

Primary Research Paper

Description of a new species from Laguna Chichancanab, Yucatan, Mexico: *Cyprinodon suaviium* (Pisces: Cyprinodontidae)

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Abstract

Cyprinodon suaviium is a new species that belongs to the endemic species flock from Laguna Chichancanab, Yucatan, Mexico, which is proposed to have evolved by sympatric speciation in the lake during the last 8000 years. *C. suaviium* is distinguished from all other known *Cyprinodon* species by a flattened and concave inter- and postorbital skull roof and a terminal mouth with distinctive thickened lips. The short gut length and dietary items found in the gut indicate that *C. suaviium* is one of the carnivorous members of the flock.

Introduction

Intralacustrine speciation of fishes resulting in flocks of different species is a phenomenon which can be observed in a series of lakes on earth. The most impressive example is the explosive radiation of the cichlids of the African Great Lakes. An example of lesser complexity is found in Laguna Chichancanab, Yucatan, Mexico, in which an endemic species flock of *Cyprinodon* has evolved. The lake is small in size (20 km long and max. 600 m wide) and consists of a series of water bodies which are periodically connected by swampy inundation zones (Fig. 1).

The most abundant species, *Cyprinodon beltrani* (Alvarez, 1949), is morphologically very similar to the coastal-dwelling Yucatan pupfish, *Cyprinodon artifrons* (Hubbs, 1936), the sister species of the Laguna Chichancanab pupfishes. The other five species differ in body shape and head morphology. *Cyprinodon labiosus* (Humphries & Miller, 1981) has fleshy lips and an elongate body. *Cyprinodon simus* (Humphries & Miller, 1981) is the smallest member of the flock with a vertical lower jaw and larger eye size. The

largest species, more than twice the size of other members of the flock is *C. maya* (Humphries & Miller, 1981). *Cyprinodon esconditus* (Strecker, 2002) is similar to *C. maya* in head shape, but is significantly smaller in standard length with a slender body. *Cyprinodon verecundus* (Humphries, 1984) shows a greater body depth and broader pectoral fins than other members of the flock. Based on molecular data it was proposed that the species flock evolved about 8000 years bp (Strecker et al., 1996), which corresponds to a desiccation phase of the lake at that time (Covich & Stuiver, 1974).

Besides the morphologically clearly distinct species, the flock contains other specimens which cannot be assigned unequivocally to one of the species mentioned above (Humphries & Miller, 1981; Strecker, 1996). However, it is unclear whether the latter individuals are hybrids, yet unidentified species, or are examples of morphological plasticity within species (Strecker et al., 1996). These forms occur in a high frequency and comprise the second largest group after *C. beltrani* (Strecker, submitted). Here, I describe a new species that was discovered among these specimens.

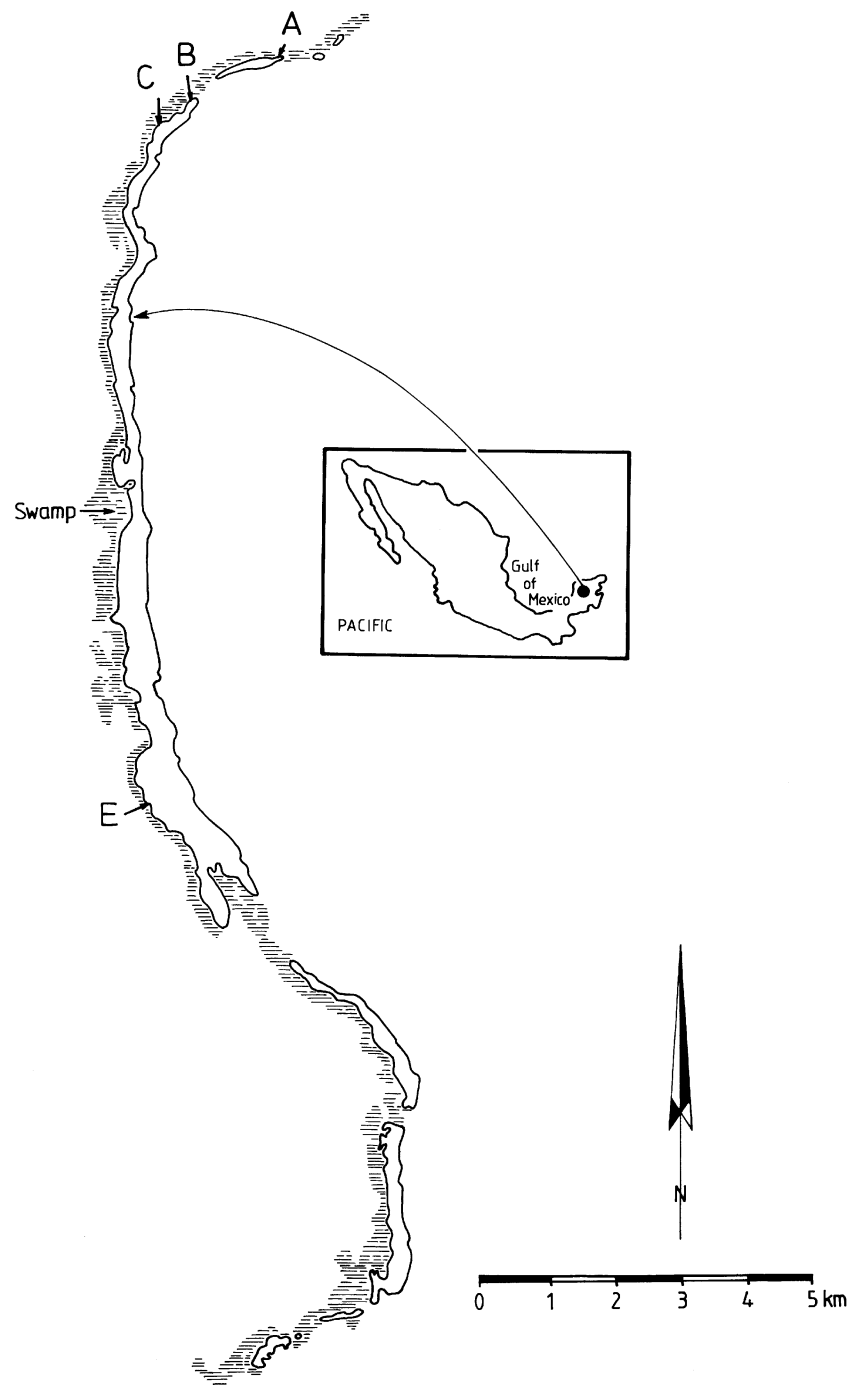


Figure 1. Sampling sites of *C. suavius* in Laguna Chichancanab, Yucatan, Mexico. (A) $19^{\circ}57' 18''$ N $88^{\circ}44' 52''$ W, northern end of north pond. (B) $19^{\circ}56' 56''$ N $88^{\circ}45' 35''$ W, northern end. (C) $19^{\circ}56' 46''$ N $88^{\circ}45' 52''$ W, dead end of road from Rancho Santa Cruz. (E) $19^{\circ}51' 10''$ N $88^{\circ}45' 58''$ W, southern end at broadest part.

Materials and methods

The material examined is deposited in the Ichthyological Collections of the Zoological Museum of the University of Hamburg (ZMH), Instituto de Biología, Universidad Autónoma de México (IBUNAM), and Colección de Peces, El Colegio de la Frontera Sur, Unidad Chetumal (ECO-CH).

Counts and measurements (in thousands of standard length (SL)) follow Miller (1948) and Humphries & Miller (1981).

For a multivariate approach a canonical discriminant function (= discriminant coordinates) was performed (Seber, 1984) using SPSS (version 10.0). The analyses included 8 males and 8 females from each of 3 species (*C. beltrani*, *C. labiosus* and *C. verecundus*), and 25 males and 15 females of *C. esconditus* (for details see Strecker, 2002). These four species are morphologically most similar to the new species. All species were determined based on morphological characters.

Premaxillary teeth were counted in two cleared and stained specimens; values indicate left and right side for the upper and lower jaw. In one specimen, scanning electron micrographs of the pharyngeal teeth were taken. Sagittal paraffin sections (10 μ m) were made from the head of *C. beltrani*, *C. labiosus* and *C. suavium* and dyed after the Pasini method (Romeis, 1948). For counts not included in Table 1 the values for the holotype are indicated in bold type.

Collection sites are shown in Fig. 1. The description of body color was made on freshly caught specimens.

Description

Holotype. IBUNAM-P13985, adult female 28.8 mm SL, from dead end of road from Rancho Santa Cruz 19°56'46s N 88°45'52s W, Yucatan Peninsula, Quintana Roo, Mexico; collected by U. Strecker and H. Wilkens, leg. 8.XI.2000.

Paratypes. Laguna Chichancanab, Yucatan, Mexico; for sampling site abbreviations (C and E) see Fig. 1. All specimens were collected by U. Strecker and H. Wilkens. ZMH 24811, female, 30.6 mm, (C.), 8. Nov. 2000; ZMH 24812, female, 35.1 mm,

(E.), 8. Nov. 2000; ZMH 24813, female, 27.6 mm, (C.), 8. Nov. 2000; ZMH 24814, female, 29.4 mm, (C.), 8. Nov. 2000; ZMH 24815, female, 39.0 mm, (C.), 8. Nov. 2000; ZMH 24816, female, 28.7 mm, (C.), 8. Nov. 2000; ZMH 24817, female, 27.9 mm, (C.), 8. Nov. 2000; ZMH 24818, female, 25.3 mm, (C.), 8. Nov. 2000; ZMH 24819, female, 45.5 mm, (C.), 8. Nov. 2000; ZMH 24820, female, 28.6 mm, (C.), 8. Nov. 2000; ZMH 24821, female, 27.7 mm, (C.), 8. Nov. 2000; ZMH 24822, female, 24.0 mm, (E.), 9. Nov. 2000; ZMH 24823, female, 26.0 mm, (C.), 8. Nov. 2000; ZMH 24824, female, 20.4 mm, (C.), 8. Nov. 2000; ZMH 24825, female, 34.4 mm, (E.), 9. Nov. 2000; ZMH 24826, female, 37.3 mm, (E.), 9. Nov. 2000; ZMH 24827, female, 40.9 mm, (E.), 9. Nov. 2000; ZMH 24828, female, 40.0 mm, (E.), 7. Dec. 1993; ZMH 24829, female, 32.8 mm, (E.), 7. Dec. 1993; ZMH 24830, female, 36.5 mm, (C.), 7. July 1991; ZMH 24831, female, 42.3 mm, (C.), 21. Dec. 1992; ZMH 24832, male, 29.7 mm, (C.), 8. Nov. 2000; ZMH 24833, male, 29.0 mm, (C.), 8. Nov. 2000; ZMH 24834, male, 24.6 mm, (E.), 9. Nov. 2000; ZMH 24835, male, 29.7 mm, (C.), 8. Nov. 2000; ZMH 24836, male, 30.4 mm, (C.), 8. Nov. 2000; ZMH 24837, male, 28.0 mm, (C.), 8. Nov. 2000; ZMH 24838, male, 40.2 mm, (E.), 9. Nov. 2000; ZMH 24839, male, 37.1 mm, (E.), 9. Nov. 2000; ZMH 24840, male, 25.8 mm, (C.), 8. Nov. 2000; ZMH 24841, male, 23.8 mm, (C.), 8. Nov. 2000. ECO-CH 5404, female, 28.7 mm, (C.), 8. Nov. 2000; ECO-CH 5405, male, 24.6 mm, (E.), 9. Nov. 2000.

Diagnosis. The species belongs to the endemic species flock of Laguna Chichancanab, which is closely related to *C. artifrons*. It is distinguished from all other known *Cyprinodon* species by a distinctive flattened and concave inter- and postorbital skull roof and thickened lips, with a terminal mouth opening. These characteristics are common to both sexes (Figs. 2 and 3). Compared to the usual lip development, e.g. in *C. beltrani*, the lips in *C. suavium* are protruding by a stronger development of the underlying cutis connective tissue in the lip region (Fig. 4). In *C. labiosus* lip enlargement is mainly due to proliferation of the epidermis. Furthermore, in *C. labiosus*, the mouth opening is superior whereas in *C. suavium* it is terminal.

Table 1. Proportional measurements of *Cyprinodon suavium* from Laguna Chichancanab for 22 females and 10 males, expressed as thousandths of SL (except SL in mm)

	Holotype	Females		Males	
		Range	Mean	Range	Mean
Standard length	28.8	20.4–45.5	32.2	23.8–40.2	29.8
Head length	292	272–350	309	263–345	298
Head width	218	203–264	233	207–256	222
Head depth	221	203–278	237	202–280	230
Postorbital length	116	104–143	124	99–140	114
Interorbital width	94	83–118	102	91–114	99
Snout length	86	65–93	78	57–101	78
Orbit length	93	88–111	98	72–105	96
Upper-jaw length	86	72–122	90	74–103	87
Mouth width	67	59–98	79	62–90	71
Predorsal length	543	512–595	557	531–590	553
Postdorsal length	524	462–529	495	477–545	506
Prepelvic length	554	506–573	525	481–580	525
Body depth	356	307–369	346	333–391	369
Caudal peduncle depth	144	134–168	149	145–173	158
Caudal peduncle length	320	254–310	283	276–331	293
Dorsal-fin length	281	243–327	270	251–333	284
Anal-fin length	232	181–241	217	221–278	249
Pectoral-fin length	243	209–270	247	238–269	254
Pelvic-fin length	120	104–135	119	109–138	126
Dorsal-fin base	182	155–186	171	151–186	171
Anal-fin base	104	98–124	108	100–121	111

As is typical for pupfish, most of the meristic and morphometric characters overlap. The new species can be discriminated from the other members of the flock by the following unique combination of characters. The head length is shorter than that of most other members of the flock (29.8% and 30.9% of SL in males and females, respectively, vs. 33.7% in *C. labiosus*, 35.6% in *C. maya*, 33.8% in *C. verecundus*), similar to *C. beltrani*, *C. simus* and *C. esconditus* (29.0%, 30.7% and 31.6%, respectively). The snout length is similar to *C. beltrani*, *C. simus* and *C. esconditus* (7.8% in males and females vs. 8.2%, 7.2% and 8.8%, respectively), but shorter than in the other species (11.2% in *C. labiosus*, 10.9% in *C. maya*, 10.1% in *C. verecundus*). The upper jaw length is the shortest (8.7% and 9.0% in males and females, respectively, vs. 13.9% in *C. maya*, 12.1% in *C. labiosus*, 11.8% in *C. verecundus*, 11.3% in *C. simus*, 9.9% in *C. esconditus* and 9.3% in

C. beltrani). The interorbital width is wider than in *C. simus*, *C. labiosus* and *C. beltrani* (10.1% vs. 6.9%, 8.4% and 8.6%). The prepelvic length is shorter than in most other species, (52.5% in males and females, vs. 59.5% in *C. maya*, 58.3% in *C. labiosus*, 59.6% in *C. verecundus*, 55.5% in *C. simus*, and 59.6% in *C. beltrani*), but similar to *C. esconditus* (51.7% and 52.7% in males and females, respectively). This prepelvic length corresponds to a lower number of precaudal vertebrae in *C. suavium* and *C. esconditus* (10.8 and 11.4) compared to *C. labiosus* and *C. maya* (12.4), *C. simus* and *C. verecundus* (12.8) as well as *C. beltrani* (13.0). Body depth is higher than in the other species but similar to *C. verecundus* (36.9% and 34.6% vs. 37.4% and 33.5% in males and females, respectively). The number of scales around the peduncle is the lowest (13.8 vs. 16.0 in *C. maya*, 15.8 in *C. labiosus*, 15.5 in *C. verecundus*, 15.4 in *C. esconditus*, 15.1 in *C. simus*, and 14.7 in



Figure 2. *Cyprinodon suavium*, above female holotype, 29.8 mm SL, IBUNAM-P13985 and male paratype, 29.7 mm SL, ZMH 24832.

C. beltrani). The number of anal fin rays is higher than in all species (10.9 and 10.8 in males and females, respectively, vs. 9.7 in *C. simus*, 9.9 in *C. beltrani* and *C. labiosus*, 10.0 in *C. verecundus* and 10.1 in *C. maya*) but similar to *C. esconditus* (10.5).

Whereas *C. maya* and *C. simus* can easily be distinguished from *C. suavium* based on their

general appearance and especially on their head morphology, it is more difficult to distinguish *C. suavium* from *C. beltrani*, *C. labiosus*, *C. esconditus* and *C. verecundus*. For this reason, a canonical discriminant analysis for these species was performed. The clusters show that most specimens of *C. suavium* can be separated from the other species, with only three overlaps (Fig. 5).

Description. The general appearance of male and female is shown in Fig. 2. The morphometric characters of the holotype and 31 paratypes (10 males and 21 females) of *C. suavium* are summarized in Table 1. Vertebrae (precaudal + caudal): 10 + 13 = 23 (1), 10 + 14 = 24 (7), 11 + 13 = 24 (9), **11 + 14 = 25** (15). Head pores (both sides counted): mandibular always absent; lacrimal left/right side 4/4 (25), 4/5 (2), 5/4 (2), **5/5** (2), 6/4 (1); preopercular 7/6 (1), **7/7** (28), 7/8 (2), 8/7 (1). Scale counts: lateral **25** (24–26, mean 24.8); dorsal to pelvic **11** (10–13, mean 11.5); circular peduncle **26** (24–31, mean 27.0); circular body **12** (12–16, mean 13.8). Fin ray counts: dorsal **11** (10–11,

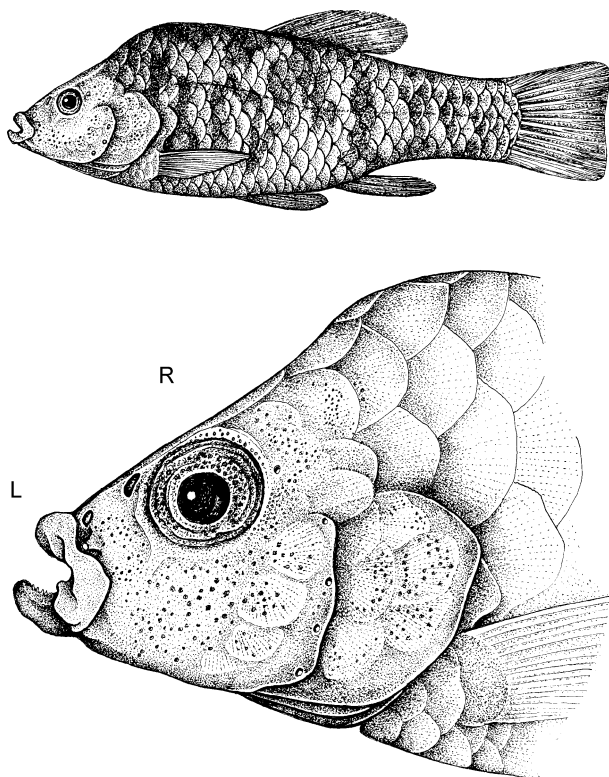


Figure 3. Lateral view of *C. suavium* (ZMH 24819, female, SL 45.5 mm, above) and of the head region (ZMH 24836, male, SL 30.4, below). R = concave inter- and postorbital skull roof, L = thickened lips.

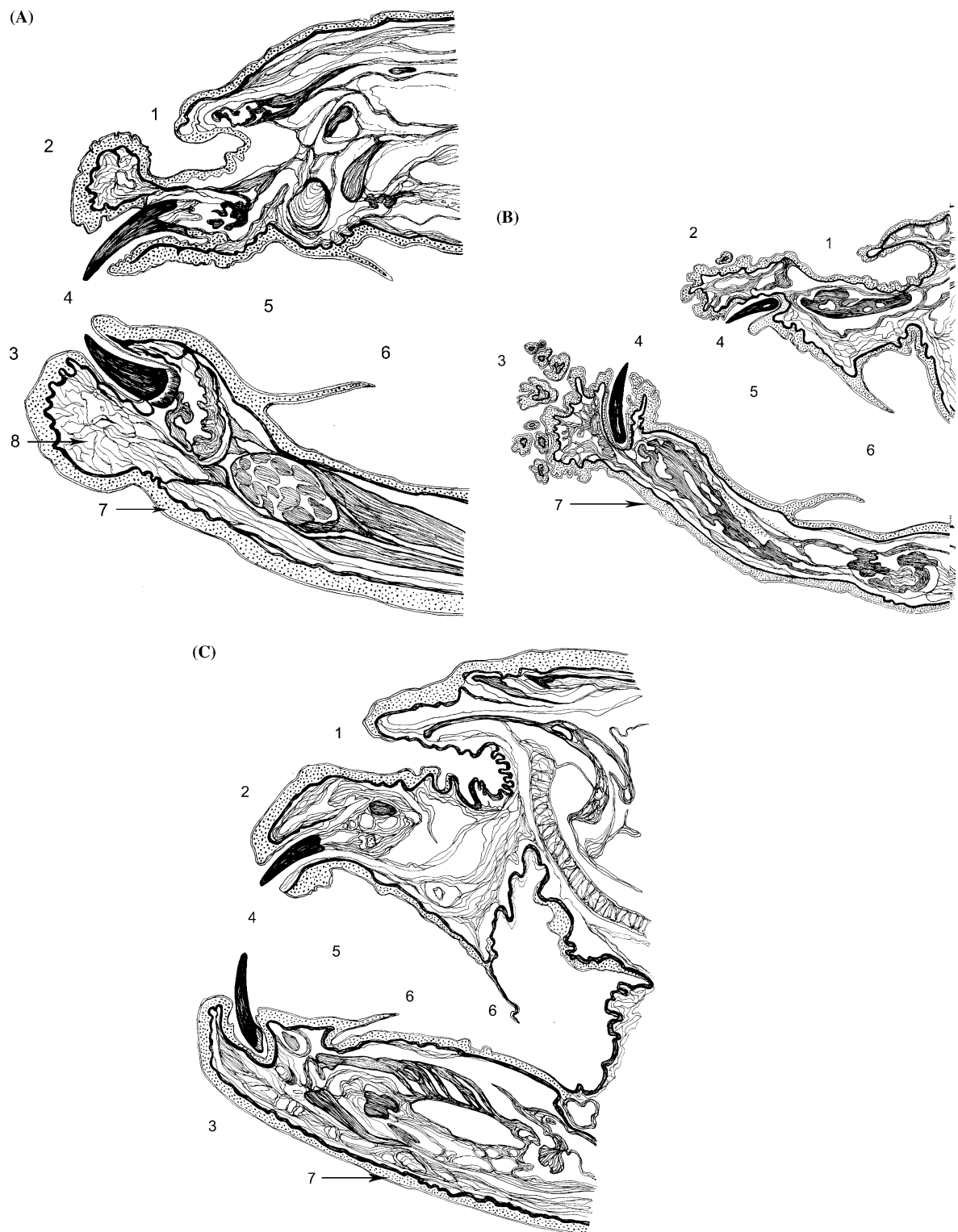


Figure 4. Sagittal section of upper and lower lips. (A) *C. suavium*, (B) *C. labiosus*, (C) *C. beltrani*. 1: olfactory chamber, 2: upper lip, 3: lower lip, 4: teeth, 5: mouth cavity, 6: velum, 7: epidermis, 8: thickened part of lip cutis.

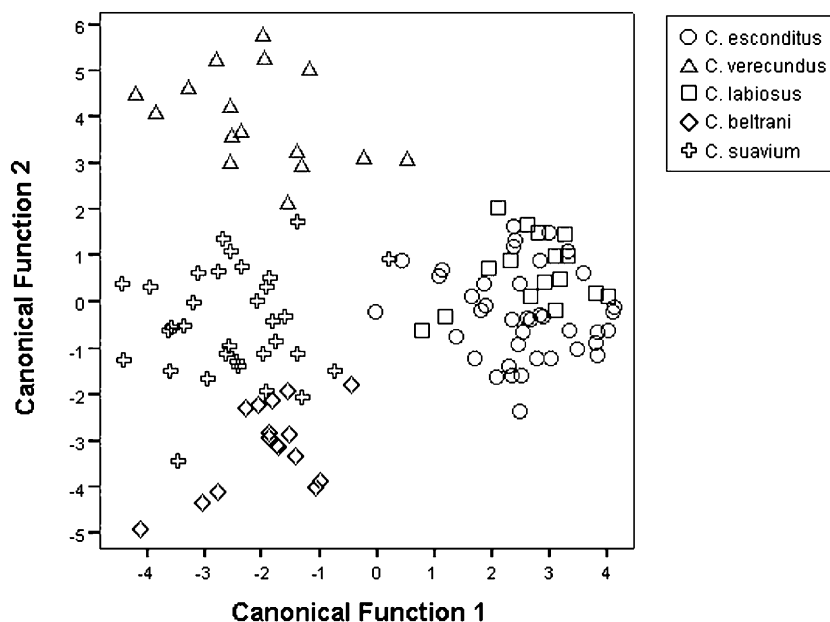


Figure 5. Scatter plots of a canonical discriminant analysis of five *Cyprinodon* species from Laguna Chichancanab using the proportional measurements of 21 morphometric characters expressed as thousandths of SL.

mean 10.3); anal **11** (10–11, mean 10.8); pectoral left side **15** (15–16, mean 15.4); pectoral right side **15** (15–16, mean 15.3); pelvic left side **7** (6–7, mean 6.8); pelvic right side **7** (6–7, mean 6.9); caudal **14** (14–18, mean 14.6).

The number of premaxillary teeth is 12 and 16 for the upper and 12 and 18 for the lower jaw (SL = 26.6 mm and 33.0 mm, respectively). Pharyngeal teeth of *C. suaviium* (Fig. 6) are similar to

those of *C. beltrani*, *C. labiosus* and *C. maya* (see figure 5 in Humphries & Miller (1981)); the inner row has broad solid teeth, the outer rows have smaller, more acute teeth. The intestine is short in length, approximately 1.1–1.6 times of SL.

Sexual dimorphism. The males are slightly deeper bodied with generally longer fins and the anal fin shows the largest prolongation. As in the other

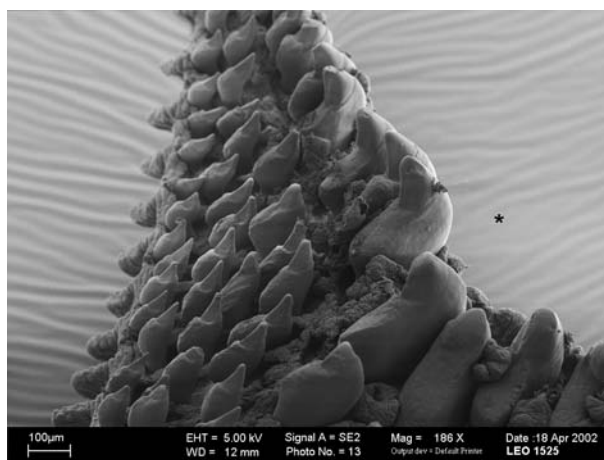


Figure 6. Scanning electron micrographs of pharyngeal teeth of *C. suaviium*. Asterisk indicates posterior margin.

members of the species flock, too, there is a protuberance in the region of the male genital opening.

Coloration. Both, males and females are very similar in coloration to the other members of the flock. They show a cryptic color pattern of buff background typical of most *Cyprinodon*. The body sides are usually covered by 6–7 vertical brown bars. In females, the dorsal fins mostly have an ocellus.

Distribution and ecology. *Cyprinodon suavium* is only known from the Laguna Chichancanab and belongs to an endemic species flock. This species was collected at sampling sites (A), (B), (C), and (E) (Fig. 1). The relatively short gut length indicates a carnivorous diet. This is confirmed by the examination of X-rays where snails *Pyrgophorus coronatus* (Pfeiffer, 1839) (in 14 specimens), ostracodes (7) and bivalves (3) were found.

Etymology. The species name *suavium* is from the Latin noun for kiss reflecting the distinctive protruded appearance of the lips.

Discussion

Speciation processes in species flocks are assumed to be driven by trophic adaptation and sexual selection. For the most famous examples, the endemic cichlid species of the Great East African Lakes, it could be shown that nuptial coloration is important for their mate choice and that parallel to this functional and morphological divergence in the feeding apparatus are responsible (Albertson et al., 2003; Allender et al., 2003; Kocher, 2004). The *Cyprinodon* flock from Laguna Chichancanab provides an example, which due to the smaller size of the lake and the low number of species is much easier to survey. For this flock, it was revealed by mate choice experiments that in addition to visual cues chemical signals play an even more important role. Furthermore, it could be shown that reproductive isolation is not completely achieved in all species

(Strecker, 1996; Strecker & Kodric-Brown, 1999, 2000; Kodric-Brown & Strecker, 2001).

With respect to morphology the most specific characteristic of *C. suavium* is the development of thickened lips. With this feature this new species groups with those members of the flock, which have developed particularly diverging mouth forms. These are *C. labiosus* which is equipped with protuberant fleshy lips (Fig. 4b) used for digging in coarse gravel, and *C. simus*, a plankton feeder (Humphries & Miller, 1981), with a vertical lower jaw as well as smaller and more numerous teeth. In contrast, *C. esconditus* and *C. verecundus* have just broader and in case of *C. maya* larger mouth openings when compared with the ancestral sister species *C. beltrani*. Studies of the gut content have revealed that the main food item in all of them is detritus, the typical food in this genus (Soltz & Naiman, 1978). However, whereas *C. beltrani* feeds nearly exclusively on detritus, all other species have additionally ingested animal prey and have a significantly shorter gut length (Humphries & Miller, 1981, Stevenson, 1992, Horstkotte & Strecker, accepted). Each of the carnivores show a preference for a specific prey item: amphipods in *C. labiosus*, ostracods in *C. maya*, bivalves in *C. verecundus* and insect larvae in *C. esconditus* (Horstkotte and Strecker, accepted). As shown above, preliminary studies have revealed for *C. suavium* that besides detritus *Pyrgophorus* snails, bivalves and ostracods were ingested. From this it can be assumed that this species might have explored a new prey niche, too, like the other carnivorous pupfish species. This is supported by the shorter gut length indicating a carnivorous diet.

Thickened lips are convergently developed in several cichlid species occurring in different East African Lakes. These fish are sucking aquatic animals from rock crevices (Kocher et al., 1993; Schön & Martens, 2004). In the Laguna Chichancanab such type of habitat is not rare and especially found on its steep rocky slope on the northern side. Ongoing field studies will have to prove, whether *C. suavium*, which was only caught in low numbers over sandy or gravelly underground, is more numerous at such rocky places.

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