

# CHAPTER 4

# WETLANDS



2014

Integrated Report

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# CHAPTER 4 WETLANDS

## INTEGRATED REPORT

### UTAH'S WETLAND PROGRAM

The Utah Division of Water Quality (DWQ) initiated its Wetlands Program in 2004 with a focus on evaluating whether wetlands associated with Great Salt Lake (GSL) are fully supporting their broadly defined beneficial use: habitat support for waterfowl and shorebirds and the necessary aquatic life in their food chain. Early efforts focused on shallow ponded areas, or impounded wetlands (IWs), where dikes, berms, and ditches have been constructed to control water flow. DWQ's interest began in response to stakeholder concern that nutrient loads from water treatment facilities and other surface water inflows adjacent to GSL may have deleterious impacts on these productive and highly valued ecosystems. Initial work focused on wetlands adjacent to Farmington Bay, where wetland managers and conservation groups observed the occasional dominance of cyanobacterial mats (Miller and Hoven, 2007), a common indicator of phosphorus-induced eutrophication (Reddy and DeLaune, 2008). An early concern was that these mats could negatively impact the health and vigor of extensive swards (i.e., an expanse of short grass or meadow) of submerged aquatic vegetation (SAV) (e.g., sago pondweed, *Stuckenia* sp.) or could alter the species composition and abundance of aquatic macroinvertebrate communities. Both SAV and benthic macroinvertebrates are key food resources for migrant waterfowl species (Miller and Hoven, 2007) and important ecological components of shallow ponds (Keddy, 2010).

In 2009, DWQ finalized a draft assessment framework for GSL IWs (DWQ, 2009). The draft framework contains an assessment tool—a multi-metric index (MMI)—that integrates physical, chemical, and biological characteristics of IWs into an evaluation of the relative health (i.e., condition) of IW sites adjacent to the lake. Included in the draft framework is an outline of next steps (see section 5.2 in DWQ, 2009) that provides a watershed-based approach for protecting GSL wetlands. This chapter summarizes results from data collected for a probabilistic survey of IWs, in an effort to validate the draft assessment framework (DWQ, 2009; CH2M HILL, 2014).

Current efforts to protect and conserve Utah's wetlands revolve around the development of water quality standards for wetlands and management of habitat for wetland-associated wildlife. The success of these efforts relies on a successful and scientifically valid wetland monitoring and assessment program. However, there are currently little monitoring and assessment data on the condition of Utah's wetlands (Sumner et al., 2010). DWQ is continuing a collaborative effort with Utah Geological Survey (UGS) (a division of the Utah Department of Natural Resources) to address the lack of information on wetland extent and condition. The key goals in developing a wetland monitoring and assessment program, as exemplified in Utah's Wetland Program Plan 2011-2016 (Hooker and Jones, 2013) are to 1) inform decision making for the derivation and implementation of statewide wetland water quality standards, 2) develop evidenced-based priorities for wetland conservation, 3) track progress of wetland management and conservation activities, and 4) assess the ecological condition of wetlands over time.

## Utah's Wetlands

Utah is not only the second driest state in the union, it is also home to the GSL ecosystem, a large inland basin that serves as a desert oasis for millions of migratory birds and other wildlife. Integrated with the GSL ecosystem are extensive wetlands that span the transition between the lake and a mosaic of cold desert, rugged mountains, and rapidly growing urban areas. Data from the updated National Wetlands Inventory (NWI) (U.S. Fish and Wildlife Service [USFWS], 2008) indicate approximately 427,000 acres of wetlands along GSL. These wetlands provide essential ecosystem services, including moderation of surface water and ground water flows, and removal of nutrients and other pollutants. In addition, plant productivity in desert wetlands commonly exceeds that of adjacent uplands, which provides valuable forage for wildlife and cattle grazing (Schlesinger, 1997; Reddy and DeLaune, 2008). There continues to be an essential need to maintain the health and extent of these ecologically critical wetlands, especially in the face of severe and persistent threats from population growth (most Utah citizens reside within the GSL watershed), industrial and urban development, excessive surface water and ground water withdrawal, invasive species, and relatively high rates of nutrient loading (Millennium Ecosystem Assessment, 2005; Dahl, 2006).

## Wetlands Associated with Great Salt Lake

GSL wetlands are dominated by two main wetland classes: IWs and fringe wetlands. Figure 4-1 illustrates the areal extent of major wetland classes associated with GSL. IWs represent areas where dikes, berms, ditches, and culverts have been constructed to control the inflow and outflow of water through wetlands. These wetlands are entirely human-made and occur as large, shallow ponds that range in size from 20 to over 500 acres (Miller and Hoven, 2007). GSL IWs encompass approximately 100,000 acres and are actively managed by both state and federal agencies as well as private duck hunting clubs for waterfowl habitat.

Fringe wetlands typically occur where freshwater flows over very gently sloping portions of the exposed lakebed. Fringe wetlands are found below freshwater sources to GSL, including outlets from IWs, wastewater treatment facility discharges, and other low-gradient surface channels or small streams. These wetlands are commonly vegetated by tall emergent marsh plant communities; however, shallow open water and hemi-marsh cover types also occur. Depending on the quantity of water flow and lake elevation, fringe wetlands can span from the border of IWs to the margin of GSL itself. As such, these wetlands can be considered the last protective effort to immobilize, transform, or remove contaminants from surface waters prior to entering GSL. Fringe wetlands adjacent to GSL encompass approximately 300,000 acres and are not typically managed by state and federal agencies, or by private hunting clubs for waterbird habitat. This chapter focuses on reporting on the overall condition (i.e., health) of IWs associated with GSL.

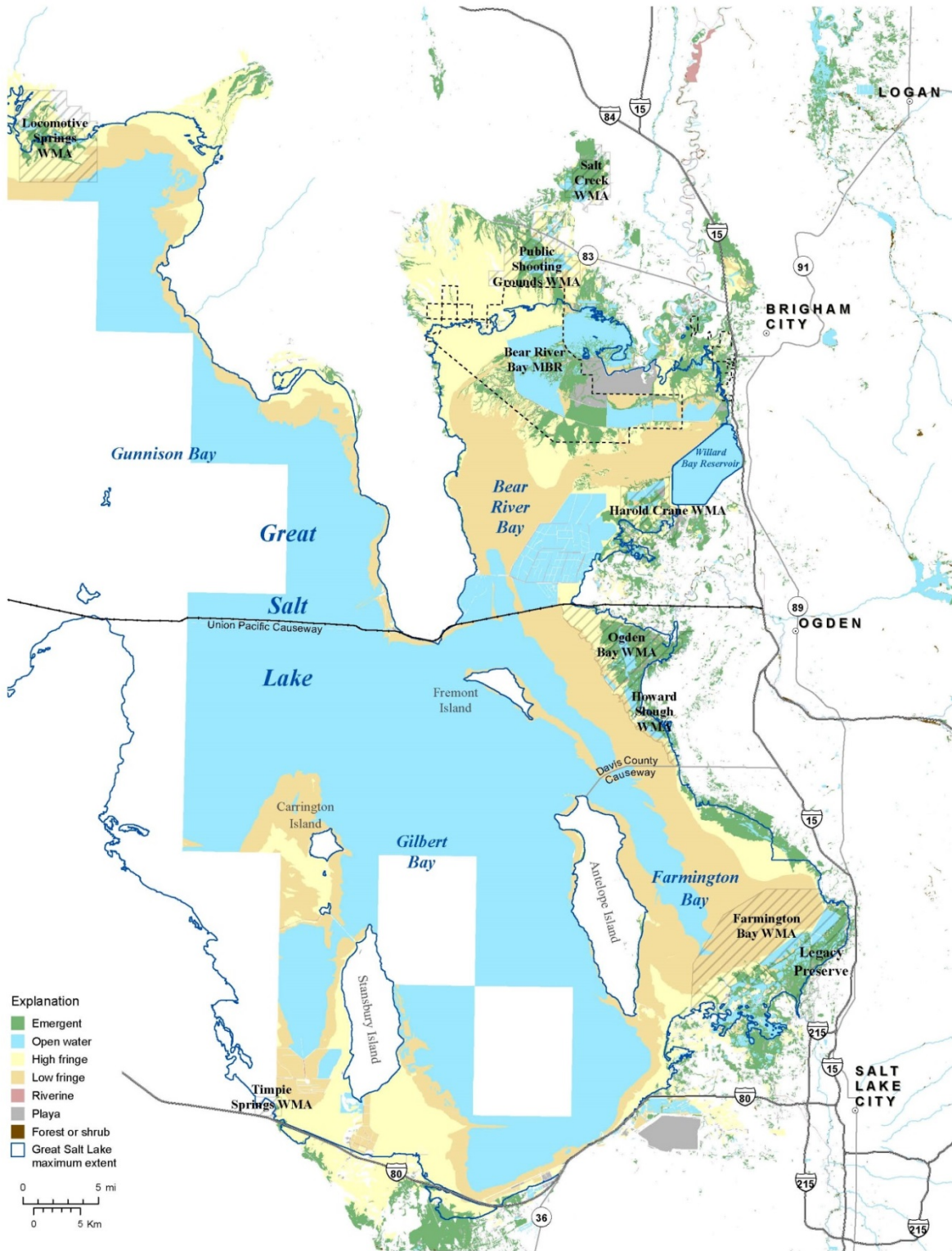


Figure 4-1. Major wetland classes associated with GSL, Utah (adapted from Emerson and Hooker, 2011).

## Wetland Classification and Mapping

Two of the most important tasks of wetland monitoring and assessment are the classification and mapping of these ecosystems. These tasks are commonly the most challenging, since most wetlands occur as a complex mosaic on the landscape, with a variety of structural and functional characteristics. The principal goal of wetland classification, within a monitoring and assessment context, is to reduce the natural within-class variability of important structural or functional features, such that differences between high-quality and degraded ecosystems can reliably be detected.

There are two commonly used approaches to wetland classification: first, a biotic approach, where characteristics of plant community structure, especially those related to waterbird habitat, define wetland classes. This approach is represented by the Cowardin system (Cowardin et al., 1979), which is used extensively by the USFWS's [NWI program](#)<sup>1</sup> to detect changes in wetland area over time. A second approach also aims to detect temporal changes, but focuses on ecosystem processes (or functions) rather than measures of vegetation structure to evaluate functional changes over time. This approach is best represented by the hydrogeomorphic (HGM) method developed by the U.S. Army Corps of Engineers (Brinson, 1993; Smith et al., 1995). The HGM system combines three components to describe wetland classes: geomorphic setting, water source, and hydrodynamics.

The details of these classification methods are beyond the scope of this report; however, two main points are relevant to Utah's wetland monitoring and assessment efforts. First, the NWI system has been extensively used to map wetlands over the last 40 years, whereas the HGM system requires further development of regional wetland classes. Second, although both wetland classification systems (NWI and HGM) include a hierarchical structure, the HGM system was specifically designed for regional characterization of wetland subclasses. This is important because the structure and function of wetlands that develop in a semiarid environment can be quite different from wetlands that develop in, for example, a montane environment. As such, the HGM system is better suited for use as a sample frame for watershed-based wetland surveys.

Current efforts by UGS to enhance the usability of wetlands spatial data involve reclassifying NWI data into the HGM framework (Emerson and Hooker, 2011; Jones et al., 2013). NWI data are only available for approximately half of the state, and much of these data are at least 25 years old; recent coordination with USFWS personnel suggests that NWI data for the remaining portions of Utah are expected in 2014. At this time, it is not possible to accurately quantify the extent of wetland resources in Utah, although it is quite clear that the wetlands associated with GSL represent a truly valuable resource of state, national, and international importance (Utah Division of Forestry, Fire and State Lands, 2013).

DWQ uses wetland spatial data derived from work described in Emerson and Hooker (2011) for GSL wetland assessments. This dataset is based on the available NWI mapping, with a crosswalk to the HGM system that includes the following seven wetland types:

- 1) Open Water: Perennial waterbodies
- 2) High Fringe: Largely nonvegetated wetlands near the historical lake margin; water supply is primarily controlled by lake level. At lower lake levels, fringe wetlands represent large mudflats
- 3) Low Fringe: Fringe wetland from the perennial shoreline to the ephemeral high water level

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<sup>1</sup> [www.fws.gov/wetlands/](http://www.fws.gov/wetlands/)

- 4) Emergent: Palustrine wetland with emergent vegetation. Commonly associated with ground water discharge (seeps and springs) or areas with shallow surface interflow over the land surface. *Note that emergent and low fringe types may coincide in areas near point-source discharges*
- 5) Playa: Ephemeral ponds or depressional features with mineral soils; primary water sources include precipitation and ephemeral surface flow inputs
- 6) Riverine: Perennial streams constrained to a channel (includes canals and ditches)
- 7) Forest/Shrub: Wetlands associated with woody plants, NWI codes FO (forest), or SS (scrub/shrub)

These data also retain some of the NWI modifiers that aid in further describing wetland types:

- a) Impounded: NWI coded “h” wetlands, waterfowl ponds, stock ponds, and recreation ponds constructed with dams or barriers that purposefully or unintentionally obstruct the outflow of water
- b) Excavated: NWI coded “x” wetlands; these wetlands include canals and ponds excavated below the land surface with no dam or barrier
- c) Evaporation Pond: Appended auxiliary water-related land-use data from Utah Division of Water Rights. *This modifier was used to exclude industrial sites from the wetland sample frame*

DWQ used these modifiers to generate the IW sample frame for the survey, as described in Appendix 1.

## Water Quality Regulatory Protections for GSL Wetlands

Water quality regulations for Utah’s waters have been developed iteratively over the past four decades, resulting in three distinct use classes with different regulatory protections. Many wetlands, such as marshes and springs are not explicitly identified but are included in Utah’s definition of “waters of the state<sup>2</sup>” and are protected by narrative standards that protect aquatic wildlife through designated uses (Utah Administrative Code [UAC] R317-2-6<sup>3</sup>; Environmental Law Institute, 2008). Wetlands associated with GSL have distinct use classes based on ownership and geographic location (i.e., relative to the historically defined high lake level elevation, 4,208 feet above sea level). For example, wetlands associated with the federal Bear River Migratory Bird Refuge (operated by the USFWS) as well as state waterfowl management areas (WMAs; operated by the Utah Division of Wildlife Resources) are provided specific beneficial use classes (see Table 2-1 in Chapter 2) that include numeric criteria to protect aquatic life uses (Classes 3B and 3D) as well as the narrative standard (UAC R317-2-7.2<sup>4</sup>). Utah’s water quality standards also define transitional wetlands (Class 5E), as those from the historically defined high lake level elevation (4,208 feet above sea level) to the current edge of the open waters of GSL. Similarly situated wetlands around GSL, with similar ecological characteristics, can fall within different designated use classes. Clearly, if criteria are intended to protect the biological and recreational uses of these waters, they should be based on their ecological characteristics, as opposed to management boundaries.

Current efforts by DWQ’s Wetlands Program include identification and evaluation of appropriate biological and ecological characteristics that can be used to refine (or establish) numeric criteria and develop assessment methods for narrative standards that are appropriately protective to people and wetland biota. Once established, DWQ can assess the chemical and physical conditions that are most strongly associated with healthy versus degraded wetlands, which ultimately can be used to define water quality goals that are specific to these ecosystems.

<sup>2</sup> [waterquality.utah.gov/lawsrules.htm](http://waterquality.utah.gov/lawsrules.htm)

<sup>3</sup> <http://www.rules.utah.gov/publicat/code/r317/r317-002.htm>

<sup>4</sup> <http://www.rules.utah.gov/publicat/code/r317/r317-002.htm>

## WETLAND HEALTH AND ASSESSMENT METHODS

To assess IWs associated with GSL, DWQ developed a MMI assessment tool that integrates measures of physical, chemical, and biological aspects of wetland condition (DWQ, 2009). Several specific biological responses are expected to reflect the health of these waters, including a focus on SAV, aquatic benthic macroinvertebrates, and floating surface mats as potential biological indicators. A probabilistic survey was developed from previously mapped GSL IWs (Emerson and Hooker, 2011; see Appendix 1) so that the results could be generalized across IWs in the GSL basin. To evaluate sensitivity to stress, data were obtained for a range of potential physical and chemical stressors within both water column and sediments (Table 4-1). An analysis of potential stressor-response relationships for these IWs is ongoing but not yet complete, and this analysis is not presented in this chapter. Additional details describing wetland measurements and the probabilistic sampling design can be found in the IW sampling and analysis plan (Appendix 1).

Biological assessments of aquatic resources, including wetlands, rely primarily on three key components. The first component entails development of integrated measures of biological integrity, most commonly derived from the taxonomic composition of aquatic assemblages, such as algae, amphibians, macroinvertebrates, or plants. The second component usually involves identification and characterization of a collection of reference standard sites (i.e., unaltered or least disturbed sites) that can be used as the baseline for all site comparisons within a given ecosystem type. The third component consists of an appropriate probabilistic survey design that allows for generalization of wetland health at the watershed scale (Stevens and Jensen, 2007). This chapter provides a preliminary evaluation of how measures of biological condition vary among GSL IWs.

However, given that all IWs associated with GSL are human-made, and most of these systems are actively managed for waterfowl and other waterbirds, there is no *a priori* set of reference standard sites to use for comparison. Instead, data from the probabilistic survey were used to evaluate a simple set of stressor and response metrics based on upper and lower quartiles of the data.

The target population for the IWs (Appendix 1) consists of ponded wetlands associated with Bear River, Farmington, and Gilbert Bays of GSL (Figure 4-2) that are primarily managed for production of a variety of habitats supporting waterfowl and shorebird populations (e.g., USFWS, 2009). Industrial ponds (i.e., evaporation ponds) and ponds managed for nonwaterfowl or waterbird wildlife were excluded from the target population. The minimum size of IWs was 5 acres (approximately 2.0 hectares). Field reconnaissance was performed to confirm that sites fit target criteria, including water depths that support healthy SAV growth and waterfowl habitat (25–100 centimeters) (USFWS, 2009), with sufficient water depth for water chemistry sampling throughout the growing season. Measurements were collected over two index periods (IP): IP-1, June through July (35 days; summer); and IP-2, late-August through September (20 days; early autumn).

### Development of an Impounded Wetland Assessment

The condition of IWs was characterized by three main indicators of ecological health:

- Persistent cover of SAV between index periods
- (Lack of) occurrence of surface mats
- Composition of benthic macroinvertebrate communities<sup>5</sup>.

These indicators are linked to both wetland management goals and beneficial use classes (DWQ, 2009).

<sup>5</sup> Defined simply as “a collection of species occurring in the same place and at the same time” (following Fauth et al., 1996).



High-quality IWs (i.e., best ecological condition) are assumed to provide excellent habitat for waterfowl and the necessary food chain (see Table 2-1, Class 3D) and support Utah's narrative water quality standard (UAC R317-2-7.2<sup>6</sup>) by supporting extensive beds of SAV, low incidence of surface mats, and diverse macroinvertebrate communities. By contrast, poor ecological conditions may include a combination of sparse cover or early senescence of SAV, extensive surface mats, or simple macroinvertebrate communities.

**Table 4-1. Partial list of potential stressor metrics.**

<b>Water Chemistry Metrics</b>		
DO	Dissolved and total nutrients (e.g., NH <sub>4</sub> <sup>+</sup> , NO <sub>2</sub> <sup>-</sup> and NO <sub>3</sub> <sup>-</sup> , and P)	Sediment extractable nutrients (e.g., NH <sub>4</sub> <sup>+</sup> , NO <sub>2</sub> <sup>-</sup> and NO <sub>3</sub> <sup>-</sup> , and P)
pH	Chlorophyll <i>a</i>	Dissolved organic carbon
TDS	Fraction of total ammonium as undissociated ammonia	Sediment organic matter
TSS and TVS	TVS:TSS ratio	Sediment total nitrogen
<b>Physical Habitat Degradation Metrics</b>		
Wetland area	Max./min. water depth (summer)	Presence of fish (carp)
Percent emergent marsh (of pond area)	Max./min. water depth (early autumn)	Specific conductivity (field)
		Water temperature
<b>Toxic Constituent Metrics</b>		
Dissolved (water) and sediment (cold acid leachate) metals (e.g., Al, As, Ba, Cd, Cu, Mn, Ni, Pb, and Zn)		
Undissociated hydrogen sulfide		Undissociated ammonia

Because there are no unaltered IWs that can be used as reference standard sites, estimates of least degraded conditions on sites were benchmarked against the best attainable condition (BAC) ecological reference standard (Stoddard et al., 2006). BAC represents the expected ecological condition of sites receiving best management practices and having the least amount of impact from adjacent land use. For this study, BAC sites were determined empirically, based on the upper 75<sup>th</sup> percentiles of biological response metrics from SAV, surface mat, and benthic macroinvertebrate community indicators. Upper (75<sup>th</sup> percentile) and lower (25<sup>th</sup> percentile) quartiles were then used to score response and stressor metrics as GOOD and POOR assessment classes, respectively (see also Box 1).

## Exploratory Data Analysis

Results are summarized for three main response indicators (SAV, surface mats, and macroinvertebrates) that represent a preliminary effort to characterize the health (i.e., condition) of GSL IWs. These efforts build on previous and concurrent projects, including development of water quality standards for Willard Spur<sup>7</sup> and

<sup>6</sup> <http://www.rules.utah.gov/publicat/code/r317/r317-002.htm#T9>

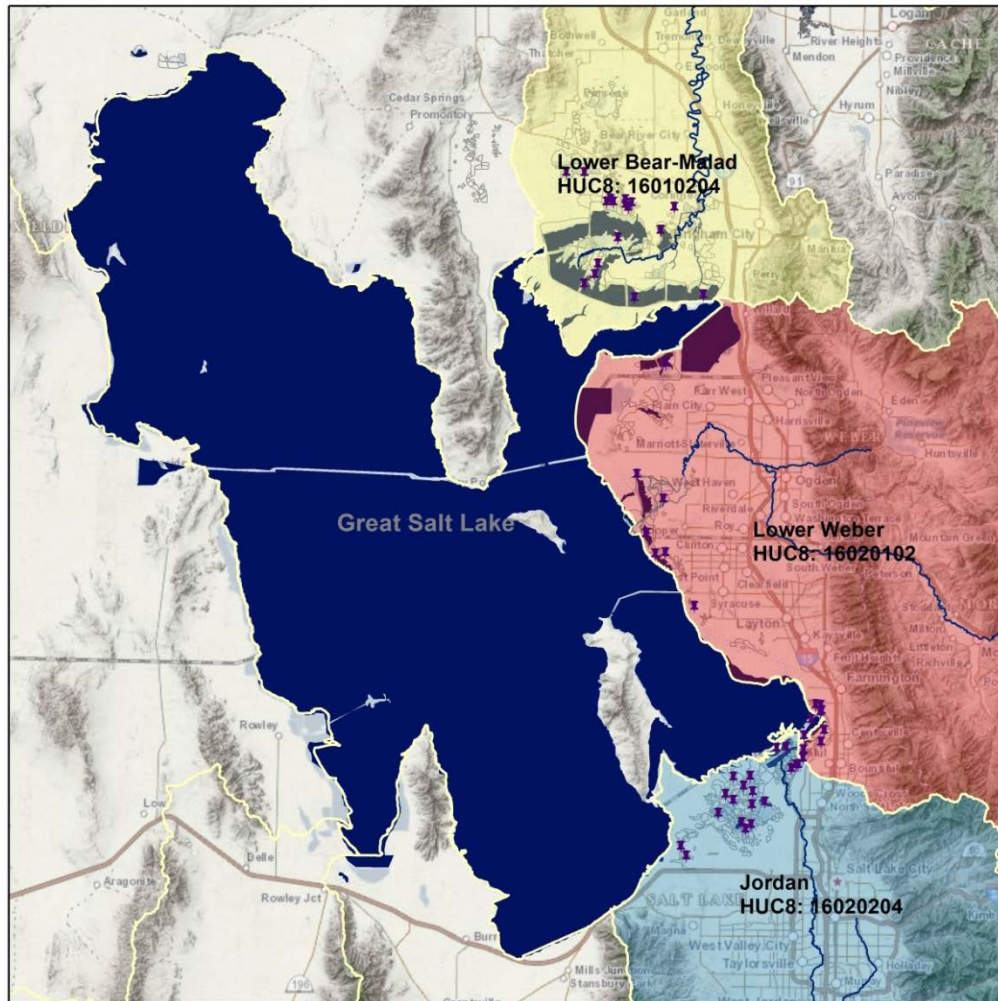
<sup>7</sup> [www.willardspur.utah.gov/research/sciencedocs.htm](http://www.willardspur.utah.gov/research/sciencedocs.htm)

other GSL wetlands<sup>8</sup>. As IW sampling and analysis methods are verified by subsequent work, the assessment framework will ultimately be used to evaluate the extent to which designated uses of IWs are currently being supported; i.e. by protecting and maintaining surface waters for waterfowl, shorebirds, and other water-oriented wildlife, including the necessary aquatic organisms in their food chain (UAC R317-2-6.3). The approach to exploratory data analysis presented in this chapter consists of three steps:

Step 1: Evaluate the distribution of response metrics among wetlands associated with Bear River, Jordan River, and Weber River watersheds (Figure 4-2). To do this, cumulative distribution functions (CDFs) of response variables were generated, using the R-package SPSurvey (Kincaid and Olsen, 2013).

Step 2: Evaluate the extent to which various stressors are able to differentiate IWs in GOOD vs. POOR conditions classes. Comparisons were made by generating side-by-side boxplots that display the distribution of each stressor for the subset of sites that were in either GOOD or POOR biological condition (Appendix 2).

Step 3: Develop an integrated measure of wetland condition, or ecosystem health, based on the response metrics, and then display the results as an MMI.



**Figure 4-2. Major subwatersheds that contribute surface water to Great Salt Lake.**

<sup>8</sup> <http://www.deq.utah.gov/ProgramsServices/programs/water/wetlands/index.htm>



## INDICATORS OF WETLAND CONDITION

### Submerged Aquatic Vegetation

SAV is an important element to waterfowl-focused wetland management (Miller and Hoven, 2007; DWQ, 2009; USFWS, 2009). Previous work on GSL wetlands has shown SAV to be sensitive to variations in water quality, which makes it a potentially valuable indicator of human-caused stress. The observation of early senescence (or decline) of SAV in some wetland ponds before the arrival of migratory waterfowl in early autumn, particularly for desirable plant species such as *Stuckenia pectinata* (sago pondweed), was considered to be an important element of the health of these wetlands (Miller and Hoven, 2007). An Index describing the seasonal pattern of SAV growth was calculated, based on a weighted average of SAV cover during both summer and early autumn index periods where early autumn cover was given twice the weight of summer SAV cover to reflect the importance of high SAV cover for waterfowl later in the growing season. This metric separates out three patterns commonly observed for SAV cover within IWs: 1) extensive cover (> 65%) of SAV swards that persist across both index periods; 2) SAV cover that declines rapidly, or ‘tanks’ prior to the second index period; and 3) little to no SAV cover (< 20% of pond area).

### Surface Mats

Extensive cover of surface mats has been reported to occur in some GSL wetlands and may provide value as an indicator of degraded conditions to recreation or biological designated uses (Miller and Hoven, 2007; DWQ, 2009). Results from a recent econometric survey of Utah duck hunters suggest that hunters are concerned about the occurrence and potential impact of several environmental conditions on waterfowl habitat and hunting, including algal mats, *Phragmites* encroachment, and water reallocation away from wetlands (Duffield et al., 2011). The surface mat metric is represented by the relative cover of algae or floating aquatic vegetation (e.g., *Lemna*) on the pond surface during the early autumn index period, in an effort to examine whether the incidence and size of surface mats within IWs could affect the recreation use or the narrative standard for GSL IWs.

### Benthic Macroinvertebrates

Common macroinvertebrates found in IWs associated with GSL are similar to taxa observed in other western wetlands (Apfelbeck, 1999; DWQ, 2009; Gray, 2009a; Gray, 2012). Aquatic benthic macroinvertebrate metrics are derived from community composition data and include 1) relative abundance of invertebrates expected to be strongly associated with SAV as plant-associated macroinvertebrates (PMI); and 2) Simpson’s Index (SI). PMI includes the relative abundance of invertebrates among the following taxonomic groups: Ephemeroptera (mayflies), Odonata (dragonflies and damselflies, excluding the genus *Aeshna*), *Hesperocorixa* spp., *Ylodes* sp., and *Gyraulid*, based on work by Dr. Larry Gray (Gray, 2009a, 2012, 2013). PMI is structurally similar to other metrics designed to detect the effects of urbanization on freshwater wetlands in California (Lunde and Resh, 2012).

### Indicators of Wetland Stress

More than 100 candidate physical, chemical, and biological metrics were measured as potential stressors to GSL IWs, including chemical constituents of surface water and wetland sediments. Metrics were grouped into three stressor classes representing cultural eutrophication, physical habitat, and toxic compounds. A partial list

of potential stressor metrics is presented in Table 4-1. Analytes and metrics representing stress from cultural eutrophication include both dissolved and total nutrients, sediment extractable nutrients, field measures of water column dissolved oxygen (DO) concentration and pH, as well as chemical-based MMIs (see DWQ, 2009 and Appendix 1). Initial metrics for physical habitat include wetland area, proportion of wetland area occupied by emergent marsh (or other wetland type), water depths and water salinity, and the observed presence of benthivorous fish (e.g., carp). Metrics indicating stress from toxic constituents include dissolved (water column) and sediment (cold-acid leachate) concentrations of trace elements, and water column concentrations of undissociated hydrogen sulfide and ammonia. These stressor metrics will continue to be evaluated for their ability to help characterize the magnitude, duration, and extent of human disturbance-related stress, and will ultimately be incorporated into a disturbance gradient for GSL wetlands. Subsequent work will incorporate rapid assessment metrics from UGS-led efforts to assess condition of emergent wetlands into DWQ's assessment frameworks for IWs and fringe wetlands.

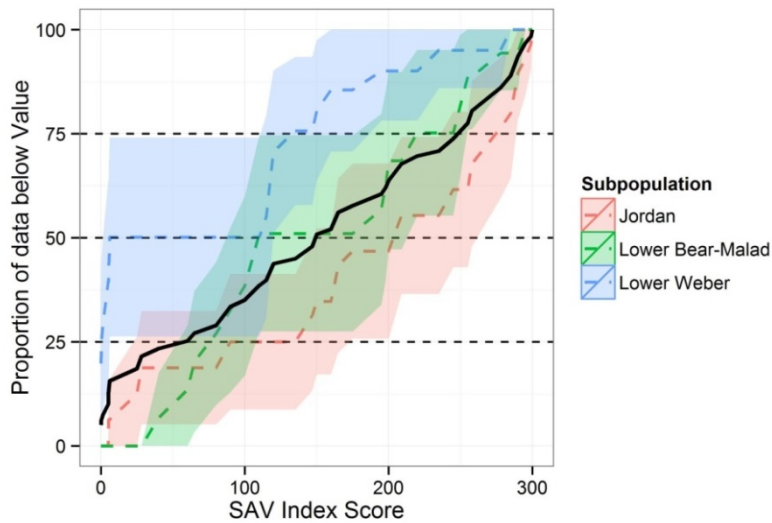
## BIOLOGICAL RESPONSES TO STRESS

The following section describes characteristics of the three main response indicators previously considered important to GSL IWs (SAV, surface mats, and macroinvertebrates), including the distribution of values among subwatersheds and breakpoint values for GOOD vs. POOR condition classes. Differences between GOOD and POOR condition classes for a suite of potential stressor metrics are presented in Appendix 2. A description of how CDF and boxplot figures can be interpreted is included in Box 1. Response: Submerged Aquatic Vegetation.

Figure 4-3 illustrates the range of SAV index scores observed for the three subwatersheds and for the GSL study area as a whole. SAV index scores were based on total SAV cover and condition class, where SAV cover for the second index period was given twice the weight of the first index period, as long as the SAV condition score was 2 or greater (i.e. not senescent). This scoring is intended to highlight the greater importance of healthy SAV in early autumn for waterfowl beneficial use support.

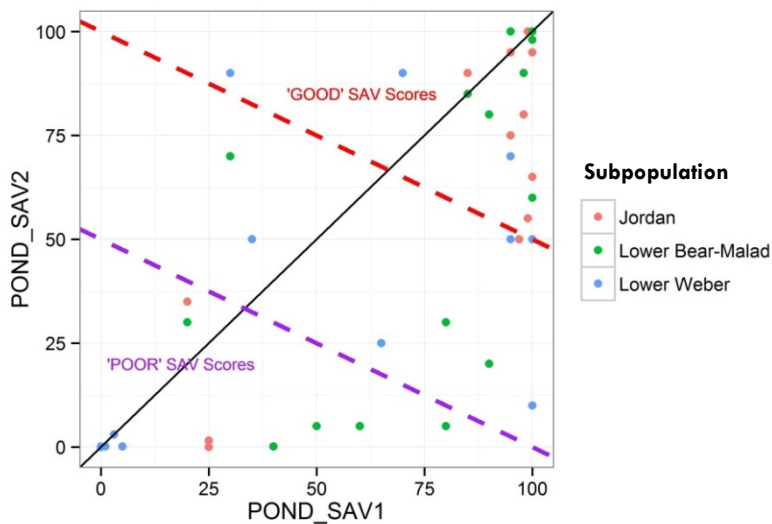
Multiple factors can influence SAV cover across the growing season including both natural sources of variation (e.g., climatic variability) as well as potential responses of SAV growth to several elements of wetland stress. This survey reports on the observed range of biological response indicators collected within one year (2012), over two index periods. As such, interannual effects are minimized. DWQ also worked to constrain the breadth of index periods as much as feasible; the median difference between sampling dates was 51 days (interquartile range of 18 days). DWQ is continuing to monitor indicators of wetland condition for several major wetland types, and across multiple years, to allow for the evaluation and improvement of DWQs assessment of Utah's wetland resources.

IWs in the Lower Weber River subwatershed had lower SAV index scores than IWs in the Jordan or Lower Bear River subwatersheds. As a starting point for evaluating the relative health (i.e., condition) of these wetlands on the basis of persistent SAV, breakpoints for GOOD and POOR condition classes of the SAV Index, calculated from 75<sup>th</sup> and 25<sup>th</sup> percentiles, are 248.75 and 68.75, respectively.



**Figure 4-3. Cumulative distribution functions of SAV index scores. CDFs for each subwatershed (subpopulation) are shown as colored dashed lines, with shaded areas as 95% confidence intervals. Weighted CDF for all sites is shown as the black solid line. Horizontal dashed lines highlight the 25th, 50th (median), and 75th percentiles of data.**

Figure 4-4 illustrates how total SAV cover differs among subwatersheds and between summer (SAV1) and early autumn (SAV2) index periods. Highest quality ponds occur in the upper right corner of the figure. Ponds of concern, particularly those that show a large reduction in SAV cover between index periods, lie along the lower portion of the figure. Few sites fall along the 1:1 line, illustrating the idea that total SAV cover in summer is a poor predictor of cover in early autumn.

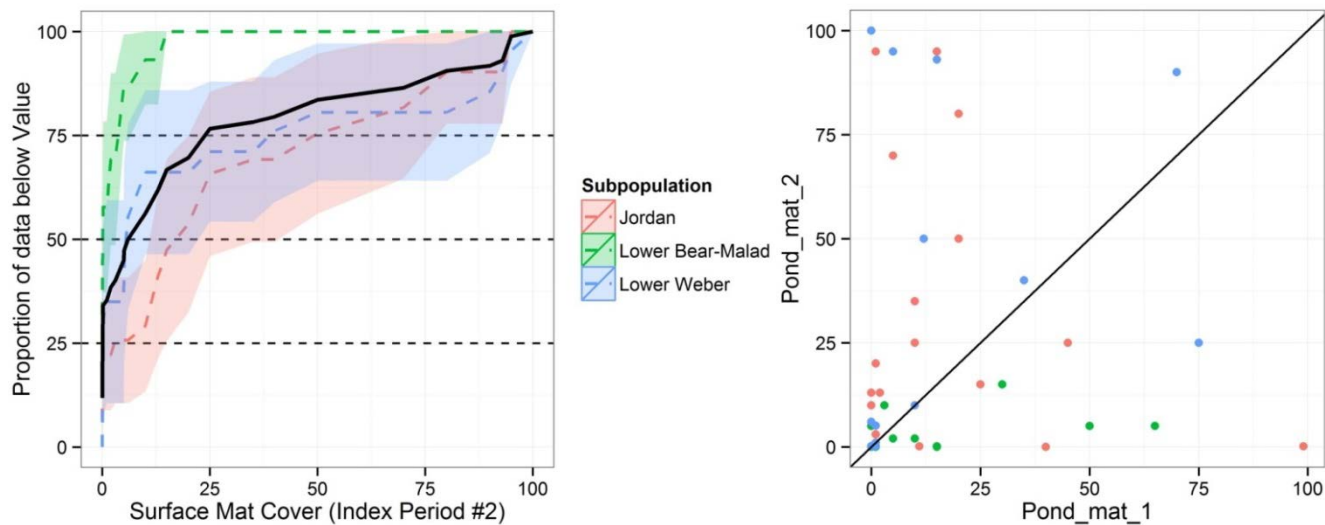


**Figure 4-4. Total SAV cover from summer (x-axis; SAV1) versus early autumn (y-axis; SAV2). Black diagonal line represents the 1:1 line, where summer SAV cover equals early autumn cover. The upper (red) and lower (purple) dashed lines indicate breakpoints for the GOOD and POOR classes of the SAV index. Data points in the lower right portion of the figure have higher SAV cover in summer than early**

autumn, while the converse is true for points in the upper left portion of the figure.

### Response: Surface Mats

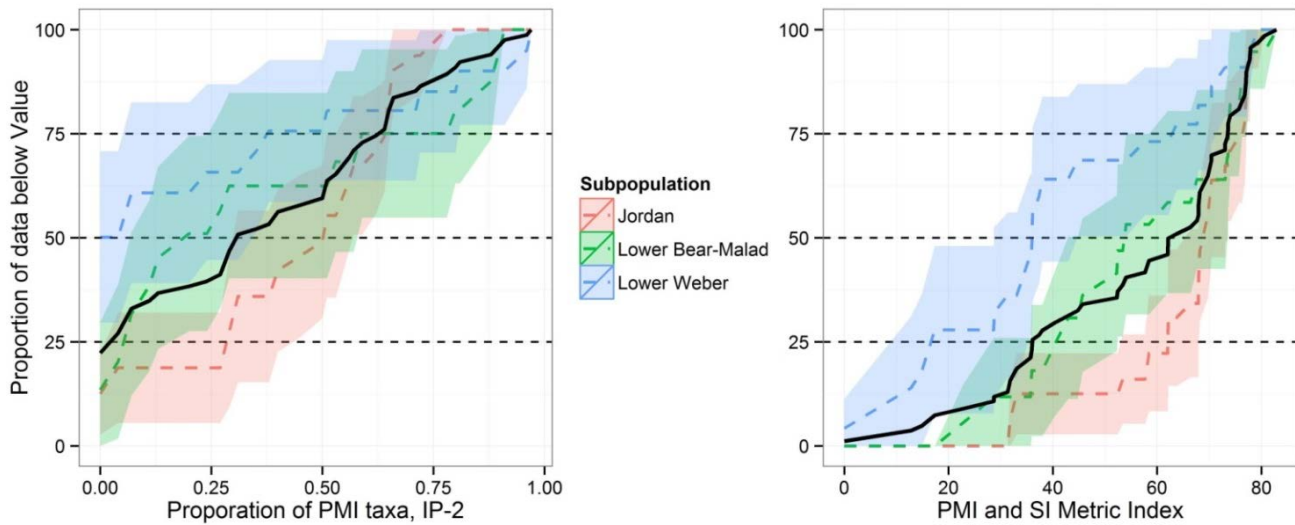
The CDFs for cover of surface mats (macroalgae and/or *Lemna* sp.) during the early-autumn index period (Figure 4-5, left) show that few ponds had extensive cover of surface mats (75<sup>th</sup> percentile of all sites was approximately 25% cover), and these sites were primarily within the Lower Weber and Jordan River subwatersheds. Lower Bear River subwatershed had the lowest extent of surface mat cover among ponds. Breakpoints for GOOD vs. POOR condition classes are calculated as less than 1% cover and greater than 25% cover, respectively. The scatterplot for surface mats (Figure 4-5, right) shows that extensive surface mats were generally uncommon in the ponds during both index periods, and that mat cover was poorly correlated between IPs among ponds.



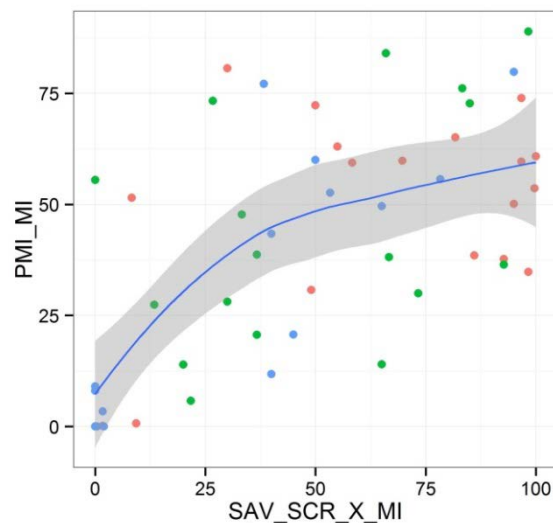
**Figure 4-5. CDF for cover of surface mats during the early autumn sampling period (left), and scatterplot of surface mat cover (right) between summer (x-axis) and early autumn (y-axis). Note that higher values of surface mat cover indicate a more degraded ecological state, whereas lower values of cover are preferred.**

### Response: Benthic Macroinvertebrates

CDFs for indices describing macroinvertebrate communities are shown in Figure 4-6. Both metrics are scaled to increase with increasing ecological condition (i.e., supportive of beneficial use). For PMI values (left), nearly all sites with POOR condition were located in the Lower Weber subwatershed, sites with GOOD condition occurred in the Lower Bear-Malad and Lower Weber subwatersheds. Combining SI and PMI into a macroinvertebrate MMI (right) increased the separation among subwatersheds, where the Lower Weber subwatershed was the main contributor to POOR condition classes, based on the PMI+SI MMI, while sites with GOOD condition classes were found mainly in the Jordan and Lower Bear-Malad subwatersheds. PMI and SI indices were poorly correlated ( $r^2 = 0.32$ ), and most of the variation in SI was observed for PMI values less than 0.30, suggesting that these two metrics are describing distinct aspects of the macroinvertebrate community. In addition, PMI increased with SAV Index (Figure 4-7), supporting the goal for biological assessments (and MMIs) to extend across multiple trophic levels (*sensu* Karr and Chu, 1997).



**Figure 4-6. CDFs describing the distribution of two indices of macroinvertebrate community composition: PMI (left) and a composite metric index of PMI and SI (as 1-D) (right), based on early autumn data and calculated as an MMI (see Appendix 2).**



**Figure 4-7. Scatterplot of PMI vs. SAV index scores, with both indices scaled as MMIs.**

### Common Patterns between Response and Stressor Metrics

The sensitivity of biological response metrics to specific stressor metrics was evaluated for GSL IWs by comparing the distribution of stressor-metric values between GOOD and POOR response metrics, as described above. A subset of stressor-response pairs is included for all three response metrics in Appendix 2. A brief description of notable stressor-response interactions is presented below.



**Response: Submerged Aquatic Vegetation**

The SAV index response metric was not sensitive to variations in summer or early autumn water depth or salinity (Figures A2-1 and A2-2), two potential covariates of IW health. GOOD sites had greater DO concentrations and pH than POOR sites, consistent with greater primary production, but SAV scores were insensitive to variation in total or dissolved nutrient concentrations (Figures A2-3 to A2-5). Most striking among stressors that were evaluated were the lower concentrations of total suspended solids (TSS) and higher percent organic matter of TSS in GOOD vs. POOR sites.

**Response: Surface Mats**

The cover of surface mats in early autumn was not sensitive to variations in water depth, but was inversely associated with specific conductivity (Figure A2-11), such that sites with greater cover of surface mats generally had lower conductivity (or were less saline) than sites with low surface mat cover. The surface mat metric was insensitive to variations in DO, pH, and chlorophyll *a* (Figures A2-12 to A2-13), as well as nutrients; however, sites with low surface mat cover had much lower dissolved organic carbon and dissolved organic nitrogen concentrations than sites with extensive mats (Figure A2-17). Interestingly, sites with greater surface mat cover also tended to have greater cover of SAV (Figure A2-20).

**Response: Benthic Macroinvertebrates**

Finally, condition classes based on macroinvertebrate metrics were insensitive to water depth and salinity (Figures A2-21 to A2-22), while GOOD sites had greater DO and pH than POOR sites, similar to the pattern for SAV metrics. Moreover, GOOD sites had greater SAV index scores (Figure A2-30), higher cover of surface mats (Figure A2-29), and slightly greater total invertebrate biomass (Figure A2-31), suggesting that these biological responses may be useful indicators of wetland condition across multiple trophic levels. Similarities between macroinvertebrate and other biological response metrics (between GOOD and POOR condition classes) could result from a variety of complex ecological processes, including trophic interactions, and could remain the subject of ongoing study.

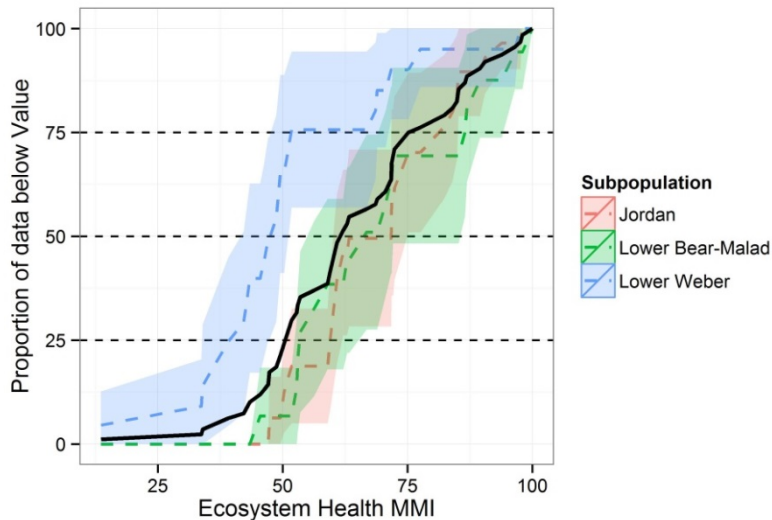
## ECOSYSTEM HEALTH - AN INTEGRATED MEASURE OF IMPOUNDED WETLAND CONDITION

The SAV, surface mat, and macroinvertebrate metric indices were combined into an integrated metric of IW condition. This metric, termed the ecosystem health MMI, is a rescaled linear combination of the response variable metrics described above. Ecosystem health MMI values ranged from 14 to 100, representing a broad range of ecological response across the three sets of metrics. Breakpoints for GOOD vs. POOR condition classes were calculated as greater than 75 and less than 50, respectively. Ecosystem health MMI CDFs (Figure 4-8) show that few ponds had scores less than 40, and that ponds within the Lower Weber subwatershed had lower scores than ponds from the other two subwatersheds.

## CONCLUSIONS

Substantial progress has been made in Utah's Wetland Program over the last decade, particularly with regard to the development of field protocols and assessment tools that evaluate the health of wetlands associated with GSL. Most recently, DWQ worked closely with UGS to develop a sample frame for GSL IWs. This spatial information was used to develop a probabilistic survey of GSL IWs, with technical assistance from

EPA, and it is a key component of watershed-based biological assessments of aquatic resources. Field data collection efforts resulted in updated field standard operating procedures, and the data were used to validate a previously developed assessment framework for IWs, based on the MMI approach (CH2M HILL, 2014). This assessment framework provides the basis for the results presented here.

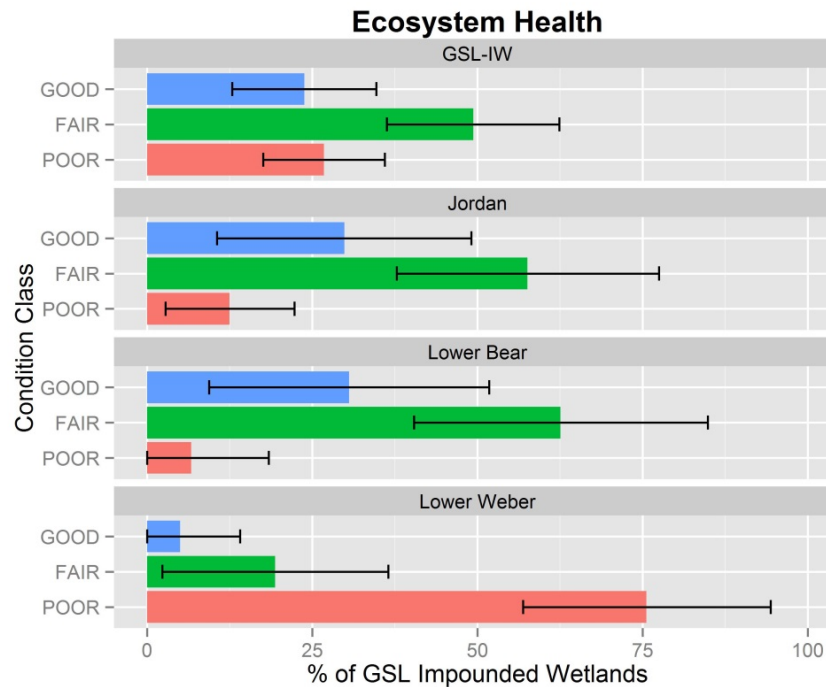


**Figure 4-8. CDFs describing the distribution of the ecosystem health MMI, which is a composite of the SAV, macroinvertebrate, and surface mat indices.**

Three key measures of the biological integrity of IWs were identified that span multiple trophic levels: seasonally weighted SAV cover, early autumn cover of surface mats, and a macroinvertebrate MMI based on community composition and plant-associated taxa. These metrics were evaluated based on statistical properties of the response variable data, because all IWs associated with GSL are human-made; as such, there is no currently available set of reference standard sites to be used as a baseline. Instead, BAC was defined for the survey results, based on the upper 75<sup>th</sup> and lower 25<sup>th</sup> percentiles. GOOD vs. POOR condition classes were then used to examine potential stressor-response relationships (Appendix 2).

This analysis revealed that desirable scores for SAV and macroinvertebrate metrics, indicating GOOD ecological condition, tended to be positively associated with higher DO concentrations and pH values, and greater organic matter (vs. mineral) contributions to TSS. In addition, the development of surface mats (considered a negative biological response) was largely restricted to waters with low-salinity and higher TP concentrations.

Integration of these metrics into an ecosystem health MMI revealed important patterns of wetland condition among subwatersheds (Figure 4-9). Specifically, one subwatershed (Lower Weber River; bottom panel of Figure 4-9) contained most of the lowest-scoring (i.e., POOR) IW sites, whereas the GOOD sites were evenly distributed among both the Jordan and Lower Bear River subwatersheds.



**Figure 4-9. Relative abundance of IWs among condition classes for all GSL IWs (top), and three subwatersheds (lower three figures), based on ecosystem health MMI. Error bars are 95% confidence intervals.**

## Next Steps

DWQ is actively pursuing projects that continue to develop, test, and refine wetland condition assessment frameworks for GSL wetlands. Two aspects of Utah's wetland assessment and reporting program have been identified for improvement over the short term. The first aspect is to identify and characterize the natural range of variation of reference standard sites for both impounded and fringe wetlands. This effort will improve our ability to compare wetland condition metrics among sites as well as subwatersheds, by providing a clearly defined and quantifiable upper bound for measures of ecological integrity. The second aspect involves a closer examination of stressor metrics, particularly how they can be integrated among a wide suite of chemical, biological, and physical indicators. There is a clear need to scale site-specific wetland water- or sediment-based measurements with more spatially integrated measures of stress (e.g., identified from rapid assessment checklists). This effort would support development of a human disturbance index for the GSL area, following on other aquatic resource assessment efforts such as Utah's comprehensive assessment of stream ecosystems or the national Wadeable Stream Assessment programs.

DWQ's Wetland Program is currently working to broaden the scope of wetland assessments to a second wetland class associated with GSL (fringe wetlands) and has identified a need for the development of appropriate sensitive, representative, and defensible tools that assess the health of these wetlands and their biota. DWQ is currently evaluating potential response metrics for fringe wetlands and anticipates having a draft assessment framework by 2016. All efforts to date are supported by funds to DWQ from competitive grants from EPA Wetland Program Development Grants.

## APPENDICES

- 1 IW assessment methods
- 2 Sensitivity of response variables to variation in stressor metrics

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