Nico & Taphorn 1984

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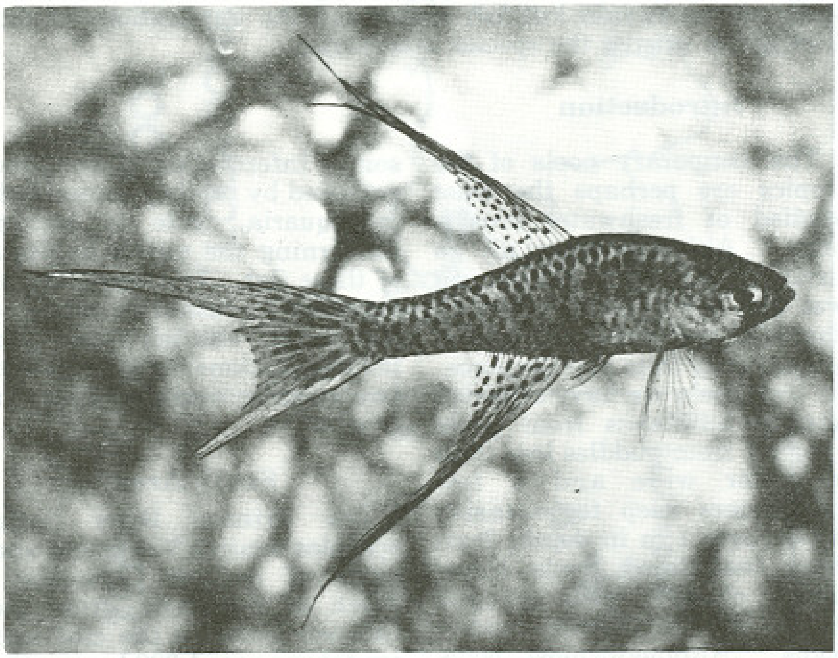
Limnology of Orinoco Basin Annual Killifish Pools

Technical Paper #24



T. dolichopterus Photo: A. Terceira

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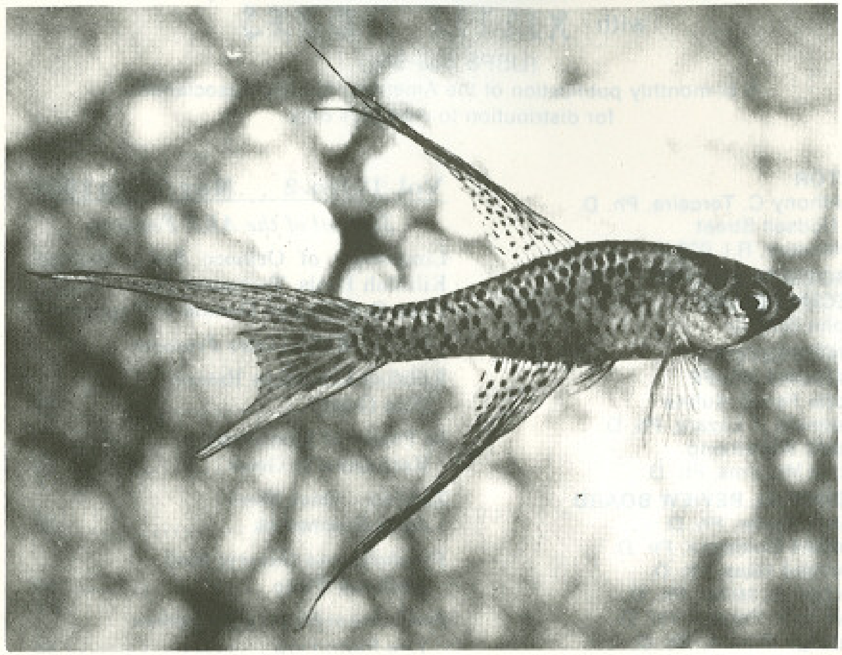

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Abstract

The limnology of four annual killifish pools were studied in the Orinoco River basin, Estado Portuguesa, Venezuela. Two of the temporary pools were in savannah and two were associated with forest. The physical, chemical and biological data are discussed in terms of the annual killifish fauna and the implications of the findings on raising the species in aquaria.

Introduction

The temporary pools of the tropics are perhaps the least studied of freshwater ecosystems. Although they all go through cycles of alternating wet and dry periods, physical, chemical and biological factors vary greatly from place to place. In Venezuela we have collected annual killifishes from pools ranging from puddles less than a meter wide and a few centimeters deep to extensive ponds over 1 m in depth; from clear tea-colored pools sometimes choked with aquatic vegetation, to barren muddy pools. Although most pools disappear during the dry season, ocasionally pools persist through to the following rainy season.

Six annual killifish species occur in the Venezuelan Orinoco River basin. All are thought to be endemic. The six species are *Austrofundulus transilis*, *Pterolebias hoignei* (known to aquarists as the "shady zonatus"). *P. zonatus* ("sunny zonatus"), *Rachovia maculipinnis*, *Rivulus stellifer* and *Terranatos dolichopterus* ("saber fin"). This paper, based in part on a thesis project (Nico, 1982), reports on the limnology of four temporary pools inhabited by killifish in Estado Portuguesa, Venezuela (Figure 1). Although some information has been gathered by raising annual fish in aquaria, little is known concerning the native habitats of these fish. The limnological data are discussed in terms of the annual killifish fauna and the implications the information has on maintaining the species in aquaria.

Study Area

The Orinoco River basin occupies central Venezuela and parts of eastern Columbia. Much of the basin, from the Orinoco Delta in the east and stretching over 1,000 km west to the Andes Mountains, consists of flat tropical savannah lowlands called llanos. Although most of the llanos are grasslands scattered with trees and wooded areas, in Portuguese large tracts of deciduous forest are present through the savannah. Regional climatic data (Aviles et al., 1983) from the Guanare airport (9°01′N, 69°44′W) over a 10 year period (1970-1979) are as follows: height above sea level 163 m, mean annual temperature 26.7°C, and mean annual precipitation 1544 mm. The rainy season, although somewhat variable, lasts some eight months, from April through November (Figure 2).

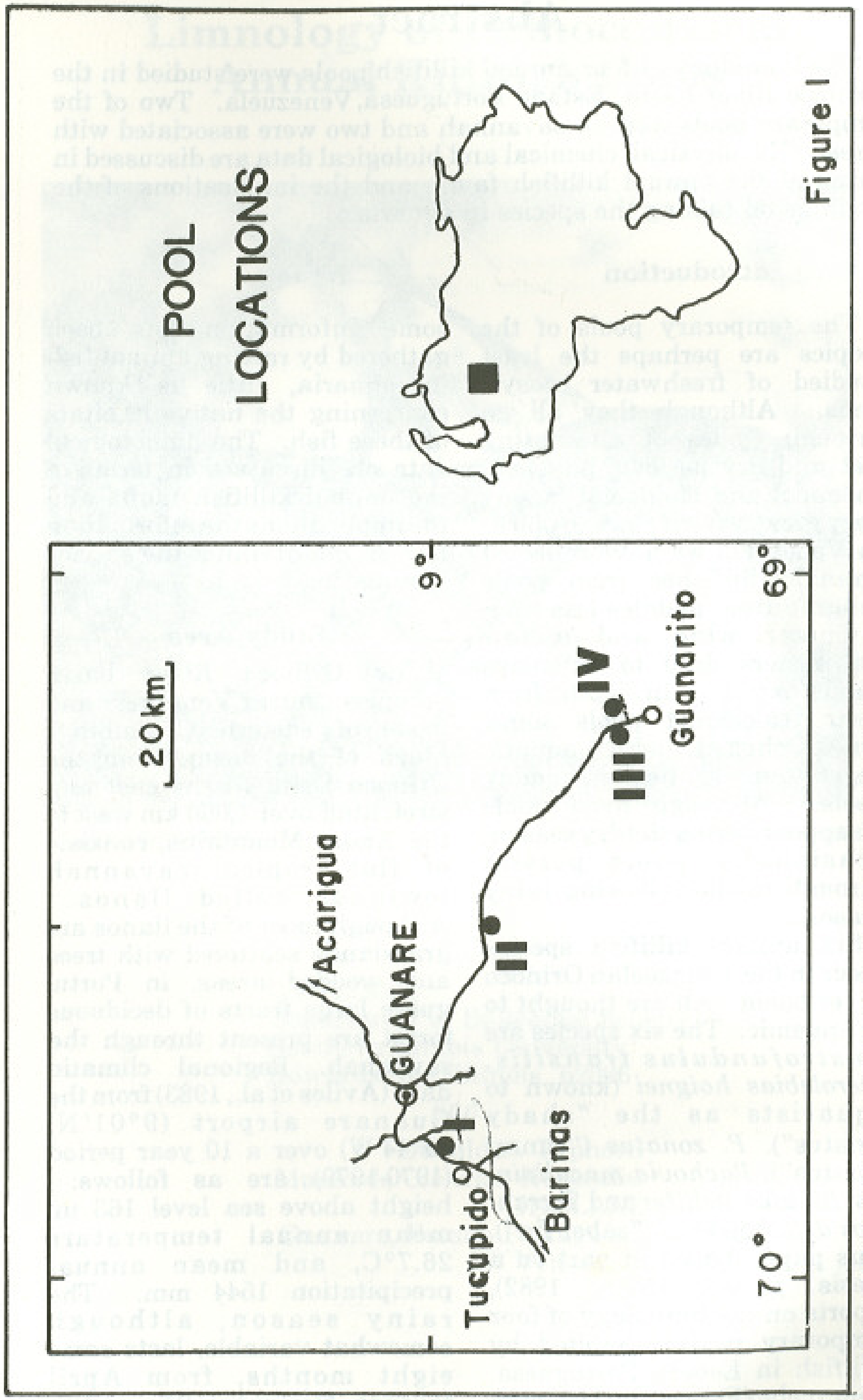


Figure 1. Locations of Pools I-IV, Estado Portuguesa, Venezuela.

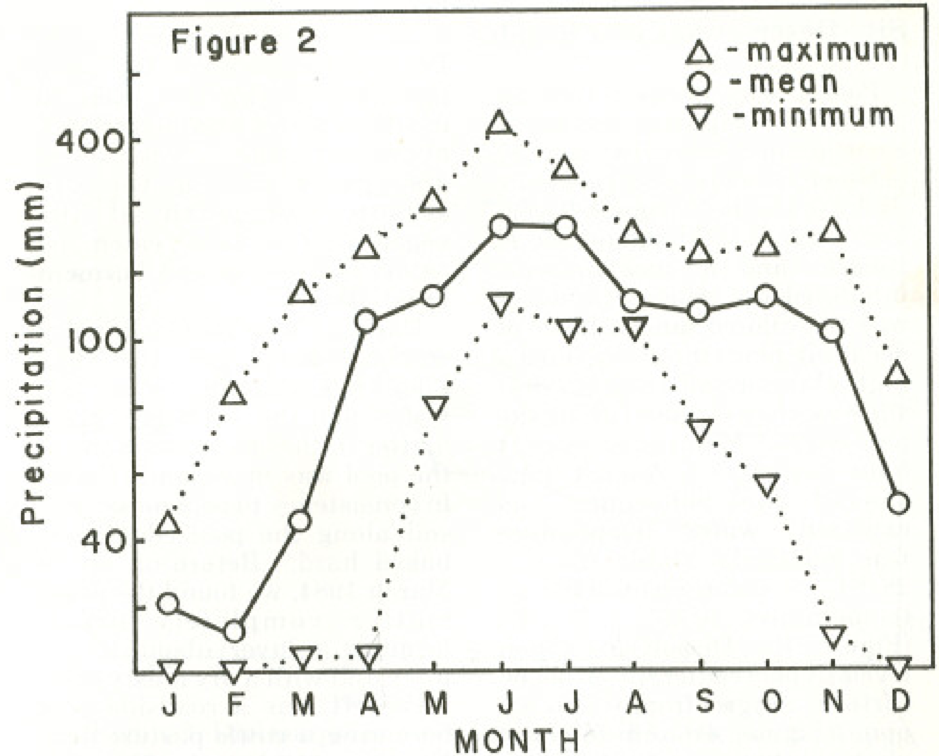


Figure 2. Monthly rainfall recorded at Guanare airport showing maximum, mean (average) and minimum values over a ten year period (1970-1979). Note changes in scale for precipitation (mm). Modified from Aviles, Ortega Mendoza and Corredor (1983).

Monthly Precipitation is usually well in excess of 150 mm and much of the llanos become inundated. During the dry season monthly rainfall is normally less than 30 mm and standing water usually becomes limited to large permanent lagoons, creeks and rivers.

Methods and Materials

In addition to a number of visits to all four temporary pools between 12 July and 30 August 1980, we made visits to one or more of the sites in the months of June and September 1979, May 1980, April and September 1981, and January and March 1984. Salinity and conductivity were taken with a YSI Model 33 S-C-T Meter, pH with a Wasser Kit colorimetric comparator, and temperature with a brass-cased thermometer. Other measurements were made with E. Merck test kits. Aquatic plants were collected from Pools I and II on 26 and 27 July 1980, respectively. Voucher specimens were deposited with the Herbario Universitario (PORT) of the Universidad Nacional Experimental de los Llanos Occidentales Ezequiel Zamora (UNELLEZ) in Guanare.

Site Descriptions and Results

Pool I was in open country alongside a highway bordering a cattle ranch near Hwy km 287 between Guanare and Tucupido. It drains to the Tucupido River. Two annual killifish species, *P. zonatus* and *R. maculipinnis*, inhabited the pool. The water was tea-colored, and a layer of decaying plant matter covered a high clay-content bottom. Soft silt was more common along the pool edges. Monitoring over 24 hour period, 3-4 August 1980 showed the following: as expected, water temperature was relatively stable (25.5° - 28.0°C) in comparison with air temperatures (23.5° - 31.7°C) (Figure 3). Dissolved oxygen levels at pool center, 10 cm below surface, ranged from 0.7 to 3.7 ppm (Figure 4) and followed photosynthetic activity (i.e., light availability). The pH was slightly acidic, ranging from 5.5 to 6.3. salinity was less then 1°/00, and conductivity varied from 30 to 50 umho/cm. Total hardness was 1.0°dH and dissolved CO^2 (carbonate) was 2.0°KH or °d.

During the latter half of the rainy season the pool was covered with emergent vegetation (Figures 5 and 6) dominated by arrowroot, *Thalia geniculata*. Other herbaceous plants included composites (*Eclipta alba*, *Spilanthes oppositifolia* and *Tridax procumbens*), sedges (*Cyperus* sp., *Eleocharis equisetoides* and *Scleria* sp.), a rush (*Limnocharis flava*), a grass (*Hymenachne amplexicaulis*), water-plantain (*Sagittaria guyanensis*) and others (*Bacopa salzmanni*, *Borreria ocimoides* and *Crotalaria* sp.). Peak dimensions of the pool, measured 30 July 1980, were 30 m x 15 m with a maximum depth about 40 cm. The water disappears during the dry season and much of the vegetation is then eaten by cattle, or dries up and burns in brush fires.

During the middle of the dry season, 15 January 1984, the Pool I site contained no surface water but the decaying plant matter in the central sections of the pool was moist and similar in consistency to peat moss. The soil along the pool edges was baked hard. Returning on 19 March 1984, we found the plant matter completely dried, forming a layer about 10 cm thick and with a dry musty odor.

Pool II was a roadside pool bordering a cattle pasture near Hwy km 29.9 between Guanare and Guanarito, Portuguesa. It was located in open land in an area characterized by mixed open land and forest. Three annual fish species, *A. transilis*, *P. zonatus* and *R. maculipinnis* were found. During the rainy season the temporary pool was choked with emergent, demersal and floating aquatic plants partially inundated shrubs and grasses. Plants included an aquatic fern (*Azolla* sp.), sedges (*Cyperus* sp. and *Fimbristylis* sp.), grasses (*Echinochloa colonum* and *Hymenachne amplexicaulis*), duckweeds (*Lemna perpusilla* and *Wolfiella welwitschii*), arrowroot (*Thalia geniculata*), platanillo (*Heliconia* sp.) and others (*Bacopa salzmanni*, *Borreria ocimoides*, *Caperomia paulustris*, *Ludwigia helminthorrliza*,

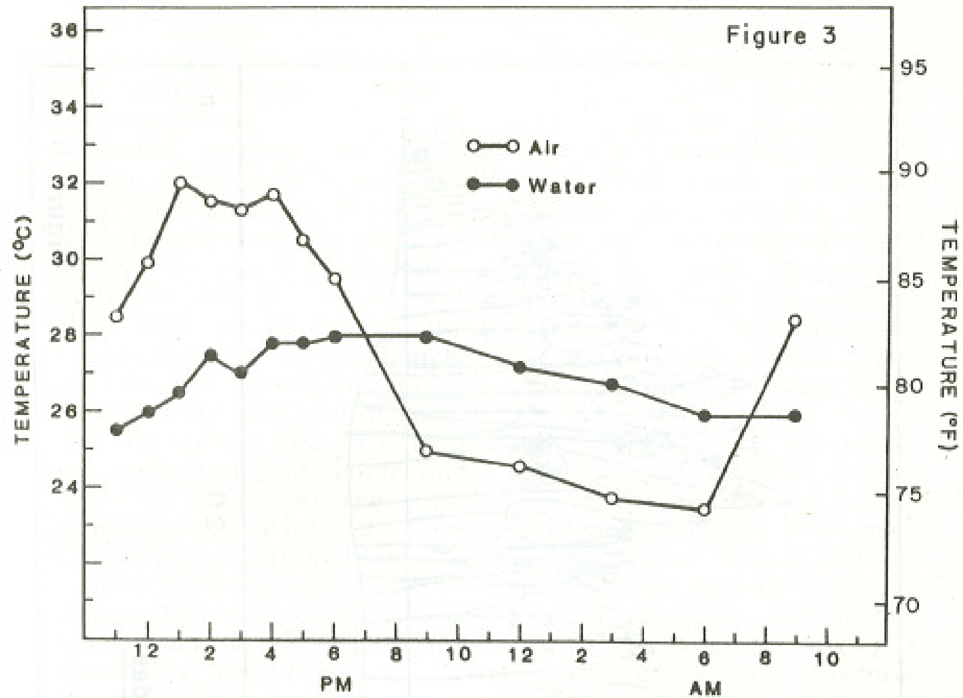


Figure 3. Diel temperature variation of Pool I, obtained 3-4 August 1980. Air temperature taken in shade at 2 m ht.

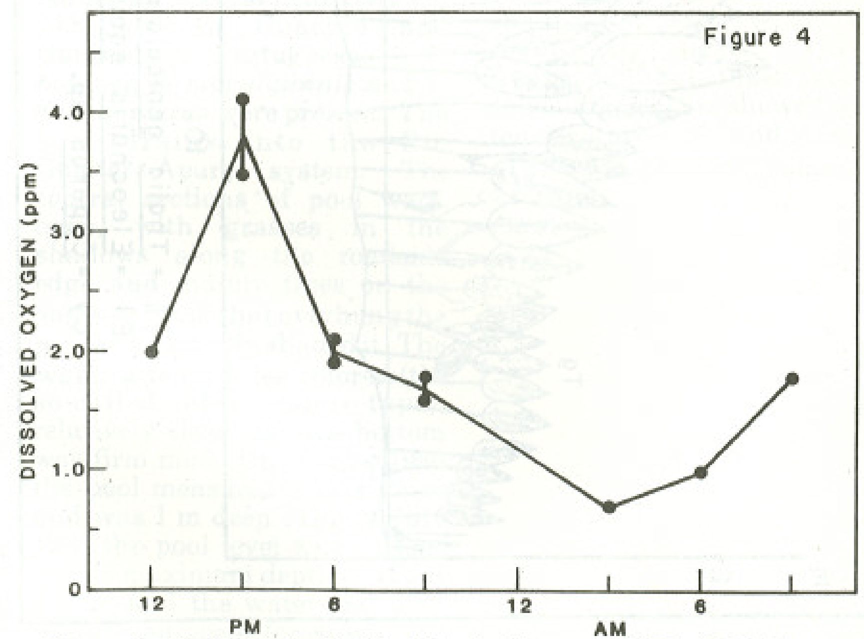


Figure 4. Daily variation in dissolved oxygen of Pool I, 3-4 August 1980.

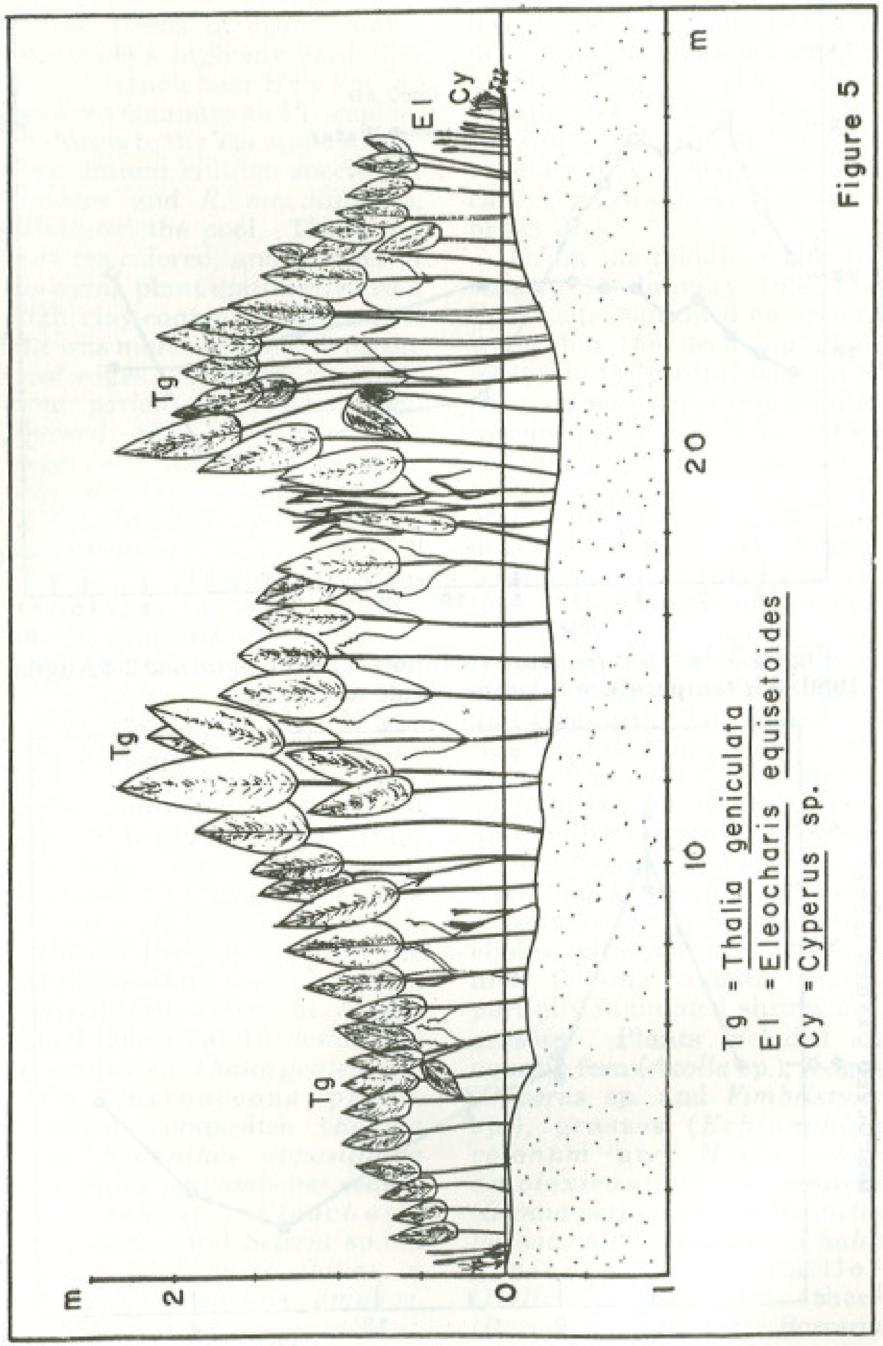


Figure 5. Cross Section of Pool I, 30 August 1980.

L. hyssopifolia, L. Octovalis, Neptunia prostata, Solanum sp. and *Spilanthes oppositifolia*).

Dimensions of Pool II, recorded during the rainy season visits in 1979 and 1980, were approximately 20 x 40 m; the central section was about 1.5 m deep, with a bottom of firm mud and detritus. Water was clear and tea-colored. Water temperature on 20 September 1979 ws 28°C at 1415 hr. At 1300 hr on 27 July 1980 readings were 25°C at bottom and 28°C near the surface at pool center, and 28.5°C near shore; air temperature was 32.5°C. Conductivity during the month ranged 38-55 umho/ho. On 27 August 1980 data taken at 1745 hr showed water temperature was 29.5°C and pH 5.

Pool III was a roadside temporary pond or ditch bordering a forest near Hwy km 74.8 between Guanare and Guarnarito, Portuguesa. *P. hoignei, R. maculipinnis* and *T. dolichopterus* were present. The pool drains into the Rio Guanare-Apure system. The central sections of pool were open, with grasses in the shallows along the roadside edge and mature trees on the opposite bank that overhung the pool and partially shaded it. The water was dark tea-colored (the so-called blackwater type), relatively clear, and the bottom was firm mud. On 24 May 1980 the pool measured 4 m x 25 m and was 1 m deep. On 19 July 1980 the pool level was higher, with a maximum depth of about 1.5 m, and the water extended into the adjacent forest without clearly defined borders. Data taken in July between 1400-1600 hours showed a water temperature of 27°-29°C, pH 6.5, and conductivity 190 umho/cm.

Pool IV was actually a mosaic of shallow small pools and puddles in deciduous forest stand and on a narrow dirt road within the forest. Its location was 0.4 km from the Guanare-Guanarito Hwy, approximately 2.1 km N of Guanarito bridge (Rio Guanare). It drains to the Rio Guanare. Three annual killifish species, *R. maculipinnis, R. stellifer* and *P. hoignei* occurred in the flooded forest. Maximum depth of these pools measured on 27 August 1980 was about 15 cm. Bottom types were mud in the road and organic debris comprising decaying leaves and branches in the fores.

Live ground cover was scant, but tree crown cover shaded most of the habitat. Some of the small pools were choked with filamentous algae. On 27 August 1980 data taken between 1100 and 1400 hrs showed water temperature of 27° and pH of 5.7.

Table 1 gives a brief summary of results.

Table 1. Summary of physical and chemical characteristics of four annual killifish pool, Estado Portuguesa, Venezuela.

Pool	I	II	III	IV
Habitat	savannah	savannah	forest	forest
Annual species	Pz, Rm	At,Rm,Pz	Rm,Ph,Td	Rm,Rs,Ph
Max depth (cm)	40 cm	150 cm	150 cm	15 cm
pH	5.5-6.5	5	5.3-6.5	5.7
Temp (°C)	25.5-28.0	28.0-29.5	27.0-29.0	27
Conductivit (umho/cm)	20-110	38-55	190	-
Dissolved oxygen (ppm)	0.7-3.7	-	-	-

a: At=*Austrofundulus transilis*; Ph=*Pterolebias hoignei*; Pz=*P. zonatus*; Rm=*Rachovia maculipinnis*; Rs=*Rivulus stellifer*; Td=*Terranatos dolichopterus*.
b: Only a single reading taken.

Discussion

The temporary pools inhabited by annual killifish in the llanos of Veneuela are typically shallow depressions that fill during the early rainy season in late April and May, normally reaching peak dimensions by July. Emergent plants often become so dense in savannah pools during the latter half of the rainy season that the water may be entirely hidden from view. Connections with other water bodies are common during the peak, and occasionally vast expanses of flat country are covered with a shallow layer of water after a particularly heavy rainfall. However, sheet flooding occurs more frequently in the low llanos of Estado Apure than the high llanos of Portuguesa.

With the onset of the dry season, loss of surface water and desiccation ultimately kill all fish that have survived to that time but have become stranded. However, rainfall pattern in the llanos can vary dramatically between nearby localities, even during the west season (Taphorn and Thomerson, 1975). Certain pools, such as the extremely shallow habitats of *Rivulus stellifer* (Thomerson and Turner, 1973; e.g., Pool IV), could dry up during the middle of the rainy season with just a slight drop in water level.

Because these annual species are adapted to a greatly fluctuating environment, they are able to survive under a variety of aquarium conditions. However, few of these fish kept in aquaria can match the brilliant colors characteristic of wild ones. One way to maintain annuals for extended periods in good condition and probably also enhance coloration is to provide a variety of live food. We found that *T. dolichopterus* accepts only live food; freshly hatched brine shrimp are readily taken. Another key may be trying to duplicate the natural water conditions. Since these species tend to be nervous in tanks, providing dense aquatic vegetation, as is common in nature, will permit fish to feel more at home and hopefully show better colors. *T. dolichopterus*, in particular, is extremely shy and nervous in aquaria. Their typical flight patter to excape consists of folding up their fins and diving into bottom debris. Thus, if a similar substrate is available in their tank they seem more secure.

Since temporary pools are typically shallow and show a greater variation in temperature than deeper permanent waters, temperature is probably not critical in aquaria for most species. However, our experience has shown that too much temperature variation is not good; the range recorded from Pool I may be a guide to follow. The pH of annual pools in the Orinoco basin is usally acidic, most likely because of rich organic content. The peat-like decaying vegetation often tints the water to a tea color. Thus, tank water should be slightly acidic and perhaps colored by pear installed in the filter. Dissolved oxygen levels often become low in temporary pools, but annual killifish probably survive the rainy season with little or no oxygen-stress. Aquatic surface respiration to meet oxygen demands in hypoxic waters is a strategy apparently used by many fishes (Lewis, 1970; Kramer and Mehegan, 1981; Kramer and McClure, 1982). Cyprinodonts are particularly well adapted to such behavior (see references above). *P. hoignei*, for example, is often seen in forest pools with its head in contact with the surface. Annual fish should have no problem surviving in the low dissolved oxygen concentrations recorded from Pool I in August 1980 (Kramer, pers. comm., 1982).

Some annual killifish species are adapted to very low light levels. In general, *R. stellifer*, *P. hoignei* and *T. dolichopterus* are not found in well-lit pools, and shading may be important in keeping them well in aquaria. *P. zonatus* and *A. transilis* are typical of sunlit pools. *R. maculipinnis* can be found in either situation.

Some fishes do not respond well to massive water changes, in these cases, cleanliness can be maintained by smaller, more frequent water changes of no

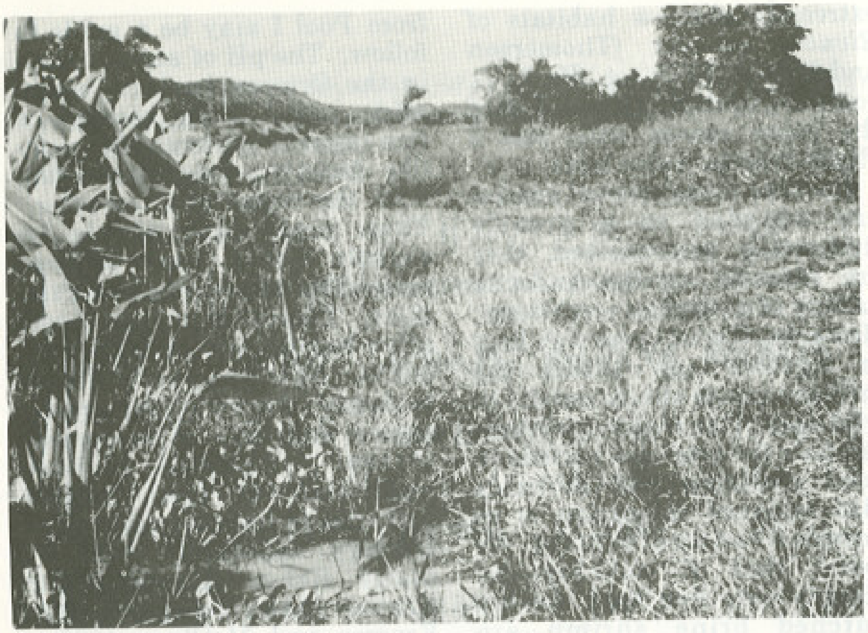


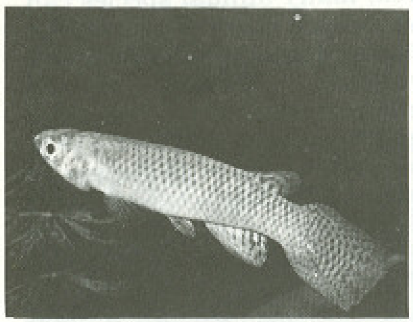
Figure 6. Photo of Pool I habitat during middle of rainy season, 30 August 1980, showing edge of pool.

Figure 7. Photo of Pool I habitat in early rainy season, 24 April 1981, showing Craig Lilyestrom collecting juvenile annual killifish with hand net.

Pterolebias zonatus Photo: A. Terceira

more than 5% of the toal water volume. Wild caught *T. dolichopterus* are the most delicate, and are more susceptible to changes in water than the other Orinoco basin species. Their normal habitat (i.e., deeper forest pools) is probably the most stable of temporary pool habitats. However, even *T. dolichopterus* can surprise you since we did collect one in an artificial savannah pond with rather muddly water and full of nonannual species including piranha. It was in apparently good condition, but considering the number of collections taken in the area (comprising some 58,000 fish specimens), *T. dolichopterus* was extremely rare.

The belief that annual fishes die shortly after spawning or have a life span roughtly equal to the rainy season or the life of their temporary pool habitat has been perpetuated from early publications on annual fishes (Haas, 1969). Although not long-lived, many annual species can live longer than a single wet season if water and food are available. Several of the Orinoco annual species raised in aquaria survive well over a year and even continue to spawn till near death (Nelson, 1980; J. Thomerson, pers. comm.; our observations). Liu and Walford (1969) reported survival of *Cynolebia bellottii,* an annual killifish of Argentina, for up to twenty-four months in males and thirty-three months in females at 23 + 2°C in the lab, and some *Cynolebias* sp. were found to survive into their second year in nature in Uruguay (Vaz-Ferreira, 1982). It has been reported that *T. dolichopterus* shows signs of "senility" by October (Weitzman and Wourms, 1967), but it may be that this actually reflects prolonged infections or starvation (Nico, 1982). Taphorn an Thomerson (1975) collected very large *P. hoignei* and T. *dolichopterus* in July, and concluded the pool had not gone dry during the previous seasonal drought and that the fishes were in their second year. None of the adult fishes from the late rainy season dissected by Nico (1982) showed signs of senescence, such as a reduction or marked loss of reproductive condition. Preserved annual killifish in the Museo de Ciencias Naturales at UNEL—LEZ thought to be more than a year old when collected include 10 *R. maculipinnis* males 56-60 mm standard length (SL), measured from tip of lower lip to base of tail fin, and 1 female 42 mm SL.



Rachovia maculipinnis
Photo: Terrceira

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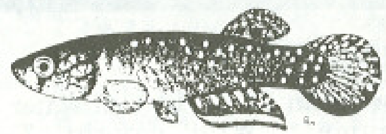


Rivulus stellifer

Literature Cited

Aviles, L. R., F. Ortega Mendoza, and G. A Corredor. 1983 Dinamica de las variaciones de la corbertura vagetal y la erosion en el piedmonte de Guannare. Vicerrect. Prod. Agric., UNEL-LEZ, Guanare, Venezuela.

Hass, R. 1969. Ethology and sexual selection the annual fish, *Nothobranchius guentheri*. Unpubl. Ph.D. thesis, University of California, Los Angeles.

Kramer, D. L., and M McClure. 1982. Aquatic surface respiration, a widespread adaptation to hypoxia in tropical fresh water fishes. Env. Biol. Fish. 7(1): 47-55.

Kramer, D. L., and J. P. Mehegan. 1981. Aquatic surface respiration, an adaptive response to hypoxia in the guppy *Poecilia reticulata* (Pisces, Poecilidae). Env. Biol Fish 6(¾): 299-313.

Lewis, W. M. Jr. 1970. Morphological adaptations of cyprinodontoids for inhabiting oxygen deficient waters. Copeia 1970 (2): 319-326.

Liu, R. K., and R. L. Walford. 1969. Laboratory studies on life-span, growth, aging, and pathology of the annual fish, *Cynolebias bellottii* Steindachner. Zoologica 54: 1-15.

Nelosn, B. 1980. *pterolebias zonatus*, a South American gem. J. Am. Killifish Assoc. 13 (6): 170-173.

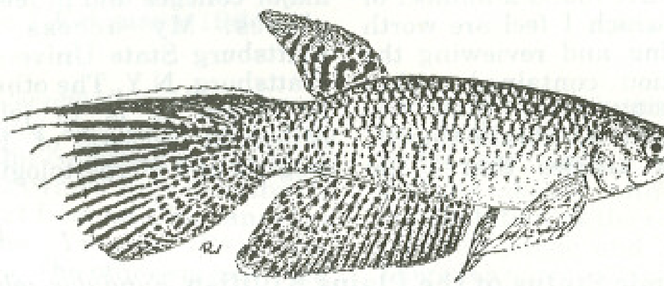
Nico, L. G. 1982. Life history and ecology of Orinoco basin annual killisish. Unpubl. MS thesis. Southern Illinois University, Edwardsville.

Taphorn, D. C., and J. E. Thomerson. 1975. Annual killifishes of the Orinoco basin of Venezuela. J. Am. Killifish Assoc. 9(3): 67-73.

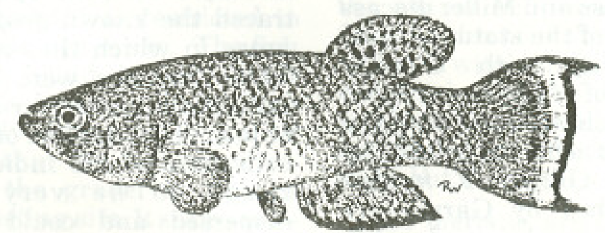
Thomerson, J. E., and B. J. Turner. 1973. *Rivulus stellifer*, a new species of annual killifish from the Orinoco basin of Venezuela. Copeia 1973 (4): 783-787.

Vaz-Ferreira, R. 1982. Some specializations for invasion and survival in tempral and permanent pools found in Cyprinodontiformes. American Society of Ichthyologists and Herpetologists 62nd Annual Meeting, Northern Illinois University. Program and Abstract.

Weitzman, S. H., and J. P. Wourms. 1967. South American cyprinodont fishes allied to *Cynolebias* with the description of a new species of *Austrofundulus* from Venezuela. Copeia 1967 (1): 89-100.



Pterolebias holgnei



Austrofundulus transilis