La Mojarra del Desierto: *Herichthys minckleyi*

*By **Juan Miguel Artigas Azas**, 1994.*

Herichthys minckleyi female guarding her free swimming fry among water lilie leaves in Poza la Becerra, Cuatro Cienegas, México. *Photo by Juan Miguel Artigas Azas*.

Introduction to the valley

Enclaved in the Chihuahuan desert there is a little valley that, for decades, has attracted a lot of interest in its flora and fauna that has resulted in fascinating biological discoveries. So much so that this place has been call "a living laboratory" Besides, Cuatro Cienegas is considered one of the most important (biological) areas yet discovered in the Western Hemisphere (Minckley 1978).

It all started in the 1950s when in the valley of "Cuatro Cienegas de Carranza" (Carranza's four

marshes), in the Mexican state of Coahuila, a new species of desert turtle was collected. This turtle drew attention because it had some aquatic algae attached to its shell and indicated the turtle spent time in the water. Another interesting feature was that when the frightened turtle would close its lower shell, it would close hermetically. This drew so much attention that several trips were made to the area to study the species. It was discovered that the turtle was endemic to this one valley and was later described as *Terrapenne coahuilae*.

That was just the beginning. Subsequent studies revealed that the valley housed a very special ecosystem of plants and animals. Contreras-Balderas (1994) estimates that a total of more than 150 species of organisms are found only in this valley and its surrounding mountains. The aquatic fauna of the desert valley thermal springs and marshes attracted the attention of the ichthyologist W. L. Minckley. The springs are formed from the water collected by the surrounding ridges "San Marcos y Pinos," "La Madera," "Menchaca" and "La Purisima," although more distant sources of water may also contribute. From the calcareous valley floor the springs emerge forming beautiful small lagoons housing representatives of eight fish families (*Ictaluridae*, *Cyprinidae*, *Centrarchidae*, *Percidae*, *Poecilidae*, *Cyprinodontidae*, *Characidae* and *Cichlidae*), with a total of sixteen species. Some species are related the aquatic fauna of genera representative to northern temperate waters (*Cyprinella*, *Micropterus*, *Lepomis*, *Pilodictis*, *Ictalurus*, *Dionda* and *Etheostoma*), some are more representative of the Mexican gulf basin (*Cyprinodon* and *Lucania*), while others are related to the aquatic fauna of the warmer waters of Central America (*Herichthys*, *Gambusia*, *Xiphophorus* and *Astyanax*). It is the species from warmer waters (*Herichthys*, *Cyprinodon* and *Gambusia*) that dominate the spring's fauna.

In spite of the fact that the fish fauna of the valley is unique and important, it has been determined that the endemic species of invertebrates out number fishes. Also, a very interesting flora of vascular plants has been discovered. Currently, of the sixteen fish species in the valley, at least eight are endemic and future studies could increase this number, at least at the sub-species level.

Laguna de los Burros, la Purisima ridge in the background, Cuatro Cienegas valley, México. *Photo by Juan Miguel Artigas Azas*.

Mojarral West lagoon, Cuatro Cienegas Valley, México. *Photo by Juan Miguel Artigas Azas*.

The Cichlids

Of all the species that inhabit the valley, those that have attracted the most attention and have been the subject of a large number of studies and controversies have been the cichlids. The unique animals that inhabit the thermal and temperate springs surrounding the tip of the San Marcos ridge have shaken the ground of traditional taxonomy by supporting species differentiated primarily based on morphological characters.

Initial studies of the valley cichlid fauna (Labounty, 1974), suggested that the magnitude of the biological differences among the three morphs living in the thermal springs showed the existence of at least three different species; something that seemed logical according to traditional taxonomy. Smaller differences among congener cichlids have been used to differentiate species (Kornfield, Smith, Gacnon & Taylor, 1982). This study showed three cichlids of different morphology, two different types of pharyngeal teeth, and different gut lengths (Kornfield, 1973).

The first, and most plentiful of the morphs is also considered the most primitive and the ancestor of the other two morphs. This form shows a deep body and a pharyngeal jaw holding many thin papiliform teeth that lack specialization which are used to crush soft foods. There is a light musculature supporting them. This form feeds mainly on detritus (Minckley, 1978) (fig. 1).

The second morph, less plentiful than the first, has a more restricted distribution in the thermal springs around the western trip of the San Marcos ridge. It is estimated that this

Herichthys minckleyi piscivorous morph in normal coloration. Poza la Becerra, Cuatro Ciénegas valley, México. *Photo by Juan Miguel Artigas Azas*.

Herichthys minckleyi young adult of the molluscivorus morph in normal coloration, swiming in Poza de la Becerra, Cuatro Ciénegas valley, México. *Photo by Juan Miguel Artigas Azas*.

morph evolved from the papiliform morph. It has a deeper body and a greater pharyngeal mill supported by a strong and massive musculature. It has large molariform teeth which it uses to crush the shells of snails in the genus *Mexipyrgus* which are endemic in the area. It also has an intestine which is 25 to 50% of the length of that found in the papiliform morph (Kornfield, Smith, Gacnon & Taylor, 1982).

The third morph has a smaller distribution, limited to just a few springs in the tip of the San Marcos ridge (Poza la Becerra, Laguna del Mojarral, Poza Churince and some others). Its more striking difference is the shape of the body which is much more elongated, something that allows it to reach faster swimming speeds. This elongated shape helps the fish to obtain its main source of food - other fishes, mainly *Astyanax fasciatus*. This morph shows two types of dentition, papiliform and molariform. The length of its gut is much shorter and more like that of a carnivore than those of the papiliform morph.

Laboratory studies (Labounty, 1974) show that the morphological characters of these three morphs, specially the pharyngeal teeth, are not ecophenotypic (e.g., induced by the habitat). The dentition's shape is not lost under different feeding conditions, (e.g., feeding individuals with molariform teeth on soft foods). An ecophenotypic change of characters happens in other species of cichlids. For example, *Archocentrus labiatus* looses its enlarged lips when they are not used to scratch algae from the rough rocks in his habitat in Central-America. Also, *Herichthys carpintis* looses its sharp teeth when they are not used to cut algae from rocky surfaces).

The Problem

The problem in the classification of the Cuatro Cienegas cichlids emerged when the ichthyologists Kornfield & Koehn (1973) carried out genetic affinity studies on these forms and got fascinating results. Electrophoresis tests showed that the genetic variation among the morphs did not match what would have been expected among different species, but it was too small to guarantee speciation. However, surprised by the results, they concluded that possibly speciation in a very constant homogeneous environment, had taken place without producing enough genetic variation. They also concluded that the differences among the morphs were great enough to guarantee, in accordance with the established taxonomic standards, three different species. Nevertheless, they considered as a possible, but unlikely, hypothesis the results actually meant the three morphs were part of a single, polymorphic species, situation without any precedence.

After this, in 1975, Sage & Selander (1975), carried out more genetic and trophic (feeding behavior) studies, obtaining similar but more extensive results to those of Kornfield and Koehn. They concluded that the differentiation among the morphs had taken place through polymorphism and not speciation. They also found out that breeding pairs of these cichlids could be formed by individuals of different morphs and the fry that were produced could also be comprised of individuals of the two parental morphs. Kornfield, et al (1982) proved later, by means of genetic comparisons, that some of the fry being tended by the breeding pair did not belong to the pair (a common observation in Central American cichlids). It was also observed that males could simultaneously attend two spawning females of different morphs. Fry with intermediate characters of the parent's morphs were present in an insignificant percentage.

Another interesting observation by Kornfield was that of the group of analyzed pairs (39), the number

of pairs with mixed morphs was over fifty percent. That could correspond very well to random choice mating in accordance to statistical methods. But this could not be assured due to the small number of pairs involved in the sample.

Sage and Selander (1975) made another interesting suggestion - that the Cuatro Cienegas cichlid very probably had its ancestor in *Herichthys cyanoguttatus*. They based this observation in the results of their genetic studies. Kornfield and Koehn (1973) had found by then the genetic variation between these two species corresponded perfectly to that found for sister species. Sage and Selander suggested that an ancestral cichlid of generalized papiliform teeth, could have been trapped in the Cuatro Cienegas springs where an abundant fauna of snails remained unexploited.

These last considerations of Sage and Selander (1975) are well supported by field observations I have undertaken in the Ocampo valley, the upper part of the pluvial basin of the Cuatro Cienegas valley, and immediately north from it. The access to the Ocampo valley from Cuatro Cienegas is through a small canyon immediately north of the town. In the Ocampo valley there are some protected springs several kilometers west of the town of Ocampo inside a county park named "La Mota." These springs show characteristics that more closely resemble the Rio Salado, whose basin is found immediately east of the Cuatro Cienegas valley, and corresponds to the lower part of the ancient Cuatro Cienegas basin. In these springs in the Ocampo valley *Herichthys cyanoguttatus* is found together with *Astyanax fasciatus* and *Gambusia marshi*, species also part of the fauna of the Rio Salado basin. These last two species are also found in the Cuatro Cienegas valley springs, although in a different geographical form. Of course there is the slight possibility that these fish were artificially introduced. But the park administrator, who had lived his entire life in Ocampo, denied this possibility when questioned.

Ocampo valley, Cuatro Ciénegas, México. *Photo by Juan Miguel Artigas Azas*.

Herichthys cyanoguttatus female guarding fry, Ocampo valley, Cuatro Ciénegas, México. *Photo by Juan Miguel Artigas Azas*.

This could show that the Cuatro Cienegas cichlid ancestor was actually isolated only in the middle range, the Cuatro Cienegas valley, in an environment different enough from the Rio Salado basin to guarantee the evolution of the isolated population in a different direction than those in the Rio Salado. It has been suggested that the Cuatro Cienegas cichlid belongs to the group of species of *Parapetenia* (actually *Nandopsis*) (Kornfield & Taylor, 1983), mainly due to the cichlid maxillary teeth (in the jaw). In this regard it was suggested it could actually be more closely related to the cichlids inhabiting the upper Rio Pánuco, in the springs in the Rio Verde valley (*Herichthys labridens* and *Herichthys bartoni*) than with *Herichthys cyanoguttatus*. However, the breeding coloration pattern of the Cuatro Cienegas cichlid (a white base coloration with black blotches in the posterior half of the middle part of the flanks) corresponds to that of the *Herichthys* genus representatives of the *H.*

cyanoguttatus group, which is consistent with Kullander recent diagnosis of the genus (Kullander 1996). To this fact you could add the coloration pattern of the fry (with a black longitudinal line in the center of the flanks), which also corresponds to the pattern of the *H. cyanoguttatus* group of species.

The Solution

Kornfield and Taylor concluded with the scientific description of the Cuatro Cienegas cichlid as *Cichlasoma minckleyi*, considering it a polymorphic species and named it after the scientist that has spent the longest amount of time studying the fish fauna of the valley. They considered also that *Cichlasoma pavonaceum*, a cichlid described by Samuel Garman in 1881 with a type locality listed as a spring near the city of Monclova in Coahuila (in the area), was actually synonymous of *Herichthys cyanoguttatus* and not the Cuatro Cienegas cichlid.

The Environment

The environment where *Herichthys minckleyi* is found is very specific. It is formed by warm crystalline water springs with visibility generally greater than twenty meters (66 feet) and with very stable temperatures. Measurements made over a ten-year period in Laguna del Mojarral, showed a range from 33.5° to 34.0° C (92.3 to 93.2°F), a variation of just 0.5°C (0.9°F)(Arnold, 1972), with maximum variations at surface level of 5°C (9°F). The springs have a maximum depth (these days) of about five meters (15 feet) (Laguna del Mojarral, Poza de la Becerra) and have smaller surface areas. El Mojarral is about 30 x 70 m (98 x 230 feet), La Becerra is about 50 x 100m (164 x 328 feet), and Poza Churince is about 15 x 30m (49 x 98 feet). These dimensions are smaller that the original sizes because of the increasing amount of water being removed for human use. Aerial observation of Poza la Becerra from the mountains of the San Marcos ridge, shows that these water bodies have been reduced to probably 50% or more of the original size.

The springs in Cuatro Cienegas are in the middle of a desert landscape full of dessert vascular plants and short cacti and are surrounded by impressive bare rocky ridges. It has been recorded that the annual pluvial precipitation in the zone does not exceed 300 mm (12 inches). Precipitation is absorbed quickly by the porous calcareous soil of the valley.

The thermal springs have bottoms with dense detritus layers over a rocky substrate with areas of exposed rocks. Other springs have gypsum floors. Some calcareous rocks can also be observed along the shores. Plants of the genus *Nymphaea* (water lilies), with floating leaves and beautiful flowers, are the most abundant aquatic vegetation. Canes and weeds occur along the edges of some lagoons along with overhanging desert vegetation. Other aquatic plants without leaves can also be observed in some springs (e.g. Poza Churince).

The pH is on the alkaline side. Measurements taken by me during several visits have ranged from 7.6 to 7.8, with general hardness readings of around 55 German degrees.

The number of cichlids in each lagoon could be roughly estimated at about 1,000 adult individuals for the larger lagoons (e.g. Poza de la Becerra) and maybe half that number for the smaller ones.

Some other lagoons and Los Mezquites river, a river running exclusively inside the valley, have cool water and some of them around the San Marcos y Pinos ridge, hold populations of the detritivorous morph of *Herichthys minckleyi.* Strematolites, which are ancient rocks formed by countless generations of bacteria, are common in those water bodies.

Social Order and Feeding Techniques

Herichthys minckleyi is a cichlid with a coloration that, while not impacting, is quite attractive. Base coloration in non-breeding individuals has some variation from light gray or tan to greenish-yellow to dark green or gray. It has black body markings, although there is a lot of variation from individual to individual. Blue or yellowish spots are distributed

over the entire body and fins on most of the individuals. An adult specimen of the detritivorous morph with albino coloration (bright canary yellow and red eyes) was found by Gary Kratochvil in Poza de la Becerra in 1993 (Konings, 1994). In spite of efforts to safely ship this very attractive specimen to an aquarium for breeding and observation, it died during transport. I have observed some other oligomelanic specimens in the same lagoon after that occurrence, although with more black on the body.

The head shape of each of the morphs is very distinctive and allows their identification (fig. 2). In addition, the head of the moluscivorous morph is different from the other two morphs when seen from above or frontally because of the massive muscles that support a larger pharyngeal jaw that make it look significantly wider.

The detritivorous morph, and to a certain extent the moluscivorous morph, are gregarious fish. They can be observed in groups, sharing a large territory. I have observed territories generally close to the shores of the springs that were delimited by objects like the edge of the spring, a rock or a group of weeds. They could have a size up to approximately 3 meters (10 feet) square. These territories are inhabited by a large number of fish, most of which are ignored by the dominant male which is usually of the detritivorous morph. This dominant male can be told apart from the rest of the cichlids because it almost always shows a large nuchal hump on top of the head. Besides, it also shows dominant coloration; a darkening of the base coloration of the body to blue or very dark gray almost black, and blue spots on the flanks and fins with an iridescent shine. The males cyclically patrol the perimeter of their territory and then retire to the back part of it. There are a large number of fish in these territories, the majority of which are females cichlids or non-dominant males of the detritivorous morph. These fish fed on the surfaces of submerged *Nymphea sp*. leaves or rocks, the detritus, or under the overhanging vegetation.

Individuals or small groups of moluscivorous cichlids move close to the detritus bottom of the springs looking for their main food - snails, which they probably locate with their auditive system. There is an interesting aspect to these mollusk-feeding cichlids. Individuals that either alone or leading a small group of two or three cichlids are hunting for snails occasionally show a dark coloration that is velvety black, many times darker than dominant males. In this coloration the iridescent blue spots sparkle brightly. The moluscivorous cichlids move very close from the bottom where, from time to time, point their body almost perpendicular to the it, burying half their bodies into the substrate and taking a mouthful of detritus in their mouths. They manipulate the detritus in the mouth for a moment and release the smaller pieces through the gills. Small snails are crushed by the pharyngeal jaws and swallowed. The remaining crushed shells and larger particles are expelled by the mouth. This behavior is interesting because it is very similar to that of *Herichthys labridens* in the springs of the Rio Verde valley in the Pánuco basin, where they have the exact same coloration. Similarity of habitats between the Cuatro Cienegas and Rio Verde valley springs is surprising. What role this similar coloration plays, I do not have any idea.

Another interesting observation was made of the piscivorous morph. This morph feds individually and shows an unique behavior. When it hunts, its coloration turns into a camouflage pattern of dark brown, yellow, black and white. The fish then rests on the bottom of the springs among some rocks. The color pattern of the fish together with the pattern of the shadows created by the sunlight hitting the waves on the surface creates a perfect camouflage. The fish waitd for a small fish to pass close to its head. Most of the time I have observed the preferred prey as *Astyanax fasciatus*. The moment the prey fish comes close enough, the ambush hunter darts from the bottom trying to engulf the passing fish, with only occasional success.

It is interesting to point out the morphological differences among the morphs of Cuatro Cienegas de Carranza cichlids has been accompanied by a singular behavior pattern that allows them to make a better use of their specialization. Studies about the feeding behavior of *Herichthys minckleyi* (Sage and Selander 1975), show that the digestive system of most of the specimens examined contained just one type of food - detritus, snails or fish, depending on the morph. Nevertheless, some specimens showed two or even three types of food in their guts. More studies carried out by Liem & Kaufman (1985) showed that when food is abundant, the feeding specialization of the cichlids stops. That is, they eat anything available. It was also found in the laboratory that under food abundance, the moluscivorous form considers snails the least desirable food. This explains the fact that arthropods have been found in the gut of the three morphs. It also shows that when the opportunity arises, they don't let it go. It is just that when food is scarce, which happens most of the time considering the springs in Cuatro Cienegas are almost underwater deserts, that the morphs focus on

their specialty feeding pattern.

Other fishes besides cichlids are found in abundance in the territories of *Herichthys minckleyi*. Small territories of males of the endemic pupfish, *Cyprinodon bifasciatus*, are found on the bottom while females congregate in the vegetated zones. *Dionda episcopa, Cyprinella xanthicara* and *Astyanax mexicanus* schools are also commonly seen swimming through the habitat. Also, the water surface is often densely occupied by *Gambusia marshi*, mainly close to the shores.

Reproduction

The cichlids of Cuatro Cienegas, regardless of feeding morph, all protect territories for reproduction. A female courts the dominant male in a territory and both select a nest site. A wide cave is normally dug in the detritus under a rock until a solid surface is found upon which to place the eggs. Occasionally, the place chosen may be a vertical surface close to the edge of the spring. During breeding, the male darkens his dominant coloration to nearly velvety black. At this time the female undergoes an astonishing transformation. The coloration of her body and fins turn completely white with three to five black blotches on the posterior middle part of her flanks, as well as a black blotch at the base of her caudal fin. The female coloration is a beautifully striking contrast of black and white.

A breeding pair of *Herichthys minckleyi* in Poza de la Becerra, Cuatro Ciénegas valley, México. *Photo by Juan Miguel Artigas Azas*.

Herichthys minckleyi female guarding her spawn placed on the base of a calcareous rock uder the spring's overhanging vegetation, Poza La Becerra, Cuatro Ciénegas valley, México. *Photo by Juan Miguel Artigas Azas*.

Several hundred ovoid adhesive yellowish eggs with a maximum length of approximately 2 mm are laid on the previously cleaned surface. The eggs are deposited in rows by the female closely followed by the male fertilizing them. I have witnessed that in some cases and in contrast with most of the Central American cichlids I have observed, the eggs are placed in tight clusters sometimes overlapping each other. The guarding female removes infertile eggs with her mouth, and circulates clean water around the fertile eggs with her pectoral fins until they hatch. The eggs take two days to hatch under aquarium conditions and the wrigglers are then placed at the bottom of the spawning cave where they spend four or five more days. The male guards the breeding territory and can easily

attend two females with eggs since he stays with a female for only the first few days after the fry become free swimming. After that he abandons the female, a behavior unique among Central American cichlids.

The lone female stays close to her fry, herding them and signaling them with spasmodic movements of her fins. The female never leaves her fry for any reason. The fry apparently feed on detritus. Weeks later, when the fry have enough size (around 2 cm or 0.75 inches) to explore by themselves, they start to disobey their mother and eventually seek shelter in the shallow vegetated areas where they spend their juvenile life.

Herichthys minckleyi female taking care of her free swimming fry in Poza de la Becerra, Cuatro Ciénegas, México. *Photo by Juan Miguel Artigas Azas*.

Discussion

It has been suggested (Sage & Selander, 1975), that the Cuatro Cienegas cichlid could be in an early stage of speciation and that with the passage of time the morphs could start choosing more and more mates of their own morph until they develop completely into new species. In relation to this there could be a precedent. Two cichlid forms of the *Herichthys labridens* complex, *Herichthys.* aff. *labridens* "tamul" and *Herichthys steindachneri*, live in the Gallinas River in the Pánuco River basin which drains the Rascón valley in San Luis Potosí, Those species have apparently taken that course of evolution. Probably faced with an unexploited niche of a predator on the plentiful *Astyanax fasciatus* (the natural predator *Gobiomorus dormitor* is absent in that river), a piscivorous cichlid similar to the moluscivorous "tamul" *labridens* evolved in the middle part of the habitat - between the waterfalls in Tamasopo and the Tamul waterfall.

The piscivorous *Herichthys steindachneri* is however very scarce compared to its congener the "tamul" *labridens* and shows significant differences in body shape, maxillary and pharyngeal teeth and breeding coloration. Still to these days, some interbreeding takes place between the two species (though not common). It has also been observed by me and some other people (Ad Konings, 1992, with a photograph) that mixed pairs hybridize, and some intermediately shaped individuals are found in the river.

Assuming that in Rascón valley geological history this habitat was never separated, I would hypothesize that the piscivorous *Herichthys steindachneri* evolved along side *Herichthys* aff. "tamul" *labridens.* These two species first started separating trophically and later reproductively until today when hybridization occurs but is rare.

Conclusions

The Cuatro Cienegas valley is, without a doubt, a valuable asset of our world. Many more studies will have to take place to understand its flora, fauna and evolution and could yield surprising results to further test our accepted theories of its development.

Recently (November 1994), the Mexican government has decreed the valley as a "protected fauna and flora area," something that may not be enough to avoid the risks that face the ecology of the valley. It is probably just a matter of time that some well-meaning, but ill-informed, aquarist introduces some exotic species in the springs, which could have a disastrous effect on their ecology. These days there are reports of the introduction of the West African cichlid *Hemichromis bimaculatus* in Poza Churince, which was absent just a couple of years ago.

The lowering of the water table in the valley, as a result of over-exploitation of the water resources for human use, is also an imminent risk and has already caused important ecological effects. As the

water table drops, shallow water bodies and wetlands may dry out, endangering shallow-water fishes such as *Cyprinodon atrorus*, *Lucania interioris* and *Gambusia longispinnis.* Finally, the operation of a gypsum plant in the valley for many years was also a risk, although it has been closed for good by the federal Mexican government. For all this, this valley deserves our attention, compassion and protection. Nature and future generations will be grateful to us!

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