CHAPTER 7

Fisheries

Fish have always been an integral part of the Tahoe's aquatic systems. Fish play in important role in the food webs of the Region's lakes and streams, and fishing is socially important activity. There are two key aquatic environments that support fish in the Lake Tahoe Basin: lakes and streams. These two ecosystems are dynamic in space and time. Combined, lakes and streams provide fish with necessary elements such as water, cover, and spawning and nursery habitat. Both environments play an important role in sustaining fish populations and some fish species use both lake and stream environments in different stages of their life cycles. The combination of chemical, biological, temperature, and physical characteristics of lakes and streams influence the suitability of these environments to sustain different fish populations. Likewise, the physical and biological integrity of the surrounding landscape plays an important role in sustaining aquatic habitats important to fish. Accordingly, degradation of lake and stream habitat and the surrounding landscape can reduce the sustainability of Tahoe's fishery.

The goal of TRPA adopted threshold standards for fisheries resources is to improve aquatic habitat important for the growth, reproduction, and perpetuation of existing and threatened fish resources in the Lake Tahoe Basin (TRPA 1982a). TRPA has adopted one numerical standard (stream habitat condition), one management standard without a numeric target (instream flow), one management standard with a numeric target (lake habitat), and two policy statements (instream flow and Lahontan cutthroat trout) (Table 7-1). There are four indicator reporting categories in the fisheries threshold category: lake habitat, stream habitat, instream flow, and Lahontan cutthroat trout.

The TRPA Regional Plan, including the TRPA Goals and Policies (TRPA 2012c) and the Code of Ordinances (TRPA 2012b), provide relevant policies and regulations for the maintenance of habitat conditions for fisheries threshold standards. The Environmental Improvement Program (EIP) administered by TRPA includes programs that result in the enhancement or restoration of fish habitats in the Basin. For example, EIP projects that reestablish the natural hydrologic regimes, remove impervious cover and enhance vegetation cover in stream zones are widely understood to enhance the quality of stream habitat for various species of fish and aquatic organisms. In addition, erosion control and stormwater treatment projects implemented through the EIP improve water quality and thus improve habitat quality for Tahoe's fishery.

According to the Goals and Policies for fisheries, the overarching goal is to "improve aquatic habitat essential for the growth, reproduction, and perpetuation of existing and threatened fish resources in the Lake Tahoe Basin." Nine policy statements support this goal and include:

1. Mitigating project impacts to fish habitat in streams and lakes.
2. Prohibiting new unnatural blockages and encouraging the removal of existing impediments to fish movement in streams, where appropriate.
3. Developing a maintenance program to inventory and remove stream blockages.
4. Establishing boating standards to reduce associated disturbance in the lake's shallow zone.
5. Encouraging habitat improvement projects in streams and lakes.
6. Maintaining and enhancing stream flows.
7. Transferring existing water diversions from streams to lake withdrawals, whenever feasible
8. Supporting state and federal efforts to reintroduce Lahontan cutthroat trout.
9. Prohibiting the release of nonnative aquatic species and controlling and eradiating existing populations.

The core of TRPA's fisheries regulations are designed to achieve threshold standards as detailed in the TRPA Code of Ordinances, Chapter 63, and applicable regulations for the management of fish habitats can be found throughout the Code of Ordinances (TRPA 2012b). For example, Chapter 30 of the Code of Ordinances restricts urban development within stream environment zones. Chapter 33 governs grading and construction practices and Chapter 53 establishes a framework for grazing livestock. Chapter 63 includes provisions that protect fish habitat and enhance degraded lake and stream habitat. For lake environments, all projects and activities conducted in the shorezone may be prohibited, limited, or otherwise regulated in prime habitat areas (spawning, feed and cover habitats that include submerged substrates comprised of gravels, cobbles, and rocks), or in situations that TRPA found to be vulnerable or critical to the needs of fish. Special conditions of project approval, such as restoring physically altered substrate, limiting construction to designated periods, or implementing shoreline protective measures, may be required for development in the shorezone to mitigate or avoid significant adverse impacts to habitat or fish. Certain activities such as boat beaching may be temporarily restricted in areas where spawning activity occurs. To support the non-degradation standard that applies to lake fish habitat, TRPA's Code of Ordinances prohibits the alteration of substrate in areas of prime fish habitat unless alterations are mitigated and approved by TRPA. Protections for instream habitats are similar. They prohibit channel alterations, permit only stream crossings that allow fish passage, require impacts to fish habitat to be mitigated, and prevent sedimentation and loss of vegetative cover More recently, TRPA adopted additional ordinances to prevent the introduction of new aquatic invasive species by requiring inspections and possible decontaminations of all boats entering regional lakes.

The diversity of Tahoe's fish community has changed considerably since the settlement of Euro-Americans in the Tahoe Basin. Prior to the influence of Euro-American settlement, seven species of fish occurred in the lakes and streams of the Tahoe Basin (Murphy and Knopp 2000; K. L. Ngai et al. 2011). Of the native fish species, Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*) and the mountain whitefish (*Prosopium williamsoni*) were abundant and revered by Native Americans because they provided ample food for their people. Since the Comstock era circa 1860, when Lahontan cutthroat trout were extirpated, mountain whitefish populations have declined substantially, and at least 20 additional species of fish have been introduced into Tahoe's aquatic communities (Murphy and Knopp 2000; K. L. Ngai et al. 2011). According to fisheries biologists, several factors have contributed to the alteration of Tahoe's fish species diversity, the decline or extirpation of native fish, and the degradation of aquatic habitats in the Basin. These factors include sedimentation associated with turn of the century logging, livestock grazing, commercial fish harvests, interruption of natural hydrologic regimes resulting from past logging practices, urban development (1950s through 1970s), and the introduction of non-native fish and other aquatic organisms (Murphy and Knopp 2000; K. L. Ngai et al. 2011; SNEP 1996). Figure 7-1 provides overview of the timeline of introduction of species to Lake Tahoe. Today, stream restoration projects and efforts to reintroduce Lahontan cutthroat trout are underway (R. Al-Chokhachy and Peacock 2009).

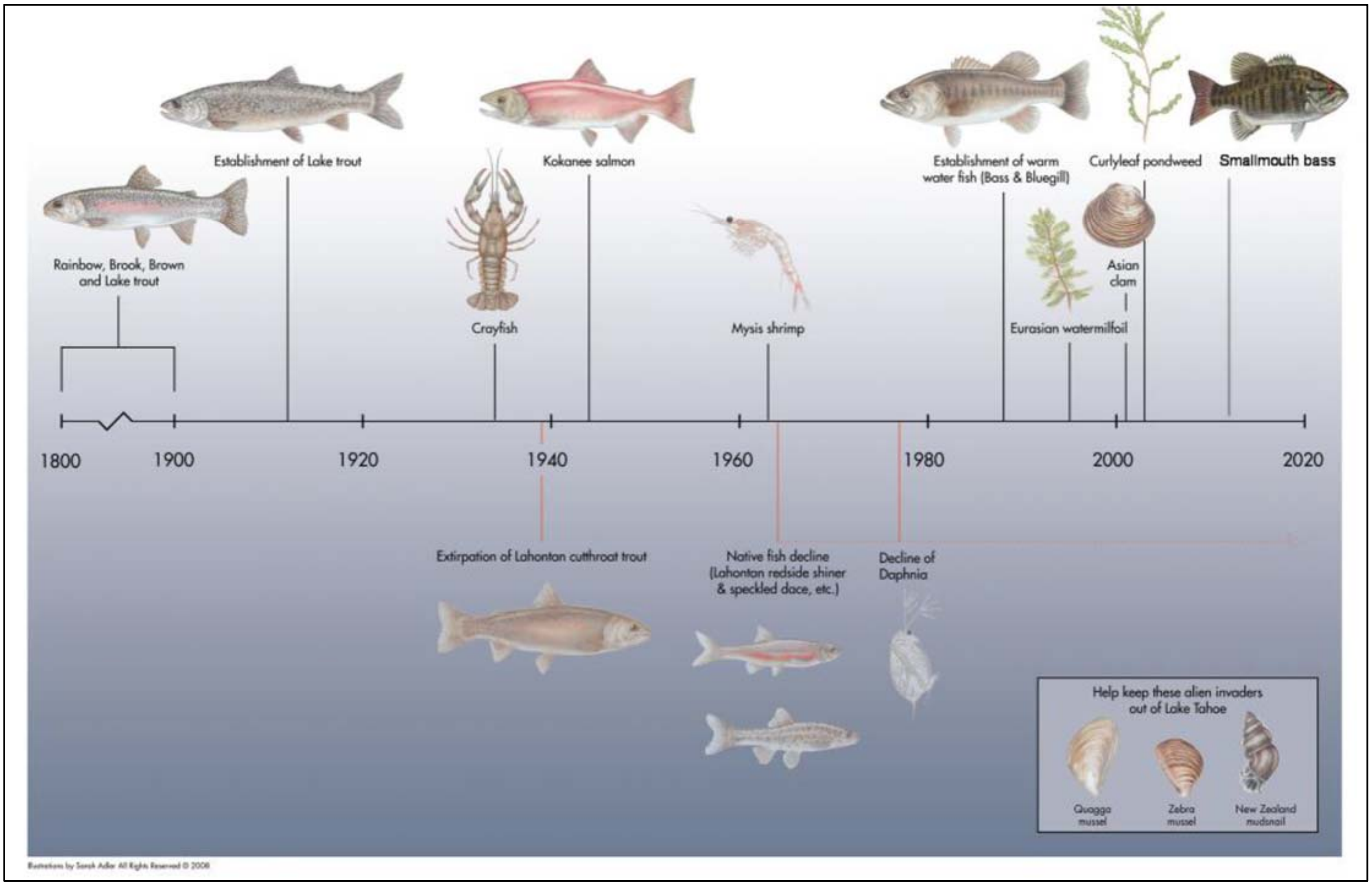


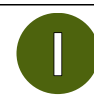
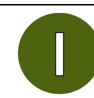
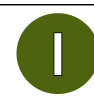
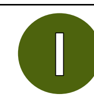
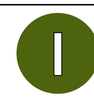
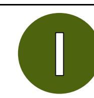
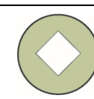
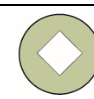
Figure 7-1: Timeline of species introduction or date first documented in Lake Tahoe. The bottom part of the timeline highlights decline or extirpation of native species (Wittmann and Chandra 2015).

Table 7-1: TRPA adopted threshold standards for fisheries

Indicator Reporting Category	Standard	Type of Standard	Indicator
Lake Habitat	A nondegradation standard shall apply to fish habitat in Lake Tahoe. Achieve the equivalent of 5,948 total acres of excellent habitat as indicated by the Prime Fish Habitat Overlay Map, which may be amended based on best available science.	Management Standard (with numeric target)	Acres of fish habitat within the nearshore of Lake Tahoe - defined by substrate size
Stream Habitat	Maintain 75 miles of excellent, 105 miles of good, and 38 miles of marginal stream habitat as indicated by the Stream Habitat Quality Overlay map, amended May 1997, based upon the re-rated stream scores set forth in Appendix C-1 of the 1996 Evaluation Report.	Numerical Standard	Miles of stream habitat in different condition classes (excellent, good and poor)
Instream Flow	Until instream flow standards are established in the Regional Plan to protect fishery values, a nondegradation standard shall apply to instream flows.	Management Standard	Evidence of TRPA support for Management Standard
	It shall be a policy of the TRPA Governing Board to seek transfers of existing points of water diversion from streams to Lake Tahoe.	Policy Statement	Evidence of TRPA support for policy statement
Lahontan Cutthroat Trout	It shall be the policy of the TRPA Governing Board to support, in response to justifiable evidence, state and federal efforts to reintroduce Lahontan cutthroat trout.	Policy Statement	Evidence of TRPA support for policy statement

The results of the 2015 assessment are summarized in Table 7-2. The table provides a summary of the status and trend of standards in the fisheries reporting categories for stream habitat, instream flows, Lahontan cutthroat trout, and lake fish habitat, for 2015 as well as the results from the 2011 Threshold Evaluation Report to facilitate comparison. Figure 7-2 and Table 7-2 provide a key to the symbols used to communicate status, trends, and confidence, and a detailed description of each is provided in the methodology section. The indicator sheets that follow contain more detailed assessments of the status and trend of each indicator and provide descriptions of the methods used and recommendations for changes to the standard or the analytic approaches used to assess it.

Table 7-2: Fisheries status & trend summary

Standard	2011	2015
Stream Habitat		
Miles of Stream Habitat in Excellent Condition		
Miles of Stream Habitat in Good Condition		
Miles of Stream Habitat in Marginal Condition		
Instream Flow		
Non-degradation Standard for Instream Flow		
Divert Stream Intakes to Lake Sources		
Lahontan Cutthroat Trout		
Lake Habitat		
Acres of "Prime" Fish Habitat		

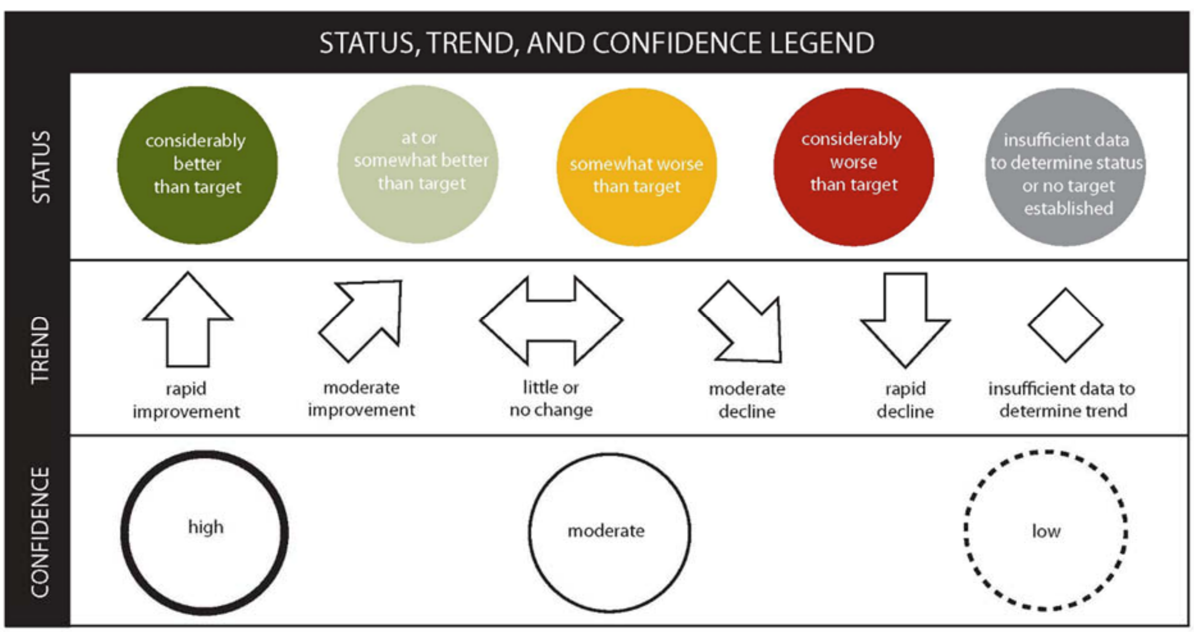


Figure 7-2: *A key to the symbols used to assess status, trends, and confidence levels.*

Table 7-3. *Key to the reporting icon used to characterize the implementation status of management standards and policy statements.*

Status Category	Description	Reporting Icon
Implemented	The management standard or policy statement has been integrated into the Regional Plan and is consistently applied to a project design or as a condition of project approval as a result of project review process. Examples of programs or actions can be identified to support the management standard's implementation. Adopted programs or actions support all aspects of the management standard or policy statement's implementation, or address all major threats to implementation.	I
Partially Implemented	The management standard or policy statement has been integrated into the Regional Plan, but is not consistently applied during the project review process. No more than two examples of programs or actions can be identified to support the management standard's implementation and/or adopted programs or actions support some aspects of the management standard or policy statement's implementation, or address some major threats to implementation.	PI
Not Implemented	The management standard or policy statement has not been integrated into the Regional Plan and is not applied during the project review process. No examples of programs or actions can be identified to support implementation.	NI

Stream Habitat

Stream systems are important aquatic resources. Streams are critical to the Lake Tahoe Basin's water cycle by feeding freshwater to lakes and ponds, recharging groundwater, providing habitat for a wide variety of aquatic and terrestrial organisms and corridors for fish and wildlife migration. TRPA refers to the areas surrounding streams as "stream environment zones." Streams also play an important role in connecting fragmented habitats, and thus in conserving biodiversity.

To aid in conserving and enhancing stream habitat in the Basin, TRPA has adopted policies and implements ordinances that limit the types of activities that occur in and adjacent to streams (TRPA 2012c). TRPA administers a basin-wide Environmental Improvement Program (EIP) that facilitates stream restoration on channel segments determined to be disturbed or impaired. Other actions, such as erosion control and stormwater treatment projects, benefit stream habitat as well.

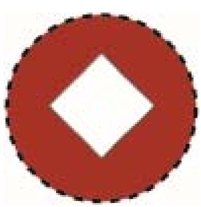
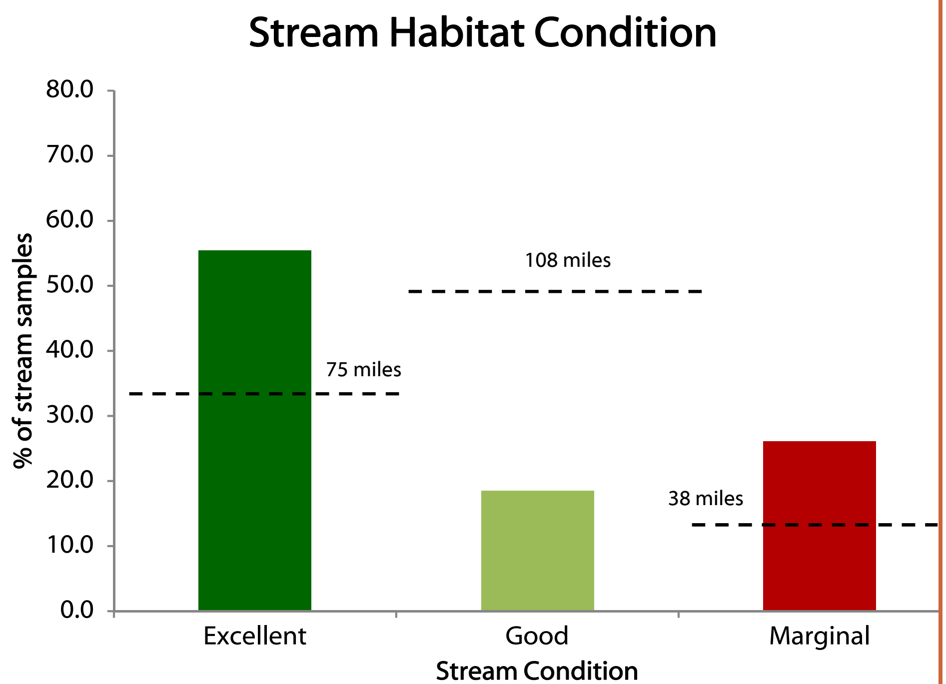
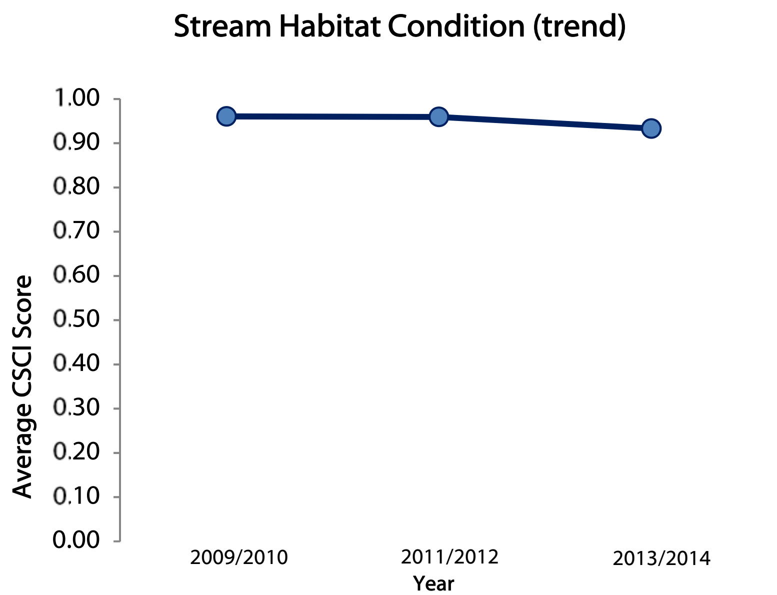
Stream habitats in the Tahoe Basin are similar to streams found throughout the Sierra. High elevation reaches are typically "v-shaped" channels bordered by deciduous and conifer vegetation. Streams at higher elevations typically contain cascades, riffles, runs and pools occasionally interspersed with low gradient meadows. Substrates most common at high elevation reaches are composed of boulder, rocks, cobbles and gravels with smaller diameter sand and silt interspersed. Lower elevation streams typically meander through low gradient flood plains bordered by willow and a variety of meadow wildflowers, forbs, sedges and grasses. Streambed substrates in lower elevation stream reaches are typical of a deposition zone generally dominated by sand and silt.

Recognizing the importance of streams for Tahoe's fishery, TRPA adopted three threshold standards related to the stream habitat indicator reporting category. The stream habitat threshold is a numerical standard to achieve 75 miles of "excellent," 105 miles of "good," and 38 miles of marginal stream habitat for streams classified as residential and migratory. According to Resolution 82-11, the standard can be evaluated based on "*re-rated stream scores set forth in Appendix C-1 of the 1996 Threshold Evaluation Report*." In response to poorly documented sampling methods in the past (discussed in "monitoring approach"), TRPA, in partnership with Nevada Division of Environmental Protection, Lahontan Regional Water Quality Control Board, California Department of Fish and Game – Aquatic Bioassessment Lab, U.S. Forest Service – Region 5, and Humboldt State University, initiated stream bioassessments in the Lake Tahoe Basin starting in 2009. Benthic macroinvertebrates (BMI) composition and physical stream habitat parameters are analyzed using the California Stream Condition Index model developed by the California Department of Fish and Game – Aquatic Bioassessment Lab (Rehn, Mazor, and Ode 2015).

Results from 2009 through 2014 stream sampling revealed:

- More streams in excellent condition than the standard
- Too many streams in marginal condition
- Standard for streams in good condition was not met
- Because only three monitoring periods exist, there was insufficient data to determine trend and confidence is low.

Stream Habitat: **Miles of Stream Habitat Condition**

Status	Graphs
 MILES OF STREAM HABITAT IN EXCELLENT CONDITION Status: **Considerably Better than Target** Trend: **Insufficient Data to Determine Trend** Confidence: **Low**  MILES OF STREAM HABITAT IN GOOD CONDITION Status: **Considerably Worse than Target** Trend: **Insufficient Data to Determine Trend** Confidence: **Low**  MILES OF STREAM HABITAT IN MARGINAL CONDITION Status: **Considerably Worse than Target** Trend: **Insufficient Data to Determine Trend** Confidence: **Low**	 Proportion of streams assessed in each condition in the Tahoe Basin based on California Stream Condition Index scores 2009-2014 (status sites only). Threshold standards for stream condition are the dotted lines. There were more excellent streams than the standard, but fewer good streams and too many marginal streams. Source: TRPA.  Average CSCI scores of Tahoe Basin streams (trend sites only) from 2009 – 2014. A small decrease in average scores has occurred, but because only three monitoring periods exist, there is insufficient data to determine a trend and confidence is low. Source: TRPA

Data Evaluation and Interpretation
BACKGROUND

Relevance – Streams and their associated riparian habitats are key components of the Tahoe Basin's aquatic ecosystems and are important to people. Concern for stream water quality and biological condition is embodied in various federal, state, and regional water quality laws, regulations, and ordinances, including the Clean Water Act, 208 Water Quality Plan, TRPA Code of Ordinances, and California/Nevada state water quality standards. Streams and associated environments significantly contribute to the Tahoe Basin's biological diversity and provide recreational opportunities for people in the Basin. The use of benthic macroinvertebrates and associated physical/chemical stream measurements (i.e. bioassessment) to assess overall biotic health of streams is a widely accepted practice used by the EPA and all 50 states in their water quality programs (Davis, Smith, and Jackson 2004; Hodkinson and Jackson 2005; Karr 2006; Karr and Chu 1999).

TRPA Threshold Category – Fisheries

TRPA Threshold Indicator Reporting Category – Stream Habitat

Adopted Standards – Maintain the 75 miles of excellent, 105 miles of good, and 38 miles of marginal stream habitat as indicated by the Stream Habitat Quality Overlay map, amended May 1997, based upon the re-rated stream scores set forth in Appendix C-1 of the 1996 Threshold Evaluation Report.

Type of Standard – Numerical

Indicator (Unit of Measure) – Miles of stream habitat in different condition classes (excellent, good and marginal)

Human & Environmental Drivers – A suite of natural environmental factors including weather and climate patterns, especially drought, and geological context such as geological origin, elevation, topography, and soils influence stream condition and habitat suitability for a variety of fish species. Past resource extraction has contributed to legacy effects on the physical features of streams and their biota. Channel modifications associated with historic logging activities (e.g., dams, water extraction and diversions, flumes, stream channelization, and flood control impoundments) altered stream channel structure and watershed-specific hydrology. Historic grazing damaged stream banks and soils and altered stream channel habitat structure through sedimentation and the simplification of riparian plant structure and composition (Murphy and Knopp 2000). The impact of these activities can be seen in the high percentage of sand and fine sediments from excess erosion in many of the Tahoe Basin streams (Tahoe Regional Planning Agency 2015b; Roll et al. 2013; Purdy, Fesenmyer, and Henery 2014). However, the unique geological features found in the Tahoe Basin can also increase the amount of natural sand and fines found in these streams (Murphy and Knopp 2000). Dams can create barriers to movement and migration of aquatic organisms and alter natural stream flow patterns. Several factors within developed areas contribute to the alterations of key stream features including: 1) the urban transportation infrastructure, 2) land cover and disturbance, 3) urban landscaping practices, and 4) water withdrawal and export. Roads can contribute sediment and chemical inputs, thereby altering streambed conditions and elevating chemical pollutant loads. Road crossings can confine streams from natural meander patterns, resulting in impediments to organism movements, stream bank instability, and channel downgrading. Increased impervious surfaces on the landscape can prevent water from naturally percolating into soils thereby affecting its rate of delivery to streams. As a result, organisms downstream of developed areas can experience more intense flooding events and flashier flow regimes as the water moves faster from the land into the channel. However, in an analysis of Tahoe Basin stream health in relation to impervious cover of the watershed, little correlation was found (O'Dowd and Stubblefield 2013). The study found that less than three percent of all monitoring sites had watersheds with impervious cover greater than five percent. Numerous studies have shown that impacts to streams generally begin to appear when five percent to 10 percent impervious cover is reached, meaning that the majority of Tahoe Basin streams do not exceed this impervious cover threshold. li (Schueler 1994; Booth and Jackson 1997; Wang et al. 1997). However, once there is a more robust stream sample size, it will be worthwhile to reassess the impacts of impervious cover on Tahoe stream health. Forest structure and fires also impact stream flow and water quality. The forests of the Sierra Nevada today are denser today as result of fire suppression than they were 200 years ago. The result of denser stands is likely reduced stream flow and increased forest thinning could increase annual average streamflow by as much as 6% (Podolak et al. 2015). Fires can also dramatically alter surface dynamics and sediment and nutrient yields from burned areas (Moody and Martin 2009). The Angora fire in 2007, which burned 22% of the watershed area, had a significant but not catastrophic impact on water quality in Angora creek (Oliver et al. 2012).

MONITORING AND ANALYSIS

Monitoring Partners – U.S. Forest Service, California Department of Fish and Wildlife, Nevada Department of Wildlife, Nevada Division of Environmental Protection, Lahontan Water Quality Control Board, Tahoe Regional Planning Agency

Monitoring Approach – Streams are monitored using widely accepted bioassessment protocols established by the EPA and further refined by the California Department of Fish & Wildlife (CDFW) (Kaufmann et al. 1999; Ode 2007; Barbour et al. 1999). Specifically, stream monitoring is conducted using *Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California* (Ode 2007). The TRPA stream monitoring program was developed in partnership with the EPA, CDFW, Nevada Department of Environmental Protection (NDEP), Lahontan Water Quality Control Board (Lahontan), and the U.S. Forest Service (USFS) (Fore 2007). Benthic macroinvertebrates (BMIs), as well as physical and chemical stream characteristics, are sampled at 48 streams annually. Of these 48 streams, 16 per year are probabilistic "status" sites randomly selected through EPA modelling (Olsen et al. 1999; Paulsen, Hughes, and Larsen 1998) and 24 are "trend" sites revisited every other year. Eight sites are visited annually as "reference" sites used to determine if any changes in the condition of Tahoe streams is occurring based on environmental factors outside of human influence (Tahoe Regional Planning Agency 2010). The species composition and relative abundance of the BMI in each stream is analysed by a lab. Results of the macroinvertebrates are analysed through the peer-reviewed model developed by the CDFW Aquatic Bioassessment Laboratory called the California Stream Condition Index (CSCI) (Rehn, Mazor, and Ode 2015). The CSCI combines two separate indices that each provides unique information about the biological condition of a stream: a multi-metric index (MMI) that measures ecological structure and function, and an observed-to-expected (O/E) index that measures taxonomic completeness. Metrics in the CSCI include BMI assemblage richness, composition, and diversity, and are chosen based on their responsiveness to human disturbance gradients and/or their ability to discriminate between reference and degraded condition. Unlike previous MMI or O/E indices that were applicable only on a regional basis or poorly represented large portions of California, the CSCI was built with a statewide (plus the Nevada side of the Tahoe Basin) dataset of nearly 600 reference sites that represents a broad range of environmental conditions across California (Rehn, Mazor, and Ode 2015). Sites are organized by elevation, geology, precipitation, temperature, and watershed catchment size so that stream scores are compared against reference sites with similar natural characteristics. For more information on the CSCI, please see Rehn, Mazor, and Ode 2015.

Past threshold evaluations (1991 and 1996) of stream habitat quality used a list of subjective evaluation criteria and a rating system to judge and classify stream habitat conditions (TRPA 2001; TRPA 2007; TRPA 1982b). These assessments were generally qualitative in nature, relying on the best professional judgement of local biologists to assign a score based on various physical habitat conditions to each stream (TRPA 1996). The qualitative nature of these assessments and lack of a standardized protocol made them unrepeatable and not scientifically rigorous. In addition, streams received one rating for their entire length (the whole Upper Truckee River rated as good for example), despite the fact that stream health varies greatly throughout their lengths. A multi-agency partnership including EPA, CDFW, NDEP, Lahontan, USFS and TRPA worked together to develop the more scientifically rigorous methods that are used today (Fore 2007).

Additional monitoring of streams, with a primary focus on characterization of flow and pollutant loads occurs as part of the Lake Tahoe Interagency Monitoring Program (LTIMP). In 2015, ccontinuous flow, temperature, and turbidity monitors were installed on five streams, which account for nearly 50 percent of tributary inflow.

Analytic Approach – The status of stream habitat in the Region is determined by the percentage of sites in excellent, good and marginal condition. The assessment converts the miles of re-rated Stream Habitat Quality Overlay of 1997 into percentage of rated streams (75 miles of excellent = 34.4 percent; 105 miles of good = 48.2 percent; 38 miles of marginal = 17.4 percent). The probabilistic sampling approach used allows us to infer the ratio of streams in different conditional classes without having to monitor every stream mile. The approach is likely to more accurately reflect on-the-ground conditions that vary throughout individual streams, and is a better representation of the fact that it is infeasible to survey all stream miles every threshold evaluation.

In the development of the CSCI, the State of California developed conditional categories for stream health and broke them into four categories of biological condition. These categories were then translated to the TRPA standards as shown in Table 1:

Table 1: *California conditional categories compared to TRPA conditional categories*

California (CSCI) conditional categories	TRPA conditional categories
CSCI Score ≥0.92 = good	CSCI Score ≥0.92 = excellent
0.91 to 0.80 = fair	0.91 to 0.80 = good
0.79 to 0.63 = poor	≤ 0.79 = marginal
≤0.62 = very poor	

Trend assessment averaged all trend site scores in a monitoring period and assessed change in average scores over time. If data is missing from any trend site in any year, that site is excluded from all trend analysis. Because only three monitoring periods exist, confidence in any trend is low. Individual site scores are used to prioritize projects to improve stream health in the basin.

INDICATOR STATE

Status – Results from stream sampling spread out across the entire Basin (n=92) between 2009-2014, indicate that:

- 55 percent of streams are in excellent condition (considerably better than the target of 34 percent)
- 19 percent of streams are in good condition (considerably worse than the target of 48 percent)
- 26 percent of streams are in marginal good condition (considerably worse than the target of 17 percent)

The proportion of the streams in excellent condition well exceeds the target and is encouraging news for stream health in the Basin. The main concern is the proportion of streams in marginal condition. Being below the target for proportion of good streams is less worrisome as most of these streams instead are in the excellent category. The high number of marginal sites is being addressed through stream restoration and stormwater management, among other activities. Low water levels caused by drought are likely the largest contributor to poor biological health of at least four of the 24 marginal sites (4.3 percent of all streams included in the sample). Consequently, if sampling only occurred during normal or above normal water years, the proportion of marginal streams would likely be lower and closer to attainment.

In addition to BMI sampling, physical stream habitat data is collected. Physical habitat is a good indicator of the stream's ability to provide habitat for fish, BMIs, and other aquatic life (Kaufmann et al. 1999). California's Surface Water Ambient Monitoring Program used stream data compiled across California's Sierra Nevada and North Coast regions to assess the linkages between habitat quality and biotic integrity of a stream. Out of all physical stream attributes, the following were deemed to have the closest link to biotic health: percent sand/fines of the substrate, level of human disturbance in the riparian area, intactness of woody riparian cover, and overall fish cover (large woody debris, undercut banks, overhanging vegetation, boulders, etc.) (Rehn 2015). Based on the data, break points were identified where, if below, the streams were very likely (greater than 90 percent) to have poor biological condition (Rehn 2015). Here is a summary of how Tahoe Basin streams sampled by TRPA measured against these attributes:

- Percent sand/fines of substrate: 63 percent of streams were above the break point
- Riparian disturbance: 72 percent of streams were above the break point
- Woody riparian cover: 81 percent of streams were above the break point
- Overall fish cover: 89 percent of streams were above the break point

Figure 1: *A degraded section of the Upper Truckee River that received marginal CSCI scores. This picture shows many of the physical habitat attributes that contribute to poor CSCI scores according to Rehn, 2015: excess fines/sand, riparian human disturbance, lack of woody riparian cover, and lack of fish cover. Photo Credit: Trout Unlimited*

Water temperature also plays a large role in stream health in the Tahoe Basin. Temperatures above 22 degrees Celsius are widely regarded in the literature as an acute stress threshold for salmonid species above which metabolism is impaired, fitness declines, and mortality increases (Purdy, Fesenmyer, and Henery 2014). In a 2012 study, continuous data loggers found water temperatures in the Upper Truckee River from Christmas Valley to Lake Tahoe were found to exceed 22 degrees Celsius for over 300 hours over the summer (Purdy, Fesenmyer, and Henery 2014). These high stream temperatures, in addition to high rates of stream bank erosion and high percent sand/fines of the streambed, likely play a large role in the low CSCI scores observed in the Upper Truckee River. Exposure to elevated temperatures below 22c can result in chronic stress in Salmonids. (Wenger et al. 2011; Isaak et al. 2012; Luce et al. 2014). Climate change is likely to both shift peak flows and increase stream temperatures in the Region, both of which influence the suitability of the Region's streams for Salmonids(Jager, Van Winkle, and Holcomb 1999).

Fish passage is also an important component of overall stream health. One of the limitations of using BMIs to rate stream health is they do not reliably capture fish passage issues such as culverts and dams (Vaughan 2002). In 2010 and 2011, the U.S. Forest Service conducted a basin-wide assessment of fish passage at man-made structures on public lands. Of the 178 structures that were fully assessed, 146 (82 percent) were barriers to at least one life stage of salmonid or sculpin (Vacirca 2010; Gross, S 2014). This does not include the numerous fish passage barriers located on private land. If the status of stream health, for example, counted any inaccessible (blocked by man-made structures) stream habitat as marginal, the standard for streams would be categorized as further degraded. Instead, streams are currently rated based on their biological health and there is a recognized need for projects to improve fish passage and restore stream habitat.

Some stream segments identified as marginal would likely have been assessed as excellent if the determination was based solely on an assessment of physical stream habitat assessment. Additionally, some streams scored as marginal in areas that are relatively free from human influence. Some streams may simply be naturally poor fish habitat, while other streams received low scores due to drought or other unknown natural factors. For example, Glen Alpine Creek above Fallen Leaf Lake is widely known as an excellent trout stream and is currently used as the main spawning stream for Lahontan cutthroat trout re-introduction into the Tahoe Basin (R. Al-Chokhachy and Peacock 2009). However, it received a marginal rating using bioassessment. Due to warm water and drought, or other unknown factors, thick algae (greater than 3 millimeter on average) was present throughout the creek when sampled. This limits the growth and survival of high quality aquatic prey species like stoneflies, mayflies, and caddisflies that would be expected in a mountain stream like Glen Alpine Creek (Mattson 2009). Since the quality and quantity of insects was poor, the stream received a marginal score.

In addition to TRPA stream sampling, The U.S. Forest Service sampled fish populations on 26 of the 63 Lake Tahoe tributaries in the last 10 years. Surveys show high percentages of non-native trout and extremely low numbers of historically important cold-water fish such as Lahontan cutthroat trout and mountain whitefish. Additionally, most streams in the Tahoe Basin have low fish species diversity, with some streams only having one species (Gross, S 2014). Surveys also reveal warm water fish highly tolerant of pollution such as brown bullhead catfish, goldfish, and bluegill present in the Upper Truckee River, Tallac Creek, Taylor Creek, and Trout Creek (LTBMU 2015). This is further evidence of degraded conditions in some stream segments of the Tahoe Basin.

Trend –Insufficient data to determine trend. There are 48 trend sites and each site is sampled every other year (24 each year). For this analysis, there are three monitoring periods. Each monitoring period consists of two years of data collection (beginning in 2009/2010) since half of trend sites are sampled in one year and the other half the following year. The average score for trend sites decreased slightly since monitoring began, with an average CSCI score of 0.96 in 2009/2010 to an average score of 0.93 in 2013/2014 (Tahoe Regional Planning Agency 2015b). However, because only three monitoring periods exist it is determined to be insufficient data to determine trend. Additionally, no statistically significant trends in physical habitat were found during the monitoring period (Tahoe Regional Planning Agency 2015a).

The impact of low flow on stream health is well documented (Mazzacano and Hoffman 2007), and recent drought conditions are likely impacting BMIs and overall stream health. Streams that rely more on snowmelt than groundwater and springs appear to be showing the greatest effects. Four trend and reference sites that went dry (Glen Alpine, Cascade, Ward, and General creeks) during the drought years of 2013 and 2014 saw their average CSCI score drop from 0.925 during the above average water years of 2010 and 2011 to an average score of 0.716 during the drought years of 2013 and 2014, a decrease of 23 percent (Tahoe Regional Planning Agency 2015b). Because human impacts around and upstream of these sites are minimal and are not likely to have occurred during the time period, this drop in biotic integrity is believed to be the result of natural factors. The change in these four sites accounted for 78 percent of decline in average site score. If these sites maintained their above average water year scores during times of drought the overall trend for all sites would be a decrease of 0.3 percent for this monitoring period, as opposed to the decrease of 1.42 percent that was observed. If the drought persists, it is likely the overall trend in stream health will continue to decline.

Confidence –

> **Status** – High. There is high confidence in the status. A large number of sites (92) covering the basin are sampled following well established and published protocols for assessing stream biotic integrity.
> **Trend** – Low. Because there are only three monitoring periods represented, confidence in the trend is low.
> **Overall** – Low. Overall confidence takes the lower of the two confidence determinations.

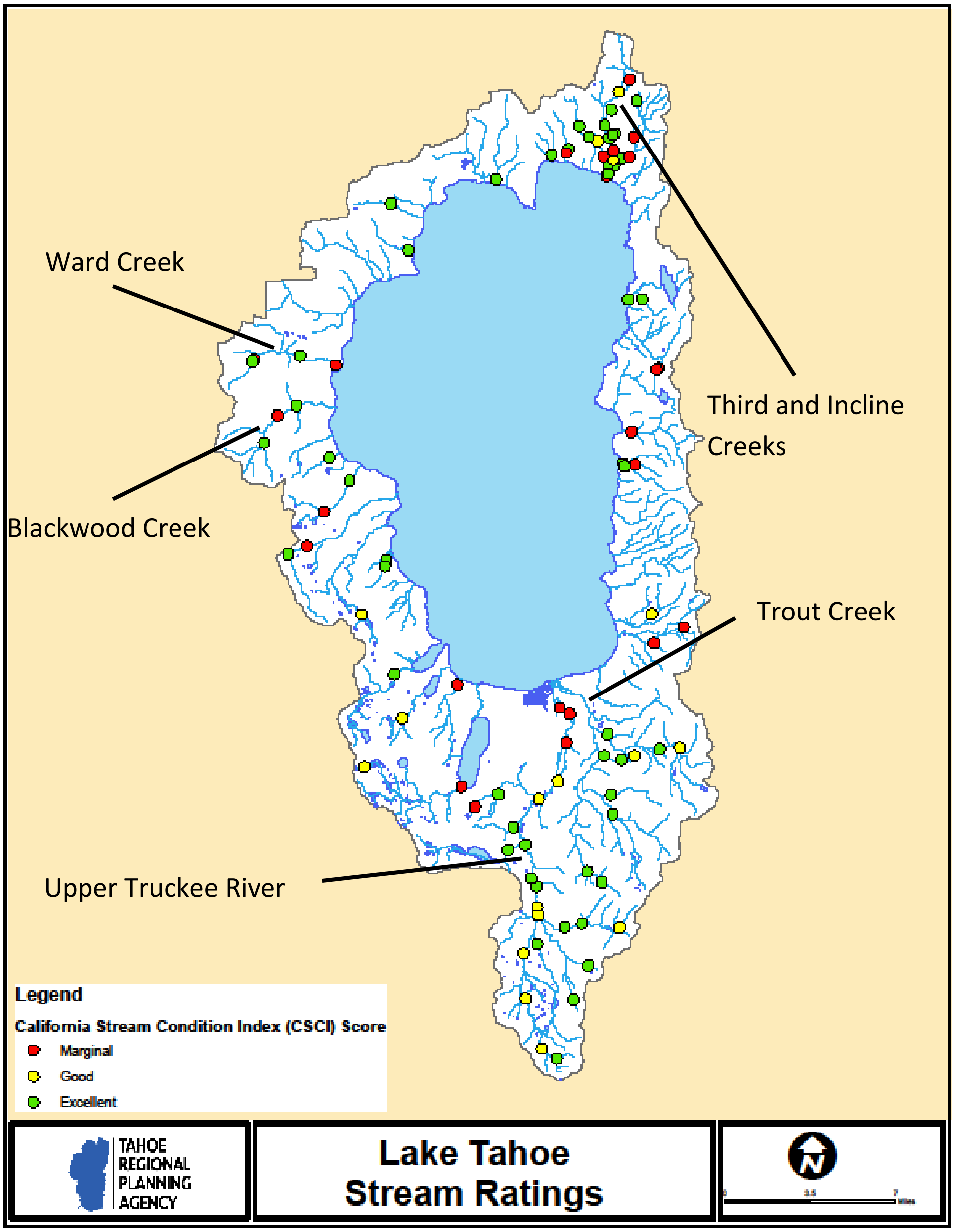


Figure 2: *"Status" monitoring locations and streams in the Tahoe Basin rated as marginal, good, and excellent from 2009-2014 (TRPA 2015).*

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – From 2011 to 2015, nearly 5 miles (26,314 feet) of stream have been restored or enhanced through the Environmental Improvement Program (TRPA 2016). Additionally, several large restoration projects are planned in the lower portion of the Upper Truckee River and elsewhere throughout the next five years. The lower portions of the Upper Truckee River are among the most highly degraded portions of Tahoe Basin streams (Purdy, Fesenmyer, and Henery 2014; Roll et al. 2013), and therefore represent great potential to improve their overall condition and potentially meet the stream habitat threshold standard. Additionally, nine of the 24 monitoring sites that ranked as marginal are located on stream reaches with recently completed or planned restoration projects (see map on right) (TRPA 2016). This suggests that if these restoration projects are successfully completed, the Basin can reach attainment of the stream habitat standard. Additionally, during the threshold reporting period of 2011-2015, eight fish passage improvement projects were implemented, providing access to an additional 7.66 miles of potential habitat (TRPA 2016). Additional fish passage improvement projects are planned beyond 2015.

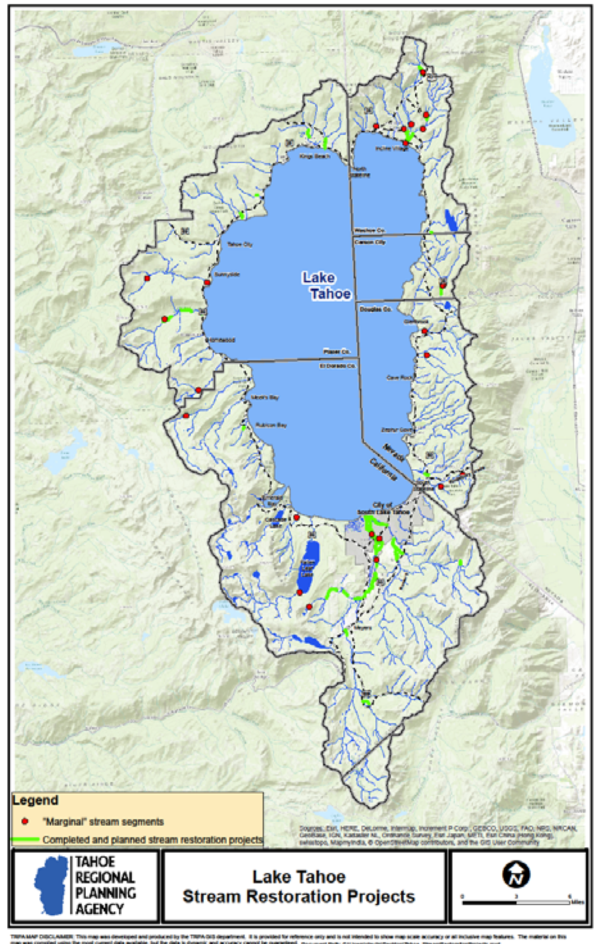


Figure 3: *Lake Tahoe steam restoration projects*

TRPA and other agencies (e.g., Lahontan Regional Water Quality Control Board, California Department of Fish and Game, US Army Corps of Engineers) regulate projects and activities in the stream environment zones, including activities in the stream itself. Additionally, the Environmental Improvement Program has initiated large-scale BMP construction, reducing pollutant load in stormwater runoff and improving aquatic habitat (TRPA 2016).

Effectiveness of Programs and Actions – While Environmental Improvement Program investments have restored nearly five miles of stream habitat in the last five years, the positive effects of these projects on overall stream health have not yet shown up. Likely reasons:

1. The probabilistic nature of TRPA's sampling design means only a small percentage of sampling points are within recently restored stream sections. As the monitoring program continues to select random sites in the future, sampling points will eventually fall in restored sections and capture improvements.
2. Many stream restoration projects have been completed only recently in the last few years. If a project was completed in 2014 or 2015, trend sites in these areas are likely to begin to show improvements in future evaluations.
3. The stream monitoring program assesses trend Basin-wide using 48 sites. The effects of individual restoration projects are often local and can be relatively small when aggregating scores for the whole Basin. Continued large-scale restoration projects and continuation of management practices across broad geographies that benefit stream health are likely required to dramatically improve aggregated regional scores.

Although the current status of stream habitat is below target, current policies and ordinances are appropriate due to their emphasis on protecting fish habitat and surrounding stream environment zones. Additionally, the Environmental Improvement Program's work to reverse legacy impacts to streams and reduce stormwater pollution intro streams are appropriate and should begin to show effects on the Basin's overall stream habitat over time.

Interim Target – Average stream habitat condition of trend sites is equal to, or better than 0.933 (the average trend site score 2013/2014).

Interim Target Attainment Date – Because limited data exists and a statistically significant trend cannot be established, it is not possible to predict a target attainment date based on trend data. Instead, we can forecast with low confidence when the target will be reached based on projecting conservative implementation progress using already approved and planned stream restoration projects. Currently, the Basin has 19 more miles (9 percent) of marginal stream habitat than the target. Assuming streams in good or excellent condition stay the same or become healthier based on the protective rules and procedures in place for streams, SEZ's, and minimizing stormwater flow to streams, we can assume streams in attainment status remain so and forecast an attainment date for other streams. During the last five years, nearly five miles of stream habitat were enhanced or restored (TRPA 2016). Large stream restoration projects are planned for the immediate future as well (TRPA 2016). If future stream restoration continues at a similar pace of approximately one mile per year, and restored streams with increased CSCI scores would move out of the marginal category, it is expected that 20 miles of marginal streams could be restored by 2035, bringing the marginal stream habitat indictor into attainment. However, if drought conditions persist or worsen, attainment may be pushed out further or may never be reached. Conversely, if wetter conditions and more sustained stream flows return, attainment may be reached sooner.

RECOMMENDATIONS

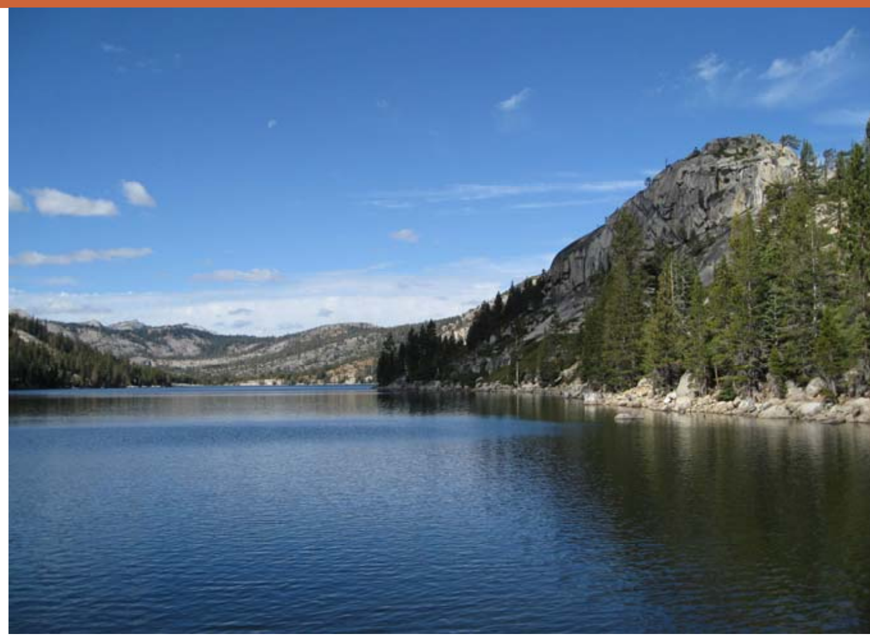
Analytic Approach – No changes recommended.

Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – Review or revision of this standard should attempt to clarify its intent. The current standard relates only to the physical habitat within streams, and is only an indirect measure of the health of fish populations in tributaries to Lake Tahoe. Factors such as connectivity between habitats types essential to support different life stages is important to population health, but not currently reflected within the standard. At a minimum, the standard should be revised so that streams moving from a lower category into a higher category would not move one category out of attainment. For example, the way the standard is currently written, if streams move out of the good category and into the excellent category, there would be less streams in the good category (and possibly move out of attainment) even though stream health is improving.

Attain or Maintain Threshold – Climate forecasts suggest a greater proportion of Region's precipitation will fall as rain, which may increase winter runoff, but decrease spring and summer streamflow (U. S. Bureau of Reclamation 2015; Hayhoe et al. 2004). Higher air temperature will also likely mean more frequent and intense droughts(U. S. Bureau of Reclamation 2015). These shifts are likely to result in higher stream temperatures in the Region (Ficklin, Stewart, and Maurer 2013). As stream temperatures increase, riparian protection, shading, and marsh/meadow restoration may be increasingly important to maintaining high quality steam habitat. Prioritization of programs and projects to improve instream fish habitat should consider factors such as connectivity between habitats types essential to support different life stages is important to population health, in addition to the aggregate measures of habitat restored.

Instream Flow: **Non-Degradation Standard for Instream Flow & Divert Stream Intakes to Lake Sources**

Status	Photo
NON-DEGRADATION STANDARD FOR INSTREAM FLOW Status: **Implemented** **DIVERT STREAM INTAKES TO LAKE SOURCES** Status: **Implemented**	 Photo: The Echo Lakes dam is one of the few existing stream diversions in Lake Tahoe. A 2003 Desert Research Institute study (Tracy and Rost 2003) found existing diversions to have a minimal impact on instream flows and overall fisheries habitat. Photo Credit: BrewBooks (https://creativecommons.org/licenses/by-nd/2.0/legalcode)

Data Evaluation and Interpretation

BACKGROUND

Relevance – There are 63 tributaries that drain into Lake Tahoe, and one tributary that drains from the basin. The amount of water flowing through a stream is primarily dependent on the size of its watershed and the amount of precipitation within a given year. Streams provide critical habitat to a diversity of native and non-native fish populations and other riverine dependent organisms. Historic logging, grazing and land uses interrupted the hydrologic integrity of many of the streams and tributaries draining into Lake Tahoe, (Murphy and Knopp 2000) and the results of these legacy activities are evident today (Tracy and Rost 2003; Vacirca 2010). Alteration of stream flow regimes, such as water diversions, can result in adverse impacts to stream habitat diversity, function, and productivity of aquatic ecosystems and organisms (Karr and Chu 1999; Stephens, S.L. et al. 2004). A component of the TRPA Regional Plan is to maintain a healthy functioning fishery through the conservation and restoration of natural flow regimes (TRPA 1986; TRPA 2012c).

TRPA Threshold Category – Fisheries

TRPA Threshold Indicator Reporting Category – Instream flow

Adopted Standards – There are two threshold standards adopted in Resolution 82-11 that address the conservation and restoration of instream flows. The management standard for instream flow states:

"*Until instream flow standards are established in the Regional Plan to protect fishery values, a nondegradation standard shall apply to instream flows.*" The policy standard states, "*It shall be a policy of the TRPA Governing Board to seek transfers of existing points of water diversion from streams to Lake Tahoe.*" A review of TRPA standards (TRPA 1982b) indicates that the original intent was to address concern over the diversion of water from streams for consumptive uses, irrigation and snowmaking. It was believed at the time that TRPA could prescribe minimum flow standards for each stream in the Basin in order to maintain a healthy fishery (TRPA 1982b).

Type of Standard – Management Standard and Policy Statement

Indicator (Unit of Measure) – Three criteria were evaluated to determine the implementation status of the instream flow threshold standards:

1. Has TRPA adopted appropriate policies, ordinances and programs to support the adopted threshold standards?
2. Has TRPA permitted or otherwise allowed for new permanent diversions or alteration of stream flows since 1987?
3. Does available scientific information support the need to adopt instream flow standards for Regional streams?

Human & Environmental Drivers – Weather, climate patterns, geology, elevation, and topography all significantly affect stream flow characteristics. Historic channel modifications associated with logging activities and land uses (e.g., dams, water extraction and within-watershed diversions, urban development and infrastructure, flumes, stream channelization, and flood control impoundments) that preceded the 1987 Regional Plan altered stream channel structure and watershed-specific hydrology.

MONITORING AND ANALYSIS

Monitoring Partners – Management standard. No monitoring exists.

Monitoring Approach – Management standard. No monitoring exists.

Analytic Approach – Not applicable.

INDICATOR STATE

Status – Implemented. Based on the evaluation criteria, the threshold standards are determined to be implemented and in attainment.

Criteria 1: TRPA and other agencies have instituted a number of regulatory actions and restoration projects that support the nondegradation management standard and policy statement set forth under the instream flow indicator reporting category. TRPA regulates projects and activities that have the potential to impact the integrity of stream habitat including impacts to stream flows in the Tahoe Basin (see TRPA 1986 and TRPA 1987a as amended in 2012). In addition, other agencies have established rules that regulate the types of projects and activities that can occur in stream habitats (e.g., California Department of Fish and Game). Under the Environmental Improvement Program, the U.S. Forest Service and other agencies such as the California Tahoe Conservancy have implemented and are planning several large-scale stream restoration projects at Cook House Meadow, Big Meadow Creek, Blackwood Creek, Cold Creek, Angora Creek, Trout Creek and Meeks Creek, as well as the Upper Truckee River. One of the main objectives of these projects is to return streams to a natural flow regime (Vacirca 2010).

Criteria 2: A review of available TRPA permit data indicates that TRPA only permitted temporary stream flow diversion/alterations when the ultimate project objective was stream enhancement and/or restoration. In no instance were permit records found indicating that TRPA permitted new permanent diversion or the extraction of water from streams for consumptive uses. There are at least four dams in the Basin that actively regulate stream flow under historic water rights. These include Echo Creek at Lower Echo Lake, Taylor Creek at Fallen Leaf Lake, Truckee River at the Lake Tahoe outlet, and Marlette Creek at Marlette Lake outlet. Of these dams, only the Echo Lake dam operation diverts stream flow from the Lake Tahoe Basin as a backup to the El Dorado Irrigation District's water system during drought conditions; in normal water years, no water is diverted from Echo Lake. Each dam is required to provide minimum stream flows necessary to support stream fisheries values as a component of the operating agreements with state and federal regulatory and fisheries management agencies. According to Madonna Dunbar (Tahoe Water Suppliers Association, personal conversation, 2011), waters for consumptive use in the Tahoe Basin are primarily sourced from lake intakes (54 percent) or from groundwater sources (46 percent), and less than one percent is drawn from other sources such as springs or streams.

Criteria 3: The Desert Research Institute (Tracy and Rost 2003) completed the following tasks to assist TRPA in understanding stream flow conditions consistent with the direction provided in the instream flow management standard:

1. A statistical analysis of stream flow rates for tributaries with continuous flow gaging records;
2. A statistical model to predict daily stream flow rates of tributaries with little or no gaging records;
3. A statistical model to predict instream flow needs for salmonid (trout) species in Lake Tahoe's streams; and
4. A field survey to locate and assess the level of anthropogenic disturbance to the hydrology of Lake Tahoe's streams.

The study developed statistical relationships for gauged and ungauged tributaries in the Lake Tahoe Basin to describe their daily flow-exceedance-frequency relationships for each month of the year. These relationships were then compared to published optimal instream flow rates for trout species for several of TRPA's listed threshold tributaries. Comparisons indicated that only a limited number of streams meet defined optimal instream flow requirements (Snider, Kershner, and Smith 1987). Trout Creek and Upper Truckee River showed the greatest potential for meeting optimal instream flow rates for both trout-rearing and spawning periods. A much larger proportion of streams provide suitable, but not optimal, stream flow for trout species and the maintenance of unrestricted stream flows, regardless of flow rates, are important to other aquatic dependent organisms, such as invertebrates, native fishes, amphibians and some reptiles. Tracy and Rost's (2003) analysis also suggested that instream flow rates could be extrapolated to a larger number of tributaries within the basin based on the tributary's physical characteristics. Finally, a field assessment of Lake Tahoe's tributaries showed that about 50 percent of the tributaries have some type of man-induced disturbance (e.g., impoundment, non-functional earthen dams, artificial stream bank stabilization) that could potentially affect the hydrologic characteristics as well as limit organism movement within the stream corridor. However, Tracy and Rost (2003) found that the effect of the majority of man-induced disturbances on stream flow was relatively small, and would likely only affect the tributary's hydrologic characteristics during very low flow conditions experienced during droughts.

Tracy and Rost (2003) found that the flow of the vast majority of streams in the Tahoe Basin is primarily affected by the amount of precipitation occurring within the watershed. Their assessment of stream flow conditions suggested but stopped short of recommending minimum flow standards for streams, largely because only two streams have a high probability to provide optimal flow conditions and because minimum flow requirements would be different for different fish species. Other recommendations include (Tracy and Rost 2003):

- Although there were a number of human instream flow impediments, the effect on stream flow characteristics was negligible. Thus, removal of structures would only marginally improve hydrologic conditions, but would likely improve stream corridor mobility for aquatic organisms during very low stream flow conditions.
- Methodologies for determining instream flow requirements for all of Tahoe Basin's fish species would be needed in order to inform scientifically supported minimum flow standards for different streams. Currently, no published studies could be found that identified instream flow needs for Tahoe's native non-game species. As an important element of the basin's aquatic ecology, their habitat needs should be placed on equal footing with those of the more well-studied introduced trout species.

Tracy and Rost's (2003) evaluation was the basis for an earlier recommendation to establish minimum instream flow conditions. The cost and benefit to the fishery of that recommendation was not evaluated. The finding that stream flow is primarily driven by within-watershed precipitation (which cannot be regulated by TRPA), and that TRPA's existing regulations restrict projects or activities from permanently diverting or impacting flow from streams, suggests that the need to establish minimum flow standards for individual streams may not be feasible or warranted and should be re-considered. It is nonetheless suggested that measures of stream flow should be integrated into stream habitat monitoring protocols as a variable to help explain drivers of stream habitat conditions.

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – As stated in evaluation criteria 1, TRPA and other agencies with jurisdictional authority regulate projects that could interfere with the health of fish populations within the Lake Tahoe Basin. Basin partners have instituted a number of actions that implement the non-degradation policy set forth under the instream flow threshold requirements. These actions include restrictions on stream zone encroachment and the funding and implementation of the Environmental Improvement Program's watershed restoration program. Overall, TRPA has permitted temporary actions altering stream flow only when the ultimate objective is improving and restoring natural hydrology, and has cooperated with partner agencies with similar goals. The U.S. Forest Service and other land management agencies have implemented and continue to plan several large-scale stream restoration projects.

Effectiveness of Programs and Actions – Based on the evaluation criteria presented, TRPA and other agencies have been effective at averting new permanent flow diversions from streams in the Lake Tahoe Basin since 1987. Diversions of streams for consumptive water use are extremely limited as the majority of water used comes from either lake or groundwater sources.

RECOMMENDATIONS

Analytic Approach – No changes recommended.

Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – Based on Tracy and Rost's (2003) study, it is questionable whether setting in-stream flow standards would have a measurable benefit on the Tahoe fishery since the primary driver of in-stream flow is precipitation and diversions have a minimal effect on stream flows in the Basin. Current regulations prohibiting new water withdrawals from streams, and only allowing temporary diversions if the ultimate goal of the project is stream restoration, are effective at maintaining instream flows.

Attain or Maintain Threshold –No changes recommended.

Fisheries: **Lahontan Cutthroat Trout**

Status

I

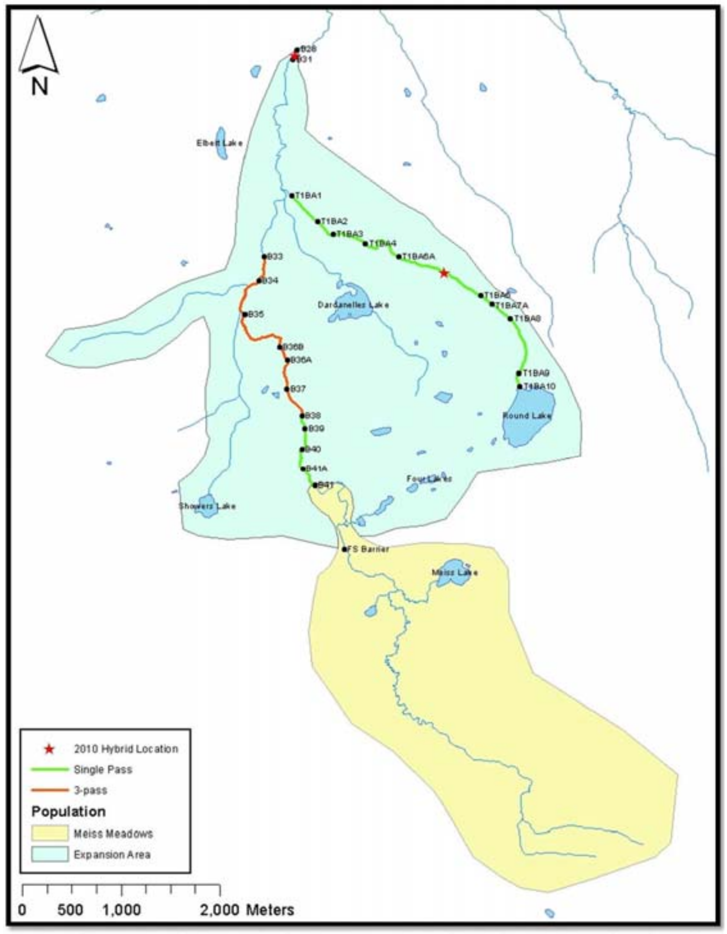
LAHONTAN CUTTHROAT TROUT

Status: **Implemented**

Photo

Photo: Lahontan cutthroat trout (LCT) spawning in Glen Alpine Creek, a tributary of Fallen Leaf Lake. 2012 marked a major milestone as the first observed natural spawning of LCT occurred as part of the Fallen Leaf Lake LCT restoration program. Credit: US Fish and Wildlife Service.

Map



Map shows the project area for the Upper Truckee River Lahontan cutthroat trout (LCT) restoration program in the headwater of the Upper Truckee River. This project is restoring the stream-based strain of LCT while the Fallen Leaf Lake project is restoring the lake-based strain of LCT.

Data Evaluation and Interpretation

BACKGROUND

Relevance – The Lahontan cutthroat trout (LCT, *Oncrhynchus clarkii henshawi*) is the only trout species native to the Lake Tahoe Basin and was once the top predator in Lake Tahoe's aquatic ecosystem (TRPA 2014; Wittmann and Chandra 2015). Due to overfishing, habitat degradation, and the introduction of non-native aquatic species, it was extirpated in the 1930s from the Lake Tahoe Basin (Allen, B.C. et al. 2003). It is listed as threatened under the Federal Endangered Species Act.

TRPA Threshold Category – Fisheries

TRPA Threshold Indicator Reporting Category – Lahontan Cutthroat Trout

Adopted Standards – It shall be the policy of the TRPA Governing Board to support, in response to justifiable evidence, state and federal efforts to reintroduce Lahontan cutthroat trout.

Type of Standard – Policy Statement

Indicator (Unit of Measure) – Two criteria were evaluated to determine the implementation status of the Lahontan cutthroat trout policy statement, including:

1. Has TRPA adopted appropriate policies, ordinances and programs to support the adopted threshold standard?
2. Is there evidence to suggest that at least one self-sustaining population of Lahontan cutthroat trout has been established in the Lake Tahoe Basin?

Human & Environmental Drivers – Due to overfishing, habitat degradation, and the introduction of non-native aquatic species, LCT were extirpated in the 1930s from Lake Tahoe Basin (Allen, B.C. et al. 2003). While overfishing is no longer an issue, degraded stream habitats, fish passage blockages (culverts, etc.), and non-native aquatic species such as rainbow trout, brook trout, and lake trout still pose a significant threat to the reintroduction of LCT. The introduction of mysid shrimp (Mysis diluviana) in the 1960s (Wittmann & Chandra 2015), significantly altered the Lake's food web.

MONITORING AND ANALYSIS

Monitoring Partners – U.S. Forest Service, U.S. Fish and Wildlife Service, California Trout, Trout Unlimited, Nevada Department of Wildlife

Monitoring Approach – Regular monitoring of LCT populations occur through a variety of standard fish population monitoring approaches including electroshocking, fish weirs, etc.

Analytic Approach – Not applicable.

INDICATOR STATE

Status – Implemented. The Lahontan cutthroat trout policy statement has been implemented by TRPA and determined to be in attainment with the adopted policy statement. Support for the Basin's attainment status includes a population of LCT established in the Upper Truckee River including a recently expanded restoration area. Additional restoration is underway to re-establish populations in Fallen Leaf Lake.

Criteria 1: Work is underway to restore the native LCT population into its historic lacustrine (lake) and fluvial (stream) habitats throughout the Truckee River Basin including the Tahoe Basin (TRPA 2007). In April 2007, TRPA joined the Tahoe Basin Recovery Implementation Team (TBRIT), which was formed as part of the ongoing work to develop and implement actions to help recover LCT. TRPA provides support in the TBRIT: TRPA is not a land manger but rather serves to facilitate protection and restoration of LCT habitat through policy, regulation and support of researchers' and implementers' reintroduction work programs (see Chapter 63 of the TRPA Code of Ordinances).

Criteria 2: California Department of Fish and Wildlife reintroduced LCT into the headwaters of the Upper Truckee River near Meiss Meadows in 1989 and 1990. Through years of population management and monitoring, the Meiss Meadows population has become established as the only self-sustaining population of LCT in the Lake Tahoe Basin. The last monitoring occurred in 2013 and determined this area was still free of brook trout and had a self-sustaining population of LCT (Lemmers 2015).

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – In 2008, the U.S. Forest Service began implementing the Upper Truckee River Lahontan Cutthroat Trout Restoration Project downstream of the existing Meiss meadows population referred to as the "expansion area" (Lemmers 2015). Since 2008, the total number of non-native salmonids species in the expansion area continues to decrease, while LCT populations continue to show signs of successful reproduction and growth. Since 2012, total numbers of LCT have been declined likely as a result of drought and decreased stream flows (Lemmers 2015).

In 2002, the U.S. Fish and Wildlife Service introduced LCT to Fallen Leaf Lake in a pilot project to learn what conditions are necessary for successful restoration of LCT in a lake environment. In 2012, biologists observed successful reproduction in Fallen Leaf Lake's tributary, Glen Alpine Creek (U.S. Fish and Wildlife Service 2013). Additionally, overwintering and multi-year survival has been recently documented. These observations are major milestones for the recovery of the species in the Tahoe Basin. While these results are positive, continuing challenges include adverse interactions with non-native species, including predation by lake trout (*Salvelinus namaycush*), hybridization with rainbow trout (*Oncorhynchus mykiss*), change in the food web as a result of Mysid shrimp and other non-natives, and competition for resources where non-native species are present (Allen, B.C. et al. 2003).

Nascent work toward reintroducing LCT into Lake Tahoe for recreational purposes began in summer 2011. The Nevada Department of Wildlife stocked approximately 22,000 LCT in Lake Tahoe as part of the work to begin stocking native aquatic species for the benefit of anglers. Additional research is needed to improve understanding of reintroduced LCT population dynamics, including seasonal habitat utilization, growth rates, and their interactions with non-native species (Robert Al-Chokhachy et al. 2009) .

Effectiveness of Programs and Actions – Based on observed successful reproduction of both the Upper Truckee River and Fallen Leaf Lake populations, it appears current projects have been initially successful in re-establishing self-sustaining populations of LCT. The health of these populations in upcoming years will determine the success of these projects.

RECOMMENDATIONS

Analytic Approach – No changes recommended.

Monitoring Approach – No changes recommended.

Modification of the Threshold Standard or Indicator – Objective determination of "attainment" status for standards without a specific target is recurrent challenge both in the Region and in the larger field of monitoring and evaluation (M&E). The standard should be assessed against best practice for the establishment of standards and indicators for M&E, and amended as necessary to improve the evaluability of the standard and the information it provides for management.

Attain or Maintain Threshold – No changes recommended.

Lake Habitat

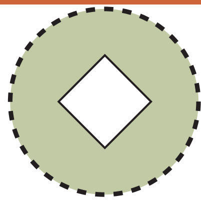
There is one threshold standard in the lake habitat indicator reporting category. The lake habitat threshold standard is listed as a management standard with a numeric target to achieve the equivalent of 5,948 acres of "prime" fish habitat. Prime fish habitat includes spawning habitat and feed and cover habitat. Spawning habitats are composed of relatively small diameter gravel substrates used by native minnows for spawning and rearing fry. Feed and cover habitats are composed of larger diameter cobbles, rocks, and boulders, used by fish as foraging habitat and to provide refuge from predation. Marginal habitats are dominated by sand and silt substrates interspersed with occasional willow thickets that establish during low lake levels.

According to TRPA (TRPA 1982a), "The quality of the lake can be evaluated and tested against the threshold using measures of habitat disturbance and substrate conditions." An indicator for the lake habitat threshold standard was identified by TRPA (1996) as "physical disturbance of rocky substrate (acres)." TRPA (1982a) considered moderate to heavy boat traffic as a disturbance that significantly contributed to the decline of lake fish habitat quality. TRPA's 1996 Threshold Evaluation Report further determined that the rearrangement or clearing of near shore substrate to accommodate beach use during low lake levels degraded fish habitat. Since the initial adoption of the threshold standard, studies have revealed that boat activity is not sufficiently frequent in the littoral zone to degrade conditions in "prime" fish habitat (Allen and Reuter 1996). In the 2006 Threshold Evaluation Report, TRPA measured and reported on the extent and distribution of rocky substrates ("prime" fish habitat in the littoral zone) because of the challenges associated with defining and measuring "disturbed rocky substrates." This approach more directly addressed whether the management target of 5,948 acres was achieved.

The indicator for lake habitat showed that the status is "at or somewhat better" than the adopted management targets with an "unknown" trend. Overall confidence in the determination of status and trend is "low" due to changes in mapping techniques. However, the higher resolution imagery and multiple images used to create the substrate map used for the 2015 evaluation offer a significant improvement over prior maps. Evidence from recent research suggests that the populations of many nearshore fish species have declined (K. L. Ngai et al. 2011; Chandra, Caires, and Ryan 2015). However, these population level changes are not detectable using the indicator associated with the existing lake habitat threshold standard. The management provisions embodied in the lake habitat threshold standard have been incorporated into the TRPA Regional Plan and are implemented through the TRPA permit review process.

Lake Habitat: **Acres of "Prime" Fish Habitat**

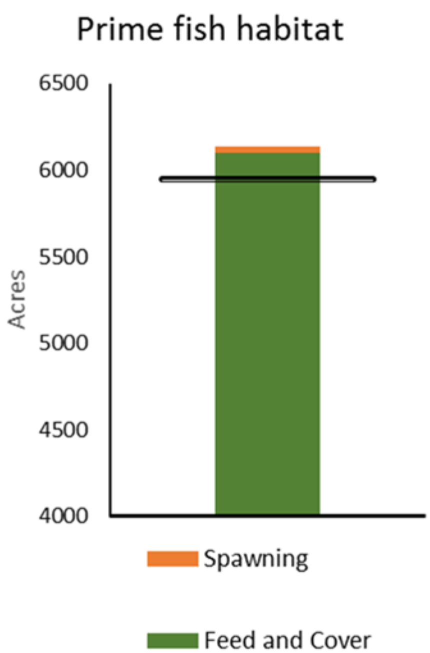
Reporting Icon	Map



ACRES OF "PRIME" FISH HABITAT

Status: At or **Somewhat Better than Target**
Trend: **Insufficient Data to Determine Trend**
Confidence: **Low**

Graph



Acres) of "prime/excellent" fish habitat (spawning habitat - orange, feed and cover habitat – green) as estimated by O'Neil-Dunne et al. (2016), relative to TRPA's Lake Tahoe habitat management standard (thick black line = 5,948 acres).

Distribution and extent of nearshore fish habitats in Lake Tahoe (O'Neil-Dunne et al. 2016) based on an evaluation of high-resolution WorldView-2 imagery collected in August 2010 and 2015. "Prime" or excellent habitat includes spawning and feed and cover. O'Neil-Dunne et al. (2016) estimated that there are 6,135 acres of prime fish habitat between an upper elevation of 6,229 feet and a lower elevation 6,199 feet.

Data Evaluation and Interpretation

BACKGROUND

Relevance –Prime fish habitat is defined as areas that satisfy habitat requirements critical to the distribution of fish or important components of their food chains and life cycles (TRPA 1996). This indicator measures the extent of rocky substrates in Lake Tahoe's nearshore (i.e., littoral zone) known as "prime" or excellent fish habitat. Fish use different diameter rock substrates in Lake Tahoe's nearshore to satisfy different life history requirements such as spawning, growth and feeding. Gravel substrates composed primarily of rocks smaller than 64 millimeters and larger than 2 millimeters in diameter are used for spawning by native minnow species, while substrates primarily composed of larger diameter cobble, rocks and boulders are used for foraging and for cover by a variety of fish species (Beauchamp, D.A., Byron, and Wurtsbaugh 1994). Marginal habitats are primarily composed of sand and silt substrates that measure less than 2 millimeters in diameter. Spawning, and feed and cover substrates together comprise "prime" or excellent fish habitat according to TRPA. TRPA's lake habitat management standard aims to prevent the loss of or disturbance to "prime" fish habitats as a result of shorezone development or other anthropogenic disturbances. This indicator does not measure the abundance of individual fish species, community composition, or trophic structure of Lake Tahoe's nearshore.

Threshold Category – Fisheries

Indicator Reporting Category – Lake Habitat

Adopted Standards – A nondegradation standard shall apply to fish habitat in Lake Tahoe. Achieve the equivalent of 5,948 total acres of excellent habitat as indicated by the Prime Fish Habitat Overlay Map, which may be amended based on best available science.

Type of Standard - Management Standard (with a numeric target)

Indicator (unit of measure) – Acres of "prime" fish habitat. Prime fish habitat is defined by substrate type and includes "spawning" (2 millimeter to 64 millimeter substrates) and "feed/cover" (greater than 64 millimeter substrates) habitat types.

Human and Environmental Drivers – The removal, rearrangement, or covering of littoral zone substrates can influence the status of this indicator (TRPA 1996). Fluctuations in lake level can also significantly affect the availability of "prime" fish habitat, especially spawning habitat (Allen and Reuter 1996). Urbanization along the shorezone, recreational activities , excessive fish harvest , excessive nutrients, increased water temperature associated with global climate change, and presence of non-native fish and other non-native aquatic plants and animals are all factors that can influence the overall quality of Lake Tahoe's fish habitat and fish species composition (K. L. Ngai et al. 2011; Heyvaert et al. 2013).

MONITORING AND ANALYSIS

Monitoring Partners – University of California, Davis; University of Nevada, Reno; California Department of Fish and Wildlife; and Nevada Department of Wildlife.

Monitoring Approach – The monitoring approach used for evaluating the attainment status of this standard involves the mapping and classification of fish habitats in the nearshore (the lake zone that exists approximately between elevations of 6,229 to 6,199). In 1971, a cooperative survey was done by various state and federal fish and wildlife agencies to identify fish and aquatic habitats of special significance. This work produced a Prime Fish Habitat Map that TRPA adopted in 1984. This map, as amended in 1997, is still the map TRPA uses today. Byron et al. (1989) as part of their fish habitat study resurveyed and mapped fish habitat around Lake Tahoe. According to TRPA (1996), the Byron et al. work represented a more accurate picture of the types of fish habitat based on lakebed substrate. The 2006 and 2011 Threshold Evaluations Reports utilized an updated fish habitat map based on satellite imagery collected in 2002 (Metz and Herold 2004; Herold, Metz, and Romsos 2007a). O'Neil-Dunne (2016) followed similar monitoring (mapping) methods used by Metz and Herold (2004) and Herold et al. (2007) to produce higher resolution estimates of fish habitat distribution.

The composite or mixed substrate classes are problematic in that they often contain a mix of habitat types (e.g., marginal with "feed and cover"). The composite classes are necessary for mapping primarily due to an inability to resolve the individual substrate classes using satellite imagery at the fine scales in which they are present. The result is that the true extent of spawning habitat could be misinterpreted to suggest there is less habitat than truly exists. For example, O'Neil-Dunne et al. (2016) noted numerous examples from field sampling where gravels substrates were commingled with other substrates such as cobble and boulder sized substrates.

Analytic Approach – Early lake fish habitat analyses used field surveys and coarse delineation to estimate fish habitat acreage and are described in Byron et al. (1989). Metz and Herold (2004) and Herold et al. (2007) describe in detail the analysis approach they used for 2002 IKONOS imagery. O'Neil-Dunne et al. (2016) used an analysis that included two primary phases: 1) applying a custom wave detection algorithm to select the best available imagery (imagery was least distorted by wave action) from 2010 and 2015 WorldView-2 datasets and 2) the creation of substrate and fish habitat map. The substrate mapping process consisted of five steps: 1) segmentation of the WorldView-2 imagery into objects, 2) assignment of each object based on the majority class in the 2002 IKONOS derived substrate map, 3) automated refinement of substrate classification using the 2010 and 2015 WorldView-2 imagery, 4) manual review and refinement of the substrate classification, and 5) a comparison of substrate classes into TRPA fish habitat types. Following these steps, attribute data were summarized using pivot tables.

INDICATOR STATE

Status – At or Somewhat Better than Target. Analysis of remotely sensed data collected in August 2010 and 2015 estimated that there are about 6,135 acres of "prime" fish habitat in Lake Tahoe's nearshore/littoral zone (O'Neil-Dunne, Romsos, and Saah 2016), suggesting that the Basin is meeting the adopted management target of 5,948 acres. Note that this acreage estimate included both dry and wet substrate; not the entire habitat was available to fish at the time of the analysis. About 118 acres or 2 percent was dry and not available to fish at the summer 2015 lake level. If only wet habitat was counted, total acreage is 6,098 and the target would still be in attainment. Since 1989, TRPA has regulated construction within Lake Tahoe's littoral zones. TRPA has not permitted the unmitigated construction of piers, boat launches or other developments that would degrade or disturb the littoral substrate. However, efforts to restore "prime" habitat have not occurred since 2002. Consequently, there were likely no substantial changes in the extent of fish habitat since 2002, other than changes that may have occurred as a result of natural littoral drift and fluctuating lake levels. At low lake levels (such as those in summer 2015) available spawning habitat can decrease by more than 85 percent (O'Neil-Dunne, Romsos, and Saah 2016).

Figure 1: *Using aerial imagery along with field verification from a boat, each color spectrum of the Lake is matched to a corresponding habitat type (boulder, gravel, etc.) to estimate distribution of fish habitat around the Lake. This method allows TRPA to track changes over time using satellite imagery.*

As discussed in the 2006 and 2011 Threshold Evaluation Reports and by others (Kamerath, Chandra, and Allen 2008; K. L. Ngai et al. 2011; Heyvaert et al. 2013), additional factors influence the quality of littoral fish habitat, such as the introduction and expansion of aquatic invasive species. Ngai et al. (2011) found that there has been a significant reduction in the abundance and distribution of minnow species in Lake Tahoe's nearshore. Other surveys have documented similar results, including the 2014 survey which estimated native fish abundance in the nearshore has declined by 57 percent since 1989 (Chandra, Caires, and Ryan 2015).

Trend – Insufficient data to determine trend. The differences between the 2002 (Metz and Herold 2004), 2007 (Herold, Metz, and Romsos 2007a), 2010 and 2015 (O'Neil-Dunne, Romsos, and Saah 2016) habitat mapping efforts should not be interpreted to mean that the substrate has changed, but rather viewed as a refinement of TRPA fish habitat mapping. Consequently, the trend determination for the extent of "prime" fish habitat is "unknown" due to differences in the mapping approach used to establish the management target (TRPA 1982a; TRPA 1982b), and the mapping approach used by Byron et al. (1989), Metz and Herold (2004), Herold et al. (2007) and O'Neil-Dunne et al. (2016).

Confidence

Status – Low. The fish habitat map used in the 2007 and 2001 threshold evaluation reports was estimated to be 86 percent accurate (Herold, Metz, and Romsos 2007b; TRPA 2012a; TRPA 2007). O'Neil-Dunne (2016) compared field data collected in 2015 to both the 2002 and 2015 substrate maps, however, did not complete traditional accuracy assessment because only 240 of the 1,000 field samples needed for a valid accuracy assessment were collected. Nonetheless, the comparison between these datasets provides some meaningful insight into the quality of the data. Principally there were very few hard classification errors in either the 2002 or 2015 mapping efforts. An example of a hard classification error is "boulder" being misclassified as "sand." There are classes with considerable confusion. For example, five locations identified as boulder in the 2015 field data collection were classified as sand/cobble/boulder in both the 2002 and 2015 mapping efforts. This error is an example of a soft classification as boulder was included in the composite class and there is no way to determine if the location observed in the 2015 field collection was part of a larger pure boulder area or just a singular boulder in an otherwise mixed substrate area. Both boulder and sand/cobble/boulder are further classified as "feed and cover" habitat and thus the misclassification does not impact the estimate of fish habitat. Despite these shortcoming reported in the O'Neil-Dunne (2016) mapping effort, their map depicts the highest resolution representation of Lake Tahoe nearshore fish habitat to date.

Trend – Low. The confidence in the trend for "prime" fish habitat is low due to differences in mapping approaches. Recent research suggests high confidence in the reduction of native minnow abundance and distribution because the same sites were sampled in previous efforts.

Overall – Low. Overall, confidence in the status and trend determination is low because of the low confidence in trend information and the lack of a traditional accuracy assessment of mapped habitat in the most recent mapping effort (O'Neil-Dunne, Romsos, and Saah 2016).

IMPLEMENTATION AND EFFECTIVENESS

Programs and Actions Implemented to Improve Conditions – TRPA regulates projects and activities in Lake Tahoe's shorezone and littoral zone that may affect lake fish habitat. TRPA requires habitat mitigation for projects that result in substrate disturbance of prime fish habitat to be restored 1.5 times the area disturbed. Mitigation is generally required in the general vicinity of the disturbance. Pursuant to Chapter 86 of the TRPA Code of Ordinances, fees collected from marina, piers, and boat ramp projects are leveraged for additional research on nearshore impacts and fish habitat restoration (TRPA 2012b). Further measures that benefit fish habitat are found in TRPA Goals and Polices and the TRPA Code of Ordinances, as well as other state and federal laws. Both prevention and control efforts related to aquatic invasive species in the lake help maintain habitat for native species. Watershed restoration work that reduces sediment loads in the basin's lakes and rivers can help prevent spawning substrates from being covered in fine sediment. Water quality improvement projects completed by Environmental Improvement Program partners between 2009 and 2015 have:

- Restored or enhanced 27,150 linear feet of stream channel.
- BMP retrofitted 120.55 miles of road and decommissioned 7.4 miles of road.
- Restored or enhanced 120 acres of disturbed forested uplands.
- Inspected 108.72 miles and maintained 98.2 miles of unpaved non-urban roads
- Issued 18,076 best management practices certificates to commercial, multifamily and single family residential properties.

- Treated over 40 acres for AIS, including the removal of invasive weeds from Emerald Bay. Emerald Bay remains free of Eurasian watermilfoil and curlyleaf pondweed.

Effectiveness of Programs and Actions – There is insufficient data available to assess the effectiveness of individual programs or actions in maintaining lake fish habitat. Programs to prevent the introduction of new aquatic invasive species have been successful and since 2012 no new aquatic invasive species (AIS) have been identified in Lake Tahoe. Greater detail on the AIS management program is included in the assessment of the AIS standard in the Water Quality chapter.

Interim Target – Target is in attainment.

Target Attainment Date – Target is in attainment.

RECOMMENDATIONS

Analytical Approach – No changes recommended.

Monitoring Approach – The substrate map used in this assessment could be improved through an integrated program to map and monitor substrate in Lake Tahoe. Field collection data and additional high-resolution satellite imagery could improve the quality of substrate and habitat maps. Updated bathymetric surveys using the newest generation of LiDAR sensors would help identify the likely extent of wet fish habitat. High-resolution mapping using unmanned aircraft systems could target specific areas of importance to develop more detailed maps and assess changes over time. The current lake habitat indicator measures only one dimension of fish habitat: the extent of physical substrates and associated habitats. Other chemical and biological aspects of fish habitat could be measured, evaluated, and integrated into the existing indicator to provide a more complete assessment of fish habitat and fish populations in Lake Tahoe.

Modification of Threshold Standard or Indicators – Modification of this standard should consider adoption of the 2016 fish habitat map. TRPA has not used the adopted fish habitat map to evaluate the standard since 2001 because of its low resolution. The adopted map for instance was found to extend onshore by up to 50 meters in some areas and overestimate the extent of habitat (TRPA 2007). TRPA adopted its current Prime Fish Habitat Overlay Map in 1997 based on work published in 1989. The standard itself suggests that the Prime Fish Habitat Overlay Map may be amended based on best available science.
The current standard focuses only on physical nearshore fish habitat. The presence of invasive species, pelagic water quality, temperature, and the presence of prey species and food sources all contribute to the suitability of the Lake as habitat and presence of target fish species. In addition, habitat requirements vary between species, and consideration should be given to all target species are addressed. Modification could consider also consider a shift to targets and monitoring of the presence, abundance or status of fish populations. Recent studies have indicated declines of nearly 60 percent in overall native fish species populations in the nearshore (C. K. L. Ngai et al. 2010; Chandra, Caires, and Ryan 2015). Conclusions and recommendations from Heyvaert et al. (2013) and the pilot nearshore monitoring related to indicators of biological community composition (Chandra, Caires, and Ryan 2015) may be helpful in informing and reviewing the lake habitat threshold standard.

Attain or Maintain Threshold - Continue to emphasize the control and prevention of aquatic invasive species as it is suspected that their presence threatens the biological integrity of Lake Tahoe's littoral fish habitats (Kamerath, Chandra, and Allen 2008; C. K. L. Ngai et al. 2010). Consider the possibility of targeting fish habitat mitigation activities in areas where value of restoration effort will be maximized.

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