

It's Not Easy to Save a River

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Abstract.—From off-road vehicle abuse in streambeds to nonnative invasive species in riparian areas, from the threat of wastewater discharge in pristine headwater creeks to proposals for burying low-level radioactive waste and landfilling of fracking byproducts on floodplains, from water marketing plans seeking to export large quantities of groundwater to bulldozing river channels, gravel mining, and diverting stream flows, it's not easy to save a river. It is really all about the people; *Homo sapiens* are an essential species of consideration in any multispecies approach to conservation. The Nueces River Authority (NRA) has served as a guardian of surface-water resources in the Nueces River basin since the agency was created by the Texas Legislature in 1935. The jurisdiction of NRA includes portions of three ecoregions and 22 South Texas counties and encompasses more than 45,300 km², extending from Rocksprings to the Gulf of Mexico. Over the past eight decades, NRA has strived to develop and implement an adaptive, systems approach that focuses on empowering people with good information and consistent messaging in order to restore and protect the Nueces River.

Introduction

The Nueces River is located in southwest Texas between San Antonio and Mexico. The Nueces River basin extends from the Edwards Plateau ecoregion near Rocksprings to the city of Corpus Christi on the Gulf of Mexico and drains a 45,300-km² watershed. In the upper basin, headwater tributaries are clear and spring-fed. These streams contain water-losing reaches, which are major contributors of recharge to the Edwards Aquifer, a water supply for millions of central Texans. An average of 412,476,326 m³ per year from 1934 to 1996 was recharged from Nueces River basin streams (HDR 1999). The middle basin is known as the “Brush Country,” where water holes are precious, oil and gas activities are abundant, and the Nueces River helps to recharge the Carrizo-Wilcox Aquifer. Finally, the river crosses the Gulf Coast Aquifer, again

imparting recharge water before delivering freshwater inflows and sediments to Nueces Bay and associated estuary.

The Nueces River Authority (NRA) is a small government agency created by the Texas Legislature in 1935. It has no authority to tax or regulate but does have broad authority to protect, preserve, and develop water resources. In addition to the Nueces River basin, NRA operates within two adjacent coastal basins (i.e., Nueces–Rio Grande and Nueces–San Antonio). Collectively, across all three basins, NRA monitors water quality and engages people to protect the creeks, rivers, bays, and lakes within approximately 77,700 km² of south Texas, equaling about 8% of the state. Funding to support operations of NRA is from contracts and contributions, and its work is acutely focused on protecting surface water resources. To cultivate understanding and advocacy for the water resources of the region, NRA uses a multi-

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species and watershed approach in schools, with landowners, and with recreational users. To inform NRA's decisions and educate the public, it organizes and assists with research and data collection. Further, NRA recognizes and responds to all threats to aquatic resources to the greatest degree possible.

My 20 years of working with NRA is just a microsecond in the life of a river, but enough time for the river to teach me a thing or two. The Nueces River has been running from its spring-fed headwaters in Edwards and Real counties to the Gulf of Mexico for more than 20,000 years (Richardson and Gold 1995). For most of that time, the impact of humankind on the river was probably negligible. The river functioned without interference, and the natural systems worked during drought and flood and normal flows in between. I have seen how quickly and easily people can alter and disrupt a river, even with the best of intentions. This is a story of how NRA has worked on behalf of the river, with help from many partners and a focus on resource protection and human education. Over the years, I have learned how hard, yet rewarding, it can be to save a river.

No Shortage of Threats

We have seen numerous threats to the river system and its natural function. One by one, NRA has found ways to respond on behalf of the river and preserve the many values it delivers. Some of the primary threats we have seen include

- Inadequate riparian buffers between creeks and agricultural operations,
 - Nonnative, invasive species, and
 - Profuse litter.
- Each of these threats to the system is the result of human activity and a lack of understanding. Sadly, the biggest overall threat to aquatic systems, not just here but everywhere, is people—uninformed, though often well-intentioned people.
- Senate Bill 155 to the Rescue*
- Off-road vehicle recreation in the streambeds of the Nueces basin became an overnight sensation in the late 1990s. Popularity of riverbed off-roading led to four-wheelers coming from near and far to conquer the big rocks, deep gravel, steep cliff sides, and other river “obstacles” in the upper Nueces River basin (Figure 1). One competition involved backing specifically modified trucks into the river until the bed filled with water and “crawling” the truck out of the stream before the water drained out. It was not unusual to observe four-wheeling events with more than a hundred vehicles traversing the riverbeds on a hot summer day. The rivers also provided nice swimming holes, cool water for overheated engines, shade trees for mechanical work, and no laws or rules.
- Not only were off-road vehicles destroying the habitat and natural condition of streams in the upper Nueces River basin, but they were also interrupting traditional river recreationists, including families, anglers, and paddlers. The Texas Parks and Wildlife Department (TPWD) underwrote studies of the damage and created a task force to evaluate solutions (Saunders et al. 2004). At the end of the day, it was determined that off-road vehicle operations in Texas rivers were, for the most part, legal, and legislation would be needed to curb it.
- The Nueces River Authority, along with a coalition of environmental, wildlife, and
- Off-road vehicles operating in streambeds,
 - Commercial gravel mines and recreational bulldozing that alter stream morphology,
 - Wastewater discharge and nutrient runoff,
 - Large-scale water marketing plans seeking to pump and export groundwater,
 - Plans for disposing radioactive and hazardous oilfield wastes within floodplains,



Figure 1. Four-wheeling rally in the Nueces River basin.

agriculture groups, engaged in several years of intensive effort resulting in the passage of Senate Bill 155 during the 78th state legislative session in 2003 (Texas Legislative Council 2003). The new law banned the operation of motorized vehicles in state-owned riverbeds and went into full effect in 2004. Since then, this state law has halted vehicle abuse in Nueces River basin streambeds where it is successfully enforced through a combined effort of TPWD enforcement and landowner vigilance.

Since 2004, more than 550 tickets (TPWD, unpublished data) have been issued in the upper Nueces River basin to offenders of this state law. Still, vehicle damage continues in some remote streambeds where the line between public and private land is obscured.

Dozers, gravel mines, and nutrients

As in most of Texas, large ranches in the upper Nueces River basin are being divided and sold as ranchettes. Landscape fragmentation has led to unprecedented rates of alteration through riverside building and landscaping. Real estate marketers are keen on advertising “live water” and river views with private access.

We have recently seen a proliferation of “recreational” bulldozing in an effort to facilitate building, expand road crossings, or dig deeper swimming holes. Regulations apply to some of these mechanical disturbances but not to others. The rules can be confusing and often seem contradictory to the point that people begin to lose respect for laws and enforcement. Occasionally, in an effort to work around the rules, people lose sight

of the reasons disturbance to streambeds or banks are discouraged in the first place.

The cumulative effects of years of “dozer” activities on stream morphology, channel and bank stability, sediment transport, water quality, aquatic habitat, and fish passage have not yet been fully evaluated and warrant further study to guide regulatory decisions.

The Nueces River Authority regularly witnesses the impacts of mechanical disturbances within streambeds. In addition to reporting observations to authorities, we have tried to respond in proactive ways. One such response has been the formation of a Riparian Landowners Network, where riparian experts lead workshops in a neighbor-to-neighbor setting. Workshops focus on riparian function, benefits, and how to maintain a healthy riparian area. Once landowners better understand how the riparian landscape works and the numerous benefits a healthy system delivers, we have seen a decrease in streambed and streambank disturbances.

The development of Eagle Ford shale oil and gas deposits and the proliferation of wind farms in the Nueces River basin are creating an increased demand for caliche and aggregate material. Along the Nueces River, and its gravel-rich tributaries, there has been a significant increase in commercial gravel mining operations. Most aggregate mines are operating just above the gradient boundary that divides public streambeds from private uplands, and therefore they are not regulated. Whether permitted or unpermitted, bed, bank, and floodplain disturbances are damaging to the river system, and their impact is cumulative. When floodwaters cut through a mined area, an unnatural type and amount of sediment can be discharged downstream (Figure 2).

Spring-fed headwater streams, like those in the upper Nueces River basin, are naturally oligotrophic (Elser et al. 1990). Even a small amount of nutrients introduced into these low-nutrient waters can cause damag-

ing algal blooms. Background levels of phosphorus and nitrogen are so low in Nueces River basin headwater streams that even a small spill of livestock mineral supplements (containing phosphorous), a leaking septic tank, or even a highly used animal bedding site near a streambank (Figure 3) can cause observable reactions in algal growth. The regular delivery of treated wastewater effluent, as has recently been proposed for permitting, would ensure unnaturally high rates of primary productivity in headwater streams.

Along the Texas coast, estuaries have long been noted for their productive fisheries (Smith et al. 2013). Important freshwater inflows come from the Nueces River and coastal creeks that drain the Nueces and adjoining coastal basins (HDR and Geraghty & Miller, Inc. 1991). In functional riparian areas and wetlands, pollutants are processed, and sediments are filtered before reaching the waterways that flow directly into the bays and estuaries. Where riparian areas are not functional and have been compromised by development or agriculture, some water bodies are experiencing water quality impairments. The South Texas Land and Water Initiative, another NRA program, grew out of the need to address water quality issues on the ground with riparian landowners. The initiative, currently, is seeking funds for a demonstration project to illustrate farming-out pollutants along Petronila Creek, a tributary to Baffin Bay, by planting specialized riparian plants within and along drainage ways leading to the impaired stream segment. This incentive-based grower program is beginning to be implemented across the United States and bears watching in the years to come.

Landfills and groundwater marketing

A proposal to establish a landfill that would accommodate oil and natural-gas drilling waste on a site within the floodplain of Salt Branch Creek, a tributary of the Frio



Figure 2. A gravel mining operation located on a large alluvial fan within the upper Nueces River basin.

River and Choke Canyon Reservoir in McMullen County, is a recent example of the long-running and ongoing threats to water resources in the Nueces River basin. With a lower population density than much of the state of Texas, the Nueces River basin has long been targeted as a site for controversial projects that pose potential contamination and pollution risks. Over the years, NRA has intervened to successfully oppose numerous applications for waste discharge permits when those projects threatened the surface or groundwater quality of the basin. Three years were spent opposing efforts by the Tex-

as Low-Level Radioactive Waste Disposal Authority to locate the state's first disposal facility in the Nueces River basin. The first proposed site was near Asherton, Texas. The second site was near Tilden, Texas, just upstream from Choke Canyon Reservoir. The Nueces River Authority was instrumental in garnering support that led to the passage of legislation banning the location of this facility within 20 mi (32 km) of a water-supply reservoir (Newberry 1994).

Exportation of large amounts of groundwater from aquifers supplying the Nueces River and its tributaries is another threat



Figure 3. An algal bloom on the upper Nueces River believed to be the result of rainfall runoff from a dense axis deer bedding ground adjacent to the riverbank and following an unusually long dry period.

that has the potential to greatly impact the river. Groundwater export projects could potentially decrease or eliminate spring flows, thus reducing surface flows. This would have adverse effects on downstream surface-water rights and water-supply facilities and impact groundwater supplies needed for current and future domestic, municipal, and agricultural uses. The scientific knowledge of groundwater supplies in the upper Nueces River basin, which is influenced by the highly fractured Edwards and Trinity-Edwards aquifers, is incomplete and at times conflicting. It is unknown how much water could be pumped before impacts would be seen and how those impacts would be mani-

festated. The threat is real, however, and since 2010, several entities have proposed the construction of pipelines to facilitate large-scale exportation of groundwater from the Nueces River basin (EAA 2018). To date, these proposals have been successfully opposed; however, more science is needed to inform legislation and guide protection of surface water resources.

Nonnative invasive species

In 2010, the invasive and nonnative giant reed *Arundo donax* began to rapidly proliferate on four headwater streams in the Nueces River basin. New plants readily propagate from fragments of existing

plants, and typical means for dispersion include transportation of road base or other construction material, nutria *Myocastor coypus* (a semiaquatic rodent) cutting stalks, wild hogs gnawing the green shoots, and humans clearing newly fragmented riverfront properties. In a short period of time, giant reed was introduced and expanded to approximately 30% of the floodplain on parts of upper basin streams. The Nueces River Authority responded with a multiyear, multipronged, landowner-directed control effort that was launched with funding from the TPWD, the U.S. Fish and Wildlife Service, private foundations, and concerned individuals.

"Pull.Kill.Plant." became the battle cry of the grassroots effort to control giant reed and restore native riparian vegetation (www.pullkillplant.org). This program is a three-pronged, multiyear effort consisting of hand-pulling new sprouts, herbicide treatment of existing stands using Imazapyr, and planting of native riparian trees in their place. Between 2010 and 2017, education, outreach, and more than 200 cooperating landowners led to treatment of more than 80 ha on 119 km of four headwaters streams. While the giant reed populations are dramatically reduced, they are not eliminated, so ongoing efforts to manage the plant are essential. Our experience in control of giant reed has led us to conclude that prevention of this invasive is preferable, and educating people is the key to success. An important target group for this education effort are road, bridge, and right-of-way construction and maintenance crews who regularly encounter the plant and have the ability to help stop its spread through proper handling. The campaign materials and implementation plan were developed by Nueces River Authority with funding from the TPWD and guidance from the Texas Department of Transportation and Texas A&M Agrilife Extension. Now the prevention effort is being implemented statewide.

In addition to riparian nonnatives, the Nueces River is home to several aquatic nonnative species, with tilapia *Oreochromis* spp. being arguably the most impactful. While no studies have been focused on tilapia in the Nueces River basin, it is locally known that at least one stocking of Blue Tilapia *O. aureus*, a hardy, vegetation-eating, warmwater fish, was conducted in the 1980s behind a low-water dam at a county park on the upper Nueces River in an attempt to help control aquatic vegetation. A 1996 investigation by the Texas Natural Resource Conservation Commission (TNRCC; now Texas Commission on Environmental Quality) documented fine suspended sediments in otherwise pristine clear water and attributed the water-quality issue to spawning tilapia (TNRCC, unpublished data). Tilapia are now abundant throughout the upper Nueces River basin, and suspended sediments are common during the spring spawning season (Figure 4).

As tropical genera, tilapia are intolerant to coldwater temperatures and tend to congregate near spring runs in the Nueces River basin during winter months. It may be possible to use this behavior pattern to capture and remove large quantities using seines, electrofishing, gill nets, cast nets, or other methods. Even artificial heating has been mentioned as a method to stimulate congregational behavior in areas away from springs for a concentrated harvest. Biological controls, including the release of sterilized breeding fish, have also been discussed (Tavares 2009). However, a comprehensive control program has yet to be organized for tilapia in the upper Nueces River basin, though the need for action is imperative.

Among the terrestrial nonnative animals becoming problematic along the Nueces River are axis deer *Axis axis*, aoudad *Ammotragus lervia*, and blackbuck *Antelope cervicapra*. These species have escaped or been released from high-fenced game ranches. They have found refuge within the



Figure 4. Crystal-clear headwater springs and creeks (left) are turned into murky ponds (right) during tilapia spawning season when their nesting behaviors disturb fine sediments and increase overall site turbidity.

wide riparian floodplains where they are often attracted to feeders operated by landowners. Their presence is placing additional stressors on the ecosystem and impacting riparian vegetation growth and regeneration. An adult female axis deer can have two fawns per year, and a single, adult consumes around 680 kg of forage per year. Because the species commonly travels in herds, riparian vegetation is easily decimated. Without riparian vegetation to slow floodwater and trap new sediments, water-storage capacity and riparian function become severely impaired. A comprehensive initiative to address the problem of axis deer, aoudad, and blackbuck impacts on riparian areas of the Nueces has not yet been launched.

More education, more dollars

While it is important to continue to address resource protection through on-the-ground conservation and regulatory enforcement, the only sure way to save a river is through changing people's minds and behaviors. It is really all about the people; *Homo sapiens* are an essential species of consideration in any multispecies approach to conservation. We have found that education is the most powerful tool in our resource protection programs, but also the most difficult to fund. With

available funding, most raised locally, NRA works to increase awareness and cultivate knowledge among the public—residents, visitors, and especially youth and landowners—to protect natural function and prevent pollution of streams in the Nueces River basin. Programs include a litter-prevention campaign, classroom presentations using a basin watershed model, and workshops for landowners and land managers about riparian function. Riparian education programs led by NRA have been especially successful and are award-winning (e.g., Environmental Law Institute's National Wetland Award for Outreach and Education 2004; Texas Environmental Excellence Award 2008; Lone Star Land Steward Award 2014; Texas Environmental Excellence Award Finalist 2015) but are still underfunded as an ongoing effort.

More than 13,000 students each year have hands-on learning opportunities with NRA's large, tabletop Nueces River basin model. The 2-m-long topographic model of the Nueces River basin demonstrates watershed function and nonpoint pollution impacts. It also introduces the relationship between river basins and aquifers. It is used to reinforce Texas Essential Knowledge and Skills state curriculum and cultivate understanding of water resources, including wa-

tersheds and river basins. Participants are able to identify where they live on the model and see how their activities impact the health of the water resources in the whole basin. It has proven to be an effective tool to show students where their water comes from, where it goes, and what they can do to protect and conserve it.

"Your Remarkable Riparian" is an NRA program that guides landowners in managing land adjacent to creeks and rivers to enhance water supply and improve water quality (Jones-Lewey 2018). Initially funded by private foundations and later supported by state agencies, more than 40 landowner workshops were delivered from 2007 to 2011, and one-on-one riparian consultations were offered throughout the Nueces River basin (Nelle 2011). Because riparian vegetation is the crucial component to riparian health, a

plant field guide was needed so that workshop participants could recognize and appreciate these specialized plants for their function, stability rating, and wetland indicator status. The first two editions of the guide were funded by contributions and given away to participants, but demand for them was bigger than the Nueces River basin, with more than 13,000 copies given away. Now in its third edition, *Your Remarkable Riparian: Field Guide to Riparian Plants* found within most of Texas and its companion, *Your Remarkable Riparian: Owner's Manual* are now the leading statewide resources on the subject (Figure 5; NRA 2016). The TPWD's *Troubleshooting Invasive Plants* manual is distributed with NRA's *Remarkable Riparian* book set as well. They are available for sale on the NRA riparian Web site (www.remarkableriparian.org).



Figure 5. *Remarkable Riparian: Field Guide to Riparian Plants* and its companion *Remarkable Riparian: Owner's Manual*.

The *Remarkable Riparian* online learning modules are widely consulted as well. Most recently, NRA developed an online college course currently being piloted at Sul Ross State University in Alpine, Texas. The Nueces River Authority is working to expand the online delivery of riparian modules for continuing education credits at Texas State University in San Marcos, Texas, as well.

River litter prevention took shape as NRA's Up2U campaign in 2005 and continues with the annual production and distribution of branded litter bags and support from local partners. The campaign name and graphic logo underscore a message of personal responsibility for clean rivers and beaches. With a growing number of recreationists now visiting the region, river litter has the potential to become a major pollution issue. More than 75,000 Up2U litter bags are distributed in the region each year, free of charge, providing visitors an active way to become advocates for litter prevention, armed with a handy tool and knowledge that anything left on the ground can wind up in our rivers and oceans.

Conclusions

The resources of the Nueces River basin are clearly better off now as compared to 20 years ago, thanks largely to efforts by NRA. The Nueces River Authority has been actively engaged in saving this river, yet there is so much more to do. The Nueces River Authority must be prepared to address rapidly growing and expanding threats such as excessive groundwater withdrawal that can impact natural flow regimes and dewater creeks and rivers. Nonnative, invasive species are a growing problem in need of creative multipronged solutions. The ongoing fragmentation of waterfront land constantly delivers a new crop of landowners, many of whom are uninformed about the value of riparian ecosystems and who need to be educated. On the Texas coast, farmers may be able to remove costly water-quality impair-

ments before they reach important estuaries, but a program needs to be funded and launched to reward their work.

Despite years of monitoring and reporting through the Texas Commission on Environmental Quality Clean Rivers Program, water quality continues to decline across the basin. Only 4 of 54 classified water bodies remain with no documented water-quality impairments or concerns. So much work needs to be done. Yet, with no dedicated funding sources and few regulatory enforcement opportunities, it is not getting any easier to save this or any other Texas river.

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