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a living river

CHARTING THE HEALTH OF THE UPPER SANTA CRUZ RIVER

CHANGES BETWEEN 2008 AND 2014 WATER YEARS

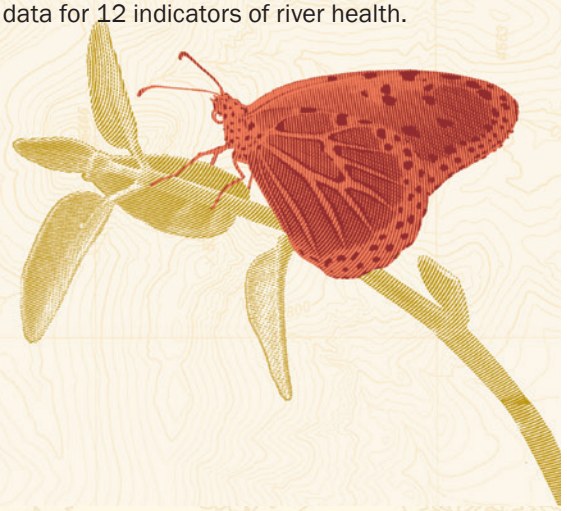
CONTENTS

THE UPPER SANTA CRUZ RIVER A LIVING ECOSYSTEM

The Upper Santa Cruz River in Santa Cruz County flows year round from Rio Rico to Amado and supports a culturally and ecologically diverse region. River flows are sustained by effluent discharges from the Nogales International Wastewater Treatment Plant (NIWTP) which treats and reclaims water from sewage from the binational communities of Nogales, Arizona and Nogales, Sonora. In the last seven years, two important changes in wastewater management have occurred.

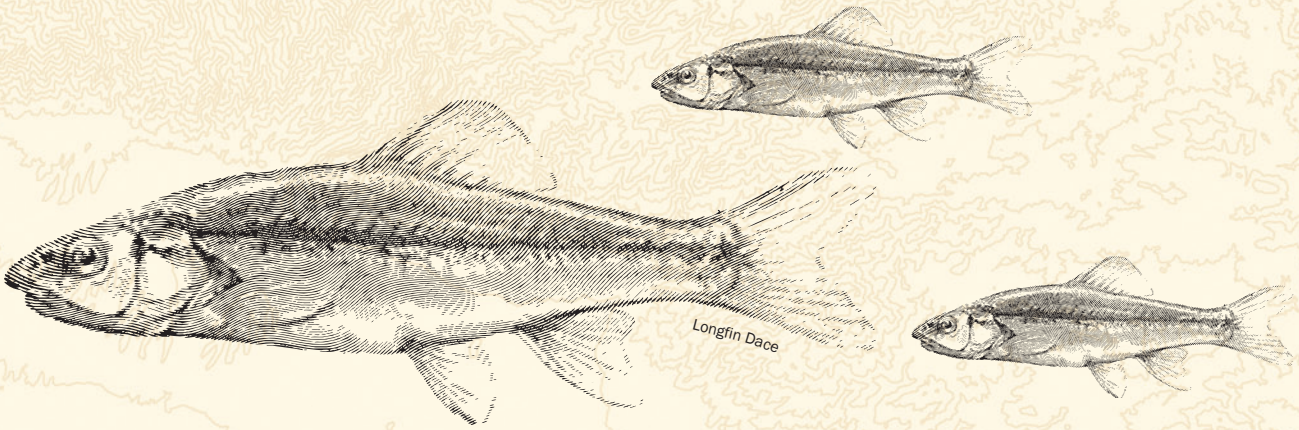
- **Upgraded Treatment Plant:** In 2009 the NIWTP completed significant upgrades to the treatment process resulting in reduced levels of nitrogen in the released effluent.
- **Wastewater Diversions:** In 2013 Nogales, Sonora completed construction of the Los Alisos treatment plant to divert and treat some of the wastewater that would otherwise be sent to NIWTP. Effluent generated at Los Alisos is released into a different river and flows south into Sonora.

Rivers are dynamic with conditions influenced by many factors. How do we know if recent management actions as well as other factors are influencing the health of this living ecosystem? The Living River reports were developed to annually track indicators of river health and determine what is changing. This assessment summarizes data from the 2008-2014 water years (each water year spans from October 1 to September 30). The pages following this executive summary provide more detail on the water context and data for 12 indicators of river health.



CHANGES IN AQUATIC AND RIPARIAN CONDITIONS

- **Improved water quality with decreased nutrient pollution:** Nitrogen and phosphorus are essential nutrients for plants and animals, but too much can degrade conditions for aquatic life. Total phosphorus and ammonia, a form of nitrogen which can be toxic to fish, significantly decreased after the treatment plant upgrades were complete.
- **Availability of dissolved oxygen increases:** Dissolved oxygen, essential for aquatic life, increased after the treatment plant upgrades were complete.
- **Pollutant metals no longer threaten aquatic wildlife:** Cadmium, a metal that is lethal to wildlife at low concentrations, has not been detected since 2011.
- **More diverse aquatic life:** Fish, virtually absent in 2008, have returned and flourished. Diversity of aquatic invertebrates has increased and more pollution-sensitive species are present.
- **Reduced flow extent:** The length of the flowing river has decreased, likely the result of a combination of factors including increased water infiltration with reduced nutrient pollution, scouring floods, and water diversions. Initial diversions to Los Alisos appear to be minor and reductions in effluent released into the river is primarily due to a decrease in wastewater from Nogales, Arizona.
- **Stressed cottonwoods at the far end of the river:** Branch die-back and death of some trees indicate that cottonwoods in the Amado Reach are suffering. Reduced flow extent is likely the primary cause of stress as flow becomes more irregular through this reach.



OTHER OBSERVATIONS

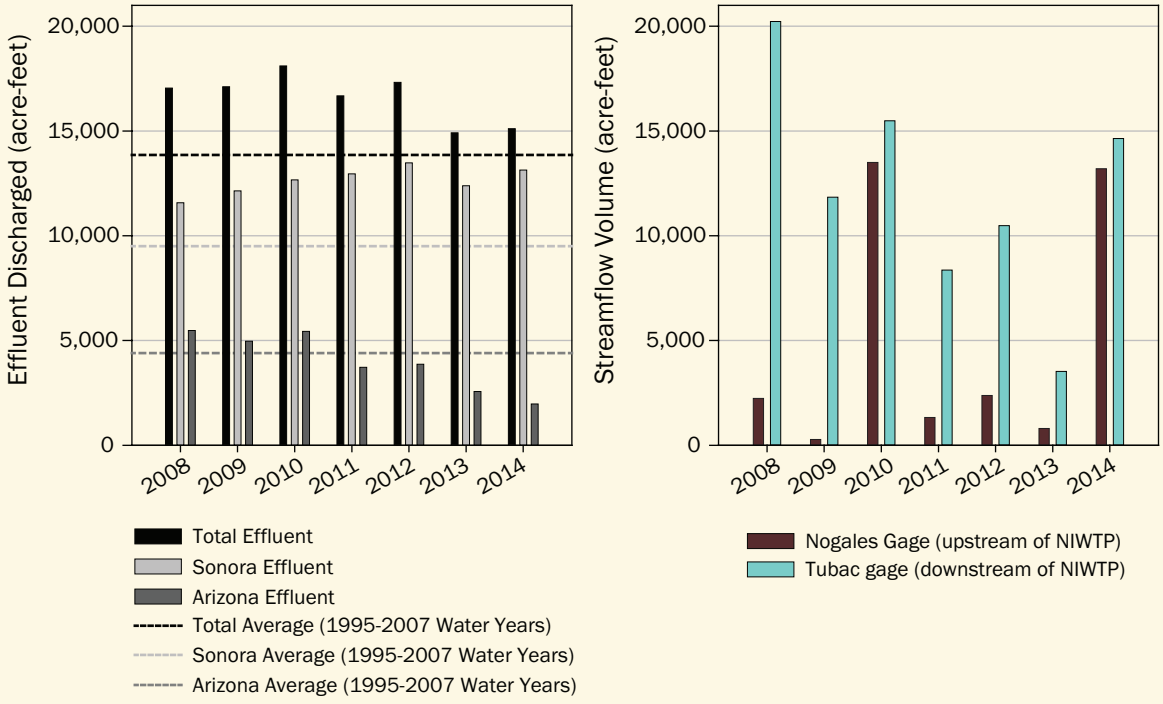
- **Fecal contamination continues to be a risk during the rainy seasons:** *E. coli* levels continue to exceed the swimming (full body contact) standard. Exceedances of *E. coli* primarily occur during rainy seasons suggesting multiple sources of fecal contamination that likely come from humans, livestock, and wildlife.
- **Groundwater levels most stable in the Tubac Reach:** Both the maximum depth to groundwater and the annual January to June decline in groundwater levels are most stable and optimal for cottonwoods in the Tubac Reach.

Streamflow and Rainfall

The amount of water flowing in the river provides an important context for the results of indicators that track the health of the Upper Santa Cruz. This water comes from two natural sources: precipitation and groundwater. A third source of water, effluent, is water that has been pumped from one location, used by people, treated in a wastewater facility, and returned to the river in a new location. The Nogales International Wastewater Treatment Plant continuously releases water into the river, which accounts for the majority of streamflow in the Upper Santa Cruz River. However, streamflow also includes stormwater from the watershed. The Santa Cruz River Watershed includes all of the land whose stormwater flows toward the river. We can get a sense of stormwater contribution by tracking total rainfall and streamflow upstream of the treatment plant near the international border. Seasonal floods (which can be measured by looking at peak flows) are important for scouring the riverbed, recharging aquifers, dispersing seeds, inducing seed germination, and clearing natural debris.

2008-2014 Summary

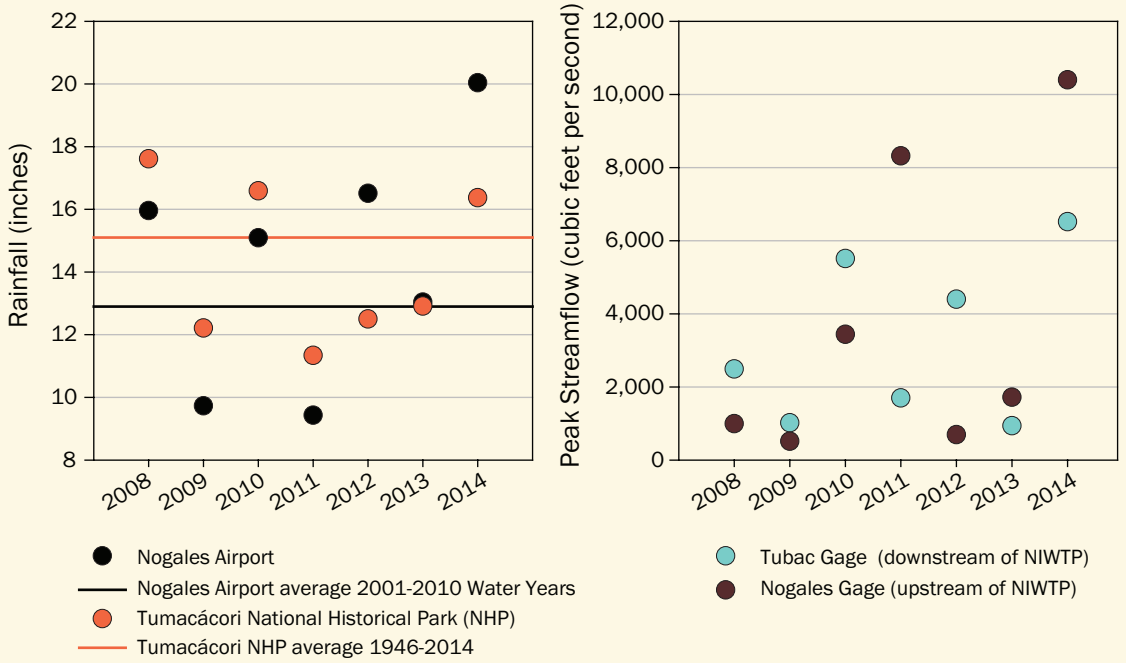
Streamflow is measured daily in Tubac. Overall, total volume of streamflow at the Tubac gage has decreased since 2008. The total volume of effluent released into the river has varied by year, but has decreased by approximately 2,000 acre-feet in the 2013 and 2014 water years. This represents a decrease of about 12% compared to 2008. Although diversions of wastewater to the new Los Alisos Treatment plant in Nogales, Sonora began in 2013, this decrease in effluent volume primarily results from reduced volume



Streamflow and Rainfall cont.

of wastewater coming from Nogales, Arizona. Overtime, there could be further reductions of effluent with increased diversions of wastewater to the new treatment plant in Nogales, Sonora.

With overall effluent volume remaining fairly constant, the decrease in total volume of stream flow could be due to several factors including changing weather patterns, floods, variability in groundwater levels, and reduced nutrient pollution which likely increased infiltration of water into riverbed to recharge local aquifers. Although, total rainfall has hovered around the historical average, peak flow has increased. Bigger floods could result in better scouring of the riverbed and increased infiltration, which results in reduced streamflow. Scouring in combination with improved water quality post treatment plant upgrade could be the main reasons for decrease in streamflow. Peaks in streamflow after 2009 occurred in 2010 and 2014 when there was a significant volume of streamflow upstream at the Nogales gage, which is most often dry. Increased streamflow and precipitation upstream of Rio Rico likely helps replenish aquifers which can raise groundwater levels and increase streamflow.



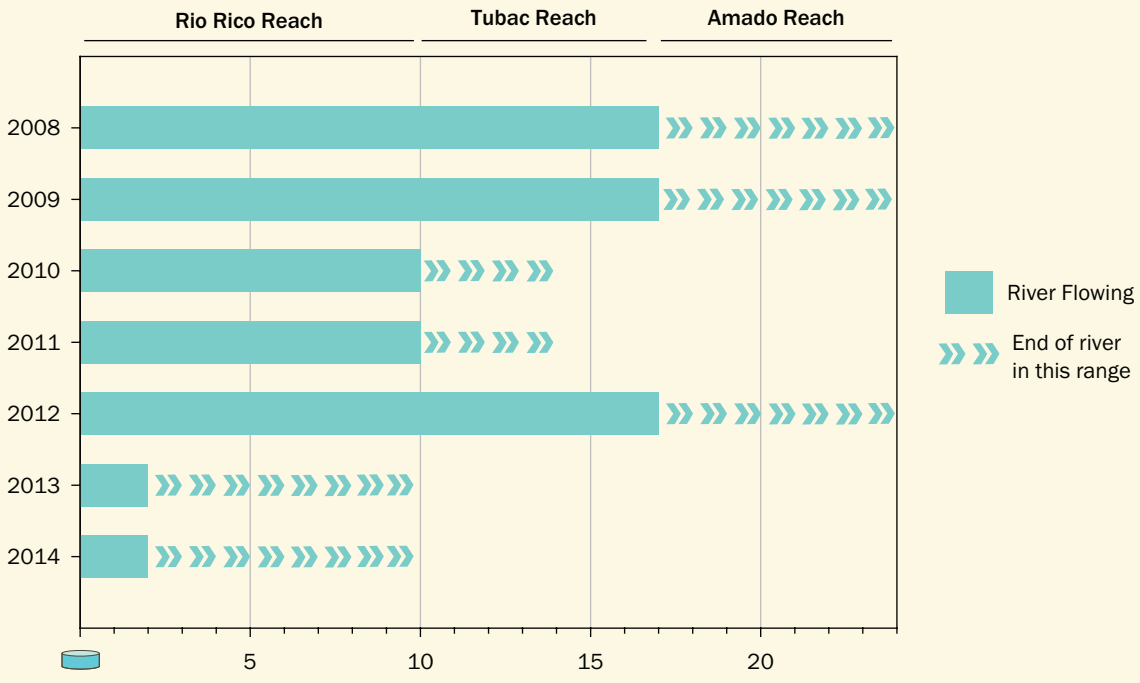
FLOW EXTENT: Miles of Flow

Measuring flow extent, or the distance the river is flowing is a quick visual way to track changes in the amount of water in the river and thus is a rough estimate of the quantity of aquatic habitat available. For example, high flow extent may indicate high availability of habitat for aquatic life. Low flow extent may indicate reduced water inputs, which could decrease aquatic habitat. Alternatively, low flow extent could indicate greater recharge of water into local aquifers.

Measuring miles of flow prior to the monsoon season determines the minimum extent of flow during the driest time of year. This is typically measured in mid-June. Friends of the Santa Cruz River track river conditions monthly at three sites along the river and streamflow is monitored continuously by a USGS stream gage in Tubac. While the exact location of the "end of flow" is unknown, we can track approximate location by knowing which monitoring sites are dry at the time of survey in June.

2008-2014 Summary

Miles of flow in June has decreased over the years. There was a decrease in miles of flow in 2010 and 2011. Prior to 2010, the river flowed 17 miles and into the Amado reach regularly in June with 2006 the only dry year between 2004 and 2009. Since the volume of effluent released into the river did not decrease during this time, increased recharge from improved water quality once the treatment plant upgrades were complete in 2009 is likely a major factor for the decreased flow extent. A further reduction in miles of flow was observed in 2013 and 2014. This coincides with the timing of diversions of wastewater to a new wastewater facility in Sonora, Mexico beginning in 2013. However, the total volume of effluent released into the river decreased only by 2000 AF over the year and this is linked primarily to decreases in wastewater coming from Nogales, Arizona.



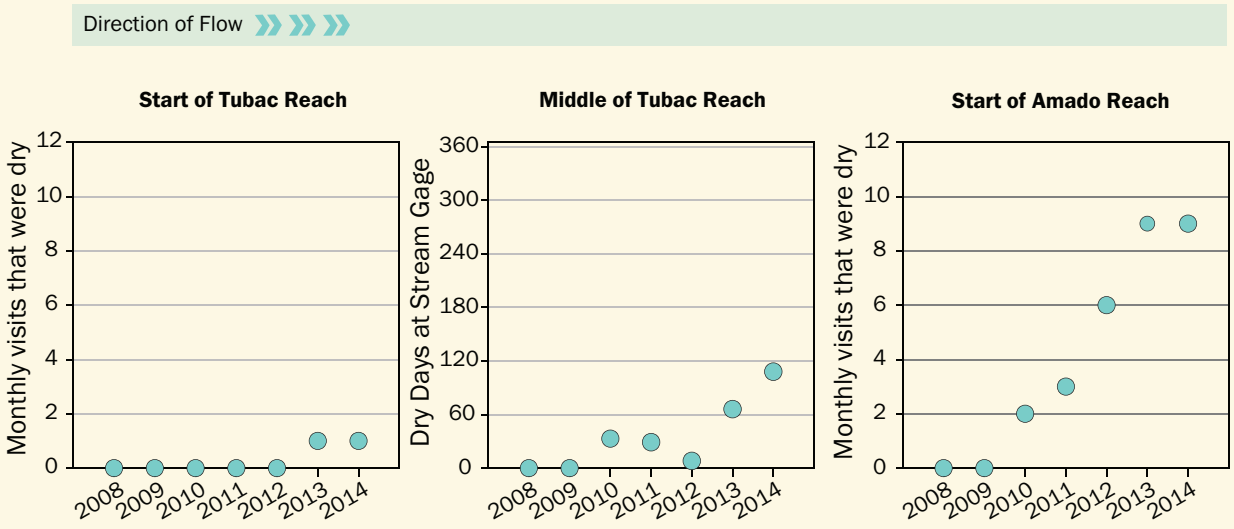
Miles of flow downstream of treatment plant in June

FLOW EXTENT: Number of Dry Days or Visits

In addition to measuring minimum flow extent in the driest part of the year, it is helpful to understand the variation throughout the year. Although we cant't know the exact length of the river at all times, measuring the amount of time a specific location along the river has no flow or is "dry" gives a sense of change in flow extent across the year. Friends of the Santa Cruz River track river conditions monthly at three sites along the river and streamflow is monitored continuously by a stream gage in Tubac managed by the U.S. Geological Survey. Measuring the number of monthly visits or days that are dry provide an estimate of changes in amount of water in the river.

2008-2014 Summary

Dry days or visits have become more common at the far end of the reach, indicating that flow extent has decreased. Prior to 2010, the river flowed every day at the Tubac stream gage with no days of zero flow since 2003. Since 2010, the number of dry days has increased, with nearly 120 in the 2014 water year. A similar pattern of increased dryness is seen at the start of the Amado reach. Though measured monthly rather than daily, the number of dry visits has increased. Only one dry visit was observed between 2005 and 2009. In contrast, 9 of 12 monthly visits were dry in both the 2013 and 2014 water years. Overall, the Rio Rico reach continues to have daily flows, though dry conditions are likely getting closer. Beginning In the 2013 water year, the start of the Tubac reach has seen 2 months with dry visits.



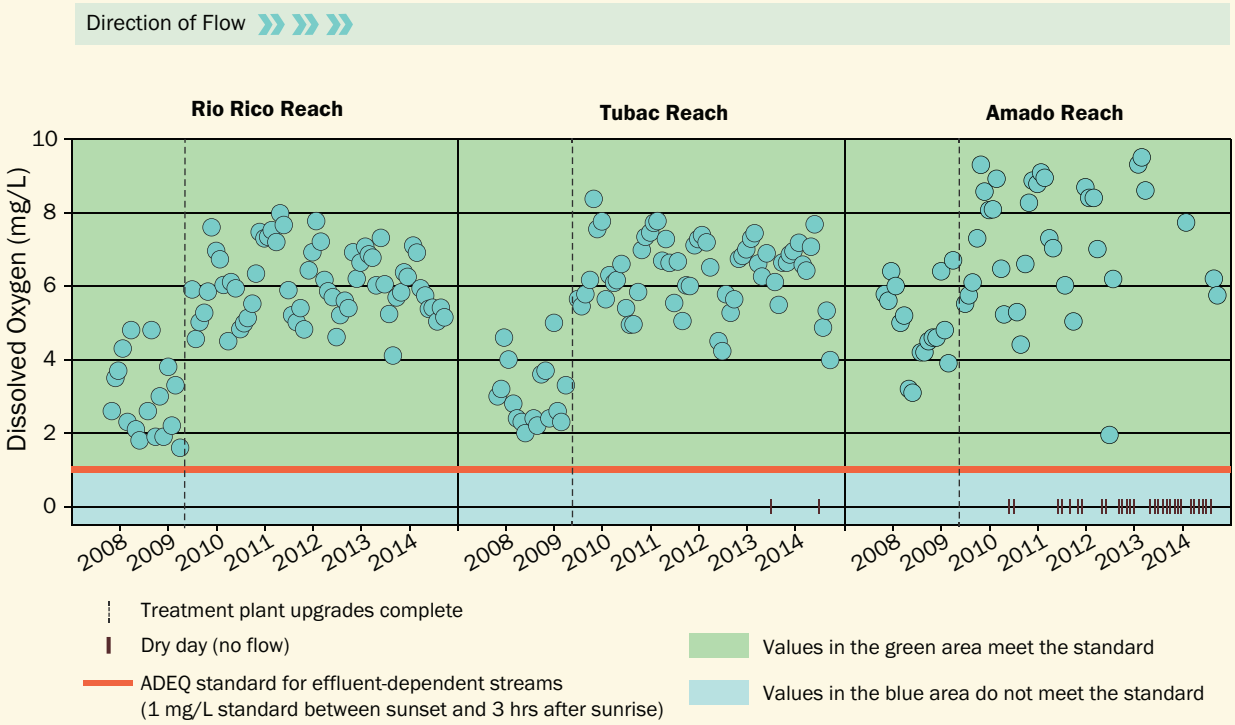
Note: Data from the Rio Rico reach are not displayed. No dry visits observed during the 2008-2014 water years.

DISSOLVED OXYGEN

Fish and other aquatic animals need oxygen to survive. Rivers absorb oxygen from the atmosphere and aquatic plants produce oxygen. Natural causes of variability in dissolved oxygen levels include nutrient levels, groundwater discharge, shading, water temperature, and time of day. ADEQ sets the minimum standard for dissolved oxygen in effluent-dependent streams at 1 milligram per liter (mg/L) measured between sunset and three hours after sunrise, and 3 mg/L at other times. All data was measured within three hours after sunrise, thus measures of dissolved oxygen that are greater than 1 mg/L meet the standard.

2008-2014 Summary

Levels of dissolved oxygen have met the standard in all three reaches. Dissolved oxygen increased after upgrades to the treatment plant were completed in 2009. Although there have been more days with no flow in the Amado reach in recent years, when water is present, levels of dissolved oxygen have been high.

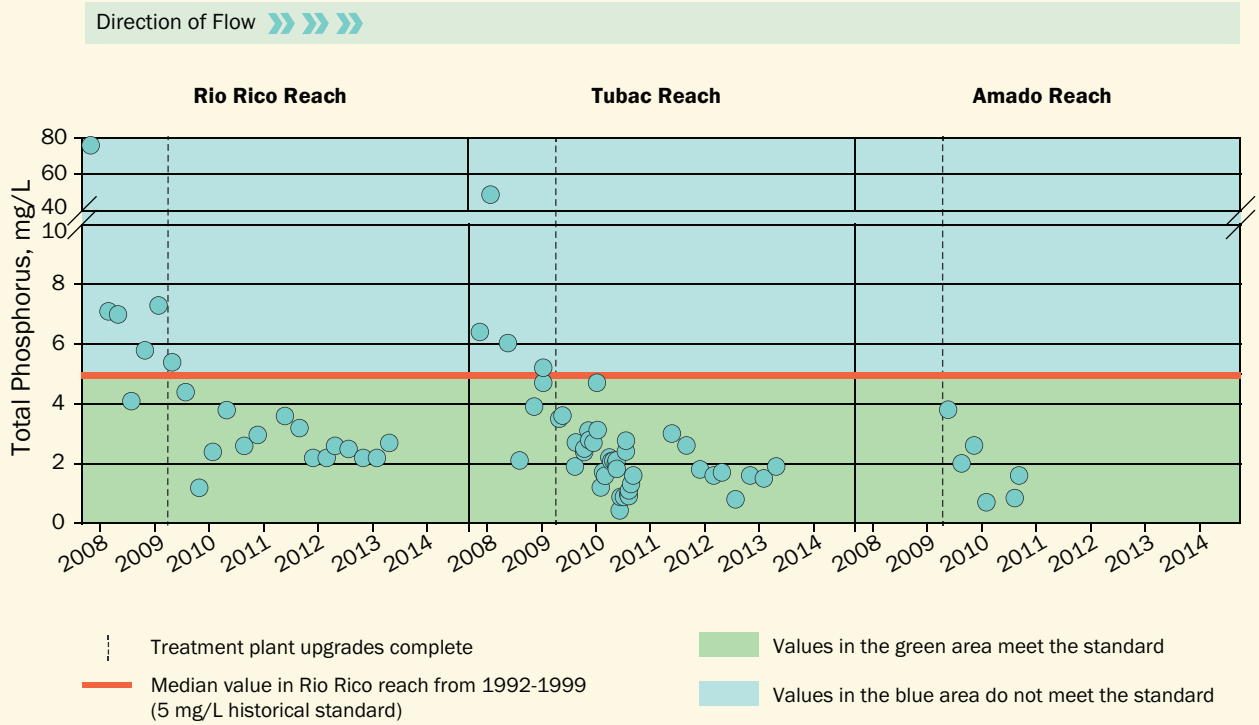


TOTAL PHOSPHORUS

Phosphorus is an essential nutrient for plant and animal life. However, too much phosphorus can reduce the quality of aquatic habitat. Elevated levels of phosphorus can accelerate plant growth. As plants decay in the river, dissolved oxygen decreases and aquatic animals can die. The median amount of total phosphorus monitored in the Rio Rico reach from 1992-1999 was approximately 5 mg/L. Because ADEQ does not have a standard for total phosphorus in this stretch of the Upper Santa Cruz River, this assessment uses the 1992–1999 median of 5 mg/L as the historical standard.

2008-2014 Summary

Phosphorus levels declined over the years in the Rio Rico and Tubac Reaches, most notably after the upgrades to the treatment plant were complete in 2009. Data is limited for the Amado reach but measures of total phosphorus are below the historical standard.

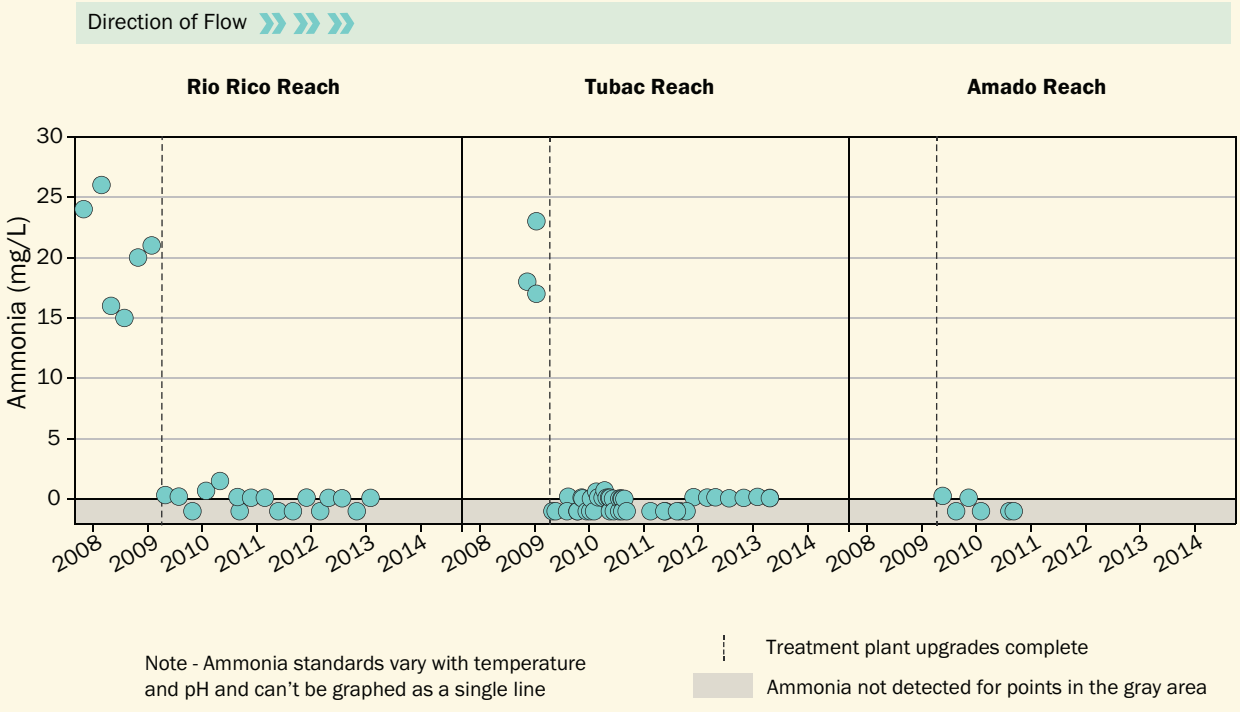


AMMONIA

Nitrogen is an essential nutrient for plant and animal life, but too much can lead to nutrient pollution. Ammonia (NH3) is one form of nitrogen that can be toxic to fish. Even at low concentrations, ammonia can reduce hatching success, among other impacts. The toxicity of ammonia varies with several factors such as pH, temperature, and dissolved oxygen. ADEQ's standard for ammonia varies by pH and temperature. As pH and temperature increase, the toxicity of ammonia increases, thus the acceptable level of ammonia decreases with high pH and temperature. Although the standard is not a constant value, generally values of ammonia greater than 6 mg/L do not meet the standard.

2008-2014 Summary

Levels of ammonia decreased dramatically and was often not detected in the Rio Rico and Tubac reaches after the treatment plant upgrade was complete in 2009. This highlights improved water quality for fish and other aquatic wildlife. Although data is limited for the Amado reach during this period, between 2000 and 2007, measures of ammonia averaged 10 mg/L and thus followed a similar pattern to the Rio Rico and Tubac reaches. Decreased ammonia is likely a factor in reducing the clogging effect in the river bed that is associated with nutrient pollution. This in turn increases local recharge and reduces flow extent.

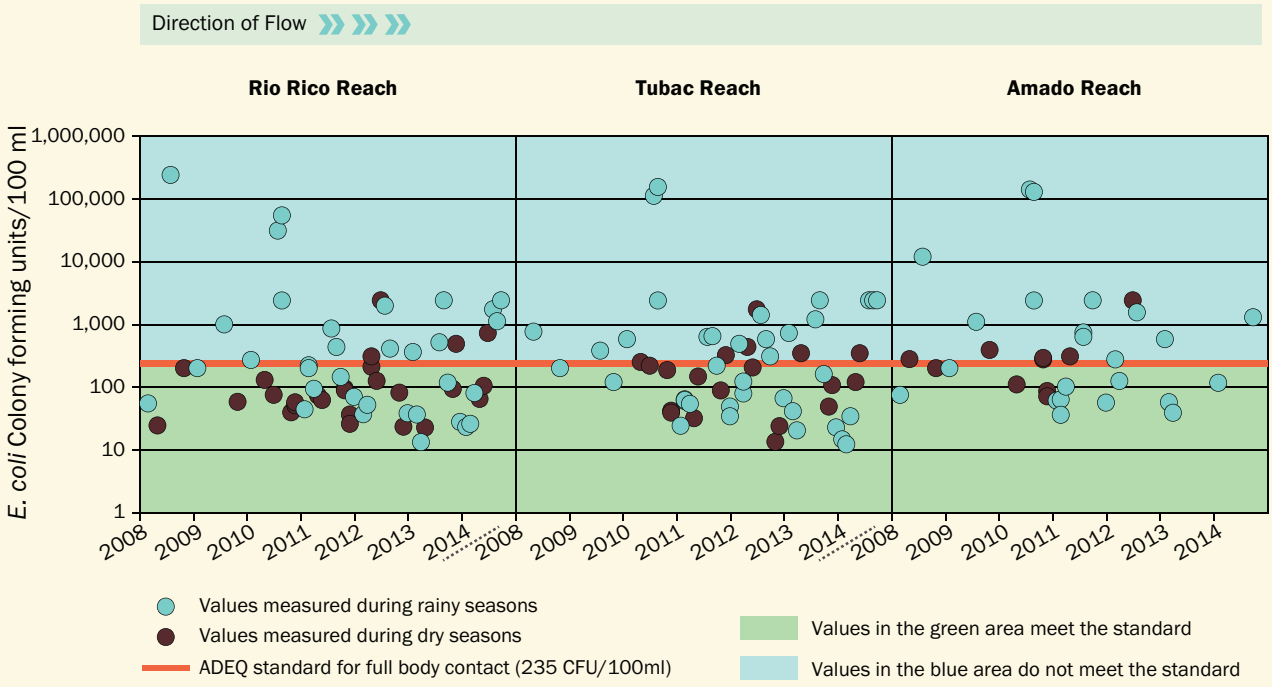


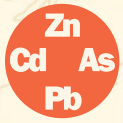
E. COLI

Escherichia coli (*E. coli*) is one of the common species of bacteria living in the lower intestines of mammals, and its presence in water is an indication of fecal contamination. The discovery of *E. coli* indicates the potential presence of other pathogenic microorganisms such as bacteria and viruses that might be a health risk to people swimming or wading in the river. The ADEQ standard for a single sample maximum for full body contact (swimming) is 235 colony-forming units per 100 milliliters of water (CFU/100mL). For partial body contact (wading), the single sample maximum is 576 CFU/100mL. The results are compared to the stricter standard, thus samples with greater than 235 CFU/100mL do not meet the standard.

2008-2014 Summary

E. coli levels varied seasonally and were similar in all three reaches. The Nogales International Wastewater Treatment Plant has always removed bacteria prior to release of effluent in the river, thus levels of *E. coli* did not change after the upgrades were complete. Levels of *E. coli* exceeded the standard most often during the rainy seasons. High levels during the rainy season suggest that rain is washing fecal contamination into the river from multiple sources within the watershed. Preliminary research identifies humans, livestock, and wildlife among the sources of contamination.





METALS

Metals in high concentrations endanger wildlife in aquatic ecosystems by lowering reproductive success, interfering with growth and development, and, in extreme cases, causing death. Most metals build up in aquatic food chains and may pose long-term threats to all organisms in the aquatic environment. The Upper Santa Cruz River is exposed to pollutant metals through numerous sources, including industrial wastewater discharge, mine drainage, roadways, and by the release of metals naturally occurring in near-surface rocks and sediments. ADEQ has set standards for the protection of aquatic wildlife. Results for the following metals are compared to their appropriate wildlife standard: arsenic, cadmium, copper, lead, and zinc.

2008-2014 Summary

Most of the water samples tested for dissolved metals in the Rio Rico and Tubac reaches met the appropriate wildlife standards. No metals were tested in the Amado reach. The only exceedances noted were for cadmium. Cadmium is lethal to aquatic wildlife at relatively low concentrations and comes from numerous human produced sources such as electroplating processes, fertilizers, pesticides, coal combustion, and mine wastes. Between 2008 and 2011, 10 of the 10 samples tested for cadmium did not meet the standard. The samples exceeded the standard on average by 2 micrograms/L. The Arizona Department of Environmental Quality and the U.S. International Boundary and Water Commission worked with the cities of Nogales, Arizona and Nogales, Sonora to mitigate metals in the binational wastewater. These actions appear to have been successful as subsequent monitoring in 2012-2014 have not detected cadmium in 17 samples from the Rio Rico and Tubac reaches.

Average values for dissolved metals tested throughout the year
concentrations in micrograms/liter (ug/L), also known as parts per billion (ppb)

	2008	2009	2010	2011	2012	2013	2014	**Average Standard** *wildlife standards vary with water hardness*
Arsenic	5.1	6.1	5.3	5.4	-	-	-	150 ug/L
Cadmium	2.1	2.3	4.2	1.3	ND	ND	ND	0.8 ug/L
Copper	6.5	4.6	6.0	5.2	5.8	8.7	-	14.2 ug/L
Lead	ND	1.1	ND	ND	ND	ND	-	4.5 ug/L
Zinc	79	58	43	ND	ND	ND	-	235 ug/L

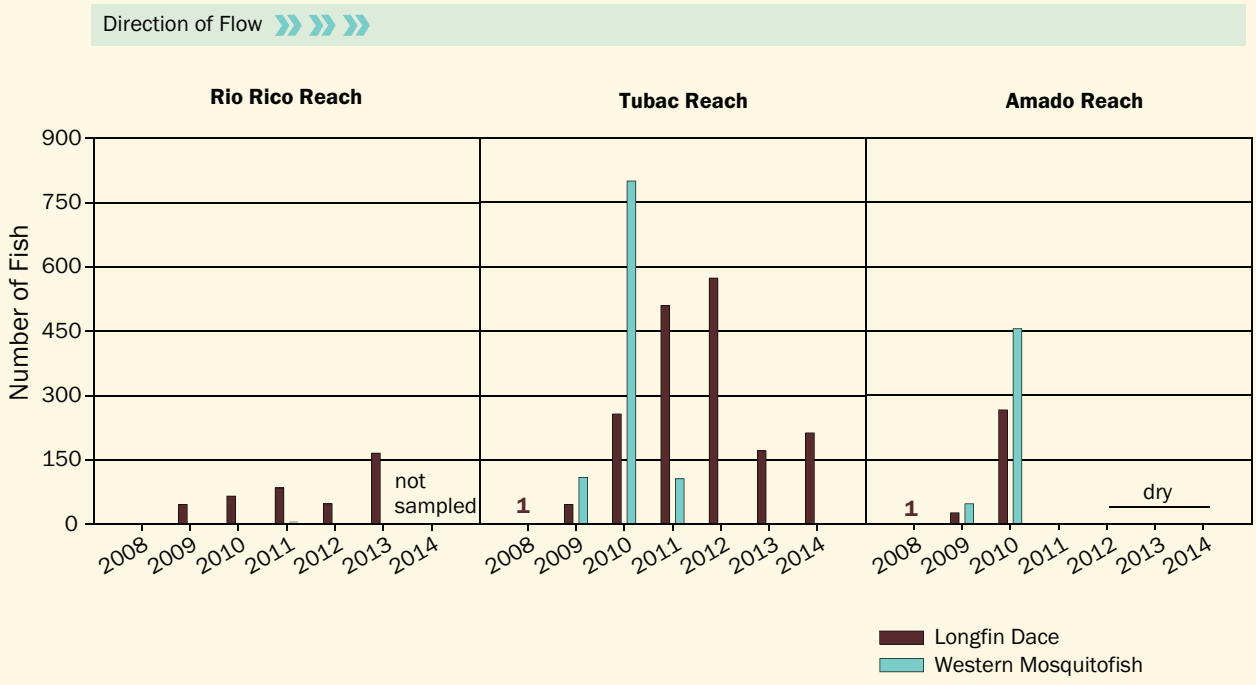
ND = Not Detected

FISH

Fish can serve as effective indicators of river health because they live for several years and differ from species to species in their tolerance to pollution. Historically, the Upper Santa Cruz River supported several native fish species: Gila Topminnow, Desert Sucker, Sonora Sucker, and Longfin Dace. Long-term monitoring has shown a decline in the number of native fish species present and the number of individual fish in the river. Three nonnative fish species--the Western Mosquitofish, Green Sunfish, and Largemouth Bass--were found in Tumacácori National Historical Park between 2001 and 2002. The 2008 baseline documented only Longfin Dace, in very low numbers (2 individual fish caught).

2008-2014 Summary

Annual fish surveys in the fall determine presence and general numbers of fish at several sites along the river; however, population numbers are not estimated. Fish numbers have increased, most notably after the 2009 upgrade was complete. Western Mosquito fish are more common further downstream from the treatment plant, though numbers have decreased and this species hasn't been observed in recent surveys. Changes in streamflow may be favoring the native Longfin Dace. Surveys have not detected any other fish species. The Amado reach was dry during surveys in 2012-2014 and thus may no longer represent habitat as streamflow becomes more variable.



Gila topminnow rediscovered!

Exciting news for the river - the November 2015 fish survey rediscovered Gila topminnow in the river after a ten year absence.

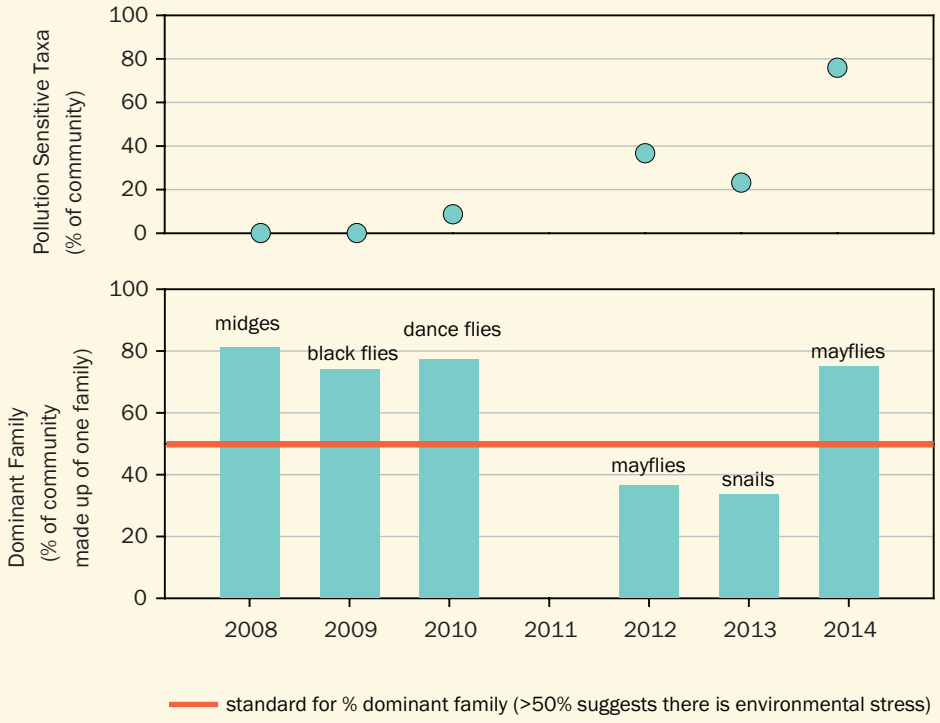
Illustration by Randall D. Babb, Arizona Game and Fish Department

AQUATIC INVERTEBRATES

Aquatic invertebrates (aquatic animals that lack a spinal column or backbone) are an important biological component in streams and an indicator of river health because they differ in their tolerances to pollution and typically live for more than a year. In general, aquatic invertebrates with high tolerances to pollution, like those in the Chironomidae family (midges), are found in higher numbers in polluted streams. In contrast, Ephemeroptera (mayflies) and Trichoptera (caddisflies) are orders (group of families) of aquatic invertebrates that are sensitive to pollution and found in lower numbers in polluted streams. Regardless of sensitivity to pollution, if a single species or group accounts for more than 50 percent of the invertebrate community, this lack of diversity suggests a stream is under environmental stress. While ADEQ has a biological standard for cold and warm water streams, there is no standard for effluent-dependent streams. Reporting the dominant species and presence of pollution-sensitive species helps track changes in water quality.

2008-2014 Summary

Information about the aquatic invertebrate community in the river is very limited. Our best data set is from Tumacácori National Historical Park in the Tubac reach. Unfortunately, data from 2011 is unavailable. With the exception of 2012 and 2013, the aquatic community has been dominated by a single family which suggests that the Tubac reach is under environmental stress. However, the percent of the aquatic community comprised of pollution-sensitive families has been increasing over the years and mayflies dominated the community in 2012 and 2014, suggesting improvements in aquatic conditions. The summer of 2013 was the first time the river went dry through the park. Regardless of improvements in water quality, the lack of water year round could be an environmental stress that reduces community diversity.



DEPTH TO GROUNDWATER

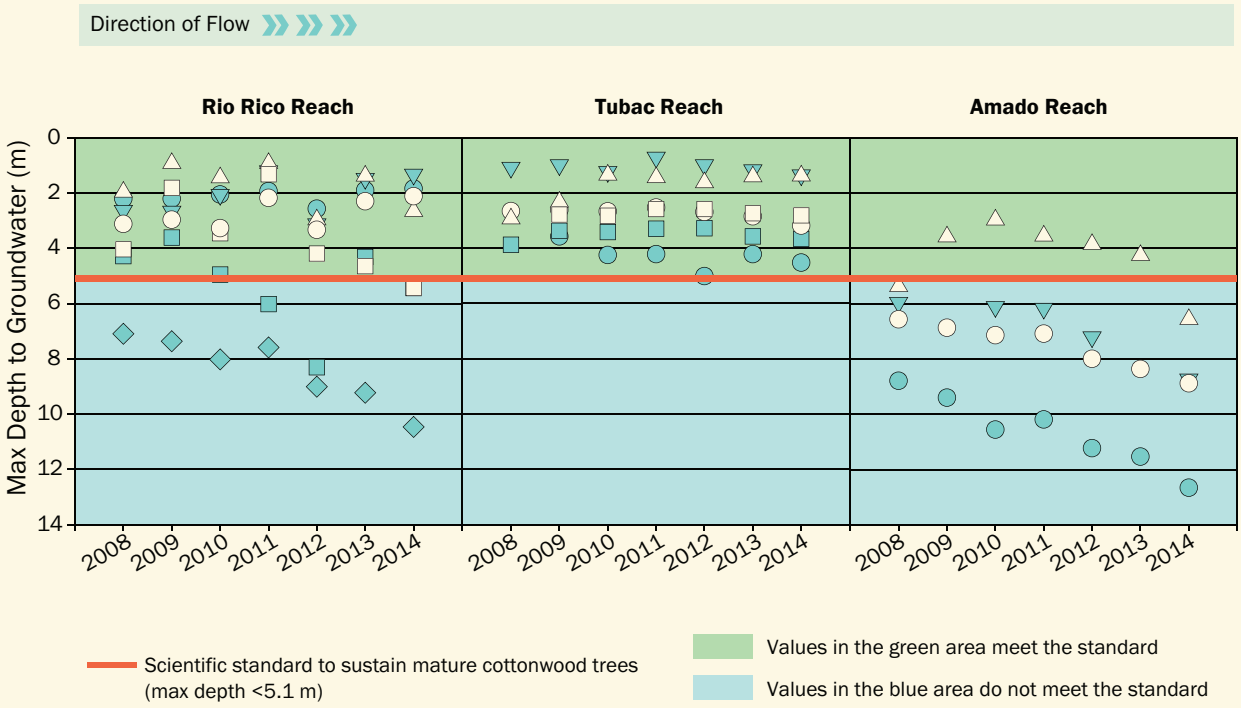
The interactions between riparian vegetation, surface water, and groundwater are important factors in overall riparian health. As with other southwestern rivers, cottonwoods and willows dominate the native riparian forests along the Upper Santa Cruz River and depend on surface water and groundwater to meet their annual water requirements.

Several scientific studies have investigated the maximum depth to groundwater required to sustain mature cottonwood trees. Scientists estimate that the maximum depth to groundwater required to sustain mature Fremont cottonwoods ranges from 2.5 to 5.1 meters (approximately 8 to 16 feet).

We compare maximum depths to groundwater to the upper end of the cottonwood range, thus locations with maximum depths less than 5.1 meters meet the scientific standard. It is important to note that areas with greater maximum depths to groundwater may support other types of riparian vegetation.

2008-2014 Summary

Number of depth measurements over the years varied by well. Some wells were measured only once a year while others were measured daily. All depth to groundwater measurements are determined relative to areas that may support cottonwoods. The Tubac reach appears to have the most stable depth to groundwater measures. In Rio Rico, the three wells with measurements below the standard were located near the beginning of the reach and represent the wells closest to the release of effluent. In contrast, the three wells in the Amado reach that were below the standard are located at the far end of the reach and represent the wells the furthest away from the release of effluent. This suggests the best conditions for supporting cottonwoods are located along the middle stretch of the Upper Santa Cruz River where geologic and hydrologic conditions are optimal and the recharge of effluent is possibly highest.

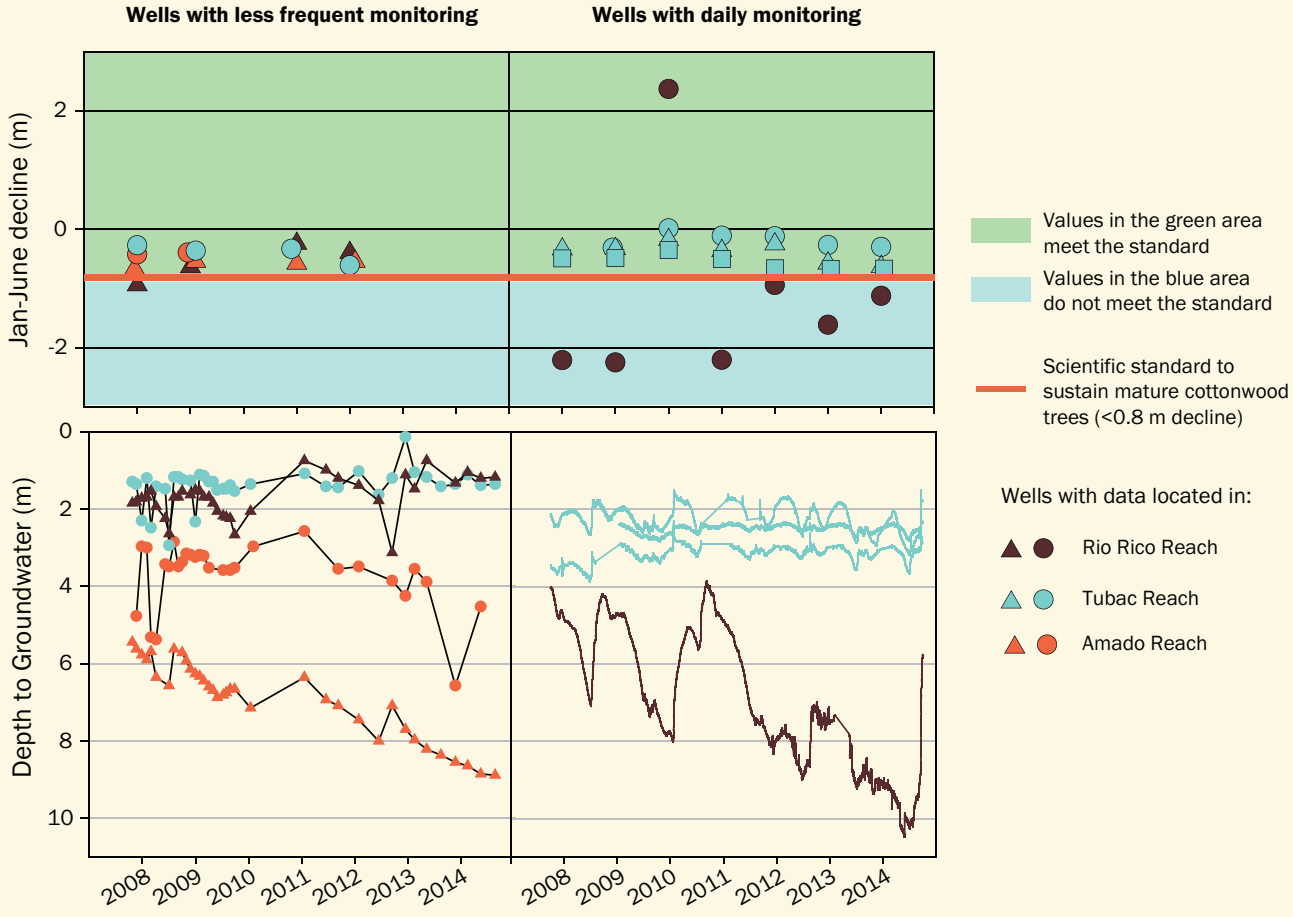


GROUDWATER VARIABILITY

Variability in groundwater levels affects the growth and survival of riparian plants. There are several natural and human causes of groundwater variability. Naturally, groundwater levels decline after the winter rainy season ends and increase once the summer monsoons begin. Studies on the San Pedro River in Arizona indicate that cottonwood trees can withstand declines in groundwater levels up to 0.8 meters (2.6 feet) from January to June. Wells with groundwater levels that decline no more than 0.8 meters between January and June met this scientific standard.

2008-2014 Summary

The number of wells with enough data to calculate the change in depth to groundwater from January to June varied over the years. Some wells with less frequent monitoring did not have enough data or data was collected at the incorrect time to determine the decline. As with maximum depth to groundwater, variability in depth to groundwater in the Tubac reach appears stable and the January to June standard was met at four well locations. Groundwater variability was less stable in the Rio Rico and Amado reaches, though less data is available. Rio Rico depths to groundwater varied between two wells. The well with less frequent monitoring is close to the Tubac reach and met the standard. The other Rio Rico well is near the effluent release and has greater fluctuations in water levels, often failing to meet the decline standard. Although both of the wells in the Amado reach met the standard, depth to groundwater decreased over the years and may not support cottonwoods.



RIPARIAN VEGETATION

Riparian vegetation represents a small percentage of the land cover in the Upper Santa Cruz watershed, but it provides important benefits to the region. Riparian vegetation's many ecosystem services include filtering contaminants from effluent-dominated water before it infiltrates into groundwater drinking supplies, slowing flood waters, reducing erosion potential along stream banks, increasing groundwater recharge, providing habitat for wildlife species, and providing recreational and spiritual enjoyment.

In 2006, Santa Cruz County, Friends of the Santa Cruz River, the University of Arizona, and the Sonoran Institute mapped the riparian vegetation along the Upper Santa Cruz River. Though there is no scientific standard quantifying the amount of riparian vegetation necessary to maintain a healthy river, a simplified version of the 2006 map establishes a baseline useful for measuring future changes in extent or composition of vegetation.

Types of vegetation and land use within the river's 100-year floodplain are divided into five categories: cottonwood forests and woodlands; mesquite forests and woodlands; other riparian vegetation; human infrastructure; and agriculture and pasture. Forests and woodlands have more than 10 percent cottonwood or mesquite tree cover. Other riparian vegetation includes areas not dominated by cottonwood or mesquite trees. Human infrastructure includes areas with roads, railroads, and housing. Agriculture and pasture include crop fields and pasture land.

2008-2014 Summary

As of 2010, there were no major changes in vegetation type and landcover since the 2006 baseline. Only about 100 acres (1.5%) of the area within the 100-year floodplain had changes in vegetation type and landcover. In total, there were over 1,000 acres (16%) dominated by cottonwoods; nearly 1,400 acres (20%) dominated by mesquites; about 2,000 acres (31%) dominated by other riparian vegetation; over 500 acres (8%) used for human infrastructure; and 1,700 acres (25%) used for crops or pastures. Of the area in the 100-year floodplain, the Tubac reach had the largest percentage dominated by cottonwoods (26%), while the Rio Rico reach had the largest percentage dominated by mesquites (28%).

A detailed analysis of vegetation change between 2010 and 2014 has not been completed. However, casual field observations of a couple locations in the Amado reach suggest that cottonwood forest and woodland cover in this area have suffered and trees have died or are showing significant die-back. With recent changes in flow extent, this is not surprising and we will likely see a shift to other riparian vegetation with increased distance from the release of effluent.

LEARN MORE

Find all the Living River reports for Santa Cruz River at **www.tiny.cc/livingriver**.

SONORAN INSTITUTE

With 25 years of experience, the Sonoran Institute inspires and enables community decisions and public policies that respect the land and people of western North America. Facing rapid change, communities in the West value their natural and cultural resources, which support resilient environmental and economic systems.

Founded in 1990, the Sonoran Institute helps communities conserve and restore those resources and manage growth and change through collaboration, civil dialogue, sound information, practical solutions and big-picture thinking.

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SONORAN INSTITUTE

100 N. Stone, Suite 400
Tucson, Arizona 85701
520-290-0828

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Data sources: Arizona Department of Water Resources, Arizona Department of Environmental Quality, Friends of the Santa Cruz River, National Weather Service, National Park Service Sonoran Desert Network, Sonoran Institute, Tumacácori National Historical Park, and U.S. Geological Survey.

Research, writing, and design - Claire A Zugmeyer

Map and illustration on page 2 and 17, and icons - Terry Moody

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