

Growth, feeding and reproduction of the catfish *Eremophilus mutisii* (Pisces: Trichomycteridae), from artificial reservoirs in Colombia

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Abstract. The catfish, *Eremophilus mutisii*, was cultured under different densities in artificial rainfall reservoirs at Caldas, Boyacá, Colombia. At capture, the average total length of the animals was 10 cm and the weight ranged between 9 and 10 g. These fish were in initial stages of sexual development. After a year in the reservoirs, they had increased in length and weight as follows (densities in parentheses): 5.22 cm and 27.23 g (0.5 individuals/m²); 1.98 cm and 8.79 g (1 individual/m²), and 2.45 cm and 0.82 g (2 individuals/m²). They were at the early stages of sexual maturity, and their condition factor fluctuated between 0.61 and 0.96. They preferably ingested insect larvae that were found in benthic and littoral communities of the reservoirs. The benthos was dominated by ephippia of *Daphnia*, lumbriculids, and chironomid larvae. The biomass of benthic organisms ranged between 0.1126 and 1.3847 g/m². In the littoral community aquatic insects were the most important component, especially the hemipterans. The biomass of the littoral fauna ranged between 0.14 and 4.05 g/m². Rev. Biol. Trop. 54(2): 589-597. Epub 2006 Jun 01.

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The catfish *Eremophilus mutisii* is an endemic species and the only catfish present in the Cundiboya highlands of Colombia. Both the catfish and the highlands have suffered considerable habitat disturbance. This fish represent an important source of vitamins and animal protein to supplement the diet of the rural population. The deterioration of natural populations of *E. mutisii* has been evident; in Fúquene Lagoon, for example, Mayorga (1992) not only observed a decrease in size but also the attainment of sexual maturity at small sizes. This suggests that the reproduction of individuals takes place at early stages, perhaps as a survival mechanism for facing adverse conditions (Mayorga 1992). The impairment of the catfish habitat is related to a decrease in quality and quantity of continental waters

due to pollution problems, loss of ground cover in the headwaters of rivers and streams, the improper use of water resources, etc. In addition to these problems, overfishing, the improper use of fishing methods and the absence of specific regulations can be added. This impairs the implementation of an adequate management of the species.

Realizing the importance of *E. mutisii*, researchers have become interested in studying different aspects of its biology and ecology (Amaya 1975, Beltrán 1992, Mayorga 1992) and also the possibility of its cultivation (Del Castillo and Garzón 1985). The first attempt to culture *E. mutisii* in small land-based reservoirs was made in the microbasin of the stream La Playa in Caldas, Boyacá, in which a preliminary study was conducted over a

one year period (Pinilla *et al.* 1998). From that investigation several observations have emerged, one of which suggested using these reservoirs (which principally function to store water for agricultural use) as places to culture the catfish. Some other studies have been conducted to attempted the culture of the species in cement reservoirs (Del Castillo and Garzón 1985, Rodríguez 1992). The current investigation was designed to determine whether culture density is a factor that affects the growth and gonadal development of individuals. The design included monitoring factors associated with the physiological well being of the fish and determining the feeding aspects of the species in this kind of aquatic ecosystem. No food supplement was added and it was assumed that the food supply offered by the reservoirs would be adequate for growth and development.

MATERIALS AND METHODS

Geographic area. The area of study corresponds to the high basin of the Suárez River, municipality of Caldas, Department of Boyacá, at 5°33'30" N and 73°1'40" W. The municipality is located between 2 550 and 3 200 masl and the mean temperatures varies between 12 and 13°C. The first rainy season is during April and May and the second is during September, October, and November; the annual mean precipitation ranges between 870 and 1000 mm (UJTL 1991).

Culture of fish. Native fishermen captured 1 551 specimens of *E. mutisii* in the Fúquene Lagoon (May-June 1995). The specimens were weighed (precision ± 0.1 g) and measured (precision ± 0.5 cm). The number of individuals placed in each reservoir depended on the surface area of the reservoirs: two individuals per square meter were placed in reservoirs one and two, one individual per square meter in reservoirs three and four, and $\frac{1}{2}$ individual per square meter in reservoirs five and six (Table 1).

Samplings. The first samplings were done between 30 June and 1 July 1995; the second between the fourth and sixth of August; the third between 21 and 23 September; and the fourth between 15 and 16 February 1996. In each sampling physical-chemical analyses of the water were performed and samples of littoral and benthic organisms were taken. We could not recover any specimens of *E. mutisii* from the reservoirs with any of various methods we tried. As a consequence, two additional samplings were made between 27 and 29 March and between 15 and 18 June 1996, just to capture the catfish. The depth and transparency of each reservoir was estimated with a Secchi disk; also were taken surface temperature, bottom temperature, surface oxygen, bottom oxygen, conductivity, dissolved solids, calcium hardness, magnesium hardness, total hardness, alkalinity, silicates, iron, ammonium, nitrates, nitrites, orthophosphates, sulfates, and chlorine. Water samples were preserved to determine

TABLE 1
Starting data for the E. mutisii experiment

	Reservoir 1	Reservoir 2	Reservoir 3	Reservoir 4	Reservoir 5	Reservoir 6
Date of culture	27 May 1995	27 May 1995	3 June 1995	3 June 1995	3 June 1995	3 June 1995
Density of culture (individual/m ²)	2.2	2.19	1.1	1.09	0.3	0.6
Number of cultured fishes	682	600	109	114	32	14
Weight average (g)	9.7	10.1	8.9	9.5	9.6	7.9
Length average (cm)	10.7	10.8	10.6	10.7	10.7	10.4

in the laboratory the total phosphorus and the biological oxygen demand (BOD) (APHA 1989). Littoral macroinvertebrates were collected using a one square meter net with 1 mm mesh. Superficial and submerged fauna of the littoral zone were collected with this net in areas where macrophytes were present; they were preserved with 10% formalin. Benthic community samples were taken in the center of each reservoir using an Eckman grab with an area of 0.19 m². The sediment was passed through a 500 µm sieve, organisms were collected in plastic bags, and they were preserved in 10% formalin. Aqueous 2.5% Rose Bengal was added to stain the organisms. Small traps were specially designed to capture catfish. They were made of 5 cm PVC tubes 40 cm long with a 1.6 mm mesh at one end and a cord to hold them on the other end. Also employed were fishing nets known in the area as “mochilos” which consisted of hoops with conical nets of 1 cm mesh and large wooden handles for maneuvering. Other fishing methods included use of 3 x 10 m nets positioned in the bottoms of the reservoirs and baited with earth worms, perforated plastic jars containing macerated river crabs as bait, and modified mochilos that were located at the outlets of the reservoirs. For the last two field trips, some reservoirs were drained to collect the fish from the muddy bottom. The collected specimens were injected with 10% formalin and were preserved in vials with the same solution.

Laboratory. Analysis of total phosphorus and biological oxygen demand (BOD) were made according to APHA guidelines (1989). The littoral and benthic organisms were put in petri dishes and identified using specialized keys (Pennak 1978, Roldán 1989). All the individuals were weighed (0.0001 g accuracy), and the data were converted to biomass per square meter for each reservoir. The preserved fish were weighed on a digital balance and measured with an ichthyometer graded in millimeters (total length and standard length). After that, a longitudinal incision was made in the ventral region of the fish and the

complete digestive tract from the esophagus to the anus was removed. The digestive tract was measured with a millimeter ruler; the stomach was separated from the esophagus and gut and was preserved in 10% formaldehyde. The gonads were removed and observed under the stereo microscope to determine their stage of maturity, according to Amaya (1975). Ovaries and testicles as well as eviscerated fish were weighed on a digital balance. In order to evaluate feeding behavior, the stomachs were weighed full and empty and their state of fullness was recorded. A longitudinal incision was made to extract the stomach contents, which were analyzed under a stereo microscope to quantify and identify the different items using keys by Roldán (1989) and Pennak (1978).

Mathematical analysis. Averages of the physical-chemical parameters of the water and of the different biological parameters of the fish, the littoral macroinvertebrates, and the zoobenthos were calculated. Intestinal coefficient and feeding indices (numeric, frequency and relative importance) were calculated with methods proposed by Prejs (1981) and the condition factor K, sex proportion and the gonadosomatic index (GSI in percentage) were calculated according to Nikolsky (1963).

RESULTS

The physical environment of the small reservoirs. The surface temperatures were slightly high, with a range between 15 and 22.5°C (18°C on average); on the bottom these values dropped to in 8°C. The transparency of the water fluctuated between 15 cm and 1.1 m. The pH of the reservoirs tended to neutrality with an average of 6.57 and a range of five to seven. Alkalinity registered 1.6 to 96.2 mg/l of CaCO₃; reservoirs five and six were characterized by their low alkalinity. Conductivity oscillated between 41 and 263 µS/cm. The highest conductivities were in reservoirs one and four and the lowest were in reservoirs five and six. Sulfates present in the reservoirs one

through four ranged between 10 and 60 mg/l of SO₄. The hardness was moderate, with exception of reservoirs five and six where was low. In summary, reservoirs one through four exhibited high mineralization, while reservoirs five and six exhibited low mineralization. Ammonia and nitrate levels were relatively high (0.32 to 1.52 mg/l and 0.2 to 2.0 mg/l, respectively). Orthophosphate levels ranged between 0.009 and 2.063 mg/l and the total phosphorous (as P) ranged between 0.024 and 0.178 mg/l. The presence of cattle can contribute, through excrement, to the enrichment of water. The BOD fluctuated between 16.50 and 73.20 mg/IO₂.

Initial conditions of the cultured catfish. The quantities of cultured fish from each reservoir and their average measurements are shown in Table 1. The total length was just over 10 cm and the weights averaged between 9 and 10 g. These specimens cannot be considered fry, but diminutive adults because they have largely completed their morphological development. The analysis of a group of fish collected from the cultured populations show that the majority exhibited early stages of gonadal maturity (state I), some had gonads in intermediate states of development (state R), and only one showed an advanced state of maturation (state M). This fish had gonadal indices ranged between 5.83 and 15.52, comparable with those reported by Mayorga (1992) of 6.9 and 13.2. This index becomes higher (20 to 30) as the animal approaches the spawning period. These data show that the cultured fish were in early stages of sexual development. Gastrointestinal tract analysis of *E. mutisii* came from Fúquene Lagoon, confirmed the carnivorous habit of the species (Amaya 1975), since it contained mainly mollusks and annelids and some arthropods (*Chironomus* spp. larvae).

Biological aspects of the cultured catfish in small reservoirs. Three samples of fish collected from three of the reservoirs are described. Five catfish were collected from reservoir two (2 individuals/m²), 40 catfish from reservoir four (1 individual/m²), and three

catfish from reservoir six (0.5 individuals/m²), for which morphometric and biological data are presented in Table 2. Collecting catfish from the small reservoirs proved to be very difficult; therefore, our analysis offers a comparative view of the cultured fish and the ones collected at the end of the experiment, as well as a descriptive view among the treatments (densities of culture). The average sizes and weights, both initial (at the moment of the culture) and final (one year later), are presented in Table 3. The greater results in growth and weight were recorded in reservoir six, where the average increase in length was 5.22 cm and in weight was 27.34 g, but it is necessary to remember that this results belong only to three fishes; the lower population densities (0.5 individuals/m²) were cultured in this reservoir. In reservoirs with higher population densities (2 and 1 individual/m², Table 1), the growth and increase in weight were only 2.45 cm and 0.82 g for the reservoir two and 1.98 cm and 8.79 g for reservoir four. At the reservoir four the growth

TABLE 2
Average of some morphometric and biological variables of E. mutisii after one year in the small reservoirs

Lake	Sex Proportions	Total length	Gonadal stage
2	3+ : 2-	11.56	4I : 1R
4	3+ : 1-	12.76	28R : 12M
6	2+ : 1-	15.43	3M

I: immature; R: in development; M: mature; + males; - females

TABLE 3
Average of the initial lengths and weights of E. mutisii after one year in the small reservoirs

Reservoir	Initial fishes		Cultured fishes	
	Length	Weight	Length	Weight
2	9.11	8.72	11.56	9.54
4	10.78	9.76	12.76	18.55
6	10.21	7.89	15.43	35.23

of the fish was less than that in the higher population density (reservoir two), but at the same time, they exhibited a greater increase in weight. Note, however, that specimens collected from reservoirs two and six were scarce and our results may be influenced by the size of the sample; for this reason, statistical analyses were not made.

The smallest K value took place in the reservoir two (0.61 average); for reservoir four the average value was 0.845, and the highest value occurred at reservoir six (0.96 average). As the culture density decreased, the condition factor increased but in all cases K values indicated well-fed fish. Of 48 individuals captured in the three reservoirs, 13 were females (F) and 35 were males (M) making the proportion of catfish 3.7M:1F. The states of maturity for *E. mutisii* cultured in small reservoirs are shown in Table 2: fifteen fish were found in a mature state (state three or M, according to Amaya 1975), 29 in a developing state (state two or R), and four in an immature state (state one or I). The fish, prior to the study, were already in an initial state of gonadal development. The GSI fluctuated between 3.3 and 7% on average and it is low if compared with the GSI of the sample of fish taken before being cultured, which averaged 8.68%. These data make suggest that, after the experiment, the animals were somewhat mature but not completely sexual developed.

The intestinal coefficient (ranged between 0.77 and 1.03) reflects the carnivorous habits of the *E. mutisii*, since values equal to or less than one are characteristic of zoophagous species (Chiriví and León 1982). The *E. mutisii* indices of feeding in the reservoirs four and six show a carnivorous habit too, since the stomach items were mainly insect larvae (Table 4). The numeric and frequency indices for the items found, as well as the index of relative importance, show that chironomids were the principal food for the three fishes captured in the reservoir six; hemipterans, odonatans, and lumbriculids were found as occasional food. The most important item for the 40 fishes captured in reservoir four was the odonatans with chironomids as secondary food. Virtually all of the stomachs analyzed had undigested contents at the time of capture; this suggests that *E. mutisii* feed not only during the day but also at night, since the captures made in the afternoon showed that the stomach contents were not digested.

Alimentary supply of reservoirs. Seventeen morphospecies of littoral macroinvertebrates were identified; these organisms were mollusks and arthropods. Hemipterans were the most abundant group. Species of *Buenoa* were present in all the reservoirs. In abundance it was followed by other hemipterans such as *Centrocorisa* spp., *Tenegobia* spp., and *Notonecta* spp. These species belong to the

TABLE 4
E. mutisii feeding indexes for reservoirs four and six

Feeding item	Numeric Index (%)		Frequency index (%)		Index of relative importance	
	Reservoir 4	Reservoir 6	Reservoir 4	Reservoir 6	Reservoir 4	Reservoir 6
Hemipterans	0.92	2.25	7.5	100	0.07	2.5
Chironomids	13.36	93.80	52.5	100	7.01	93.8
Odonats	79.50	1.69	92.5	66.6	73.54	1.1
Lumbriculids	0.23	2.26	2.5	100	0.06	2.3
Gordians	0.92	0	2.5	0	0.02	0
Coleopterans	5.07	0	12.5	0	0.63	0

families Corixidae and Notonectidae that are characterized as being excellent swimmers (Pennak 1978). The coleopterans were less abundant; they are typical from riverine areas and swim freely or are located in the vegetation. Species of *Androgyrus* (Gyrinidae) were the most abundant. Other groups that contributed low proportions to the total of collected organisms were odonats, dipterans, and mollusks from the genus *Lymnaea*. The biomass of the littoral organisms from all the reservoirs ranged between 0.1 g/m² and 4.0 g/m². *E. mutisii* apparently prefer chironomid and odonat larvae.

The major groups of zoobenthic community were arthropods, nematodes, and annelids. The arthropods included *Chironomus* spp. and *Pentaneura* spp. (Insecta), *Daphnia* spp. (represented by its cyst form known as ephippium; Cladocera), and *Cypris* spp. (Ostracoda). The nematodes belonged to the species *Nygolaimus* and the annelids to a morphospecies of the family Lumbriculidae. The most numerous species was *Daphnia* in its ephippium stage. The ephippium of this primary consumer corresponds to resistant structures produced by the organism when it faces stress situations. High numbers were found on the sediments of the reservoirs, which indicate that adverse conditions for this species exist in the reservoirs. The oligochaete family was the second most abundant, followed by chironomid larvae, especially in reservoirs five and six. These dipterans, as well as the littoral odonats, were the preferred preys for *E. mutisii*. The nematode *Nygolaimus* sp. was found only in reservoirs one and two and, although abundant, its frequency was irregular. The biomass of the benthic community ranged between 0.1 and 1.3 g/m².

DISCUSSION

The majority of the reservoirs showed hypoxic or anoxic conditions in the bottom waters. Arteaga (1999) and Pinilla and Guillot (1999) demonstrated the formation of thermoclines and oxicles in these aquatic

environments, in spite of their scant depths (2 to 3 m). The low transparency is associated with the composition of the ground and depends on its time of construction; in general, the most recently constructed reservoirs are more turbid because they have more clay along their bottoms. Alkalinity for some of the reservoirs was high, even though it was within the values reported for neotropical waters (less than 100 mg/l, Esteves 1988, Roldán 1992). Conductivity was high compared to ranges reported for some neotropical systems such as the Amazonian black rivers (10 µS/cm, Payne 1986) or the high Andean environments (3.2 to 35.0 µS/cm, Gaviria 1993). Nitrite was undetectable indicating normal oxidative processes from the ammonia to nitrate were occurring in these reservoirs; low nitrite suggests a stable aquatic ecosystem (Margalef 1983). Orthophosphate was high compared with the ranges for Amazonian waters and high mountain regions with 0.001 to 0.020 mg/l (Roldán 1992) and follow, just as nitrogen, the fertilization processes of agrochemicals in the zones surrounding the reservoirs. The pH and calcium magnesium values are found within the expected values for the Andean regional waters (Roldán 1992); all the physical-chemical parameters agree with the investigations carried out in the region by Fernández and Pinilla (1996), Páramo and Pinilla (1996), Pinilla *et al.* (1998), Arteaga (1999) and Pinilla and Guillot (1999). *E. mutisii* tolerates the conditions of these small reservoirs and it does not seem to alter the physical-chemical characteristics of the water.

The fish condition factors in the reservoirs are similar to those reported by Mayorga (1992) for the Fúquene Lagoon. Amaya (1975) found excessive feeding among the catfish with monthly variations. However, is necessary to keep in mind that K formula is based in spherical fishes, while *E. mutisii* trends to be elongated. This is the reason that a high condition factor in this fish could be influenced by length with respect to weight in comparison to other species. The sizes and states of maturity reported here are similar to those found by Mayorga

(1992) for *E. mutisii* of Fúquene Lagoon. Amaya (1975), however, found maturing specimens larger than 17.7 cm in length and mature fish longer than 20.5 cm. According to some authors (Amaya 1975, Cala and Sarmiento 1982, Cala 1986, Beltrán 1992), *E. mutisii* first reach sexual maturity between 14 and 20 cm of total length. Mayorga (1992) found that this size is reduced to 9 cm for fish in the Fúquene Lagoon, the place from which the cultured fish in the reservoirs were collected. Apparently the individuals coming from the Fúquene Lagoon tend to grow faster than the ones coming from other places. In relation with the sex distribution, in Fúquene Lagoon the proportion reported by Mayorga (1992) was 1.26M:1F and, in the Neusa Dam, Beltrán (1992) found 3M:1F. Only Amaya (1975) reported a proportion of 1:1 for the Tota Lagoon; our data are looked like those of the first authors, although they can be affected by the small size sample.

The development of the gonads after a year of experimentation indicates that the fish were maturing sexually but not completely. Even though the majority of the fish at the end of the experiment appear to reach some grade of maturity, *E. mutisii* populations confined in the small reservoirs were unable to spawn. According to Beltrán (1992), for some dams of the Cundiboyacense highlands, the water level must rise in order for the fish to spawn. Our data suggest that water in the rainfall reservoirs does not reach sufficient levels for *E. mutisii* to spawn. Apparently *E. mutisii* is not exposed in the small reservoirs to the environmental mechanism that triggers maturation of its gonads, or the food source was insufficient for normal reproductive development and, on the contrary, was channeled into an increase of the body weight and into the maintenance of other vital processes. Fries would be needed to repopulate reservoirs periodically or to develop hormonal methods for obtains the reproduction of *E. mutisii* under these conditions.

The stomach contents observed for the catfish in small reservoirs have some differences with those found by Mayorga (1992) in the Fúquene Lagoon, which can be attributed

to the fact that in the small reservoirs the composition of the benthic and littoral communities is different. The maturity and antiquity of the lagoonal system of the Fúquene, in contrast to the immaturity and recent creation of the rainfall reservoirs, may be responsible for these differences. The reservoirs had a small number of benthic and littoral macroinvertebrate species with reservoir one showing the greatest variety, possibly for being the oldest. The biomass of the littoral and especially of the benthic organisms is relatively low. These data show the ecological simplicity of the small aquatic ecosystems studied. Nevertheless, the found taxonomic groups in the content of stomach of catfish, such as larvae of insect and oligochaetes, reflect the utilization of reservoirs food provision.

Increases in length and weight of the catfish did not achieve commercial size in reservoirs one through four, while catfish did achieve commercial size in the lower population density (0.5 individuals/m²) of reservoirs five and six. A higher population density would lead to greater competition for food resources; our data suggest that there isn't abundant availability of food in the reservoirs. Moreover, *E. mutisii* exhibits certain selectivity for particular species; this preference detracts from the amount of food available for the catfish and may explain the increase of interspecific competition for food as the population density of the culture is increased. These observations, suggest the necessity of establishing a supplementary diet to improve the growth and fattening of the fish under high densities. Apparently competition for space is other important phenomenon that influences the development of *E. mutisii* in this type of reservoir. It is known that this species is very territorial and that it requires refuges to avoid the competition for space (Del Castillo and Garzón 1985). In the artificial reservoirs these natural refuges are scarce.

The catfish *E. mutisii* are hard to capture in the small, artificial reservoirs. Benthic fishes like *E. mutisii* are located in the "deep or benthic zone, above or within the substrate"

(Lagler 1975). Its benthic habit apparently precluded the periodic capture of specimens raised in the small reservoirs, even though several different techniques were used to recapture them. The traps utilized had been used successfully in previous research (Pinilla *et al.* 1998), but in the present investigation they were not effective. The other technique (mochilo) was the more efficient tool for recapturing fish in the investigation developed by Mayorga (1992); however Mayorga used the mochilos at night and under floating vegetation. In the small reservoirs fishing occurred during the day and there is no surface vegetation except that which is rooted in the littoral zone. Other methods used (nets baited with earthworms, perforated containers with freshwater crabs as bait, and nets at the outlets of the reservoirs) were not effective. The only way to recover the fish was to drain the reservoirs. In the future other different methods for capturing the catfish should be investigated. One alternative could be an annual drying of the reservoirs to collect the fish, programming this activity to the beginning of the rainy season so the reservoirs would recover rapidly.

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RESUMEN

El "capitán de la sabana", *Eremophilus mutisii* (Humboldt, 1805), fue cultivado en diferentes densidades

en pequeños lagos artificiales localizados en Caldas, Boyacá, Colombia. Al inicio, el promedio de la longitud corporal fue 10 cm y el peso osciló entre 9 y 10 gr. Los peces se encontraban en estados iniciales de desarrollo sexual. Luego de un año de experimentación, los peces cultivados a una densidad de 0.5 ind/m² incrementaron 5.22 cm en longitud y 27.23 gr en promedio (1 ind/m²: 1.98 cm y 8.79 gr; 2 ind/m²: 2.45 cm y 0.82 gr). Los peces se encontraban iniciando su madurez sexual, y su factor de condición fluctuó entre 0.61 y 0.96 y consumían principalmente larvas de insectos. El bentos estaba dominado por efípios de *Daphnia*, lumbricúlidos y larvas de quironómidos. La biomasa de organismos benticos osciló entre 0.1126 y 1.3847 gr/m². En la comunidad litoral, los insectos acuáticos fueron los componentes más importantes, especialmente los hemipteros. La biomasa de la fauna litoral osciló entre 0.14 y 4.05 gr/m².

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