Vernal Pool Management and Monitoring on Northeast National Wildlife Refuges

Structured Decision Making Workshop Report – February 2019

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Introduction

Vernal pools are small, seasonal wetlands (depressions) that hold water for at least two months in the spring or early summer, are largely absent of fishes, and provide critically important habitat for many amphibian species of conservation concern. Their contribution to biodiversity of forests is disproportionally large compared to their temporal and spatial presence (days to weeks to months), with several amphibian species using these habitats exclusively for breeding and larval development (termed vernal pool obligate species, such as spotted salamanders and wood frogs). North American amphibian populations are declining at an average rate of 3.7% annually (Adams et al. 2013). A variety of threats to amphibian persistence have been identified, including land-use change, infectious diseases, pesticide use, and climate change, and the impact of these threats varies regionally, with an estimated mean 1.87% to 5.21% annual decline in the northeast (Grant et al. 2016). Vernal pools also provide resting and feeding habitat for USFWS Northeast Region At-Risk turtles, including spotted, wood and Blanding's turtles. Vernal pools have been identified as a priority ecosystem for research and management by the Northeast Refugia Research Coalition (https://www.climaterefugia.org/vernal-pools), and Northeast Partners in Amphibian and Reptile Conservation (http://northeastparc.org/vernal-pools/), with vernal pool obligates often selected as Species of Greatest Conservation Need (SGCN) in many State Wildlife Action Plans (https://www.fishwildlife.org/afwa-informs/state-wildlife-action-plans). Because federal wetland regulations largely do not provide adequate protection for these habitats, a few states (e.g., Massachusetts and Maine) offer protections if they are "certified" vernal pools.

Studies by U.S. Geological Survey (USGS) suggest that occupancy of two vernal pool obligates (i.e., spotted salamander and wood frog), are declining across the northeastern U.S. Occupancy on many National Wildlife Refuges (NWR) in the Northeast Region over the past 10-years have demonstrated slow declines, with a few NWRs also showing stable or increasing populations

(Grant and Brand 2017). Northeast NWRs provide a unique opportunity to implement management strategies to mitigate declines because 1) habitats are located on federally protected lands, 2) NWRs policies enable the ability to conduct land management activities, 3) individual NWRs often contain at least one or more metapopulations (i.e., vernal pool network), 4) NWRs are broadly distributed across the species' range, and are thus protect potential genetic variability (adaptability), 5) NWRs occur in a diversity of landscape contexts (habitat types and urban gradient, climate change impacts). Perhaps most importantly, NWRs planning policies (Comprehensive Conservation Plan, Habitat Management Plan, and Inventory and Monitoring Plan) provide a framework for setting biological objectives for vernal pool obligates (e.g. Resources of Concern), as well as developing management strategies and monitoring elements that process toward biological objectives and to evaluate management effectiveness over time.

The PrOACT Process

We used a structured decision-making process (SDM; Hammond et al. 1999, Gregory et al. 2012) with the "roadmap" approach to biological monitoring (Reynolds et al. 2016) to prototype a management framework and identify information needs for each of four participating NWRs. The steps of the SDM process (PrOACT) can be summarized as 1) framing the problem, 2) clarifying the management objectives, 3) developing alternative actions and strategies, 4) predicting consequences of actions in terms of the objectives, 5) evaluating trade-offs, and 6) making decisions and taking action (Figure 1). We preliminary diagnosed why the problem was difficult from a decision analysis perspective for each NWRs, which could include 1) there are many trade-offs to consider (multiple-objective problem), 2) there are too many options to choose from (portfolio problem), 3) we lack basic core information to frame the problem (information gap problem), 4) there is too much uncertainty in responses (uncertainty problem), 5) the ecological system is too complex to make reasonable predictions (prediction problem) 6) actions are applied over time and depend on previous actions (dynamic decisions problem). Using the roadmap, refuges assessed which type of survey would be likely be most desirable, which could include inventory, trend monitoring, threshold monitoring, effectiveness monitoring, or monitoring to reduce uncertainty that informs iterative decisions (adaptive management).

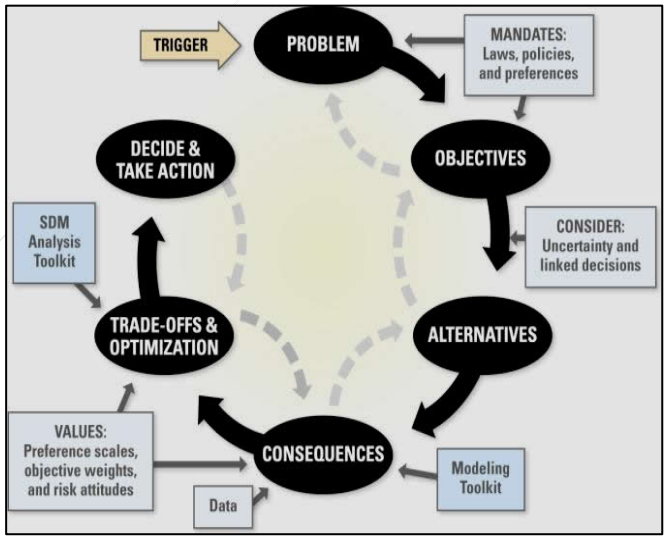


Figure 1. Structured decision-making PrOACT process. Figure developed by USFWS/USGS.

Four refuges (Canaan Valley NWR, Patuxent Research NWR, Assabet NWR, and Erie NWR) were identified as focal refuges based on estimated or suspected declines in wood frog or spotted salamander occupancy (egg mass presence) using USGS monitoring data collected across 18 refuges (Table 1; Grant and Brand, 2017). Due to staffing constraints, Patuxent Research NWR

was not able to attend the workshop and Erie NWR was not contacted to participate (SM1). Despite a lack of evidence of decline to date, Umbagog NWR was included because the refuge was interested in testing active forest management practices to mitigate species declines in northern forests as part of the Land Management Research and Demonstration (LMRD) program. Additionally, the refuge biologist for Assabet NWR also manages Oxbow NWR and decided to consider management at both refuges. As a result, three staffed refuges participated in the full workshop: Canaan Valley NWR, Eastern Mass NWR Complex (Assabet NWR and Oxbow NWR), and Umbagog NWR, while Patuxent NWR participated in our pre-workshop conference call only (SM2).

We coordinated a 1.5-hr pre-workshop conference call, a 30-min pre-workshop survey, and a 2.5 day in-person workshop held in the USFWS Northeast Regional Office in Hadley, MA on February 5-7, 2019. Workshop participants were selected to encourage co-production (scientists and management working together) to solve management problems, and included refuge biologists (at least 1 per refuge), USGS and USFWS subject matter experts (amphibian, hydrology, forestry, contaminants, spatial analysis; at least 1 per refuge), and facilitators familiar with the SDM process (at least 1 per refuge; SM3). As a result, each refuge team was composed of 4-6 participants. During the workshop, we conducted mini-lectures (30-min) for each step of ProACT and held refuge-specific breakout sessions (1-2 hrs for each step). During each breakout session, refuges used the workshop template presentation to work through each PrOACT step (SM4). Between steps, refuge teams shared progress to identify common or unique concerns that would benefit from a broader group discussion. All workshop materials can be found here: https://ecos.fws.gov/ServCat/Reference/Profile/110606.

Table 1. Results from USGS analysis indicating increasing (+), decreasing (-), or stable (x) trends (or never detected, nd) for occupancy of wood frog (RSYL) and spotted salamander (AMAC) egg masses at 13 NWRs based on the sampling period and number of years of monitoring data (Grant and Brand 2017).

USFWS National Wildlife Refuge	RSYL Trend	AMAC Trend	Number of Years	Sampling Period
Canaan Valley NWR	-	-	13	2004-2016
Patuxent Research NWR	-	-	13	2004-2016
Great Swamp NWR	x	nd	13	2004-2016
Wallkill NWR	x	x	10	2004-2016
Erie NWR	-	-	12	2004-2016
Iroquois NWR	x	nd	13	2004-2016
Assabet NWR	-	-	13	2004-2016
Oxbow NWR	x	x	3	2014-2016
Rachel Carson NWR	+	+	13	2004-2016
Umbagog NWR	x	+	4	2013-2016
Moosehorn NWR	x	x	10	2004-2016
Aroostook NWR	x	+	4	2013-2016
Eastern Virginia Rivers NWR	nd	nd	1	2018

Prototype Solutions

Problem Framing

We began identifying the problem for each refuge prior to the workshop using the pre-workshop conference call and survey. Each refuge created a prototype problem statement that included the trigger for the decision, the decision maker(s), spatial and temporal scale for management, general types of actions under consideration, important goals and objectives for management, potential constraints, and key uncertainties (see below). Additionally, each refuge conducted a preliminary assessment (ranked 0 = not important, 10 = very important) of why they thought the refuge problem was difficult during the problem framing stage. These prototype problem statements were reviewed and revised throughout the decision-making process to ensure that solutions address each refuge's management problem.

Eastern Mass NWR Complex (Assabet and Oxbow NWR) Problem Statement: Due to recently observed declines in wood frog and spotted salamander occupancy and the presence of diseases and contaminants, Eastern Mass NWR Complex staff will decide every 5-years how to restore natural hydrology, conduct vegetation management, manage road use, and/or conduct population reintroductions at Assabet NWR and Oxbow NWR. Management will aim to ensure species persistence and vernal pool integrity and health in 50 years, while considering limited staff time, funding, refuge access, and uncertainty in causes of decline, beaver influences, and amphibian status within all non-monitored pools. The decision problem is challenging because of the extensive information gaps and uncertainties described above.

Umbagog NWR Problem Statement: Due to concern for vernal pool buffer effectiveness, the Umbagog NWR Refuge Manager will decide how to conduct active forest management on a 15-yr cycle and to utilize ecological forestry and commercial forest practices to rehabilitate current habitat conditions that promote focal management species (softwood, mixed-wood, and hardwood communities), while maintaining or increasing vernal pool obligate species over 45-years within 40k acres (20k acres subject to uneven-aged forest management and 20k not subject to uneven-aged forest management), while considering impacts to other species, available resources, and demonstration of management utility, and uncertainty in forest economics and ecosystem status and function. This decision problem is challenging because there are many management alternatives (a portfolio of specific pools, treatment areas, and buffer types) and responses are challenging to predict due to potentially low samples sizes.

Canaan NWR Problem Statement: Due to declines in wood frog and spotted salamander populations, Canaan Valley NWR staff will decide every 15 years how to manage habitat, alter hydrology, and/or manipulate populations to maintain biodiversity and vernal pool integrity throughout the Refuge over the next 50 years, while considering cost and accessibility, as well as impacts to other species, and uncertainty in the effects of climate change and disease. The decision problem is challenging because of these uncertainties, as well as habitat management responses.

Management Objectives

Refuges identified multiple biological objectives that they hope to be achieve with the vernal pool management decision. Objectives reflected refuge purpose, BIDEH policy, and if available,

goals and objectives described in Comprehensive Conservation Plans or Habitat Management Plans. Refuges identified five fundamental objectives (level 1): maintain biological diversity, maintain biological integrity, maintain environmental health, and maximize learning (Figures 2a-2d). Within the biological diversity fundamental objective, each refuge developed sub-objectives to maximize the persistence of two vernal pool obligate species (wood frogs and spotted salamanders). One refuge included a biodiversity sub-objective related to sustaining rare plant communities and another refuge included sub-objective related to minimizing harm to two at-risk turtle species (Blanding's turtles and spotted turtles). Two refuges included sub-objectives for biological integrity, which included maintaining hydrologic resiliency and forest conditions (e.g. mature conifer community), and one refuge, which is a part of the LMRD program, identified learning as fundamental objective (i.e., export knowledge to other sites and/or partners).

Refuge teams developed one or more measurable attributes (i.e., performance metrics) that would indicate success in achieving each sub-objective (Table 2). Since this workshop was motivated by vernal pool obligate species declines, we focused efforts on developing attributes for these objectives following the SMART criteria (specific, measurable, attainable, realistic, and time-specific; Adamcik et al. 2004). Attributes (termed performance measure, criterion, and metric) are indicators of success toward a particular objective and should contain clear metrics that can be measured in the field. These metrics may be natural attributes (i.e. direct measurements of achievement of the objective), proxy attributes (i.e. indirect measurements of the achievement of the objective), or constructed scale attributes (i.e. two or more distinct levels appropriately defined when no natural scales exist; Keeney and Gregory 2005).

Proposed attributes (see Table 2) for vernal pool obligate species persistence objectives included the number of sites occupied and population size, as measured by a mean 3-year egg mass count. Three years was considered sufficient to account for year-to-year variability, as well as allow enough time for eggs deposited in year 1 to return as breeding adults in year 3. Rare plant community objectives included attributes of species/community richness, stem density, and percent cover attributes. One refuge decided that vernal pool management actions within this management framework would not be designed to specifically increase Blanding's and spotted turtle habitat or populations (individuals use vernal pool habitats as post-hibernation feeding grounds in the spring and as "stepping stones" for movement), but that any proposed actions would have to minimize potential harm to individuals or other upland habitats they depend on. Therefore, this refuge selected a constructed scale (0 = no harm to 5 = high likelihood of negative impacts) as the attributes for minimizing harm to at-risk turtle species. Hydrologic resiliency was an important sub-objective for biological integrity and was represented by the proportion of ponds within the management unit with short (< 45 days), moderate (45-75 days), or long (>75 days) hydroperiods (Mid-April through July). Since annual variability in precipitation, in combination with pond depth, is a key driver of hydroperiod, a 5-year average deviation from equal proportions was proposed as a measure. Forest condition sub-objective was represented by percent canopy cover and percent conifer cover (at the management unit area scale) because these indicate a northern forest mature hardwood ecosystem, as well as the mean 3-year breeding bird density of three focal bird species (blackburnian warbler, BLBW; black-throated green warbler, BTNW; and Canada warbler, CAWA). A three-year average was suggested based on previous analysis of year-to-year variability in occupancy and counts of these species. The learning objective was measured as the number of acres benefiting from knowledge

gained on other NWRs and acres managed by other partners. Additionally, trophic structure and contaminants were identified as important sub-objectives, but measures were not developed during the workshop.

During the process, many other objectives and sub-objectives were brainstormed, but not included in the refuge prototype for various reasons. Eastern Mass NWR Complex considered marbled salamanders, however Jacob Kubel (MA DFW) indicated that there is a very low probability that they are present at Assabet NWR and not present at all on Oxbow NWR due to the lack of suitable upland habitat (glacial deposits). Canaan Valley NWR considered recreational use (i.e., access to horse and hiking trails); however, staff agreed that these activities would not be impacted by vernal pool-related management decisions and thus this objective was irrelevant to this particular decision. All three refuge teams had an objective to be efficient (i.e., minimize cost in terms of time and dollars), but decided not to explicitly include cost as an objective because funds may become available (RFPs and partner support) from various sources. Instead, the cost of each management strategy can be estimated to evaluate potential return-on-investment during the trade-offs step of the decision-process.

Table 2. Measurable attributes (performance measures), with preferred directions and proposed measures for each sub-objective and objectives across all three NWRs. TBD indicates metrics need to be developed. Proposed measures are suggested values only and should be updated based on anticipated temporal and spatial variability and responsiveness to management actions at each refuge.

Objective	Sub-Objective	Attribute	Preferred Direction	Proposed Measure
Maintain Biological Diversity				
	Wood frog persistence	# occupied sites	increase	mean 3-year egg mass occupancy (counts)
		population size	increase	mean 3-year egg mass abundance (counts)
	Spotted salamander persistence	# occupied sites	increase	mean 3-year egg mass occupancy (counts)
		population size	increase	mean 3-year egg mass abundance (counts)
	Rare plant communities	species richness	maintain	number of unique communities
		stem density	increase	mean stem density
		percent cover	increase	total area (m^2)
	Blanding's turtle	level of harm	decrease	0 = no harm 5 = high likelihood of negative impact
	Spotted turtle	level of harm	decrease	0 = no harm 5 = high likelihood of negative impact
Maintain Biological Integrity				
	Hydrologic resiliency	Distribution of hydroperiods	decrease	mean 5-year deviation from equal proportions (short, moderate, and long)
	Forest condition	Percent canopy	increase	1 $\geq$ 75% canopy 0 < 75% canopy
		Percent confer	increase	1 $\geq$ 75% confer composition 0 < 75% confer composition
	Focal bird species	BLBW breeding pairs	increase	mean 3-year density
		BTNW breeding pairs	increase	mean 3-year density
		CAWA breeding pairs	increase	mean 3-year density
	Tropic structure	TBD	TBD	TBD
Maintain Environmental Health				
	Contaminants	TBD	TBD	TBD
Maximize Learning				
	Knowledge application	Partner benefits	increase	acres off-refuge influenced
		NWRS benefits	increase	acres of other NWRs influenced

Figure 2a. Objective hierarchy with all potential objectives across refuges (Eastern Mass NWR Complex, Umbagog NWR, and Canaan Valley NWR) nested under three fundamental objectives: biological diversity, biological integrity, environmental health, and learning. Attributes are indicated with bolded boxes.

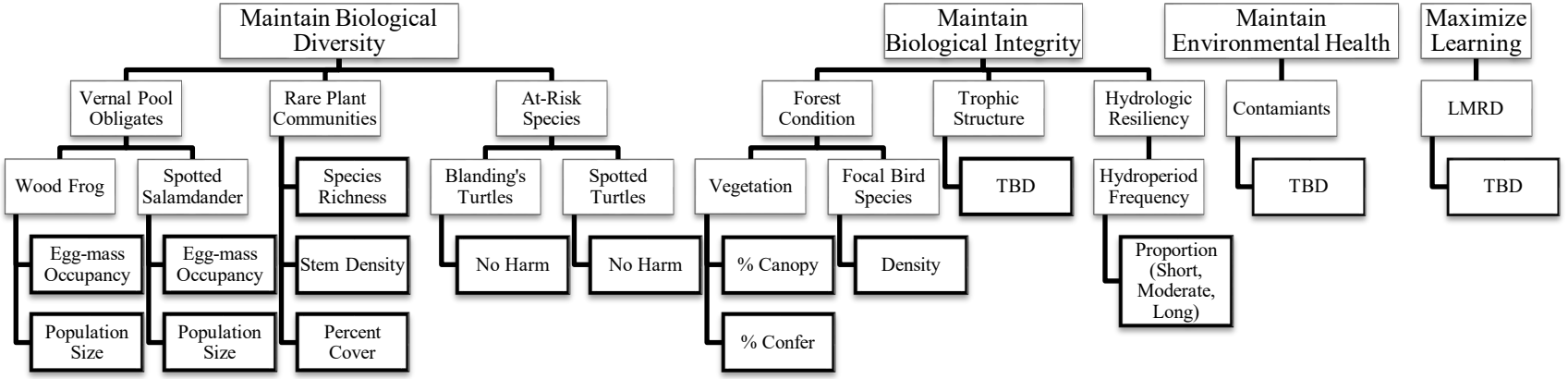


Figure 2b. Objectives selected (grey) to inform vernal pool management decisions at Eastern Mass NWR Complex

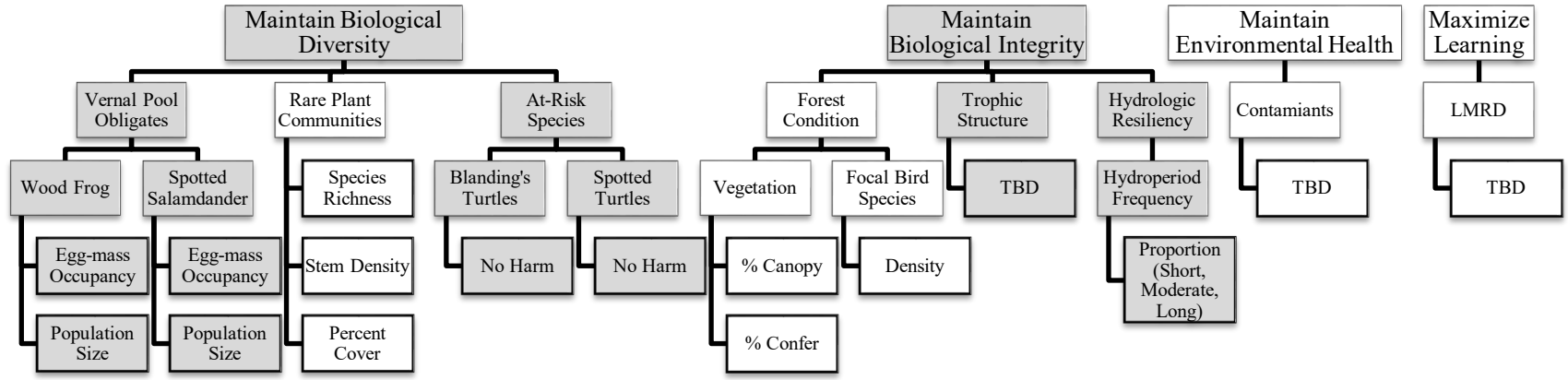


Figure 2c. Objectives selected (grey) to inform vernal pool management decisions at Umbagog NWR.

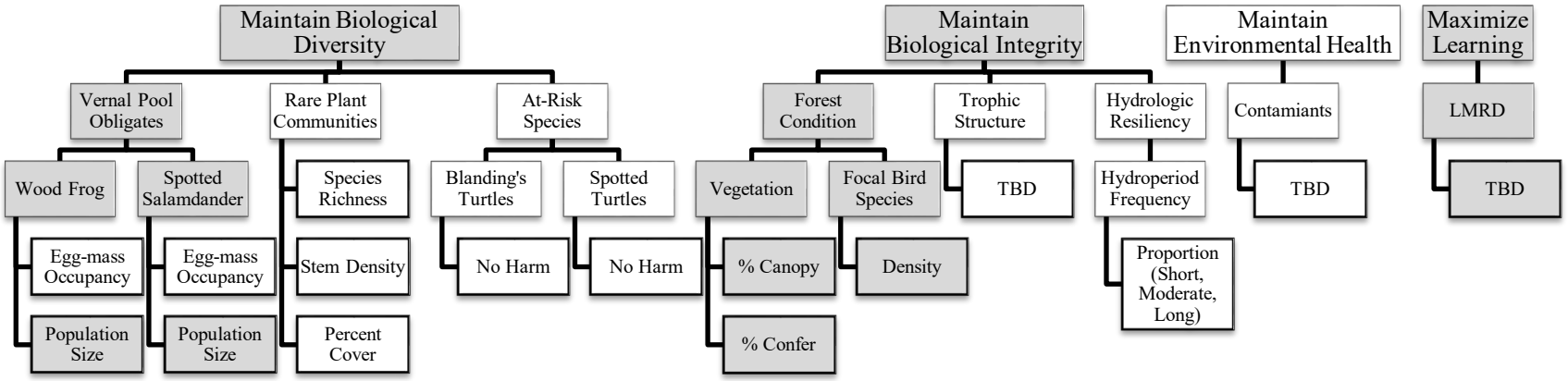
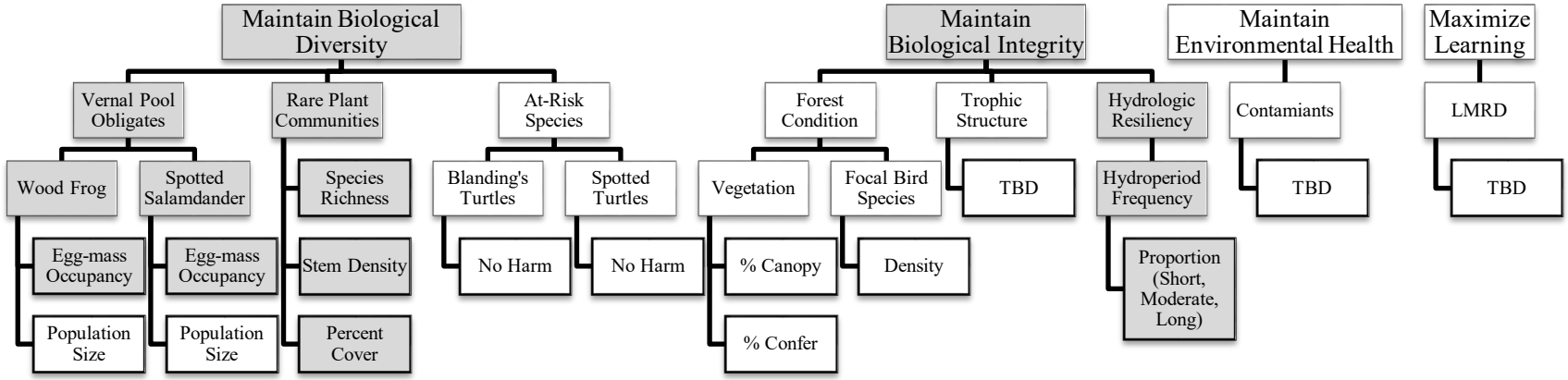


Figure 2d. Objectives selected (grey) to inform vernal pool management decisions at Canaan NWR.



Limiting Factors and Threats

Understanding limiting factors and threats to each achieving objectives can help generate new management actions and help evaluate the consequences of various strategies. Refuge teams brainstormed 10 demographic states and rates that drive vernal pool obligate species population persistence and included the following:

- Fecundity
- Egg survival
- Larval survival
- Metamorph survival
- Non-breeder survival
- Breeder survival
- Number of breeders
- Movement
- Dispersal
- Genetic diversity

Additionally, refuge teams brainstormed abiotic and biotic factors that would influence vernal pool obligate species population persistence. Depending on the refuge, these factors could be considered as external (outside of the refuge's management control) or internal (could be affected by refuge management) and included the following:

- Pool size
- Number of pools
- Proximity to pools (within metapop)
- Proximity to other metapopulations
- Hydroperiod (water depth and timing)
- Temperature (water and air)
- Water quality (pH)
- Nutrients
- Coarse wood
- Canopy closure
- Upland forest cover
- Competition
- Predation
- Road mortality
- Disease (ranavirus)
- Contaminants (Hg, pesticides, and road salt)
- Climate change (precipitation and temperature)
- Weather events (ice storms and wind)
- Timber harvest and fire management
- Movement barriers (roads, infrastructure, unsuitable habitats)

Refuges connected factors to objectives using conceptual models (Figures 3a-3c) to identify which factors may have the largest potential to influence objectives via management. The conceptual model for Eastern Massachusetts NWR Complex focused on maximizing spotted salamander abundance and wood frog occupancy (i.e., biological diversity; Figure 3a), Umbagog NWR focused on maximizing forest conditions (i.e., biological integrity; Figure 3b), and Canaan Valley NWR focused on maximizing spotted salamander persistence (i.e., biological diversity; Figure 3c). Refuge teams also identified the likely most important factors driving persistence (e.g. recruitment success, vernal pool basin size, hydroperiod, disease, competition, foraging habitat, over-wintering habitat, vegetation structure and composition, connectivity, soil condition, and water temperatures, predation, and recreational use) and the direction of influence of these factors (i.e., positive or negative).

As time permitted, refuge teams identified limiting factors and threats to the remaining refuge objectives. These can be found in refuge-specific workshop supplemental materials (https://ecos.fws.gov/ServCat/Reference/Profile/110606). Additional factors included forest regeneration, site suitability (soil and topography) of mature conifers, plant germination, seedling survival, seed dispersal, competition, herbivory, and invasives.

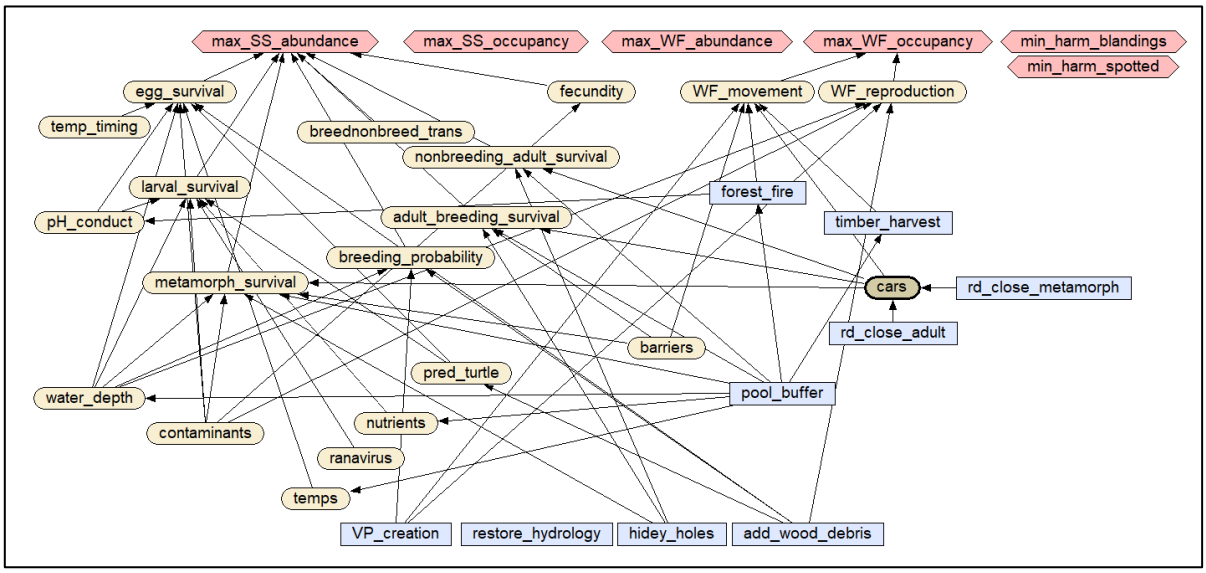


Figure 3a (above). Eastern Massachusetts NWR Complex prototype conceptual model for the biological diversity spotted salamander occupancy and wood frog occupancy objective and attributes (pink), with limiting factors and threats (yellow), and potential management actions (blue).

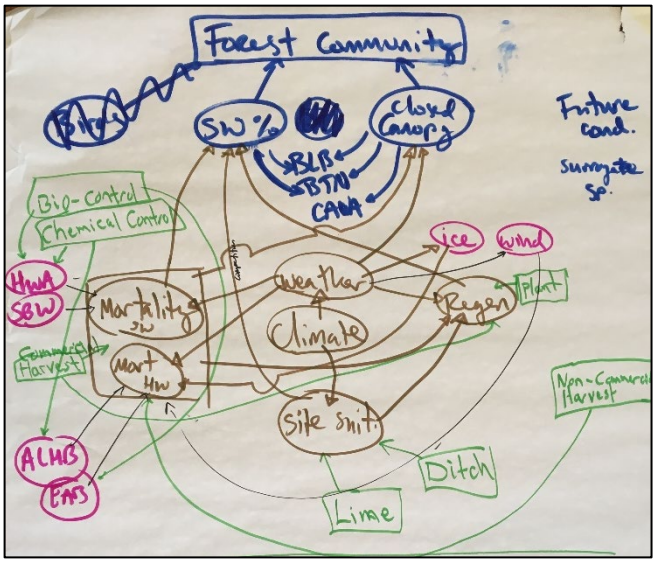
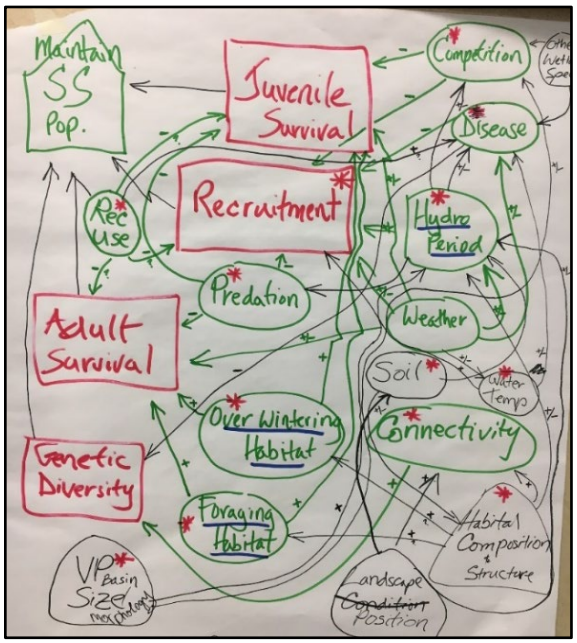


Figure 3b (above). Umbagog NWR prototype conceptual model for the biological integrity forest condition objective and attributes (blue), limiting factors (brown), threats (pink), and potential management actions (green).

Figure 3c (below). Canaan Valley NWR prototype conceptual model for biologigical diversity spotted salamander persistence objective (green hexagon) with limiting demographic factors (red), threats (green and black). Red asterisks indicate factors with large influences and positive/negative signs indicate the hypothesized direction of influence.



Alternative Management Actions

Using the conceptual models, refuge teams brainstormed any actions that could be taken (theoretically) to alter a particular factor (demographic rate or state, limiting factor, or threat). Facilitators encouraged teams not to eliminate actions due to perceived feasibility or plausibility to increase the likelihood of generating potentially effective management actions. As a result, over 50 unique actions were identified and were categorized into 4 broad themes: population, hydrologic, vegetation, and human impacts (see lists below). Actions could be applied at various spatial scales including the individual pool-levels (or multiple pools) and landscape-level (i.e., between pools, across upland habitats or across multiple metapopulations).

Population Management (Pool-level and/or Landscape-level)

- Move stranded eggs or larvae
- Translocate eggs
- Predator exclusion at pools
- Move turtles out of pools
- Cage egg masses
- Conduct head starting
- Translocate adults and/or juveniles
- Captive rear and translocate larvae

Hydrology Management (Pool-level)

- Create vernal pools
- Install liners
- Deepen pools
- Fill in portions of pools
- Add supplemental food (inverts)
- Add nutrients
- Increase shade (artificial)
- Soil clean up
- Remove sediments
- Cap sediments

Hydrology Management (Landscape-level)

- Modify basin size
- Eliminate vernal pools
- Restore natural hydrology
- Manage (remove) beavers
- Remove or replace culverts

Vegetation Management (Pool-level)

- Add coarse wood
- Establish vegetation buffers
- Overstory management (light)
- Vegetation management
- Limit herbicide application (buffers)
- Limit forest management (buffers)
- Limit fire management (buffers)
- Increase buffer width

Vegetation Management (Landscape-level)

- Forest management
- Beech brush management
- Hardwood vs softwood management
- Tree/shrub planting
- Plant forest species that add carbon
- Promote forest regeneration in old fields (appropriate locations)
- Increase duff layer thicknesses (hardwood vs. softwood)
- Remove competing wetland species
- Use BMPs for timber harvest

- Provide hibernacula (insulation)
- Establish conservation easements on adjacent lands

Human Impacts (Landscape-level)

- Refuge closure
- Relocate/close trails
- Road closure during adult migration
- Road closure during metamorph migration
- Remove existing fencing
- Add fences on roads to direct individuals to crossings
- Implement decontamination protocol
- Add tunnels below roads
- Outreach to visitors
- Outreach to partners
- De-ice roads with beet sugar

Since there were numerous actions to choose from for each refuge, each refuge team developed a more condensed set of management alternatives that were composed of multiple actions. These alternatives were generated to gain insight into which types of actions may be most effective at achieving their objectives and allowed refuges to compare the relative benefits of focusing management efforts on particular life-history stages and/or habitat types (i.e., recruitment vs. movement focus, pool vs. upland habitat focus, hydrology vs. forest management focus).

Umbagog NWR developed 6 distinct alternatives that were hypothesized to have varying impacts on their objectives. These alternatives included different combinations of selective tree timber harvest buffer size (100 or 400 ft), buffer tree composition (increase hardwood or not), large wood within the buffer (increase or not), create upland movement corridors (yes or no), create successful vernal pools (yes or no), and use commercial harvest (yes or no; Table 3). At Canaan Valley NWR, 9 distinct alternatives were developed by focusing on various life stages and/or within pool or upland management focused on either vegetation management within a 50 m buffer, increasing or decreasing hydro periods, high and low intensity recruitment, adult movements, larval survival, or upland management (Table 4). Eastern Mass NWR Complex attempted to develop strategies, but then realized that the potential drivers need to be better understood before developing alternatives. Thus, after the workshop, USGS worked with the refuge biologist to flesh out their conceptual model so that strategies can be developed in the next prototype.

Table 3. Individual actions (columns) comprising each alternative strategy (rows) considered at Umbagog NWR. The decision is which strategy (row) to implement that will benefit all management objectives.

	Actions						
Alternative Strategy	**Open canopy in Buffer**	**Buffer size**	**Increase HW in buffer**	**Increase cwd in buffer**	**Create upland corridor**	**Create new pools**	**Harvest method**
Status quo	Status quo	100ft	Status quo	Status quo	No	No	commercial
Existing buffer	Yes	100ft	Yes	Yes	No	No	commercial
Uplands only	No	No	Status quo	Status quo	Yes	Yes	commercial
Increase buffer	Yes	400ft	Yes	Yes	No	No	commercial
Connectivity corridor	Yes	100ft	Yes	Yes	Yes	No	commercial
Do it all	Yes	400ft	Yes	Yes	Yes	Yes	commercial

Table 4. Individual actions (columns) comprising each alternative strategy (rows) at Canaan Valley NWR The decision is which strategy (row) to implement that will benefit all management objectives.

Alternative Strategy	**Actions**			
Status quo	None			
Buffer vegetation	Plantings	Cuttings / overstory mgt		
Increase hydroperiod	Modify basin morphology	Increase shade	Install liners	Pool veg mgt
Decrease hydroperiod	Modify basin morphology	Veg mgt within pools	Beaver Management	
High intensity recruitment	Headstarting	Moving egg masses	Create in-pool structure	
Low intensity recruitment	Moving egg masses	Create in-pool structure		
Adult movement	Translocation	Population augmentation		
Larval survival	Predator control	Supplemental feedings	Reduce Competition	
Upland management	Plantings	Overstory management		

Predicting Consequences and Evaluating Trade-offs

Predicting consequences of each alternative management strategy is essential to understanding potential trade-offs among management objectives and ultimately deciding on a course of action. Predictions can be made using field data, quantitative or qualitative models, published values from the literature, and/or expert judgements. Due to the time constraints of the workshop, we used a rapid single-point expert elicitation process in this prototype.

Umbagog NWR predicted consequences for all 6 alternatives (Tables 5), while Canaan Valley predicted consequences for 6 of 9 alternatives (Table 6). Eastern Mass NWR Complex did not complete the prediction step, but chose to continue building their conceptual model in order to improve development of alternative strategies.

USGS experts predicted the effects of actions on vernal pool obligate objectives (wood frog and spotted salamanders), while refuge and regional biologists predicted consequences for all other objectives. To facilitate more accurate judgements, participants first discussed the outcomes for the "Status Quo" alternative and used this prediction as a "baseline". Then, each refuge asked how much each objective would increase or decrease attributes for each objective relative to the baseline given a particular alternative strategy (set of actions in Tables 3 and 4) was implemented. Keep in mind that predictions were intended to represent potential consequence of taking action to benefit objectives over much long-term time horizons (e.g. 30-50 years, see Problem Statements). Predictions would likely need to be revised to include uncertainty in the second prototype.

Information Needs Assessment and Developing Surveys

After each refuge's first prototype decision model was completed, refuge teams brainstormed what information needs would be useful to improve their predictions and decision making. Canaan Valley NWR and Umbagog NWR listed information needs. Teams predicted if each item could be known perfectly, if the information would have low, moderate, or high value to decision-making, and whether there is currently low, moderate, or high uncertainty in the information (Table 7). This step can should completed for Eastern Mass NWR after the first prototype is completed.

After these information needs are refined in subsequent prototypes, each information need can be evaluated in terms of the additional survey needs they require (field data collection). Using the Road Map (Reynolds et al. 2016), refuges can identify the most appropriate type of survey (i.e., inventory, trend monitoring, effectiveness monitoring, trigger monitoring, or learning via adaptive management monitoring). Using the SDM PrOACT process, it is likely that most refuges would have a clear understanding of high priority inventory surveys and focal attributes, as well as high priority trigger monitoring surveys with key decision-points. It is worth noting that effectiveness monitoring and learning to inform adaptive management surveys require substantially higher sample sizes and effort (data management and analysis), which may be beyond the capacity of individual refuges and may require regional resources and/or outside partners (e.g. USGS).

Table 5. Predicted consequences of 6 alternative strategies (rows) for 7 management objectives (columns) at Umbagog NWR using single-point expert judgements.

Management Objectives							
Objective	Biological Diversity	Biological Diversity	Biological Integrity	Biological Integrity	Biological Integrity	Biological Integrity	Biological Integrity
Sub-objective	Wood frog persistence	Spotted salamander persistence	Forest condition	Forest condition	Focal bird species	Focal bird species	Focal bird species
Attribute	population size (egg mass abundance)	population size (egg mass abundance)	Percent conifer	Canopy closure	BLBW density[1]	BTNW density[2]	CAWA density[3]
Preferred direction	increase	increase	>75%	>75%	increase	increase	increase
Alternative Strategies							
Status Quo	135,000	135,000	Yes	Yes	600	1,400	500
Existing buffer	+ 0.08 of 10K upland	+ 0.10 of 10K upland	Yes	Yes	600	1,400	500
Uplands only	+ 0.25 of 10k upland	+ 0.25 of 10k upland	Yes	Yes	300	700	575
Increase buffer	+ 0.20 of 10k upland	+ 0.20 of 10k upland	Yes	Yes	600	1,400	500
Connectivity corridor	+ 0.15 of 10K upland	+ 0.12 of 10K upland	Yes	Yes	450	1,120	575
Do it all	+ 0.31 of 10K upland	+ 0.30 of 10K upland	No	Yes	240	560	575

[1]The attribute is the density of breeding pairs based on the assumption that 3,000 acres of soft-wood are currently available.
[2]The attribute is the density of breeding pairs based on the assumption that 10,000 acres of mixed hard/soft wood are currently available.
[3]The attribute is the density of breeding pairs based on the assumption that 7,000 acres of hard wood are currently available.

Table 6. Predicted consequences of 5 alternative strategies (rows) for 5 management objectives (columns) at Canaan Valley NWR using single-point expert judgements.

Management Objectives					
Objective	Biological Diversity	Biological Diversity	Biological Integrity	Biological Integrity	Cost
Sub-objective	Spotted Salamander Occupancy	Rare Plant Communities	Hydrologic Resiliency	BIDEH[3]	Cost
Attribute	# occupied sites (% of total)[1]	number of communities	proportion (%) of ponds with medium hydroperiods[2]	integrity impacts[3]	total dollars of over 15-years
Preferred direction	increase	increase	increase[2]	increase	decrease
Alternative Strategies					
Status quo	25	3	16	5	0
Increase hydroperiod	50	3	66	7	$$$$
High intensity recruitment	100	3	16	7	$$
Low intensity recruitment	70	3	16	6	$
Larval survival	50	3	16	6	$

[1]This attribute was modified to the percent of total sites occupied instead of the absolute number of sites occupied.
[2]This attribute was modified to only include the proportion (or percent) of medium hydroperiod ponds for the prototype, with increases being preferred.
[3]The attribute was added during the consequence step to represent all other potential impacts to integrity other than hydrology (10 = high integrity and 1 = low integrity).

Table 7. Information needs identified at the end of the prototyping process for Umbagog NWR and Canaan Valley NWR. Highest priority information needs have both high relative importance to decision-making and high levels of uncertainty.

Information Need	Relative importance to decision-making (high, moderate, low)	Current level of uncertainty (high, moderate, low)
Umbagog NWR		
Percent of vernal pools within HW and SW and localities at LKU	high	high
Vernal pool species population-levels at LKU	high	high
Effects of corridor width, size, and composition	high	high
Effects of buffer mgt on SW, MW, HW and VP species	high	high-moderate
Effects of buffer size on SW, MW, HW, and VP species	high	high-moderate
Effectiveness of vernal pool creation	high	moderate
Land-owner preferences in Northern forests	high	moderate
Interaction of size and mgt on SW, MW, HW, and VP spp	high	moderate
ALB, HWA, EAB other invasive pest modeling	moderate	high
Vernal pool site suitability locations within Northern forests	moderate	high
Northern forest site suitability map	high	moderate-low
Forest bird and vernal pool species habitat modeling	low	high
Canaan Valley NWR		
Distribution of rare plant communities	high	high
Cause of decline	high	moderate
Occupancy of other amphibian species	high	low
Adult movement (habitat use)	moderate	high
Impacts of beaver	moderate	high
Impacts of disease	moderate	high
Effectiveness of headstarting	moderate	low
Forest composition and structure at each pool	low	high
Effectiveness of vernal pool creation	low	moderate
Average distance between pools	low	low

Syntheses

This workshop provided an opportunity to begin understanding objectives and strategies to benefit (and potentially reduce declines) of two vernal pool obligate amphibians at three northeast NWRs. We hope that by demonstrating the unique aspects of management decisions at individual refuges, additional NWRs and National Parks can use these prototypes as a foundation to frame and solve their own vernal pool management problems. To increase utility to a range of NWRs, we explored the potential for the NWRS, as a system, to be able to address vernal pool amphibian conservation. We conducted a NWRS-wide Strengths, Weaknesses, Opportunities, and Threat Assessment, synthesized lessons learned from workshop participants, and identified key next steps may increase our capacity to effectively manage vernal pool ecosystems.

SWOT Assessment

We conducted a Strengths, Weaknesses, Opportunities and Threats (SWOT) Assessment at the end of the workshop to increase understanding of the capacity for the NWRS to address vernal pool management problems over the next 10-years. Results from such assessment can be used to inform regional and national refuge support (DNRCP and I&M). We used a round-robin approach to collect all unique responses (SM5) and identified several shared components (Table 8). Each participants was asked the following questions:

- Strengths: What does the NWRS institution have that will allow us to collectively tackle the problem of amphibian declines (vernal pool obligates)?
- Weaknesses: What does the NWRS institution lack that will prohibit us to collectively tackle the problem of amphibian declines (vernal pool obligates)?
- Opportunities: What opportunities do you foresee that the NWRS should be poised to take advantage of that are largely outside of NWRS control?
- Threats: What threats do you foresee that the NWRS should be guarding against that are largely outside of NWRS control?

In summary, key strengths of the NWRS included the fact that the agency is management-focused and has laws (refuge founding legislation and purpose, Comprehensive Conservation Plans) and policies (Habitat Management Plans and Inventory and Monitoring Plans, and Biological Integrity, Diversity, and Health) that allow refuges to implement habitat and population management actions. NWRs are also distributed across a diverse landscape and at similar spatial scales of commonly distributed vernal pool obligates in the Northeastern US, with refuges often containing one or more metapopulations within refuge boundaries. Many refuges have strong local partnerships (volunteers, NGOs, State agencies), which can help both conduct survey and explore diverse management strategies. The Northeast Region's priorities include "Aquatic Connectivity" and "At-Risk" species, which may allow refuges to priorities vernal pools management to increase hydrologic connectivity and benefit at-risk turtle populations. Additionally, the NWRS has substantial amount of data already related to vernal pool obligates (USGS and other I&M efforts) and partnerships with USGS to provide technical support (collect, store, analyze, and interpret data). Lastly, the NWRS has the ability to acquire lands, which may allow for increased habitat protection and future management opportunities. Factors that may limit refuges' abilities to conserve vernal pool obligates (weaknesses), included limited refuge-

level expertise about vernal pool habitats on refuges, competing refuge priorities (migratory birds and listed species, priority 1 habitats), an imperfect knowledge of vernal pool ecosystems on individual refuges (distribution of pools, local threats) and the relative effectiveness of various actions, and a limited ability (staff time and effectiveness) to control invasive species. Although important, many of these weaknesses may be explicitly overcome, at least in part, by developing decision support and monitoring frameworks that include uncertainty and staffing constraints, but the fact that vernal pool habitats are often not selected as a priority 1 habitat on refuges may leave refuges without adequate support to address declines of vernal pool ecosystems.

Opportunities that may be emerging over the next 10-years that NWRS could take advantage of to better support vernal pool management and conservation include the re-focusing of the I&M Initiative, increases in technologies for modeling and measuring vernal pool hydrology, increased public awareness of "Big Night" citizen science events (volunteers move amphibians across roads to reduce road mortality and increase breeding opportunities), increased awareness of NEAFWA to support vernal pool conservation (Regional Conservation Needs grant program), and increased funding to support conservation related to emerging infectious diseases (i.e., USGS), in which amphibians are very susceptible. Lastly, threats that may limit NWRS' ability to conserve vernal pool ecosystems includes non-stationarity in predicting future climate change impacts (temperatures and precipitation patterns across the system), new emerging infectious diseases, unknown budgets (national, regional, and refuge-level staffing and project dollars).

Table 8. Strengths, weaknesses, opportunities, and threats associated with the Northeast NWRS' ability to address vernal pool conservation problems over the next 10-years.

Strengths	Weaknesses	Opportunities	Threats
Management focus	Imperfect knowledge	I&M Initiative	Climate change
Landscape diversity	No silver bullet	NEAFWA & RCNs	Emerging disease
Refuge partnerships	Unknown effectiveness	"Big Night" volunteers	Limited wetland and contaminant policies
Regional priorities	Competing priorities	Hydrology Tools	Land development
Lots of data (I&M)	Invasive control	Disease Funding	Public use
Technical support	Limited staff	USGS support	Unknown budgets
NWRS Policies			
Ability to acquire land			

Lessons Learned

Lastly, we synthesized lessons learned across workshop participants (SM6) with several common themes emerging:

- management problems and objectives are challenging to develop,
- vernal pool habitats are important to consider in achieving BIDEH,
- subject matter experts (USGS) were essential partners in all parts of the process,
- actions for vernal pools may also benefit a range of species and habitats on refuges,
- conceptual models help understand how actions influence objectives,
- management can be hard because there are a lot of actions to choose from (portfolio),
- action effectiveness and environmental variability are unknown (uncertainty),

- operational constraints may limit what can be implemented (multiple-objective),
- the SDM process can help develop ROCs, HMPs, and IMPs, and
- project leaders will be essential to include when evaluating and implementing strategies.

Conclusion

The workshop was viewed as successful for many participants and key reasons for success included (SM6, SM7): there was a diverse group of participants with different expertise working together on the same general problem across multiple-refuges. The format of the workshop (mini-lectures and break-out sessions) was also a positive, allowing participants to share concerns, ideas, and solutions while also focusing on individual-refuge problems. In contrast, the workshop could be improved by conducting more pre-work before the workshop (problem statement and objectives), allowing more time for developing a monitoring framework, and reducing focus on learning SDM along the process, and potentially extending the workshop to 4 full days in order for refuges to flesh out more components in greater detail. Since this workshop was considered a "pilot" for conducting future workshops on a range of refuge management problems, it was encouraging that most participants recommended using a similar format for additional habitat types and including subject matter experts (i.e., USGS) is essential for success.

The total effort required by NWRS staff (DNRCP and refuge staff) to complete the workshop and vernal pool management prototypes for three NWRs (planning, workshop implementation, and finalized report) was approximately 60 days (0.27 FTE). Note that Rachel estimated effort for each of the following participants based on best professional judgement. Approximately 44 days (0.17 FTE) were required by DNRCP staff (Rachel = 13d, Laura E = 6d, Erin = 6d, Becky = 6d, Jeff = 4d, Nate = 4d, Troy = 3d, Austin = 1d, Dave = 1d), and 26 days (0.10 FTE) were required by refuge biologist staff (Stephanie = 6d, Sean = 5d, Dawn = 5d, and Kristen = 5d). Collectively, USGS staff spend 21 days (0.08 FTE) supporting this project to date: Evan = 5d, Adrianne = 5d, Jill = 4d, Courtney = 4d, and Brittany = 3d).

As a group, we identified a list of potential next steps (SM8). Participants volunteered to take on a few immediate needs. For example, USGS experts will continue to work with participating refuge biologists to revise their vernal pool management framework and further refine information and survey needs. Additionally, USGS will share modeling efforts and literature that support making better predictions of vernal pool hydrology and amphibian responses. The DNRCP Freshwater and Data Management Network will explore remote sensing and other survey methods for inventorying more vernal pools and their hydrologic resilience across the region. The DNRCP Freshwater, in collaboration with the Forest Network, will share our products and lessons learned from this workshop with other refuge biologists (i.e., this report, the executive summary (SM9), brown bag webinar, and the Forest Ecology Working Group). The Planning Network will continue to develop objectives and attributes for vernal pools for refuges to utilize in the development of HMPs and IMPs.

Overall, the DNRCP and refuge biologists see great potential for Northern NWRs to contribute substantially to vernal pool conservation. Although any single refuge comprises a fraction of the overall habitat for vernal pool obligates across their range, recent declines suggest that NWRs may play a critical role in maintaining sustainable populations in a fragmented landscape under

future climate change. If developed strategically, the NWRS could play a unique role in understanding which management actions are most effective in various habitats, climates, and threats, and export this knowledge to partners throughout the Northeastern U.S., potentially contributing to increasing persistence of vernal pool obligate species conservation across their range.

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Supplemental Materials

SM1. Workshop Invitation

Email sent to invited participants on 7 September 2018.

To: John <john_bourne@fws.gov>, Dawn Washington <dawn_washington@fws.gov>, Colin Osborn <colin_osborn@fws.gov>, Stephanie Koch <Stephanie_Koch@fws.gov>, "Flint, Sean" <sean_flint@fws.gov>, Evan Grant <ehgrant@usgs.gov>, Adrianne Brand <abrand@usgs.gov>, Troy Wilson <troy_wilson@fws.gov>, "Eaton, Laura" <laura_eaton@fws.gov>, Jennifer Casey <jennifer_casey@fws.gov>, "Horan, Jeff" <jeff_horan@fws.gov>, Nathan Bush <nathan_bush@fws.gov>, Erin King <erin_king@fws.gov>

You are invited to participate in a R5 NWRS 2.5-day Vernal Pool Management (Structured Decision-Making) Workshop this winter (February 2019) to be held in the Hadley, MA (RO)

The DNRCP has identified a subset of refuges (Patuxent Research NWR, Canaan Valley NWR, Great Swamp NWR, Eastern Mass NWR Complex, and Umbagog NWR) to attend this workshop in order to maximize our efficiency in learning about management actions that can be taken to benefit these ecosystems across the region. You been identified for one or more of the following reasons: 1) your NWR has documented long-term (> 5 years) occupancy declines in one or more species, 2) you contribute unique expertise in amphibian ecology and/or forest management, and/or 3) you provide a critical conservation and planning perspective that affects on-the-ground management decisions of NWRs.

Overall, the goal of this workshop is two-fold:
1) to increase understanding of vernal pool ecology and management issues among refuge and regional staff and
2) to begin developing on-the-ground management objectives and strategies for vernal pools across R5 refuges using a SDM approach.

Please **read the attached announcement for details** about the 2.5 day workshop and pre-workshop work activities (2 webinars and 1 online survey), and **indicate your interest and availability to participate** in the workshop and your concerns about vernal pool conservation on your refuge here (https://goo.gl/forms/0Rr24HYD4mUDyWMT2) by **Friday September 28, 2018.**

Feel free to call with any questions or concerns. We look forward to hearing from you!
-Rachel, Laura, and Troy

Summary:

In 2004, the Northeast Amphibian Research Monitoring Initiative (NE ARMI) received funding from the National Park Service's Park-Oriented Biological Support, and combined these monies with ARMI funds to initiate a region-wide study on the distribution of vernal pools and estimate the proportion of pools that were occupied by pool-associated amphibians (wood frogs, *Rana sylvatica*, and spotted salamanders, *Ambystoma maculatum*). These results were previously discussed, and a publication in 2008 outlined the estimation procedure and results. A paper by Adams et al (2013) analyzed data from the Northeast sites as well as sites in the midwest and west and concluded that overall occupancy by amphibians declined 3.7% annually.

Five National Parks, 12 National Wildlife Refuges, and 1 State Park have participated in this study in the Northeast. Funding since 2006 has come from ARMI and FWS Region 5 to continue monitoring at sites identified in 2004-05. Results from the 2017 analysis of NWRs showed no substantial declines in occupancy at the regional-level, although there was a shallow downward trend in occupancy of both species. However, 4 refuges showed occupancy declines, 7 showed stable trends and 3 showed increasing trends in at least one species (Table 1).

Table 1. Results from NEARMI occupancy monitoring indicating increasing (+), decreasing (-), or stable (x) trends (or never detected, nd) in wood frogs (RSYL) and spotted salamanders (AMAC) at each NWR based on the sampling period. NWR with asterisks are strongly encouraged to attend the SDM workshop.

R5 NWR	Total Years	Sampling	RSYL	AMAC
Canaan Valley NWR*	13	2004-2016	-	-
Patuxent NWR*	13	2004-2016	-	-
Great Swamp NWR*	13	2004-2016	x	nd
Wallkill NWR	10	2004-2016	x	x
Erie NWR	12	2004-2016	-	-
Iroquois NWR	13	2004-2016	x	nd
Eastern Mass - Assabet NWR*	13	2004-2016	-	-
Eastern Mass - Oxbow NWR	3	2014-2016	x	x
Rachel Carson NWR	13	2004-2016	+	+
Umbagog NWR*	4	2013-2016	x	+
Moosehorn NWR	10	2004-2016	x	x
Aroostook NWR	4	2013-2016	x	+
Eastern VA River	1	2018-X	?	?

Although regional trend assessments are useful for detecting potential problems, the mechanisms of vernal pool amphibian decline can be the result of complex abiotic and biotic interactions that requires **site-specific assessments of threats and development of management strategies**. Some threats may include direct road mortality, direct loss of habitat, population fragmentation, disease, contaminants (roadside salt, mercury, pesticides, oil runoff, nutrients/algal blooms), reduced forest overstory, and frequency, severity, and duration of extreme climate events (droughts and floods). Specifically, many northeastern and mid-atlantic refuges experienced drought in the spring of 2016, with ten NWRs monitoring vernal pools reporting low water levels or completely dried pools, reducing amphibian productivity (reproductive success). Additionally, one refuge reported that 4 vernal pools were washed out by flood events.

By using a structured process, we aim to provide clarity to refuges about *if, what, and where management should occur* to improve and mitigate declines of vernal pool amphibians. A structured process (SDM/PrOACT) includes 1) defining the decision Problem, 2) identifying and structuring stakeholder Objectives, 3) developing a set of management Alternatives, 4) evaluating the Consequences of alternatives relative to objectives (usually via modeling), and 5) selecting an optimal decision action given potential Trade-offs.

Workshop Goals:

The goals* of this 2.5-day SDM workshop are to:

1. Increase understanding of refuge-specific trends (declines or increases) in vernal pool amphibian populations by sharing insights among refuge and regional biologists and species experts (outcome: problem framing for each refuge, conceptual model with list of threats)
2. Develop SMART management objectives and measures of success that can be integrated into refuge plans (i.e., CCPs and HMPs) (outcome: draft objectives and metrics)
3. Brainstorm a range of potential management strategies for each refuge (outcome: list of strategies by refuge)
4. Outline potential constraints in implementing various strategies and predict consequences (outcome: trade-offs analysis)
5. Identify key uncertainties or data-gaps that are critical to inform decisions that can be used to improve the NEARMI monitoring program (outcome: ranked list of monitoring and research needs for future projects)
6. Clarify roles and responsibilities for regional staff and refuges for supporting vernal pool conservation efforts on NWRs (outcome: updated 2019 Aquatic Ecosystem Network Plan)

*While we will likely not get to all of these goals in great detail in 2.5 days, we plan to at least get a working draft of most of them and will follow up with participants on highest priority items as needed.

Proposed Timeline (dates may change):

Week of November X 2018 - Webinar 1 (1.5 hr)

- Overview - what are we trying to do? why now?
- Summary results from USGS/NEARMI monitoring program
- Demonstrate results via AGOL maps
- Discussion about results/findings
-

Week of December/January X, 2018 - Pre-workshop Survey (30-min)

- Complete pre-workshop refuge-specific survey (objectives, strategies, uncertainties/knowledge gaps)

Week of January X, 2018 - Webinar 2 (1.5 hr)

- SDM overview, results from survey, workshop roles and expectations

Monday, February X, 2018 - Travel day

Tuesday, February X, 2018 - Day 1

Time	**Topic**	**Outcome**
0800-0900	Welcome and SDM Overview	
0900-1000	Problem Framing	Problem Statement
1000-1200	Identify Objectives	Objective Hierarchy
1200-1300	Lunch	
1300-1500	Link Threats to Objectives	Conceptual Model
1500-1700	Develop Actions/Strategies	Mgt Alternatives List

Wednesday, February X, 2018 - Day 2

Time	**Topic**	**Outcome**
0800-0900	Insights/Review	
0900-1100	Revise Strategies	Mgt Alternatives List
1100-1200	Predict Consequences	Consequence Table/BBN
1200-1300	Lunch	
1300-1500	Trade-offs Analysis	Refuge SDM Tool
1500-1700	Information Gaps	I&M Needs

Thursday, February X, 2018 - Present Tools and Travel Day

Time	**Topic**	**Outcome**
0900-1030	Present Prototype SDM Tool	Lessons Learned
1030-1200	Next Steps	Action Items
1200	End Workshop	

SM2. Pre-Workshop Webinar Notes

The presentation used for the pre-workshop webinar (SM2_VernalPoolSDMWorkshop_PreWorkshopWebinar_20191214.pptx) can be found on https://ecos.fws.gov/ServCat/Reference/Profile/110606.

Pre-workshop conference call agenda and meeting notes.
The call was on December 14, 2018 2:00-3:30pm.

Attendees: USFWS: Rachel Katz (regional biometrician), Erin King (regional data manager), Laura Eaton (assistant regional biologist), Becky Longenecker (regional wildlife biologist), Jeff Horan (Regional forest ecologist), Sandy Spencer (biologist Patuxent), Sean Flint (biologist Umbagog), Stephanie Koch (biologist E. Mass. Complex), Dawn Washington (biologist Canaan Valley).

USGS-NEARMI: Brittany Moser (post doc), Jill Fleming (biologist) Courtney Davis (PhD student, Penn State, climate change and vernal pools), Evan Grant (PI), Adrianne Brand (biologist/data manager)

(Will be present at the workshop but not available today- USFWS: Troy Wilson (regional I&M coordinator), Tom LaPointe (Forester Umbagog and LMRD), Nate Bush (regional GIS/data manager))

Agenda:

1) Introductions
2) Overview of SDM
3) USGS vernal pool synthesis and insights
4) Survey results and workshop dates
5) Workshop format and roles
6) Refuge-specific management concerns (~10 min per refuge)
7) Next steps: problem statements

Why are you interested in this workshop?

Stephanie Koch - E. Mass. Complex-have a lot of pools that have been monitoring for a lot of years. Gearing up for HMP and have a lot of questions about impacts of disease and climate change.
Sean Flint - Umbagog-interested in how forest management is affecting vernal pools
Sandy Spencer - Patuxent- been mapping vernal pools -about 249 on the North Tract. USGS has come up with interesting results regarding disease issues at Patuxent.
Dawn Washington - Canaan Valley-concerned about climate change impacts and diseases, and how management impacts pools, and how habitat changing around pools is affecting them. Ultimately, how do we protect/conserve the vernal pools?

USGS Synthesis and Insights (Evan Grant)

- Started monitoring 2004

- Started with a mapping effort- looked at random locations- so can now estimate the number of vernal pools on a refuge. Been tracking about 500 northeast pools since 2005.
- Focused on breeding effort of wood frog and spotted salamanders (egg mass counts)
- Added productivity later-hatching of egg masses
- In the south, see declines. In the north tend to see stable and increasing. But individual refuges are all over the place
- Occupancy has been 30-80%
- Across the US, amphibians are declining by about 3-5% annually
- Calling frog surveys in the northeast also showed a decline of 3-5%
- Stressors: Contaminants, disease, climate change and changes in hydroperiod

Jeff Horan - Suggestion: May want to develop objective hierarchies in advance of workshop- maybe a webinar- because really eats time during workshops.

Dates of the SDM workshop changed to February 5,6,7 2019 (T-Th)

Refuge-Management Concerns

1. *What is the biggest problem facing your vernal pools from a conservation perspective?*

   Sandy - Don't know the biggest problem, but disease threats appear significant and can affect wood frogs and box turtles.

   Dawn - Climate change is the biggest concern (and disease). In 5 years, have seen warming in February, which has caused eggs to be laid early and refreezing then reduces egg masses (higher mortality)

   Sean - Umbagog was late getting into the regional USGS monitoring effort (started around 2014). In 2017, they hit the 30 pool minimum. Didn't do monitoring last year because put effort into wood turtles. We need more inventorying of pools to help with forest management. We are assuming that the Ecological Forestry methods used at Umbagog are of benefit to the pools but would like to verify.

   Steph - Climate change and disease are biggest problems. Both chytrid and ranavirus have been detected. What should we be doing to minimize the spread of disease? Hard to get everyone on board with decontamination protocols. Also, seeing bigger fluctuations in water levels and temperatures. Changes in beavers at Assabet and now there is more flooding.

2. *Are vernal pools explicitly identified in your CCP or HMP as high priority habitats?*

   Sandy - Do have a detailed CCP and it references vernal pools in the forest habitat objective.

   Dawn - Vernal pools are listed under Herbaceous and Shrub Wetland habitat type in the HMP. No specific species are listed. Goal 1 includes a biodiversity objective for wetlands (is this BIDEH?).

   Sean - It may be designated as "critical habitat" in HMP?

   Steph - Vernal pools are barely mentioned in the CCP, only mention is for monitoring. Working on HMP soon and want this process to inform habitat priorities and objectives.

3. *What species (if any) are of particular management concern? Why?*

   Sandy - Wood frogs and box turtles (have detected ranavirus in turtles near the refuge). Don't know if box turtles on refuge have ranavirus. Have sampled 400 individual turtles and no external evidence of ranavirus, but did not take swabs.

Dawn - No specific species, more of a biodiversity objective, but seen declines in wood frog and spotted salamanders.

Sean - Only monitoring spotted salamanders. Probably have blue spotted salamanders as well. Could be others that they should think about. Vernal pools may be used for foraging habitat for wood turtles.

Steph - Wood frogs and spotted salamanders, as they are vernal pool obligates and have good information because of the past monitoring. Also interested in if/how spotted and Blanding's turtles use or benefit from vernal pools, as they may be important foraging habitat for turtles.

4. What types of actions (management, not monitoring) could your refuge consider taking over the next 15 years to benefit vernal pool habitats and critters?

Sandy - Would be interest in what actions others have taken to address disease threats.

Dawn - Plant vegetation around pools (i.e., buffer) to decrease temperature of pools, pools are in open habitats. Would do most plantings by hand. May also need to manage invasive plants (no knowledge of invasives in/near pools yet, but it is likely to come).

Sean - Potential change forest management activities. Evaluate effectiveness of buffers. Change to only hand harvesting adjacent to pools, leave coarse/downed wood during harvest activities.

Steph - Consider changing decontamination policies and implementation rates, also hoping to gain some ideas on actions that can take from the workshop.

5. Are there any legal constraints on what can or cannot be done?

Sandy - None identified.

Dawn - None identified.

Sean - None identified.

Steph - MA has some of the strictest wetland protection laws in the US that will need to be considered.

Additional Questions:

Rachel - Are box turtles and wood frogs specifically addressed in CCP. Sandy- Used as an example in the objective"*…such as for wood frogs and box turtles"*.

Rachel - Do you have good temperature data for pools at Canaan? Dawn- yes, it is part of protocol.

Rachel - Have you specified how to measure biodiversity? Dawn- We want to develop a biodiversity index for wetlands. The Nature Conservancy has a template. Need a way to measure changes. Considering including invertebrate species.

Sandy - We may need to consider other stressors such as road salt and road mortality.

Laura - were any conclusions drawn from the contaminants work that was conducted?

Evan - Looked at endocrine disrupting compounds- metals and pesticides. Insecticides and total contaminants increased the amount of ranavirus. May have direct effect on survival and secondary effect on disease.

Rachel - Building conceptual models can help work out all the various pathways in which actions may affect vernal pools and link actions to outcomes (i.e. results chains).

Homework: Each refuge should develop a problem statement. Rachel has a template that will be sent out. Will consist of 1-2 paragraphs (4-6 sentences max) that address each component of the problem.

SM3. Participant List

Table SM3. Workshop participants with affiliation, email, primary refuge team, and role. Affiliations are assumed to be USFWS and NWRS, unless otherwise noted as USGS's Northeast Amphibian Research and Monitoring Initiative (NEAMRI).

Name	Affiliation / Position	Email	Refuge Team	Role
Rachel Katz	Regional Biometrician	rachel_katz@fws.gov	All	Lead Facilitator
Dawn Washington	Refuge Biologist	dawn_washington@fws.gov	Canaan Valley	Refuge Mgmt
Kristin Lantz	Refuge Intern	kristin_lantz@fws.gov	Canaan Valley	Field Support
Erin King	Regional Data Manager	erin_king@fws.gov	Canaan Valley	Facilitator
Adrianne Brand	USGS NEARMI	abrand@usgs.gov	Canaan Valley	Amphibian Expert
Jeff Horan	Regional Ecologist	jeff_horan@fws.gov	Canaan Valley	Vegetation Expert
Country Davis	USGS NEARMI	cld303@psu.edu	Canaan Valley	Hydrology Expert
Stephanie Koch	Refuge Biologist	Stephanie_Koch@fws.gov	Eastern Mass	Refuge Mgmt
Rebecca Longenecker	Regional Biologist	rebecca_longenecker@fws.gov	Eastern Mass	Facilitator
Jill Fleming	USGS NEARMI	jefleming@usgs.gov	Eastern Mass	Amphibian Expert
Laura Eaton	Regional Biologist	laura_eaton@fws.gov	Eastern Mass	Aquatics Expert
Britney Mosher	USGS NEARMI	bmosher@usgs.gov	Eastern Mass	Amphibian Expert
Dave Zimmerman	Regional Data Manager	david_zimmermann@fws.gov	Eastern Mass	Observer
Sean Flint	Refuge Biologist	sean_flint@fws.gov	Umbagog	Refuge Mgmt
Troy Wilson	Regional I&M Coordinator	troy_wilson@fws.gov	Umbagog	I&M / Facilitator
Evan Grant	USGS NEARMI	ehgrant@usgs.gov	Umbagog	Amphibian Expert / Facilitator
Nathan Bush	Regional GIS Specialist	nathan_bush@fws.gov	Umbagog	Vegetation Expert
Austin Rizzo	Regional Planner	austin_rizzo@fws.gov	Umbagog	Observer

SM4. Workshop Materials

SM4.A – SM4A_VernalPoolSDMWorkshop_MiniLectures_201902.pptx
PowerPoint presentation that includes a series of mini-lectures (10-20 minutes) that was given before the refuge-specific breakout groups. Presentations introduced the key concepts and how to fill out the template for each topic.

SM4.B – SM4B_VernalPoolSDMWorkshop_RefugeTemplate_201902.pptx
PowerPoint template provided to reach refuge to work through each step of the process during the workshop.

SM4.C – SM4C_EasternMassNWRComplex_WorkshopMaterials_201902.zip
All workshop materials pulled down off of the google drive for Eastern Mass NWR Complex.

SM4.D – SM4D_UmbagogNWR_WorkshopMaterials_201902.zip
All workshop materials pulled down off of the google drive for Umbagog NWR.

SM4.E – SM4E_CanaanValleyNWR_WorkshopMaterials_201902.zip
All workshop materials pulled down off of the google drive for Canaan Valley NWR.

SM4.F– SM4F_VernalPoolSDMWorkshop_PreWorkshopWebinar_20191204.pptx
PowerPoint presentation that includes a series of mini-lectures (10-20 minutes) that was given before the refuge-specific breakout groups. Presentations introduced the key concepts and how to fill out the template for each topic.

SM5. SWOT Assessment

Each workshop participant individually listed strengths, weaknesses, opportunities, and threats to vernal pool conservation on Northeastern NWRS over the next 10-years. We used a round-robin approach to elicit responses and recorded all unique elements from all participants.

Strengths
What does the NWRS institution have that will allow us to collectively tackle the problem of amphibian declines (vernal pool obligates)?

- NWRS is protected land (land acquisition tool)
- Ability to acquire land and management it as we see fit
- Network of partners to help support us and off refuge
- Ability and willingness try actions
- Distribution of NWRS across species ranges (e.g., climate change)
    - Different treatments across broad landscape types and context/settings
- Local knowledge and expertise (NWRS good job of sharing)
- Refuge maintenance capacity (low cost, expertise)
- Total land area (try new actions, broad applicability, finding winning actions can make a national difference)
- Lots of pools/populations available can speed up rate of learning
- Lots of data (already)
- Already have monitoring programs going on in many refuges
- I&M focus on aquatic connectivity and hydrology (support right now for issue involving water)
- Overlap with at-risk species (turtles) - a FWS regional priority
- Access to scientific expertise (i.e., USGS)
- SDM and planning infrastructure (HMP/IMP) support - ability to create monitoring/analysis/planning frameworks to support multiple refuges
- Interest and excitement about protecting these habitats/obligates
- Policy (BIDEH and LMRD) allows latitude to try and learn from actions (refuge-specific autonomy for decision-making)

Weaknesses
What does the NWRS institution lack that will prohibit us to collectively tackle the problem of amphibian declines (vernal pool obligates)?

- Existing data are scattered (poor data management and availability), may not answer the questions we need answered
- Don't have perfect knowledge (and precision) about the current system state, predictions of what will happen, what is most important to decision-making (at each refuge)
- Almost all refuges have obligates selected as ROC's or in HMPs (only 1 refuge = RI has Wood Frogs at an ROC)
- Competing objectives and priorities (need coordination among biological staff, maintenance staff, VS staff) - priority for the refuge (needs to be a priority from SLT so that PL's have that direction/on board)
- Competing priorities with other species and habitats
- Push to increase public use may conflict with protection/threats to VPs

- VPs are unique/variable (land use, contaminants, context, habitat, hydrology) - there isn't a one-size fits all solution
- Each refuge has specific historical management/priority context
- Limited ability to act outside refuges
- Confusion in wetland regulation and permitting (lack of access to a solicitor, diverse opinions, supreme court regulations are still being debated/clarified)
- 75 refuges, but limited staff at each refuge (only 35 staffed refuges)
- Lots of institutional hierarchies to maintain momentum/excitement/support
- DNRCP communication system may be inefficient/outdated with the field
- Balancing meeting objectives vs. learning is not clear
- Perception that learning takes a lot of resources (time and money) and with limited budgets this is difficult
- Limited actions and understanding of threats (disease)
- Lack of knowledge by biologists of vernal pool species and outcomes
- Limited ability to control/manage invasive and introduced (non-native competitors) species

Opportunity (external to NWRS)
What opportunities do you foresee that the NWRS should be poised to take advantage of that are largely outside of NWRS control?

- USGS has capacity to help refuge problems (can justify with a specific ask w/ names and items)
- NSF funding for Long term ecological research projects or urban projects with agency support
- People feeling helpless in the world (conservation crisis), so volunteers may be useful
- New quantitative methods to link data types
- Climate change - tide of public opinion is acknowledging this is a problem, young people are realizing they could/should do something
- Amphibian and Reptile Committee is in NEAFWA (big deal), also have some regional funding (RNC)
- Provide a template for VPs to regenerate, then States and PARC may re-engage/support
- Still an interest in amphibians b/c of global disease interest, may leverage this to do habitat mgt
- Better data collection/estimation tools (data loggers/hydrologic models, soil modeling more refined, finer spatial scales)
- Tools to do comprehensive mapping for vernal pools (and easy to implement with volunteers)
- Partners (FS - they are creating vernal pools), TNC, States) could be involved more in the process/expertise/actions/funding
- I&M push for IMPs may allow us to consider amphibians more explicitly in objective-setting
- Monitoring network in place provides an opportunity to learn from changes/actions
- People love "Big Night"
- I&M ability to adjust monitoring programs as needs change
- CRISPR?

Threats (external to NWRS)
What threats do you foresee that the NWRS should be guarding against that are largely outside of NWRS control?

- Unknown/uncertain budgets
- Limited staff/budgets
- Climate change and uncertainty
- Emerging diseases
- Public support/understanding for the USFWS/mission
- Erosion of legal protection for wetlands
- Push for different types of public land uses
- Population growth and land use conversion off-refuge (landscape context) - development
- New/unknown invasive and introduced (non-native competitors) species
- Limited and variable contaminant regulations (mercury)
- Reduced water availability, changes in hydrology (increase human use/need)
- Amphibian biology/life history constraints
- Water quality, nutrient, sedimentation off-refuges influencing refuge lands (various land use types)

SM6. Lessons Learned

Each workshop participant individually listed lessons learned over the 2.5 day workshop. We used a round-robin approach to elicit responses and recorded all unique elements from all participants.

- Subject matter expertise were essential
- Actions may not negatively influence/harm BIDEH
- Need more research on effects of actions
- UMB: Vernal pools/site suitability = may benefit both VP obligates and confir objectives
- Common themes among refuges - building in hydrology resilience
- SS/WF appear are important ROCs, but they aren't showing up in refuge plans (CCP/HMP/IMPs) and refuge bio assessment - why?
- Community of practice for management actions (share knowledge of if/how actions are implemented/useful) - management action list/effectiveness and update
- Objectives are hard
- Classification of problems (why is this hard) was useful
- Conceptual models were useful for seeing how actions affect objectives
- BIDEH is hard to interpret (attributes)
- Many more actions in/near pools than we thought (more actions than we thought) - actions brainstorming was useful
- Rich conversations in our groups
- More context (spatial) was needed/lacking (i.e., map of wetlands)
- More information about major drivers of decline
- Sometimes uncertainty doesn't matter (the conceptual models can help with this)
- Conceptual models help clarify factors influencing abundance/occupancy are different.
- SDM is straight forward, yet painful (good pain), provides sound reasoning for taking actions.
- This process will help with HMP.
- Sometimes hard to think about objectives without PL's there (i.e., cost, road closures).
- Pre-work may be more helpful (get caught up on refuge issues)

SM7. Post-Workshop Survey

After the workshop, we created a post-workshop survey to evaluate success and identify elements to change in subsequent workshops. Five workshop participants provided feedback on multiple questions, but we are only providing response to three questions below.

What was one thing you liked about the workshop?

- Hard to pick just one! Was great to have so many people focused on one topic together.
- That there was different expertise and point of views all working on the same general problem. The reflection at the end of the workshop helped to bring everything together, and hopefully motivate further progress after the workshop.
- I liked the format of brief lecture, then returning to group to discuss
- It was well thought out and I was able to participate via phone.
- My limited experience with SDM has involved working through a stand alone site specific issue. I found it beneficial that the workshop simultaneously addressed three related problems. The collective discussions that took place throughout the workshop brought to light ideas, concerns, and solutions encountered while working through individual refuge problems.

What was one thing you would have like to change about the workshop?

- The refuge I was facilitating kept wanting to talk about monitoring, but we never got there. I think that was OK (they got a lot out of the management action discussion), but I wished we could have had time to at least talk about monitoring a bit.
- There wasn't much that could have been done about this with the shutdown, but it would have been nice to have each refuge sit down with their team prior to coming to the workshop to outline problem statement and objectives. That could have saved us a bit of time at the start of the workshop and allowed us to work through another full round of the SDM wheel.
- Wish I could have been there in person.
- I found that the SDM terminology often complicated the SDM process. The process often felt rushed and the SDM terminology added complexity to the process. Making the workshop less about learning SDM and more about fluently facilitating the SDM process would allow for more time and energy to address the problems.
- Increase to maybe 3 or 4 full days?

Would you recommend a similarly structured 2.5 day workshop to other refuge biologists focused on other priority habitat types? (constructed scale: 1 = absolutely not, 5 = yes, definitely).

- All five responses included "5 – yes, definitely".

SM8. Next Steps

Next steps were brainstormed by participants individually and shared with the group. Then, participants volunteered to lead specific tasks (bold) with the support of additional team members.

We may know more about drivers of decline than we realize - this should be synthesized (i.e., clear cutting at CAN). Synthesize of Refuge-specific hypothesized drivers of declines - **Evan**

EMC:

- Refining BBN/parameters (**NEARMI**)
- 1 day follow-up **Steph (Adrianne, Evan, Jill)**
- Upload Netica file/screenshot to google drive - **Rachel**

CAV:

- Identify plant expert (actions and strategies)
- Ask Dawn what is missing and determine the priority of VP to assess if actions are feasible
- 1 day follow-up **Adrianne (Dawn, Kristen)**

UMB/CAV: species inventory on pools

- 1 day follow-up with experimental design **Sean (Evan, Tom/Jeff)**

PWR:

- Update Sandy with our efforts - **Rachel**

Multi-refuge:

- Inventory/mapping of vernal pools on each refuge **Laura (Dave, Nate, Sean F)**
- NALCC Vernal Pool Maps
- Hydrologic resiliency and relation to soils
- Hydrology and geomorphology expertise (Fred's term)
- WRIA's are not enough
- Use WRIA foundation to add assessing hydro resiliency/soils (aquatic network team)
- Evaluate utility of inventory to decision-making for each refuge
- Explore "hydrologic resilience" and what it means for each refuge

DNRCP:

- Ensure USGS protocol is in Servcat/PRIMR
- I&M Protocol Framework could help evaluate action effectiveness
- Vernal pool obligate workshop/webinar/discussion?
- Community of Practice
    - Compiling Resources (refworks, bibliography) - **Becky**
- Workshop report - **Rachel (Evan, Troy, Steph, Laura)**
- Share insights/lesson learned/knowledge sharing (VPs/SDM) -
    - state of VP knowledge in the NE - **Evan Brown Bag**
    - forestry working group webinar - **Jeff (Evan)**
- Using SDM to build HMPs and objectives (Jennifer/Meghan) - **Rachel (Erin, Steph)**

NEARMI:

- What data are missing? Assess how to reduce key uncertainties via data collection
- Literature review and USGS data dump (compile) (parm models and conceptual models)
    - Interface between hydrology and wetland amphibian breeding ecology paper/synthesis/lit review - **Courtney**

SM9. Executive Summary

See R5DNRCP_VernalPoolSDMWorkshopExecutiveSummary_02292019.pdf on https://ecos.fws.gov/ServCat/Reference/Profile/110606