CHAPTER 3 STATEWIDE ASSESSMENT

2014 Integrated Report

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Chapter 3 Statewide Assessment

INTEGRATED REPORT

INTRODUCTION

Since the Clean Water Act (CWA) was passed in 1972, the U.S. Congress, the American public, and other interested parties have asked national, state, and tribal water quality agencies to examine and describe the water quality conditions of U.S. waterbodies. In fact, Section 305(b) of the CWA requires programs that have primacy administering water quality within their borders to report the water quality conditions to congress. These requests include seemingly simple questions:

- ***Is there a water quality problem?***
- ***How extensive is the problem?***
- ***Which environmental stressors affect the quality of the nation's waters, and which are likely to be most detrimental?***

Typically, these requests are covered through "routine" monitoring of local, popular waters through an annual survey. These strategies have led to a human bias of visiting waters of a certain size or location, which has skewed the condition of a relatively small sample size. However, to answer these questions in a statistically valid manner, Environmental Protection Agency (EPA), other federal agencies, states, and tribes decided to collaboratively use probabilistic surveys as the primary tool (EPA, 2006). However, EPA and states are still developing reporting tools and methods to populate the Assessment and Total Maximum Daily Load (TMDL) Tracking and Implementation System (ATTAINS), which is the national database for storing and distributing state's assessment results. For 2014, the 305(b) component will be populated utilizing the categorical results and from the 303(d) assessment for lakes and rivers.

Designing Statewide Assessments

From 2000 through 2009, DWQ participated in two surveys of the nation's rivers and streams: the Wadeable Stream Assessment[1] (WSA) and the National Rivers and Streams Assessment[2] (NRSA). Additionally, there was a survey of the nation's lakes called the National Lake Assessment[3] (NLA) conducted in 2007. The sampling design for these surveys was probability-based rather than hand-selected. In other words, locations were randomly selected yet balanced across the landscape. These surveys (think census) provide statistically valid water quality conditions for the population of U.S. rivers, streams, and lakes with a known confidence. Through this probabilistic design, the state was able to use the results of samples collected in Utah (Figure 3-1) to determine the condition of the rivers, streams, and lakes in a statistically valid manner. The results of this analysis provide a clearer assessment of the physical, chemical, and biological quality of rivers, perennial streams, and lakes across the state.

[1] http://water.epa.gov/type/rsl/monitoring/streamsurvey/index.cfm
[2] http://water.epa.gov/type/rsl/monitoring/riverssurvey/riverssurvey_index.cfm
[3] http://water.epa.gov/type/lakes/lakessurvey_index.cfm

What issues are addressed by the national water assessments?

1. ***Report the percentage of rivers, streams, and lakes in the state that are categorized as "GOOD," "FAIR," and "POOR" physical and chemical condition.***
2. ***Describe the biological conditions of these waterbodies using direct measures of aquatic life.***
3. ***Identify and rank the relative importance of chemical and physical stressors impacting aquatic life.***

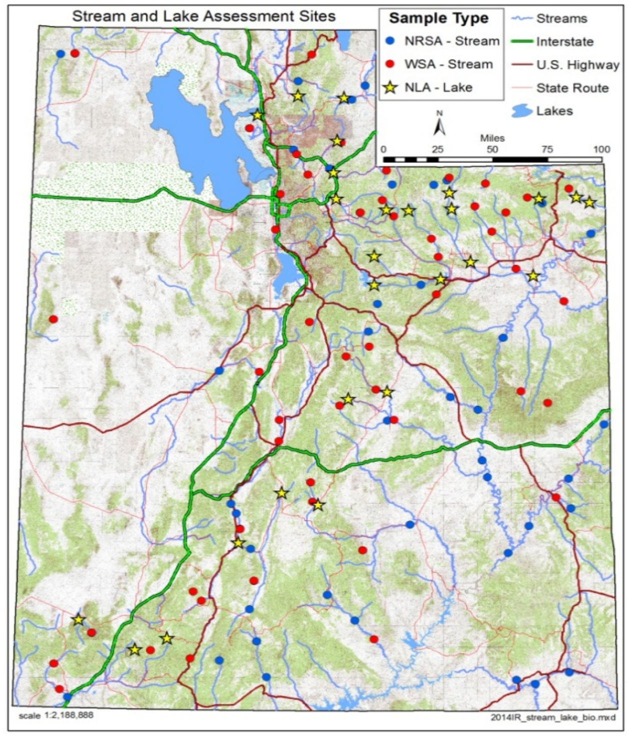

Figure 3-1. Map of river, stream, and lake locations.

Why Focus on These Waters?

Rivers and streams form a network that carries water to all parts of the state, and they are used and valued for many diverse purposes. Most of the state's (and nation's) waterways are smaller stream systems that form a linkage between the land and water. In fact, approximately 90% of stream miles in the United States are small streams. However, Utah is also home to three major rivers: the Colorado, Green, and San Juan. Lakes are an important source for drinking water, recreation, and irrigation. In addition, these types of surveys aren't limited to streams and lakes. There are probability-based national surveys for wetlands and estuaries that will be reported in upcoming reports.

How were Utah's Sampling Sites Chosen?

Utah's sampling locations were selected using a probabilistic survey design. These survey designs are used in a number of disciplines (e.g., election polls) when a population of interest is too large or too cost-prohibitive to sample all components (Utah has ~ 30,000 stream and river miles). For the selection of streams, all Utah streams were ordered based on stream size (i.e., Strahler stream order), length, and location. For lakes, there are about 650 lakes/reservoirs that are named in Utah and likely that many more that are unnamed, small lakes located in remote areas. Lakes were classified into five size categories: 4–10 hectares, 10–20 hectares, 20–50 hectares, 50–100 hectares, and > 100 hectares. However, due to the unique saline environment of Great Salt Lake, it was omitted from the design. Sites were selected using a random sampling technique so that each site was assigned a probability of being selected based on the above attributes. This ensures that the full range of diverse streams and lakes have a chance of being selected, and limits the bias toward any particular region or waterbody size. The unbiased site selection ensures that assessment results represent the condition of most waterbody types throughout the state. The streams and rivers were selected with Utah as the target population; whereas the lakes were selected within Utah's two Level III ecological regions (ecoregions): Western Mountains and Xeric (Figure 3-2).

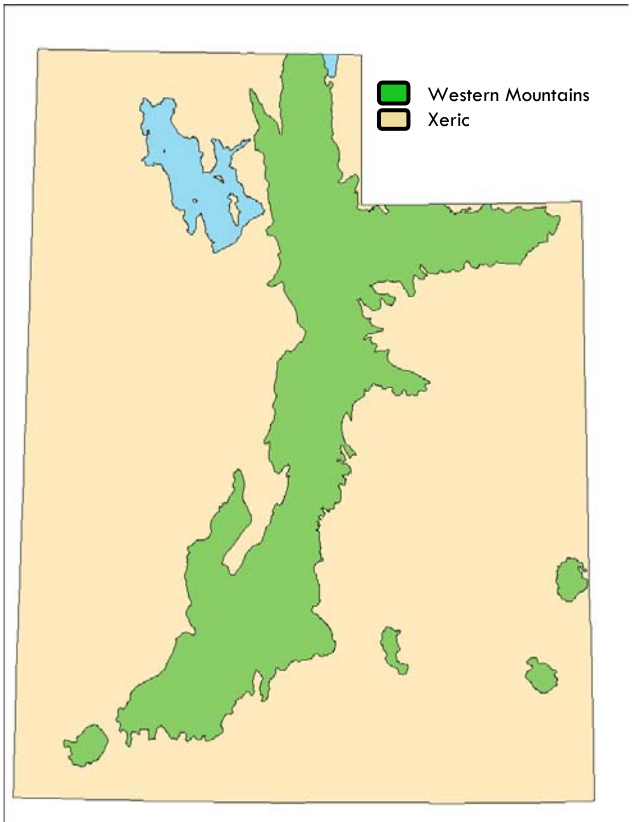

Figure 3-2. Aggregated Level III Omernik ecoregions used for statewide and WMU assessments (Omernik, 1987). Ecoregions were used to link random sites to the appropriate reference site thresholds (EPA, 2006).

How were the Waters Assessed?

For rivers and streams, sites were sampled by a two- to four-person field crew between May and September. Using standardized field protocols (SOPs) to reduce collection variability between field persons, crews positioned a sample reach and 11 sampling transects within the sampling reach at 100 site locations (50 sites WSA/50 sites NRSA) throughout Utah (see Figure 3-1). For lakes, sites were sampled by two-person crews between May and September at 26 lakes across the state. Most sites were accessible by a road so that sampling the site was relatively easy. However, packing equipment was required to reach some remote sites.

All water and biological samples were sent to EPA-approved laboratories for analysis. Additional data collection efforts also included documentation field forms, which included measurable field data and observational information about the physical characteristics of the waterbody and the adjacent areas.

For the rivers and streams statewide assessments, the two surveys (WSA and NRSA) were combined to increase the level of statistical power. For measures with DWQ water quality standards (e.g., chemical measures), those values were used as thresholds. For measures that lacked water quality standards (e.g., physical stressors), thresholds were created based on reference site data from the West-wide WSA and made specific for the Western Mountains and Xeric ecoregions (Figure 3-2). Those thresholds were typically the 95th and 75th percentiles of reference to create three condition categories. When applied to the data, the thresholds categorized each measure for the sites into GOOD (i.e., within range of reference condition), FAIR (i.e., disturbed), and POOR (i.e., most disturbed).

Further reading

For more information on how DWQ collects data, please refer to DWQ's division-wide SOPs, *Strategic Monitoring Plan* (SMP), and *Quality Assurance Project Plan* (QAPP).[4]

[4] http://www.deq.utah.gov/Compliance/monitoring/water/qaqc.htm

THE CONDITION OF UTAH'S STREAMS

Utah examines the chemical, physical, and biological integrity of its state's waters through a set of commonly used and widely accepted indicators. Although this report does not include an analysis of every possible stressor known to affect water quality, it does evaluate those measures found to be best water quality indicators across the range of natural and human-influenced conditions. This section describes the indicators used to assess the condition of Utah's rivers and streams as well as major stressors to aquatic life. The three major results from the statewide rivers and streams assessment are as follows:

1. ***Indicators of biological stress (e.g., benthic macroinvertebrate [BMI] observed/expected [O/E] ratio of taxa loss)***

2. ***Aquatic measures of stress (e.g., chemical and physical habitat stressors)***

3. ***Ranking of stressors (e.g., the relative extent and severity of stressors that affect biologic condition)***

Indicators of Biological Stress

Stream ecologists evaluate the biological condition of streams by examining the organism communities that live in the streams. Specific aspects of the biologic community such as the composition, abundance, or life history traits of the organisms can be measured to determine the overall impact that stressors are having on that community. DWQ focuses its water quality assessments on two animal communities: BMIs and fish.

Using a dataset that provided the type and number of taxa (e.g., the lowest practical taxonomic resolution to which individuals are identified), DWQ used two indicators of biological condition to interpret the results from state laboratories and taxonomists:

- ***O/E ratio of BMI taxa loss***

- ***Fish index of biological integrity (fish IBI)***

Benthic Macroinvertebrate Observed/Expected

Because Utah does not have numeric biological criteria, outputs generated from models are used to guide assessments under the narrative standards for biological assessments of the Utah Clean Water Act (Utah Administrative Code [UAC] **R317-2-7.3**.[5]). To quantify the biological integrity in Utah, DWQ uses the River Invertebrate Prediction and Classification System (RIVPACS) model approach: a method that predicts the expected macroinvertebrate community that exists based on known predictions of collecting specific taxa linked to specific climatic, geologic, and physical characteristics at any river or stream location. To quantify biological conditions, a RIVPACS model compares the list of taxa that are observed (O) at a site to the list of taxa expected (E) in the absence of human-caused stress (e.g., a reference site collection). In practice, these data are expressed as the ratio O/E.

O/E quantifies the loss of biodiversity and is easily interpreted because it simply represents the extent to which taxa have become locally extinct as a result of human activities. For example, an O/E ratio of 0.70 implies that, on average, 30% of the taxa have become locally extinct as a result of human-caused alterations to the stream. The condition thresholds developed for Utah are < 76% taxa loss is GOOD, 69%–76% taxa loss is FAIR, and > 69% taxa loss is POOR.

[5] http://www.rules.utah.gov/publicat/code/r317/r317-002.htm#T9

Why sample bugs and fish?

Measuring biological communities such as macroinvertebrates and fish has the direct advantage of integrating the cumulative effects of multiple stressors on a waterbody. This allows a direct examination of how stressors are affecting the condition of a stream ecosystem (Karr, 1981). Moreover, because aquatic macroinvertebrates and fish spend most of their lives in aquatic environments, they are capable of integrating the effects of stressors over time, providing a measure of the past and present conditions (Karr and Dudley, 1981).

Fish Index

The fish IBI is a quantitative measure used to estimate whether the river or stream has a healthy fish community. The index relies on characteristics of the fish community found at the site such as the percentage of certain fish taxa present, percentage of certain life history traits such as feeding and spawning, and percentage of pollution-tolerant and -intolerant fish. The comparisons are represented by fish communities found in least-disturbed reference locations. Utah DWQ uses the Fish IBI for statewide and watershed probabilistic surveys. Although fish IBIs are used more comprehensively by other states, Utah's fish community diversity is relatively small, which limits its application to other water quality programs. Additionally, the reference sites used to create the fish IBI were mostly limited to cooler, wadeable creeks, whereas the sites used in this survey cover larger waterbodies across a larger thermal gradient.

Figure 3-3 represents the biological conditions in the rivers and streams across Utah. The BMI O/E scores indicate that nearly 80% of waters are in GOOD condition for BMI communities. On the other hand, nearly 60% of waters are in POOR condition for fish communities. This higher number is likely due to the way in which the fish IBI was created using reference sites limited to wadeable streams. Therefore, the BMI O/E indicator will be used as the biological response for which the stressors will be compared and ranked.

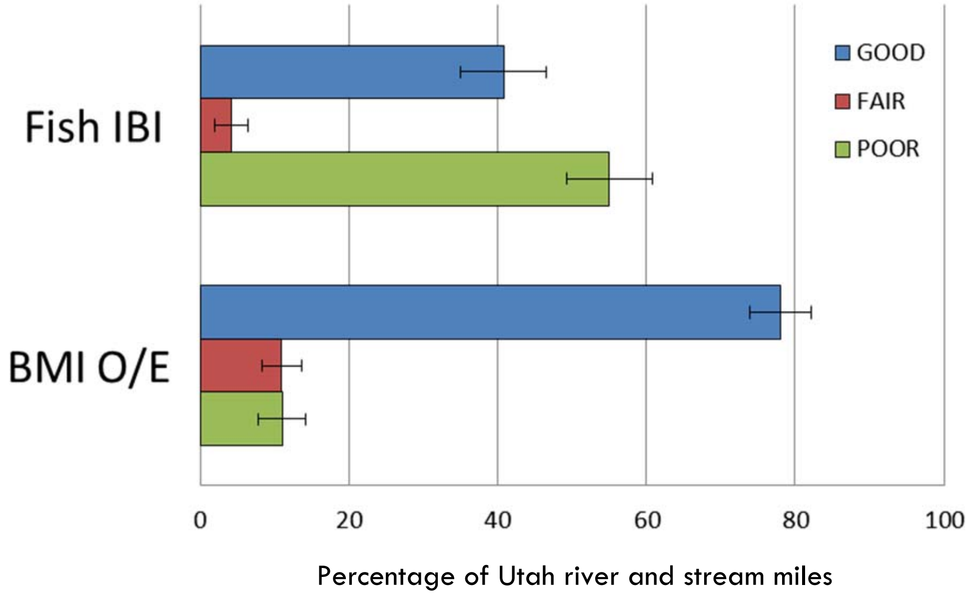

Figure 3-3. Percentage of Utah's river and stream miles in GOOD, FAIR, and POOR condition for response variables.

Chemical Stressors

Nutrients: Phosphorous and Nitrogen

Phosphorous and nitrogen are two chemical stressors identified by EPA and DWQ. Though nutrients occur naturally in surface waters and are necessary to support aquatic life, at high concentrations they can cause excessive primary production, which sometimes leads to low levels of oxygen in the water, which fish and other aquatic organisms need to survive. Excessive nutrients can also cause problems with taste, odor, and overall aesthetics, which impede recreation, reduce property values, and can lead to increased drinking water treatment costs.

Salinity

Salinity is a measure of salt dissolved in water. Salt (in its many forms) arrives in water through both natural and human-induced processes. Water quality agencies typically measure salinity by measuring chloride or specific conductivity as a surrogate. Chloride is a common component of salt and in most cases not concentrated enough to be directly toxic to stream biota, but it is often used as an indicator of urban pollution. Sources of chloride include road salt, septic tanks, wastewater systems, animal waste, fertilizers, and some natural sources. Additionally, Western landscapes are particularly prone to excess salts and minerals due to the dry climate. Furthermore, waters surrounded by areas of higher salt content can be further harmed by certain irrigation practices.

Sediment

Sediment in the water column is measured by total suspended solids (TSS), which is a measure of the weight of solids that are suspended in water. High TSS concentrations can lead to high rates of sedimentation in streams, and can indicate general pollution. Geology, soils, and stream geomorphology can all account for natural variation in background TSS concentrations in a stream. Although sediment in the water column is not typically fatal to stream biota, excess concentrations impair respiration and eventually settle into the streambed, which chokes out habitat needed to fulfil the lifecycle.

Figure 3-4 illustrates the condition of streams and rivers in Utah with respect to the chemical stressors measured in the water. Nutrients, both phosphorus and nitrogen, account for the largest percentage of streams miles with POOR (i.e., excessive) concentrations. Sediment has the second highest percentage of stream miles having POOR concentrations. However, salinity, generally considered a problem in Western states, has a limited extent of POOR stream miles in Utah.

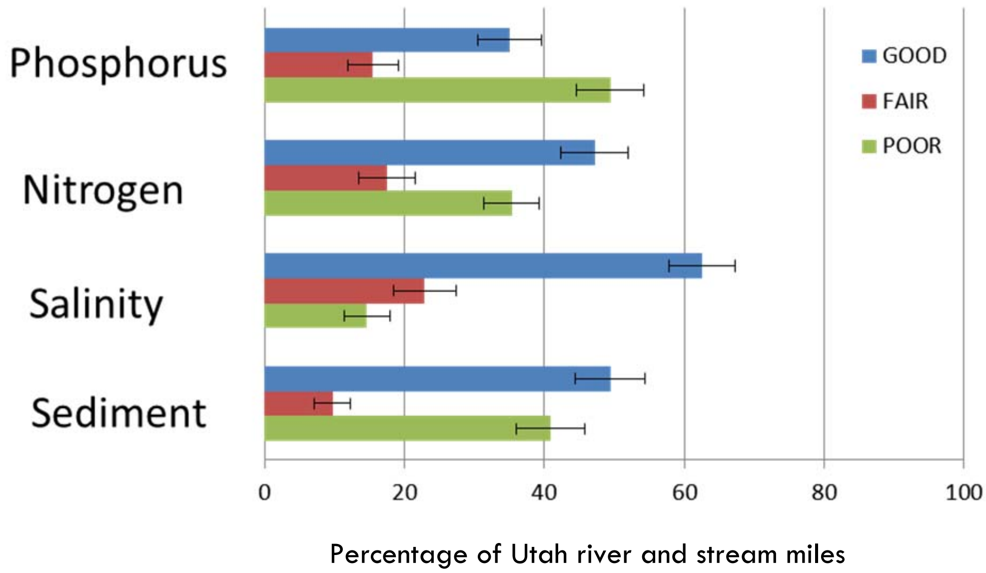

Figure 3-4. Percentage of Utah's river and stream miles in GOOD, FAIR, and POOR condition for chemical stressor measures.

Physical Stressor Metrics

Physical stressors were collected at each site along a longitudinal profile approximately 40 times the wetted width of the waterbody. The metrics used as measures of physical stressors include a variety of quantitative measures such as stream slope, bank angles, substrate size and density, riparian condition, and cover and in-stream habitats. For the complete list and details of these physical attributes and the full suite of measures and methods used for these surveys, please visit DWQ's website[6].

Sediments

Sediments on the stream bed are measured in numerous ways such as collecting systematic random samples at cross-sections and along the longitudinal thalweg (deepest part of channel), and visually estimating sedimentation (embededness) of stream substrate. As mentioned earlier, sediments are not typically directly toxic to stream biota, but cause physical displacement of habitat or reduce the ability of oxygen to reach organisms in the substrate.

[6] http://www.deq.utah.gov/Compliance/monitoring/water/docs/2014/05May/UCASE%20Field%20Manual_Master_2014.pdf

Hydrologic Function

Hydrologic function can be a loaded and difficult concept to understand, but in the most basic sense, the metric attempts to establish whether or not the physical nature of the stream (the banks, substrate, habitat, etc.) is in a relatively stable condition. Hydrology plays a significant role influencing this condition. For example: Is the stream receiving enough flow to flush fine sediments from the bed or is it receiving too much water at a rate beyond the existing capability (i.e., excess runoff)? Indeed, Utah has some extreme geologic features that may create conditions considered "POOR," but the thresholds for this indicator are specific for each ecological region. More often, the hydrologic function metric is measuring physical changes that have occurred in the watershed's landscape such as channel straightening, impervious surface creation, and vegetation removal.

Riparian Cover

The riparian cover metric includes measures of width and depth of the riparian area as well as canopy and ground cover. These measures are useful for understanding the riparian area condition of a waterbody. Riparian areas in GOOD condition are indicators of streams that have adequate runoff filtering and shading, stable banks, and habitat for aquatic organisms. Nearly 60% of Utah river and stream miles have GOOD riparian cover.

In-Stream Habitat

In-stream habitat measures the habitats that are suited for fish and other aquatic communities. These include measures of in-stream cover, substrate-type, and aquatic habitat types such as pools, glides, and riffles. Across Utah rivers and streams, this metric has the highest extent in POOR condition—over 40%.

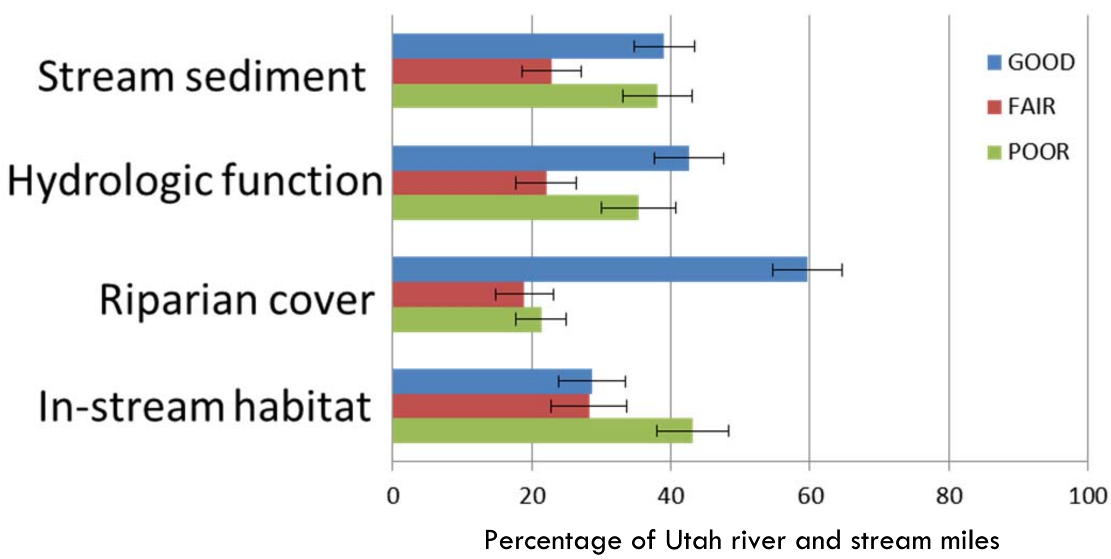

Figure 3-5. Percentage of Utah's river and stream miles in GOOD, FAIR, and POOR condition for physical stressor metrics.

Figure 3-5 illustrates the extent of conditions on the physical factors associated with streams and rivers in Utah. All four metrics are fairly distributed across condition categories. However, riparian cover appears more often in GOOD condition compared to other metrics. This distribution is not too surprising given the diversity of water uses and demands in the state. More important is how much of an influence each of these metrics exerts on creating POOR biological metrics. The answer to this question is evaluated in the Ranking Stressors section below.

Ranking Stressors

Relative Risk

To better manage the impact of potential chemical and physical stressors on Utah's rivers and streams, DWQ examined both the prevalence (i.e., the extent) and severity (i.e., the risk) of the chemical and physical stressors discussed above. This required examining the spatial extent of the stressor (compared to other stressors), the influence of the stressor on biological conditions (BMI O/E), and the level of influence the stressor has on creating POOR biological conditions. Reviewing the extent of stressors across a given region simply provides a snapshot of conditions on a rather limited number of sites. An excellent next step is to determine if there are linkages of these stressors to the condition of aquatic communities. Relative risk and attributable risk measure the strengths of relationships between a biological response variable and one or more stressor variables, where all variables are categorical descriptions of condition GOOD, FAIR, and POOR, as noted above. The risk is the probability that a river or stream will be in a POOR biological condition, given that it is also in POOR condition for a stressor. This is expressed relative to the risk of the stream having POOR conditions of aquatic biota given that the stressor is not in POOR condition. Therefore, a relative risk of 1 is equal to the null value, and values > 1 increase the strength of the effect.

The calculation is accomplished by examining the extent of the stressors and ranking the stressor according to the proportion of the stream length that is in POOR condition. The relative risk (or severity of the effects) of the stressor utilizes the same relative-risk ratio used in the medical field. For an example, EPA relates how doctors use the same relative-risk ratio to determine if a person with a certain cholesterol level has a risk of developing heart disease (e.g., a person with a total cholesterol level greater than 300 milligrams [mg] is four times more likely to develop heart disease than a person with a total cholesterol level of less than 150 mg) (EPA, 2006).

The left and center charts in Figure 3-6 contain eight metrics evaluated at each site. The chart on the left illustrates the extent of all stressor metrics categorized as "POOR" across the state. The chart in the center ranks the relative risk of each stressor to the biological condition, in this case BMI O/E. The top stressor linked to POOR aquatic communities is the hydrologic function metric, followed by salinity and nitrogen. This is actually not too surprising because other states have discovered the same strong relationship (e.g., Virginia Department of Environmental Quality) between hydrologic functions and aquatic life condition. It is interesting to note that although POOR conditions of salinity are not widespread across the state, instances where it occurs appear to strongly affect biological condition.

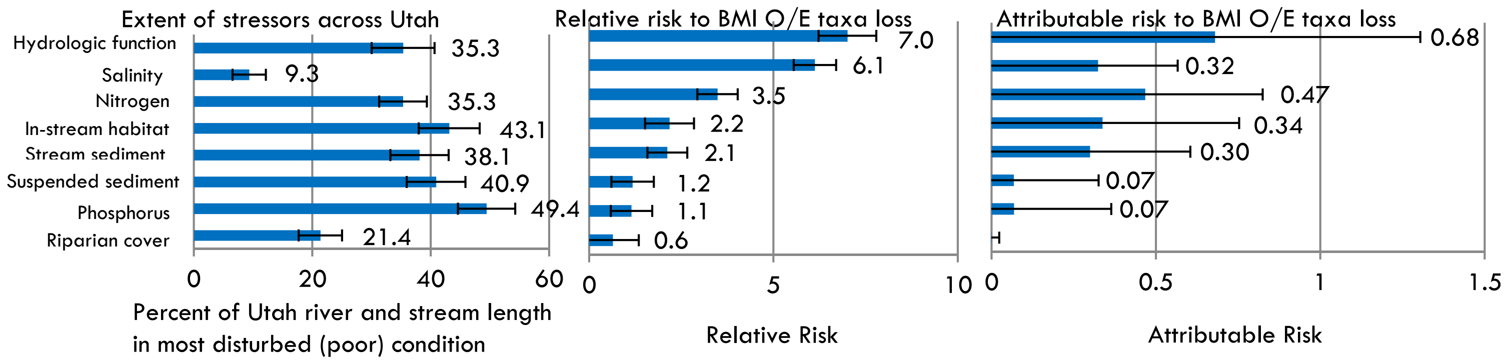

Figure 3-6. Extent, relative risk to biological condition, and attributable risk of stressors across Utah rivers and streams.

Attributable Risk

Attributable risk (AR) is the standardized product of the stressor's extent and the relative risk. Thus, the attributable risk measures the overall impact of a stressor on the biological response variable throughout a river or stream population. The attributable risk for a stressor can be interpreted as the proportional reduction in the POOR condition of aquatic biota that would be achieved by eliminating that stressor from all streams. To eliminate a particular stressor is to assume all rivers and streams in POOR condition for that stressor are restored to not POOR (i.e., FAIR or GOOD). Although, this attributable risk scenario carries presumptions of cause and effect on a biological response, the scenario is still a useful exercise for evaluating stressors (Van Sickle, 2014). The chart on the right in Figure 3-6 provides the ranking of stressors in Utah that if eliminated, could provide the best recovery to aquatic biota. The hydrologic function and nitrogen stressors are the top two (recall relative risk ranking above), and are likely the best candidates to target additional monitoring and protection for other waterways. Also, bear in mind, that although this exercise combines two surveys, the standard error of attributable risk for these stressors is still very high in this dataset. Typically, attributable risk calculations improve when surveys include more than a couple hundred sample locations. Nonetheless, these rankings appear genuine, given that other states and the national survey have discovered similar results. The Next Steps section below describes how DWQ plans to improve the confidence in these results.

Next Steps

The statewide rivers and streams surveys revealed a few observations that will be used as a baseline hypothesis for further investigation. From this rivers and streams statewide survey, excess nutrients emerged as affecting a significant percentage of river and stream miles. Nitrogen in particular, occurred in the top three relative and attributable risk stressors in the survey. DWQ is already collecting additional nutrient data where biological conditions are considered POOR and enacting programs to provide additional protections against excess nutrients[7]. Additionally, since 2009 DWQ has been collecting probability-based data intensively throughout the six management units covering the state. Each year through 2015, a new unit is surveyed. Preliminary results have been calculated for the first three basins, and when the data for the final three basins are available, those results will be reported. Obviously, as these probabilistic data are collected, the certainty of the patterns observed in the first statewide surveys will become clearer.

[7] http://www.nutrients.utah.gov/

THE CONDITION OF UTAH'S LAKES

As mentioned in the stream/river section above, DWQ examines the chemical, physical, and biological integrity of lakes through a set of commonly used and widely accepted indicators. Although this report does not include an analysis of every possible stressor known to affect lake water quality, it does evaluate those measures found to be best water quality indicators across the range of natural and human-influenced conditions. This section will provide a description of the indicators used to assess the condition of Utah's lakes and major stressors to aquatic life. The three major results from the statewide lake assessment are as follows:

1. ***Indicators of biological stress (e.g., plankton O/E ratio of taxa loss)***
2. ***Aquatic measures of stress (e.g., chemical and physical habitat stressors)***
3. ***Ranking of stressors (e.g., the relative extent and severity of stressors that affect biologic condition)***

Indicators of Biological Stress

The NLA survey focused on collecting biological data on three types of organisms: phytoplankton, zooplankton, and diatoms. Phytoplankton is a term representing the floating, microscopic organisms that use photosynthesis to obtain energy. More commonly referred to as "algae", phytoplankton in Utah lakes are mostly composed of diatoms, green algae, and cyanobacteria (blue-green algae). The green color of some waters is due to the pigment, chlorophyll, used by phytoplankton to absorb solar rays. The higher the density of phytoplankton, the more green a lake becomes; therefore, chlorophyll (specifically, chlorophyll *a*) is used as a surrogate measure for phytoplankton growth (i.e., primary productivity). Due to the range of environmental conditions in lakes, there is a large diversity of phytoplankton that tolerate or specialize in conditions that benefit them most. Zooplankton are the small animals that consume phytoplankton. They play an important role transferring the energy produced by the phytoplankton to larger organisms such as fish. Like the phytoplankton, the zooplankton community is reflective of the environmental conditions of the water and change when disturbances occur. As mentioned above, diatoms are a group of algae found in all Utah waterbodies. They are a widespread and highly diverse group, with estimates of 100,000 species on Earth. Diatoms are particularly special in that their cell wall is composed of silica. Although they may be short-lived, when diatoms decompose, the unique shape of the silica cell wall remains. This feature allows investigations to compare current communities to those buried deep in the sediments of time.

Two biological measures were created during the analysis of the national lakes assessment survey: a plankton O/E measure and a sediment diatom IBI. Although both measures were equally effective at describing lake conditions, the O/E measure proved to be more effective describing differences across lake types (natural lakes and impoundments), whereas the sediment diatom IBI was most effective for natural lakes. However, because Utah's survey was composed of only four natural lakes, it was decided that the following would be used:

- ***Plankton O/E ratio of taxa loss***

Plankton (zoo/phyto) Observed/Expected

Similar to the RIVPACS model approach that was used in identifying changes to the macroinvertebrate community in the rivers and streams, an O/E model was generated specifically for the region that encompasses Utah (combined Western Mountains and Xeric Level III ecoregions) and predicts the expected plankton community. However, this measure combined the two planktonic communities found in the lakes: phytoplankton and zooplankton. Again, as explained in the rivers and streams section, the O/E compares the list of taxa that are observed (O) at a lake to the list of taxa expected (E), which is determined from environmentally similar yet least-disturbed reference sites. The condition thresholds developed for this measure are < 20% taxa loss is GOOD, 20%–40% taxa loss is FAIR, and > 40% taxa loss is POOR.

An additional measure of biological response—the condition class of chlorophyll *a*, a surrogate measure of primary production—was included to provide conditions in a productivity context. Like rivers and streams, excess primary production in lakes can lead to low oxygen conditions that negatively affect fish and other desirable organisms.

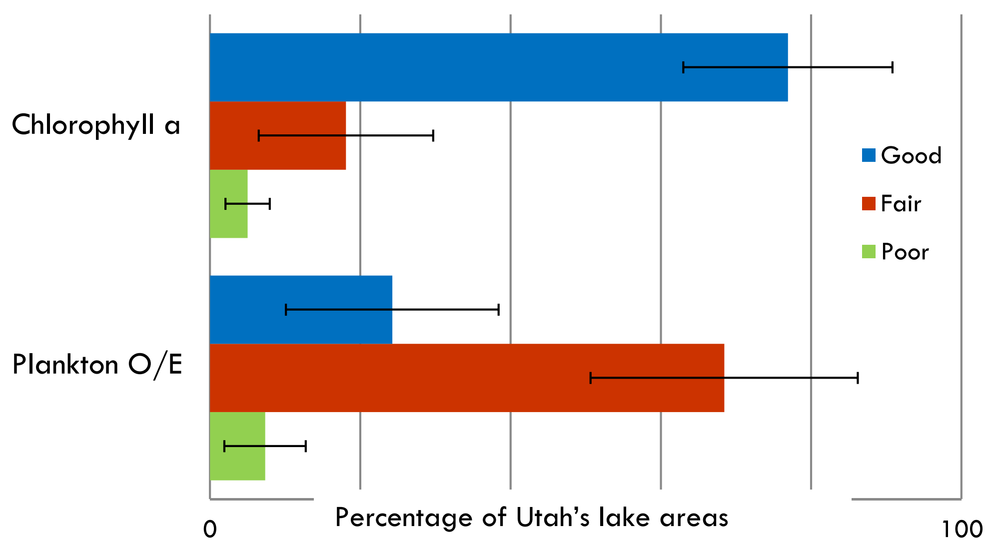

Figure 3-7. Percentage of Utah's lake areas in GOOD, FAIR, and POOR condition for response variables.

Figure 3-7 illustrates the extent of GOOD, FAIR, and POOR conditions for measures of plankton taxa loss and chlorophyll *a* concentration. Overall, 25% of lake areas are considered in GOOD condition for taxa loss. However, the largest portion of lake area (~ 70%) is in FAIR condition. Less than 10% is in POOR condition. Nearly 80% of Utah lakes are in GOOD condition for primary production growth (chlorophyll *a* concentration). However, there 5% are in POOR condition and potentially susceptible to low oxygen conditions. In the chemical stressor paragraph below, dissolved oxygen will be evaluated individually.

Chemical Stressors

Dissolved Oxygen

Dissolved oxygen (DO) in water is a critical requirement for the aquatic life in lakes. Although there is an optimal oxygen range for each organism (DO levels > 5 mg/L are considered sufficient), DO measures < 3 mg/L indicate a higher likelihood that conditions that would suffocate aquatic life exist. In Utah, nearly 100%

of lakes are in GOOD condition for DO; and only 1% is considered in FAIR condition. None of the lakes sampled had conditions where low DO was a concern.

Salinity

Salinity is a measure of salt dissolved in the water. Salt (in its many forms) arrives in water through both natural and human-induced processes. Water quality agencies typically measure salinity by measuring chloride or specific conductivity as a surrogate. Sources of salinity include road salt, septic tanks, wastewater systems, animal waste, fertilizers, and natural sources such as high mineral soils. Additionally, western landscapes are particularly prone to excess salts and minerals due to the dry climate. In Utah, salinity is typically only a concern in smaller, shallow lakes due to higher evaporation and subsequent concentration of the minerals, but these circumstances are not common and typically already lack aquatic life. Furthermore, only lakes with a depth greater than 3 meters are included in these surveys. The majority of lakes surveyed (~ 98%) have GOOD conditions for salinity; only a small percentage (~ 5%) are in FAIR condition. No lakes were found to have POOR conditions of salinity.

Turbidity

Turbidity is a measure of light scattering commonly observed as the clarity of the water. Turbidity measures can be affected by levels of suspended particles in the water such as suspended sediments and algae. High readings of turbidity can correspond to high rates of sedimentation in lakes, as well as indicate an instable lake bottom lacking vegetation and/or excess algae. Geology, soils, and lake geomorphology can all account for natural variation in background turbidity. Although sediment in the water column is not typically fatal to aquatic life, excess concentrations limit light from penetrating to the lake bottom and reduce the type and density of aquatic vegetation. Utah had a high number of lakes in FAIR condition for turbidity, nearly 80%.

Nutrients: Phosphorus and Nitrogen

Phosphorous and nitrogen are two chemical stressors prioritized by EPA and DWQ. Although nutrients occur naturally in surface waters and are necessary to support aquatic life, high concentrations can cause excessive primary production, which sometimes leads to low oxygen levels in the water that fish and other aquatic organisms need to survive. Excessive nutrients can also cause problems with taste, odor, and overall aesthetics, which impede recreation, reduce property values, and can lead to increased drinking water treatment costs. In lakes, excess primary productivity leads to algal blooms typically dominated by cyanobacteria, which emit harmful toxins that have resulted in death to livestock and pets in the state. Additionally, when these conditions occur, the shading by the algal cover limits vegetation growth. Vegetation growth, especially in the shallow areas of a lake, is especially helpful to aquatic organisms and limits suspended sediments (for more, see the Physical Stressor Metrics section below). In Utah lakes, approximately 75% of areas have both phosphorus and nitrogen in FAIR condition. The high number indicates that a large proportion of lakes have elevated values of these nutrients, and may be at risk for affecting the water quality and biological life.

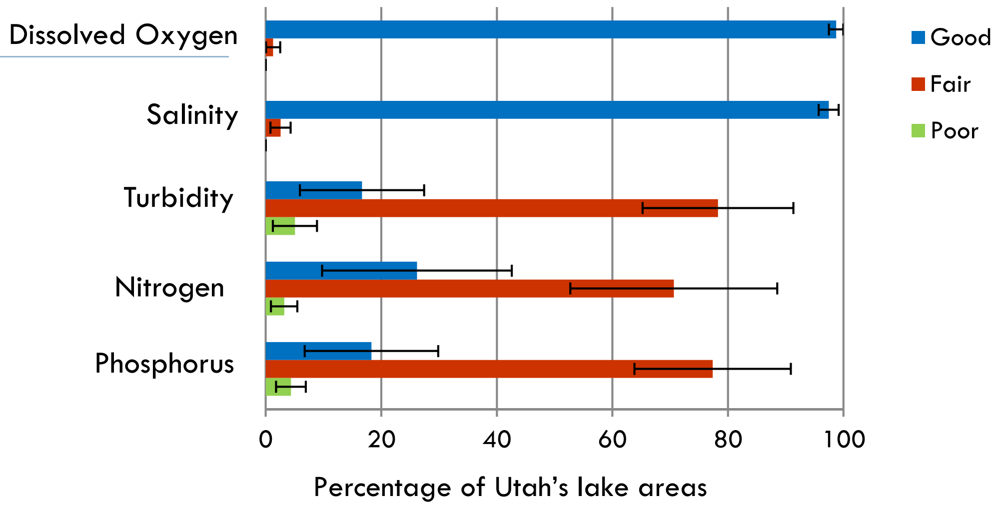

Figure 3-8. Percentage of Utah's lake areas in GOOD, FAIR, and POOR condition for chemicalstressor variables.

Figure 3-8 illustrates the condition of lakes in Utah with respect to the chemical stressors measured in the water. Overall, the chemical stressors measured revealed few lakes in POOR condition due to these stressors. However, nutrients, both phosphorus and nitrogen, and sediment (turbidity) account for large percentages (> 70%) of lake areas in FAIR condition. This indicates that these stressors are the most important potential threats that need attention.

Physical Stressor Metrics

Physical stressors were collected at 10 evenly spaced points around the perimeter of each lake. The metrics used as measures of physical stressors include a variety of quantitative measures such as bank angle and condition, substrate type, near-shore habitat and condition, and shoreline cover and condition. The thresholds for these measures are based on least-disturbed conditions for the specific region where the particular lake is located. For the complete list and details of these physical attributes and the full suite of measures and methods used for these surveys, please visit EPA's **NLA website**[8].

Lakeshore Habitat

The lakeshore habitat metric evaluates the amount and type of vegetation around the shoreline of the lake. Specifically, it is a combination of observational measures of vegetation canopy, mid-story, and ground cover surrounding the lake. Obviously, in Utah, there are lakes in some environments that cannot support the vegetation that are observed in this measure. The thresholds for these lakes are based on reference lakes in the same ecological region. Nonetheless, the measure is important because lakes with a complex of vegetation around the shoreline are typically in better ecological condition. In Utah, nearly 70% of lakes have lakeshore habitat in GOOD condition; however, about 20% are in POOR condition. Of the four physical habitat metrics evaluated in the lake survey, the lakeshore habitat metric has the highest extent in POOR condition in Utah.

[8] http://water.epa.gov/type/lakes/lakessurvey_index.cfm

Lakeshore Disturbance

The lakeshore disturbance metric evaluates the amount of human alteration that has occurred on the lakeshore. This includes measures of infrastructure development such as cabins, homes, roads, etc. to measures of modification of the shoreline itself such as retaining walls and vegetation removal. As mentioned in the lakeshore habitat metric above, lakeshores that have significant human modification normally have negative effects on the lake water quality and biological community. Across Utah lakes, nearly 80% have minimal to zero lakeshore disturbance, and about 5% are in a POOR lake disturbance condition.

Shallow Water Habitat

The shallow water habitat metric evaluates the complexity of the habitat within the near-shore (littoral) zone of the lake; typically, 10 meters out from the water's edge. Measures include the type and density of aquatic plants, woody snags, overhanging vegetation, and other features that contribute to a complex littoral habitat. This area of the lake is important for aquatic life because the sun's rays typically reach the lake bottom, prompting vegetation to grow. The vegetation provides food and cover for aquatic life to fulfill most or part of their lifecycle. Nearly 90% of the shallow water habitat in Utah's lakes is in GOOD condition.

Physical Habitat Complexity

The physical habitat complexity metric combines measures from the lakeshore and shallow water habitat metrics discussed above. Through evaluation of these metrics, it was discovered that when evaluated individually, the strength of response was not as strong as when the measures were combined as a more true, near-shore habitat complexity metric. This result will be explained more fully when discussing the relative extent and risk ranking below.

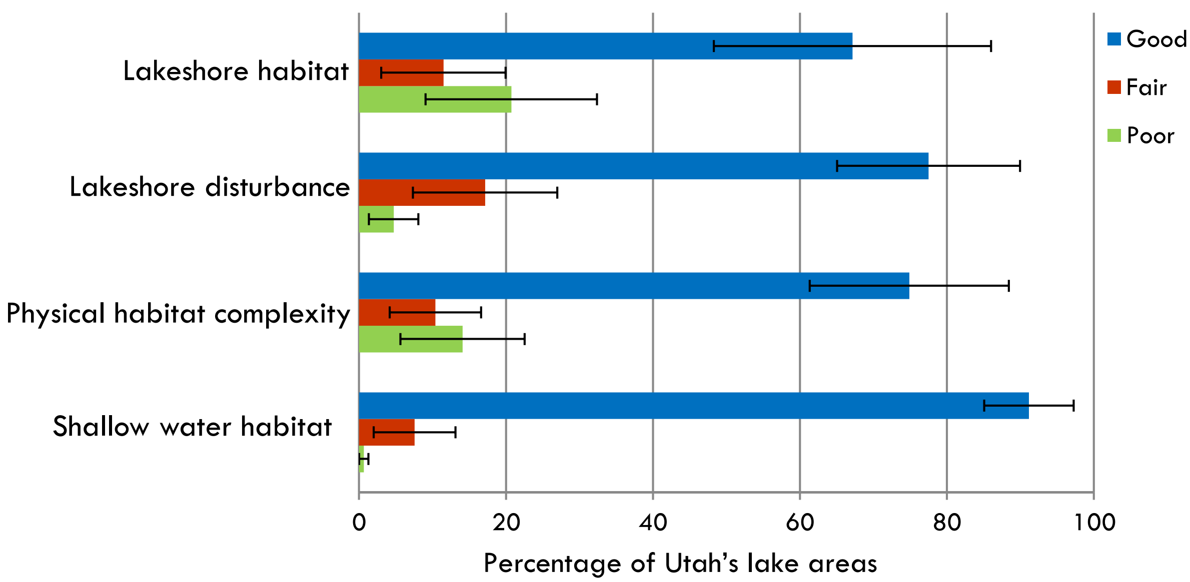

Figure 3-9. Percentage of Utah's lake areas in GOOD, FAIR, and POOR condition for physical stressor metrics.

Figure 3-9 illustrates the condition of lakes in Utah with respect to the physical stressors measured. The lakeshore habitat metric accounts for the largest percentage of lake area in POOR condition. However, most lake areas (>67%) are in GOOD condition for physical habitat.

Ranking Stressors

Relative and Attributable Risk

Similar to rivers and streams, DWQ examined both the prevalence (i.e., the extent) and severity (i.e., the risk) of the stressors (chemical and physical) for the lake survey. This required examining the geographic extent of the stressor (compared to other stressors), the influence of the stressor on the biological condition (plankton O/E), and the degree of influence the stressor has on creating POOR biological conditions. Reviewing the extent of stressors across a given region simply provides a snapshot of conditions on a rather limited number of sites. However, it is important to determine if there are linkages between these stressors to the condition of aquatic communities. Relative risk and attributable risk measure the strengths of relationships between a biological response variable (in this case plankton O/E) and one or more stressor variables, where all variables are categorical descriptions of "GOOD," "FAIR," and "POOR," as noted above. The risk is the probability that a lake will be in a POOR biological condition (plankton O/E), given that it is also in POOR condition for a stressor. This is expressed ***relative*** to the risk of the lake having POOR biological conditions given that the stressor is **not** in POOR condition. Therefore, a relative risk of 1 is equal to the null value (no effect), and values > 1 increase the strength of the effect by the stressor. It is calculated by examining the extent of the stressors and ranking the stressor according to the proportion of the lake area that is in POOR condition.

The left and center charts in Figure 3-10 contain four metrics evaluated at each lake. Only four metrics were reported because the other metrics did not have incidences linked to POOR biological condition. The chart on the left illustrates the extent of all stressor metrics categorized as "POOR" across the state. The chart in the center ranks the relative risk of each stressor to the biological condition; in this case, plankton O/E. By a large margin, the top stressor linked to POOR aquatic communities in Utah lakes is the physical habitat metric. Recall that the physical habitat metric is a combination of the riparian and shallow water habitat measures. Interestingly, stressor disturbances affecting the riparian and near-shore area of the lake are linked to taxa loss in the plankton community.

Recall that attributable risk is the standardized product of the stressor's extent and the relative risk. It is a measure of the overall impact of a particular stressor on the biological indicator. The chart on the right in Figure 3-10 illustrates the ranking of stressors in Utah lakes that, if eliminated, could provide the best recovery to lake plankton. The physical habitat measure ranks at the top (see relative risk ranking discussed above), and is clearly the best candidate to target additional monitoring and protection for other lakes. Similar to the results in the rivers and streams survey, the standard errors for attributable risks of these stressors are very high in this dataset. However, the rankings are very similar to the national survey results. The Next Steps section discusses how DWQ plans to improve the confidence in these results.

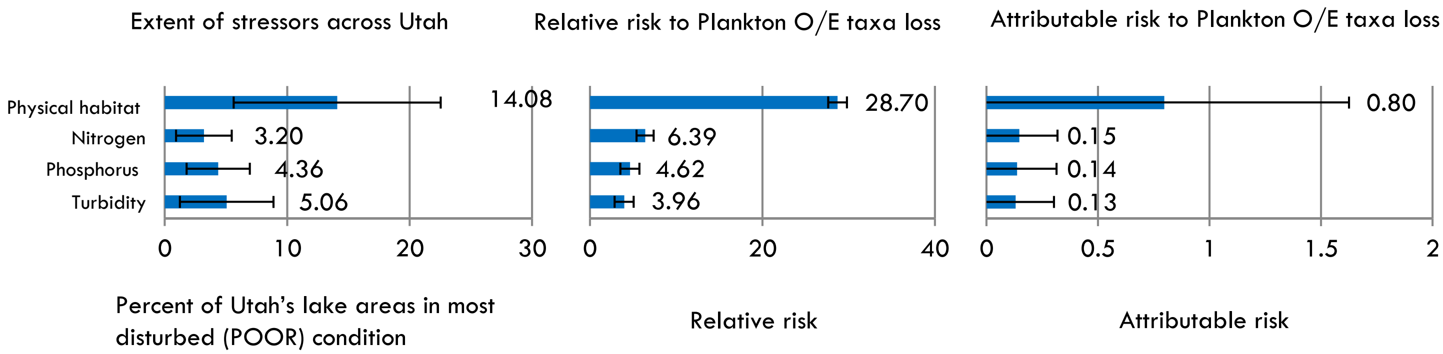

Figure 3-10. Extent, relative risk to biological condition, and attributable risk of stressors across Utah lakes.

Next Steps

Although this survey included a smaller dataset, the results provided an interesting and yet unbiased condition of the lakes in Utah. It revealed observations that will be used as a baseline for further investigation and as an initial report from which to build. In 2012, Utah DWQ participated in another NLA survey; however, the sample size was increased to 50 lakes statewide. When those data become available, they will be integrated into this survey and likely reported in the 2016 integrated report. DWQ plans to continue participating in the NLA surveys, which occur every 5 years. In the meantime, DWQ will begin integrating the results from this survey (i.e., significant metrics and required measures) into the monitoring strategy for lakes that are sampled annually in the state.

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