Developing Core Indicators for Assessing Wetlands in Utah

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March 2017
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Utah Department of Natural Resources
Salt Lake City, UT
A contract deliverable for the U.S. Environmental Protection Agency Regional Enhancing State and Tribal Programs Funding X7-96820201

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Cover: Clockwise from top left: Mule deer in seasonally flooded wetland near the Jordan River, boreal chorus frog in montane meadow, and white pelican in impounded wetland adjacent to Great Salt Lake.

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Abstract

The Utah Geological Survey's (UGS) Wetland Section received funding from the U.S. Environmental Protection Agency to develop a set of core indicators for assessing wetland function that could be used across organizations in Utah, leading to an increase in the amount of uniform wetland data. The UGS surveyed stakeholders in Utah's wetlands to rank wetland functions by importance, conducted working group meetings to develop indicators, field tested wildlife habitat indicators, and disseminated results through a wrap-up meeting and email to stakeholders. Survey results indicated that stakeholders were most interested in assessing wetland habitat, which became the focus of most this project.

Participants at the first working group meeting concluded that a simple checklist of indicators was the best rapid method for assessing wetland wildlife habitat potential because it would be more repeatable between observers and easier to justify measures. The UGS compiled a list of potential indicators from existing assessment protocols and asked wildlife specialists to rate each indicator for its importance to taxa of interest (e.g., wading birds, amphibians). The list of indicators was refined at a second working group meeting, through meetings with wildlife specialists, and through literature review. Two teams of working group members tested a draft field form at two sites to compare inter-observer variability and ease of use of the form. The groups agreed on 75% of indicators at a marsh site and 81% at a meadow site. Areas that could use improvement include clarifying language on some of the indicators and helping surveyors obtain background information before surveying sites.

We have made substantial progress towards the development of a final protocol for the core indicators, but additional work is needed in three key areas before the indicators can be broadly adopted across the state. First, additional field testing should be conducted with the indicators at more sites and with more teams of observers to determine the degree to which site scores are subject to observer variability. Such testing will make it easier to recommend the tool for regulatory purposes. Second, an overall scoring index should be developed to allow for comparison across an array of wetland sites and within wetland types. Third, the UGS should develop a workflow and tools to assist surveyors with gathering preliminary site data before surveys are conducted. The UGS currently has funding to achieve the first goal and recently applied for funding to help with the third goal.

This project accomplished its goals of increasing collaboration between Utah agencies, developing a template for creating core indicators, and improving the Wetland Section's ability to meet monitoring needs for the state's stakeholders. A total of 67 individuals participated in this project and, over the course of this project, the active wetland working group grew from just over 70 to 110 participants. Other outcomes of this project include a compilation of information on existing wetland and riparian protocols in use in Utah, better understanding of potential uses of functional indicators, and better understanding of the ability of Utah's wetland stakeholders to collect, share, and use assessment data.

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Introduction

The Utah Geological Survey's Wetland Section conducted a survey of stakeholders in December 2014 to evaluate the need for wetland monitoring and assessment data and protocols currently in use. Over 90% of the respondents indicated a need for this type of data; the most commonly indicated needs included evaluating results of restoration, summarizing wetland information in a study area, identifying restoration and preservation targets, and evaluating change over time (table A1, appendix A). Many protocol attributes were important to stakeholders, including that it was standardized across the state or region and included information on wetland condition, function, and habitat provisioning (table A2, appendix A). The Wetland Section began compiling a list of protocols that can or have been used for monitoring wetlands and riparian areas in the state; the list currently includes over 40 methods.

The Wetland Section applied for the Environmental Protection Agency's Enhancing State and Tribal Programs Funding grant in 2015 to work on developing a standardized list of core indicators for assessing wetlands in Utah. Collection of core indicators will greatly increase the amount of standardized data available on wetland condition and function statewide and will provide a well-supported and broadly agreed upon list of indicators for any group interested in conducting monitoring. We focused on development of functional core indicators since there was a clear interest in assessment of wetland function (including habitat) based on the December 2014 survey and other stakeholder feedback. This report provides a summary of the process used and the progress made towards development of statewide core indicators.

Project Participants

This project was led by Diane Menuz, the State Wetlands Coordinator at UGS. Ryhan Sempler, Wetlands Specialist with UGS, attended all meetings and helped review material before it was shared with other project participants. Potential stakeholders to Utah's wetlands were surveyed in December 2014 to gauge their level of interest in participation in a statewide Wetland Working Group. Those contacted included individuals who attended the Region 8 Wetland Program Development Workshop in Salt Lake City in 2013, individuals with a history of collaborating with the Wetland Section, individuals identified through searches at relevant organizations within state, federal, and tribal governments, and individuals recommended by other stakeholders. The survey was sent to 130 people and 86 responded. Respondents who indicated interest in receiving email updates or actively participating in the Wetland Working Group received emails about the core indicator project.

The exact number of people contacted throughout the project fluctuated because some people asked to be added to the email list while others asked to be removed. Over the course of the project (18 months), the Wetland Working Group grew from just over 70 people to 110 participants. Sixty-seven people contributed in some capacity to this project from the initial project introduction to the final wrap-up meeting. Thirteen people (including Diane and Ryhan) participated in at least three project components. These frequent participants included individuals associated with the UGS, Utah Division of Water Quality (DWQ), U.S. Bureau of Land Management (BLM), U.S. Army Corps of Engineers (USACE), Utah Department of Agriculture and Food (UDAF), and the Utah Division of Wildlife Resources (UDWR). A list of project participants is available in appendix B.

Timeline

- October 20, 2015: Introduced project at Wetland Working Group meeting (27 participants)
- February 1, 2016: Sent survey on functions and interest in participation (86 recipients; 21 respondents).
- March 2, 2016: Held first core indicator meeting (13 participants).
- March 25, 2016: Emailed wildlife indicator checklist to working group (89 recipients).
- June 10, 2016: Emailed regional UDWR regional native aquatic ecologists to solicit more feedback on amphibian habitat needs (9 recipients).
- July 14, 2016: Emailed Wetland Working Group (94 recipients) and key individuals to solicit more feedback on aquatic mollusk (1 recipient) and bird habitat needs (7 recipients) and set up second meeting.
- August 31, 2016: Held second core indicator meeting (11 participants).
- September 1, 2016: Emailed meeting summary and requested more feedback on indicators (95 recipients).
- September 15, 2016: Met with Ella Sorensen (National Audubon Society) to discuss shorebird indicators; emailed Becka Downard (DWQ) to discuss her knowledge of Great Salt Lake birds (based on extensive interviews she conducted with Great Salt Lake land managers).
- September 21, 2016: Conducted field test of current indicators (8 participants).
- October 20, 2016: Gave talk at Water Quality Task Force meeting to discuss water quality indicator checklist and solicit feedback.
- December 1, 2016: Met with Great Salt Lake avian specialists to discuss habitat needs (9 participants).
- March 8, 2017: Held wrap-up meeting in conjunction with Wetland Working Group meeting (28 participants).

Summary of Activities

Project Introduction

The core indicator project was introduced to the Wetland Working Group at a meeting on October 20, 2015. This meeting also included a presentation on the background of the UGS Wetland Section, results of the December 2014 survey, and a discussion of the next steps.

Stakeholder Survey

Diane sent a survey on February 1, 2016 to 86 individuals previously involved in the Utah Wetland Working Group to rate wetland functions in terms of perceived importance as well as level of interest in helping develop indicators for each function. Respondents were asked to rate the following wetland functions based on the perceived importance and their level of interest in participation: wildlife habitat, groundwater recharge or discharge, nutrient removal or transformation, sediment and toxicant retention, floodwater storage and floodflow alteration, fish habitat, shoreline and sediment stabilization, uniqueness/rarity, recreational and education opportunities. Diane received responses from 21 individuals, including affiliates from federal and state agencies, universities, non-profit groups,

and private consultants. Wildlife habitat was ranked as the highest priority and had the most people likely to participate in development (tables C1 and C2, appendix C).

First Core Indicator Meeting

The first working group meeting for this project was held March 2, 2016 and included 12 participants, including individuals from Utah State University (USU), UDWR, the BLM, Utah Department of Natural Resources (UDNR), UGS, and private consultants. The goal of the meeting was to come up with a recommended format for collecting habitat core indicator data. Diane presented examples of habitat protocols used by other states to lead the discussion. The consensus of the group was the following:

- Simple methods are preferred over more complex methods, both to increase repeatability between observers and because there is a lack of information to validate more complex methods.
- Consider a two-tiered approach that may allow for more intensive data when needed for specific projects.
- Collect data on whether sites have potential habitat regardless of actual level of wildlife use. Wildlife use is difficult to determine, often seasonally dependent, and requires a lot of effort. Furthermore, unoccupied sites could be used for reintroduction or may become colonized through time.
- Despite issues with detecting species, there was interest in at least writing down species seen to help supplement other information, such as tadpoles, beaver ponds, bullfrogs, etc. This could be used to refine data for specific purposes (e.g., is it worth trying to do a reintroduction somewhere where you saw bullfrogs?). Absence data should not be assumed to indicate a true species absence.

Wildlife Indicator Checklist Development

Diane prepared a list of potential wildlife habitat indicators based on a brief literature review (appendix D) and sent the list to stakeholders to request feedback on the repeatability of each measure (i.e., do you think you could reliably evaluate this?) and the utility of each measure for specific taxa (i.e., is this indicator important for species in this group?). The list of indicators was sent to 89 stakeholders in the Wetland Working Group on March 25, 2016. Focal taxa included raptors, migratory songbirds, sage grouse, waterfowl, shorebirds, wading birds, muskrats, beaver, small mammals, aquatic mollusks, and amphibians.

Unfortunately, the rate of response was low. Diane sent the checklist to the entire stakeholder group on two additional occasions and to individuals with known expertise with certain taxa, including specialists for aquatic mollusks, amphibians, and avian species. Feedback on indicators was received from seven people for wildlife in general, five people for amphibians, three people for aquatic mollusks, two people each for songbirds, raptors, and salmonids, and one person each for sage grouse, beaver, and native wetland fishes. Native wetland fishes were added to the taxa list based on feedback from a later participant and thus was not asked about in early iterations of the checklist. Diane set up meetings with a shorebird specialist and with eight land managers with avian expertise to obtain feedback on habitat requirements for shorebirds, waterfowl, wading birds, piscivorous birds, and secretive marsh birds, using an interview format that roughly followed the list of indicators. The secretive marsh bird taxon was added based on conversations with the avian experts. Diane also received responses from

nine individuals who rated their ability to evaluate each indicator. Information on the avian field species was received after the field testing.

Second Core Indicator Meeting

The second core indicator meeting was held on August 31, 2016. Much of the meeting focused on refining the language of the wildlife habitat indicators to provide more clarity and reduce redundancies. We also discussed the benefits and costs of whole-wetland versus plot-based assessments. There was general agreement that it is important to evaluate single systems (e.g., marshes, meadows) instead of lumping all systems together, but that it is also important to think about how components may work in aggregate. Different systems may need separate checklists or at least different expected ranges of values. Groups of wetlands may need to be considered together to better understand the net benefit of a complex of wetlands. Last, there was discussion of coming up with a workflow for evaluating some of the indicators in the office before site visits.

Indicator Field Test

Diane created a field form with a list of habitat indicators divided into groups, such as landscape context and hydrology (appendix E), as well as a list of taxa, including waterfowl, shorebirds, amphibians, aquatic mollusks, raptors, salmonids, songbirds, and sage grouse. Indicators were modified or excluded based on responses from the wildlife indicator checklist survey and feedback from participants at the second core indicator meeting. Each indicator and taxon combination was only evaluated for a particular taxon if the indicator had been deemed relevant to the taxon. Relevancy to waterfowl was adapted from comments Diane received from Becka Downard, PhD candidate at USU and Wetland Specialist at DWQ, regarding what she had learned from land managers about avian habitat needs around Great Salt Lake.

Diane led field testing of the wildlife habitat indicators at the Great Salt Lake Shorelands Preserve on September 21, 2016. The participants were divided into two groups, and each group separately evaluated the same wet meadow and depressional marsh sites. The two groups then compared their findings and discussed discrepancies. The following is a summary of the findings of the field comparison:

- The groups tested 32 indicators, excluding those related to species' observations. Of these, the two groups agreed 100% of the time (or selected not applicable) for 26 indicators at the meadow site and 24 at the marsh site; the groups agreed on 21 of the indicators across both site types.
- Hydrology and water quality indicators showed the most disagreement at both wetland types. Structural feature and vegetation indicators showed disagreement at the marsh site.
- Most disagreement was related to interpretation of the indicator, such as how close to a site a stream had to be or how much cover was required for a plant species to be considered present. Issues of interpretation can probably be fixed by adjusting the wording of the indicators for clarity.
- Indicators related to societal value were scored differently due to differences in user expertise regarding species likely to occur at sites.
- Some indicators were scored differently due to subjectivity and disagreement over site conditions. For example, groups disagreed on whether the marsh had *severely* altered water timing and on the

source of water to the meadow. These issues are difficult to fix because they are dependent on individual evaluation of a site.

In addition to the findings above, the following recommendations arose from the group discussion:

- Come up with a project workflow for obtaining site information before surveys, such as specific data to obtain from Google Earth and other sources.
- Address need for better data to assess societal values of species, including maps, workflow of individuals to call at regional DWR offices, and list of conservation plans and regional reports for species. May also want to create a list of wetland types per species as well.
- In some cases, it would be nice to score indicators with decimal values on a scale of 0 to 1 to indicate degree of adherence to indicator. Overall, though, it is probably better to leave the indicators as strictly binomial due to the degree of arbitrariness that would be introduced with a scale system.

Water Quality Indicators

Very few people indicated that they were likely to participate in the development of water quality functional indicators in the stakeholder survey (table B1). Therefore, Diane developed a checklist of water quality indicators from the water quality assessment protocol used for the Washington State Wetland Rating System (http://www.ecy.wa.gov/programs/sea/wetlands/ratingsystems/). This checklist was used by the Utah Geological Survey's wetland technicians in the summer of 2016 at all field sites. Diane then presented the methods and results from 2016 surveys at a meeting on October 20, 2016 for the Water Quality Task Force, a group that convenes four times per year to discuss issues related to nonpoint source pollution. The meeting was announced to the entire Wetland Working Group in case other individuals were interested in participating. The checklist presented at the meeting can be found in appendix F. Some of the discussion from the meeting included the following:

- Thresholds for some of the indicators seem arbitrary, such as using 10% for assessing run-off in surrounding area.
- Results would be more useful if they could be extrapolated to all wetlands instead of just surveyed sites so that it would be easier to identify targets for restoration.
- Unclear how indicators would relate to more quantitative measures of wetland water quality. May want to link indicators to water quality data at some point.

Wrap-Up Meeting

A wrap-up meeting for this project was held on March 8, 2017 in conjunction with a broader wetland working group meeting. Twenty-eight people participated in-person or remotely in this meeting, including individuals representing the UGS, DWQ, UDWR, USU, UDAF, BLM, USACE, U.S. National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, and non-profit organizations. Diane discussed the wildlife habitat and water quality indicator checklists, including the general structure, development process, and results of the field testing. She also presented where results could be found online and presented the next step for the project, discussed below.

Conclusions and Recommendations

The goal of this project was to develop a set of core indicators for assessing wetlands that could be used across organizations, leading to an increase in the amount of uniform wetland data available in the state. We focused on developing functional indicators for two of the top-rated functions in our February 2016 stakeholder survey: wildlife habitat and water quality improvement. We made substantial progress towards the development of a final protocol for the core indicators, but additional work is needed before the indicators can be broadly adopted. Nevertheless, this project accomplished its goals of increasing collaboration between Utah agencies, developing a template for creating core indicators for other focal targets, and improving the Wetland Section's ability to meet monitoring needs for the state's stakeholders.

Challenges Encountered

We had slightly less participation in our working group meetings than predicted based on the February stakeholder survey and less participation than hoped for on the wildlife habitat indicator checklist. We reached out to wildlife specialists individually and in small groups to solicit feedback for groups lacking information which allowed us to include important avian taxa in our checklist. Diane ended up using literature review to supplement the working group's feedback (appendix G). Current results could be improved with additional literature review, feedback from more wildlife specialists, or field validation (see discussion below).

The wildlife habitat assessment developed for this project was unique compared to other protocols we evaluated because it focuses on neither individual species nor on wildlife in general. Most wetland wildlife habitat protocols reviewed for this project focused on a wetland's ability to provide habitat for wildlife in general, often favoring complexity of features. This approach is not sufficient for Utah's wetlands because some of the state's most important wetlands for wildlife, those around Great Salt Lake, have very little heterogeneity. Focusing on individual taxa may improve our ability to properly rate Great Salt Lake's wetlands.

Accomplishments

This project accomplished its goal of increasing collaboration and communication amongst Utah's aquatic resource stakeholders and increasing participation in the Utah Geological Survey's Wetland Working Group. The Wetland Working Group has been a good forum for informing stakeholders about on-going wetland projects, learning about needs that are not yet met, and increasing efficiencies between organizations. Over the course of this project, the active working group has grown from just over 70 people to 110 participants. These participants represent a broad range of state and federal agencies, non-profit organizations, consulting companies, and institutions of higher education. Stakeholders are not always able to participate in-person in working group activities, but they receive updates on projects and often forward information on to other interested parties, helping to grow the working group and ensuring that information reaches those that need it most. This project was very successful at growing the Wetland Working Group and engaging stakeholders in providing input into the Wetland Section's activities. Other accomplishments from this project include:

- **Compilation of information on wetland and riparian protocols in use in Utah.** We compiled information on field and GIS-based mapping and assessment methods used on wetlands, riparian areas, and streams in Utah. This information is valuable for anyone considering conducting aquatic systems monitoring in Utah because it provides a quick reference to existing protocols that can be utilized. We created a spreadsheet currently listing 43 methods, with information on the organization using the method, the monitoring target, monitoring areas (i.e., statewide, federal land only), a brief description of the data, and links to more information on the protocol when available. We wrote a brief descriptive summary of 31 of the field assessment methods and further described 21 of the methods in spreadsheet form to provide information on features such as how aquatic systems are classified by the protocol, the size of the assessment area, and the goals of the assessment method (monitoring change or one-time site evaluation). We created a list of all the indicators used by each of 15 of the methods, grouped into categories. Summary information and copies of some of the protocols are available online at: https://drive.google.com/open?id=0ByX4v9Jw05raTERwT053QUhvSjQ; this link was shared with the Wetland Working Group in March 2017.
- **Compilation of information on the importance of habitat indicators to taxa**. We received feedback from 19 individuals on the importance of specific wildlife habitat indicators to taxa of interest and compiled this information in a spreadsheet available online at: https://drive.google.com/open?id=0ByX4v9Jw05raTERwT053QUhvSjQ. This information is valuable for any future efforts to modify or improve habitat indicators and serves as a reference for the current checklist.
- **Better understanding of potential uses of functional indicators.** The functional indicator checklists are a rapid assessment method, so they are not appropriate for all uses. Some regulatory uses, such as setting water quality standards for wetlands or setting discharge limits for a discharger, will almost always require more detailed, quantitative evaluation. The checklist method is probably also not appropriate for monitoring change over time or monitoring the results of mitigation and restoration efforts because the method only measures large changes between presence/absence of a trait (e.g., presence of large woody debris), rather than the more gradual changes that are often the focus of monitoring (e.g., percent cover of large woody debris). Some potential uses of the functional indicator checklists include:
    - Evaluating potential impacts and losses from wetland conversions; setting mitigation goals
    - Estimating functional capacity in a watershed or project area through surveys at randomly selected sites; results could be used to predict low functioning wetland types or regions within project area to determine areas for focusing wetland creation or restoration activities
    - Evaluating targets for conservation; comparing potential conservation targets
    - Preliminarily screening sites to identify those that may be suitable for wildlife introductions (would require follow-up evaluation; only relevant to wildlife habitat checklist)
    - Preliminarily screening sites to identify those that may need restoration (would require follow-up evaluation)
    - Engaging citizen scientists to collect data to expand knowledge and appreciation for wetlands

- **Better understanding Utah's wetland stakeholders' ability to collect, share, and use assessment data.** Agencies that primarily collect data on private land, such as UDAF and the U.S. Natural Resources Conservation Service (NRCS), have indicated that they could only share data if they had written permission from landowners. Agencies that follow national agency protocols, including NRCS and the BLM, could only collect data using a new protocol in conjunction with existing protocols and only if the new protocol took minimal time. The BLM is currently developing an assessment method for lentic systems as part of their assessment, inventory, and monitoring (AIM) strategy. The AIM protocol will likely be more detailed and time consuming than the checklist of indicators developed by this project. The BLM will have to use the AIM protocol in Utah when it becomes available, but may also be able to collect the checklist data at sites if it does not add too much additional time to field surveys. The USACE is interested in using a rapid assessment tool to evaluate site impacts at proposed project areas. If the functional checklists are adopted for use by USACE, this may encourage private consulting companies to collect this data as well. USACE would potentially both collect and use the assessment data. Consulting companies have indicated an interest in having a tool that is consistent and rapid to use. Non-profit groups have expressed interest in collecting data as part of citizen scientist monitoring or student educational training. Non-profit groups have also expressed interest in collecting the data to evaluate potential or actual land easements. Data from USACE and non-profit groups would probably be shareable amongst agencies. Individuals in the DWQ's watershed protection section have expressed interest in using information to help determine the best places to utilize non-point source funding.

Recommendations and Next Steps

We recommend three additional steps to improve the wildlife and water quality indicators before they are broadly adopted for use. First, indicators should be rigorously tested at multiple sites and with multiple pairs of observers to determine the degree to which site scores are subject to observer variability. Some indicators may need to be reworded or dropped entirely from the checklists if they exhibit too much variability. Such testing will make it easier to recommend the tool for regulatory purposes. The Utah Geological Survey received a Wetland Program Development Grant that will allow us to conduct testing of our protocol, including the functional components.

Second, the checklist of indicators may need to be converted to a final score to allow comparison of similarly situated wetlands and validation of method. One potential method for developing scores is to obtain data at a variety of sites, evaluate scores by wetland type (e.g., marsh, meadow), and then select thresholds for each wetland type to indicate low, medium, and high functioning wetlands. The Utah Geological Survey plans to collect data using the new indicator checklists for a funded project in the Bear River watershed and in future project areas, as funding allows, which will provide data to help develop scoring. Scoring for the wildlife habitat checklist could be improved and validated if wetland assessments are combined with wildlife surveys. For example, surveys for secretive marsh birds could also collect data on the wildlife habitat indicators to determine whether high indicator scores correlated with high bird use. The Utah Geological Survey currently has no plans to conduct joint wildlife/habitat surveys, but will seek opportunities to collaborate with wildlife specialists in the future.

Third, the Utah Geological Survey should develop a workflow and tools to assist surveyors with gathering preliminary data before surveys are conducted. For example, we could write a protocol that explains how to obtain site background data using Google Earth and other freely available sources. Some items on the habitat indicator checklist require a significant amount of user expertise, including indicators regarding whether a site is listed as important for species in a conservation plan or regional report, or whether a site has potential to provide habitat for threatened or endangered species. The Utah Geological Survey could improve assessors' ability to correctly answer these indicators if they compiled and made public this type of information. We recently applied for funding from the Utah Endangered Species Mitigation Fund to compile and manage data on range and wetland habitat associations for federally listed and state sensitive amphibians. If funded, this project will make it easier for assessors to determine whether a site has the potential to harbor any of these species.

Appendix A: Results from December 2014 survey of assessment needs

Table A1. Percent of respondents (n=86) with each monitoring and assessment need.

Monitoring Need	% of respondents
Evaluate restoration	67.4%
Summarize wetlands in study area	62.8%
Identify restoration targets	59.3%
Evaluate change/repeat monitoring	58.1%
Conservation/preservation targets	55.8%
Evaluate habitat	51.2%
Evaluate stressors	51.2%
Evaluate mitigation	47.7%
Determine mitigation	45.3%
Other	8.1%
No need	7.0%

Table A2. Mean and 10th, 25th, 75th, and 90th percentiles of respondent (n=72) ratings of important wetland field assessment protocol attributes, with 1 indicating not important and 5 indicating very important.

Assessment Protocol Attribute	Mean	10th	25th	75th	90th
Evaluates wetland condition	3.94	3	3	5	5
Evaluates wetland function	3.89	3	3	5	5
Evaluates habitat	3.87	2.2	3	5	5
Includes water quality data	3.85	2.3	3	5	5
Standardized across state or region	3.74	2	3	5	5
Validated	3.52	2	3	5	5
Approved for regulatory work	3.43	1	2.75	5	5
Specific to wetland types	3.38	2	3	4	5
Rapid	3.27	1	3	4	5
Requires minimal user expertise	3.01	1	2	4	5
Universal across wetland types	2.86	1	2	3	4.9

Appendix B: Project participants

Table B1. List of participants in one or more components of core indicators project.

Name	Email Address	Position	Organization/Affiliation
Diane Menuz	dmenuz@utah.gov	State Wetlands Coordinator	Utah DNR Utah Geological Survey
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Ann Neville	ann.neville@tnc.org	Northern Mountains Regional Director	The Nature Conservancy
Arlo Wing	arlowing@utah.gov	Assistant Wetland Manager	Utah DNR Division of Wildlife Resources
Becka Downard	rdownard8@gmail.com	PhD candidate, Wetland Specialist	Utah State University, Utah Division of Water Quality
Ben Lardiere		Wetland technician	Utah DNR Utah Geological Survey
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Bryan Dixon	brlc@BearRiverLandConservancy.org		Bear River Land Conservancy
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Charlie Condrat	ccondrat@fs.fed.us	Hydrologist	Uinta-Wasatch-Cache National Forest
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Colton Anderson	clanderson@utah.gov	Assistant Wetland Manager	Utah DNR Division of Wildlife Resources
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Jimi Gragg	jimigragg@utah.gov	Wildlife Biologist, Wildlife Action Plan	Utah DNR Division of Wildlife Resources
John Neill	johnneill@utah.gov	Great Salt Lake Aquatic Biologist	Utah DNR Division of Wildlife Resources

Name	Email Address	Position	Organization/Affiliation
Josh Vest	josh_vest@fws.gov	Science Coordinator, Intermountain West Joint Venture	U.S. Fish and Wildlife Service
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Kathleen Anderson	Kathleen.Anderson@usace.army.mil	Regulatory Assistant	U.S. Army Corps of Engineers
Kent Sorenson	kentsorenson@utah.gov	CUP Project Leader	Utah DNR Division of Wildlife Resources
Kerry Julvezan		Wetland technician	Utah DNR Utah Geological Survey
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Mindy Wheeler	mindywheeler@utah.gov	Consultant and Botanist	Utah Department of Natural Resources
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Unknown survey respondent			
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Unknown Army Corps employee		Bountiful field office	U.S. Army Corps of Engineers
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Table B2. List of participant roles in core indicator project. See table B1 for list of all participants.

Name	Pre-Meeting	Survey	1st Meeting	2nd Meeting	Field Test	Wrap-up Meeting	Feedback on Checklist of Habitat Indicators by Taxa
Diane Menuz	x		x	x	x	x	mollusks, general wildlife, Great Salt Lake bird meeting[1]
Alan Clark	x						
Amy Defreese		x					songbirds, raptors, general wildlife
Ann Neville					x	x	
Arlo Wing							Great Salt Lake bird meeting[1]
Becka Downard	x	x	x	x		x	
Ben Lardiere					x		
Betsy Herrmann	x						
Bracken Davis	x	x					
Bryan Dixon	x	x		x			
Carly Ferro		x					
Cassie Mellon	x	x	x			x	amphibians, mollusks, salmonids
Chad Cranney						x	Great Salt Lake bird meeting1
Charlie Condrat	x						
Chris Brown					x		Great Salt Lake bird meeting1
Chris Crockett	x						
Chris Keleher	x	x	x	x		x	
Colton Anderson			x				Great Salt Lake bird meeting1
Craig Walker	x						
Edd Hammill		x	x				
Elaine York		x					
Ella Sorenson							shorebird conversation[2]
Emma McGowan	x						
Eric McCully	x		x				
Erin Bragg	x						
George Weekly							amphibians, salmonids, general wildlife
Howard Browers							Great Salt Lake bird meeting[1]
Jason Gipson				x	x	x	
Jason Jones			x			x	Great Salt Lake bird meeting[1]
Jay Martini							sage grouse, general wildlife
Jay Olsen	x	x				x	
Jeremy Jarnecke		x				x	
Jimi Gragg	x	x	x	x			amphibians, beaver, general wildlife
John Neill							Great Salt Lake bird meeting[1]
Josh Vest	x						
Karin Kettenring		x				x	
Kathleen Anderson	x						

Name	Pre-Meeting	Survey	1st Meeting	2nd Meeting	Field Test	Wrap-up Meeting	Feedback on Checklist of Habitat Indicators by Taxa
Kent Sorenson	x						
Kerry Julvezan				x			
Krissy Wilson							aquatic mollusks, amphibians, native wetland fishes[3]
Marc Coles-Ritchie		x					
Meredith Albers	x	x					
Mindy Wheeler	x		x				
Pam Kramer	x	x	x			x	
Randy Kaufman		x		x			
Rebecca Weissinger		x				x	
Rich Hansen	x		x			x	Great Salt Lake bird meeting[1]
Richard Emerson	x					x	
Robin Naeve	x	x		x			
Ryhan Sempler	x	x	x	x	x	x	general wildlife
Rod Hess	x						
Sam McKay							amphibians
Sara Jo Dickens				x		x	
Stephanie Graham							songbirds, raptors, general wildlife
Unknown survey respondent		x					
Matt Wilson					x	x	
Unknown Army Corps employee					x		
Joslin Heyward						x	
Miles McCoy-Sulentic						x	
Sarah Quistberg						x	
Jim Spencer						x	
Justin Jimenez						x	
John Rice						x	
Ann Marie Aubry						x	
Erica Shotwell						x	
Jeri Ledbetter						x	
David Tart						x	

[1]Participated in working group meeting to discuss Great Salt Lake avian habitat using habitat checklist as guiding document.

[2]Participated in working group meeting to discuss shorebird habitat using habitat checklist as guiding document.

[3]Added native wetland fishes to habitat checklist.

Appendix C: Results from February 2017 survey on wetland functions

Table C1. Number of individuals contacted and number of responses by organization and affiliation.

Organization	# Responded	# Contacted
Federal	**6**	**20**
Army Corps of Engineers	0	4
Bureau of Land Management	3	3
Bureau of Reclamation	0	1
National Park Service	1	1
Natural Resources Conservation Service	1	5
Fish and Wildlife Service	1	3
Forest Service	0	3
State	**7**	**25**
Department of Natural Resources	1	1
DNR Division of Wildlife Resources	2	11
DNR Forestry, Fire, and State Lands	1	2
DNR Utah Geological Survey	1	1
Utah Department of Agriculture and Food	2	1
Utah Division of Water Quality	0	6
Other state agencies	0	3
University	**4**	**11**
Non-profit	**2**	**9**
Private (consultant)	**1**	**9**
Unknown/other	**1**	**12**
Total	**21**	**86**

Table C2. Wetland functions/values, sorted by median ranking and then mean ranking to break ties (low ranks indicate high priority). The participation score is calculated as the number of likely participants multiplied by one-half the number of participants who responded with maybe.

Function	Ranks (Low Value = High Priority)				Participation (# of Individuals)			
	Mean Rank	1st Quartile	Median	3rd quartile	Likely	Maybe	Unlikely	Score
Wildlife habitat	3.83	1	3	7	13	2	6	**14**
Groundwater recharge or discharge	4.36	3	4	6	6	8	6	**10**
Nutrient removal or transformation	4.43	3	4	6	4	9	7	**8.5**
Sediment and toxicant retention	4.26	2	5	5	4	5	11	**6.5**
Floodwater storage and floodflow alteration	4.86	3	5	7	7	2	10	**8**
Fish habitat	5.29	4	6	7	8	2	11	**9**
Shoreline and sediment stabilization	5.45	3	6	7	6	8	6	**10**
Uniqueness/rarity	5.60	3	7	8	8	8	4	**12**
Recreational and educational opportunities	6.93	6.5	8	8	5	5	10	**7.5**

Appendix D: List of potential wildlife indicators

Table D1. Key indicator list sent to stakeholders. Stakeholders were asked whether they could reliably assess each indicator (dropdown options included “Yes”, “No”, “Not Evaluated”, and “Too time consuming”). Stakeholders were also asked to assess each indicator for its importance to wildlife in general and any taxa for which they had expertise (including aquatic mollusks, amphibians, waterfowl, shorebirds, wading birds, piscivorous birds, beaver, sage grouse, salmonids, raptors, migratory songbirds, small mammals, muskrats). Dropdown options included “Not evaluated”, “Necessary”, “Good”, and “Not important.” Stakeholders could also add comments for each indicator.

Category	Key Indicator
Potential Habitat Features	
Hydrology	Shores of seasonally or permanently inundated waterbodies are predominantly gentle, creating a lot of area with <10 cm deep water
Hydrology	Open water (with no emergents/shrubs) is present at site for at least two months during the growing season
Hydrology	Wetland has year-round surface water that does not completely freeze in the winter
Hydrology	Site has intermittent or permanent stream within boundary or along edge
Hydrology	Site has a diversity of hydroperiods (e.g., permanently flooded, seasonally flooded, saturated, etc.) [would come up with a list]
Hydrology	Site has a diversity of water depths [would need to come up with depth categories]
Structure	Vegetation layers and natural unvegetated areas (water, mudflat) show a moderate to high degree of interspersion [maybe with photo example]
Structure	Features such as logs and rocks that provide structural complexity at site are present in areas that do not have surface water for most of the growing season
Structure	Features such as logs and rocks that provide structural complexity at site are present in areas that **do** have surface water for most of the growing season
Structure	Large woody debris is present at site
Structure	Standing snags are present in site
Structure	Site has at least three distinct elevation gradients (at least 15 cm in height difference), such as benches, slopes of varying steepness, channels, and pools [could select #]
Structure	Site has ample microtopographic features (such as soil cracks, natural vegetation hummocks, sediment mounds, tufts of litter) that provide small-scale complexity
Structure	Animal burrows are present at site
Structure	Soil cracking is present at site
Structure	Undercut banks are present at site along intermittent or perennial watercourses
Structure	The stream, ditch, or shore is shaded by overhanging vegetation
Structure	Thin-stemmed persistent plants are present in permanently or seasonally flooded areas
Structure	At least x# plant layers are found within site (e.g., tree, shrub, tall emergent, low emergent) [would need to come up with list of vegetation layers]
Structure	Site has healthy recruitment of native woody species (all size/age classes present)
Vegetation	At least x# of tree species found at site OR expected diversity of tree species present [would need to select appropriate number]
Vegetation	Tree species are present at site
Vegetation	Woody invasive species uncommon or absent
Vegetation	At least x# of shrub species found at site OR expected diversity of shrub species present [would need to select appropriate number]
Vegetation	Shrub species are present at site
Vegetation	At least x# of herbaceous species covering at least 10 sq ft found at site OR site is not dominated by only one or two herbaceous/graminoid species OR no single herbaceous or graminoid species makes up more than half of the ground cover at site
Vegetation	Herbaceous invasive species uncommon or absent

Vegetation	Non-wetland plants are uncommon or absent within wetland
Vegetation	Water supports at least two of the following three: emergents, submerged aquatic vegetation, and floating leaf vegetation
Vegetation	Submerged aquatic vegetation is found at site
Vegetation	Cattails or bulrushes are present at site
Water quality	Water does not show any evidence of turbidity, unnatural oil sheens, or other pollutants
Water quality	Water does not appear to have excessive filamentous algae growth
Species presence	Dragonfly species are observed at site
Species presence	Beaver activity is evident at site (dams, gnawed logs)
Disturbances	
Hydrologic	Wetland does not receive water from waterbodies listed as impaired by DWQ
Hydrologic	There are no local scale hydrologic manipulations at site (local diversions, drainage, spring development, etc.)
Hydrologic	There are no distant hydrologic upshed manipulations impacting site (upstream dams and withdrawals, etc.)
Hydrologic	Site had natural inundation and saturation frequency
Landscape setting	Barriers impeding movement to surrounding aquatic habitat are nonexistent or easily passed by most organisms (such as minor at grade culverts, minor levees)
Landscape setting	Barriers impeding movement to surrounding upland habitat are nonexistent or easily passed by most organisms (such as gravel roads, minor levees, ditches, barbed-wire fences)
Landscape setting	Less than one-third of the area within 1 km of site has high intensity development (housing, strip mines, etc.) [exact percent, distance, and examples could be selected later]
Landscape setting	At least two-thirds of area within 1 km of site is in a natural undisturbed or very minimally disturbed land cover [would need to define, but probably low intensity grazing and some recreation would be okay]
Landscape setting	At least 1/3 of area within 1 km of site is **directly connected** to wetland (e.g., no roads or other barriers) and undisturbed or minimally disturbed
Landscape setting	A 30-m buffer of relatively intact vegetation and soils extends along at least 90% of the wetland perimeter
Landscape setting	Several different wetland types are found within 1 km of site [may want to create list]
Site disturbance	Site not grazed or only lightly grazed by livestock
Site disturbance	No evidence of intense wild horse use at site
Site disturbance	Site not used for agricultural activities such as haying
Site disturbance	Site not used recreationally (evaluated based on trash, trails, ATV tracks, etc.)
Background data and threat observations	
Background data	Site known to be used regularly by species in group (based on observations, reports, etc.)
Background data	Sites provides habitat for threatened or endangered species or species of highest conservation need
Background data	Site is listed as an important site for species in group in a conservation plan, regional report, or other planning document
Predators/Threats	Evidence of mammalian predators observed (footprints, dens, scat) [this would be a negative indicator)
Predators/Threats	Potential aquatic predators observed (bullfrogs, tiger salamander, certain fish species) [this would be a negative indicator]
Predators/Threats	Positive test for chytrid documented at site [this would be a negative indicator]

Appendix E: Form used for field testing

Site ID:	**Site Name:**

Does site receive water directly from waterbody listed as impaired by Utah DWQ? (http://mapserv.utah.gov/surfacewaterquality)
Yes No Comments:

Is site along a stream that has an evident dam within 5 km upstream? Yes No NA (not along stream)

Tally # of times site appears to have surface water in Google Earth and then write note about general hydrology:

Months	***Wet***	***Dry***
April, May, June		
July, August, Sept.		
Oct. through March		

Survey Date:	**Surveyors:**
Ecological System:	HGM Class:
Is site whole-wetland? Yes No	Site area: ha

Briefly describe rationale for site boundary if not whole wetland:

Key to species: 1 Waterfowl; 2 Shorebirds; 3 Amphibians; 4 Aquatic mollusks; 5 Raptors; 6 Salmonids; 7 Songbirds; 8 Sage grouse

Put a 1 in box if true; otherwise put a 0. Leave blank if box is shaded grey.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
SPECIES OBSERVATIONS AT SITE								
Species in taxonomic group observed during site survey.								
Evidence of mammalian predators observed (footprints, dens, scat) [**score as -1 or 0]**	-	-						-
Potential aquatic predators observed (bullfrogs, salamanders, certain fish species) [**score as -1 or 0**].			-	-				
Dragonflies or damselflies observed at site.								
Beaver activity is evident at site (dams, gnawed logs).								
SOCIETAL VALUE OF SITE								
Site has potential to provide habitat for federal threatened or endangered species or Utah sensitive species within group (based on range and wetland type).								
T&E species or sensitive species known to occur at site.								
Site is listed as an important site for species in group in a conservation plan, regional report, or other planning document.								
Societal Value score (out of 3)								
LANDSCAPE CONTEXT								
Site is along stream and there are no dams evident within 5 km upstream?								
Barriers (such as above-grade culverts, levees) impeding aquatic connectivity are nonexistent or easily passed by most organisms.								
Less than 1/3 of area within 1 km of site has high intensity development (urban/industrial areas, high-intensity agriculture (excluding haying/pasture), or high-intensity recreation (golf courses, ball fields).								
At least 1/3 of area within 1 km of site is directly connected to site (e.g., no regularly used roads, development, etc.) and undisturbed or minimally disturbed.								
At least 3 of the 4 are found within 1 km of site: playas, emergent marsh, submergent marsh, and upland.								
30-m buffer of relatively intact vegetation and soils extends along at least 90% of the site perimeter.								
Landscape Context score								
Maximum score	**4**	**4**	**5**	**5**	**3**	**5**	**3**	**3**
SITE DISTURBANCE								
Site not grazed or only lightly grazed by livestock or wild horses OR livestock known to be kept off site during key development periods for wildlife species.								
Site does not appear routinely disturbed by activities such as mowing, mechanical plant removal, vehicle travel, dredging, excavation, filling of sediment, etc.								
Site not used or only lightly used for recreation (evaluated based on trash, trails, ATV tracks, etc.).								
Site Disturbance Total								
Maximum score	**3**	**3**	**3**	**3**	**2**	**2**	**3**	**3**

Key to species: 1 Waterfowl; 2 Shorebirds; 3 Amphibians; 4 Aquatic mollusks; 5 Raptors; 6 Salmonids; 7 Songbirds; 8 Sage grouse								
Put a 1 in box if true; otherwise put a 0. Leave blank if box is shaded grey.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
HYDROLOGY AND WATER QUALITY								
There are no apparent hydrologic manipulations at site that are likely to artificially reduce water levels (local diversions, drainage, spring boxes, etc.) or severely alter water timing.								
Site has intermittent or perennial stream or canal within boundary or along edge OR wetland includes springs that flow most of the year. For salmonids, only mark 1 if stream is present.								
Site does not have any obvious water quality issues. Site does not receive water directly from impaired streams and lakes, does not have excessive (>20% cover in open water) filamentous algae, and shows no evidence of turbidity, unnatural oil sheens, or other pollutants.								
HYDROLOGY: SITES WITH SURFACE WATER								
Shores of seasonally or permanently inundated waterbodies are predominantly gradual creating a lot of area with shallow water and a diversity of water depths when site is inundated. For shorebirds, water must draw down to expose shore by late May/early June or end of September.								
Site typically has open water (can have submergents/floating, but no emergents or shrubs) during spring (April, May, June), summer (July, August, September) or both. For shorebirds, water must typically be <20 cm in depth.								
Site typically has surface water year-round. For shorebirds, water must typically be <20 cm in depth.								
Site has areas of open water with structural features in water such as tufted vegetation/litter, logs, or rocks that could provide shelter and habitat for wildlife.								
Site is a hemi-marsh with a lot of interspersion between emergent vegetation and open water (at least 30% cover of each).								
Submerged aquatic vegetation is found at site.								
STRUCTURAL FEATURES								
Undercut banks are present at site along intermittent or perennial watercourses.								
Shore along the stream, ditch, pond, or lake is at least partially shaded midday by overhanging vegetation or by tall herbaceous vegetation.								
Animal burrows are readily apparent at site.								
Features such as logs, tufted litter, and rocks that provide structural complexity at site are present in drier areas of wetland (providing cover and potential food sources.								
VEGETATION								
Site is not a monoculture of only one or two herbaceous or graminoid species (may be unvegetated) and problematic plant species, such as noxious weeds, are uncommon or absent.								
Site includes *Salicornia rubra* or *Distichlis spicata* (for shorebirds) or *S. rubra, D. spicata, Schoenoplectus acutus, S. americanus,* or *S. maritimus* (for waterfowl)								
VEGETATION: SITES WITH OR EXPECTED TO HAVE WOODY VEGETATION								
Site has at least 5% cover of non-native woody species, but is not typically expected to have any woody species cover (**score as -1 or 0**).	-	-	-	-	-	-	-	-
Trees are found growing in or along edge of wetland (woody species with DHB >7.5 cm).								
Shrubs are growing within site (woody species with DBH<7.5 cm).								
Standing dead trees or snags are present at site (>5 cm DBH).								
Woody vegetation is not composed of only decadent/dying individuals with no sign of recruitment. Examples of decadent vegetation include mushroom-shaped shrubs and short-statured woody plants with thick bases that have been repeatedly grazed back.								
HABITAT POTENTIAL SCORING								
Habitat Potential score (sum of above values)								
Maximum possible score	10	9	14	6	8	12	8	2
Maximum possible score, sites without woody species	10	9	12	6	4	8	4	2

Appendix F: Draft water quality improvement functional checklist

Capacity to improve water quality

- ☐ The top 5 cm of soil is true clay or true organic.
- ☐ At least ½ of AA is covered by **persistent** (meaning dead stalks will be standing in winter) **herbaceous vegetation ≥13 cm tall** (~height of clipboard) and dense enough to obscure ground; estimate vegetation height based on likely flood season conditions. Ignore areas with water >1 m deep for percent estimates.
- ☐ At least 1/3 of AA is covered by **persistent herbaceous vegetation ≥1 m tall** and dense enough to obscure ground (see definitions from above). Ignore areas with water >1 m deep for percent estimates.
- ☐ At least 1/3 of AA has over-story cover from **tree or shrubs at least 1 m tall** (ignore stream channels).
- ☐ At least ¼ of AA is seasonally ponded (surface water ≥2 consecutive months, but drying annually).
- ☐ Wetland is **lacustrine fringe**, **depressional impoundment**, or **depressional** and waterbody either has no surface water outlet or an intermittently flowing outlet.
- ☐ Wetland is **riverine** and at least 1/5 of wetland has surface depressions that can trap sediments during flooding events.
- ☐ Wetland is **lacustrine fringe** or **depressional impoundment fringe** and the average width of vegetation (including aquatic bed) extending into the lake or impoundment is at least 5 m.
- ☐ Wetland is **slope** or **impoundment release** and average surface slope is 1% or less (1.75°)

Landscape potential

- ☐ *There are homes within 75 m of wetland that are likely to be on septic system (outside special service district and municipal boundaries).*
- ☐ Stormwater pipe directly feeds wetland.
- ☐ At least 10% of the area within 50 m that could run-off to AA is in land use likely to generate sediment or nutrient (fertilizer, animal manure, etc.) runoff to site (cropland, dirt roads, pasture, clearcut forest, OHV tracks, golf course, etc.). If surrounding land use is pasture or rangeland, check box only if 10% of area has disturbed soils or if density of animal dung is very high.
- ☐ At least 10% of the area within 50 m that could run-off to AA is in land use likely to generate pollutants besides nutrients/sediment (paved roads, parking lots, houses, commercial buildings, oil and gas wells, mines, etc.)
- ☐ Wetland is immediately adjacent to a lake used by power boats.
- ☐ Wetland is immediately adjacent to lake or stream with known algal blooms issues[1].
- ☐ There are other sources of pollutants coming into wetland not listed above. List:

Sites connected to streams/rivers (including lakes along rivers). Determine portion of wetland watershed between site and nearest upstream major tributary or lake; this will be the *contributing basin.*

- ☐ *Wetland is within an incorporated city.*
- ☐ *≥10% of contributing basin is composed of land use likely to generate pollutants (see list above).*
- ☐ *≥10% of contributing basin is composed of land use likely to generate sediment or nutrients (see list above).*

Valued by society

- ☐ *Site scores high for amphibian species habitat.*
- ☐ Wetland is within 50 m of and at least occasionally dischargers to stream, river, or lake.
- ☐ *Wetland is in area designated as category 1 or category 2 for anti-degradation (see KMZ file at http://www.deq.utah.gov/ProgramsServices/programs/water/wqmanagement/standards/AntiDeg.htm).*

Use UDWQ's Beneficial Uses and Water Quality Assessment Map at http://mapserv.utah.gov/surfacewaterquality

- ☐ *Wetland is in an undefined Assessment Unit.*
- ☐ *Wetland is in a Category 5 Assessment Unit.*
- ☐ *Wetland is in a Category 4 Assessment Unit (may also be category 5; check both if both apply)*
- ☐ *Wetland is in a Category 3 Assessment Unit AND has records of exceedances (search assessment unit ID in the latest Integrated Report results and determine whether sub-category is "insufficient data, exceedances").*

Appendix G: References for some core indicators and species' associations

The initial habitat indicator list was developed by compiling indicators listed in other wetland functional assessments and consolidating similar indicators in the protocols into a single indicator (U.S. Army Corps of Engineers New England District, 1999; Prichard, 2003; Johnson, 2006; U.S. Natural Resources Conservation Service, 2009; Johnson and others, 2013; Delaware Department of Natural Resources and Environmental Control, 2014; Hubry, T., 2014; U.S. Natural Resources Conservation Service, 2014; Menuz and others, 2016). Indicators were modified based on feedback at the second core indicator meeting and the results of field testing. Indicators were also added or modified to address unique habitat needs based on feedback on the wildlife indicator checklist and from targeted meetings with wildlife specialists.

Additional research was sometimes used to refine indicators, particularly for avian and landscape setting indicators. Avian habitat association information was obtained from U.S. Natural Resources Conservation Service (2005) for wading birds, Ortega and others (2014) for dabbling ducks and, to a lesser extent, secretive marsh birds, and Olsen and others (2004) for all avian groups.

The following are brief reviews of appropriate distances for preserving aquatic water quality and wildlife habitat.

The critical distance at which the surrounding landscape affects wetland wildlife habitat varies by taxa, species, and wetland system. A meta-analysis by Semlitsch and Bodie (2003) found that a 289-m buffer zone around wetlands and riparian habitats is critical for amphibians and reptiles for forage, reproduction, and overwintering. Land use had the largest effect on plant species community metrics at distances between 250 to 400 m in one study (Houlahan and others, 2006) and at 100 m in another study (Rooney and others, 2012). Similarly, wetland bird assemblages have been best predicted by land cover at 500 m (Rooney and others, 2012) and 2500 m (Whited and others, 2000), depending on the study. Keate (2005) conducted a literature review and summary of best professional judgment for disturbance tolerance distances for Great Salt Lake bird species. Disturbance distances for the lowest intensity disturbance ranged from 100 m to 1230 m, though types of disturbances evaluated and species' responses (e.g., nest success, population density) differed by study. The first, second, and third quartiles of the distances from the Keate study were 150, 315, and 530 m. Based on the literature review, we selected distances of 300 m and 1000 m as reasonable buffers against low intensity and high intensity development, respectively.

The degree to which a buffer can mitigate impacts to a wetland depends in part on buffer width. Wider, intact buffers can filter out more pollutants before they reach a wetland and often have less human visitation and associated stress. A review by the Environmental Law Institute found that effective widths for wetlands are 9-30 m for sediment and phosphorus removal and 30-49 m for nitrogen removal (measured as 30-100 ft and 100-160 ft by McElfish and others, 2008). Recommended widths for wetland water quality for the Minnehaha Creek Watershed District in Minnesota were between 15 and 30 m, depending on the particular function and buffer slope (measured as 50 and 100 ft by Emmons & Olivier Resources, 2001). A meta-analysis found that 30 m buffers could remove between 68 and 100% of sediment, nitrogen, phosphorus, and pesticides, with differences in effectiveness depending on pollutant, slope, and vegetative cover of buffer (Zhang and others, 2010). Johnson and Buffler (2008) recommended minimum buffer widths in agricultural areas in the arid west of between 21 and 67 m (and wider if certain features were present in the buffer) for agricultural areas in the intermountain

west, depending on soil type, slope, and surface roughness. We selected 30 m for the wildlife habitat buffer indicator distance.

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