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Research paper

A review of environmental hazards and vertebrate biodiversity of upper San Marcos river, Texas, USA

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Abstract

The San Marcos River arises in a series of springs in Hays County, Texas. This is the second largest and important spring system in Texas, which has more environmental stability and a diverse known biotic diversity of any other ecosystems in the southwestern United States of America. The upper San Marcos River contains a relatively larger number of protected biota, including the vertebrate fauna like San Marcos salamander (*Eurycea nana*) and the fountain darter (*Etheostoma fonticola*). Many environmental hazards are increasing day by day due to human's development and groundwater extraction. This area receives a great deal of conservation efforts to protect/ enhance habitats, protect biodiversity and ecological condition of the river but still much more priority actions are needed.

Keywords: *San Marcos River; Texas; Vertebrate Biodiversity; Threats.*

1. Introduction

The San Marcos River flows primarily southeastward for approximately 100 km before joining the river Guadalupe in the vicinity of Gonzales County of Texas State. This river is a rapidly flowing, unusually clear spring run of some 5-15 m in width and up to 4 m in depth. The river flows mostly over a firm gravel bottom with many shallow riffles alternating with deep pools for the first few kilometers near the Blanco River confluence. The junction between the Guadalupe River and the Blanco River confluence has fewer attributes of a spring run. The thermally constant water from the San Marcos Springs has long been noted by (Brown, 1953) and generally varies annually by less than 2 C^0 in the head waters. At the lower end of the spring run habitat only a slightly greater range of variation in temperature from 25.5 C^0 in Aug to 20.4 C^0 in Feb has been recorded (USDI 1967-1971; Beaty 1972). Waters tend to be neutral or alkaline due to the limestone aquifer spring. The PH range is 6.9-7.8 (Texas Water Development Board, 1968). The stability of this stream, both in terms of thermal characteristics and flow dependability, provided the appropriate ecological conditions which are necessary to allow the un-usually high degree of endemism of the San Marcos biota. The biological uniqueness of this ecosystem has been known since many years. Many of the species of San Marcos River ecosystem are found nowhere else and are restricted to the first few kilometers of the San Marcos spring run.

The upper San Marcos River and its headwaters are located in the margin of the Edwards Plateau, which is associated with a large number of endemic springs, aquifer-associated biota, and rapidly expanding human populations (Bowles and Arsuffi, 1993). Due to the large number of protected/threatened species with limited geo-graphic ranges within this area and the threat of human development, groundwater extraction and some other anthropogenic activities, the upper portion of the San Marcos River receives a great deal of conservation effort to protect and conserve its natural habitats. The constant temperature of the river and flow from the springs provide a unique ecosystem for many endangered and threatened species including the Texas Wild Rice, Texas Blind Salamander and the fountain darter fish. The Edwards Aquifer, the source of the San Marcos River, is a very unique groundwater system and one of the richest artesian springs in the southwestern United States.

Due to a variety of environmental hazards, including increased use of the aquifer waters for human activities, increased urbanization in the San Marcos region resulting in increases in flood intensity, pollution, recreational use and alterations of the river ecosystem, the San Marcos River ecosystem is in danger of losing its unique flora and fauna. Presently, four San Marcos River species are recognized by the U.S. Fish and Wildlife Service as threatened species with or in danger of extinction; The San Marcos Gambusia (*Gambusia porgei*), the fountain darter (*Etheostoma fonticola*), the San Marcos salamander (*Eurycea nana*), and the Texas wild rice (*Zizania texana*).

The object of this review study is to highlight the pollution problems San Marcos is currently struggling with, so that I can instill the need for change in the future.

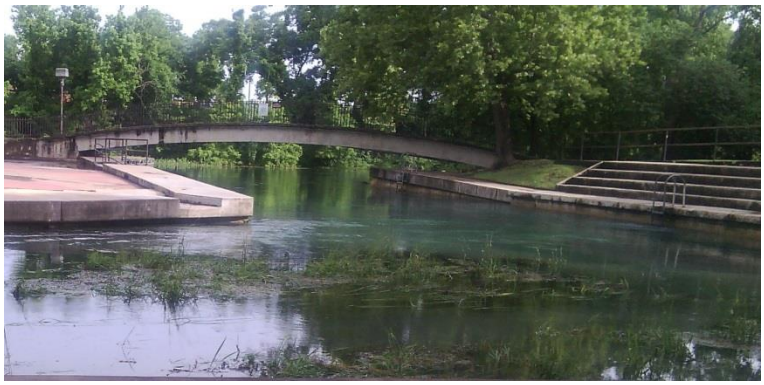

Fig. 1: Texas State's Sewell Park, San Marcos River.

2. Discussion

The San Marcos River starts at the San Marcos Springs on the campus of Texas State University, San Marcos in Hays County. These springs are home of five endangered or threatened species including Texas Wild Rice and the Texas Blind Salamander. Normal daily flows on the San Marcos are around 100 million gallons per day. The San Marcos flows about 85.5 miles through Caldwell and Guadalupe Counties to the confluence of the Guadalupe River in Gonzales County.

The San Marcos River is one of the best places of bass fishes like Small mouth bass, largemouth bass, Guadalupe bass and Guadalupe small mouth hybrids bass. Good numbers of catfishes, Rio Grande Perch, several species of sunfishes, carp and gar fishes are also found here. Twenty seven fish species were recorded by Raymond & Mathew (2005). Freshwater turtles and some important amphibians including *Eurycea rathbuni* and E. *nana* are also found here (Tab. 1&2). Eighteen frogs and 11 turtle species are also found in this area of Hays County (Rose, 2000).

Table 1: List of Some Important Icthyo-Fauna of San Marcos River

Common Name with Scientific Name		Family
1.	Roundnose minnow *Dionda episcopa*	Cyprinidae
2.	Blacktail shiner *Cyprinella venusta*	Cyprinidae
3.	Western mosquitofish *Gambusia affinis*	Poeciliidae
4.	Largespring gambusia *Gambusia geiseri*	Poeciliidae
5.	Sailfin molly *Poecilia latipinna*	Poeciliidae
6.	Spotted gar *Lepisosteus oculatus*	Lepisosteidae
7.	Longnose gar *Lepisosteus osseus*	Lepisosteidae
8.	Blackstripe top minnow *Fundulus notatus*	Fundulidae
9.	Fountain darter *Etheostoma fonticola*	Percidae
10.	American eel *Anguilla rostrata*	Anguillidae
11.	Texas shiner *Notropis amabilis*	Leuciscidae
12.	Mimic shiner *Notropis volucellus*	Leuciscidae
13.	Channel catfish *Ictalurus punctatus*	Ictaluridae
14.	Black bullhead *Ameiurus melas*	Ictaluridae
15.	Suckermouth catfish *Hypostomus plecostomus*	Loricariidae
16.	Spotted bass *Micropterus punctulatus*	Centrarchidae
17.	Longear sunfish *Lepomis megalotis*	Centrarchidae
18.	Bluegill sunfish *Lepomis macrochirus*	Centrarchidae
19.	Green sunfish *Lepomis cyanellus*	Centrarchidae
20.	Redbreast sunfish *Lepomis auritus*	Centrarchidae
21.	Largemouth bass *Micropterus salmoides*	Centrarchidae
22.	Redear sunfish *Lepomis microlophus*	Centrarchidae
23.	Spotted sunfish *Lepomis punctatus*	Centrarchidae
24.	Rio Grande cichlid *Cichlasoma cyanoguttatum*	Cichlidae
25.	Blue tilapia *Tilapia aurea*	Cichlidae
26.	Pacu *Colossoma spp.*	Serrasalmidae
27.	Mexican tetra *Astyanx mexicanus*	Characidae

Fig. 2: Fishes Captured by Hooks in San Marcos River.

Table 2: List of Some important Herpeto-Fauna of San Marcos River area

Species	Common name	Class
Eurycea nana	San Marcos salamander	Amphibia
Eurycea rathbuni	Texas Blind Salamander	Amphibia
Syrrhophus marnocki	Cliff Chirping Frog	Amphibia
Acris crepitans	Northern Cricket Frog	Amphibia
Hyla chrysoscelis	Cope's Gray Tree Frog	Amphibia
Rana berlandieri	Rio Grande Leopard Frog	Amphibia
Rana catesbeiana	Bull Frog	Amphibia
Pseudemys texana	Texas river cooters	Reptilia
Trachemys scripta elegans	Red-eared sliders	Reptilia
Terrapene ornata	Western Box Turtle	Reptilia
Sternotherus odoratus	Musk turtles	Reptilia
Apalone spinifera guadalupensis	Spiny Softshell turtles	Reptilia
Chelydra serpentina serpentina	Common snapping turtle	Reptilia
Graptemys caglei	Cagle's map turtle	Reptilia

Fig. 3: A View of San Marcos River.

Over 40 species of highly adapted, aquatic, subterranean species are known to live in this ecosystem. These include amphipod crustaceans, gastropod snails, and interesting vertebrates like blind catfish (Longley, 1981). Seven aquatic species are listed as endangered in the Edwards Aquifer system, and one is listed as threatened. The main problems for all the species are reduced spring flows caused by increased pumping, elimination of habitat, and degradation of water quality caused by urban expansion (https://www.edwardsaquifer.net/species.html).

The three endangered vertebrate species of this system are: Fountain Darter (*Etheostoma fonticola*), *Texas Blind Salamander (Typhlomolge rathbuni*) and San Marcos Gambusia (*Gambusia georgei*), While one threatened species is San Marcos Salamander (Eurycea nana).

This river is a beautiful recreational and picnic point, and is frequented swimming, tubing, canoeing and fishing. The upper river flows through beautiful San Marcos city. Many conservational groups, government/Non-government organizations have given conservative status to some important vertebrate species of this eco system in Table 3.

Table 3: The Status of Some Important Vertebrate Species of San Marcos River

Species	Common name	FWS	TPWD	TOES	IUCN
Gambusia georgei	San Marcos gambusia Fish	E	E	E	EX
Etheostoma fonticola	Fountain Darter	E	E	E	E
Eurycea nana	San Marcos salamander	T	P	T	V
Eurycea rathbuni	Texas Blind Salamander	E	E	E	V

FWS = U.S. Fish and Wildlife Service
TPWD= Texas Parks and Wildlife Department
TOES = Texas Organization for Endangered Species
IUCN = International Union for Conservation of Nature and Natural Resources
E = Endangered R = Rare
T = Threatened V — Vulnerable (=Threatened)
P = Protected nongame (P* = P.N.G.) (=Threatened)
EX= Extinct in the Wild

3. Threats and environmental hazards

Wetland ecosystem plays a vital role in ecological balance in nature. Importance of wetlands and their role in ecosystem management is well studied but so many environmental hazards are occurring which directly or indirectly affect the health of wetlands. Hazards are may be natural or artificial which are influenced by human activities (Khan et al., 2017). The San Marcos River ecosystem is facing a number of threats, the most prominent threats are:

- The most serious problem is cessation of flow of thermally constant, clear, clean water from the San Marcos Springs due to over drafting of groundwater from the Edwards Aquifer.
- Other threat is habitat modification and loss from anthropogenic actions in the river, along the river bank, and on the watershed.
- Solid pollution such as trash is the biggest pollution culprit in the San Marcos River. Plastics such as grocery bags and water bottles are made up of many toxic chemicals, when they are left in the river overtime they decompose inhibiting the growth of plants and the movement of wild life.
- Another big problem is Micro-litter “the small stuff”: water bottle caps, cigarette butts or plastic straw wrappers. Small stuff that normally wouldn’t be picked up by anybody that is just walking along or even crew members because they pick up the big stuff like water bottles (Amy Kirwin, coordinator for Keep San Marcos Beautiful). Confetti is another common type of micro-litter that ends up in the river. Colleen Cook, an environmental specialist at Texas State University, says fish and other wildlife are at risk of eating the confetti and dying. When peoples leave confetti behind, it’s washed into the drains, which lead back to the river, endangering wildlife (https://www.kut.org/energy-environment/2018-01-15/san-marcos-fights-to-protect-its-river-and-parks-from-littering).
- When it rains, the dumping substances and trash goes into river which is one of the worst ways of pollution of the river.
- San Marcos Springs flow is tied inseparably to water usage over the entire Edwards Balcones Fault Zone Aquifer, human population growth coupled with increased utilization of groundwater in the region will decrease flow of water from the San Marcos Springs.
- The City of San Marcos is growing rapidly (U.S. Bureau of the Census, 1982; Edwards, 1976) found that increased urbanization caused increased flooding and erosion (due to uncontrolled runoff), pollution, siltation, and a general decrease in species diversity and species numbers in adversely impacted aquatic environments.
- Another threat to the aquatic species is the anticipated increase in storm water runoff as the city grows. This runoff should be discharged into the river at a point downstream from the essential habitat of these species.
- Exotic species are another threat. The effects of the exotic Species combined with habitat alteration may synergistically extirpate species, e.g. the San Marcos Gambusia fish. The San Marcos gambusia also requires relatively constant temperature regimes and shading in its habitats. Modifications arising from increased urbanization must take these factors into account.
- In addition, the abundance of the predaceous characin (*Astyanax mexicanus*) may have an additional adverse impact on the abundance of San Marcos gambusia. Competition for resources may be one factor which imposes extreme limits on the abundance of *G. georgei*. In addition to expected high levels of interspecific competition from other Gambusia, especially *G. affinis*, other less closely related species also have been found associated with *G. georgei*. Studies have shown that many small fishes have very similar food habits. If exotic, or non-native, species are added to aquatic systems, greater competition or overlap among species is possible. These exotic species may be able to acquire resources with greater efficiency than native species. Also, during the exponential population growth phases of recently introduced exotics, even short term extensive niche overlap with *G. georgei* is likely to impact this species negatively (Hubbs et al. 1978).
- Nematodes are the most common parasites of *E. fonticola*. The most common adult nematode was *Camallanus sp*. and the maximum number found in any one fish was six. Some fish contained many larval nematodes. Five darters each were parasitized by single *strigeoid trematodes* and two were hosts to single unidentified leeches (Schenck and Whiteside, 1977).
- The direct impact of pollution is creating detrimental effects on the Texas Blind Salamander can no longer live freely in its own habitat. It is forced to live in conservation away from its home due to eco-system changes caused by pollution. This Salamander in addition to the other general threats that affecting this species are an overabundance of predators and the removal of vegetation which provides cover and harbors this species food supply (i.e., Duck fecal droppings polluting moss habitat, ducks feeding on moss and algae, removal of algal mats by Aquarena Springs personnel).
- Urban pollutants such as locally applied pesticides and herbicides also may be negatively impacting on the San Marcos biota.
- Littering is another big threat for this ecosystem, so efforts are needed to protect this from littering.
- Freshwater turtles are opportunistic scavengers that also take live prey, making them vulnerable to getting caught on baited fishing hooks. Some hooks get caught in the mouth of the turtle, which can making feeding difficult. Other hooks are swallowed and lodge in the throat or even the stomach, which can be fatal (Safi et al., 2020).

4. Priority actions and conservation efforts

Many efforts have been made by the different governmental and non-governmental organizations for the conservation of natural ecosystem of San Marcos River and its springs.

- Government should preserve as much land here to remain vegetated and not built on any construction near the river.
- Monitor populations, distribution and hotspots of endangered/threatened species and must be highlight.
- Community based awareness should be utilized and encourage volunteers.
- Every Thursday morning, a group of volunteer divers meets at Spring Lake to clean out harmful vegetation to preserve the lake's ecosystem. Divers focus on uprooting harmful native and non-native plants. To prevent overgrowth, the Meadows Center also sends out an aquatic harvester to scoop up excess plants that don't die off during the winter. The goal of the program is to keep unwanted vegetation from clogging up the mouth of the spring and taking away oxygen from native species that thrive in the lake.

Major steps to meeting the recovery criteria include.

- In 2016, the volunteers for the annual cleanup collected 261 bags of trash, 63 bags of recycling and 77 tires for a total of 9,050 pounds of waste. Seven hundred volunteers worked four hours each to remove the waste. So every effort must be made to allow for public participation in recovery actions. "The San Marcos River Foundation", one of the largest volunteer groups for the cleanups, creates events to educate locals and tourists about littering. Volunteer efforts have been just enough to prevent the rate of littering from increasing. "HEAT" is a group of Texas State University students that, throughout the year, help keep the San Marcos River clean by picking up trash and planting native species.
- Manage the river for the benefit of the species (Establish guidelines, reduce pollution, augment recharge, establish pumping controls).
- Establish recreational guidelines. Short-term "emergency" actions include bringing the species into protected refuge.
- The legislation for conservation of ecosystem should be properly implemented to insure the conservation of ecosystem in such a manner as to maximize survival potential of the San Marcos species.
- Preparations to supplement flows in the river via pumping. Long-term actions include working with water managing agencies to assure flows in the San Marcos River.
- The Texas Highway Department has used a herbicide (Roundup) along the bridge pilings and concrete aprons at the IH-35 crossing of the San Marcos River as a part of their highway grounds maintenance program for years (D. Chance, Texas Department of Highways and Pueblo Transportation, San Marcos, pers. comm.)
- Although San Marcos has a number of city ordinances that ban certain types of containers or objects from the parks, such as glass bottles and cigarettes, but still need more for protecting it from littering. The river is really the heart of San Marcos and without it, this town has nothing special.

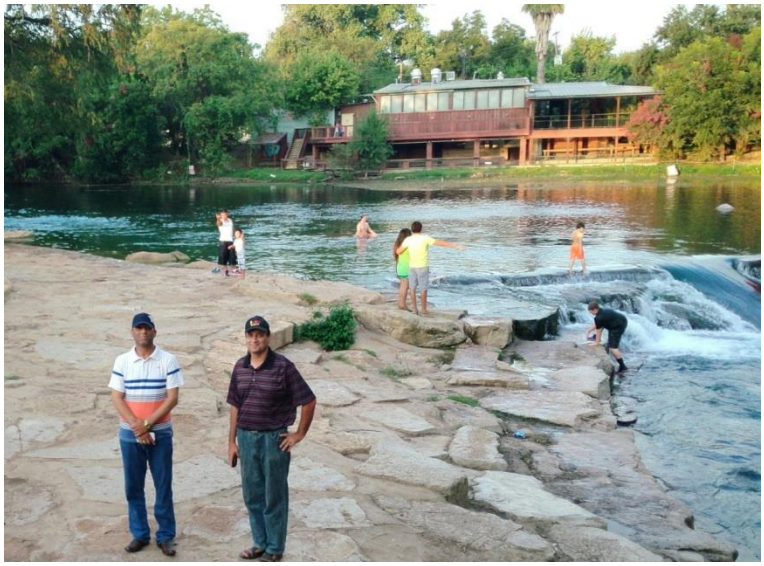

Fig. 4: Rio Vista Dam Park in San Marcos, Texas.

5. Conclusion

Based on this review, it is concluded that a more scientific detailed studies of San Marcos River should be taken by academia of Texas State University, Texas State Government and other organizations with respect to habitat modifications due to environmental hazards and anthropogenic activities in the river to protect local wildlife. The major threats should be point out and highlighted. All sources of pollution should be blocked. More volunteers should be prepared to monitor, clean and maintain the indigenous Biota systematically through scientific methods. The activities of visitors should be noted and there should be a check and balance on their activities. The rare or vulnerable species should have special protection. There should be regular survey about condition of biota which will enable us to conserve them more effectively. There is a need to increase public awareness to enhance public participation in conservation activities particularly directed towards freshwater animals and their habitats.

Further studies are needed to collect more data for preparing the conservation and management plan for San Marcos River.

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