# THE LIFE, DEATH, AND REBIRTH OF THE FISHES OF THE TEUCHITLÁN SPRINGS OF CENTRAL MEXICO

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The story of the fishes of the Teuchitlán Springs (Figure 1), in the state of Jalisco, Mexico, illustrates the difficult challenges but also the opportunities that exist for the protection of the freshwater fishes of Mexico. Most of the native fishes of the Springs have declined or disappeared over the last 50 years, part of the region-wide biodiversity crisis facing the fish fauna of central Mexico. But an international restoration project, spearheaded by the faculty, staff, and students of the Michoacán State University in Morelia, Mexico, and aided by aquarists and scientists from around the world, gives hope that the losses at Teuchitlán can be reversed. The project, described here, could serve as a catalyst and model for fish conservation throughout the country.

Our story begins deep in the mists of ancient times. Twenty million years ago, two plates of the earth's crust collided in what is now central Mexico. As with most geological processes, the collision was gradual and slow, but it was nonetheless massive and violent. A line of volcanoes termed the Trans Mexican Volcanic Belt (aka Neovolcanic Axis) was formed, running from the Pacific Ocean near Puerto Vallarta to the Gulf of Mexico near Veracruz. Volcanic eruptions and massive earthquakes occurred often within this belt, up to and including the present, fundamentally reshaping the landscape on a regular basis. Over the course of many millennia, springs, rivers, and lakes were created, altered, and redirected, and their fish populations were fragmented, isolated, and then reconnected repeatedly. The result was a rich variety of aquatic habitats and a relatively small but highly endemic fish fauna, with many unique species restricted to a small sub-watershed or even a single spring, stream, or small lake.

The current native fish fauna of central Mexico, with about 110 species, is a mix of Nearctic, Neotropical, and local elements, most of which are endemic; that is, found nowhere else in the world but in this region. From the Nearctic have come minnows (formerly family Cyprinidae, now Leuciscidae) and suckers (Catostomidae) and from the Neotropics have come tetras (Characidae) and cichlids (Cichlidae). The local elements are comprised primarily of splitfins—livebearers from the endemic subfamily Goodeinae (Goodeidae) with at least 40 different species—and many more unique populations, and silversides (Atherinopsidae), egg layers from the endemic genera *Chirostoma* and *Poblana* with at least 25 species. Splitfins have adapted to all habitats from tiny headwaters to major rivers to

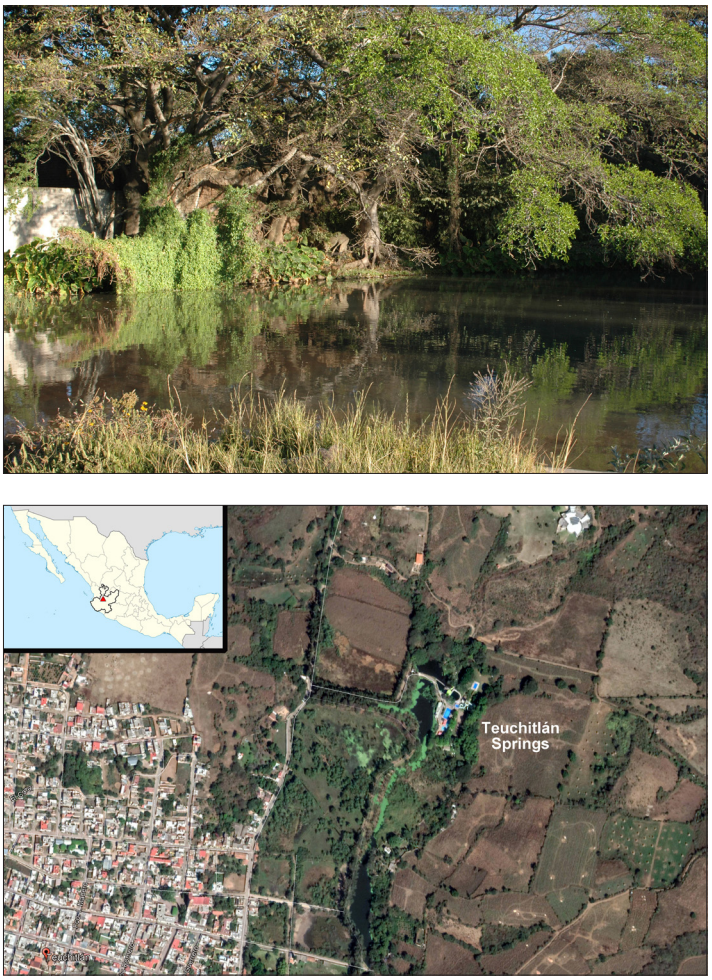


**Figure 1. Top: Teuchitlán Springs. Bottom: aerial photo with inset showing approximate location in the state of Jalisco.**

Photos by the author.

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**Figure 2. Male Tequila Splitfin.**

large lakes, but they have particularly thrived in spring habitats. Silversides have done best in lakes and larger rivers. Teuchitlán, a large complex of springs in the town of the same name, located about 50 miles west of Guadalajara—(the second largest city in Mexico)—has been particularly important for the splitfins with six species occurring there, one of which, the Tequila Splitfin (*Zoogoneticus tequila*) (Figure 2), is found nowhere else in the world.

The Teuchitlán Springs are located at the base of the Tequila Volcano (Figure 3), the mountain that gives the famous Mexican liquor its name. The Tequila Volcano is dormant, having last erupted about 200,000 years ago. This last eruption left a major deposit of obsidian, also known as volcanic glass, a rock with very sharp edges that was of tremendous value to pre-historic humans and long used to make knives, hatchets, arrowheads, and cutting and digging tools. The eruption also created rich soils. The combination of a reliable source of water from the Springs, large amounts of obsidian, and fertile agricultural lands made it almost inevitable that the area around the Springs would give rise to an important area of human settlement.

About 2,500 years ago, the city of Guachimontones arose on the slope of the Tequila Volcano overlooking the Teuchitlán Springs. This city, which controlled much of the trade in obsidian throughout what is now western Mexico, persisted for over 1,000 years, and was characterized by unique, large, circular, stepped, ceremonial buildings (Figure 4). Only recently have archeologists come to realize just how large and important this city was. At its height, about 1,500–2,000 years ago, it was one of the largest urban centers in what is now Mexico, with at least 40,000 inhabitants, and it controlled an area of several thousand square miles and had trade networks that stretched from what is now the southwestern United States into Central America. Excavations reveal that the marshy areas downstream from the Springs were heavily modified and cultivated for crops, and that fishing in these marshes and in the Springs was an important source of protein. Based on observations of more recent indigenous patterns of fish consumption, it seems likely that all the fishes of the Springs, despite their generally small size, were eaten regularly. I also like to imagine that some of the fishes, especially the splitfins, which are quite attractive, may have also been kept as pets in the small earthen pottery that characterized this ancient civilization, now known at the Teuchitlán Culture.

The city of Guachimontones collapsed over 1,000 years ago for unknown reasons; the edifices were soon overgrown and fell into ruin and were eventually forgotten. In the 1500s the Spanish came to the region, subjugating the native peoples and eventually organizing them into large, self-sustaining farming communities known as *haciendas*. These haciendas, which had hundreds to thousands of inhabitants, were controlled by a single family and occupied huge areas of land. Initially the haciendas grew mainly subsistence crops such as corn and beans, but over time they diversified to include cash crops, and by the 1800s they increasingly focused on sugar cane and blue agave (Figure 5) used to produce tequila. Water from the Springs was essential for irrigating crops, and a variety of canals and other modifications to the Springs and its outflows were built over the years to move water to agricultural fields in the region. Although documentation is scant, fishing no doubt continued to be an important source of food. The hacienda system collapsed following the Mexican Revolution in 1910, but extensive sugar cane and blue agave cultivation continues in the region to this day. In the early 1950s, a dam was built on the Teuchitlán River, which was the outlet of the Springs, forming La Vega Reservoir. Water from the reservoir was used to irrigate a vast area south of the Springs. The Springs themselves were increas-

**Figure 3. Tequila Volcano.**

**Figure 4. Guachimontones archeological site.**

**Figure 5. Blue Agave field.**

**Figure 6. Male Butterfly Splitfin.**

**Figure 7. Female Golden Skiffia.**

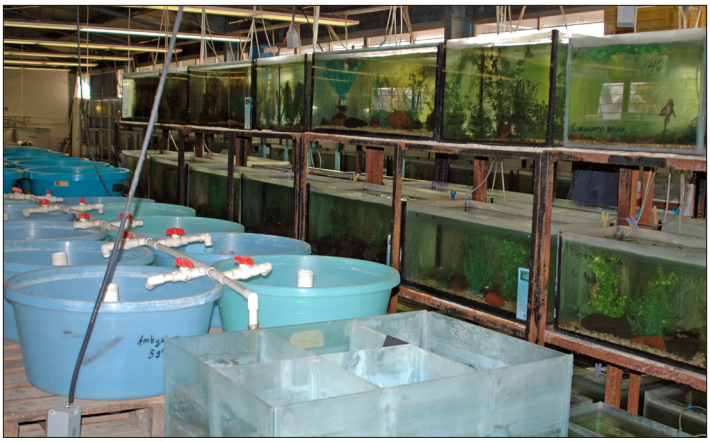

**Figure 8. Captive facility at Michoacán State University in Morelia.**

ingly used for recreation by local inhabitants, and over time a series of water parks, termed *balnearios*, were constructed at the spring heads, including concrete-lined pools and water slides fed by spring water. All of these habitat modifications no doubt influenced the fish fauna, but no scientific surveys of the fishes were undertaken until the mid-1950s long after the habitat alterations had begun.

The great ichthyologist and student of Mexico fishes, Dr. Robert R. Miller of the University of Michigan Museum of Zoology, undertook the first scientific survey of the fishes of the Teuchitlán Springs in 1955. At that time, the Springs were anything but pristine, and he reported that they were already a major source of water for irrigation. He found the Springs to be polluted by runoff from agricultural fields and the adjacent town of Teuchitlán, and observed that the they were heavily used by residents for bathing and washing clothes. But he also found that the Springs had tremendous numbers of fish, and he collected ten native species, including six splitfins (Table 1). At the time, only three of those ten species were known to science. Miller and his students conducted follow-up surveys in 1966, 1974, 1976, and 1980 and brought back live specimens of three splitfin species, the Tequila Splitfin, the Butterfly Splitfin (*Ameca splendens*) (Figure 6), and the Golden Skiffia (*Skiffia francesae*) (Figure 7). These three species eventually entered the aquarium hobby and are now kept by hobbyists and scientists in Mexico, the United States, Canada, Europe, and Asia.

Despite pollution and habitat modification, the native fish fauna of the Teuchitlán Springs remained intact until the mid-1970s. At that time, the first non-native species was introduced, the Southern Platyfish (*Xiphophorus maculatus*), and other non-natives eventually followed (Table 1). The appearance of non-native species was associated with the decline and disappearance of several native species, and by 2010 only three native species remained: (Lerma Livebearer, *Poeciliopsis infans*, Butterfly Splitfin, and Blackfin Goodea, *Goodea atripinnis*). By 2010, the Tequila Splitfin and Golden Skiffia had become extinct in nature and persisted only in captivity. The rise of non-native species and the fall of native species at the Teuchitlán Springs reflected a general pattern across central Mexico: as non-natives became established, the distribution and abundance of native species decreased precipitously, and several native species became extinct. Habitat modification, water loss, and water pollution also contributed to native fish declines. By the 2010s, the loss of native fish biodiversity in Central Mexico had become a crisis, with over 80% of the native species classified as either extinct in the wild, endangered, or vulnerable to extinction. The situation was particularly acute for the splitfins, with 93% extinct, endangered, or vulnerable.

Mexican fish biologists and conservationists recognized the crisis early on and began conservation efforts in the 1980s. Of note was the establishment of two captive facilities to maintain rare native fishes, the first at the Nuevo León State University in Monterrey in the late 1980s under the direction of Dr. Aracdio Valdes, and the second at the Michoacán State University in Morelia in the late 1990s under the direction of Dr. Omar Domínguez (Figure 8). Aquarium hobbyists from Mexico, the United States, and Europe played a key role in the establishment of these two facilities, providing technical and financial support

**Table 1. Occurrence of fish species in the Teuchitlán Springs by decade. For native fishes, a specific year indicates the last capture of the species, and for non-native species it indicates the first capture. The Blue Tilapia probably includes hybrids with Nile and Mozambique Tilapia; hybridization and introgression are widespread among Mexican tilapia species.**

| Common Name | Scientific Name | 1950s | 1960s | 1970s | 1980s | 1990s | 2000s | 2010s |
|---|---|---|---|---|---|---|---|---|
| **NATIVE SPECIES** | | | | | | | | |
| **Minnow Family — Leuciscidae (Cyprinidae)** | | | | | | | | |
| Ameca Chub | *Algansea amecae* | X | X | 1974 | | | | |
| Ameca Shiner | *Notropis amecae* | X | X | 1974 | | | | |
| Amatlán Chub | *Yuriria amatlana* | X | X | 1974 | | | | |
| **Livebearer Family — Poeciliidae** | | | | | | | | |
| Lerma Livebearer | *Poeciliopsis infans* | X | X | X | X | X | X | X |
| **Splitfins — Goodeidae** | | | | | | | | |
| Butterfly Splitfin | *Ameca splendens* | X | X | X | X | X | X | X |
| Blackfin Goodea | *Goodea atripinnis* | X | X | X | X | X | X | X |
| Golden Skiffia | *Skiffia francesae* | X | X | 1976 | | | | |
| Black Splitfin | *Xenotoca melanosoma* | X | X | 1976 | | | | |
| Tarascan Splitfin | *Zoogoneticus purhepechus* | X | X | X | X | X | X | X |
| Tequila Splitfin | *Zoogoneticus tequila* | X | X | X | X | X | 2008 | |
| **NON-NATIVE SPECIES** | | | | | | | | |
| **Livebearer Family — Poeciliidae** | | | | | | | | |
| Guppy | *Poecilia reticulata* | | | | | | 2008 | X |
| Mexican Molly | *Poecilia sphenops* | | | | | 1997 | X | X |
| Twospot Killifish | *Pseudoxiphophorus (Heterandria) bimaculatus* | | | | | | | 2012 |
| Green Swordtail | *Xiphophorus helleri* | | | | | | 2000 | X |
| Variable Platyfish | *Xiphophorus variatus* | | | 1974 | X | X | X | X |
| **Cichlid Family — Cichlidae** | | | | | | | | |
| Redbelly Tilapia | *Coptodon (Tilapia) zilli* | | | | | | | 2017 |
| Blue Tilapia | *Oreochromis aureus* | | | | | 1990 | X | X |

and most importantly, captive fish, including Tequila Splitfin and Golden Skiffia whose ancestors came from the Teuchitlán Springs.

About 10 years ago, Dr. Domínguez and his colleague Dr. Martina Medina began discussing using captive populations to re-establish native fishes in locations where they had been extirpated. The big question was whether the captive populations had become too "domesticated" to survive in the wild. Drs. Domínguez and Medina and their staff and students built several semi-natural ponds in the Michoacán University's Arboretum (Figure 9) on the edge of Morelia and stocked them with a variety of captive fish species, mostly splitfins. The ponds were subject to seasonal fluctuations in day length, temperature, precipitation, water quality, and food availability, the vagaries of weather, and predation from a variety of mammals, birds, reptiles, and invertebrates. Some of the stocked species did not survive, but others thrived over multiple generations, including the Tequila Splitfin and another Teuchitlán Springs species, the Ameca Shiner (*Notropis amecae*) (Figure 10). This proved that, for at least some species, possible domestication of captive populations was not an insurmountable problem.

The Michoacán team decided to try to re-establish Tequila Splitfin and Ameca Shiner at the Teuchitlán Springs. With support from Mexican and international conservation funding organizations, European zoos, and US and European hobbyist organizations, they conducted a detailed and thorough analysis of the current environmental status of the Springs, looking at habitat and water quality and the plant, invertebrate, fish, and fish parasite communities present. From this analysis, it was evident that the best place to attempt re-establishment was at the El Rincon Balneario at the main springhead, and that the primary impediment to re-establishment was the dense population of non-native fishes in the Springs, particularly the rapidly expanding Twospot Livebearer (*Pseudoxiphophorus* (*Heterandria*) *bimaculatus*) (Figure 11). The Michoacán team worked closely with the owners of El Rincon and with the municipal government of Teuchitlán to plan and implement the re-introduction. With the cooperation of the owners of El Rincon, they designated a partially isolated, spring-fed, semi-natural pool within the Balneario for the stocking of Tequila Splitfin and Ameca Shiner (Figure 12). This pool had concrete sides but a natural bottom and limited connections with the rest of the Springs. Here the non-native population could be effectively controlled, and the re-introduced fishes could be readily tracked. During 2014 and 2015, the Michoacán team carried out intensive efforts to remove as many non-native fishes as possible. It was impractical to remove every fish, but the non-

**Figure 9. Pond in the Michoacán University's Arboretum.**

**Figure 12. Release site of Tequila Splitfin and Ameca Shiner at the El Rincon Balneario.**

**Figure 10. Ameca Shiner.**

**Figure 11. Non-native Twospot Livebearer.**

native population was reduced by about 90%. With the pool prepared, 1,500 Tequila Splitfin and Ameca Shiner were re-introduced on November 1, 2015. This was an appropriately symbolic date, falling within the traditional Mexican "Day of the Dead" holiday, when it is believed that deceased loved ones return to be with their living family and friends. The hope was that the Tequila Splitfin and Ameca Shiner would also "return from the dead" and once again become part of the Teuchitlán Springs fish community.

To date, the re-introduction has gone well. Survival of Tequila Splitfin and Ameca Shiner in the pool has been good, and both species have reproduced successfully. A few individuals have moved out of the pool into adjacent areas of the Springs. Non-native abundance in the pool remains relatively low. I visited the Springs in 2017 and 2018 and was excited to be able to snorkel among the newly established Tequila Splitfin and Ameca Shiner in the re-introduction pool.

However, it is too early to declare the re-introduction a success. Non-native species remain a threat. Their complete eradication from the Springs is impossible, and without regular control they are likely to gradually increase in abundance to the point where they may again impact the Tequila Splitfin and Ameca Shiner. Thus, suppression of non-native species will probably be an ongoing need for the Springs. The Michoacán team is not in position to control non-native species indefinitely, so they have been working with the town of Teuchitlán to take over this role. They have developed a comprehensive environmental education program for both the local government and the local schools to build community pride in and a better understanding of the Teuchitlán Springs and its unique fish fauna. They are training Teuchitlán residents how to monitor water and habitat quality in the Springs and how to sample the fish there and to identify and remove the non-natives. Banners, signs, and social media posts celebrate the Springs and its rich biological and cultural heritage. School classes visit the Springs as part of their curriculum and participate in clean-up and educational projects. This sort of community involvement in the protection of rare fishes is innovative, and in some ways is unprecedented. It provides a model for fish conservation elsewhere in Mexico, where the needs are great, but government resources are limited.

The positive results from the first three years of the re-introduction of the Tequila Splitfin and Ameca Shiner at the Teuchitlán Springs have inspired plans to re-introduce other extirpated fishes in springs in central Mexico. The Michoacán team is proposing to re-establish the Golden Skiffia in the Teuchitlán Springs and the Polka-dot Splitfin (*Chapalichthys pardalis*) in the Tocumbo Springs in the state of Michoacán west of Morelia. In the state of Morelos to the south of Mexico City, the state government has begun to re-introduce the Balsas Shiner (*Notropis boucardi*) in a spring system within the city of Cuernavaca, and there are proposals to also re-introduce the Balsas Splitfin (*Ilyodon whitei*).

The situation is still grim for many fishes in central Mexico, but the successful removal of non-natives and the re-introduction of extirpated fishes in the Teuchitlán Springs offer a ray of hope and a start on the long hard road of ecosystem restoration.