# CONSERVATION ASSESSMENT
*for*
# Walker Lake
*In*
# Mineral County, Nevada



*May 2013 Edition*

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# Acknowledgements

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# Executive Summary

The National Fish and Wildlife Foundation's (NFWF's) Walker Basin Restoration Program (referred to here as "the Program") was established by Congress as part of Public Law 111-85 to restore and maintain Walker Lake. The Program seeks to restore Walker Lake's ecological health through a comprehensive restoration strategy.

As part of this effort, the Program enlisted The Nature Conservancy (TNC) to produce the following Conservation Assessment to identify: the key conservation targets that comprise Walker Lake's ecosystem; the current condition of those targets; stresses to the targets; and strategies to abate the stresses.

This Assessment was produced according to TNC's Conservation by Design methodology (Conservation Action Planning (CAP)) (Appendix 2), and its findings are based on available literature and expert opinion gained through a series of planning workshops. The scope of this assessment is limited to the lake itself and its immediate catchment basin. The suite of conservation targets chosen through this process include:

- Lake ecosystem
- Native fish assemblage
- Water birds
- Freshwater marsh
- Riparian delta

The primary threat to the ecological health of Walker Lake is the depleted freshwater inflows, which have resulted in declines of the lake's elevation and volume and increases in salinity. Prior to the late 1800s, most of the water in the Walker River Basin flowed into Walker Lake. Since then, agricultural diversions have increased to the point that, except during flood flows, most stream flow is consumed by agriculture. As Figure 1 illustrates, total dissolved solids (TDS), the metric for salinity, have been steadily increasing in the lake for decades. Since 1927, the elevation of Walker Lake has declined by nearly 140 feet and the TDS levels have risen nearly 14,000 mg/l since the mid-1930s[1]. Due to an extremely low snowpack in the winter of 2011-2012, TDS rose to roughly 19,000 mg/l by fall 2012, the highest level yet recorded.

[1] It should be noted that the two major reservoirs on the system were completed in the late 1920s. The year after the reservoirs were completed marked the first year on record in which water from the headwaters did not reach Walker Lake.

**Figure 1.** Walker Lake elevation and TDS levels over time.

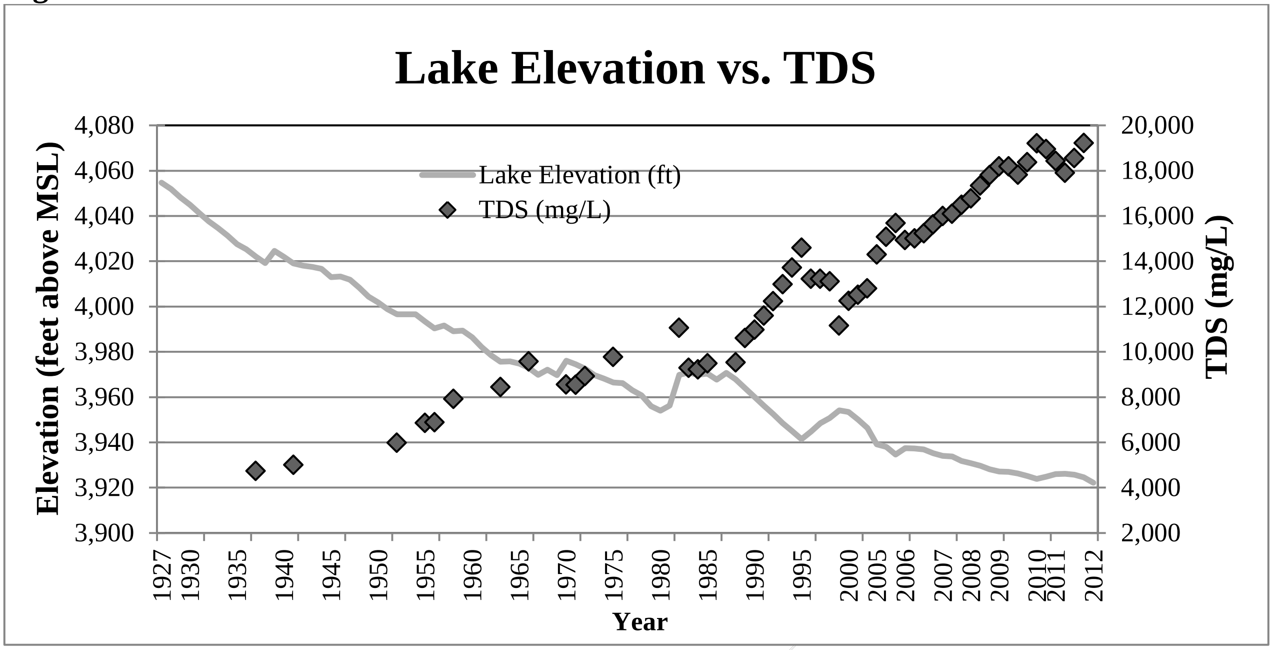


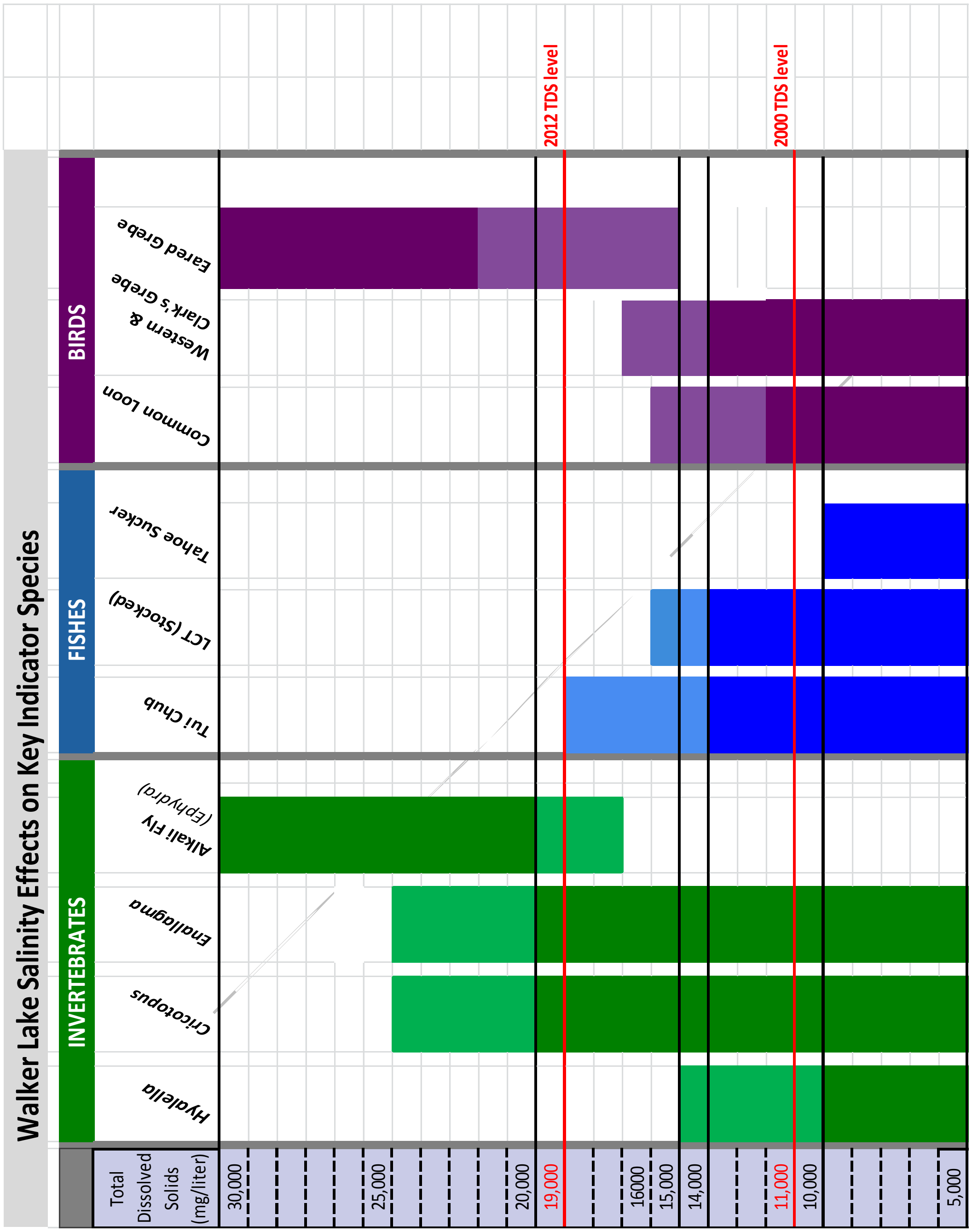

**Figure 2.** Water budget to maintain lake-surface altitudes between 3,952 and 3,986 feet at Walker Lake, Nevada. (Modified from Table 18 in Lopes and Allander, 2009)

| | Lake-surface elevation | | | |
|---|---|---|---|---|
| | 3,952 ft | 3,964 ft | 3,965 ft | 3,986 ft |
| TDS (mg/L) | 12,000 | 10,200 | 10,000 | 8,000 |
| Supplemental volume (acre-ft) | 700,000 | 1,100,000 | 1,200,000 | 2,000,000 |
| Supplemental Annual Inflow (acre-ft/yr) | | | | |
| Supplemental inflow (acre-ft/yr) | 26,000 | 35,000 | 36,000 | 53,000 |

Supplemental volume is the amount of water, in addition to current stream flow that reaches the lake, that is needed to raise lake-surface elevation from 3,931 feet (2008 elevation). Supplemental inflow is the amount of inflow in addition to current average annual inflows that is needed to maintain elevation. Stream and subsurface discharge into the northern end of Walker Lake currently totals around 110,000 acre-ft/yr (Lopes and Allander, 2009).

All of the priority conservation targets have been stressed by this change. Figure 3 indicates the key TDS thresholds that dictate the presence and health of key indicator species. The chart includes macroinvertebrates and macrophytes, as they represent key ecological indicators or bellwethers for monitoring lake-wide health as well as limnologic strata conditions, which drive almost all resulting vertebrate biological diversity in the lake. The current level of TDS in the lake suggests that several key species, including Lahontan tui chub, common loon, western and Clark's grebes, and two critical invertebrate species, are at risk of extirpation.

**Figure 3.** Walker Lake Salinity Effects on Key Indicator Species. Lighter shading in certain columns indicates a trend of decreasing abundance of the particular taxon. These are estimates and not absolute thresholds. The concept for this figure is attributed to D. Herbst (2012).




Additional stresses to the ecosystem include channel incision and head-cutting where the Walker River enters Walker Lake, due to the declining lake level; an invasion of the non-native salt cedar (tamarisk) plant along the river above the lake; and adverse impacts from feral horses on the important marsh area at the south end of the lake.

In light of the selected conservation targets and threats to those targets, the primary restoration strategy recommended in this assessment is to increase the quantity and quality of freshwater inflows to the lake.

NFWF's Program is designed to achieve this outcome through several mechanisms, which include but are not limited to the purchase and lease of water rights and the transfer of those rights for use at the lake. The ecological range for maximal viable native biodiversity of the lake is at a TDS level of between 9,500 and 13,500 mg/l. A U.S. Geological Survey water budget analysis estimated supplemental inflows and annual inflows to Walker Lake to maintain a range of surface elevations and TDS concentrations (see Figure 2, below) (Lopes and Allander, 2009). Water budgets were calculated for a range of supplemental inflows needed to maintain TDS concentrations at 8,000; 10,000; and 12,000 mg/l. It was estimated that approximately 700,000 to 2,000,000 acre-feet are needed to dilute the lake to these concentrations, and between 26,000 and 53,000 acre-feet/year of supplemental inflow are needed to maintain TDS concentrations between 8,000 and 12,000 mg/l. Years of supplemental inflow, above average inflow, or both, will be needed to raise the lake-surface elevation and dilute TDS concentrations (Lopes and Allander, 2009).

# Introduction and Scope

The primary purpose of the National Fish and Wildlife Foundation's (NFWF) Walker Basin Restoration Program ("Program") is to restore and maintain Walker Lake in a manner consistent with protection of the ecological health of the Walker River and the riparian and watershed resources of the West, East, and Main Walker Rivers (PL 111-85 Section 208(a)(1)). To help clarify the outcomes that the Program seeks to achieve, NFWF contracted with The Nature Conservancy (TNC) to develop the following Conservation Assessment for Walker Lake. The chief purpose of this assessment is to help inform the ecological outcomes anticipated with the implementation of the water rights acquisition program being led by NFWF to benefit the lake and associated riparian and watershed resources (PL 107-171 Section 2507(b) as amended)[2].

The document considers the broad context of the Walker Lake ecosystem, including the full range of conservation targets, threats to those targets, and reasonable conservation strategies that could be undertaken to mitigate those threats. In addition to serving NFWF's needs, the document is intended to provide information to partners in making water and land use management decisions that affect the lake, and provide information on expected outcomes as water is acquired and protected. To remain current, this document should be reviewed and revised in the future, based upon results of conservation actions undertaken and other exogenous changes, along with additional review and comments from partner organizations.

The mission of The Nature Conservancy is to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. *Conservation Assessment for Walker Lake* applies the methods of Conservation by Design (The Nature Conservancy, 2004), which draws upon the best scientific information available to identify a clear vision for conservation action and success.

Prior to this application, TNC had already used Conservation by Design to identify Walker Lake as a priority site for conservation within the Great Basin. TNC considers the preservation of Walker Lake to be critical to sustaining the biodiversity of the Great Basin ecoregion in perpetuity. The portfolio sites of the Great Basin are identified and described in *Great Basin: An Ecoregion-based Conservation Blueprint* (The Nature Conservancy, 2001). TNC entered into a contract with NFWF in July of 2011 to help identify strategic conservation targets and help refine the priority actions that will accomplish the overarching goal of delivering more water, thus reducing the trend of decline in the Walker Lake ecosystem.

The Walker River Basin comprises an area of approximately 4,050 square miles from the headwaters of the eastern Sierra Nevada to its terminus at Walker Lake (Figure 4). The basin has been subjected to extensive human impacts, including conversion of land for agriculture, diversion and pumping of water, introduction of invasive species, and construction of in-stream barriers. These impacts have altered the physical and biological integrity of the basin,

[2] Future assessments will focus on Mason and Smith Valleys and, largely, on the Walker Basin as a whole. These future assessments will help inform upstream activities associated with the Walker Basin Restoration Program, including restoration potential and possibly guiding acquisitions and revegetation efforts.

causing water-quality degradation, habitat fragmentation, geomorphic instability, and a decline of native fish populations.

The surface flows of the Walker River Basin leading to Walker Lake are primarily determined by: 1) the amount of water available in the headwaters of the East and West forks of the Walker River and their tributaries; 2) storage and managed releases from three major and several smaller reservoirs; and 3) diversion of surface water and groundwater (well) pumping, primarily in Mason and Smith Valleys, with significant surface water and groundwater use in Antelope Valley and surface water use in Bridgeport Valley.

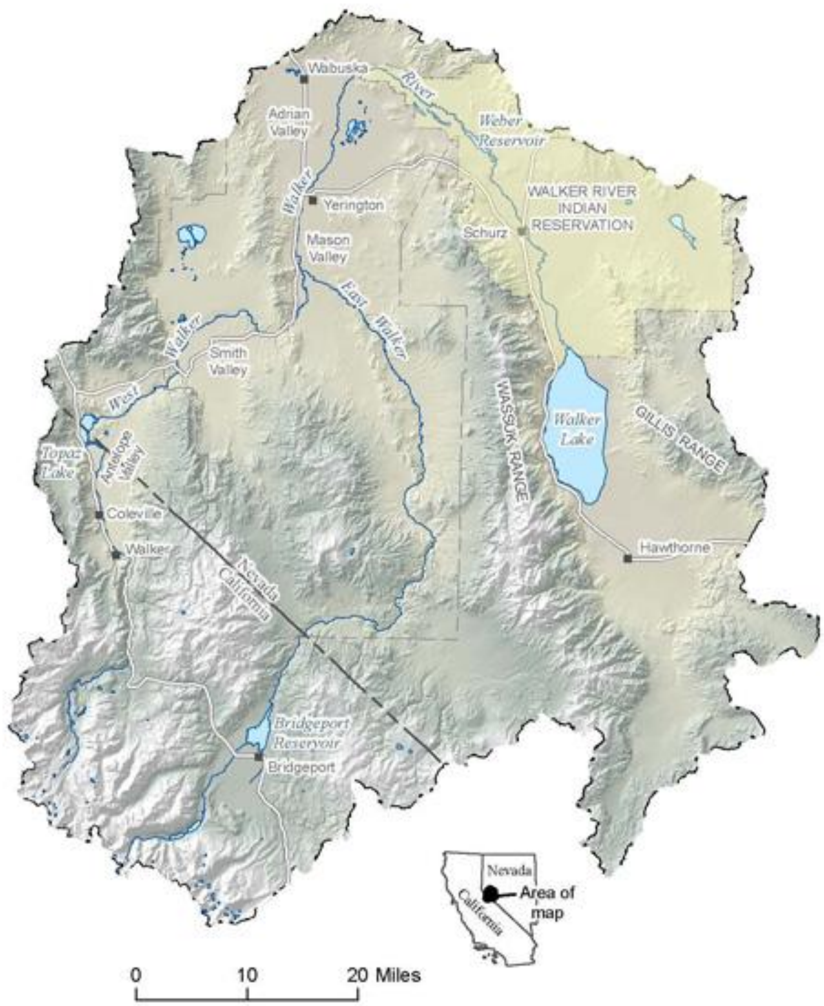
The Walker River extends approximately 160 miles from the headwaters to the terminus at Walker Lake, a terminal lake system. The basin is characterized by alpine lakes; high-, moderate-, and low-gradient streams; and a desert terminal lake. The Walker River exhibits extremes in hydrologic conditions, typical of Great Basin rivers, ranging from nearly dry during drought periods to high water from flood events (USFWS 2003).

The geographic scope of this plan focuses on Walker Lake, including the mouth of the river at the lake, with consideration of approximately 21 miles of the river upstream of the lake to Weber Reservoir. The reservoir and diversions at Little Dam into Canals 1 and 2 downstream of the reservoir are the last major impediments to natural river flows before reaching the lake. The lake exists within the valley between the Wassuk Range to the west and the Gillis Range to the east. It includes the delta of the Walker River to the north, and its southern boundary is shared with Hawthorne Army Ammunitions Depot (Figure 4).

The rationale for choosing this scope is based on the fact that NFWF's primary objective is to enhance the lake ecosystem. NFWF is also interested in the broader ecological health of the larger Walker River Basin. Additional conservation action planning efforts will be needed to address this greater context. Since the lake is interconnected and dependent on the larger basin, the future, broader, basin-wide assessment will more comprehensively account for interactions between the lake and the attendant basin.

The U.S. Fish and Wildlife Service (USFWS); U.S. Geological Survey (USGS); Nevada Department of Wildlife (NDOW); Great Basin Bird Observatory (GBBO); University of Nevada, Reno (UNR); and the Desert Research Institute (DRI) have been engaged in researching and monitoring a wide range of environmental attributes of the Walker River Basin, including the ecology of Walker Lake, with funding from the Desert Terminal Lakes Program under U.S. Bureau of Reclamation grants. Since 2005, the USFWS, with funding from the U.S. Bureau of Reclamation, has sponsored research focused on improving the fishery of Walker River Basin and Walker Lake.

**Figure 4.** Location of Walker Lake in the Walker Basin.




Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000; 1978-88.

DRI's Center for Watersheds and Environmental Sustainability (CWES) has been conducting research in the Walker Lake Basin since it was formed in 1999. In 2007, UNR and DRI began a multidisciplinary research program in the Walker Lake Basin to provide information for restoration of Walker Lake and the Walker River, including the possible acquisition or lease of water rights in the watershed. Desert Terminal Lakes funding managed by the U.S. Bureau of Reclamation is the principal funding source for research, restoration work, and water acquisition in the Walker River Basin.

With Desert Terminal Lakes funding, UNR initiated a water acquisition program in 2005 that was focused on conveying more water to Walker Lake. Legislation for this funding was amended in 2009 to establish the Walker Basin Restoration Program, and the water acquisition program was transferred to NFWF. The Program's core purpose is to restore and maintain Walker Lake. In order to reverse Walker Lake's decline, NFWF is striving to find balance among the interests of landowners, water-user organizations, Indian Tribes, local governments, state and federal agencies, and non-profit organizations. This conservation program seeks to increase instream flows to Walker Lake through a comprehensive basin-wide strategy that relies on voluntary water transactions and water management initiatives, community-based conservation and stewardship, and applied research and demonstration projects.

## Physical Setting

Walker Lake, approximately 90 miles southeast of Reno, is a remnant of ancient Lake Lahontan, which covered much of northwestern Nevada until it mostly dried up some 9,000 years ago. The elevation of Walker Lake in 2012 was 3,920 feet mean sea level, a decrease of more than 337 feet since its highest elevation, which occurred 13,000-14,500 years before present (Sharpe, 2010). Fed by inflows but lacking surface outlets, Walker Lake is one of only three desert terminal lakes in North America to support a freshwater fishery, the others being Summit Lake and Pyramid Lake. Since there is no water outflow from these lakes, their sizes are dependent on the balance between water inflow and evaporation, or other draws on water volume such as human use for agriculture, mining or municipal purposes. Long before settlers began farming and ranching in the Walker Basin in the late 1800s, Paiute Indians thrived on Walker Lake's abundant Lahontan cutthroat trout.

Walker Lake is located in a watershed that supports significant agricultural activity. The primary source of the lake's water is snowmelt runoff from the Sierra Nevada, which flows through several agricultural valleys before reaching the lake. The earliest rights to divert Walker River water (apart from the rights of the Walker River Paiute Tribe) were established in 1860. By the 1930s, nearly 100,000 acres of desert were irrigated. As a result of diversions and reservoir storage, it is now not unusual, during low precipitation years and during the drier months of most years, for the river to run dry before it reaches the lake (Umek, Chandra, & Brownstein, 2009).

Since the late 1800s, lake levels have decreased almost 150 feet, during which time the volume of the lake has decreased from about 10 million acre-feet to less than 2 million acre-feet (Umek, Chandra, & Brownstein, 2009). As a result of this decline, the total dissolved solids (TDS) of the lake have increased over this same period from about 2,500 mg/l to more than 19,000 mg/l. These changes to the lake have had dramatic implications on the viability of the complex food web that is supported by it. Toxic TDS levels in Walker Lake have eliminated other native fishes such as Lahontan cutthroat trout (LCT) (*Oncorhynchus clarki henshawi*), Tahoe sucker (*Catostomus tahoensis*), Lahontan redside (*Richardsonius egregious)*, and speckled dace (*Rhinichthys osculus)* that once lived in the lake. Lahontan tui chub (*Siphateles bicolor pectinifer)* and *S. b. obesa* are the last remaining native fish species in Walker Lake (Wright, 2013).

Although fish species diversity found in the lake is now low, at one time, prior to its recent elevation decline, Walker Lake supported a large population of LCT and the forage fish, Lahontan tui chub. Dam construction on the Walker River stopped cutthroat trout spawning runs and, in conjunction with other environmental factors, the original Walker Lake cutthroat trout strain was extirpated by the early 1940s. From the late 1940s through 2009, NDOW and

USFWS maintained the fishery through an intensive stocking program of non-Walker strains of LCT (Elliott, 1995).The construction of upstream dams and diversion works resulted in the loss of the historic connection between the lake and upstream spawning habitat for the native LCT. However, the lake supported a hatchery-based fishery for decades thereafter until it was discontinued in 2009 due to the lake's elevated TDS levels. The first report that Walker Lake's LCT had become scarce appeared in the Walker Lake Bulletin in 1892 (Nevada Division of Water Planning, 1996). The article reported that "diversion dams along the Walker River in Mason Valley were the cause of the declining fish populations," and that "nearly every farmer in the valley had a [diversion] dam to divert river water for irrigation purposes, thereby making it virtually impossible for the trout to go upstream to spawn" (Nevada Division of Water Planning, 1996, p. II-14.

In an effort to restore Walker Lake (and other "at-risk natural desert terminal lakes" in Nevada), Congress enacted a series of laws beginning in 2002, which eventually authorized and provided funding for the acquisition of land, water rights, and related interests from willing sellers in the Walker River Basin and led to the establishment of the Walker Basin Restoration Program in 2009 (see http://www.usbr.gov/mp/lbao/desert_terminal/index.html) and http://www.walkerbasin.org). In order to enact an ecologically and economically sustainable program of water acquisitions, a large-scale integrated research program was also established in 2005. The primary objective of this research program was to provide the hydrologic, ecologic, economic, and agricultural data needed to inform decisions related to water acquisitions from willing sellers (Collopy and Thomas, 2010).

## Conservation Targets

The most important step in any conservation planning process is to choose the right targets for the conservation analysis and strategies. The species or natural communities chosen should reflect the current situation of the ecosystem's condition, viability, and restorability as long as the correct conservation actions are decided upon. The targets should be sensitive to the key threats identified through planning workshops, and their key ecological attributes have to be discrete measures that can be tracked over time to gauge conservation progress and, ultimately, how we define success. Developed in consultation with experts on the ecology of Walker Lake, the conservation targets selected for Walker Lake (listed below) capture all the major ecological components associated with the lake system.

- Lake ecosystem
- Native fish assemblage
- Water birds
- Freshwater marsh
- Riparian delta

**Lake ecosystem.** There was significant discussion in the 2011/12 planning workshops over whether to include the lake ecosystem itself as a target. Typically, species and natural communities are conservation targets for which ecological attributes can be defined, stresses identified, and strategies for abating those stresses devised. In the case of the lake ecosystem, all of these criteria are applicable since it does behave as a giant, somewhat complex organism or community. It also harbors a robust invertebrate community that is key to the viability of both the native fish assemblage target and the water birds target. Some of the invertebrate components are closely tied to lake-surface elevation, lake-bottom morphology, the vegetative community below the surface, and the salinity of the lake itself. Therefore, it was decided that lake ecosystem would be a stand-alone target in this planning exercise.

Since the late 1800s, when agricultural diversions and groundwater pumping began, the level of Walker Lake has decreased approximately 150 feet and the salinity (total dissolved solids, or TDS) of the lake has continued on an upward trajectory, having increased significantly (see Figure 1, History of Walker Lake volume and TDS). Today, agricultural water diversions put the river's water in a position of being over-appropriated by 140 percent, and the amount of freshwater reaching the lake is minimal by pre-European settlement standards.

Historically, Walker Lake, Walker River, the riparian corridor, and the system's wetlands provided critical habitat for many species. However, since 2010, Lahontan cutthroat trout (LCT) have not been observed in the lake, and tui chub (*Siphateles bicolor pectinifer*) currently are represented by a dwindling number of adults. It is likely that *S. b. obesa* no longer occurs in Walker Lake (Umek, Chandra, & Brownstein, 2009). The lake serves as a migratory stopover for as many as 35 water bird species (Collopy and Thomas, 2010), including the common loon and American white pelican. These fish-eating birds are visiting the lake in much lower numbers, and future surveys will provide additional information in the coming years.

As of the date of this report, Walker Lake is approximately 13 miles long and 5 miles wide, with a maximum depth of 80 feet, encompassing an area that is approximately 50 percent smaller than it was in 1882. Flows from the Walker River, occasional runoff from the Gillis Range and the northern portion of the Wassuk Range, and direct precipitation provide the only inflow to Walker Lake. The Hawthorne Army Depot captures some of the runoff from the Wassuk Range into a catchment (Humberstone, 1999) (Figure 5). Walker Lake has a chemical composition of a mix of sodium, chloride, sulfate, and carbonate (Cooper and Koch, 1984), which are an important determinant of the potential species inhabiting this lake (Herbst, 2001).

Walker Lake is a biologically productive, nitrogen-limited, terminal lake, and is classified as a monomictic lake, meaning that it turns over once annually, typically in the fall (Beutel and Horne, 1997). During the summer, Walker Lake normally stratifies into three distinct layers:

- ***Epilimnion*** – upper layer of the lake, which may have surface water temperatures exceeding 20°C
- ***Hypolimnion*** – the lower layer of the lake, which has less dissolved oxygen, cooler temperatures, and increased levels of hydrogen sulfide and ammonia.
- ***Metalimnion*** – the transition area between the top (epilimnion) and bottom (hypolimnion) layers of Walker Lake.

**Figure 5.** Hydrology of Walker River Basin and Walker Lake.


Being monomictic, Walker Lake mixes from top to bottom during one mixing period each year, with turnover usually occurring in October, followed by winter holomixis (temperature-based, wind-driven water circulation). Surface water summer temperatures range from 20 to 25ºC. The thermocline (a transition layer between deep and surface water) was observed at 14 m in 2011 and 19 m in 2012. During summer stratification, the surface waters have dissolved oxygen in the range of 6.7–8.7 mg/l, but the hypolimnion (the dense, bottom layer of water that lies below the thermocline) becomes anoxic (oxygen-depleted). (Herbst, Medhurst, Roberts, & Jellison, 2012).

The benthic environment of Walker Lake consists of mud deposits in the deep water zone (10 m and below); beds of the rooted macrophyte *Ruppia maritima* (widgeon grass) growing with epiphytic filamentous algae (*Cladophora glomerata)* in the near-shore and offshore littoral zone (the shoreline region of the lake); and mixed sand, gravel-pebble, and cobble rock deposits in shallow littoral regions (See Figure 6).

Herbst, et al. (2012) characterized and mapped the subsurface habitats and invertebrate community of Walker Lake. They noted that sand and small gravel substrates support few invertebrates except oligochaetes, which were most common in shallow littoral areas. In 2010-11, the extent of *Ruppia* beds was determined using hydroacoustic sounding, which showed that these beds were most well-developed in a zone from 1.25 to 5 m deep. The estimated area of productive shallow littoral zone habitat at different lake levels showed that coverage was lowest near the current surface elevation. They also surmised that rising lake levels would result in expansion of suitable habitat, and while falling levels could also expand near-shore habitat, this would likely occur on areas of poorer substratum quality and under high salinities that may inhibit growth.

While invertebrates did not emerge as stand-alone conservation targets for this assessment, they arguably are one of the most important ecological indicators of the lake ecosystem health. The insects that inhabit the lake are known as osmoregulators, since they maintain a constant balance of salt despite changes in the salinity of their environment. They expend energy to maintain that balance, which creates stress for the insects as salinity levels rise (USFWS, 2011). The damselflies, midges, and alkali flies that have been identified as critical food sources for the native fishes as well as many of the migratory waterfowl can be quantified over time and, as such, provide a sensitive measure of changing conditions in the lake ecosystem. These organisms are integrative indicators rather than "iconic" species. The lake invertebrates, along with riverine stream invertebrates, could be the most effective indicator of degradation or recovery of these systems under differing scenarios of water management.

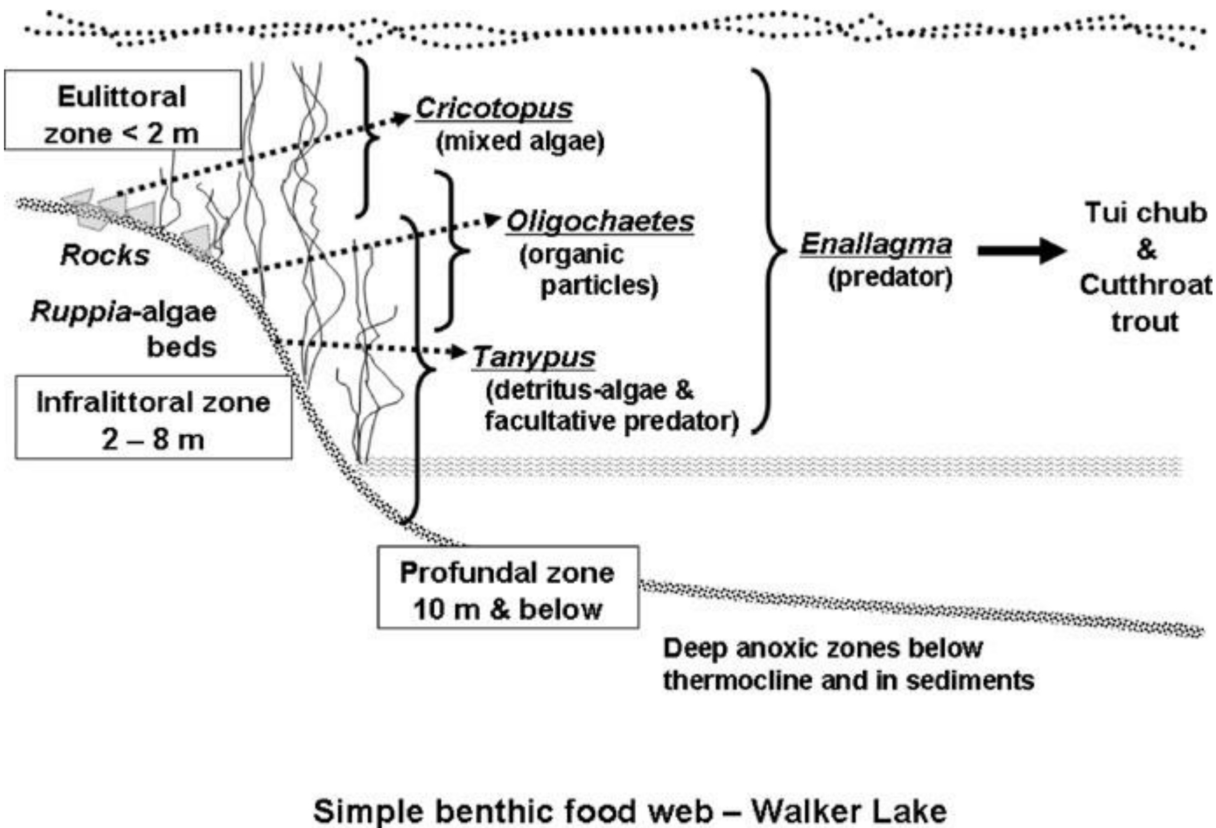
While Walker Lake invertebrates have been shown to be tolerant of salinity levels approaching 30,000 mg/liter, which are lethal limits, it is the sublethal effects that are most important in determining how changes in these species affect the aquatic food web. The sublethal effects are occurring at lower salinity levels in the native invertebrates of the lake and viability is already diminished (D. Herbst, personal communication,  2013).

Both the macroinvertebrates and the macrophytic plants depend heavily on specific substrates present in the shallow water zone at the edge of Walker Lake (D. Herbst, personal communication, 2012). Researchers have expressed concern that if water levels continue to decline, these important cobble zones will be exposed and not available to these invertebrate species, since their food sources, the filamentous algae and *Ruppia* widgeon grass, require this type of substrate to attach and flourish in a warmer water zone of the lake (D. Herbst, personal communication,  2012). Further research is needed to evaluate whether there are salinity limits of the productivity of these primary producers, especially the benthic algae of the lake.

A 2010 report by the Desert Research Institute (Sharpe, 2010), documented the following worrisome trends in the lake:

> As the level of Walker Lake has declined, both the chemistry and biology of the lake have been adversely impacted. The water quality is generally poor and declining with very high total dissolved solids (>18,000 mg/l), alkaline pH (around 9.0), and major-ion chemistry dominated by sodium, sulfate, chloride, and bicarbonate plus carbonate. Despite low lake levels and high salinity from reduced water inflows, Walker Lake still exhibited complete mixing (holomixis) during the winter and stratification during the summer. Anoxic conditions develop in the hypolimnion during the summer, resulting in high concentrations of ammonia. The high ammonia concentrations combined with elevated phosphorus levels in the lake produce large odiferous blooms of phytoplankton during the summer.
>
> Observations and data analysis indicate that large nuisance blooms and deep water hypoxia will continue in Walker Lake as long as enhanced internal nutrient loading through oxygen depletion in the hypolimnion continues. The volume and areal extent of the hypolimnion oxygen depletion has decreased over time simply due to the reduction in volume of the hypolimnion as lake level has declined. The production of organic matter leading to the hypoxia is sustained by exceedingly high levels of phosphorous (in excess of 20 uM) which sustain the N-fixing Nodularia blooms. If the current rate of lake level decline continues, the lake may soon transition to a polymictic status (where thermal stratification no longer occurs). . (Sharpe, 2010)

**Figure 6.** Benthic food web of Walker Lake indicating dominant taxa under conditions in 2007. Primary feeding habit is shown in parentheses below names of taxa. *Ruppia* beds indicated by vertical strands. Taxa not shown but expected to become important components; would be the amphipod *Hyalella* at higher lake levels, and the more salt-tolerant alkali fly, *Ephydra hians*, at lower lake levels. (Herbst, Medhurst, Roberts & Jellison, 2012)




The phytoplankton of Walker Lake, although attaining high levels of biomass, are relatively depauperate in regards to richness and diversity, with only a few taxa comprising the plankton assemblage during all seasons (Chandra, et al., 2010). *Nodularia crassa* mostly dominates the phytoplankton assemblages in terms of biovolume, with lesser volumes of *Spermatozopsis* and a small autotrophic flagellate during spring and summer. During winter, other taxa are more prevalent, notably *Chaetocerous*, a small chain-forming diatom, and *Chlorophytes*. *Synechoccocea* also are prevalent and abundant.

The zooplankton community in Walker Lake consisted of three dominant species—*Hexartha* spp, *Moina hutchinsoni*, *Leptdiaptomus sicilis*—during 2007. Zooplankton abundance is highly variable in time with the greatest abundance occurring in the late spring and fall (Chandra, et al., 2010).

The benefits of increasing the water flow into Walker Lake and the effects it will have on the ecological community will depend upon the timing of release and the quantity and quality of the water. To determine the impacts of increased water flow on the food web and the energetics of the fish community, monitoring the phytoplankton, zooplankton, and benthic invertebrate community will be critical (Chandra, et al., 2010).

The **Native fish assemblage** target is comprised of LCT, tui chub, and the Tahoe sucker. Two of these native fish (LCT and tui chub) could have been considered a target unto themselves, but it was decided that the key ecological attributes attendant to each of the species was tied to the same two ecological measures: salinity levels and food resources (primarily invertebrates). LCT stocking in the lake was curtailed in 2009, and LCT have not been observed in the lake since 2010. Tui chub recruitment is limited by the saline conditions in the lake. Studies of the lake food web show that both species are mostly dependent on benthic production, which is consistent throughout the season. Pelagic production of edible phytoplankton and zooplankton is highly variable, both spatially and temporally (Chandra, et al., 2010).

The Tahoe sucker was not common in Walker Lake after 1982, when TDS levels first approached 10,000 mg/liter (NDOW, 2010). Aside from one lone Tahoe sucker captured in the early 2000s, 1982 was the last year that the suckers were caught in gill nets (K. Wright, personal communication, 2013). However, Tahoe suckers remain as a key indicator target, whose return to the lake, in the form of a naturally sustaining population, would signal a significant conservation achievement of reduction of salinity levels to that critical threshold for maintenance of native biodiversity. Four other native fishes—Lahontan redside (*Richardsonius egregius)*, Lahontan speckled dace (*Rhinichthys osculus robustus)*, LCT, and both forms of the tui chub (Umek, et al., 2009)—would be expected to respond favorably to the reduction in salinity levels and, depending on the degree to which salinity is reduced, potentially could establish self-sustaining populations.

The LCT (Figure 7) was listed as an endangered subspecies in 1970. In 1975, pursuant to the Endangered Species Act of 1973 as amended (ESA), LCT was reclassified as threatened, to facilitate management of the species and to allow for regulated angling. In 1995, the USFWS released its recovery plan for LCT, encompassing six river basins within LCT historic range, including the Walker River Basin. The *Lahontan Cutthroat Trout Recovery Plan* (1995) identified development of ecosystem plans for LCT in the Truckee and Walker River Basins. This Short-Term Action Plan ("Action Plan") (2003) for the Walker River Basin represents a three-year planning effort to develop the "ecosystem"-based plan identified in the 1995 Recovery Plan. The Action Plan identifies short-term activities and research that will further understanding of the conservation needs of LCT specific to the Walker River Basin and utilizes adaptive management to refine the long-term recovery strategy.

The Nevada Department of Wildlife (NDOW) and the USFWS intensively stocked LCT annually in Walker Lake up until 2006. High TDS have resulted in unsuccessful acclimation of stocked trout. The LCT stocking program for Walker Lake was suspended in 2009.

Water temperature in the lake continues to be a challenge for LCT. The upper thermal limits for river-dwelling LCT ranges from 22°C to 24°C as experienced in laboratory studies (Dickerson & Vinyard, 1999; Dunham, Peacock, Rieman, Schroeter & Vinyard, 1999; Meeuwig, 2000; Dunham, Schroeter & Rieman, 2003). Research at indicated a lethal temperature range of between 18° and 20°C for LCT in Walker Lake. (USFWS, 2003)

**Figure 7.** Lahontan cutthroat trout (*Oncorhynchus clarki henshawi)*. Photo © Laurie Moore.

Higher temperatures decrease the maximum amount of oxygen that can be dissolved in water, leading to oxygen stress if the water is receiving high loads of organic matter (Michaud, 1991).

As Walker Lake continues to decrease in volume and elevation, the combined effects of increased TDS and alkalinity will lead to osmoregulatory problems for aquatic organisms. The 2003 LCT Action Plan (USFWS, 2003) indicated that osmoregulatory stress directly affects kidney function, gill hyperplasia, gill cell function, and blood congestion in the kidneys.

The Lahontan tui chub is a cyprinid fish of the Great Basin, including the Truckee River and Walker River drainages. Finger and May (2010) found that the tui chub population in Walker Lake is genetically differentiated relative to other populations of tui chub throughout the Walker, Carson, and Truckee River Basins, and has robust genetic diversity. The tui chub (Figure 8) is a schooling fish capable of surviving in both deep and shallow water lacustrine habitats. When young fish reach 1 to 2 cm., they move from aquatic vegetation beds to deeper offshore waters. NDOW has determined ages of hundreds of tui chub, with ages ranging from the upper teens to early 20s (K. Wright, personal communication, 2013). Walker Lake tui chub have been observed to reach maximum lengths of about 38.5 cm. Stable isotope data suggest that the tui chub's diet is dominated by benthic insects, at least under recent conditions (D. Herbst, personal communication, 2013;Chandra, et al., 2010; Umek, et al., 2009).

In general, larger tui chub have a diurnal cycle of occupying deeper water during the day and shallow waters at night. It is believed that successful spawning, egg hatching, and larvae survival are dependent upon access to shallow water and inshore algal beds.

Dr. Sudeep Chandra stated that:

> …70 to 80 percent of the only two species of fish at Walker Lake, the Lahontan cutthroat trout and the tui chub, eat and receive their energy from the bottom of the Lake. Similar lakes in the Great Basin typically have both the bottom tui chub and the open water tui chub, which refers to how they feed. Interestingly, there is only an open

water tui chub at Walker, but its diet comes from the bottom of the lake. (Chandra, et al., 2010)

**Figure 8.** Tui chub, *Siphateles bicolor*. From UC Davis, California Fish Website.


**Water birds** include common loon, western grebe, Clark's grebe, eared grebe, American white pelican, double-crested cormorant, and several waterfowl species. The fish-eating birds share common ecological attributes in that they are seeking large bodies of open water in the region that supports their common fish prey species—the Lahontan cutthroat trout and the tui chub. However, each of the three species also responds to different size class availability of those fish species, and appear to be acting as reverse indicators of lake health. Eared grebes and some waterfowl feed on aquatic invertebrates and/or macrophytes.

As salinity levels have risen over time, common loons and western and Clark's grebes have decreased in abundance at Walker Lake, since the smaller size classes of tui chub are no longer available due to a cessation of successful breeding by this native fish. In recent years, annual common loon counts at Walker Lake have averaged around 285 birds, compared to around 1,000 birds in the 1990s. NDOW and GBBO staff have noted that there have been increased numbers of common loons on Topaz Lake during migration in recent years, suggesting that loons may be finding alternate feeding sites.

American white pelicans and double-crested cormorants use Walker Lake where these species are able to feed on the larger size classes of the tui chub. It should be noted that avian surveys at Walker Lake have included waterfowl surveys since 1949 (NDOW), water bird surveys in fall and spring (twice yearly when possible) since 1988 (NDOW), an annual loon survey since the 1990s, and Audubon Christmas Bird Counts sporadically since 1997. GBBO initiated avian surveys in fall 2012 that will continue for at least three years. Our current understanding of bird use at Walker Lake is based on incomplete information (G. Chisholm, personal communication, 2012).

**Freshwater marsh** is present at the southern end of Walker Lake and is a result of meager creek flows coming from the Hawthorne Army Ammunitions Depot (Figure 9) which originates in the western Wassuk Range.

**Figure 9.** Google Earth™ view of freshwater marsh at southern end of Walker Lake (note shoreline retreat).

Prior to upstream diversions, Walker Lake had freshwater marshes surrounding the central open water (Sherow, 2007). The existing marsh of approximately 320 acres sustains an important marsh community of riparian emergent vegetation, numerous insects that attract many species of birds, and the Western toad ((K. Wright, personal communication, 2013)). The freshwater marsh is heavily grazed by feral horses with as many as 100 horses counted on a single day. The freshwater marsh is heavily grazed by feral horses, with as many as 100 horses counted on a single day (G. Chisholm, personal communication, 2013).

While currently to a highly restricted extent, it serves as a temporary refuge for a subset of wetland marsh species until such time as a more robust marsh community can be established through restoration and conservation protections such as managed grazing and/or fencing for feral horses out of the system. It was selected as a target since it represents a unique ecosystem associated with Walker Lake that enhances the biological diversity scores for the lake target, but it is not dependent upon it *per se*. Native amphibians could serve as indicators of success for the conservation of the freshwater marsh on the south end of the lake. This community remains to be inventoried for aquatic invertebrates, which may tell us more about this as a refuge habitat.

**Riparian delta.** The extent of this target community in this planning exercise is from the south end of Weber Reservoir, south to the entry point of the river into Walker Lake. Weber Reservoir was determined to be a logical boundary since it represents a major change in ecosystem function as the last impediment to natural river flow before Walker Lake, and the dam is a barrier to LCT spawning. The exact boundary of the lake itself is difficult to determine, since it is a moving target as evaporation and lack of inflow continues to lower the lake's elevation. As the lake level continues to recede, it exposes softer sediments to the erosive effects of the river flow into it, thereby making incision and head-cutting more prevalent.

In arid regions such as the Walker Basin, riparian zones generally consist of bands of habitat along waterways where high soil moisture permits the development of vegetation that is entirely dependent on wet conditions, such as cottonwood and willow. The riparian vegetation in turn supports an aquatic and terrestrial fauna that collectively make up a riparian community.

Riparian habitat may occur as linear bands that parallel the river, or as dense and broad patches of habitat that may extend a considerable distance from the main river channel. Substrates are generally well-drained and coarse-textured soils derived from alluvium (sediment that eroded from upstream areas and was deposited by flood waters). Cottonwood trees (*Populus fremontii)* are dependent on annual or periodic flooding, followed by a gentle decline in water levels so that the roots of young seedlings can get established.

Cottonwood forests were not as extensive along the Walker River as they were along the Truckee and Carson Rivers. The most extensive forest occurred at the former Walker River delta at Walker Lake. The dominant direction of change observed in an historical analysis of Walker River vegetation indicates a riparian environment that has become narrower, more channelized, and with reduced groundwater availability (Weisberg, Yang, Dilts, & Olson, 2010). The riparian zone at the terminus of the Walker River through the Walker River Paiute Reservation has become dominated by the highly invasive salt cedar (*Tamarix ramosissima),* resulting in a virtual monoculture except at the riparian delta before the river enters the lake (Figure 10).

**Figure 10.** A view of a virtual tamarisk monoculture on the Walker River Paiute Indian Reservation. Photo © J. Moore, 2011.

As summarized in the 2010 Walker Basin Project Report, scientists report that, due to a drop in water levels at Walker Lake, the lower Walker River has spread across the former lakebed, severely cutting into the fairly soft sediments left exposed as lake waters receded. Simulations from a sediment transport model and estimates of erosion made from aerial photography indicate that hundreds of thousands of metric tons of sediment are eroded from the bed and banks of the lower Walker River during an "average" runoff year, attesting to the instability of this system. Most of this instability is concentrated in the lowermost reaches of the river (Collopy & Thomas, 2010).

As the preceding discussions reveals, conservation action planning is a dynamic and adaptive process subject to revision as knowledge and understanding of existing and potential conservation targets come into greater focus and clarity. The process of adding or refining conservation targets is important only insofar as it aids in the identification of discrete and measureable strategies for improving viability scores of the targets and the ecosystem as a whole.

# Target Viability

Viability[3] refers to the status or "health" of conservation targets and indicates the ability of a target to recover from most natural or human-caused disturbances and, thus, to persist for many generations and over long time periods. Overall, the viability rankings for targets reflect historic land and water management activities and the cumulative impacts of those activities over time. Viability rankings are used to indicate the overall status and condition of the targets. Rankings of "good" and "very good" indicate that the target is conserved, and that the target exists within an acceptable range of variation. Rankings of "poor" and "fair" indicate that the target is not conserved and exists outside of an acceptable range of variation. A "fair" ranking reveals that the target is in a state of degradation, or may decline to a "poor" ranking if actions are not taken to enhance viability or abate threats. A "poor" ranking reveals that the target may go locally extinct within 10 to 25 years if actions are not taken to restore, conserve, or abate threats to the target. Viability rankings are snapshots of current conditions and generally reflect the cumulative impact of past changes and disturbances. Viability rankings do not take into account current and potential threats that may cause viability rankings to decline in the future.

**Figure 11.** Target viability summary.

**Viability Summary**

**Walker Lake CAP 2012**

| | **Conservation Targets** (Current Rating) | Landscape Context | Condition | Size | Viability Rank |
|---|---|---|---|---|---|
| 1 | Lake Ecosystem | Poor | Fair | Poor | **Poor** |
| 2 | Lahontan Cutthroat Trout | Poor | Poor | Poor | **Poor** |
| 3 | Tui Chub | Poor | Poor | Fair | **Poor** |
| 4 | Piscivorous Birds | Poor | Poor | Poor | **Poor** |
| 5 | Freshwater Marsh/Spring | Fair | Fair | Poor | **Fair** |
| 6 | Riparian Delta Forest | Poor | Poor | Poor | **Poor** |
| | **Project Biodiversity Health Rank** | | | | **Poor** |

The overall viability ranking for targets on Walker Lake is "poor" (Figure 11), and, individually, only the freshwater marsh target ranks above that, with "fair" ranking. As noted previously, the primary cause of the "poor" ranking stems from diminished and altered freshwater inflows. In addition, the Walker River flowing into the lake has been incised and

[3] Viability analyses and rankings in this report are based on the professional judgment of participants in the three planning workshops that were held between December 2010 and April 2012. The rankings reflect the best scientific information available at the time, and include the input of additional technical experts that may not have attended the workshops.

the river bed is now lower than historic conditions. Upstream wet meadow and wetland habitats that filter and absorb water for more moderated release into the lake over time have been lost primarily to agricultural and some real estate developments in the Mason and Smith Valley regions. Agricultural production from farmland and rangeland includes some historic practices that were harmful to riparian habitats, such as spraying and mechanically removing riparian plants, continuous livestock grazing, and facilitation of invasion by non-native weeds. The cumulative impacts of these changes have reduced the area and integrity of riparian, wet meadow, and wetland habitats and, ultimately, the lake itself, since the lake is the end-point recipient of the quantity and quality of water resulting from all those upstream modifications and uses. The riparian habitat specifically addressed in this plan, from Weber Reservoir south to the lake, has been severely compromised by reduced instream flow, unregulated grazing, down-cutting of the river as the lake level has dropped, and salt cedar (tamarisk) invasion.

## Threats

Threats are current and future conditions that will damage the viability of targets. Threats are evaluated in terms of *stress* (such as habitat destruction) and *source* of stress (such as the residential development that causes habitat destruction). Note that “very high” threats have the capacity to cause extensive degradation of the target that may include local extinction within 10 to 25 years unless the threat is significantly alleviated. Figure 12 and the following discussion provide information on threats to the Walker Lake conservation targets.

The current threats to the Walker Lake ecosystem (rated “very high”) primarily stem from upstream water use due to the operation of three dams and reservoirs (Bridgeport Reservoir, Topaz Lake, and Weber Reservoir), as well as the irrigation diversion and drainage systems. These modifications to the hydrological system have limited the water in the river and the volume of water reaching the lake and increased salinity in the river. Because Walker Lake is a terminus lake, without outflow, water quality is deteriorating with the decline in water volume and the increased salt loading, both natural and anthropogenic. As the lake continues to decline, it becomes more alkaline. In 2011, alkalinity decreased slightly with a bump in lake elevation due to floodwater from a year with a deep snowpack. However, at the current levels, the lake has become too saline to support any sort of significant population of the native fishes that live in it (e.g. Lahontan cutthroat trout and tui chub), and consequently may no longer be able to support the migratory water birds that survive on the lake’s fisheries.

Raising the lake level without restructuring the management of the upstream nutrient conditions may only result in nominal changes in the lake’s condition. The levels of nutrients presently within the lake are very high and are likely to continue to promote nuisance blooms and hypoxic conditions even when lake level rises (Fritsen, Memmott, Davis & Wirthlin, 2010). If TDS concentrations continue to increase, eventually the plankton, which forms the base of the food chain, will not survive. In the event that the concentrations of TDS decrease, it is unclear how long a recovery of the plankton, and therefore the fish communities, could take. However, studies from Walker Lake and other lakes suggest that populations of benthic invertebrates can respond rapidly to changes in salinity, and that recovery can occur quickly (Herbst, personal communication, 2012).

**Figure 12.** Summary of threats to conservation targets.

**Summary of Threats**
**Walker Lake CAP 2012**

| | **Threats Across Targets** | Lake Ecosystem | Lahontan Cutthroat Trout | Tui Chub | Piscivorous Birds | Freshwater Marsh/Spring | Riparian Delta Forest | Overall Threat Rank |
|---|---|---|---|---|---|---|---|---|
| | Project-specific threats | 1 | 2 | 3 | 4 | 5 | 6 | |
| 1 | High Total Dissolved Solids | Very High | Very High | Very High | Very High | | | Very High |
| 2 | Agricultural water use upstream | Very High | High | Very High | | | Very High | Very High |
| 3 | Dams & Water Management/Use | Very High | High | High | | | Very High | Very High |
| 4 | Lack of adequate food resources | | Very High | | Very High | | | Very High |
| 5 | Drought | | | Very High | | High | | High |
| 6 | Unmanaged livestock grazing | | | | | | Very High | High |
| 7 | Feral horses | | | | | High | | Medium |
| 8 | Invasive plant species (tamarisk) | | | | | | High | Medium |
| 9 | Invasive aquatic species (Gambusia) | | | | | Medium | | Low |
| 10 | Pelican predation on larger classes | | | Medium | | | | Low |
| | Threat Status for Targets and Project | Very High | Very High | Very High | Very High | High | Very High | Very High |

(More detailed Threat and Stress tables are included in Appendix 1.)

Invasive plant species are a highly ranked threat because invasive and weedy plant species are very common on the Walker River leading to the lake, and they are displacing native and desirable plants in natural habitats, agricultural fields, and livestock pastures. In ecology, a native species is an organism which is indigenous to a given region or ecosystem. Native species contrast with non-native species[4]. The reason non-native species are treated differently in conservation planning is that non-native species often cause great harm to native species and ecosystems. For example, non-native plants that are invasive and noxious, such as cheat grass, tamarisk, and tall whitetop, can displace and, in some cases, eliminate native plants and animals and damage natural dynamics such as fire regimes.

Activities that cause disturbance, such as grazing, clearing of fields, and other agricultural practices, and development that transports seeds among areas, accelerate the spread of invasive species. Recent plant surveys documented the high cover of invasive and weedy plant species throughout the river corridor (Otis Bay Ecological Consultants, 2009). While

[4] A non-native species is also known as an introduced species, naturalized species, or exotic species. A non-native species is not indigenous to a given place, but has been transported there as a result of human activity. When non-native plants or animals have harmful ecological or economic impacts, they are often called invasive species or, in the case of some plants, noxious weeds.

trees and shrubs generally are dominated by native species, the cover of invasive and weedy species is very high for herbaceous plants (grasses, flowering plants, and other low-growing plants).

## Strategies

The most challenging component of strategy development was identifying and quantifying a vision of conservation success in the Walker Lake project area that is distinct from a conservation vision for the Walker River Basin as a whole system, since they are inextricably linked. Professional judgment played a significant role in our deliberations over a quantitative vision of success for Walker Lake. To assist NFWF's evaluation of what might constitute conservation success, a chart was developed (Figure 3), showing several key TDS thresholds that are associated with different levels of ecological health. Lighter shading in certain columns in Figure 3 indicates a trend of decreasing abundance of the particular taxon.

In light of the chosen conservation targets and threats to those targets, the primary restoration strategy recommended in this Assessment is the following:

**Increase the quantity and quality of freshwater inflows to the lake.**

NFWF's Program is designed to achieve this outcome through several mechanisms, which include but are not limited to the purchase and lease of water rights and the transfer of those rights for use at the lake. The ecological range for maximal viable native biodiversity of the lake is at a TDS level between 9,500 and 13,500 mg/l. A U.S. Geological Survey water budget analysis estimated supplemental inflows and annual inflows to Walker Lake to maintain a range of surface elevations and TDS concentrations (see Figure 2 below) (Lopes and Allander, 2009). Water budgets were calculated for a range of supplemental inflows needed to maintain TDS concentrations at 8,000; 10,000; and 12,000 mg/l. It was estimated that approximately 700,000 to 2,000,000 acre-feet are needed to dilute the lake to these concentrations, and from 26,000 to 53,000 acre-feet/year of supplemental inflow is needed to maintain TDS concentrations at 8,000 to 12,000 mg/l. Years of supplemental inflow, above average inflow, or both will be needed to raise the lake-surface elevation and dilute TDS concentrations (Lopes and Allander, 2009). TDS thresholds associated with different levels of ecological health are as follows (Figure 3):

a. <u>TDS above 20,000 mg/l</u>. Should salinity levels increase above their current levels, a significant shift in the invertebrate fauna could occur, with midge numbers declining significantly and the alkali fly (*Ephydra hians*) appearing. Native fish will disappear and phalaropes and other shorebirds, such as red-necked and Wilson's phalaropes, could increasingly dominate as alkali fly densities soar, enabling them to exploit dense populations of the alkali fly as a food source. It is likely that a complete loss of the tui chub in Walker Lake will occur when TDS levels approach the 20,000 mg/l threshold. Above 25,000 mg/l, alkali flies will become the dominant invertebrate, and Walker Lake would become more similar in biotic composition to Mono Lake.
b. <u>TDS below 15,000 mg/l.</u> This quantity allows for acceptable survival rates of acclimated in-lake-stocked Lahontan cutthroat trout, and the amphipod *Hyalella* (an important food resource to trout) could return to the lake.

c. TDS below 14,000 mg/l. Tui chub could be expected to become reproductively successful, which in turn would positively affect the populations of water birds, including the common loon and western and Clark's grebes, which depend on smaller-size classes of this species for food. Stocked LCT would be expected to survive and grow at increased rates, but LCT reproductive success is primarily dependent upon spawning habitat upstream, which is not presently accessible due to a variety of factors, including structures/diversions, water quality and temperature, and channel conditions.
d. TDS below 10,000 mg/l. A diverse community of aquatic invertebrates would exist in the lake, and these would support the native fish and birds that would use the lake under conditions most similar to what the lake would be today without stream diversions. Milne (1987) reconstructed the historical record of lake-level changes for Walker Lake to determine pristine conditions prior to human intervention. The study concluded that Walker Lake would have risen above the historical highest lake elevation and remained at that level until the present day without human diversions and other water-use interventions.

**Figure 1.** Walker Lake volume and TDS levels over time.

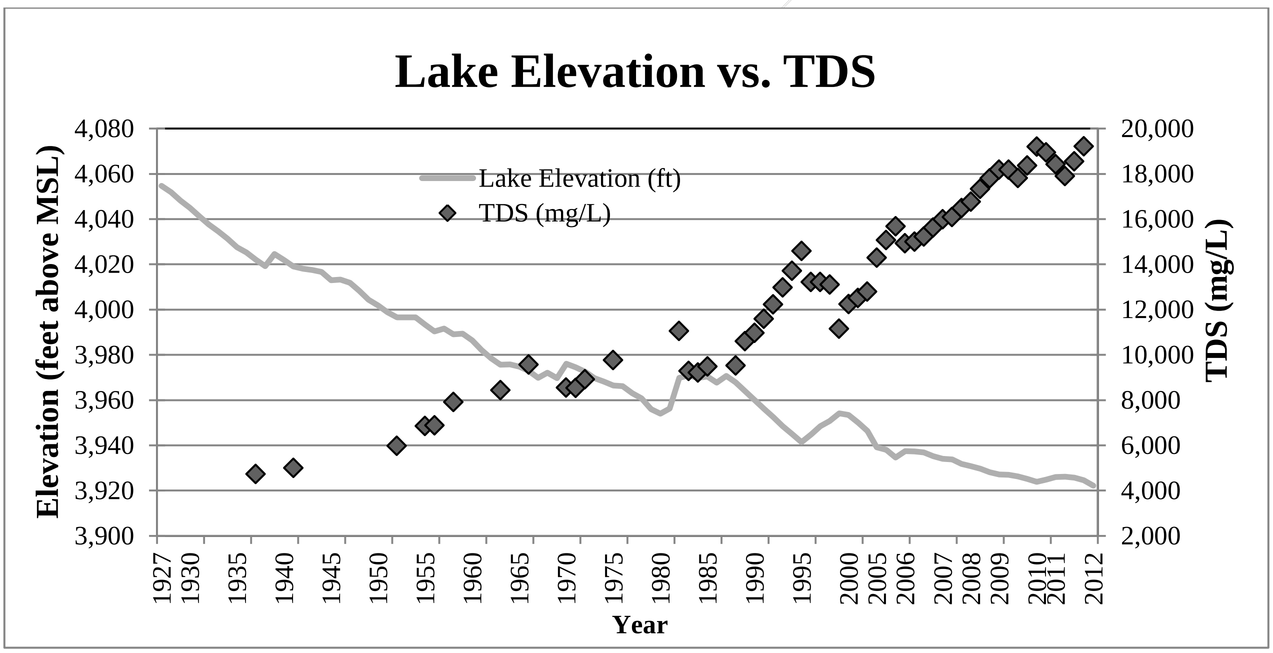
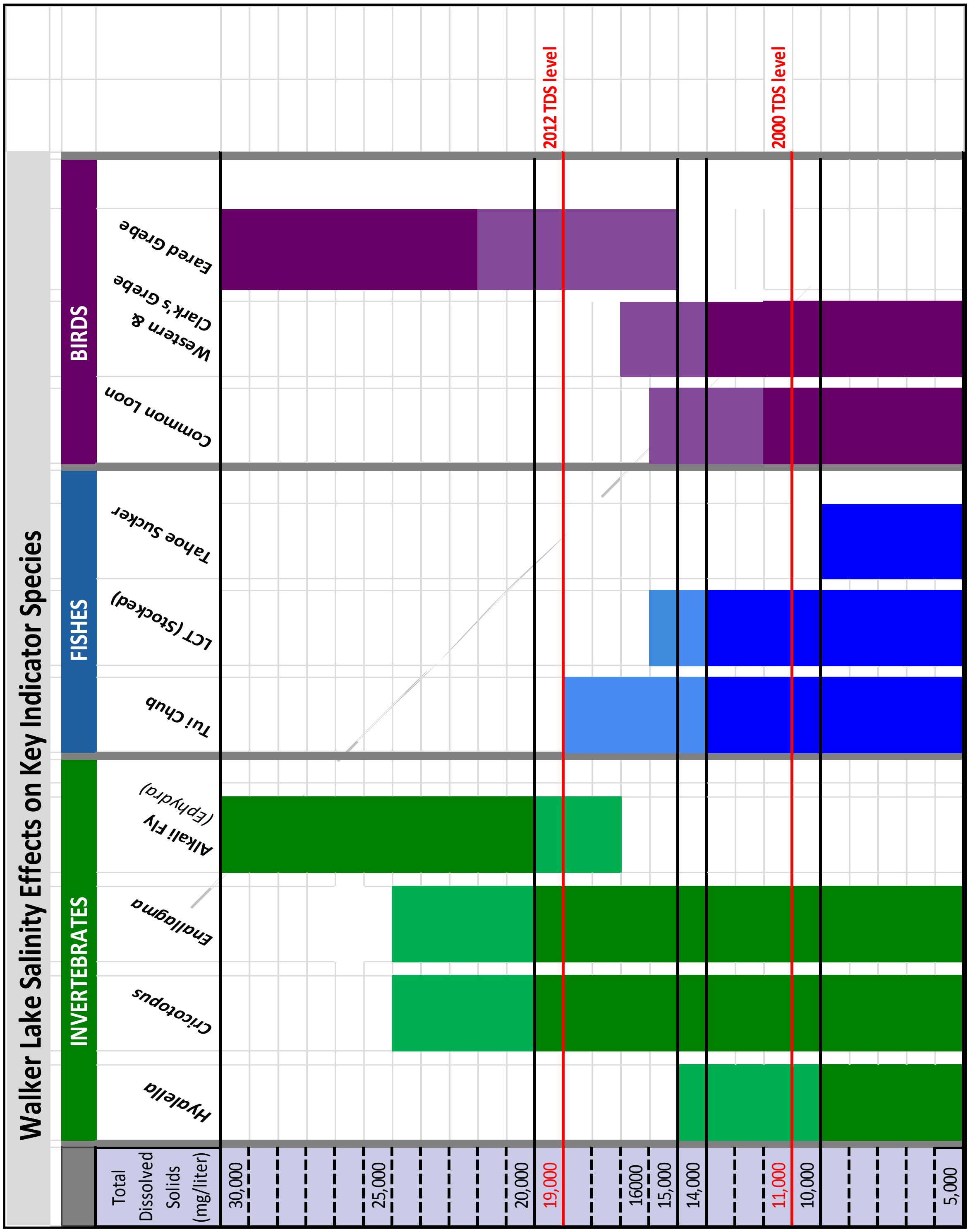


**Figure 2.** Water budget to maintain lake-surface altitudes between 3,952 and 3,986 feet at Walker Lake, Nevada (modified from Table 18 in Lopes and Allander, 2009).

| | Lake-surface elevation | | | |
|---|---|---|---|---|
| | 3,952 ft | 3,964 ft | 3,965 ft | 3,986 ft |
| TDS (mg/L) | 12,000 | 10,200 | 10,000 | 8,000 |
| Supplemental volume (acre-ft) | 700,000 | 1,100,000 | 1,200,000 | 2,000,000 |
| Supplemental Annual Inflow (acre-ft/yr) | | | | |
| Supplemental inflow (acre-ft/yr) | 26,000 | 35,000 | 36,000 | 53,000 |

Supplemental volume is the amount of water in addition to current volume that reaches the lake that is needed to raise lake-surface elevation from 3,931 feet (2008 elevation). Supplemental inflow is the amount of inflow in addition to current average annual inflows needed to maintain elevation. Stream and subsurface discharge into the northern end of Walker Lake currently totals around 110,000 acre-feet/year (Lopes and Allander, 2009).

**Figure 3.** Walker Lake salinity effects on key indicator species. Lighter shading in certain columns indicates a trend of decreasing abundance of the particular taxon. These are estimates and not absolute thresholds. (D. Herbst, personal communication, 2012)



## Measures of Success

"Measures of success" consist of the monitoring programs that USFWS, NDOW, USGS, GBBO, NFWF and others intend to implement in order to gauge success toward objectives. Monitoring allows for adaptive management and changes to strategies as we learn what is and is not working. Monitoring will also help land and water managers adapt to unforeseen and changing circumstances, such as climate change, new invasive species, disease among plant or animal populations, new economic trends and forces, and other unanticipated change to our work. Monitoring is the only way to know what is actually happening at the lake and in the river with respect to how the system is responding to both natural variation and management actions. Single-species or target monitoring should be integrated with other measurements so that we know why a desired target is responding the way it is and can begin to understand the intricacies between the species.

The sampling at Walker Lake, conducted by NDOW in collaboration with the Walker Lake Fisheries Improvement Team, has been part of a long-term monitoring program on Walker Lake that, along with USGS data, has contributed substantially to the Walker Lake Database and the Walker Lake modeling effort. These are the longest-term monitoring programs on the lake and they should be maintained, with minor modifications and some additional features as noted above, to provide continued support for development of the Walker Lake ecological model and to track the progress of Walker Lake restoration (DRI, 2010).

Walker Lake is unique and important ecologically; it is in trouble, but there is hope. Reduced inflows to the lake are the major problem, but water acquisitions are underway, and offer promise that recovery is possible.

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**Appendix 1.** Stresses and threats worksheets for this Conservation Assessment.

## Stress Matrix

### Walker Lake CAP 2012

| | Stresses (Altered Key Ecological Attributes) Across Targets | Lake Ecosystem | Lahontan Cutthroat Trout | Tui Chub | Piscivorous Birds | Freshwater Marsh/Spring | Riparian Delta Forest |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | Altered Water chemistry | Very High | Very High | Very High | | | |
| 2 | Altered Population structure & recruitment | | Very High | Very High | | | |
| 3 | Altered Hydrologic regime - (timing, duration, frequency, extent) | Very High | High | High | | | |
| 4 | Hydrologic regime - (timing, duration, frequency, extent) | | | | | High | Very High |
| 5 | Depredation & parasitism | | | Low | | Medium | Very High |
| 6 | Absence of key communities or seral stages | | | | Very High | | |
| 7 | Altered Nutrient concentrations & dynamics | | | Very High | | | |
| 8 | Species composition / dominance | | | | | High | High |
| 9 | Absence / lowered abundance of key functional guilds | High | | | | | |
| 10 | Altered Size / extent of characteristic communities / ecosystems | High | | | | | |
| 11 | Altered Trophic structure | | | | High | | |
| 12 | Community architecture | | | | | High | |
| 13 | Soil / sediment stability & movement | | | | | | High |
| 14 | Soil / sediment structure & chemistry | | | | | | High |
| 15 | Altered Population size & dynamics | | | Medium | | | |
| 16 | Altered Primary productivity | Medium | | | | | |
| 17 | Lack of adequate/appropriate food resources | | Medium | | | | |
| 18 | Absence of adequate/appropriate food resources | | | Low | | | |
| 19 | Lack of Connection to riparian system | | | Low | | | |
| 20 | Lack of Connectivity among communities & ecosystems | | | | Low | | |

## Stresses and Threats

**Viability assessment for this target (double click here)**

**Click the page-down icon ▼on the toolbar to the right to reach the Threats table.**

**Walker Lake CAP 2012**

| 6 | Riparian Delta Forest |
|---|---|

**<-- To change targets, click on the target name (current target input will be saved).**

**▼-- Type a stress, or double-click for the key attribute toolbar.**

| | **Stresses** | Severity | Scope | Stress Rank | User Override |
|---|---|---|---|---|---|
| 1 | Soil / sediment stability & movement | High | High | High | |
| 2 | Soil / sediment structure & chemistry | High | Very High | High | |
| 3 | Depredation & parasitism | Very High | Very High | Very High | |
| 4 | Hydrologic regime - (timing, duration, frequency, extent) | Very High | Very High | Very High | |
| 5 | Species composition / dominance | High | High | High | |
| 6 | | | | - | |
| 7 | | | | - | |
| 8 | | | | - | |

| | **Threats - Sources of Stress** | Soil / sediment stability & movement | Soil / sediment structure & chemistry | Depredation & parasitism | Hydrologic regime - (timing, duration, frequency, extent) | Species composition / dominance | - | - | - | Threat to Target Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stresses #.. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | Rank.. | *High* | *High* | *Very High* | *Very High* | *High* | - | - | - | |
| 1 | Threat | Dams & Water Management/Use | | | | | | | | Very High |
| | *Common Taxonomy* | *Dams & Water Management/Use* | | | | | | | | |
| | Contribution | Very High | High | | Very High | | | | | |
| | Irreversibility | High | High | | High | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | High | High | - | Very High | - | - | - | - | |
| 2 | Threat | Agricultural water use upstream | | | | | | | | Very High |
| | *Common Taxonomy* | *Annual & Perennial Non-Timber Crops* | | | | | | | | |
| | Contribution | Very High | Very High | | Very High | | | | | |
| | Irreversibility | Very High | Very High | | Very High | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | High | High | - | Very High | - | - | - | - | |
| 3 | Threat | Unmanaged livestock grazing | | | | | | | | Very High |
| | *Common Taxonomy* | *Livestock Farming & Ranching* | | | | | | | | |
| | Contribution | | | Very High | | | | | | |
| | Irreversibility | | | Medium | | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | - | Very High | - | - | - | - | - | |
| 4 | Threat | Invasive plant species (tamarisk) | | | | | | | | High |
| | *Common Taxonomy* | *Invasive Non-Native/Alien Species* | | | | | | | | |
| | Contribution | | Medium | | | Very High | | | | |
| | Irreversibility | | High | | | High | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | Medium | - | - | High | - | - | - | |

## Stresses and Threats

**Viability assessment for this target (double click here)**

Click the page-down icon ▼on the toolbar to the right to reach the Threats table.

**Walker Lake CAP 2012**

| | |
|---|---|
| 1 | Lake Ecosystem |

<-- To change targets, click on the target name (current target input will be saved).

▼-- Type a stress, or double-click for the key attribute toolbar.

| | Stresses | Severity | Scope | Stress Rank | User Override |
|---|---|---|---|---|---|
| 1 | Altered Hydrologic regime - (timing, duration, frequency, extent) | Very High | Very High | Very High | |
| 2 | Altered Water chemistry | Very High | Very High | Very High | |
| 3 | Absence / lowered abundance of key functional guilds | High | High | High | |
| 4 | Altered Primary productivity | Medium | High | Medium | |
| 5 | Altered Size / extent of characteristic communities / ecosystems | High | Very High | High | |
| 6 | | | | - | |
| 7 | | | | - | |
| 8 | | | | - | |

| | **Threats - Sources of Stress** | Altered Hydrologic regime - (timing, duration, frequency | Altered Water chemistry | Absence / lowered abundance of key functional guilds | Altered Primary productivity | Altered Size / extent of characteristic communities / ecosystems | - | - | - | Threat to Target Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stresses #.. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | Rank.. | *Very High* | *Very High* | *High* | *Medium* | *High* | - | - | - | |
| 1 | Threat | Agricultural water use upstream | | | | | | | | Very High |
| | *Common Taxonomy* | *Annual & Perennial Non-Timber Crops* | | | | | | | | |
| | Contribution | High | Medium | | Medium | High | | | | |
| | Irreversibility | Very High | High | | High | High | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | Very High | High | - | Low | High | - | - | - | |
| 2 | Threat | Dams & Water Management/Use | | | | | | | | Very High |
| | *Common Taxonomy* | *Dams & Water Management/Use* | | | | | | | | |
| | Contribution | Very High | | High | | Very High | | | | |
| | Irreversibility | Very High | | High | | High | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | Very High | - | High | - | High | - | - | - | |
| 3 | Threat | High Total Dissolved Solids | | | | | | | | Very High |
| | *Common Taxonomy* | *Dams & Water Management/Use* | | | | | | | | |
| | Contribution | | Very High | Very High | Very High | Very High | | | | |
| | Irreversibility | | Very High | Very High | High | Very High | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | Very High | High | Medium | High | - | - | - | |

## Stresses and Threats

Viability assessment for this target (double click here)

Click the page-down icon ▼on the toolbar to the right to reach the Threats table.

**Walker Lake CAP 2012**

| | |
|---|---|
| 2 | Lahontan Cutthroat Trout |

<-- To change targets, click on the target name (current target input will be saved).

**▼-- Type a stress, or double-click for the key attribute toolbar.**

| | Stresses | Severity | Scope | Stress Rank | User Override |
|---|---|---|---|---|---|
| 1 | Altered Water chemistry | Very High | Very High | Very High | |
| 2 | Altered Hydrologic regime - (timing, duration, frequency, extent) | High | Very High | High | |
| 3 | Lack of adequate/appropriate food resources | Medium | High | Medium | |
| 4 | Altered Population structure & recruitment | Very High | Very High | Very High | |
| 5 | | | | - | |
| 6 | | | | - | |
| 7 | | | | - | |
| 8 | | | | - | |

| | **Threats - Sources of Stress** | Altered Water chemistry | Altered Hydrologic regime - (timing, duration, frequency | Lack of adequate/appropriate food resources | Altered Population structure & recruitment | - | - | - | - | Threat to Target Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stresses #.. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | Rank.. | *Very High* | *High* | *Medium* | *Very High* | - | - | - | - | |
| 1 | Threat | High Total Dissolved Solids | | | | | | | | Very High |
| | *Common Taxonomy* | *Dams & Water Management/Use* | | | | | | | | |
| | Contribution | Very High | | Very High | Very High | | | | | |
| | Irreversibility | Medium | | High | Medium | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | Very High | - | Medium | Very High | - | - | - | - | |
| 2 | Threat | Agricultural water use upstream | | | | | | | | High |
| | *Common Taxonomy* | *Annual & Perennial Non-Timber Crops* | | | | | | | | |
| | Contribution | Medium | High | | | | | | | |
| | Irreversibility | Medium | High | | | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | High | High | - | - | - | - | - | - | |
| 3 | Threat | Dams & Water Management/Use | | | | | | | | High |
| | *Common Taxonomy* | *Dams & Water Management/Use* | | | | | | | | |
| | Contribution | | Very High | | High | | | | | |
| | Irreversibility | | Medium | | Medium | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | High | - | High | - | - | - | - | |
| 4 | Threat | Lack of adequate food resources | | | | | | | | Very High |
| | *Common Taxonomy* | *Other Ecosystem Modifications* | | | | | | | | |
| | Contribution | | | Very High | High | | | | | |
| | Irreversibility | | | High | High | | | | | |
| | Threat Rank (override) | | | Medium | | | | | | |
| | Threat Rank | - | - | Low | Very High | - | - | - | - | |

## Stresses and Threats

**Viability assessment for this target (double click here)**

**Click the page-down icon ▼ on the toolbar to the right to reach the Threats table.**

**Walker Lake CAP 2012**

| 3 | Tui Chub |
|---|---|

**<-- To change targets, click on the target name (current target input will be saved).**

**▼-- Type a stress, or double-click for the key attribute toolbar.**

| | Stresses | Severity | Scope | Stress Rank | User Override |
|---|---|---|---|---|---|
| 1 | Lack of Connection to riparian system | Low | Medium | Low | |
| 2 | Altered Hydrologic regime - (timing, duration, frequency, extent) | High | Very High | High | |
| 3 | Altered Nutrient concentrations & dynamics | Very High | Very High | Very High | |
| 4 | Altered Water chemistry | Very High | Very High | Very High | |
| 5 | Absence of adequate/appropriate food resources | Low | High | Low | |
| 6 | Depredation & parasitism | Low | Medium | Low | |
| 7 | Altered Population structure & recruitment | Very High | Very High | Very High | |
| 8 | Altered Population size & dynamics | Medium | Very High | Medium | |

| **Threats - Sources of Stress** | | Lack of Connection to riparian system | Altered Hydrologic regime - (timing, duration, frequency) | Altered Nutrient concentrations & dynamics | Altered Water chemistry | Absence of adequate/appropriate food resources | Depredation & parasitism | Altered Population structure & recruitment | Altered Population size & dynamics | Threat to Target Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| Stresses | #.. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | Rank.. | *Low* | *High* | *Very High* | *Very High* | *Low* | *Low* | *Very High* | *Medium* | |
| 1 | Threat | High Total Dissolved Solids | | | | | | | | Very High |
| | *Common Taxonomy* | *Dams & Water Management/Use* | | | | | | | | |
| | Contribution | | High | Very High | Very High | Very High | | Very High | High | |
| | Irreversibility | | High | High | High | High | | High | High | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | High | Very High | Very High | Low | - | Very High | Medium | |
| 2 | Threat | Pelican predation on larger classes | | | | | | | | Medium |
| | *Common Taxonomy* | *Problematic Native Species* | | | | | | | | |
| | Contribution | | | | | | Medium | Low | | |
| | Irreversibility | | | | | | Very High | Very High | | |
| | Threat Rank (override) | | | | | | | Low | | |
| | Threat Rank | - | - | - | - | - | Low | Medium | - | |
| 3 | Threat | Drought | | | | | | | | Very High |
| | *Common Taxonomy* | *Droughts* | | | | | | | | |
| | Contribution | High | High | | High | Medium | | | | |
| | Irreversibility | Very High | Very High | | Very High | Medium | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | Low | High | - | Very High | Low | - | - | - | |
| 4 | Threat | Dams & Water Management/Use | | | | | | | | High |
| | *Common Taxonomy* | *Dams & Water Management/Use* | | | | | | | | |
| | Contribution | High | Very High | | | | | | | |
| | Irreversibility | Medium | Medium | | | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | Low | High | - | - | - | - | - | - | |
| 5 | Threat | Agricultural water use upstream | | | | | | | | Very High |
| | *Common Taxonomy* | *Annual & Perennial Non-Timber Crops* | | | | | | | | |
| | Contribution | | | High | High | | | | | |
| | Irreversibility | | | High | High | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | - | Very High | Very High | - | - | - | - | |

## Stresses and Threats

**Viability assessment for this target (double click here)**

**Click the page-down icon ▼on the toolbar to the right to reach the Threats table.**

**Walker Lake CAP 2012**

| 4 | Piscivorous Birds |
|---|---|

**<-- To change targets, click on the target name (current target input will be saved).**

**▼-- Type a stress, or double-click for the key attribute toolbar.**

| | Stresses | Severity | Scope | Stress Rank | User Override |
|---|---|---|---|---|---|
| 1 | Lack of Connectivity among communities & ecosystems | Low | Low | Low | |
| 2 | Altered Trophic structure | High | Very High | High | |
| 3 | Absence of key communities or seral stages | Very High | Very High | Very High | |
| 4 | | | | - | |
| 5 | | | | - | |
| 6 | | | | - | |
| 7 | | | | - | |
| 8 | | | | - | |

| **Threats - Sources of Stress** | | Lack of Connectivity among communities & ecosystems | Altered Trophic structure | Absence of key communities or seral stages | - | - | - | - | - | Threat to Target Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| Stresses | #.. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | Rank.. | *Low* | *High* | *Very High* | - | - | - | - | - | |
| 1 | Threat | High Total Dissolved Solids | | | | | | | | Very High |
| | *Common Taxonomy* | *Dams & Water Management/Use* | | | | | | | | |
| | Contribution | | Very High | High | | | | | | |
| | Irreversibility | | High | High | | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | High | Very High | - | - | - | - | - | |
| 2 | Threat | Lack of adequate food resources | | | | | | | | Very High |
| | *Common Taxonomy* | *Other Ecosystem Modifications* | | | | | | | | |
| | Contribution | | | Very High | | | | | | |
| | Irreversibility | | | High | | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | - | Very High | - | - | - | - | - | |

## Stresses and Threats

**Viability assessment for this target (double click here)**

**Click the page-down icon ▼on the toolbar to the right to reach the Threats table.**

**Walker Lake CAP 2012**

| 5 | Freshwater Marsh/Spring |
|---|---|

**<-- To change targets, click on the target name (current target input will be saved).**

**▼-- Type a stress, or double-click for the key attribute toolbar.**

| | **Stresses** | Severity | Scope | Stress Rank | User Override |
|---|---|---|---|---|---|
| 1 | Community architecture | High | Very High | High | |
| 2 | Depredation & parasitism | Medium | Medium | Medium | |
| 3 | Species composition / dominance | High | High | High | |
| 4 | Hydrologic regime - (timing, duration, frequency, extent) | High | High | High | |
| 5 | | | | - | |
| 6 | | | | - | |
| 7 | | | | - | |
| 8 | | | | - | |

| | **Threats - Sources of Stress** | Community architecture | Depredation & parasitism | Species composition / dominance | Hydrologic regime - (timing, duration, frequency, extent) | - | - | - | - | Threat to Target Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stresses #.. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | Rank.. | *High* | *Medium* | *High* | *High* | - | - | - | - | |
| 1 | Threat | Feral horses | | | | | | | | High |
| | *Common Taxonomy* | *Invasive Non-Native/Alien Species* | | | | | | | | |
| | Contribution | Very High | High | High | | | | | | |
| | Irreversibility | Low | Low | Low | | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | High | Low | Medium | - | - | - | - | - | |
| 2 | Threat | Invasive aquatic species (Gambusia) | | | | | | | | Medium |
| | *Common Taxonomy* | *Invasive Non-Native/Alien Species* | | | | | | | | |
| | Contribution | | High | Medium | | | | | | |
| | Irreversibility | | Medium | Medium | | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | Low | Medium | - | - | - | - | - | |
| 3 | Threat | Drought | | | | | | | | High |
| | *Common Taxonomy* | *Droughts* | | | | | | | | |
| | Contribution | | | | Very High | | | | | |
| | Irreversibility | | | | Very High | | | | | |
| | Threat Rank (override) | | | | | | | | | |
| | Threat Rank | - | - | - | High | - | - | - | - | |

**Appendix 2.** Methods of Conservation Action Planning

The following is a summary of the methods of Conservation Action Planning (CAP) used by The Nature Conservancy (TNC) for this Conservation Assessment. More information is available in the following chapters, and at the *Conservation by Design Gateway* (http://conserveonline.org/workspaces/cbdgateway). The Walker Lake CAP was conducted in consistence with this methodology, although certain steps are emphasized more than others (i.e. There is less emphasis on strategies in this document due to the fact that NFWF is developing that information outside of the context of this plan).

**Geographic Scope.** The geographic area subject to conservation planning is determined by the biodiversity features of interest and can be thought of as the geographic or ecological "frame" within which TNC or its partners will act to preserve or restore biodiversity. The scope of the project is depicted by a base map illustrating the applicable project area and a general text description. To facilitate analysis and strategic evaluation of the Walker Rivers and Lake Basin, TNC divided the area into three segments and three separate planning processes: 1) the whole basin, 2) Walker Rivers (East and West Forks), and 3) Walker Lake. This report covers the third segment of the analysis and was prioritized to coincide with data and information availability as well as conservation opportunities from partner organizations.

**Conservation Targets.** Conservation targets consist of species, ecological communities, and ecological systems that TNC seeks to preserve. A species is the basic unit of biological organization and consists of a group of organisms recognized as distinct from other groups. Ponderosa pine trees and Lahontan cutthroat trout are species. Ecological communities are co-occurring plants and animals that form a cohesive and distinguishable unit, and generally exist at small to medium spatial scales. Freemont cottonwood riparian habitat and tule wetlands are ecological communities. Ecological systems are co-occurring ecological communities that are distributed across large spatial scales; temperate conifer forest and sagebrush steppe are examples. Within an ecological system, such as temperate conifer forest, one might find many ecological communities such as fens, wet meadows, aspen stands, lodgepole pine forest, and red fir forest.

Target selection is an extremely important component of CAP, because the conservation needs of targets drive all subsequent analyses and the subsequent array of conservation actions that TNC or its cooperating partners will undertake. For more information on this important topic, please consult Poiani, et al. (2000), and Groves (2003).

**Target Viability.** Viability refers to the status or health of a population of a specific plant or animal species. Viability indicates the ability of a conservation target to withstand or recover from most natural or anthropogenic disturbances and thus to persist for many generations or over long time periods.

Viability assessments begin by determining the key ecological attributes (KEAs) for each of the conservation targets. At its most basic, a KEA is an aspect of a target's ecology that, if present, defines a healthy target and, if missing or altered, would lead to the outright loss or extreme degradation of that target over time. Ecological attributes of a target may include age distribution, number of individuals, spatial area of an ecological community, competition with invasive species, or the physical structure of a plant community. KEAs also include environmental regimes and landscape processes such as fire, flooding, and a dynamic river corridor.

It is important to develop indicators that can be used to assess KEAs over time. An indicator is measured to keep track of the status of a KEA. For example, an indicator of fire regime for a grassland target might be the number of years between fires. An indicator of population size for a migratory fish target might be the number of spawning adults observed during the breeding season. Indicators are a guide to the data that must be collected to measure the success of conservation objectives and strategies.

TNC applies a viability rating scale to rank the status of KEAs. This rating scale specifies our assumption as to what constitutes a conserved target versus one that is in need of management intervention:

VERY GOOD: Ecologically desirable status; requires little intervention for maintenance. *Conserved*.

GOOD: Indicator within acceptable range of variation; some intervention may be required for maintenance. *Conserved.*

FAIR: Outside acceptable range of variation; requires human intervention. *Conservation status is tenuous*.

POOR: Restoration increasingly difficult; may result in extirpation of target. *Not conserved.*

The final step in the viability assessment is to use this rating scale to determine the current status of the conservation target (where the target is today) and the desired status of the target (where we would like it to be at some point in the future). One of the primary goals of conservation strategy under a CAP is to restore or improve the viability of conservation targets by bringing the key ecological attributes into an acceptable range of variation.

**Threat Analysis.** Threats to targets are evaluated in two parts: first in terms of stresses to targets, and then in terms of sources of stress. Stresses are circumstances or actions that harm the viability of targets. Stresses are generally degraded key ecological attributes, and for purposes of clarity and simplicity, are defined as *altered key ecological attributes*. For example, if *channel sinuosity* is a key ecological attribute for riparian habitat, because a sinuous channel provides point bars and suitable substrates for establishment of new stands of riparian forest, then the stress would be *altered channel sinuosity*.

Sources of stress are the activities or processes that are responsible for the stress. Sources are often related to human activities. For example, consider again the stress category *altered channel sinuosity*. If clearing the river channels of sand and debris every year maintains the river in an entrenched and straight condition, then the source of stress is *annual clearing of the river channel*.

It is important to clarify that viability rankings capture the "errors of the past," whereas threat rankings capture the "errors of the future." In other words, past circumstances are reflected in the viability rankings, whereas current and future circumstances that harm a target's viability are reflected in the threat rankings. Threat rankings also depend on the species-specific adaptability to particular stressors; some species have greater capacity than others.

The difference between "sins of the past" (viability) versus "sins of the future" (threats) is relevant to a consideration of cumulative impacts. The viability rankings probably do a better job of capturing the cumulative effect of many historic impacts to viability and also to evolutionary constraints on adaptability—that is, the physiological, developmental, life history, and ecological constraints on a species' responses to the threats under consideration. Looking forward, it is important to be aware that separate threat rankings may not fully capture the interaction and cumulative impact of multiple threats.

Rating criteria for stresses and sources should reflect the level of damage to the conservation target that can reasonably be expected within 10-25 years. The abatement of *VERY HIGH* and *HIGH* threats is generally one of the primary objectives of conservation strategy under a CAP.

> VERY HIGH: The threat is likely to destroy or eliminate the conservation target over some portion of the target's occurrence at the site.
>
> HIGH: The threat is likely to seriously degrade the conservation target over some portion of the target's occurrence at the site.
>
> MEDIUM: The threat is likely to moderately degrade the conservation target over some portion of the target's occurrence at the site.
>
> LOW: The threat is likely to only slightly impair the conservation target over some portion of the target's occurrence at the site.

**Situation Analysis.** Situational factors consist of the key cultural, economic, political, and opportunity features of the landscape. Situational factors should capture the "drivers of change" such as rapid population increases, real estate development, listing of an endangered species, or the construction of a major new public works project. Situational factors also include the people who live, work, or recreate in the conservation planning area, such as landowners, hunters, fishers, loggers, farmers, ranchers, miners, residents, businesses and industry, regulatory agencies, and more. In general, these people and institutions that have some relationship to the conservation targets are referred to as *stakeholders*.

**Strategies.** A conservation strategy is a broad course of action intended to achieve a specific objective that abates a critical threat, enhances the viability of a conservation target, or secures project resources and support. There are two fundamental components to conservation strategies: Objectives and Strategic Actions.

Objectives are specific and measurable statements of what we hope to achieve within our project. They represent our assumptions as to what we need to accomplish and, as such, become the measuring stick against which we will gauge the progress of the project. Objectives can be stated in terms of reducing the status of a critical threat, enhancing or maintaining the status of key ecological attributes of focal targets, securing project resources, and/or the outcomes of specific conservation actions. Objectives should meet the following criteria:

> **Specific**: What exactly does the project team want to achieve?
>
> **Measurable**: The objective needs to be defined in relation to a quantitative or qualitative scale to allow progress to be measured.
>
> **Achievable**: Can it be done in the proposed timeframe within the social and political context of the project and with available funds?
>
> **Relevant**: The results need to be impact-oriented and represent the necessary changes in key ecological attributes, critical threat factors, or project resources to achieve the project goal.
>
> **Time Limited**: When will the objective be reached?

Strategic actions are broad or general courses of action undertaken by a project team to reach one or more of a project's stated objectives. Collectively, the strategic actions should be sufficient to accomplish the objectives. A good strategic action is directly linked to an objective, and is focused, feasible, and appropriate.

**Measures of Success.** For most conservation action plans, the direct measure of success concerns the status of indicators for each key ecological attribute. The KEAs and their associated indicators are the primary measure by which the CAP process evaluates the status and condition of the conservation targets. Strategy effectiveness measures are designed to tell us if our actions are abating threats and improving the viability of targets.

Strategic actions may affect biodiversity indirectly by focusing on underlying causes behind the sources of stress. In these cases, we consider measuring indicators at multiple stages of the causal chain(s) that link the actions to the biodiversity to better assess whether the strategies are working. Consider the conservation action of finding ways to improve crop and pasture irrigation efficiency, and leaving the conserved water in the channel to benefit fish who are suffering from low river flows influenced by agricultural water diversions. This might be accomplished, for example, by switching from high-water-demand crops to low-water-demand crops. Simply identifying ways to improve irrigation efficiency and providing incentives offers an insufficient measure of strategy effectiveness—what if the new incentive program is never implemented? Similarly, tracking the number of fish in the river does not provide a sensitive measure of strategy effectiveness given the series of linked changes that must occur for the conservation action to affect the fish.

Developing a plan for measuring results ultimately involves determining the indicators monitored and the methods used to measure the indicators. Direct indicators are identified in the viability process and are linked to each indicator and key ecological attribute. Good indicators have the following characteristics:

**Measurable**: Able to be recorded and analyzed in quantitative or in discrete qualitative terms.

**Clear**: Presented or described in such a way that its meaning will be the same to all people.

**Sensitive**: Changing proportionately in response to actual changes in the condition or item being measured.

See Salzer and Salafsky (2006) for more insights into measuring success.