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## Review of the mouthbrooding *Betta* (Teleostei, Osphronemidae) from Thailand, with descriptions of two new species

### Übersicht der maulbrütenden *Betta*-Arten (Teleostei, Osphronemidae) aus Thailand, mit der Beschreibung zweier neuer Arten

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**Summary:** The mouthbrooding species of the genus *Betta* from Thailand are reviewed. Six species are reported: *Betta pallida*, *B. prima*, *B. pi*, *B. simplex* and two new species of the *B. pugnax* species group, *B. apollon* sp. nov. and *B. ferox* sp. nov., both from peninsular Thailand. Diagnosis, description, illustrations and habitat notes are provided for all six species. *Betta apollon* sp. nov. is characterised by an unusually extended last branchiostegal ray and 25-26 anal fin rays. *Betta ferox* sp. nov. is distinguished from all other species of the *B. pugnax* group by the combination of the following character states: body depth at dorsal fin base 31.4-35.0 % of SL, head length 30.0-33.6 % of SL, transverse bars on caudal fin, chin-bar and postorbital stripe present, 26 anal fin rays, 29-31 (mode 30) lateral scales, a lanceolate caudal fin shape and absence of a broad dark marginal band on anal fin. Statistical analyses of selected characters were calculated to test significance of differences between species and species groups.

**Key words:** *Betta*, Thailand, *Betta apollon*, *Betta ferox*, *Betta* species groups

**Zusammenfassung:** Eine Überarbeitung der maulbrütenden Arten der Gattung *Betta* aus Thailand wird vorgestellt. Sechs Arten werden anhand des untersuchten Materials dokumentiert: *Betta pallida*, *B. prima*, *B. pi*, *B. simplex* sowie zwei neue Arten der *B. pugnax*-Gruppe, *B. apollon* sp. nov. und *B. ferox* sp. nov., beide aus dem südlichen Thailand. Für alle Arten werden eine Diagnose, eine Beschreibung, Abbildungen und Notizen zum Habitat präsentiert. *Betta apollon* sp. nov. ist durch einen ungewöhnlich langen letzten Branchiostegalstrahl und 25-26 Afterflossenstrahlen gekennzeichnet. *Betta ferox* sp. nov. unterscheidet sich von den übrigen Arten der *B. pugnax*-Gruppe durch die Kombination folgender Merkmalsausprägungen: Körperhöhe 31,4-35,0 % der SL, Kopflänge 30,0-33,6 % der SL, dunkle Querreihen auf der Schwanzflosse, Kinn- und Postorbitalstreifen auf den Kopfseiten vorhanden, 26 Afterflossenstrahlen, 29-31 (im Mittel 30) Lateralschuppen, Schwanzflosse lanzettförmig und Fehlen eines breiten dunklen Bandes auf der Afterflosse. Zur Prüfung, ob die Unterschiede zwischen den Arten und Artengruppen signifikant sind, wurden für ausgewählte Merkmale statistische Tests durchgeführt.

**Schlüsselwörter:** *Betta*, Thailand, *Betta apollon*, *Betta ferox*, *Betta*-Artengruppen

#### 1. Introduction

Members of the genus *Betta*, so called fighting fishes, are widely distributed in Southeast Asia and inhabit a variety of freshwater environments (SCHMIDT 1996) including hill streams, forest creeks, lakes and swamps. This monophyletic genus (BRITZ 2001) consists of 55 nominal species with several species groups (TAN & NG 2005a, 2005b, 2006). According to their

brood care behaviour the species are divided into bubble nest builders and mouthbrooders. This review deals with the mouthbrooding *Betta* species of Thailand.

In the still most comprehensive treatment of the freshwater fishes of Thailand, SMITH (1945) recognized one mouthbrooding species, *B. taeniata*. However, *B. taeniata* Regan is described from Borneo and does not occur in Thailand (KOTTELAT 1994, TAN & NG 2005a). Later LADI-

GES (1972) mentioned *B. pugnax* (type locality Penang Island, Malaysia) as another species from Thailand. KOTTELAT (1994) described *B. simplex* from Krabi (peninsular Thailand) and *B. prima* from south-east Thailand and showed that the material identified as *B. taeniata* by SMITH (1929, 1945) actually represents *B. prima*. The next mouthbrooder described from Thailand was *B. pi* TAN, 1998 from Sungai Kolok. Finally SCHINDLER & SCHMIDT (2004) added *B. pallida* from Narathiwat (most southern peninsular Thailand). These mouthbrooding species of Thailand are members of three different species groups (*B. picta*, *B. pugnax* and *B. waseri* group).

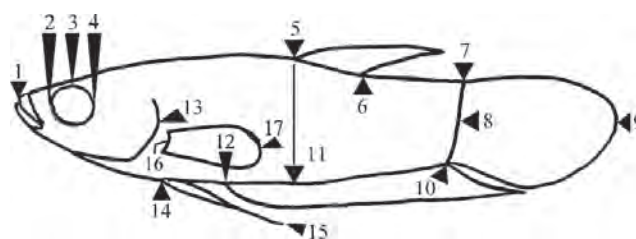
Recent collections by H. LINKE and N. THAN-TAHA in Thailand made it possible that we received information of new records of the mouthbrooding *Betta* and became aware of new species which were formerly identified as *B. pugnax*. The purpose of the present study is to review the mouthbrooding species of the genus *Betta* from Thailand in order to clarify their taxonomy. A comparative description of the reproductive behaviour of the species from Thailand will be the subject of a forthcoming article by the authors.

## 2. Material and methods

The measurements taken follow WITTE & SCHMIDT (1992) with the modification that all

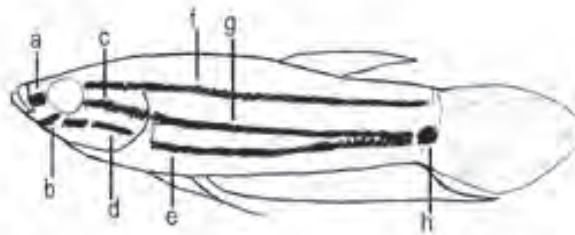
measurements were taken as straight-line between two landmarks. The corresponding LMs are noted in figure 1. The distances are measured on the left side of a specimen with a dial calliper reading to the nearest 0.1 mm. Measurements are given only for those distances which are currently used in descriptions of new *Betta* species (e.g. KOTTELAT & NG 1994, TAN & NG 2005a). Counts were made as described by WITTE & SCHMIDT (1992) except for the number of predorsal scales which were counted continuously (NG & KOTTELAT 1994). Only such counts are given which have a diagnostic value. Numbers in brackets indicate the number of specimens examined with that count. Terminology of colour patterns follows TAN & NG (2005a) with the addition that the most dorsal longitudinal dark line on body sides is called upper central stripe (fig. 2). The description follows the general format used by TAN & NG (2005a). Beside the data obtained from material examined, data from previously described and redescribed species (KOTTELAT 1994, 1995a, KOTTELAT & NG 1994, TAN 1998, TAN & KOTTELAT 1998a, 1998b, TAN & NG 1996, 2005a, 2005b, TAN & TAN 1994, 1996, VIERKE 1984) were also used.

BRITZ (1994) included the type genus of Osphronemidae BLEEKER, 1859 within Belontiidae LIEM, 1963 in a proposed monophyletic group.



**Fig. 1:** Landmarks used for morphometric characters. Standard length = d1-8; total length = d1-9; predorsal length = d1-5; postdorsal length = d6-7; preanal length = d1-12; body depth = d5-11; caudal peduncle depth = d7-10; head length = d1-13; orbit diameter = d2-4; snout length = d1-2; postorbital length = d4-13; interorbital width = d3-3; dorsal-fin base length = d5-6; anal-fin base length = d10-12; pelvic fin length = d14-15; pectoral fin length = d16-17.

**Abb. 1:** Zur Ermittlung der morphometrischen Merkmale verwendete kritische Punkte. Standardlänge = d1-8; Totallänge = d1-9; Predorsallänge = d1-5; Postdorsallänge = d6-7; Preanallänge = d1-12; Körperhöhe = d5-11; Schwanzstielhöhe = d7-10; Kopflänge = d1-13; Augendurchmesser = d2-4; Schnauzenlänge = d1-2; Postorbitallänge = d4-13; Augenabstand = d3-3; Rückenflossenbasislänge = d5-6; Afterflossenbasislänge = d10-12; Bauchflossenlänge = d14-15; Brustflossenlänge = d16-17.



**Fig. 2:** Schematic presentation of dark pattern. a = preorbital stripe, b = chin-bar, c = postorbital stripe, d = second postorbital stripe, e = second central stripe, f = upper central stripe, g = central stripe, h = caudal base spot.

**Abb. 2:** Schematische Darstellung des dunklen Zeichnungsmusters. a = Preorbital Streifen, b = Kinnstreifen, c = Postorbitalstreifen, d = zweiter Postorbitalstreifen, e = zweiter zentraler Längsstreifen, f = oberer zentraler Längsstreifen, g = zentraler Längsstreifen, h = Schwanzflossenbasisfleck.

Following the rules of priority the valid family group name of this family is Osphronemidae. Although there is no comparative diagnosis for the Osphronemidae in BRITZ (1994), we are using this family group name here (instead of Belontiidae) because it seems the best choice according to current knowledge (see BRITZ 2001, RÜBER et al. 2006).

The number of recognized species strongly depends on the species concept used (LAAMANEN et al. 2001). Therefore it is recommended that authors have to specify which species concept they use (LAAMANEN et al. 2001). We adopted here the so-called pragmatic species concept (KOTTELAT 1995a, 1997), which is a more practicable approach (KOTTELAT & NG 1994) and delimitate species on discrete characters or divergent character states.

The usage of the term 'species group' follows TAN & KOTTELAT (1998). The number of groups and the included species follow TAN & NG (2005a) with few modifications mentioned in the species descriptions. TAN & NG (2005a) described a separate monotypic group for *B. edithae*. However, we believe that such monotypic group is in contradiction to the general concept used. Therefore, we consider *B. edithae* a member of the *B. picta* group (SCHMIDT 1996).

Canonical variate analyses were used to investigate patterns of morphological variation between observed species groups from Thailand. Both the material examined and the comparative material were used for the statistical evaluations. In addition, the representative specimens of *B. prima* and

*B. simplex* (data adopted from KOTTELAT 1994) are also included in the statistics.

To correct the differences in size all measurements are standardized by expressing them as proportions of standard length as recommended by VAN VELZEN et al. (1992). For this purpose the formula  $\log(x') = \log(SL) - \log(x)$  is used (BLACKITH & REYMANT 1971). The CVA scores were calculated on the basis of standardized metric and meristic data, using the program PAST (HAMMER et al. 2004).

In the one-dimensional case the formula  $x' = x \times 100 / SL$  is used to standardize measurements. The significance of the pairwise differences between two samples in one-dimensional standardized data is tested with the modified *t*-test based on range (MOORE 1957). Data of each sample were tested for goodness of fit the normal distribution by the *K-S*-test as described in SACHS (1992). Since the normal distribution of the standardized measurements is confirmed for all tested samples, the normal distribution is also assumed for such samples where only range data were available.

Comparative material: *Betta smaragdina*: CIS, 3 specimens, 32.5-34.9 mm SL; Thailand, Udon Thani, Nam Luang drainage; leg. N. THANTAHA & I. SCHINDLER Oct. 1999. CIS, 2 specimens, 30.8-36.5 mm SL; Thailand, peat swamp 15 south-east of Nong Khai between Khok Chang and Phen; leg. N. THANTAHA & I. SCHINDLER, Oct. 1999. *B. imbellis*: CIS, 5 specimens, 28.1-39.5 mm SL; Thailand, Krabi; leg. N. THANTAHA, Sept. 1999. CIS, 4 specimens, 29.2-32.1 mm SL; Thai-

land, Narathiwat, between Marubo and Ruso; leg. N. THANTAHA, May 2000. *B. splendens* (feral): CIS, 5 specimens, 27.5-33.0 mm SL; Thailand, Trat; leg. N. THANTAHA & I. SCHINDLER, Oct. 1999. CIS, 4 specimens, 26.6-38.5 mm SL; Thailand, 30 km north of Bangkok, Mae Nam Chao Phraya drainage; leg. N. THANTAHA & I. SCHINDLER, Sept. 1999. *B. splendens* (domesticated Siamese fighting fish): CIS, 5 specimens, 40.5-42.7 mm SL; Thailand, Bangkok; leg. N. THANTAHA & I. SCHINDLER, Sept. 1999. *B. pugnax*: CIS, 10 specimens, 38.5-61.6 mm SL; Malaysia, westcoast of Penang Island, small creek between Telok Bahang and Sungai Pinang; leg. H. LINKE, May 2005.

Abbreviations: CIS = Collection of the authors; CVA = canonical variate analysis; d = distance between two LMs; ICZN = International Code for the Zoological Nomenclature; LM = landmark (landmarks = LMs); MTD F = Staatliches Museum für Tierkunde, Dresden; SL = standard length.

### 3. Results

#### 3.1. Species

##### 3.1.1. *Betta apollon* sp. nov.

Holotype: MTD F 30341, 51.0 mm SL, adult male. Thailand, Province Narathiwat, about 20 km west of Narathiwat at street to Marubo (app.

6°23' N, 101°38' E); leg. N. THANTAHA, May 2000 (fig. 3).

Paratypes: MTD F 30342-30345, 4 specimens, 46.1-51.8 mm SL; same data as the holotype. MTD F 30346-30348, 3 specimens, 30.9-51.2 mm SL; about 10 km east of Ruso (app. 6°26' N, 101°34' E); leg. N. THANTAHA, May 2000.

Diagnosis: Member of the *B. pugnax* group. It is differentiated from other *Betta* by the elongated last branchiostegal ray extending beyond posterior margin of the operculum (fig. 4). It is further characterised by 25-26 total anal-fin rays and 29-30 lateral scales.

Description: For general appearance see figure 3. Meristic and morphometric data are summarized in table 1. Maximum known size 51.8 mm SL. Body comparatively slender (body depth at dorsal-fin origin 28.4-33.0 % of SL), head long (head length 32.4-35.5 % of SL), snout pointed. Dorsal, caudal and anal fins pointed; dorsal fin placed comparatively far posterior (predorsal length 62.7-65.9 % of SL); caudal fin slightly asymmetrically lanceolate (dorsal part more developed); length of anal-fin base more than half of standard length (50.3-54.9 % of SL); dorsal-fin base length 12.8-15.8 % of SL; pelvic fins with long filamentous ray (up to 41 % of SL); pectoral fins rounded (length 20.2-23.9 % of SL). Dorsal fin rays I,8(2) or I,9(6). Anal fin rays II,23(5), II,24(2) or III,24(1). Pectoral fin rays 12(3) or 13(5). Pelvic fin rays



**Fig. 3:** *Betta apollon* (holotype, male).

**Abb. 3:** *Betta apollon* (Holotypus, Männchen).

**Tab. 1:** Morphometric (as percentage of standard length; SL, in mm) and meristic data of *B. apollon*, *B. ferax* and *B. pugnax* (topotypes); mean = arithmetic mean; sd = standard deviation; min = lowest value; max = highest value.

**Tab. 2:** Morphometric (in Prozent der Standardlänge; SL, in mm) und meristische Daten von *B. apollon*, *B. ferax* und *B. pugnax* (Topotypen); mean = arithmetrischer Mittelwert; sd = Standardabweichung; min = kleinster Wert; max = größter Wert.

Character	<i>Betta apollon</i> sp. nov. (n=8)				<i>Betta ferax</i> spec. nov. (n=8)				<i>Betta pugnax</i> ; Penang (n=10)			
	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max
Standard length (mm)	44.6	8.11	30.9	51.8	54.7	6.08	42.1	62.9	46.4	6.66	38.5	61.6
Total length	144.6	7.70	136.9	157.8	138.4	6.01	129.0	148.1	141.6	3.44	135.3	146.9
Predorsal length	64.3	1.25	62.7	65.9	65.4	1.89	63.5	68	65.6	1.29	63.8	68.0
Postdorsal length	22.7	2.63	18.7	26.0	24.3	0.77	23.1	25.5	23.8	0.99	22.6	25.3
Prenasal length	50.0	1.98	46.9	53.6	48.0	1.97	45.7	51.0	45.4	0.56	44.6	46.5
Body depth at dorsal fin	29.5	1.49	28.4	33	32.9	1.37	31.4	35.0	27.2	0.70	25.9	28.6
Caudal peduncle depth	19.8	0.83	18.9	21.4	20.4	1.02	19.0	22.1	17.9	0.58	17.1	18.8
Head length	33.8	1.22	32.4	35.6	31.8	1.28	30.1	33.6	30.8	0.76	29.7	32.3
Orbit diameter	9.7	0.44	9.0	10.4	8.8	0.55	8.1	9.4	8.5	0.37	7.8	9.1
Postorbital length	16.1	0.59	15.4	17.0	15.0	0.72	13.8	15.8	14.5	0.31	14.0	15.1
Interorbital width	11.7	0.79	10.5	12.5	12.3	0.89	11.1	13.5	11.2	0.41	10.4	11.9
Dorsal-fin base length	14.2	1.06	12.8	15.9	12.3	0.54	11.5	13.0	12.6	0.83	11.7	14.5
Anal-fin base length	52.6	1.39	50.3	54.9	50.9	1.75	48.3	53.6	51.7	1.00	49.8	53.4
Pelvic fin length	33.4	5.22	25.9	40.2	30.0	4.76	23.0	38.6	30.2	2.12	27.1	34.1
Lateral scales	29.5	0.54	29	30	29.9	0.64	29	31	30.1	0.52	29	31
Predorsal scales	20.6	0.52	20	21	22	0.53	21	23	22.3	0.48	22	23
Postdorsal scales	10.1	0.35	10	11	10.9	0.35	10	11	10.1	0.32	10	11
Transverse scales	9.3	0.46	8.5	10	9.5	0.18	9.5	10	9.1	0.21	9	9.5
Total anal-fin rays	25.4	0.74	25	27	26.1	0.35	26	27	27.9	0.74	27	29
Anal-fin rays ("spines")	2.1	0.35	2	3	1.8	0.46	1	2	2.1	0.32	2	3
Anal-fin rays (articulated)	23.2	0.46	23	24	24.4	0.74	24	26	25.8	0.63	25	27
Total dorsal-fin rays	9.75	0.46	9	10	9.25	0.46	9	10	9.2	0.42	9	10



**Fig. 4:** Head of *B. apollon*, arrow indicates tip of elongated branchiostegal ray.

**Abb. 4:** Kopf von *B. apollon*, der Pfeil deutet auf die Spitze des verlängerten Branchiostegalstrahls.

I,1,4. Lateral scales 29(4) or 30(4). Transverse scales at dorsal fin origin 9(1), 9½(6) or 10(1). Predorsal scales 20-21, postdorsal scales 10-11.

Colouration preserved male: Body brown, ventral part light brown. Opercle and throat area in males darkly pigmented. Lower lip black; chin-bar present; pre- and postorbital stripes present; second postorbital stripe present, but sometimes split in larger staggered parts or masked by dark pigmentation. Dorsal and caudal fin brown with transverse bars; anal fin brown with a thin dark distal margin, some specimens with transverse bars on the most posterior anal fin rays; pelvic fins brown at base with light, whitish filaments; pectoral fins hyaline. Upper stripe continuously from upper margin of eye to dorsal caudal fin base. Central stripe from upper pectoral fin base continuously to middle caudal fin base, not connected with caudal base spot. Second central stripe from lower pectoral fin base to lower caudal fin base, conjunct with central stripe above the middle of anal fin base. Longitudinal stripes very faint in adult specimens. Distinct caudal base spot present.

**Distribution:** Known only from the hill streams west of Narathiwat in peninsular Thailand (fig. 9).

**Habitat notes:** *Betta apollon* has been collected in hill-streams strongly shaded by forest. It was mostly found in shallow water close to the shores between roots, plants or leaf litter. Some specimens were also caught in the swift flow-

ing area between boulders. The water of the type locality was colourless, clear and with a pH of 6.2, an electric conductivity of 20-40 µS/cm and a temperature of 24-26 °C.

**Etymology:** Apollon (Apollo by the classic romans) is the mythological Greek god of (among others) music, poetry, medicine and archery and also refers to handsome young man. The name is an allusion to the beautiful appearance of this species.

**Comparative notes:** *Betta apollon* is diagnosed by the unique character of an elongated last branchiostegal ray. In larger males, the tip of this branchiostegal ray is laterally compressed and marked whitish (fig. 4). It is further distinguished from the other species of the *B. pugnax* group in having a chin-bar and second postorbital stripe (*versus* no chin-bar and/or no second postorbital stripes in *B. breviobesus*, *B. fusca*, *B. lebi*, *B. pugnax*, *B. pulchra*, *B. raja*, *B. schalleri*), in having transverse bars on caudal fin (no bars in *B. breviobesus*, *B. fusca*, *B. lebi*, *B. raja*, *B. schalleri*), longer head (head length 32.4-35.6% of SL *versus* 30.8-31.7% in *B. cracens*) and lower number of lateral scales than in *B. cracens* (29-30 *versus* 32-33). It differs from the topotypes of *B. pugnax* by a longer head (head length 32.4-35.6% of SL *versus* 29.7-32.3% of SL) and less articulated anal fin rays (23-24 *versus* 25-27). From *B. prima* and *B. pallida* it is distinguished by a higher number of lateral scales (29 or 30 *versus* 27-28 (mode 27) in *B. prima* and 27-29 (mode 28) in *B. pallida*; fig. 13 d), presence of dark transverse bars on caudal fin (*versus* no bars in *B. prima* and *B. pallida*) and larger size (>50 mm SL *versus* < 45 mm SL in *B. prima* and *B. pallida*). *Betta apollon* is similar to its geographic neighbours *B. stigmosa* and *B. ferox* regarding the pattern of dark marks on head (in *B. ferox* this pattern is much less intense than in *B. apollon* and *B. stigmosa*). It differs from *B. ferox* in body depth (28.4-33.0% (29.5% average) of SL *versus* 31.4-35.0% (average 32.9%) of SL; *t*-test  $p < 0.001$ ; fig. 13a), in head length (32.4-35.6% (average 33.8%) of SL *versus* 30.0-33.6% (average 31.8%) of SL; *t*-test  $p < 0.001$ ; fig. 13 b) and a broad, slightly asymmetrically lanceolate caudal fin (*versus* narrow lanceolate, acuminate

caudal fin shape in *B. ferox*). *Betta apollon* shares with *B. stigmosa*\* that at least some specimens of *B. apollon* show transverse bars on few most posterior anal fin rays as described for *B. stigmosa* (see TAN & NG 2005a). *Betta apollon* is distinguished from *B. stigmosa* in having 25-27 anal fin rays (*versus* 23-24 in *B. stigmosa*; fig. 13 c) and a deeper body (body depth at dorsal-fin base 28.4-33.0% of SL *versus* 25.6-28.2% of SL; fig. 13 b).

Remarks: Formerly specimens of *B. apollon* were classified as *B. pugnax*.

\*The specific name *B. stigmosa* TAN & NG, 2005 (first mention on p. 43) is also spelled *stigosus* in the original description (TAN & NG 2005a: 45, 53). However, the valid name is *B. stigmosa*; *B. stigosus* is an erroneous spelling, because a Latin or latinized adjective species-group name must agree in gender with the generic name (art. 31.2. ICZN).

### 3.1.2. *Betta ferox* sp. nov.

Holotype: MTD F 30355, 62.9 mm SL, Thailand, Hat Yai, about 30 km south-west of Rattaphun, Bori Pat, at the national street 406, 150 m before the junction into the Bori Pat waterfall park (07°00'05" N, 100°08'55" E); leg. H. LINKE, Febr. 2005 (fig. 5).

Paratypes: MTD F 30349-30354, 42.1-54.9 mm SL, same data as holotype; not catalogued one specimen 56.3 mm SL, same data as holotype.

Diagnosis: Member of the *B. pugnax* group. A comparatively deep-bodied species (body depth at dorsal-fin base 31.4-35.0 % of SL), which differs from the other species of the genus by the combination of a head length of 30.0-33.6% of SL, transverse bars on caudal fin, chin-bar and second postorbital stripe present, 26 anal fin rays, 29-31 (mode 30) lateral scales, caudal fin lanceolate and no broad dark marginal band on anal or caudal fin.

Description: For general appearance see figure 5. Meristic and morphometric data are summarized in table 1. Maximum size 62.9 mm SL. Body comparatively deep-bodied (body depth at dorsal fin origin 31.4-35.0% of SL), head comparatively short (30.0-33.6% of SL), snout blunt. Dorsal, caudal and anal fins pointed; dorsal fin placed far posterior (predorsal length 63.5-68.0 % of SL); caudal fin lanceolate; length of anal fin base about half of standard length (48.3-53.6 % of SL); dorsal fin base length 11.8-13.0 % of SL; pelvic fin with long filamentous ray (up to 39 % of SL); pectoral fin rounded (length 21.1-23.8 % of SL). Dorsal fin rays 0,9(1), I,8(5) or I,9(2). Anal fin rays II,24(6), I,25(1) or I,26(1). Pectoral fin rays 12(8). Pelvic fin rays I,1,4. Lateral scales 29(2), 30(5) or 31(1). Transverse scales at dorsal fin origin 9½(7) or 10(1). Predorsal scales 21-22, post-dorsal scales 10-11.

Colouration: For live colouration see GEISLER (1981; named *B. pugnax*) and front cover. Male:



Fig. 5: *Betta ferox* (holotype, male).

Abb. 5: *Betta ferox* (Holotyp, Männchen).

body reddish brown, belly whitish. Scales on body sides have a greenish-blue iridescent centre. Operculum and throat greenish-blue iridescent (dark pigmented when preserved). Lower lip black; chin-bar present, but not always complete; pre- and postorbital stripes present; second postorbital stripe present, but sometimes split into larger staggered parts or masked by dark pigmentation. Dorsal and caudal fin brown with alternating dark and bluish transverse rows on interradiation area; anal fin brown with bluish submarginal band and thin dark distal margin; pelvic fins brown at base and bluish in distal area and filaments; pectoral fins hyaline. Upper stripe continuously from upper margin of eye to dorsal caudal fin base. Central stripe continuous. Second central stripe from lower pectoral fin base to lower caudal fin base, conjunct with central stripe above the posterior third of anal fin base. Distinct caudal base spot present. Female: body tannish. Belly whitish. Less intense iridescent scales on body, less colour in fins and less distinct transversal bars on dorsal and caudal fin as in males.

Distribution: Only known from Bori Pat, around 35 km west of Hat Yai (fig. 9).

Habitat notes: The type locality is described by GEISLER (1981) as a small river with remarkable current (0.4 m/s). The ground was formed by gravel and in parts by sand. The fighting fishes were found at the banks, where the current was slower, between roots and plants (Araceae). The following water parameters were given (GEISLER 1981): pH 5.8-6.3, 30-52  $\mu\text{S}/\text{cm}$ , 23.3-24.2 °C. LINKE (pers. comm.) collected the type specimens at the same locality and in February 2005 he measured pH 6.3, electric conductivity 51  $\mu\text{S}/\text{cm}$  and water-temperature 25.5 °C.

Etymology: The specific epithet *ferox* (Latin), meaning wild, bold, courageous, fierce, refers to the behaviour of the 'fighting fish'.

Comparative notes: *Betta ferox* is distinguished from the other members of the *B. pugnax* group by the presence of a chin-bar (*versus* no chin-bar in *B. breviobesus*, *B. fusca*, *B. schalleri*, *B. raja*), complete second postorbital stripe (*versus* no stripe in *B. pugnax*, *B. pulchra*, *B. breviobesus*, *B. fusca*, *B. raja*, *B. schalleri*), caudal fin transverse

bars present (*versus* absent in *B. breviobesus*, *B. fusca*, *B. lebi*, *B. raja*, *B. schalleri*), higher body depth (31.4-35.0% of SL *versus* 21.2-24.2% of SL in *B. cracens*), lower number of lateral scales 29-31 (mode 30) *versus* >31 in *B. cracens*. In comparison to the examined topotypes of *B. pugnax* it has a deeper body (body depth 31.4-35.0% of SL *versus* 25.9-28.6% of SL) and less total anal fin rays (26-27 *versus* 27-29). From *B. prima* (included in the *B. pugnax* group by KOTTELAT 1994 and TAN & NG 2005a) and *B. pallida* it differs by a higher number of lateral scales >28 *versus* <29 (fig. 13 d), smaller head length (30.0-33.6% of SL *versus* 32.1-36.4% of SL in *B. pallida* and >34% of SL in *B. prima*; fig. 13 a), possession of transverse bars on caudal fin (*versus* no transverse bars) and larger size (>60 mm SL *versus* <45 mm SL in *B. prima* and *B. pallida*). *Betta ferox* is similar in dark pattern below suborbital stripe to *B. stigmosa* and *B. apollon*. It is distinguished from *B. stigmosa* by a larger body depth (>31% of SL *versus* <29% of SL in *B. stigmosa*; fig. 13 b), higher number of anal fin rays (>25 *versus* <25; fig. 13 c), absence of dark transverse bars on posterior few anal fin rays (*versus* present), shorter head (head length 30.0-33.6% of SL *versus* 33.6-36.5% of SL, fig. 13 a) and larger size (>60 mm SL *versus* <45 mm SL). For differences between *B. ferox* and *B. apollon* see above.

Remarks: Formerly, specimens of this species from southern Thailand were classified as *B. taeniata* (see SMITH 1945) or identified as *B. pugnax* by VIERKE in GEISLER (1981).

### 3.1.3. *Betta pallida*

*Betta pallida* SCHINDLER & SCHMIDT, 2004: 2. Holotype: MTD F 28389. Type locality: Thailand, Narathiwat Province, about 30 km west of Narathiwat at the street to Ruso (app. 6°21' N, 101°38' E).

Material examined: MTD F 30356-30366, 11 specimens, 39.8-47.8 mm SL; Thailand, Province Surat Thani, Ko Samui, Mae Nam; leg. H. LINKE, Febr. 2005. CIS, 1 specimen, 24.7 mm SL, Thailand, Province Narathiwat, north of Sungai Kolok; leg. N. THANTAHA, May 2000.



**Fig. 6:** *Betta pallida* (Ko Samui); **a** male, **b** female.  
**Abb. 6:** *Betta pallida* (Ko Samui); **a** Männchen, **b** Weibchen.

**Diagnosis:** Member of the *B. picta* group. This species differs from all other *Betta* species by the combination of a lanceolate caudal fin, chin-bar and second postorbital stripe present, no transverse bars nor broad dark marginal band on caudal fin, a low number of lateral scales (up to 28) and anal fin rays (up to 26).

**Description:** The species was recently described by SCHINDLER & SCHMIDT (2004). The additional data are based on the specimens from Ko Samui. General appearance is shown in figure 6. Morphometric and meristic data are given in table 2. Maximum known size 47.8 mm SL. Body comparatively deepbodied and short (body depth at dorsal fin origin 29.4-32.0% of SL), head length 32.1-35.9% of SL. Dorsal, caudal and anal fins pointed; dorsal fin situated comparatively far posterior (predorsal length 64.8-68.9% of SL); caudal fin lanceolate in males, rhomboid in females; length of anal fin base more than half of standard length (50.2-

54.5% of SL); dorsal fin base 11.0-14.0 % of SL; pelvic fins with long filamentous ray (up to 41 % of SL); pectoral fins rounded (length 21.0-24.4% of SL). Dorsal fin rays I,8(2), I,9(7) or I,10(2). Anal fin rays II,22(1), II,23(4), II,24(2), I,25(1), II,25(1) or II,26(2). Pectoral fin rays 11(1), 12(6), 13(4). Pelvic fin rays I,1,4. Lateral scales 27(1), 28(8) or 29(2). Transverse scales at dorsal fin origin 9(1), 9<sup>1</sup>/<sub>2</sub>(9) or 10(1). Predorsal scales 20-22, postdorsal scales 9-10.

**Colouration (preserved):** Body greyish, dorsally darker, ventrally lighter, belly whitish. Lower lip black; chin-bar, pre- and postorbital stripes present; second postorbital stripe present. Dorsal fin colourless with transverse rows of dark dots. Caudal fin colourless without transverse bars. Anal fin with faint dark marginal band. Upper and central stripes continuous, second central stripe through the anterior third of the anal fin continuous, posteriorly disrupted into several irregular parts. No distinct

caudal fin spot. For live colouration see LINKE (2006).

Distribution: The species is distributed on the east coast of peninsular Thailand from Surat Thani, Ko Samui in the north to Sungai Kolok in the south (fig. 10).

Habitat notes: The specimens examined were collected by LINKE in February 2005 in a slowly flowing creek which was only 20 to 50 cm deep. The water was clear and slightly tanned. The bed was covered densely with leaf litter. The water parameters were: pH 6.3, 82  $\mu$ S/cm and 25.5 °C. At another creek containing this species the following measurements were obtained: pH 6.5, 69  $\mu$ S/cm and 26.6 °C (LINKE 2006).

Comparative notes: *Betta pallida* is regarded as member of the *B. picta* group by SCHINDLER & SCHMIDT (2004). It differs from the other species of this group by having a lanceolate caudal fin (*versus* round or slightly pointed in *B. editbae*, *B. falx*, *B. picta*, *B. prima*, *B. simplex* and *B. taeniata*), complete second postorbital stripe present (*versus* non or reduced in *B. enisae*, *B. simplex* and *B. taeniata*), no broad dark band on anal fin (*versus* broad dark marginal or submarginal band present in *B. editbae*, *B. enisae*, *B. falx*, *B. picta*, *B. simplex* and *B. taeniata*), distinct longitudinal stripes (*versus* very faint stripes in *B. enisae*, *B. simplex*, *B. taeniata* and *B. editbae*), lower number of anal fin rays (usually <29 *versus* usually >28 in *B. editbae*) and less lateral scales as in *B. editbae* (usually <29 *versus* usually >29). It mostly resembles *B. prima*. Both are differentiated in caudal fin shape (figs. 6, 7), central stripe not interrupted in *B. pallida* (*versus* often posteriorly interrupted in *B. prima*) with more defined clear dorsal and ventral margins, no distinct caudal spot (usually distinct caudal spot in *B. prima*).

Remarks: Formerly specimens of this species from Ko Samui were misidentified as *B. taeniata* (see CHITRAKARN & INDRAMBARAYA 1932). TAN & KOTTELAT (1998) and TAN & NG (2005a) included only *B. picta*, *B. falx*, *B. simplex* and *B. taeniata* in the *B. picta* species group. However, SCHMIDT (1996) included *B. prima* and *B. editbae* in this group and SCHINDLER & SCHMIDT (2004) added *B. pallida*. Since *B. enisae* strongly re-

sembles *B. simplex* and *B. taeniata* in general appearance and in the low number of lateral scales and anal fin rays (26-28, and 23-26 anal fin rays), it is treated herein as an additional member of the *B. picta* species group (*viz.* *B. editbae*, *B. falx*, *B. pallida*, *B. picta*, *B. prima*, *B. simplex*, *B. taeniata*).

### 3.1.4. *Betta prima*

*Betta prima* KOTTELAT, 1994: 298. Holotype: ZRC/CMK 10798. Type locality: Thailand, Province Chantaburi, creek about km 1 on road to Nam Tok Phliu, after leaving Chantaburi-Trat highway, 12°32' N 102°11'E.

Material examined: CIS, 5 specimens, 30.3-38.5 mm SL; swamp area east of Chantaburi, on highway to Trat (app. 12°33' N, 102°10' E); leg. N. Thantaha & I. Schindler, Oct. 1999. CIS, 1 specimen (not measured), creek at street (344) from Chonburi to Klaeng, near to Pa Yup (app. 13°01' N, 101°27' E); leg. N. Thantaha, April 2000.

Diagnosis: Member of the *B. picta* group. This species differs from the remaining mouth-brooding *Betta* species by the combination of an almost round caudal fin, a small size (40 mm SL), presence of chin-bar and second postorbital stripe and no broad dark marginal band along anal and caudal fin.

Description: Based on the examined material. For general appearance see figure 7. Meristics and measurements are summarized in table 2. Maximum known size 40 mm SL. Body comparatively slender (body depth at dorsal fin origin 28.0-31.6% of SL), head comparatively long (head length 34.5-37.2 % of SL) and relatively pointed. Dorsal and anal fin pointed; dorsal fin situated far posterior (predorsal length 66.2-70.1% of SL); caudal fin round, median rays in males slightly elongated, giving a pointed appearance; length of anal fin base about half of standard length (49.7-53.5% of SL); dorsal fin base length 10.4-14.0 % of SL; filamentous second pelvic fin ray reaching up to 37 % of SL); pectoral fins rounded (length 18.5-24.4% of SL). Dorsal fin rays I,8(6). Anal fin rays II,23(2), II,24(3) or II,25(1). Pectoral fin rays 12(4) or 13(2). Pelvic fin rays I,1,4. Lateral



**Fig. 7:** *Betta prima*, male.

**Abb. 7:** *Betta prima*, Männchen.

scales 27(4) or 28(2). Transverse scales at dorsal fin origin  $9\frac{1}{2}$ (5) or  $10\frac{1}{2}$ (1). Predorsal scales 21-22, postdorsal scales 9-10.

Colouration (preserved): Body greyish, dorsal darker, belly lighter. Lower lip black; chin-bar, pre- and postorbital stripes present; second postorbital stripe present. Dorsal fin with rows of dots on the interradiar area. Caudal fin plain, colourless without transverse bars. Anal fin with a very narrow dark margin. Upper and central stripe continuous, second central stripe from ventral edge of pectoral fin to lower caudal fin base. Distinct caudal fin spot usually separated from central stripe. For live colours see KOTTELAT (1994).

Distribution: The species is widely distributed in the south-east part of Thailand (fig. 10) and in Cambodia (KOTTELAT 1994). This region is separated as a particular subregion of the fish fauna of the Sundaic district by KOTTELAT (1989). There are also specimens from southern Vietnam, which are identified as conspecific with *B. prima* (pers. observ.).

Habitat notes: The habitat of the examined specimens was a swamp area near a large pond. *Betta prima* were collected between overflowed plants. The water was clear and colourless. The following measurements (pers. observ.) were obtained (Oct. 1999, 2:00 pm): pH 6.6, 180  $\mu$ S/cm and 25.8 °C.

Comparative notes: According to SCHMIDT (1996) *Betta prima* is a member of the *B. picta* group. It can be differentiated from the other

species of this group by a round or slightly pointed caudal fin (*versus* lanceolate caudal fin in *B. enisae* and *B. pallida*), a complete second postorbital stripe (*versus* non, reduced or strongly masked stripe in *B. enisae*, *B. simplex* and *B. taeniata*), no broad dark band on anal fin (*versus* broad dark marginal or submarginal band present in *B. edithae*, *B. enisae*, *B. falx*, *B. picta*, *B. simplex* and *B. taeniata*), distinct central stripes (*versus* very faint in *B. enisae*, *B. simplex* and *B. taeniata* or fainter and disrupted in *B. edithae*) and lower number of anal fin rays (<28 *versus* >27 in *B. edithae*). For further differences between *B. prima* and *B. pallida* see 3.1.3.

Remarks: Formerly this species was identified as *B. taeniata*, *B. macrophthalmia* or *B. pugnax* (e.g. SMITH 1945, KOTTELAT 1989).

### 3.1.5. *Betta simplex*

*Betta simplex* KOTTELAT, 1994: 301. Holotype: ZRC 38486. Type locality: Thailand, Krabi Province, northwest of Krabi, spring of Tham Sra Kaew and Nine Ponds, behind Ban Nai Sra village, 2.2 km from National Highway 4034, 1800 m behind Public Health Center.

Material examined: CIS, 2 specimens, 30.1 and 31.9 mm SL; creek south-east of Sra Kaew on road to Krabi (app. 8°06'N 98°50'E); leg. N. Thantaha & I. Schindler, Oct. 1999.

Diagnosis: Member of the *B. picta* group. Distinguished from other species by the combination of a broad dark marginal band along anal



**Fig. 8:** *B. simplex*; **a** male, **b** female.  
**Abb. 8:** *B. simplex*; **a** Männchen, **b** Weibchen.

fin and ventral part of anal fin, round dorsal, anal and caudal fin in males and females, low number of anal fin rays (up to 24), central stripes faint in males and small size (up to 40 mm SL).

Description: Based on material and data published by Kottelat (1994). For general appearance of body shape and colour pattern see figure 8. Morphometric and meristic data are summarized in table 2. Maximum known size 40 mm SL. Body with comparatively deepbodied appearance (body depth at dorsal fin origin 26.8-32.3% of SL), head long (head length 34.6-38.6 % of SL) and pointed. Dorsal, caudal and anal fins rounded in males and females; dorsal fin situated far posterior (predorsal length 65.8-69.8% of SL); length of anal fin base up to half of standard length (48.3-50.0% of SL); dorsal fin base length 11.2-15.4 % of SL; pelvic fin short reaching up only to 30% of SL; pectoral fin rounded (length 18.0-22.4% of SL). Dorsal fin rays 0,9(3) or I,8(3). Anal fin rays

II,21(1) or II,22(5). Pectoral fin rays 11(3) or 12(3). Pelvic fin rays I,1,4. Lateral scales 27(3) or 28(3). Transverse scales at dorsal fin origin  $9\frac{1}{2}$ (3),  $10\frac{1}{2}$ (1) or  $11\frac{1}{2}$ (2). Predorsal scales 20-21, postdorsal scales 9-10.

Colouration (live): Male: body light reddish to brown. Scales on body with greenish-blue iridescent centre. Operculum and throat greenish-blue iridescent (dark pigmented when preserved). Lower lip black; chin-bar, pre- and post-orbital stripes present; second postorbital stripe present, but sometimes split in larger staggered parts or masked by pigmentation. Dorsal fin brown with a thin light distal margin, caudal fin brown with a light distal margin and a broad dark subdistal band, no transverse rows on interradial area; anal fin brown at base with a bluish thin distal margin and a broad dark band on caudal and ventral parts. Pelvic fins brown at base and blueish in distal area and filaments; pectoral fin hyaline. Upper stripe faint, con-

**Tab. 2:** Morphometric (as percentage of standard length; SL in mm) and meristic data of *B. pallida*, *B. prima*, *B. simplex* and *B. pi.\** = from Tan 1998; mean = arithmetic mean; sd = standard deviation; min = lowest value; max = highest value.

**Tab. 2:** Morphometrische (in Prozent der Standardlänge) und meristische Daten von *B. pallida*, *B. prima*, *B. simplex* und *B. pi.\** = from Tan 1998; mean = arithmetrischer Mittelwert; sd = Standardabweichung; min = kleinster Wert; max = größter Wert.

Character	<i>B. pallida</i> ; Ko Samui (n=11)				<i>B. prima</i> (n=5)				<i>B. simplex</i> (n=2)		<i>Betta pi.*</i>	
	mean	sd	min	max	mean	sd	min	max	min	max	min	max
Standard length (mm)	42.6	2.62	39.8	47.8	34.5	3.19	30.6	38.1	30.1	31.9		54.9
Total length	142.2	4.09	136.0	149.2	139.0	2.33	134.9	140.6	134.2	137.9		
Predorsal length	66.7	1.42	64.8	69.0	66.9	0.79	66.2	68.2	65.8	68.0	62.7	67.2
Postdorsal length	21.5	0.89	19.8	22.9	20.6	1.96	18.8	23.7	17.4	19.2	20.1	25.0
Prenal length	49.1	1.01	48.0	51.5	50.6	1.79	48.8	52.6	51.7	52.8	44.3	47.8
Body depth at dorsal fin	30.9	0.74	29.4	32.0	29.9	1.26	28.0	31.5	26.7	29.5	26.4	29.7
Caudal peduncle depth	19.5	0.77	18.1	20.5	19.7	0.57	18.8	20.2	18.2	21.1	16.3	18.4
Head length	33.8	1.31	32.1	35.9	36.2	0.78	35.1	37.2	36.2	38.6	32.3	34.4
Orbit diameter	9.5	0.32	8.9	9.9	11.0	0.45	10.5	11.7	10.3	10.3	8.4	9.8
Postorbital length	16.5	0.87	15.1	17.7	16.6	1.20	15.0	17.8	16.9	20.3		
Interorbital width	12.9	0.65	12.0	14.1	12.9	0.76	11.9	13.9	13.9	14.7		
Dorsal-fin base length	12.9	1.17	11.0	14.9	12.5	1.29	10.4	13.9	13.6	15.4		
Anal-fin base length	52.9	1.32	50.2	54.5	51.6	1.21	49.8	52.8	48.6	49.5	53.0	57.5
Pelvic fin length	35.5	3.67	28.8	40.4	28.5	4.07	21.4	31.9	29.2	29.6	32.2	41.9
Lateral scales	27.9	0.35	27	29	27.0	0	27	27	27	28	32	33
Predorsal scales	21.4	0.52	21	22	21.8	0.45	21	22	21	21	24	25
Postdorsal scales	9.4	0.58	8.5	10	9.2	0.27	9	10	9	9	11	12
Transverse scales	9.3	0.26	9	9.5	9.5	0	9.5	9.5	9	9	9.5	10
Total anal-fin rays	25.9	1.30	24	28	25.8	0.83	25	27	24	24	30	32
Anal-fin rays ("spines")	1.9	0.30	1	2	2	0	2	2	2	2	1	2
Anal-fin rays (articulated)	24.0	1.34	22	26	23.8	0.83	23	25	22	23	28	31
Total dorsal-fin rays	10.0	0.63	9	11	9.0	0	9	9	9	9	8	10

tinuously from upper margin of eye to dorsal caudal-fin base. Central stripe faint, continuously from posterior part of opercle to middle of caudal-fin base. Second central stripe very faint from lower pectoral fin base to lower caudal fin base, conjunct with central stripe above the posterior third of anal fin base. Caudal base spot present, inconspicuous. Female: body pale yellowish brown. Dark stripes on head and body more conspicuous. Fins mostly hyaline, anal fin with a narrow dark submarginal band.

Distribution: Known only from the area around Krabi at the west coast of southern Thailand (fig. 10).

Habitat notes: The type locality is described as a pool of 10-15 m diameter, up to 10 m deep. The fishes were collected along the banks. The water temperature was 27 °C, pH 7.0, electric conductivity 530 µS/cm (LINKE 1991). The examined specimens were collected in a comparatively fast flowing, clear-water creek. The specimens were found between plants.

Comparative notes: *B. simplex* differs from *B. pallida* and *B. prima* by the presence of a broad prominent dark margin (bluish in live) on anal fin and lower half of caudal fin (*versus* a thin diffuse marginal or submarginal dark stripe on anal fin and no dark pattern on caudal fin) and a rounded caudal fin (*versus* lanceolate in *B. pallida* and slightly pointed in *B. prima*). From *B. picta*, *B. falx*, *B. pallida* and *B. prima* it is distinguished by a round anal fin in both males and females (*versus* pointed in males) and faint lateral stripes (*versus* distinct lateral stripes). From *B. picta* and *B. falx* it is differentiated by a deeper body (body depth at dorsal fin origin 27.7-32.3 % of SL *versus* 21.5-28.0 % of SL) and a more caudally positioned dorsal fin (predorsal fin length 65.8-69.8 % of SL *versus* 60.0-67.6 % of SL). It differs from *B. enisae* by the round caudal fin without transverse bars (*versus* caudal fin lanceolate with transverse bars), from *B. taeniata* by a smaller size (up to 40 mm SL *versus* up to 55 mm SL) and less scales in lateral line (mode 28 *versus* mode 29) and from *B. edithae* by a lower number of anal fin rays (<26 *versus* >27) and less lateral scales (<29 *versus* >28).

Remarks: The more protruded lower jaw used by KOTTELAT (1994) to distinguish *B. simplex* from similar species cannot be confirmed herein. It seems that the observed character shown in the original description (KOTTELAT 1994) is an individual structure of the type specimens instead of a diagnostic character of the species. The character of head length used by TAN & NG (2005a: 78) to separate *B. taeniata* from *B. simplex* is not useful since the data for *B. taeniata* broadly overlap with those of *B. simplex*.

### 3.1.6. *Betta pi*

*Betta pi* TAN, 1998: 285. Holotype: ZRC 40289. Type locality: Thailand, Province Narathiwat, Mae Nam Tod Deng, about 6 km north of Sungai Kolok.

Material examined: CIS, 2 specimens, 30.5 and 36.3 mm SL; small creek and swamp few kilometres north of Sungai Kolok at the road from Narathiwat to Sungai Kolok; leg. N. THANTAHA & I. SCHINDLER, May 2000.

Diagnosis: Member of the *B. nuseri* group. It is distinguished from all remaining species of *Betta* from Thailand by the unique character of a dark p-shaped mark on throat, a higher number of lateral scales (32-33) and anal fin rays (30-32).

Description: This species was described and illustrated by TAN (1998). For morphometric and meristic data (adopted from Tan 1998) see table 2. For general appearance see figure 11.

Distribution: The species is known only from the southern part of the Narathiwat Province (fig. 9).

Habitat notes: The primary habitats of this species are well shaded peat forest blackwater swamps and creeks which drained out such swamps. The beds are usually covered with dense leaf litter and lots of roots and plants. The free water area is often small and the pH of such habitats is about 6.0 (TAN 1998, pers. observ.).

Comparative notes: The species is easily recognized (even subadult specimens) within the *Betta* species of Thailand by the characteristic dark p-shaped mark below the mouth and a prominent dark central stripe (figs. 11,12).



**Fig. 9:** Distribution of *B. apollon* (dots), *B. ferox* (square) and *B. pi* (triangles) in Thailand. The arrow indicates the Island Penang (type locality of *B. pugnax*).

**Abb. 9:** Verbreitung von *B. apollon* (Punkte), *B. ferox* (Quadrat) und *B. pi* (Dreiecke) in Thailand. Der Pfeil deutet auf die Insel Penang (Typuslokalität von *B. pugnax*).

Remarks: *Betta pi* is the most northern member of the *B. waseri* group (TAN 1998). This species group is diagnosed by TAN & KOTTELAT (1994). The species of this group resemble each other very much and further investigation is needed to confirm the separateness of *B. pi* to its geographic neighbour *B. waseri*.



**Fig. 10:** Distribution of *B. pallida* (triangles), *B. prima* (dots) and *B. simplex* (squares) in Thailand.

**Abb. 10:** Verbreitung von *B. pallida* (Dreiecke), *B. prima* (Punkte) and *B. simplex* (Quadrat) in Thailand.

### 3.2. Statistical analyses

The variation of four selected measurements and counts of samples of 13 taxa are given in figure 13; results of pairwise *t*-tests are summarized in table 3. The variation in head length (fig. 13 a) shows a gradual increase in head length from the bubble-nest building species (*B. bellica*, *B. imbellis*, *B. smaragdina* and *B. splendens*; head



**Fig. 11:** *Betta pi*, male. Photo: H. Linke.

**Abb. 11:** *Betta pi*, Männchen. Foto: H. Linke.



**Fig. 12:** *Betta pi*, male,  $\pi$ -shaped marking below the mouth. Photo: H. Linke.

**Abb. 12:** *Betta pi*, Männchen,  $\pi$ -förmige Markierung unter dem Maul. Foto: H. Linke.

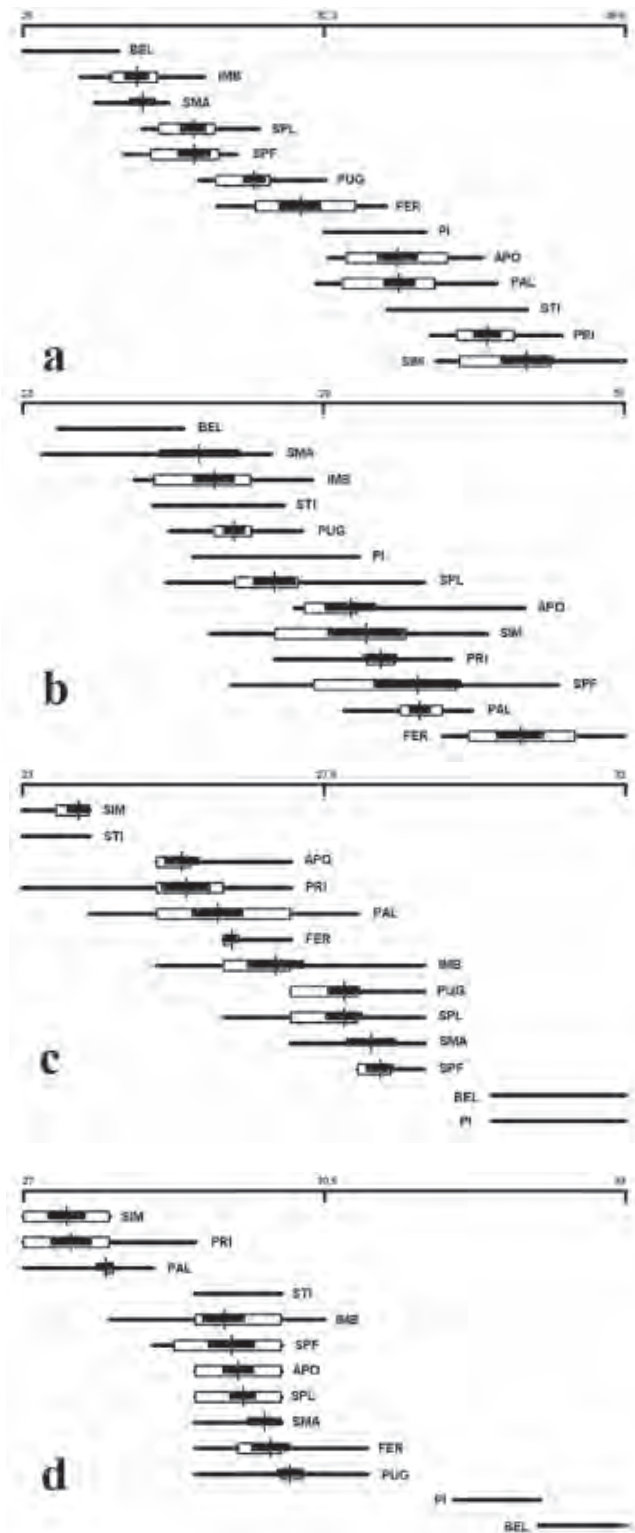
length  $<31\%$  of SL), mouthbrooders with more or less intermediate values (*B. pugnax* Penang and *B. ferox*;  $>29.6$  and  $<33.7\%$ ) to the remaining mouthbrooding species (*B. pi*, *B. apollon*, *B. pallida*, *B. stigmata*, *B. prima*, *B. simplex*;  $>32.0\%$ ). The pattern of variation of body depth (fig.

13 b) does not reveal any unambiguous cluster and shows bubble-nest breeding mixed with mouthbrooding species. However, the deep-bodied *B. ferox* differs significantly in body depth (except for the domesticated *B. splendens*) from all other species (tab. 3). There are three obvious clusters in the variation of numbers of anal fin rays (fig. 13 c). The species with the lowest numbers are *B. simplex* and *B. stigmata*, followed by a cluster which is divided into two subclusters, the first including *B. apollon*, *B. prima*, *B. pallida*, *B. ferox* and *B. imbellis*, the second *B. pugnax*, *B. splendens* and *B. smaragdina*. The cluster with the highest number is built by *B. pi* and *B. bellica*. The analyses of the lateral scale counts (fig. 13 d) reveal three unambiguous clusters (which differ significantly; tab. 3). The lowest number of lateral scales (up to 28) is found in *B. simplex*, *B. prima* and *B. pallida* (members of the *B. picta* group). The intermediate numbers (usually 29 to 31) are represented by *B. stigmata*, *B. imbellis*, *B. splendens*, *B. apollon*, *B. smaragdina*, *B. ferox* and *B. pugnax*. The highest numbers ( $>31$ ) are observed in *B. pi* and *B. bellica*.

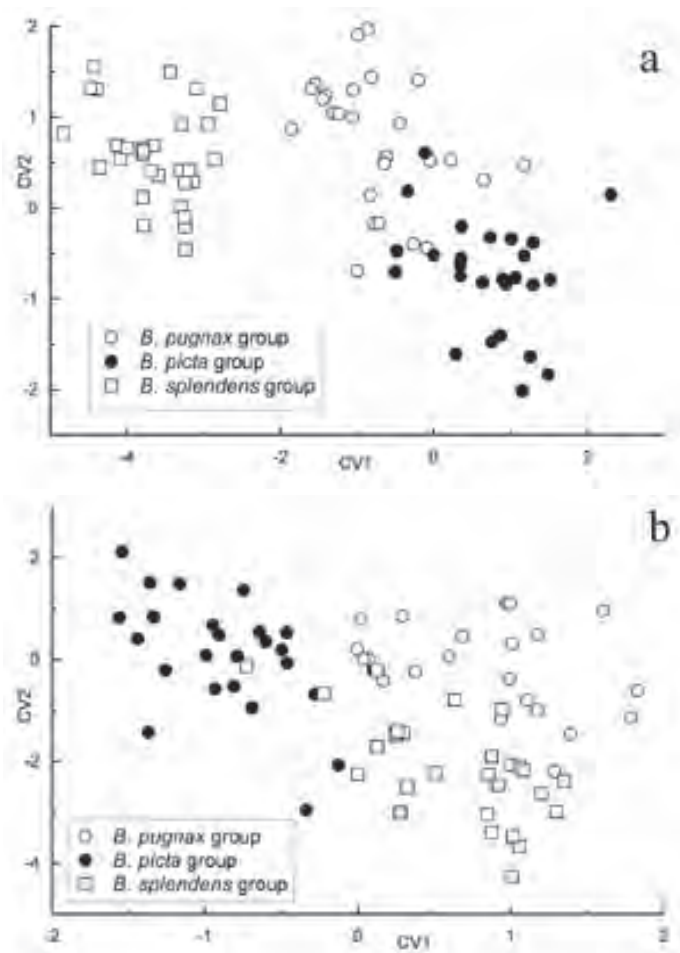
The CVA was calculated to obtain the differences between three of the species groups for with members occurring in Thailand (except for *B. pi* of the *B. waseri* group, because there

**Figs. 13 a-d:** Box-plots for four descriptive characters: **a** head length in per cent of SL, **b** body depth at dorsal-fin origin in per cent of SL, **c** count of total anal fin rays, **d** count of lateral scales. Given are the range (line), the 1st and 3rd quartile (open box), standard deviation of mean (filled box) and arithmetic mean (bar). APO = *B. apollon* (n = 8), BEL = *B. bellica*\*, FER = *B. ferax* (n = 8), IMB = *B. imbellis* (n = 9), PAL = *B. pallida* (n = 13), PI = *B. pi* #, PRI = *B. prima* (n = 9), PUG = *B. pugnax* (n = 10), SIM = *B. simplex* (n = 6), SMA = *B. smaragdina* (n = 5), SPL = *B. splendens* (feral) (n = 9), SPF = *B. splendens* (domesticated) (n = 10), STI = *B. stigmosa*°. \* = data from TAN & NG (1996), # = data from TAN (1998), ° = data from TAN & NG (2005a).

**Abb. 13 a-d:** Balkendiagramme für vier ausgewählte Merkmale: **a** Kopflänge in Prozent der SL, **b** Körperhöhe am Rückenflossenansatz in Prozent der SL, **c** Zahl der gesamten Afterflossenstrahlen, **d** Zahl der Lateralschuppen. Angegeben sind die Spannweite (Linie), das 1. und 3. Quartil (offener Balken), Standardfehler des Mittelwertes (gefüllter Balken) und der arithmetische Mittelwert (Querstrich). APO = *B. apollon* (n = 8), BEL = *B. bellica*\*, FER = *B. ferax* (n = 8), IMB = *B. imbellis* (n = 9), PAL = *B. pallida* (n = 13), PI = *B. pi* #, PRI = *B. prima* (n = 9), PUG = *B. pugnax* (n = 10), SIM = *B. simplex* (n = 6), SMA = *B. smaragdina* (n = 5), SPL = *B. splendens* (Wildform) (n = 9), SPF = *B. splendens* (domestizierte) (n = 10), STI = *B. stigmosa*°. \* = Daten aus TAN & NG (1996), # = Daten aus TAN (1998), ° = Daten aus TAN & NG (2005a).







**Figs. 14 a and b:** Scatter-plot of the scores CV1 and CV2 obtained **a** from the measurements and **b** from the counts (result of CVA of morphometric data). **Abb. 14 a und b:** Auftragung der CV1- und CV2-Werte aus **a** den Mess- und **b** den Zählwerten (Ergebnis der CVA aus den morphometrischen Daten).

group from the *B. picta*- and *B. pugnax* group. However, the separation between the clusters is not as clear as in the CVA of the measurements data. The loadings on CV2 contrasted the counts of the anal and dorsal fin rays with the number of the postdorsal scales.

#### 4. Discussion

The species of the genus *Betta* tend to be morphologically conservative, with only few clear-cut interspecific differences in morphometric or meristic characters within a species group or even between different groups (KOTTELAT & NG 1994). Live colouration, pattern of dark markings on head and body sides, fin shape and selected metrics are useful in distinguishing

species. However, some of these characters or character states are difficult to describe and therefore often difficult to use for ichthyologists who are unfamiliar with the variation and the specific characters of taxa within the genus (TAN & NG 2005a). In the recently published descriptions of new *Betta* species proportional metrics and meristics were also used to discriminate closely related species, even in cases where the range of the character states overlaps (TAN & TAN 1996, TAN & NG 1996, 2005a, 2005b). The lack of any statistic test in these publications makes it difficult to decide if the difference is significant or not. In our point of view it is necessary to evaluate such a predicted difference with a statistic test to proof if it is diagnostic or just informative. Furthermore, some

species are discriminated based mainly on minor difference of head or snout shape, hue of the pelvic fin tip or slight modifications in the dark pattern on lower lip (NG & KOTTELAT 1992, TAN & NG 1996, NG & KOTTELAT 1994). These species delimitations are problematic, because such differences often lie in the observed variation range within a single species and make it difficult to confirm the validity of these taxa by subsequent researchers (SCHMIDT 1996). The species described herein are delimited by the correlated presence of (at least) two discrete characters or divergent character states obtained from independent character complexes (e. g. the combination of a distinguishable meristic character and a diagnostic character in colour pattern). A single character can only be used as a diagnostic distinction if it is representing an unambiguous autapomorphy for the concerned taxon. Using this approach makes it more likely that only genetically different units are recognized as separate species (SEEHAUSEN et al. 1998).

The two new species *B. apollon* and *B. ferox* belong to the *B. pugnax* group and are similar to *B. pugnax*. The diagnostic differences discussed above, the description of *B. stigmosa* (formerly enclosed in *B. pugnax*, see TAN & TAN 1996 and TAN & NG 2005a) and the morphometrics obtained on the topotypes of *B. pugnax* (tab. 1; for a description of *B. pugnax* based on topotypes from Penang see ALFRED 1963) makes it necessary to examine the concept of the taxon *B. pugnax* again. Earlier interpretations of this taxon (e.g. TWEEDIE 1952) and the redescription by TAN & TAN (1996) enclosed more than one species. Although a revision of *B. pugnax* is not within the scope of this paper, presently it seems likely to assign such populations to *B. pugnax* with a strongly reduced or absent second postorbital stripe which are found in the fluvial habitats draining to the west and south coast of the Malayan Peninsular (including the synonyms *B. macrophthalmia* and *B. brederi* as pointed out by WITTE & SCHMIDT 1992, TAN & TAN 1996, TAN & NG 2005a).

The elongated branchiostegal ray (reaching beyond posterior edge of operculum) in *B.*

*apollon* was first thought to be a temporary appearance during male mouthbreeding or as an artefact of preservation. However, the facts that this structure is observed in males, females and subadult specimens, both in mouthbrooding active and non active adult males, and that the skin on the tip of the last branchiostegal ray is distinctly less pigmented relative to the surrounding skin in adult males (fig. 4) suggest that the presence of the extended branchiostegal ray is a distinctive character of this taxon.

The species of genus *Betta* are divided in species groups (review in TAN & NG 2005a). The species in the different groups differ from one author to the other (KOTTELAT & NG 1994, NG & KOTTELAT 1994, SCHMIDT 1996, TAN & NG 2005a, WITTE & SCHMIDT 1992). This reflects the difficulties to discriminate the species groups. The lack of a comprehensive phylogenetic analysis (which should consider different kinds of character complexes) makes it impossible to decide if a proposed species group entity is monophyletic or not. In particular the differentiation between the *B. picta* and the *B. pugnax* group and the species included in these groups are under discussion (see 3.1.). In contrast to KOTTELAT (1994, 1995a) and TAN & NG (2005a) we include *B. prima*, *B. pallida* and *B. enisae* in the *B. picta* group, because they share a low number of lateral scales, a comparatively low count of anal fin rays and a relatively small maximum size with *B. picta* as the nominal member of the group (cf. figs. 13, 14). Although *B. brevipobesus* is described as superficially similar to *B. enisae* (see TAN & KOTTELAT 1998a) it is not included in the *B. picta* group because of the higher number of lateral scales (29-30). Anyway, all statements and classifications must be provisional until a comprehensive phylogenetic analysis is available. In the reconstructed tree of the genus *Betta* using nuclear and mitochondrial DNA sequences no monophyletic cluster can be detected neither for the *B. picta* nor for the *B. pugnax* group (RÜBER et al. 2004). Nevertheless, there are differences between the *B. picta* and the *B. pugnax* group

in the morphometric data (see 3.2., figs. 13, 14) obtained from the specimens examined. Thus for practical reasons it seems better to keep both groups separate.

RICHTER (1981) attempted to divide the genus *Betta* into two separate genera, one for the bubble-nest builders and the other for the mouthbrooders. He created the new genus *Pseudobetta* with *B. pugnax* as type species. However, both type species of the proposed genera *Pseudobetta* and *Betta* (type species *B. picta*) are mouthbrooders. Therefore *Pseudobetta* was immediately rejected (KOTTELAT 1982) or treated as a synonym (ROBERTS 1989). Despite this taxonomic confusion, there is a clear difference between the bubble-nest builders of the *B. splendens* group and the herein examined mouthbrooders of the *B. picta*, *B. pugnax* and *B. waseri* group regarding morphometrics, patterns of dark markings, ecological requirements, behaviour and molecular data (VIERKE 1986, SCHMIDT 1996, RÜBER et al. 2004, pers. observ.). Although a comprehensive discussion of the genus *Betta* is not dealt with in this paper, there are some obvious differences to be mentioned. The CVA of the morphometric

data (fig. 14 a) shows that both units (bubble-nest builders *versus* mouthbrooders) are well separated in general body proportions (figs. 13 a, 13 b). The second central stripe is absent or at least strongly reduced in species of the *B. splendens* group (*versus* presence). The members of the *B. splendens* group inhabit a different ecological niche (e. g. ALFRED 1963, VIERKE 1986). There are differences in ethological characters, which are not only concerned with the reproductive behaviour and therefore not necessarily causally connected with it (SCHMIDT 1996). Furtheron, the analysis of the molecular data detected a well supported separate cluster for the genetically similar species of the *B. splendens* group (RÜBER et al. 2004). Nevertheless, at this time it seems to be best to keep only a single genus *Betta*, because the generic division of the genus only on the reproductive behaviour is problematic (ROBERTS 1989), particularly, since there are species which show ethological elements of both groups (SCHMIDT 1996). Further phylogenetic studies will have to show whether the genus has to be split or subgenera should be established.

**Tab. 5:** Key for the mouthbrooding species of *Betta* from Thailand.

**Tab. 5:** Bestimmungsschlüssel der maulbrütenden *Betta*-Arten von Thailand.

- |     |  |                            |
|-----|--|----------------------------|
| 1a) | Total anal-fin rays > 29; number of lateral scales > 31; a characteristic dark $\pi$ -shaped mark on lower mouth (fig. 12) ...             | <i>B. (waseri) pi</i>      |
| 1b) | Total anal-fin rays < 30; number of lateral scales < 31; no $\pi$ -shaped mark ...   | 2                          |
| 2a) | Lower part of caudal fin and anal fin with a broad dark marginal band; anal fin round ...  | <i>B. (picta) simplex</i>  |
| 2b) | Caudal- and anal fin without such broad dark band; anal fin pointed ...  | 3                          |
| 3a) | Caudal fin plain, without transverse bars; lateral scales usually < 29; second central stripe posteriorly disrupted ...                    | 4                          |
| 3b) | Caudal fin with transverse bars; lateral scales usually > 28; second central stripe continuously ...                                       | 5                          |
| 4a) | Caudal fin lanceolate; central stripe continuously not clearly separated from caudal fin base spot ...                                     | <i>B. (picta) pallida</i>  |
| 4b) | Caudal fin round or slightly pointed; central stripe often posteriorly interrupted and usually separated from the caudal-fin base spot ... | <i>B. (picta) prima</i>    |
| 5a) | Last branchiostegal ray elongated (Fig. 4); body depth 28.4–33.0% (mean 29.5%) of SL; head length 32.4–35.6% (mean 33.8%) of SL ...        | <i>B. (pugnax) apollon</i> |
| 5b) | No particular elongated branchiostegal ray; body depth 31.4–35.0% (mean 32.9%) of SL; head length 30.0–33.6% (mean 31.8%) of SL ...        | <i>B. (pugnax) ferox</i>   |

## 5. Key for the mouthbrooding species of *Betta* from Thailand

The key (tab. 5) was prepared for species occurring in the study area. The character state fin shape is valid for adult males only. In cases of proportional data of measurements it is intended for use with a series of specimens including mature specimens. The species diagnoses, descriptions and photographs provided above should also be consulted. Interpolated names (to be given in parentheses; art. 6.2. ICZN) are used to allow easy cross references to species groups.

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