

**A review of the Malagasy *Pachypanchax*  
(Teleostei: Cyprinodontiformes, Aplocheilidae),  
with descriptions of four new species**

PAUL V. LOISELLE

*New York Aquarium, Surf Ave. & West 8<sup>th</sup> St., Brooklyn, NY 11225, USA. E-mail: ploiselle@wcs.org*

**Table of contents**

Introduction .....	2
Methods and materials .....	3
Generic placement of the Malagasy aplocheilids .....	4
Species accounts .....	7
<i>Pachypanchax omalonotus</i> (Duméril, 1861) .....	7
<i>Pachypanchax sakaramyi</i> (Holly, 1928) .....	14
<i>Pachypanchax varatraza</i> <b>sp. nov.</b> .....	20
<i>Pachypanchax patriciae</i> <b>sp. nov.</b> .....	25
<i>Pachypanchax sparksorum</i> <b>sp. nov.</b> .....	30
<i>Pachypanchax arnoulti</i> <b>sp. nov.</b> .....	34
Specimens examined .....	40
Comparative material .....	41
Acknowledgments .....	42
Literature cited .....	43

## Abstract

The history of the genus *Pachypanchax* Myers, 1933 in the literature is reviewed and the utility of the diagnostic characters proposed by various authors is evaluated. On the basis of five synapomorphies, four skeletal and one squamational, six of the seven presently known Malagasy aplocheilids are found to be unambiguously referable to the genus *Pachypanchax*. The seventh, *Poecilia nuchimaculata* Guichenot 1866, known only from the unique type specimen, displays several peculiar skeletal and squamational features. Pending the acquisition of additional material, it is tentatively assigned to the genus. Of the six species treated here, *Pachypanchax omalonotus* (Duméril, 1861) and *P. sakaramyi* (Holly, 1928) are redescribed from recently collected topotypical material; and the following four are described as new: *P. varatraza*., *P. patriciae*, *P. sparksorum*, and *P. arnoulti*. Data on life colors, distribution, natural history and conservation status on all six Malagasy *Pachypanchax* species are presented.

**Key words:** Aplocheilidae, biogeography, conservation, distribution, *arnoulti*, Madagascar, natural history, *Pachypanchax*, *nuchimaculatus*, *omalonotus*, *patriciae*, *playfairii*, *sakaramyi*, *sparksorum*, *varatraza*

## Resumé

L'histoire du genre *Pachypanchax* Myers, 1933 dans la littérature est examiné et l'utilité des caractères diagnostiques proposés par plusieurs auteurs est évaluée. D'après cinq caractères synapomorphiques, quatre squelettiques et un touchant sur l'écaillage, six des sept Aplocheilidae malgaches connus sont incontestablement attribuable au genre *Pachypanchax*. Le septième, *Poecilia nuchimaculata* Guichenot, 1866, connu seulement du spécimen-type unique, démontre quelques particularités squelettiques et de l'écaillage. Jusqu'à l'acquisition du matériel supplémentaire, cette espèce est provisoirement assigné au genre. Six espèces sont ici considérées. *Pachypanchax omalonotus* (Duméril, 1861) et *P. sakaramyi* (Holly, 1928) sont redécrits d'après des spécimens topotypiques récemment collectionnés. Quatre nouvelles espèces, *P. varatraza* **sp. nov.**, *P. patriciae* **sp. nov.**, *P. sparksorum* **sp. nov.** et *P. arnoulti* **sp. nov.** sont décrites et des données sont présentées sur le coloris à l'état vivant, la distribution, l'histoire naturelle et le statut de la conservation de ces six espèces de *Pachypanchax* malgaches.

## Introduction

Myers (1933) established the genus *Pachypanchax* for *Haplochilus playfairii* Günther, 1866, a robust killifish endemic to the granitic Seychelles (Playfair and Günther, 1866). He included two Malagasy species, *Poecilia omalonota* Duméril, 1861 and *Panchax sakaramyi* Holly, 1928 in his new genus. This attribution appears to have been made on biogeographic grounds, as Myers clearly indicated that he had not examined specimens of either Malagasy species. Scheel (1968) refined Myer's definition of the genus with the addition of two additional diagnostic characters. However, the material of *P. omalonota*

available to Scheel consisted of aquarium-reared specimens descended from fish collected from the lower reaches of the westward-flowing Betsiboka River, on the mainland of Madagascar (Arnoult, 1955), whereas the type material of *P. omalonotus* actually came from the island of Nosy Be, off northwestern Madagascar. Subsequent collecting has demonstrated these two taxa differ sufficiently in coloration and morphology to warrant recognition as separate species. Parenti (1981) subsequently redefined the genus, placing particular emphasis upon several skeletal apomorphies. However, Parenti neither examined topotypical material of *P. omalonotus* nor specimens of the other two nominal Malagasy species, *P. sakaramyi* and *P. nuchimaculatus* (Guichenot, 1866). Her inclusion of the Malagasy species within the genus was thus tentative.

Fieldwork in Madagascar undertaken since 1993 has resulted in the collection of larger series of both *P. omalonotus* and *P. sakaramyi*, and in the discovery of additional aplocheilid taxa that cannot be referred to previously published nomina. In light of these discoveries, it is appropriate to reexamine Parenti's definition of the genus *Pachypanchax*, redescribe *P. omalonotus* and *P. sakaramyi*, and describe four of these new taxa. Three more recently discovered Malagasy species remain to be described.

## Methods and materials

Morphometric measurements were obtained with digital calipers to the nearest .01 mm and are expressed as percentage of standard length (SL). MANOVA (SPSS Version 11.5) was used to test morphometric data for overall intergroup differences. Significant differences were found [Wilks'  $\lambda = .001$ , df: 14, 96,  $p < .05$ ]. A comparison of character means undertaken using one-way ANOVA, and Tucky's HSD was used to test *post-hoc* for significant [ $p < .05$ ] between-species differences. Meristic counts were made using a dissecting microscope. Fin rays were counted under transmitted light and include all discernable elements (Thomerson and Taphorn, 1993; Romand, 1994). Terminology for prefrontal squamation and the associated pores of the cephalic lateral line system follows Hoedemann (1958, 1961) and Scheel (1968). Osteological characters were examined using radiographs and cleared and stained specimens. Vertebral counts exclude the ural centrum. Descriptions of life colors are based upon the author's field notes and photographs of either wild-caught specimens or their captive-bred progeny held under aquarium conditions. None of the specimens photographed were subsequently preserved. Institutional abbreviations follow Leviton *et al.* (1985), as follows:

- AMNH American Museum of Natural History, New York
- MNHN Muséum National d'Histoire Naturelle, Paris
- MSNM Museo Civico di Storia Naturale, Trieste
- NMW Naturhistorisches Museum, Vienna
- UMMZ University of Michigan, Museum of Zoology, Ann Arbor

Place names follow contemporary usage, as indicated by the Foiben-Taosarintanin'i Madagasikara. The equivalent colonial-era name previously utilized in the literature is given within brackets, following the first use of a place name. The position and altitude of collecting sites were determined using a Magellan 2000 GPS receiver. Altitudes are given in meters above sea level, abbreviated as m a.s.l. Air and water temperatures were taken using a mercury thermometer. Electrical conductivity in micro-Siemens ( $\mu\text{S}$ )/ $\text{cm}^2$  was measured with a Nestor Instruments MicroMHO Pen. A colorimetric pH test from the Tetra Laborett water test kit was used to measure pH values. Total (GH) and carbonate (KH) hardness were also measured using the Tetra Laborett.

### Generic placement of the Malagasy aplocheilids

Myers (1933) based the genus *Pachypanchax* upon four diagnostic characters: (1) limited mobility of the maxilla, resulting from its attachment posteriorly by the skin to the postorbital region of the skull; (2) presence of unexpanded haemal arches; and (3) a rounded caudal fin whose (4) basal half is heavily scaled, the scales in straight rows, one scale wide, each series covering the interspace between two caudal rays. Myers placed particular emphasis on the caudal squamation of *Pachypanchax*, which he found to be unique among Old World aplocheilid cyprinodonts examined by him, and matched only by that of the Neotropical genus *Austrofundulus*.

Myers' conclusions regarding the diagnostic value of the caudal squamation of *Pachypanchax* are supported by the examination of specimens of several species of the aplocheiloid genera *Aplocheilus*, *Epiplatys*, *Aphyosemion*, (subgenera *Chromaphyosemion*, *Fundulopanchax*, *Mesaphyosemion* and *Scriptaphyosemion*), and *Nothobranchius*; the rivulid genera *Austrofundulus*, *Austrolebias*, *Rachovia* and *Rivulus*; the cyprinodontid genera *Cyprinodon*, *Cubanichthys* and *Orestias*; the fundulid genus *Fundulus*; and the profundulid genus *Profundulus*. *Aplocheilus lineatus* and *A. panchax* both possess one or two basal rows of small scales on the caudal fin that overlap the fin rays, a condition also present in *Epiplatys fasciolatus* and *Nothobranchius melanospilus*. In specimens of the remaining aplocheiloid genera examined, the caudal is unscaled. Caudal squamation comparable to that seen in *Aplocheilus* has been observed in *Austrolebias bellottii*, *Rachovia pyropunctata*, *Cubanichthys cubensis*, and *Fundulus lima*. A narrow triangular patch of scales extending from the base of the caudal half way to its margin was observed in large specimens of *Rivulus hartii*, but a degree of caudal squamation comparable to that seen in *Pachypanchax* is present only in the distantly related Neotropical cyprinodontiform genera *Austrofundulus* and *Profundulus*.

Scheel (1968) proposed two additional morphological features that served to differentiate *Pachypanchax* from the aplocheiloid genera *Aplocheilus* and *Epiplatys*. He found the central rays of the caudal fin to be prolonged in the latter two genera, producing

a median lobe, whereas, in the absence of such a feature, the caudal fin is rounded in *Pachypanchax*. He also noted that, in *Pachypanchax*, the frontal squamation was of the E-type *sensu* Hoedemann (1958), usually with prominent H scales. In *Aplocheilus* and *Epiplatys*, to the contrary, the frontal squamation was of the G type, without H scales. The presence of a rounded or truncate caudal fin characterizes all of the Malagasy aplocheilids known to date. However, examination of larger series of Malagasy material suggests that the E type of frontal squamation does not unequivocally characterize these killifish. While Scheel's observation regarding this character is generally correct, occasional aberrant individuals with the G pattern have been found to occur in several Malagasy species.

Following a more detailed morphological investigation of *Pachypanchax*, Parenti (1981) discovered six additional apomorphic characters, of which two were deemed to have particular diagnostic value: a) the squamation of adult males, in which the posterior edge of the scales of the dorsum and flanks is angled away from the body; and b) the fusion of the five hypural bones into a single fan-shaped plate. As previously noted, in the absence of Malagasy material, Parenti was unable to determine whether *P. omalonotus* shared derived skeletal characters with *P. playfairii*.

The absence of a reflective pineal (frontal) spot in living individuals is a further feature that unites *P. playfairii* and the Malagasy taxa. A reflective pineal spot is a conspicuous feature of the color pattern of the aplocheiloid genera *Aplocheilus*, *Adamas* and *Epiplatys*. However, this feature is lacking in the color pattern of *Pachypanchax* and in the remaining aplocheiloid genera, although it occurs sporadically within a number of New World cyprinodontiform lineages.

The distribution of this suite of diagnostic characters within the genus *Pachypanchax* is presented in Table 1. It is clear that neither the absence of dorsal and anal fin filaments in males nor the presence of dark markings in the gular region unambiguously defines the genus. Furthermore, the raised dorsolateral scales on the body of male *P. playfairii* are not found in any Malagasy representatives of the genus, nor in all populations of nominal *P. playfairii* (P. de Rham, pers. com.), and thus represent an autapomorphy of the topotypical population of this Seychellois endemic. The ocellated black spot in the dorsal of juvenile and female *P. playfairii* is also characteristic of all known species of *Aplocheilus*. It is not present in any Malagasy aplocheilid, although a diffuse dusky blotch is present in some females of *P. sakaramyi*. This color pattern is most parsimoniously interpreted as pleisomorphic within the Aplocheilidae. However, *P. playfairii* shares diagnostic skeletal characters: a heavily scaled, rounded caudal fin; and lack of a reflective pineal spot with all save one of the presently known Malagasy aplocheilids. These data support both Myers' and Parenti's inclusion of *Poecilia omalonota* and *Panchax sakaramyi* within the genus *Pachypanchax*, and no further ambiguity should attend their generic placement. With the exception of *Poecilia nuchimaculata* Guichenot, 1866, the same holds true for Madagascar's remaining aplocheilids.

**TABLE 1.** Distribution of diagnostic characters of the genus *Pachypanchax* within the Malagasy aplocheilid taxa.

Key	
PLA = <i>Pachypanchax playfairii</i>	VAR = <i>Pachypanchax varatraza</i> <b>sp. nov.</b>
OMA = <i>Pachypanchax omalonotus</i>	PAT = <i>Pachypanchax patriciae</i> <b>sp. nov.</b>
SAK = <i>Pachypanchax sakaramyi</i>	SPA = <i>Pachypanchax sparksorum</i> <b>sp. nov.</b>
NUC = <i>Pachypanchax nuchimaculatus</i>	ARN = <i>Pachypanchax arnoulti</i> <b>sp. nov.</b>

Character	Species							
	PLA	OMA	SAK	NUC	VAR	PAT	SPA	ARN
Maxilla attached posteriorly to post-orbital region of skull	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Haemal arches unexpanded	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No pleural ribs on haemal spines	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hypural bones fused into a single fan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Posterior edges of scales angled away from body in males	Yes	No	No	No	No	No	No	No
Caudal fin rounded	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basal third to three-quarters of caudal fin heavily scaled	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dorsal and anal fins of males lacking filamentous extensions	Yes	No	Yes	?	Yes	No	No	Yes
Reflective pineal spot absent	Yes	Yes	Yes	?	Yes	Yes	Yes	Yes
Throat bar present	Yes	No	No	?	No	No	No	Yes
Ocellated black dorsal spot in females	Yes	No	No	?	No	No	No	No

Guichenot (1866) described *Poecilia nuchimaculata* from a single specimen collected by J. P. Goudot, a French resident of Madagascar from 1835 until his death in the early 1860's. The specimen lacks precise locality data and as Goudot's journals were lost when he disappeared while in the field (Dorr, 1997), subsequent efforts to determine its provenance have proved fruitless. Published data (Huber, 1998) indicate that with regard to both morphometric and meristic characters the type falls within the range that defines the Malagasy representatives of the genus *Pachypanchax*. He noted that the prefrontal scales of this specimen are smaller than those of other *Pachypanchax* species, while the lateralis system consists of open rather than enclosed pores. The caudal squamation is rather light, with scales present only on the basal third of the fin (de Soutter, pers. com.), a feature shared with only one other Malagasy congener. Radiographic examination of the caudal skeleton confirms Huber's observation that a shallow notch separates the upper plate, formed by the fusion of third, fourth and fifth hypural bones and the lower plate,

formed by the fusion of the first and second bones. This condition is more reminiscent of that found in many representatives of the Nothobranchidae (upper and lower plates separated by a deep groove), than that seen in *Aplocheilus* (hypural skeleton made up of three independent elements, the upper- and lowermost comprising the fused fourth and fifth and first and second hypural bones respectively).

In the absence of additional material of *P. nuchimaculatus*, there is no way to determine whether the observed anomalies in squamation and caudal skeleton of the type specimen are idiosyncratic or reflect significant population-level differences. Pending the acquisition of additional material of this species, it seems advisable to follow Parenti (1981) and provisionally assign *Poecilia nuchimaculata* to the genus *Pachypanchax*.

*Pachypanchax* Myers, 1933 may thus be diagnosed as follows: Maxilla ry relatively immobile, bound at its posterior end to the preorbital by a fold of skin. Premaxillary ascending processes flat and broad, tapered posteriorly and not overlapping in the midline. A single pair of tubular nares present. Reflective pineal spot absent. Frontal squamation typically of the E-type, with prominent H scales. In very large specimens, a shallow pit may be present in the center of some scales along the midlateral line, but there is no evidence of any connection to an underlying neuromast. Scales and fin rays lacking papillae. Haemal arches unexpanded, no pleural ribs on haemal spines. Hypural plates fused to form a hypural fan in adults, joint lines visible in juveniles. Caudal fin rounded or rounded-truncate, the middle rays never extended. Basal third to three quarters of caudal fin heavily scaled, the scales in straight rows, one scale wide, each series covering the interspace between two caudal rays. Caudal fin lacking a median lobe. Filamentous extensions of the dorsal and anal fins of males variably present. Dark gular bar variably present. Pigmentation pattern does not include cross bars on body. Basal dorsal-fin spot absent in males, variably present in females. Type species: *Pachypanchax playfairii* (Gunther 1866).

The genus is endemic to Madagascar and the granitic Seychelles. The Zanzibari population of *Pachypanchax playfairii* represents a recent translocation and (Parenti [1981] notwithstanding) there are no confirmed records of this species from the East African mainland (Seegers, 1980). Apart from two species native to eastward- and northward flowing drainages in the extreme north, Malagasy *Pachypanchax* are restricted to the island's western versant, from the Ambohitra Massif (Massif d'Ambre) south to the basin of the Tsiribihina River.

## Species accounts

### *Pachypanchax omalonotus* (Duméril, 1861)

*Poecilia omalonota* Duméril, 1861: 257, pl. 22, fig. 7 (type locality: Nosy Be [Nossi-Bé], off northern Madagascar, 12°42'S, 48°16'E. Lectotype: MNHN 2935).

*Diagnosis*

*Pachypanchax omalonotus* males differ from male *P. playfairii* in lacking raised dorsolateral squamation and in having a color pattern that does not feature rows of discrete red spots. The dorsal fin of female *P. omalonotus* lacks the ocellated black basal blotch present in female *P. playfairii*. *P. omalonotus* has the shortest ( $14.0 \pm 0.9$  % SL) and deepest ( $15.2 \pm 0.9\%$  SL) caudal peduncle of any Malagasy *Pachypanchax*, and also differs from *P. sakaramyi* and *P. sparksorum* **sp. nov.** in having the scales of the chest the same size as those of the flanks and in its marked color polymorphism. The presence of rows of discrete metallic gold spots on the flanks and the absence of iridescent white edging along the upper and lower margins of the caudal fin distinguishes living male *P. omalonotus* from all remaining Malagasy congeners.

*Description*

Morphometric characters appear in Table 2. A *Pachypanchax* of moderate size, with a distinctly pointed snout. Mouth wide, cleft directed upward. A single row of slightly recurved, conical teeth present in each jaw. Eight to eleven (mode=10) branchiospines on first gill arch. Two scale rows present on cheeks. Frontal squamation of E-type, with H scales present. Cephalic neuromast pattern open in 18 of 21 specimens examined, closed in the remainder. Scales cycloid, 31–34 (mode=32) along midlateral line. Fourteen transverse scale rows immediately anterior to origin of anal fin; 18 scale rows around caudal peduncle. Scales on chest the same size as those on flanks. Vertebrae 14 pre-caudal + 16 caudal.



**FIGURE 1.** *Pachypanchax omalonotus*, wild-caught yellow morph male, 73.0 mm SL. Djabala Creek, Nosy Be.



**TABLE 2.** Morphometric data for *Pachypanchax omalonotus*, based upon 25 specimens collected from Djabala Creek and 10 specimens from an unnamed creek on the Andoany-Ambatozavavy road, Nosy Be.

Measurement	Range	Mean $\pm$ SD
Standard length (mm)	31.3–62.2	
In percentages of standard length		
Head length	27.4–32.7	30.0 $\pm$ 1.3
Snout length	6.2–9.1	7.9 $\pm$ 0.8
Eye diameter	6.2–9.4	7.8 $\pm$ 0.7
Interorbital distance	11.5–15.7	13.5 $\pm$ 0.9
Postorbital distance	10.7–15.4	12.7 $\pm$ 1.2
Maximum depth	20.3–25.7	23.5 $\pm$ 1.2
Longest pectoral-fin ray	12.9–19.0	16.4 $\pm$ 1.4
Predorsal length	70.5–79.4	76.5 $\pm$ 2.3
Prepelvic length	44.9–55.1	50.8 $\pm$ 2.0
Preanal length	60.5–69.8	64.4 $\pm$ 2.2
Length of dorsal-fin base	9.6–14.2	12.1 $\pm$ 1.3
Length of anal-fin base	18.0–26.2	22.3 $\pm$ 1.7
Length of caudal peduncle	12.4–16.2	14.0 $\pm$ 0.9
Depth of caudal peduncle	12.5–17.2	15.2 $\pm$ 0.9

Dorsal-fin origin above midpoint between origins of tenth and eleventh anal-fin rays. Dorsal-fin rays ii,9 (2); iii,9 (4); i,10 (2); ii,10 (24); iii,10 (5); ii,11 (9). Ninth or tenth dorsal ray longest in males, fifth or sixth dorsal ray longest in females. Anal fin rays ii,14 (9); ii,15 (10); ii,16 (14); iii,16 (7); ii,17 (4); iii,17 (5). Sixteenth or seventeenth anal ray longest in males, seventh or eighth ray longest in females. Longest ray in both dorsal and anal fins elongated, forming a short filamentous extension in males. Base of dorsal and anal fins scaled. Caudal fin rounded truncate, basal half to two-thirds heavily scaled. Pelvic-fin rays i,5. Pectoral-fin rays 12–16 (mode=14).

#### Coloration

Live individuals (males). Males of *Pachypanchax omalonotus* are characterized by color polymorphism. Figure 1 depicts a sexually quiescent yellow-morph male from the Djabala Creek population, which also occurs in a red morph. Figure 2 depicts a sexually quiescent blue morph male from the Ambatozavavy population. Red morph males of the latter population differ from those of the Djabala population in having fewer rows of golden spangles forming a discrete band along the midlateral region. Figure 3 depicts a red morph male of the Sambirano basin population, which also occurs in a blue morph. Black submarginal banding in the dorsal and anal fins has not been observed, to date, in

Sambirano or Djabala males, and is encountered much less often in red than in blue morph Ambatozavavy males. A narrow black anal-fin margin is variably present in red morph Ambatozavavy males, but appears to be a consistent element of the color pattern of Sambirano males. Courting males of all populations develop a narrow black midlateral stripe that extends from the snout to a point immediately beneath the dorsal fin origin. Figure 4 depicts a female of the Djabala Creek population.

Preserved specimens (males). Upper half of head, lips and dorsum pale brown, shading to beige on the cheeks, operculum and flanks. Throat and venter yellowish white. Scale centers paler in large males, forming lines of light spots on the flanks. Vertical fins and ventrals clear beige. A reticulate pattern of small light dots variably present basally in dorsal and caudal fins. Vertical fins of some males in the both the Djabala Creek and Ambatozavavy populations may be marked with darker submarginal bands of varying intensity. The pectorals are hyaline. (Females): Similar to that of males, but lacking regular lines of lighter spots on flanks. Fins uniformly hyaline.



**FIGURE 2.** *Pachypanchax omalonotus*, captive-bred (F<sub>7</sub>) blue morph male, 53.0 mm SL. Ambatozavavy, Nosy Be.

### *Range*

Contrary to the widely held view that *P. omalonotus* is broadly distributed on the western versant of Madagascar (Arnoult, 1959; Kiener, 1963; Scheel, 1968), this species is restricted to the island of Nosy Be, to the basin of the Sambirano River on the immediately-adjacent mainland, and to several small independent coastal streams on the Ankify peninsula (O. Lucanus, pers. com.), immediately to the south of the mouth of the Sambirano (Figure 5). *Pachypanchax omalonotus* is replaced in river drainages to the north and south by as yet undescribed congeners.



**FIGURE 3.** *Pachypanchax omalonotus*, wild-caught red morph male, 64.0 mm SL. Beandrona Creek (Sambirano drainage).



**FIGURE 4.** *Pachypanchax omalonotus*, wild-caught female, 70.0 mm SL. Djabala Creek, Nosy Be.



absent from the island's numerous crater lakes and has never been collected in brackish water. In this regard, *P. omalonotus* and its Malagasy congeners differ significantly from *P. playfairii*, which moves freely between brackish and fresh water (Hartig-Beecken, 1980). On the mainland, it inhabits both shaded streams and the marshy shallows of lakes in the Sambirano River flood plain. Table 3 presents data on the water chemistry of *P. omalonotus* habitats on both Nosy Be and on the mainland. According to local informants, stream populations are stable, but the size of lacustrine populations varies both seasonally and from one year to the next, depending upon rainfall. No other fish or macrocrustaceans were collected syntopically with *P. omalonotus* on Nosy Be. Sambirano drainage populations have been found to occur syntopically with the following fish species: *Teramulus waterloti*, *Ambassis natalensis*, *Paretroplus damii*, *Ptychochromis oligacanthus*, *Oreochromis niloticus*, *Awaous aenofuscus*, and *Glossogobius giuris*; as well as several crustaceans, including *Macrobrachium* spp. and several small atyid shrimp species.

**TABLE 3.** Environmental parameters for *P. omalonotus* habitats on Nosy Be and the adjacent mainland.

Habitat	pH	GH [°DH]	KH [°DH]	µS/cm <sup>2</sup>	Temperature Range [° C]
Djabala Creek	7.5	12°–15°	11°	160–173	26.1°–27.8°
Ambatozavavy	7.0	4°	4°	79	27.8°
Ankaze Creek	7.0	2°	2°	29	26.6°
Ramena River	7.5	2°	2°	34	25.2°

Feces of freshly captured specimens contained recognizable remains of both the imagos of terrestrial insects and the nymphs and larvae of aquatic insects. This suggests that, in the wild, *P. omalonotus* feeds both at the surface and from the bottom. On Nosy Be, *Glossogobius giuris* is the only fish large enough to pose a threat to adult *P. omalonotus*. On the mainland, it is also at risk from the three *Anguilla* species reported from northwestern Madagascar, as well as from the native cichlid *Paratilapia polleni*. Its preference for shallow water renders *P. omalonotus* vulnerable to both herons and *Corythornis vintsioides*, the Malagasy malachite kingfisher.

Captive specimens taken from Djabala Creek, on Nosy Be, in mid-October began spawning within a week of their arrival in the United States in early November. Based upon observations of the growth rate of juveniles in captivity, the size distribution of captured specimens suggests a protracted breeding season lasting through the austral summer, which coincides with the rainy season in northwestern Madagascar.

#### *Conservation status*

*Pachypanchax omalonotus* is abundant throughout its range and to date must contend

with neither exotic predators nor competitors. It is classified as vulnerable following the criteria established by the World Conservation Union (Raminosoa *et al.*, 2002).

### Discussion

Most localities from which *P. omalonotus* has been collected are less than 100 m a.s.l. The exception to this pattern is a single lot of fish (AMNH 232475), collected from the shallows of the main channel of the Ramena River, the principal tributary of the Sambirano, at an altitude of 700 m a.s.l. These six specimens are 54.8–70.2 mm SL, large for wild-caught *P. omalonotus*. They differ from low-altitude populations in having three, rather than two rows of scales on the cheeks, a greater number of transverse scale rows immediately anterior to the origin of the anal fin (15 vs. 14) and around the caudal peduncle (22 vs. 18). The scales on the lower two-thirds of the flanks are marked with dark, rather than lighter centers, and a dusky submarginal band comparable to that present in some Nosy Be populations of *P. omalonotus* is evident in the anal fin of some males. Regrettably, no data on life colors were recorded when the specimens were collected (C.J. Raxworthy, pers. com.). Pending the collection of additional *Pachypanchax* material from other high-altitude localities in the Sambirano-Ramena drainage, there is no way to determine the relative importance of genetic and environmental factors in producing these unusual phenotypes. These specimens are thus provisionally assigned to Duméril's species. However, due to their uncertain status, neither meristic nor morphological data from this series were used in the redescription of *P. omalonotus*.

### *Pachypanchax sakaramyi* (Holly, 1928)

*Panchax sakaramyi* Holly, 1928:313, Fig. 2 (type locality: "Ein Bach im Gebirge ca. 300 m hoch bei Sakaramy, 30 km landinwärts von Diego Suarez auf Madagascar" [=Sakaramy River, at village of Sakaramy, ca. 30 km south of Antsiranana (Diego Suarez), 12°27'S, 49°16'E, 500 m a. s. l.]). Syntypes: MSNM 56 [ex MSNM 4426 and NMW] (1); NMW 13463–13489 (16).

### Diagnosis

Male *P. sakaramyi* differ from male *P. playfairii*, with which they have been conflated, in lacking raised dorsolateral squamation. Males also lack rows of discrete red dots on the flanks, red edging to the dorsal and anal fins, and a black caudal-fin margin. Their unpaired fins may instead be marked with black basal bands of variable width. Large female *P. sakaramyi* sometimes display a diffuse dusky basal zone in the dorsal fin, but lack the ocellated black basal marking present in the dorsal fin of female *P. playfairii*. *Pachypanchax sakaramyi* has the shortest dorsal fin base ( $10.7 \pm 1.4\%$  SL) of any Malagasy *Pachypanchax*, and further differs from all save one congener in having chest scales significantly smaller than those of the flanks. It differs from *P. sparksorum* **sp. nov.**, which also possesses comparable pectoral squamation, in having a row of scales at the

base of the dorsal and anal fins. Male *P. sakaramyi* differ further in their base color [yellow vs. blue], in having a shorter based dorsal fin and in their more rounded dorsal and anal fins. Female *P. sakaramyi* lack the reduced pattern of reddish-brown spots on the flanks characteristic of female *P. sparksorum*.

#### Description

Morphometric characters appear in Table 4. A *Pachypanchax* of moderate size, with a somewhat rounded snout. The mouth is wide, with the cleft directed upward. A single row of slightly recurved, conical teeth present in each jaw. Ten (13) or 11 (8) branchiospines on first gill arch. Two scale rows present on cheeks. Frontal squamation usually of E-type, with H scales present. In three of 18 specimens examined, the frontal squamation was of the G-type. Cephalic neuromast pattern open in 15 of 18 specimens examined, closed in the remainder. Scales cycloid, 31–32 (mode=31) along the midlateral line. 14–15 (mode=15) transverse scale rows immediately anterior to origin of anal fin; 20–22 (mode=22) scale rows around caudal peduncle. Deviations from modal values were observed only in aquarium-reared specimens. Scales on chest approximately one-third size of those on flanks. Vertebrae 14 pre-caudal + 16 caudal.

**TABLE 4.** Morphometric data for *Pachypanchax sakaramyi*, based upon 19 specimens collected from the Sakaramy River at Ambohitra.

Measurement	Range	Mean $\pm$ SD
Standard length (mm)	21.3–66.3	2
In percentages of standard length		
Head length	25.5–30.5	28.0 $\pm$ 1.4
Snout length	4.8–8.8	7.3 $\pm$ 1.3
Eye diameter	7.3–10.4	8.8 $\pm$ 1.0
Interorbital distance	11.4–15.1	13.2 $\pm$ 0.9
Postorbital distance	9.8–14.0	11.5 $\pm$ 1.1
Maximum depth	19.9–25.7	22.3 $\pm$ 1.4
Longest pectoral-fin ray	13.8–18.9	16.3 $\pm$ 1.4
Predorsal length	68.6–76.6	73.7 $\pm$ 2.1
Prepelvic length	47.0–52.3	50.0 $\pm$ 1.6
Preanal length	56.7–65.6	61.5 $\pm$ 2.3
Length of dorsal-fin base	7.0–12.7	10.3 $\pm$ 1.9
Length of anal-fin base	18.1–22.8	20.5 $\pm$ 1.3
Length of caudal peduncle	20.5 $\pm$ 1.3	16.9 $\pm$ 1.6
Depth of caudal peduncle	11.8–15.7	13.8 $\pm$ 0.9

Dorsal-fin origin above midpoint between origins of tenth and eleventh anal-fin rays. Dorsal-fin rays ii,9 (6); ii,10 (16); ii,11 (3). Sixth or seventh branched dorsal ray longest in both sexes. Anal fin rays ii,14 (9); ii,15 (10); ii,16 (14); iii,16 (7); ii,17 (4); iii,17 (5). Eleventh or twelfth anal ray longest in males, seventh or eighth ray longest in females. Longest ray in neither dorsal nor anal prolonged in either sex. Bases of dorsal and anal fins scaled. Caudal fin rounded truncate, the basal half to seven eighths heavily scaled. Pelvic-fin rays i,5. Pectoral-fin rays 14–16 (mode=16).

#### *Coloration*

Living specimens: Figure 6 depicts a reproductively active captive-bred male from the Sakaramy River population. Figure 7 depicts a wild-caught female of the same provenance.



**FIGURE 6.** *Pachypanchax sakaramyi*, captive-bred ( $F_3$ ) male, 71.0 mm SL. Descended from founders collected from the Sakaramy River at Ambohitra.

Preserved specimens (males): Dorsum, top of head, and lips dark brown. Dark gular bar absent. Upper half of flanks light brown anteriorly, shading to beige posteriorly. Scales on upper half of body narrowly edged in darker brown. Cheeks, opercula, throat, lower half of the flanks and venter yellowish-white. Dorsal and anal fins light brown. A narrow black basal band variably present on both fins. Caudal fin beige basally, shading to gray distally; a pattern of light brown interradial dots present basally; narrow black submarginal bands variably present along the upper and lower leading edges of fin. Ventral fins beige basally, shading to gray distally. Pectoral fins hyaline.





**FIGURE 7.** *Pachypanchax sakaramyi*, wild-caught female, 62.0 mm SL. Sakaramy River at Ambohitra.

(Females): Coloration similar to males, but with an indistinct dark basal zone present on dorsal fin. All other fins hyaline.

#### *Range*

*Pachypanchax sakaramyi* was originally described (Holly, 1928) from specimens collected in the Sakaramy River, at the village of the same name (12°27'S, 49°16'E), ca. 30 km south of the city of Antsiranana [Diego Suarez], at 500 m above sea level. The Sakaramy is a tributary of the Sahakazoambany River, which flows into the Bay of Ambavarano at 12°26'S, 48°29'E. The only extant riverine populations of this species are restricted to a short stretch of the river between Ambohitra [Joffreville] and the village of Sakaramy, and to the upper reaches of the adjacent Antongombato River (Figure 5). Specimens in the collection of the MNHN, as well as data from interviews carried out in 1996 and 2001, suggest that *P. sakaramyi* was aboriginally present along the northern and eastern versant of the Ambohitra Massif, a Plio-Pleistocene volcanic formation that dominates the northern extremity of Madagascar, from the Antongombato River east and southwards to the headwaters of the Irodo River in the vicinity of the town of Anivorano. According to local informants, *P. sakaramyi* is still found in several low-altitude crater lakes, notably Farihy Texier and the nearby Farihy Fantany. Published reports to the contrary (Arnoult, 1959), this species does not occur in the Grand Lac, a high altitude crater lake situated to the west of the hydrographic divide, nor in any of the other high-

altitude crater lakes located within the boundaries of Manokan' Ambohitra [Montagne d'Ambre] National Park (Loiselle and Ferdenzi, 1997). De Rham (2000a, b) reports finding a population of superficially *sakaramyi*-like *Pachypanchax* in a westward-flowing stream on the southern piedmont of the Ambohitra Massif on the road between Bobasokoa and Anivorano, near the village of Andranotohiliny. The identity of this population remains to be verified, but should these fish prove to be *P. sakaramyi* the range of this species would comprise both slopes of the Ambohitra Massif.

#### *Natural history*

*Pachypanchax sakaramyi* inhabits high-gradient streams flowing under both degraded and intact forest cover and the peripheral waters of low-altitude crater lakes. Individuals of all sizes occur in both areas of strong current and tranquil pools, but are most abundant in the latter. Water temperatures between 20.5° and 22.2° C. were measured in partially shaded segments of the Sakaramy River in October. The water of the Sakaramy River and other streams draining the Ambohitra Massif is free of suspended matter, unstained by tannins, moderately soft (total and carbonate hardness 36.0–72.0 ppm), slightly alkaline (pH 7.2–7.5) and deficient in dissolved substances (conductivity 58.0–75.0  $\mu\text{S}/\text{cm}^2$ ).

Stream bottoms range from bare bedrock to rounded basaltic cobble, interspersed with boulders up to 60 cm in diameter. Waterlogged branches are common along the margins of larger pools. No submerged aquatic plants were observed growing in the upper Sakaramy River, although a dwarf form of the umbrella papyrus, *Cyperus alternifolius*, does occur in small numbers wherever the stream margin is well illuminated. The Madagascar lace plant, *Aponogeton madagascariensis*, an unidentified epilithic Podostemonaceae and the exotic water hyacinth, *Eichornia crassipes*, were observed growing in *P. sakaramyi* habitat in the Antsahalalina River.

*Pachypanchax sakaramyi* has been observed feeding upon both stranded terrestrial insects at the surface of the water and upon small aquatic invertebrates taken from the bottom. As the upper Sakaramy River is devoid of other fish, its only enemies therein appear to be the Malagasy malachite kingfisher, and predatory invertebrates such as dragonfly nymphs and large prawns of the genus *Macrobrachium*. According to local informants, this species was formerly sufficiently abundant to be harvested for domestic consumption using *tandroho* (wicker fishing baskets).

Juvenile *P. sakaramyi* live in loose associations of up to a dozen individuals in the shallows. Adults frequent deeper water away from the banks. Large individuals of both sexes are solitary. Females tend to swim slowly in a stop-go manner, while males are in constant, active motion throughout their habitat. Territorial behavior was not observed, although courtship and spawning were. This suggests a consort-type mating system, in which males contend for access to ripe females rather than for control of spawning sites. No aggressive interactions were observed between males. However, as the fins of wild-caught males often show bite marks, bouts of serious fighting must occasionally occur.

Juveniles ranging in size from 1.0–3.0 cm TL were observed in both the Sakaramy and Antsahalalina rivers in 1994 and 1995. Based upon observations of the growth rate of juveniles in captivity, this size distribution suggests either a completely aseasonal reproductive pattern or a very protracted breeding season extending from early spring through the austral summer and into the autumn. Spawning was observed in October of 1995. The courting male assumes a position alongside and slightly to the rear of the female and attempts to maintain body contact while driving her towards a spawning site. Oviposition follows the typical cyprinodont pattern, with the pair assuming an S-curve, both sexes quivering intensely for a moment and the female then jerking abruptly away from the male. Multiple bouts can occur in rapid succession. Pairs were observed spawning upon waterlogged branches and among the cobbles of the stream bottom.

#### *Conservation status*

*Pachypanchax sakaramyi* has been extirpated from most of its aboriginal range since its description in 1928. Local residents ascribe its disappearance to predation by introduced *Poecilia reticulata* and *Gambusia holbrooki* upon *P. sakaramyi* fry. These observations are consistent with the known impact of introduced *G. holbrooki* upon populations of indigenous cyprinodontiform fishes elsewhere (Courtenay and Meffe, 1989; Galat and Robertson, 1992). A factor of equal importance is ongoing deforestation of the Ambohitra Massif, which changes the hydrological regime of small streams from permanent to intermittent, resulting in the extirpation of their populations of *P. sakaramyi*. The most recent loss of habitat was occasioned by the diversion of the source of the Sakaramy River in 2000 to provide drinking water for several private residences and the guesthouse of the Benedictine monastery located on the outskirts of Ambohitra. This has resulted in the virtual disappearance of the robust population of this species formerly present in the headwaters of the Sakaramy River (Loiselle and Ferdenzi, 1997). At present, substantial riverine populations of *P. sakaramyi* persist only in the stretch of the river between Ambohitra and the village of Sakaramy and in the headwaters of the adjacent Antongombato River (O. Lucanus, pers. com.).

*Pachypanchax sakaramyi* is thus classified as critically endangered, following the criteria established by the World Conservation Union (Raminosoa *et al.*, 2002). A managed population has been established in North America and Europe, but barring the immediate implementation of an aggressive program of habitat protection and restoration, the extirpation of the remaining riverine populations appears inevitable.

#### *Discussion*

Arnoult (1959) regarded *P. sakaramyi* as a subspecies of *P. playfairii*, apparently on the basis of superficial similarity in overall facies and coloration. However, as noted in the Diagnosis, male *P. sakaramyi* lack the raised dorsolateral squamation of topotypical *P. playfairii*, and both sexes differ significantly from their Seychellois congener in details of

coloration. The two taxa also manifest significant behavioral differences in captivity (Loiselle and Ferdenzi, 1997). Kiener (1963) apart, Arnoult's assessment of its taxonomic status has not been accepted by subsequent workers, who have continued to afford *P. sakaramyi* full specific rank (Scheel, 1968; Parenti, 1981; Lazarra, 1984). Subsequent genetic studies have confirmed the distinctiveness of these two taxa at the species level (Collier, pers. com.).

***Pachypanchax varatraza* sp. nov.**

**Holotype:** AMNH 235858 (male, 63.3 mm SL), Mahazava Creek at village of same name (13°52'97"S, 49°56'22"E), 30 m a.s.l. (Ampanobe drainage), P. V. Loiselle and J. Miandrizava, 9 Oct. 2000.

**Paratypes:** AMNH 231244 (8, 29.9–53.5 mm SL), paratopotypes, collected with holotype. AMNH 235519 (1, 64.2 mm SL), Andampy Creek, at Ampizametana Village (13°31'15"S, 49°49'73"E), 70 m a.s.l. (Menambery drainage), P. V. Loiselle and J. Miandrizava, 8 Nov. 2000. AMNH 211333 (7, 24.0–40.1 mm SL), Antafiabe Creek, at Antsahandrero Village (13°39'05"S, 49°39'00"E) (Fanambana drainage), C. J. Raxworthy, 24 April 2002.

*Diagnosis*

*Pachypanchax varatraza* differs from *P. playfairii* in lacking raised dorsolateral squamation, and in details of its color pattern. Males lack rows of discrete red dots on the flanks and red edging to the vertical fins. Females lack any sort of black markings on the dorsal fin. *Pachypanchax varatraza* has the shortest pectoral fins ( $13.4 \pm 1.6\%$  SL) of any Malagasy *Pachypanchax*. The absence of pectoral scales of reduced size distinguishes both sexes from *P. sakaramyi* and *P. sparksorum* **sp. nov.** The rounded dorsal and anal fins of males and their lack of discrete metallic gold spangling on the flanks set them apart from *P. omalonotus*, whereas the absence of iridescent white edging to, or darker submarginal banding on, the vertical fins distinguishes it from the remaining Malagasy congeners.

*Description*

Morphometric characters appear in Table 5. A robust *Pachypanchax*, capable of reaching 80.0 mm SL in nature, with a distinctly pointed snout. Mouth wide, with cleft directed upward. A single row of slightly recurved, conical teeth present in each jaw. Ten (5), 11(10) or 12 (2) branchiospines on first gill arch. Two scale rows present on cheeks. Frontal squamation of E-type, with H scales present. Cephalic neuromast pattern open in all specimens examined. Scales cycloid, 30–32 (modes=31, 32) along midlateral line. Fourteen transverse scale rows immediately anterior to origin of anal fin; 20 scale rows

around caudal peduncle. Scales on chest same size as those on flanks. Vertebrae 14 precaudal + 16 caudal.

**TABLE 5.** Morphometric data for *Pachypanchax varatraza* **sp. nov.**, based upon the 17 specimens of the type series.

Measurement	Range	Mean $\pm$ SD
Standard length (mm)	28.7–64.2	
In percentages of standard length		
Head length	25.8–31.3	28.1 $\pm$ 1.8
Snout length	6.7–9.2	7.9 $\pm$ 0.7
Eye diameter	7.4–9.4	8.6 $\pm$ 0.7
Interorbital distance	10.8–13.9	12.5 $\pm$ 0.7
Postorbital distance	9.8–13.9	11.5 $\pm$ 1.2
Maximum depth	19.3–23.7	22.0 $\pm$ 1.4
Longest pectoral-fin ray	10.3–15.2	13.7 $\pm$ 1.3
Predorsal length	66.4–78.2	74.3 $\pm$ 3.1
Prepelvic length	45.3–53.8	48.7 $\pm$ 2.5
Preanal length	56.2–64.1	61.7 $\pm$ 2.2
Length of dorsal-fin base	9.1–15.5	12.7 $\pm$ 1.7
Length of anal-fin base	17.1–26.7	21.5 $\pm$ 2.8
Length of caudal peduncle	13.0–18.1	16.0 $\pm$ 1.1
Depth of caudal peduncle	11.3–14.9	13.4 $\pm$ 1.1

Dorsal fin origin above midpoint between origins of ninth and tenth anal fin rays. Dorsal fin rays iii,8 (3); iv,8 (1); iii,9 (6); iii,10 (6); ii,11 (1). Seventh or eighth dorsal ray longest in both sexes. Anal-fin rays iii,14 (1); iii,15 (6); ii,16 (8); iii,16 (1); ii,17 (2). Fifteenth or sixteenth anal ray longest in males, seventh or eighth longest in females. Bases of both dorsal and anal fins scaled. Caudal fin rounded truncate, with basal half heavily scaled. Pelvic-fin rays i,5. Pectoral-fin rays 14–16 (mode=16).

#### Coloration

Living specimens: This species is characterized by male color polymorphism. Figure 8 depicts the red morph and Figure 9 the green morph of *P. varatraza*. Rusty brown to maroon edging is present on the scales of the posterior half of the body in all individuals of the green morph, but its extent and intensity varies among populations. Males of the Ampanobe basin population have redder unpaired fins and the maroon scale edging on the flanks is more intense. Figure 10 depicts an adult female.



**FIGURE 8.** *Pachypanchax varatraza* **sp. nov.**, wild-caught red morph male, 68.0 mm SL. Mahazava Creek (Ampanobe drainage).



**FIGURE 9.** *Pachypanchax varatraza* **sp. nov.**, captive-bred (F<sub>1</sub>) green morph male, 57.0 mm SL. Andampy Creek (Menambery drainage).



**FIGURE 10.** *Pachypanchax varatraza* sp. nov., wild-caught female, 62.0 mm SL. Mahazava Creek (Ampanobe drainage).

Preserved specimens: Males: Dorsum and top of the head reddish brown, shading to off-white on lower third of flanks and venter. A faint dark midlateral stripe, one scale row deep, extends along flanks from posterior margin of orbit to base of caudal peduncle. Cheeks, opercula and throat off-white. Dorsal fin clear gray, with a well-developed pattern or darker interradiial dots present in its posterior third. Anal fin clear gray basally, with traces of a narrow darker submarginal band. Caudal fin clear gray, with a pattern of fine dark interradiial dots on basal two-thirds. Pelvic fins clear gray, pectorals hyaline. Females: Similar to males, but longitudinal stripe fainter and all vertical fins hyaline, with interradiial dots less evident.

#### *Etymology*

*Varatraza* is the Malagasy word for the east wind. The name acknowledges the unanticipated presence of a *Pachypanchax* species in rivers draining the eastern slope of the Tsaratanana Massif, and is to be treated as a noun in apposition.

#### *Range*

*Pachypanchax varatraza* is native to the basins of the Menambery, Fanambana and Ampanobe rivers in northeastern Madagascar (Figure 5). South of the Ampanobe, *Pachypanchax* is replaced by representatives of the ecologically analogous endemic atheriniform family Bedotiidae.

*Natural history*

*Pachypanchax varatraza* inhabits a wide range of habitats. The Menambery population was collected from the Andampy, a small stream flowing under relatively intact forest cover at an altitude of 70 m above sea level. At this point, the stream consists of a series of quiet pools with clay/sand bottoms, interspersed with short stretches of flowing water over sand/gravel bottoms. The water was very turbid, with ca. 20.0 cm visibility, slightly acidic (pH: 6.5), soft (general hardness < 18.0 ppm, carbonate hardness 36.0 pp), with a conductivity of 49.0  $\mu\text{S}/\text{cm}^2$ . Extensive stands of *Marsilea* sp. were present in the shallows of flowing stretches of the stream. Neither filamentous algae nor other aquatic macrophytes were observed. No other fish were captured, but a small atyid shrimp and a variety of aquatic insects, including dragonfly nymphs and the adults of a number of aquatic Coleoptera and Hemiptera, were present. According to local informants, *P. varatraza* is relatively rare at this altitude, but becomes more abundant as one moves upstream towards the headwaters of the Andampy.

Representatives of the Ampanobe basin population were collected from the Mahazava, a small stream flowing through modified low-altitude rain forest at an altitude of 30 m above sea level. The bottom was clay/sand, interspersed with patches of bedrock. The water was clear and the current moderate. No aquatic macrophytes or attached algae were observed. *Gambusia holbrooki* and fry of *Oreochromis mossambicus* were also collected. According to local informants, large gobies of the genera *Awaous* and *Glossogobius*, atyid shrimps, and freshwater crabs also occur in the Mahazava.

Feces of freshly captured specimens contained recognizable remains of both the imagos of terrestrial and the nymphs and larvae of aquatic insects. This suggests that, like its congeners, *P. varatraza* feeds both at the surface and from the bottom. The most likely predators of adults of this species in both the Menambery and Ampanobe basins are *Glossogobius giuris* and the Malagasy malachite kingfisher.

Specimens from both localities collected in early October began spawning within three weeks after their arrival in the United States in early November. Based upon observations of the growth rate of juveniles in captivity, the size distribution of specimens from the Andampy suggests a protracted breeding season lasting through the austral summer, which coincides with the rainy season in northeastern Madagascar.

*Conservation status*

This species has been extirpated from the lower reaches of the Menambery, Fanambana and Ampanobe rivers by an exotic predator, *Channa maculata*. It persists in one high-gradient tributary of the upper Menambery, whose watershed lies in a surviving patch of forest. As a result of deforestation, the remaining headwater s tributaries of this river are devoid of water during the dry season, and thus are no longer viable *Pachypanchax* habitats. The basin of the Fanambana is subject to the same sharply seasonal pattern of precipitation, but as its watershed is not deforested to the same degree



as that of the Menambery, habitat loss has not affected *P. varatraza* as seriously. The Ampanobe River marks the transition between the rain forest of the east coast and deciduous forest of Madagascar's extreme north (Gautier and Goodman, 2003). Its watershed benefits from a less seasonal pattern of rainfall and retains most of its forest cover. While the presence of *G. holbrooki* in the middle and upper reaches of the Ampanobe is cause for concern, the dominance of vanilla culture in the local economy strongly discourages extensive deforestation. This should prevent the large-scale habitat loss that has negatively impacted *P. varatraza* in the Fanambana drainage and threatens its survival in the Menambery.

Following the criteria established by the World Conservation Union (Raminosoa *et al.*, 2002), *P. varatraza* is thus classified as a species of special concern, whose status needs to be monitored on a regular basis.

#### ***Pachypanchax patriciae* sp. nov.**

**Holotype:** AMNH 232450 (male, 43.8 mm SL), Ampandra River ca. 2 km upstream of village of the same name (13°24'90"S, 48°50'20"E), altitude of 44 m a.s.l, P. V. Loiselle and J. Miandrizava, 27 Oct. 2001.

**Paratypes:** AMNH 235860 (11, 28.1–51.8 mm SL), paratopotypes, collected at same time as holotype. AMNH 232426 (8, 26.9–37.5 mm SL), oxbow lake of Ifasy River at Ambodipont (13°22'13"S, 48°52'38"E), altitude 6 m a.s.l., P. V. Loiselle and J. Miandrizava, 24–25 Oct. 2001. AMNH 232452 (5, 29.8–45.6 mm SL), unnamed creek below bridge on RN-5A, flowing into main channel of Mahavavy du Nord River (13°12'46"S, 49°04'38"E), altitude 57 m a.s.l, P. V. Loiselle and J. Miandrizava, 28 Oct. 2001. MNHN 1931 0198 (4, 20.9–40.5 mm SL), Antikotazo Creek, near town of Ambilobe (Mahavavy du Nord drainage), E. G. Waterlot.

#### *Diagnosis*

The absence of raised dorsolateral scales in males and of an ocellated black basal spot in the dorsal fin of females preclude confusion of this species with *P. playfairii*. The scales on the chest are the same size as those on the flanks in *Pachypanchax patriciae*, which clearly differentiates that species from both *P. sakaramyi* and *P. sparksorum* **sp. nov.** The presence of iridescent white edging in the caudal fin of males, as well as a longer caudal peduncle ( $16.1 \pm 1.9$  % SL vs.  $14.7 \pm 1.6$  % SL) and wider orbital diameter ( $9.8 \pm 1.0$  % SL vs.  $7.8 \pm .07$  % SL) differentiate *P. patriciae* from *P. omalonotus*. The dorsal and anal fins of males come to a sharp point in *P. patriciae*, in contrast to the more rounded vertical fins of *P. varatraza* **sp. nov.** and *P. arnoulti* **sp. nov.** It differs further from *P. varatraza* in its longer pectoral fins and from *P. arnoulti* in its shorter head and presence of broad iridescent white caudal and anal-fin margins.

*Description*

Morphometric characters are given in Table 6. A *Pachypanchax* of moderate size, with a distinctly pointed snout. The mouth is wide, its cleft directed upward. A single row of slightly recurved, conical teeth present in each jaw. Nine (1), 10 (22) or 11 (10) branchiospines on first gill arch. Two scale rows present on cheeks. Frontal squamation of E-type, with H scales present. Cephalic neuromast pattern open in all specimens examined. Scales cycloid, 30–32 (mode=32) along midlateral line. Fourteen transverse scale rows immediately anterior to origin of anal fin; 18–20 (mode=18) scale rows around caudal peduncle. Scales on chest same size as those on flanks. Vertebrae 14 precaudal + 17 caudal.

Dorsal-fin origin above midpoint between origins of either the ninth and tenth, or tenth and eleventh anal-fin rays. Dorsal-fin rays iii,8 (2); iv,8 (1); ii,9 (4); iii,9 (3), iv,9 (1), ii,10 (11), iii,10 (10), iv,10(1) ii,11 (2). Seventh or eighth dorsal ray longest in females, eighth or ninth longest in males. Anal-fin rays iii,14 (6); ii,15 (9); iii,15 (2); ii,16 (10); iii,16 (7), iii,17 (2). Fourteenth or fifteenth anal ray longest in males, seventh or eighth longest in females. Bases of both dorsal and anal fins scaled. Caudal fin rounded truncate, basal third to half heavily scaled. Pelvic-fin rays i,5. Pectoral-fin rays 13–15 (mode=14).

**TABLE 6.** Morphometric data for *Pachypanchax patriciae*, based upon the 29 specimens of the type series and 5 additional specimens collected from Matsabory Farengniny at Ampasindava Village.

Measurement	Range	Mean $\pm$ SD
Standard length (mm)	26.9–51.8	
In percentages of standard length		
Head length	24.8–32.3	28.8 $\pm$ 1.6
Snout length	5.6–10.1	7.7 $\pm$ 1.1
Eye diameter	7.4–11.6	9.8 $\pm$ 1.0
Interorbital distance	10.6–14.4	12.8 $\pm$ 0.8
Postorbital distance	8.8–14.6	11.5 $\pm$ 1.5
Maximum depth	21.8–25.8	23.6 $\pm$ 1.1
Longest pectoral-fin ray	12.6–19.0	16.6 $\pm$ 1.4
Predorsal length	68.5–77.8	74.3 $\pm$ 2.1
Prepelvic length	45.0–56.8	50.0 $\pm$ 2.5
Preanal length	59.3–67.2	63.0 $\pm$ 1.8
Length of dorsal-fin base	9.6–15.6	12.3 $\pm$ 1.4
Length of anal-fin base	17.2–26.6	21.6 $\pm$ 2.5
Length of caudal peduncle	11.9–19.3	16.3 $\pm$ 1.7
Depth of caudal peduncle	12.3–17.7	14.3 $\pm$ 1.0

### Coloration

Living specimens: This species is characterized by male color polymorphism. Figures 11 and 12 depict males of the red and blue morphs, respectively, while Figure 13 depicts an adult female. The percentage of each color form varies between populations, with red males disappearing completely as one moves from south to north. Figure 14 represents the frequency of occurrence of each color form in populations sampled in 2001.

Preserved specimens: Males: Dorsum and top of the head reddish brown, shading to off-white on lower third of flanks and on venter. Dark longitudinal stripe, ca. one scale row deep, extending from posterior margin of eye to origin of pectorals. A faint dark midlateral stripe, two scale rows deep, extending along flanks from edge of operculum to base of caudal peduncle. Lower jaw narrowly edged in dark gray. Cheeks, opercula and throat off-white. Dorsal clear gray, with a broad dark gray distal margin. Anal fin clear gray basally, darker gray distally, with a narrow clear distal margin present anteriorly. A narrow dark gray submarginal band variably present. Caudal fin clear gray, with a pattern of fine dark inter-radial dots in its median portion and a narrow dark gray distal margin along upper and lower leading edges. Pelvic fins clear gray, pectoral fins hyaline. Females: Similar to males, but longitudinal stripe less evident and all fins uniformly hyaline.



**FIGURE 11.** *Pachypanchax patriciae* sp. nov., wild-caught red morph male, 50.0 mm SL. Ampandra River.

### Etymology

The species name honors Patricia Yazgi, and recognizes her support of ongoing efforts to document and conserve the Malagasy freshwater ichthyofauna.



**FIGURE 12.** *Pachypanchax patriciae* **sp. nov.**, wild-caught blue morph male, 51.0 mm SL. Matsabory Farengniny (Mananjeba drainage).



**FIGURE 13.** *Pachypanchax patriciae* **sp. nov.**, wild-caught female, 47.0 mm SL. Ampandra River.

#### *Range*

*Pachypanchax patriciae* is native to the basins of the Mananjeba, Mahavavy du Nord, Ifasy, Manehoko and Ampandra rivers in northwestern Madagascar (Figure 5).

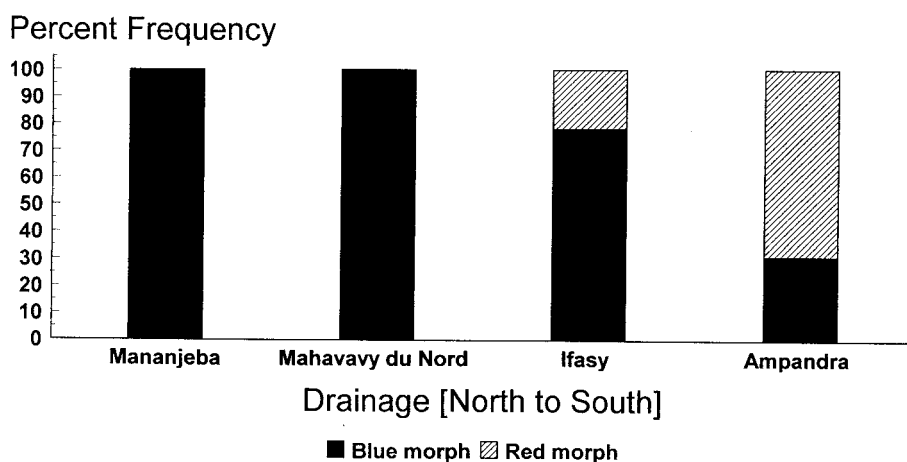


FIGURE 14. Representation of red and blue morph males in four different populations of *P. patriciae*.

#### Natural history

The range of *P. patriciae* spans two distinct biomes, the monsoon or Sambirano forest of the northwest, and the deciduous forest of the extreme north of Madagascar, with the Ifasy River marking the transition between the two. The Ampandra and Manehoko are small rivers flowing through the somewhat degraded Sambirano forest. Limnologically, they resemble the streams draining the eastern versant of Madagascar. Their waters are tannin stained, acidic (pH: 5.0–6.0), very soft (GH and KH < 18.0 ppm), and deficient in dissolved substances (conductivity: 19–24  $\mu\text{S}/\text{cm}^2$ ). Their bottoms are compacted clay/sand, overlain with organic detritus. Extensive stands of the emergent aroid *Typhonodorum lindleyanum* and both blue and white-flowered *Nymphaea* are present in their shallows, but neither filamentous algae nor other aquatic macrophytes were observed. Juvenile *Oreochromis mossambicus*, small atyid shrimps, and a wide variety of aquatic insects were collected syntopically with *P. patriciae*. Local residents interrogated about the presence of other fish species recognized photographs of *Paratilapia polleni*, *Ptychochromis oligacanthus* and *Glossogobius giuris*, and indicated that, together with *Anguilla bicolor*, all three inhabited deeper water.

The Ifasy, Mahavavy du Nord and Mananjeba are larger rivers more typical of streams draining the western versant of Madagascar. They are characterized by a markedly seasonal hydrological regime and substantial flood plains, which contain numerous *matsabory* (shallow lakes). Their waters range from clear to turbid, but are never tannin-stained, are less acidic (pH: 6.5–7.2), harder (total and carbonate hardness 36.0–71.6 ppm), and carry a greater concentrations of dissolved minerals (conductivity: 38–74  $\mu\text{S}/\text{cm}^2$ ).

According to local informants, *Pachypanchax* are restricted to such lakes and to small tributary streams of these three rivers. Matsabory Faregniny, in the flood plain of the

Mananjeba, was characterized by turbid water, a compacted clay bottom, the presence of much waterlogged wood and the absence of aquatic macrophytes or filamentous algae. Juvenile *Tilapia zillii* and *O. mossambicus* were the only other fish captured there. The water of the unnamed lake in the Ifasy basin where *P. patriciae* was found had clear water and a clay/sand bottom overlain with a thin layer of organic detritus. It was bordered by an extensive marshy zone dominated by emergent sedges that gave way to a white-flowered *Nymphaea* species in deeper water. Neither filamentous algae nor other aquatic macrophytes were observed. In addition to *P. patriciae*, *Paratilapia polleni*, atyid shrimps and a wide variety of aquatic insects were collected there.

A small unnamed creek flowing into the main channel of the Mahavavy du Nord was the final site from which this species was collected. The water was clear, with minimal flow evident. The bottom consisted of sand/clay, heavily overlain with organic detritus. Stands of a *Marsilea* species and clumps of filamentous green algae were present. *Pachypanchax patriciae* was the only fish caught, although dragonfly nymphs and an assortment of aquatic Coleoptera and Hemiptera was also present.

Feces of freshly captured specimens contained recognizable remains of both the imagos of terrestrial and the nymphs and larvae of aquatic insects. While this species is at risk from both predatory aquatic insects and such piscivorous fishes as *P. polleni* and *G. giuris*, its most important predators in most habitats appear to be fish-eating birds and dragonfly nymphs.

Specimens collected in early October began spawning within a week after their arrival in the United States in early November. Based upon observations of the growth rate of juveniles in captivity, the size distribution of specimens from the Ampandra and Manehoko Rivers and from the Matsabory Farengniny suggests a protracted breeding season lasting through the austral summer.

#### *Conservation status*

This widely distributed species presently faces no threats from introduced predators or competitors. However, habitat loss caused by deforestation of the watersheds of the Mananjeba, Mahavavy du Nord and Ifasy rivers threatens the survival of the northern populations of *P. patriciae*. This species is thus classified as vulnerable following the criteria established by the World Conservation Union (Raminosoa *et al.*, 2002).

#### *Pachypanchax sparksorum* sp. nov.

**Holotype:** AMNH 235770 (male, 53.6 mm SL), Bentainkilotra Creek (14°52'20"S, 48°14'52"E), (Ankofia River drainage), collected by P. V. Loiselle and J. Rasoloarinianina, 16 Oct. 2004.

**Paratypes:** AMNH 235771 (9, 39.7–49.7 mm SL), paratopotypes, collected with holotype. AMNH 215504 (1 male, 55.0 mm SL), Anjingo River (Ankofia drainage), at km

40 on the Antsohihy-Bealanana road, P. de Rham, Oct. 1992. UMMZ 240104 (8, 26.7–55.3 mm SL), Behmamavony Creek, in Bora Special Nature Reserve (14°52'20"S, 48°14'52"E) (Ankofia drainage), J. S. Sparks and K. Riseng, 31 July 1994. UMMZ 240415 (5, 26.4–37.8 mm SL), Behmamavony Creek, at same locality as preceding series, J. S. Sparks and K. Riseng, 15 Nov. 1994.

### Diagnosis

The absence of raised dorsolateral scales in males and of an ocellated black basal spot in the dorsal fin of females preclude confusion of this species with *P. playfairii*. The reduced size of its pectoral scales sets it apart from all Malagasy congeners save *P. sakaramyi*, from which it differs in its unscaled dorsal and anal fin bases, its longer dorsal-fin base ( $12.8 \pm 1.8\%$  vs  $10.3 \pm 1.9\%$  SL), the presence of discrete red spots and faint reddish-brown spots on the flanks of males and females, respectively, and the presence of a narrow black anal-fin margin in males.

### Description

Morphometric characters appear in Table 7. A *Pachypanchax* of moderate size with a distinctly pointed snout. Mouth wide, cleft directed upward. A single row of slightly recurved, conical teeth present in each jaw. Ten to 11 (mode=11) branchiospines on first gill arch. Two scale rows present on cheeks. In the largest male and in two smaller individuals from UMMZ 240104, the frontal squamation is of the G-type, without H scales. In all other specimens examined, the frontal squamation is of the E-type. H scales are absent in five of the 24 specimen examined, and present in the remainder. Cephalic neuromast pattern closed in two individuals from AMNH 235771, open in the remaining specimens examined. Scales cycloid, 32–33 (mode=33) along midlateral line. Fourteen transverse scale rows immediately anterior to origin of the anal fin; 18–20 (mode=18) scale rows around caudal peduncle. Scales on chest half the size as those on flanks. Vertebrae 14 pre-caudal + 17 caudal.

Dorsal-fin origin above midpoint between origins of eighth and ninth anal-fin rays. Dorsal-fin rays iii,8 (1); iv,8 (1); iii,9 (1); iv,9 (3); ii,10 (3); iii,10 (3); iii,11 (3). Eighth or ninth dorsal ray longest in males, seventh or eighth longest in females. Anal-fin rays iii,14 (1); ii,15 (2); iii,15 (1); ii,16 (7); iii,16 (1); ii,17 (1); iii,18 (1). Fourteenth or fifteenth anal ray longest in males, ninth or tenth longest in females. Base of dorsal and anal fins unscaled. Caudal fin rounded truncate, basal half to three quarters heavily scaled. Pelvic-fin rays i,5. Pectoral-fin rays 14–16 (mode=16).

### Coloration

Living specimens: Figures 15 and 16 depict an adult male and female *P. sparksorum*.

Preserved specimens (Males): Dorsum, top of head, and lips reddish brown, shading to off-white on cheeks, operculum, lower third of flanks and venter. No dark longitudinal stripe present on flanks, but scales on posterior two-thirds of body with dark centers.

Posterior third of body marked with indistinct narrow vertical lines. Dorsal and anal fins clear gray, with a narrow black margin and a complex pattern of dark interradiial streaks and dots. Basal two thirds of caudal fin clear gray, with a pattern of fine dark interradiial dots. Distal third of caudal fin hyaline. A fine black distal margin present along the lower leading edge in some specimens. Pelvic fins clear gray with a darker leading edge. Pectoral fins hyaline. (Females): Similar to males, but without dark-centered scales or vertical markings on flanks. All fins uniformly hyaline.

**TABLE 7.** Morphometric data for *Pachypanchax sparksorum* **sp. nov.**, based upon the 24 specimens of the type series.

Measurement	Range	Mean $\pm$ SD
Standard length (mm)	26.4–55.3	
In percentages of standard length		
Head length	25.2–30.8	28.1 $\pm$ 1.6
Snout length	5.7–8.6	7.2 $\pm$ 0.8
Eye diameter	6.2–10.4	8.3 $\pm$ 1.2
Interorbital distance	8.8–14.6	12.2 $\pm$ 1.4
Postorbital distance	9.7–13.2	11.3 $\pm$ 1.0
Maximum depth	18.7–24.6	21.5 $\pm$ 1.6
Longest pectoral-fin ray	12.5–17.3	15.2 $\pm$ 1.4
Predorsal length	70.1–76.7	73.1 $\pm$ 1.7
Prepelvic length	47.0–54.7	49.9 $\pm$ 1.9
Preanal length	58.3–67.5	62.9 $\pm$ 2.3
Length of dorsal-fin base	9.6–16.1	12.9 $\pm$ 1.6
Length of anal-fin base	17.7–25.1	20.7 $\pm$ 2.1
Length of caudal peduncle	12.7–21.6	17.8 $\pm$ 1.9
Depth of caudal peduncle	11.3–15.4	13.2 $\pm$ 1.2

#### *Etymology*

The species name honors John S. and Karen Riseng Sparks, who first documented the presence of a distinctive *Pachypanchax* in the Ankofia drainage and collected much of the type series.

#### *Range*

This species has, to date, only been collected from streams flowing into the Ankofia River and from its principal tributary, the Anjingo (Figure 6). The Ankofia empties into the drowned estuary of the Loza River at 14°40'00"S, 48°03'20"E. The presence of *P. sparksorum* in the Maevarano, the next drainage to the north, remains to be confirmed. It is replaced in the Loza basin proper by an undescribed congener.





**FIGURE 15.** *Pachypanchax sparksorum* sp. nov., wild-caught male, 65.0 mm SL. Behmamavony Creek (Ankofia drainage).



**FIGURE 16.** *Pachypanchax sparksorum* sp. nov., wild-caught female, 54.0 mm SL. Behmamavony Creek.

*Natural history*

This species inhabits both the main channel of the Anjingo and Ankofia rivers (de Rham, 2000a) and their small tributary streams flowing through more or less degraded deciduous forest (Sparks, 2002). During the dry season, these streams are shallow, with a moderate current. Their water is clear, with a pH of 6.8–7.0, soft (total hardness 34.2–40.0 ppm), and deficient in dissolved substances (electrical conductivity 28–31  $\mu\text{S}/\text{cm}^2$ ). Stream bottoms are bedrock interspersed with cobble and patches of sand/gravel. The banks of the Ankofia and Anjingo rivers are overgrown with dense overhanging riparian vegetation, but neither filamentous algae nor vascular aquatic plants are present. Here, *Pachypanchax sparksorum* is restricted to the shallows, where it finds shelter along the banks or among rocks, and occurs syntopically with *Arius festinus*, *Teramulus waterloti*, *Ambassis natalensis*, *Scatophagus tetracanthus*, *Ptychochromis inornatus*, *Paretroplus damii*, and unidentified representatives of the families Mugilidae, Eleotridae and Gobiidae. In tributary streams it coexists with *T. waterloti* and *A. natalensis*.

Feces of freshly captured specimens contained recognizable remains of the imagos of terrestrial insects, the nymphs and larvae of aquatic insects, and small freshwater shrimps. The most important predators of this species appear to be predatory aquatic insects and fish-eating birds.

Based upon observations of the growth rate of juveniles in captivity, the size distribution of the type series suggests that *P. sparksorum* breeds throughout the austral summer. While courtship behavior and the mechanics of spawning are similar to what have been observed in other *Pachypanchax*, this species differs from its congeners in that, at least under aquarium conditions, individual eggs may remain attached to the female's vent after fertilization, eventually forming a cluster that falls off several hours later (J. S. Sparks, pers. com.). Such post-fertilization retention of the eggs has been reported from only one other cyprinodontiform species, the Neotropical *Cubanichthys cubensis* (Innes, 1959; Wildekamp, 1995), although it is the norm in the beloniform families Oryziatidae and Adrianichthyidae (Kottelat *et al.*, 1993).

*Conservation status*

*Pachypanchax sparksorum* is present in substantial numbers throughout its range and to date must contend with neither exotic predators nor competitors. However, because of its circumscribed distribution, it is classified as endangered following the criteria established by the World Conservation Union (Raminosoa *et al.*, 2002).

***Pachypanchax arnoulti* sp. nov.**

**Holotype:** AMNH 235862 (male, 58.8 mm SL), F<sub>2</sub> descendant of fish collected from a *Pandanus-Dracaena* swamp draining into a tributary stream of the Ikopa River, flowing

parallel to RN-4 at Antanimbary Village (17°10'79"S, 46°50'97"E), 246 m a.s.l. (Betsiboka River drainage), P. V. Loïsele, R. Haeffner and J. Davidson, 7 Oct. 1997.

**Paratypes:** AMNH 229576 (7, 43.2–55.1 mm SL), paratopotypes, from same stock as holotype. AMNH 229575 (5, 27.2–36.9 mm SL), Boinakely River, immediately below bridge on RN-4 (16°51'49"S, 46°57'80"E), 153 m a.s.l. (Betsiboka River drainage), P. V. Loïsele, R. Haeffner and J. Davidson, 8 Oct. 1997. MNHN 1928 0297 (5, 23.0–35.7 mm SL), Namahota River at Namoroka Village (16°24'S, 45°17'E) (Andranomavo River drainage), G. Petit. MNHN 1963 0173 (7, 24.3–58.2 mm SL), Ampijoroa (Betsiboka drainage), J. Arnoult.

#### Diagnosis

The absence of raised dorsolateral scales and red lateral spots in males and of an ocellated black basal spot in the dorsal of females preclude confusion of this species with *P. playfairii*. It differs from *P. sakaramyi* and *P. sparksorum* **sp. nov.** in lacking reduced pectoral squamation. *Pachypanchax arnoulti* has the longest head ( $30.2 \pm 1.8\%$  SL) of any Malagasy *Pachypanchax*. This feature, together with lack of red coloration on the body and fins, distinguishes it from *P. patriciae* and *P. varatraza*. The combination of more rounded dorsal and anal fins, a longer caudal peduncle ( $17.0 \pm 1.9\%$  SL vs.  $14.7 \pm 1.6\%$  SL), absence of rows of discrete metallic lateral spots and the presence of a narrow iridescent white margin along the anal and lower edge of the caudal in males set it apart from *P. omalonotus*.

#### Description

Morphometric characters are given in Table 8. A *Pachypanchax* of moderate size with a distinctly pointed snout. The mouth is wide, cleft directed upward. A single row of slightly recurved, conical teeth present in each jaw. Nine (1), 10 (11) or 11 (15) branchiospines on the first gill arch. Two (11) or 3 (15) scale rows present on the cheeks. Frontal squamation of E-type, with H scales present. Cephalic neuromast pattern closed in three specimens in the type series, open in the remaining 22 and in all the additional material examined. Scales cycloid, 29–33 (mode=30–31) along the midlateral line. Fourteen or 15 (mode=14) transverse scale rows immediately anterior to origin of anal fin; 16–20 (mode=18) scale rows around caudal peduncle. Scales on chest same size as those on flanks. Vertebrae 14 pre-caudal + 17 caudal.

Dorsal fin origin above midpoint between origins of fifth and sixth anal-fin rays. Dorsal fin rays iii,8 (6); ii,9 (1); iii,9 (2); ii,10 (11); iii,10 (1); ii,11 (4); iii,11 (1); ii,12 (5). Seventh or eighth branched dorsal ray longest in both sexes. Anal-fin rays iii,12 (2); iii,13 (3); ii,14 (1); iii,14 (7); ii,15 (5); iii,15 (3); ii,16 (5); ii,17 (5). Twelfth or thirteenth anal ray longest in males, seventh or eight longest in females. Base of dorsal and anal fins scaled. Caudal fin rounded truncate, basal two-thirds to three-quarters heavily scaled. Pelvic-fin rays i,5. Pectoral-fin rays 14–16 (mode=16).

**TABLE 8.** Morphometric data for *Pachypanchax arnoulti* sp. nov., based upon the 25 specimens of the type series.

Measurement	Range	Mean $\pm$ SD
Standard length (mm)	28.6–55.1	
In percentages of standard length		
Head length	26.9–34.2	30.1 $\pm$ 1.7
Snout length	6.6–11.0	8.3 $\pm$ 1.2
Eye diameter	7.7–11.4	9.0 $\pm$ 1.1
Interorbital distance	10.4–15.5	13.0 $\pm$ 1.1
Postorbital distance	9.9–14.2	12.2 $\pm$ 1.0
Maximum depth	20.1–25.8	22.9 $\pm$ 1.8
Longest pectoral-fin ray	13.3–22.7	16.5 $\pm$ 2.1
Predorsal length	69.5–79.3	73.6 $\pm$ 2.2
Prepelvic length	44.3–55.3	50.9 $\pm$ 2.8
Preanal length	57.6–68.1	63.5 $\pm$ 2.5
Length of dorsal-fin base	10.0–16.8	13.3 $\pm$ 1.7
Length of anal-fin base	16.5–24.7	20.8 $\pm$ 2.1
Length of caudal peduncle	13.4–19.9	16.9 $\pm$ 1.7
Depth of caudal peduncle	12.2–15.8	14.0 $\pm$ 0.7

### Coloration

Living specimens: Figures 17 and 18 depict, respectively, an adult male and adult female of *P. arnoulti*. As they age, individuals of the topotypical population of *P. arnoulti* sometimes develop amelanic patches on the dorsum. These appear as irregular areas of coppery or brassy pigmentation. These aberrant phenotypes occur more frequently in captivity than in the wild, possibly because such wild heteromelanic individuals are more vulnerable to avian predation.

Preserved specimens (Males): Dorsum, upper half of head, lips, and upper third of flanks brown, shading to beige on cheeks, operculum, throat, lower two-thirds of flanks, and venter. Scales of dorsum and upper two-thirds of flanks narrowly edged in dark brown. A pattern of faint, narrow, irregular dark vertical lines present on posterior half of body. Dorsal area gray, narrowly edged anteriorly with opaque white. Caudal fin gray, marked with a pattern of darker inter-radial dots basally and a narrow opaque white margin. Anal fin clear gray, narrowly edged with opaque white and marked basally with light blotches. Pelvic fins clear gray, with a darker leading edge. Pectoral fins hyaline. (Females): As in males, but without dark lines on flanks. All fins hyaline.



**FIGURE 17.** *Pachypanchax arnoulti* **sp. nov.**, captive-bred ( $F_2$ ) male, 70.0 mm SL. Descended from founders collected at Antanimbary (Betsiboka drainage).



**FIGURE 18.** *Pachypanchax arnoulti* **sp. nov.**, captive-bred ( $F_2$ ) female 63.0 mm SL. Descended from founders collected at Antanimbary (Betsiboka drainage).

*Etymology*

The species name honors Jacques Arnoult, in recognition of his many contributions to Malagasy ichthyology, and who first introduced this and other fishes from Madagascar to science and to the aquarium hobby in the 1950's.

*Range*

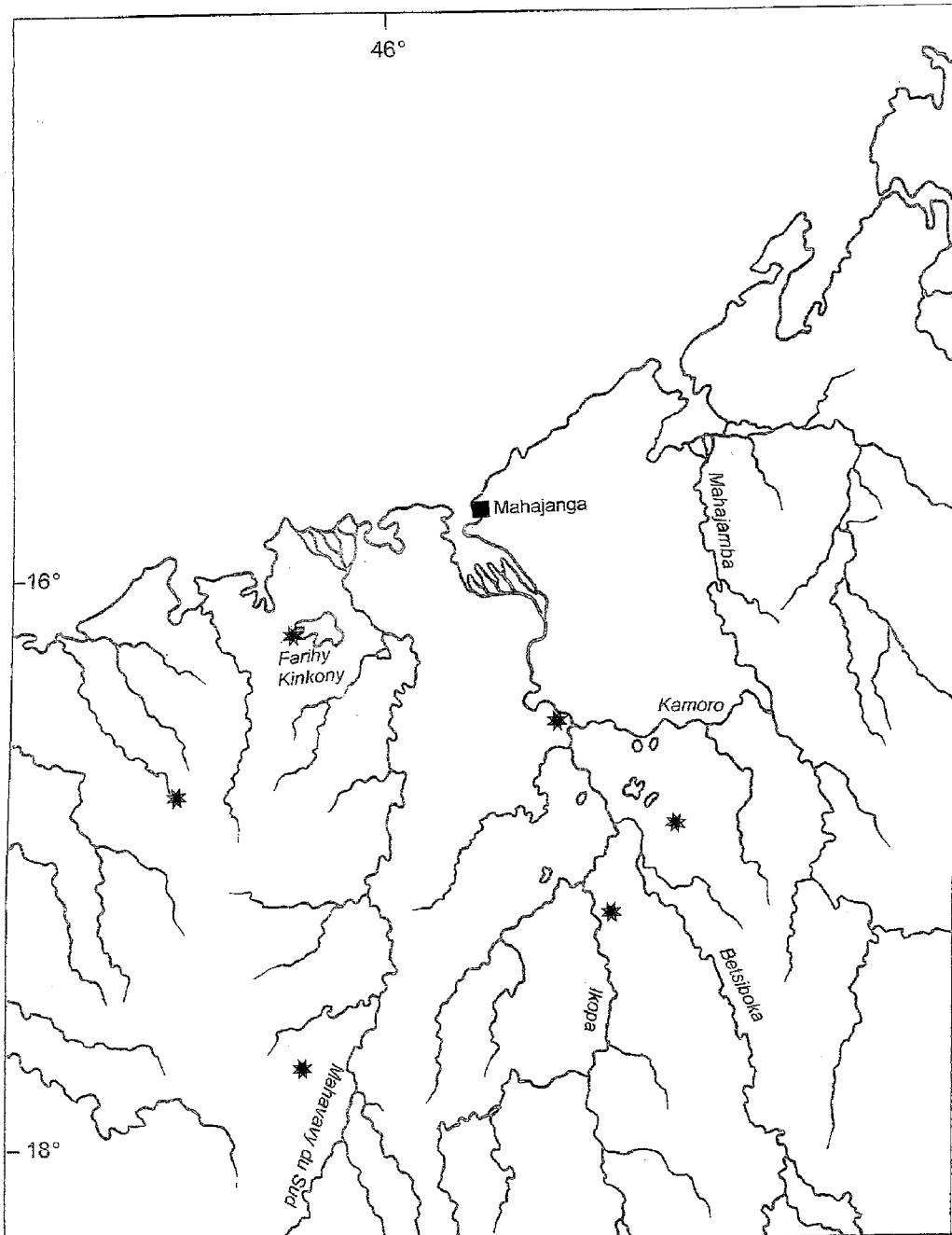
*Pachypanchax arnoulti* is native to the basins of the Mahavavy du Sud and the Betsiboka, to the small independent streams that flow into the Mozambique Channel between the estuaries of the Betsiboka and Mahavavy du Sud, and to Lake Kinkony and its satellite lakes (Figure 19). It has also been collected from a hill stream draining the Tampoketsa highlands, which crosses the Antananarivo-Maevatanana road at the Kilometre 240 marker, 53 km east of the town of Maevatanana, and from the upper Kamoro drainage (P. de Rham, pers. com.). Its presence in the Mahajamba drainage, which lies to the north of the Betsiboka and is connected to it by the Kamoro, is probable but has yet to be confirmed. It is replaced in the Sofia River basin by an undescribed congener. Reports of this species from the Soahany drainage near the town of Antsalova, south of the Mahavavy du Sud (de Rham, 2000a), require confirmation.

*Natural history*

This species, like *P. patriciae*, has been collected from a wide range of habitats. The type locality is a *Pandanus-Dracaena* swamp, whose waters are clear, tannin stained, acidic (pH of 6.2), soft (total hardness < 17.1 ppm), and deficient in dissolved substances (electrical conductivity 16  $\mu\text{S}/\text{cm}^2$ ). Neither filamentous algae nor vascular aquatic plants were present. *Xiphophorus hellerii* was also collected from the swamp's outflowing stream, but *P. arnoulti* was the only species present in the swamp proper, which did supports a diverse assemblage of aquatic Coleoptera and Hemiptera.

This species was also collected in a small creek flowing into the Akalimolitra River, a tributary of the Betsiboka, and was observed in the shallows of the main channel of the Akalimolitra proper. Its waters were clear, colorless, with a neutral pH, moderate hardness (total hardness 68.4 ppm), and deficient in dissolved substances (electrical conductivity 34  $\mu\text{S}/\text{cm}^2$ ). Neither filamentous algae nor vascular aquatic plants were present in either the main channel of the Akalimolitra or its tributary. Only *P. arnoulti* and dragonfly nymphs were collected from this creek, but, in the main channel of the Akalimolitra, this species occurs syntopically with *Paretroplus kieneri*, *P. tsimoly*, *Oreochromis mossambicus*, *Glossogobius giuris* and *Awaous macrorhynchus*.

Feces of freshly captured specimens contained recognizable remains of both the imagos of terrestrial insects and the nymphs and larvae of aquatic insects. Although this species is at risk from such piscivorous fishes as *G. giuris*, its most important predators in most habitats appear to be fish-eating birds and dragonfly nymphs.



**FIGURE 19.** Distribution of *P. arnoulti* sp. nov. (\*).

Specimens collected in late October began spawning within a week after their arrival in the United States in early November. Observations of the growth rate of juveniles in captivity taken with the size distribution of specimens from the type locality suggest a protracted breeding season lasting through the austral summer.

*Conservation status*

The conservation status of *P. arnoulti* varies over its extensive range. During the past fifty years, its numbers have declined significantly within the Betsiboka-Ikopa drainage. Recent efforts to recollect this species from streams near the town of Maevatanana, where Arnoult (1955) found it to be abundant, were unsuccessful. These localities now are home to substantial populations of naturalized *Xiphophorus hellerii*. This species has also become very rare in the Ampijoroa Forest Reserve, where Arnoult collected a large series of specimens in the 1960's (J. S. Sparks, pers. com.), and appears to be under significant pressure from *X. hellerii* at the type locality and from *G. holbrooki* in the lower reaches of the Kamoro (P. deRham, pers. com.). However, it remains abundant in both the upper Kamoro River and in the small streams situated between the mouths of the Betsiboka and Mahavavy du Sud (P. de Rham., pers. com.), as well as in satellite lakes of the Kinkony basin in the delta of the Mahavavy du Sud (N. Raminosoa, pers. com.). Following the criteria established by the World Conservation Union (Raminosoa *et al.*, 2002), *P. arnoulti* is thus classified as a species of special concern, whose status needs to be monitored on a regular basis.

*Discussion*

Most literature published since 1950 purporting to deal with various aspects of the biology of *P. omalonotus* (Arnoult, 1955, 1959; Kiener, 1963; Kiener and Th erezien, 1963; Scheel, 1968; Parenti, 1981; Lazarra, 1984) actually refers to this species.

**Specimens examined***Pachypanchax omalonotus*

AMNH 215525 (7, 36.0–63.5 mm SL), Djabala Creek, Nosy Be, P. V. Loiselle and O. Lucanus, 20 Oct. 1994. AMNH 232413 (30, 28.9–57.7 mm SL), Djabala Creek, Nosy Be (13°23'11"S, 48°14'22"E), P. V. Loiselle, 21 Oct. 1994. AMNH 232417 (21, 27.6–62.7 mm SL), unnamed stream on Andoany (Hell-Ville)-Ambatozavavy road, Nosy Be (13°22'04"S, 48°18'41"E), P. V. Loiselle, 19 Oct. 1994. AMNH 231244 (16, 26.5–61.6 mm SL), Mahazava Creek, at village of the same name (13°46'86"S, 48°29'21"E) (Sambirano River drainage), P. V. Loiselle, 26 Oct. 2001. AMNH 232442 (5, 31.5–40.3 mm SL), Beandrona Creek, at Ambodidimaka Village (13°45'30"S, 48°29'50"E) (Sambirano River drainage), P. V. Loiselle, 26 Oct. 2001. AMNH 232475 (7, 55.7–69.7 mm SL), main channel of the Ramena River, Tsaratana Strict Nature Reserve (Sambirano River drainage), at 700 m a.s.l., C. J. Raxworthy, 12 April 2001.



***Pachypanchax sakaramyi***

AMNH 215524 (34, 33.2–43.4 mm SL), Sakaramy River at Joffreville (12°29' 65''S, 48°12'55''E), P. V. Loiselle and O. Lucanus, 23 Oct. 1994. AMNH 211465 (8, 42.0–56.3 mm SL), aquarium-bred F<sub>2</sub> specimens descended from founders collected from the Sakaramy River at Joffreville by P. V. Loiselle and O. Lucanus. MNHN 1893 0120 (3, 25.5–46.5 mm SL), Maki Creek (Antongombato drainage), C. Allaud. MNHN 1921 00550 (1, 56.0 mm SL), Antsiranana [Diego Suarez], J. Chretien. MNHN 1932 0179–80 (4, 64.0–72.0 mm SL), Ambery Creek (Rivière Ambre), Antsiranana, G. Petit.

***Pachypanchax patriciae***

AMNH 232451 (5, 27.1–44.7 mm SL), Matsabory Farengniny at Ampasindava Village (13°13'07''S, 49°10'08''E) (Mananjeba drainage), P. V. Loiselle and J. Miandrizava, 28 Oct. 2001. AMNH 232449 (25, 19.8–32.4 mm SL), Manehoko River at village of the same name (13°26'08''S, 48°47'51''E), P. V. Loiselle and J. Miandrizava, 27 Oct. 2001. MNHN 1900 0234–35 (2, 26.0–32.5 mm SL), Rivière Ampasina at Andrialana Village (Mananjeba drainage), Joly. MNHN 1939 0148 (4, 23.2–53.5 mm SL), Ambilobe (Mahavavy du Nord drainage), R. Decary.

***Pachypanchax arnoulti***

MNHN 1922 0169 (5, 28.6–37.7 mm SL), Ambatomainty Village (Mahavavy du Sud drainage), C.N.R.O. MNHN 1932 0047 (5, 19.1–31.6 mm SL), Maroparasy Creek, affluent of Lake Kinkony, at Andrafiavelo Village (Mahavavy du Sud drainage), R. Decary.

**Comparative material****Aplocheilidae**

*Aplocheilus lineatus*: AMNH 38429 SW (alizarin preparation); *Aplocheilus panchax*: AMNH 21957 SW (alizarin preparation); *Pachypanchax playfairii*: AMNH 20637; AMNH 38413 SW (alizarin preparation).

**Nothobranchidae**

*Aphyosemion (Aphyosemion) punctatum*: AMNH 232096; *A. (Chromaphyosemion) bivittatum*: AMNH 97638; *A. (Fundulopanchax) gulare*: AMNH 14606; *A.*

(*Scriptaphyosemion*) *roloffi*: AMNH 59616; *Epiplatys fasciolatus*: AMNH 59622 (alizarin preparation); *Epiplatys spilargyreus*: AMNH 21867 (alizarin preparation); *Nothobranchius melanospilus*: AMNH 20597.

### Rivulidae

*Austrolebias belloti*: AMNH 12291; *Rachovia pyropunctata*: AMNH 57348; *Rivulus hartii*: AMNH 215254.

### Cyprinodontidae

*Cubanichthys cubensis*: AMNH 96405; *Cyprinodon dearborni*: AMNH 58766; *Orestias agassizi*: AMNH 52162.

### Fundulidae

*Fundulus grandis*: AMNH 96340; *Fundulus lima*: AMNH 32474; *Fundulus kansae*: AMNH 28600.

### Profundulidae

*Profundulus guatemalensis*: AMNH 31713; *Profundulus labialis*: AMNH 32106; *Profundulus punctatus*: AMNH 32306.

### Acknowledgments

I wish to thank the Service des Eaux et Forêts and the Service des Pêches of the Malagasy Republic for issuing the collecting and export permits required to carry out research in the field. Benjamin Andriamihaja and the staff of the Madagascar Institute for the Conservation of Tropical Environments provided administrative and logistical support for collecting trips made between 1993 and 1997, as did the staff of the Antananarivo office of the Wildlife Conservation Society for subsequent field work. I am particularly grateful to Guy Duhamel (MNMH) and Douglas Nelson (UMMZ) for the loan of material under their care, to Martine de Soutter (MNMH) for examining the holotype of *P. nuchimaculatus*, to Patrice Pruvost (MNMH) for arranging to have it radiographed, and to Patrick de Rham for his very helpful review of the manuscript and for many fruitful discussions of the natural history of *Pachypanchax* in Madagascar and in the Seychelles. Fieldwork in northern Madagascar would have been much less productive without the indispensable assistance of Julian Miandrizava. Oliver Lucanus accompanied me into the field in 1994 and 1995, as did Rick Haeffner (Denver Zoological Society) in 1997 and 1998, John

Davidson (Denver Zoological Society) in 1997, Aleksei Saunders (Denver Zoological Society) in 1999, Tsilavana Ravelomanana in 2003, and Jean Rasoloariniainina in 2004. Field work in Madagascar was supported by Rogih and Patricia Yazgi and Aquaria, Inc.

## Literature cited

- Arnoult, J. (1955) *Pachypanchax homalonotus* (Duméril 1861). *L'Aquarium et les Poissons*, 5, 5–8.
- Arnoult, J. (1959) Poissons des eaux douces. *Faune de Madagascar*, ISRM, Tananarive, 10, 1–169.
- Courtenay, W.R. & Meffe, G.K. (1989) Small fishes in strange places: a review of introduced poeciliids. In: Meffe, G.K. & Snelson, F.F. (Eds.), *Ecology and Evolution of Livebearing Fishes (Poeciliidae)*. Prentice-Hall, Englewood Cliffs, pp. 319–331.
- De Rham, P. (2000a) Les *Pachypanchax*, killies de Madagascar. Première partie: les espèces. *Aqua Plaisir* (47), 28–33.
- De Rham, P. (2000b) Les *Pachypanchax*, killies de Madagascar. Deuxième partie: les *Pachypanchax* dans la nature. *Aqua Plaisir* (48), 32–36.
- Dorr, L.J. (1997) *Plant Collectors in Madagascar and the Comoro Islands: a Biographical and Bibliographical Guide*. The Trustees, Royal Botanic Gardens, Kew, 571 pp.
- Duméril, A.H.A. (1861) Poissons de la côte occidentale d'Afrique. *Arch. Mus. Natl. Hist., Nat.* (Paris) (for 1858), 10, 241–268, pls. 20–23.
- Galat, D.L. & Robertson, B. (1992) Response of endangered *Poeciliopsis occidentalis sonoriensis* in the Rio Yaqui drainage, Arizona, to introduced *Gambusia affinis*. *Environmental Biology of Fishes*, 33, 249–264.
- Gautier, L. & Goodman, S.M. (2003) Introduction to the Flora of Madagascar. In Goodman, S.M. & Benstead, J.P. (Eds.), *The Natural History of Madagascar*. University of Chicago Press, Chicago, pp. 229–250.
- Guichenot, M. (1866) Catalogue des poissons de Madagascar de la collection du Musée de Paris. *Mémoires de la Société Impériale des Sciences Naturelles de Cherbourg*, (1)12, 129–148.
- Hartig-Beecken, J. (1980) *Pachypanchax playfairii* — mein Souvenir von den Seychellen. *Deutsche Killifische Gemeinschaft Journal*, 12(6), 81–84.
- Hoedemann, J.J. (1958) The frontal scalation pattern in some groups of toothcarps (Pisces, Cyprinodontiformes). *Bulletin of Aquatic Biology*, 1, 23–28.
- Hoedemann, J.J. (1961) Preliminary key to the species and subspecies of the genus *Rivulus*. *Bulletin of Aquatic Biology*, 2, 65–74.
- Holly, M. (1928) Zwei noch nicht beschriebene Fischeformen aus Afrika. *Zoologische Anzeiger*, 76, 312–314.
- Huber, J.H. (1998) Miscellaneous notes on some systematic difficulties regarding Old World cyprinodonts. *Journal of the American Killifish Association*, 31(1), 3–17, 28–32.
- Innes, W.T. (1959) *Exotic Aquarium Fishes*. Innes Publishing, Philadelphia, 511 pp.
- Kiener, A. (1963) Poissons, pêche et pisciculture à Madagascar. *Publication du Centre Technique Forestier Tropical*, (24), 1–244.
- Kiener, A. & Thérézien, V. (1963) Principaux poissons du Lac Kinkony. Leur biologie et leur pêche. *Bulletin de Madagascar*, (204), 395–440.
- Kottelat, M., Whitten, A.J., Kartikasari, S.N. & Wirjoatmodjo, S. (1993) *Freshwater fishes of Western Indonesia and Sulawesi*. Periplus Editions, Jakarta, 221 pp.
- Lazara, K.J. (1984) *The Killifish Master Index*. American Killifish Association, Cincinnati, 295 pp.
- Leviton, A.E., Gibbs R.H. Jr., Heal, E. & Dawson, C.E. (1985) Standards in herpetology and ichthyology: Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. *Copeia*, 1985(3), 802–832.

- Loiselle, P.V. & Ferdenzi, J. (1997) The natural history and aquarium husbandry of *Pachypanchax sakaramyi* (Holly 1928), the "lost" killifish of Madagascar. *Journal of the American Killifish Association*, 30 (1–2), 29–41.
- Myers, G.S. (1933) *Pachypanchax*, a new genus of cyprinodont fishes from the Seychelles Islands and Madagascar. *American Museum Novitates*, 592, 1.
- Parenti, L.R. (1981) A phylogenetic and biogeographic analysis of the cyprinodontiform fishes. *Bulletin of the American Museum of Natural History*, 168(4), 335–557.
- Playfair, R.L. & Gunther, A.C. (1866) *The Fishes of Zanzibar*. John van Voorst, London, xiv, 153 pp.
- Raminosoa, N.R., Loiselle, P.V., Rafomanana, G., Rafiliarison, J.R., Ramanantsoa, M.A., Ramanarana, J., Randriantsizafy, V., Raveloson, H.N., Razafindrakoto, J. & Saindou (2002) Poissons. In: *Evaluation et Plans de Gestion pour la Conservation (CAMP) de la Faune de Madagascar: Lémuriens, Autres Mammifères, Reptiles et Amphibiens, Poissons d'Eau Douce et Evaluation de la Viabilité des Populations et des Habitats de Hypogeomys antimena (Vositse)*. Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, 488 pp.
- Romand, R. (1994) *Epiplatys guineensis*, a new species of killifish from Guinea, West Africa (Pisces: Cyprinodontidae). *Ichthyological Exploration of Freshwaters*, 5(4), 365–370.
- Scheel, J. (1968) *Rivulins of the Old World*. T. F. H. Publications. Jersey City, 473 pp.
- Seegers, L. (1980) Zum Vorkommen von *Pachypanchax playfairii* auf Zanzibar und in Ostafrika. *Deutsche Killifische Gemeinschaft Journal*, 12(6), 87–93.
- Sparks, J.S. (2002) *Ptychochromis inornatus*, a new cichlid (Teleostei: Cichlidae) from northwestern Madagascar, with a discussion of intrageneric variation and the taxonomic status of *P. grandidieri*. *Copeia*, 2002 (1), 120–130.
- Thomerson, J.E. & Taphorn, D.C. (1993) *Rivulus corpulentus*, a new killifish from the Cordillera de la Macarena, Colombia (Cyprinodontiformes: Rivulinae). *Ichthyological Exploration of Freshwaters*, 4(1), 365–370.
- Wildekamp, R.H. (1995) *A World of Killies. Atlas of the oviparous cyprinodontiform fishes of the world*. Volume II. American Killifish Association, Mishawaka, 384 pp.