparisons across experts (what was consistent and what wasn’t)
  + Plot of raw values?
  + Plot of mean and sd (assume equal weight)
* Weighted averages across experts
* Which uncertainties influenced occupancy predictions the most?
* New hypothesis/insights from experts

**Discussion**

**Literature**

Adams-Hosking, C. *et al.* Use of expert knowledge to elicit population trends for the koala (*Phascolarctos cinereus*). *Divers. Distrib.* 249–262 (2016). doi:10.1111/ddi.12400

Ban, S. S., Pressey, R. L. & Graham, N. A. J. Assessing the Effectiveness of Local Management of Coral Reefs Using Expert Opinion and Spatial Bayesian Modeling. *PLoS One* **10,** e0135465 (2015).

Burgman, M.A., McBride, M., Ashton, R., Speirs-Bridge, A., Flander, L., Wintle, B., Fidler, F., Rumpff, L. & Twardy, C. (2011) Expert status and performance. PLoS ONE, 6, e22998

Charney, N. D. Evaluating expert opinion and spatial scale in an amphibian model. *Ecol. Modell.* **242,** 37–45 (2012).

James, A., Choy, S.L., Mengersen, K., 2010. Elicitator: an expert elicitation tool for regression in ecology. Environmental Modelling & Software 25, 129–145

Low Choy, S., O’Leary, R. & Mengersen, K. Elicitation by Design in Ecology : Using Expert Opinion to Inform Priors for Bayesian Statistical Models. *Ecology* **90,** 265–277 (2016).

Kuhnert, P. M., Martin, T. G. & Griffiths, S. P. A guide to eliciting and using expert knowledge in Bayesian ecological models. Ecol. Lett. **13,** 900–14 (2010).

Martin, T. G., Kuhnert, P. M., Mengersen, K. & Possingham, H. P. Power of Expert Opinion in Ecological Models Using Bayesian Methods : Impact of Grazing on Birds. Ecol. Appl. 15, 266–280 (2005).

Martin, T. G. et al. Eliciting Expert Knowledge in Conservation Science. Conserv. Biol. **26,** 29–38 (2012).

McBride, M.F., Fidler, F. & Burgman, M.A. (2012b) Evaluat- ing the accuracy and calibration of expert predictions under uncertainty: predicting the outcomes of ecological research. Diversity and Distributions, 18, 782–794.

Kuhnert, P. M., Martin, T. G. & Griffiths, S. P. A guide to eliciting and using expert knowledge in Bayesian ecological models. Ecol. Lett. **13,** 900–14 (2010).

Speirs-Bridge, A. et al. Reducing overconfidence in the interval judgments of experts. Risk Anal. **30,** 512–23 (2010).

Runge, M. C., Converse, S. J. & Lyons, J. E. Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. Biol. Conserv. **144,** 1214–1223 (2011).

Table 3. List of relevant literature provided to experts:

*Suggested References Papers:*

Non-forest impacts (urban, agriculture):

Barrett, K. & Price, S. J. Urbanization and stream salamanders: a review, conservation options, and research needs. *Freshw. Sci.* **33,** 927–940 (2014).

Grant, E. H. C., Green, L. E. & Lowe, W. H. Salamander occupancy in headwater stream networks. *Freshw. Biol.* **54,** 1370–1378 (2009). Summary: Eurycea complex mean occupancy = 0.99 (0.03 SE) branched streams, 0.90(0.07 SE) unbranched streams. Two regions: National Capitol Region (3 national park units surrounded by urban) and VA (3 units surrounded by forest; Shenandoah National Park and George Washing and Jefferson National Forest) sites. Lower occupancy in NCR than VA.

Price, S. J., R. A. Browne, and M. E. Dorcas. 2012a. Evaluating the effects of urbanisation on salamander abundances using a before-after control-impact design. Freshwater Biology 57: 193–203.

Price, S. J., K. K. Cecala, R. A. Browne, and M. E. Dorcas. 2011. Effects of urbanization on occupancy of stream salamanders. Conservation Biology 27:547–555.

Price, S. J., M. E. Dorcas, A. L. Gallant, R. W. Klaver, and J. D. Willson. 2006. Three decades of urbanization: estimating the impact of land cover change on stream salamander pop- ulations. Biological Conservation 133:436–441.

Climate-niche models:

Sutton, W. *et al.* Predicted Changes in Climatic Niche and Climate Refugia of Conservation Priority Salamander Species in the Northeastern United States. *Forests* **6,** 1–26 (2014).

Milanovich, J. R., Peterman, W. E., Nibbelink, N. P. & Maerz, J. C. Projected Loss of a Salamander Diversity Hotspot as a Consequence of Projected Global Climate Change. *PLoS One* **5,** e12189 (2010).

Streamflow impacts:

Price, S. J., R. A. Browne, and M. E. Dorcas. 2012b. Resistance and resilience of a stream salamander to supraseasonal drought. Herpetologica 68:312–323.

Fish-salamander studies:

Barr, G. & Babbitt, K. Effects of biotic and abiotic factors on the distribution and abundance of larval two-lined salamanders ( Eurycea bislineata ) across spatial scales. *Oecologia* **133,** 176–185 (2002).

Lowe, W. H., Nislow, K. H. & Bolger, D. T. Stage-Specific and Interactive Effects of Sedimentation and Trout on a Headwater Stream Salamander. **14,** 164–172 (2004).

Appendix A. List of experts requested to take this survey.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **last** | **first** | **invite** | **email** | **affiliation** | **website** |
| Barr | Garrett | yes | garrettbarr@kings.edu | Department of Biology and the Environmental Program, King's College, Wilkes-Barre, PA 18711, USA | http://staff.kings.edu/garrettbarr/ |
| Barrett | Kyle | yes | rbarre2@clemson.edu | Department of Forestry and Environmental Conservation, Clemson University, Clemson, SC 29634, USA | https://sites.google.com/site/clemsonbarrettlab/home |
| Babbitt | Kim | yes | kbabbitt@unh.edu | Department of Natural Resources & the Environment, University of New Hampshire, Durham, NH 03824, USA | https://colsa.unh.edu/administrator/babbitt |
| Bourne | John | yes | ? |  |  |
| Bruce | Richard | yes | ebruce1563@aol.com | Department of Biology, Western Carolina University, Cullowhee, NC 28723, USA | https://drrichardcbruce.wordpress.com/ |
| Camp | Carlos | ? | ccamp@piedmont.edu | Piedmont College | https://www.researchgate.net/profile/Carlos\_Camp |
| Connette | Grant | ? | ? | Smithsonian Conservation Biology Institute, Smithsonian Institution,Washington, D.C., DC, USA | https://www.researchgate.net/profile/Grant\_Connette/contributions |
| Consentino | Brad | yes | cosentino@hws.edu | Department of Biology, Hobart and William Smith Colleges, Geneva, NY 14456, USA | http://people.hws.edu/cosentino/home.html |
| Crawford | John | yes | joacrawford@lc.edu | National Great Rivers Research and Education Center, East Alton, IL 62024, USA | http://crawfordlab.weebly.com/ |
| Fields | Will | yes | wfields@usgs.gov | USGS |  |
| Grant | Evan | yes | ehgrant@ugsg.gov | USGS |  |
| Hocking | Daniel | yes | djhocking@usgs.gov | USGS | https://danieljhocking.wordpress.com/research/ |
| Lowe | Winsor | yes | winsor.lowe@umontana.edu | Division of Biological Sciences, University of Montana, Missoula, MT 59812, USA | http://hs.umt.edu/dbs/labs/lowe/default.php |
| Moseley | Kurtis | ? | kmoseley@mix.wvu.edu | Division of Forestry and Natural Resources, West Virginia University, Morgantown, WV 26506, USA? | ? |
| Niemiller | Matt | yes | mniemill@illinois.edu | Postdoctoral Research Associate, Illinois Natural History Survey, University of Illinois Urbana-Champaign, Champaign, IL 61820, USA | http://www.speleobiology.com/niemiller/cv/ |
| Osbourne | Mike | ? | osbournms@appstate.edu | Department of Biology, Appalachian State Univeristy, Boone, NC ZIP, USA | https://www.researchgate.net/profile/Michael\_Osbourn |
| Pauley | Tom | yes | pauley@marshall.edu | Department of Biological Sciences, Marshall University, Huntington WV 25755, USA | http://www.marshall.edu/herp/pages/Pauley\_Profile.htm |
| Peterman | Bill | yes | peterman.73@osu.edu | School of Environment and Natural Resources, The Ohio State University, Columbus, OH 43210, USA | http://petermanresearch.weebly.com/dr-bill-peterman.html |
| Petranka | Jim | yes | petranka@ret.unca.edu | Department of Biology, University of North Carolina, Asheville, NC 28804, USA | https://biology.unca.edu/faces/jim-petranka-phd |
| Resetarits | William | yes | wresetar@olemiss.edu | Department of Biology,University of Mississippi, University, MS 38677, USA | http://www.olemiss.edu/resetaritslab/ |
| Richter | Stephen | yes | stephen.richter@eku.edu | Department of Biological Sciences, Eastern Kentucky Unversity, Richmond, KY 40475, USA | http://people.eku.edu/richters/ |
| Rocko | ? | ? | ? | ? | ? |
| Snodgrass | Joel | yes | joels@vt.edu | Department of Fish and Wildlife Conservation, Virginia Tech, Blacksburg, VA 24061, USA | http://www.fishwild.vt.edu/faculty/snodgrass/index.htm |
| Southerland | Mark | yes | southerlandmar@versar.com | Versar, Inc., ESM Operations, Columbia, MD 21045, USA | https://www.researchgate.net/profile/MT\_Southerland/publications |
| Tilley | Stephen | yes | stilley@smith.edu | Department of Biological Sciences, Smith College, Northampton, MA 01063, USA | http://www.smith.edu/biology/faculty\_tilley.php |
| Willison | JD | yes | willson@srel.edu | Savannah River Ecology Laboratory, Drawer E, Aiken, SC 29802, USA | http://comp.uark.edu/~jwillson/ |

Appendix. Initial Survey Results

Table 1. Experience and expertise among stream salamander experts (self-ranking) (question 1)

Figure 1. Conceptual catchment

Figure 2. Overall mean occupancy (upper and lower bounds and confidence intervals) expected by each expert by species and region (question 2)

Figure 3. Overall mean occupancy (upper and lower bounds and confidence intervals) expected by each expert by species and region (question 3)

Figure 4. Number of reaches occupied (out of 100) in relation to stream size (sqkm) and log(stream size; sqkm) (question 4).

Figure 5. Number of reaches occupied (out of 100) in relation to mean summer (June, July, August) stream temperature (C) (question 5).

Figure 6. Number of reaches occupied (out of 100) in relation to streamflow for small and large streams. (question 6)

Figure 7. (question 7)

Figure 7. (question 8)

Table 2. GLM for occupancy (+ model fit)

Figure 8. Residuals

Figure 9. Predicted vs. observed

Figure 10. Example of mean predicted occupancy (Deerfield)