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J. Herler [a] , R. A. Patzner [b] & C. Sturmbauer [c]

[a] Institute of Zoology , University of Vienna , Austria

[b] Institute of Zoology , University of Salzburg , Austria

[c] Institute of Zoology , University of Graz , Austria

[d] Institute of Zoology , University of Vienna , Althanstraße 14, A-1090 Vienna, Austria E-mail:

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A preliminary revision of the *Gobius auratus* species complex with redescription of *Gobius auratus* Risso, 1810

J. HERLER[1], R. A. PATZNER[2], & C. STURMBAUER[3]

[1]*Institute of Zoology, University of Vienna, Austria,* [2]*Institute of Zoology, University of Salzburg, Austria, and* [3]*Institute of Zoology, University of Graz, Austria*

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Abstract
The study focused on two gobiid taxa from the northern Adriatic Sea. External features and coloration suggest identification of one of these with *Gobius auratus* Risso, 1810. This species is characterized by a deeply emarginated pelvic disc and meristic features of typically second dorsal fin rays I/14, anal rays I/13 and scales in lateral series 45. The live coloration of the northern Adriatic population shows a yellow basic coloration but with distinct longitudinal lines of red dots and, therefore, its colour significantly differs from the uniformly yellow coloration supposed to be typical for this species. A redescription of this putative *G. auratus* Risso, 1810 is carried out to extend the morphological characteristics of the species to cover also the northern Adriatic population. Two colour morphs are described and morphometrics as well as details on the lateral line system of the species are newly included in the species description. The second Adriatic taxon was assigned to *G. fallax* Sarato, 1889. Both taxa from the northern Adriatic were compared to *G. xanthocephalus* Heymer and Zander, 1992 from the western Mediterranean and Atlantic indicating their clear distinction. The northern Adriatic specimens of *G. auratus* show some similarities with the western Mediterranean and Atlantic *G. xanthocephalus* concerning life coloration, but differ in a series of features such as certain morphometrics (head and pelvic disc longer in the former, fifth pelvic ray, relative to fourth, longer in the latter), meristics (second dorsal rays mostly I/14 in the former and I/15 in the latter, anal rays mostly I/13 versus I/14, scales in lateral series about 45 versus 48). *Gobius fallax* is distinguishable by a different coloration pattern and shows the lowest values in mean fin and scale meristics. Phylogenetic analysis of DNA sequences of the first section of the control region revealed that all individuals of both colour morphs of *G. auratus* and of *G. fallax* form a single cluster of closely related haplotypes which are not sorted according to the species, suggesting their recent origin. Only *G. xanthocephalus* is, in agreement to morphology, also genetically distinct and represents a separate clade. The existence of a *Gobius auratus* species complex is therefore confirmed.

Keywords: *Gobius auratus, Gobius fallax, Gobius xanthocephalus, Mediterranean Sea, morphology, mtDNA control region*

Introduction

The family Gobiidae is the most diverse marine fish family and includes more than 1800 species. The centre of diversity of these mostly small and cryptic fish is the tropical and

Correspondence: J. Herler, Institute of Zoology, University of Vienna, Althanstraße 14, A-1090 Vienna, Austria. E-mail: Juergen.Herler@univie.ac.at

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warm temperate seas (Nelson 1994). Also, the Mediterranean Sea harbours a diverse gobiid fauna with a relatively high degree of endemism compared to the north-eastern Atlantic (Miller 1986). The genus *Gobius* Linnaeus, 1758 is the most diverse in the Mediterranean and its species are distinguished taxonomically mainly by features of their lateral line system. A close morphological resemblance in certain species is obvious. These were accordingly placed in a *G. auratus* species complex by Miller and El-Tawil (1974) because of their great similarity to *G. auratus* Risso, 1810. However, due to the brief species description of *G. auratus* given by Risso (1810), the validity of this species remains in discussion (Ninni 1938; Bini 1969; Miller and El-Tawil 1974; Miller 1986) and also led to various misidentifications as summarized by Heymer and Zander (1992, 1994). The latter authors concluded that a second species exists, which was often confused with *G. auratus* in the past. Since these authors were convinced that the ''true'' *G. auratus* of Risso (1810) is an unmistakable canary yellow-coloured gobiid species, they named the second species *G. xanthocephalus*; which was characterized by paler trunk coloration with a few distinct longitudinal series of dots and a yellow head. Morphological differences between the two species were also evident from meristic features, and from the shape of the ventral and caudal fin. The habitat choice and behaviour were noted as additional distinguishing characters. Reliable records of *G. auratus* are known from throughout the Mediterranean (Miller 1986 (as *G. luteus*); Heymer and Zander 1994), while *G. xanthocephalus* is currently known to occur in the eastern Atlantic and the western Mediterranean only (Heymer and Zander 1994; Wirtz and Herrera 1995; Almeida and Arruda 1998). Closely related species are thought to be *G. fallax* Sarato, 1889, which is widely distributed throughout the Mediterranean (Miller 1986) and the recently described *G. kolombatovici* Kovačić and Miller, 2000, which at present is found only in the northern Adriatic Sea. Miller and El-Tawil (1974) also included *G. gasteveni* Miller, 1974 and *G. couchi* Miller and El-Tawil, 1974 in this *Gobius auratus* species complex. The presence of abundant populations of a gobiid fish in the northern Adriatic Sea, similar to *G. xanthocephalus* in life coloration, but with great affinities to *G. auratus* concerning habitat choice and behaviour, prompted detailed morphological studies in order to reveal its taxonomic identity. It was expected that additional studies of the closely related *G. fallax* from this region would enable a clear discrimination between these sympatric species. The morphological comparisons of the so far undescribed northern Adriatic specimens with material of *G. auratus sensu* Risso, 1810 from Dalmatia, and *G. xanthocephalus* from the western Mediterranean and Atlantic Sea, as well as with descriptions given by previous authors (Heymer and Zander 1992, 1994; Wirtz and Herrera 1995; Almeida and Arruda 1998) led to its assignment to *G. auratus* Risso, 1810, albeit the southern Adriatic, western Mediteranean and Atlantic specimens represent a different colour morph.

This study provides additional details about coloration, body proportions, meristic values and lateral line system for *G. auratus* and *G. fallax* from the northern Adriatic Sea and for *G. xanthocephalus* from the western Mediterranean and Atlantic Sea. To evaluate further the comparative morphological data, a molecular genetic analysis of these closely related taxa was carried out, based on sequences of the first section of the mitochondrial control region (D-loop). This section is known to be highly variable (Faber and Stepien 1997) and is thus suitable for examining evolutionary relationships at the population level and among closely related species (Lee et al. 1995; Mukai et al. 1997; Chen et al. 1998; Stefanni and Thorley 2003). It contains two regions of high mutation rate and also evolutionarily conserved regions. The present paper proposes a *Gobius auratus* species complex, as already suggested by Miller and El-Tawil (1974), based on morphological and molecular genetic results.

Material, methods and abbreviations

Our study includes 61 specimens of *G. auratus* (54 from the northern Adriatic, six from the central Adriatic plus the holotype from France, MNHN 1988-630 by Heymer and Zander 1992); 58 specimens of *G. fallax* (54 from the northern Adriatic plus four specimens from Greece, SMF 10803–10806 by Bath 1971), and 13 specimens of *G. xanthocephalus* from the eastern Atlantic and western Mediterranean (including the three types ZMH 6195 and 7328 by Heymer and Zander 1992). Detailed material lists are given in the species descriptions. Sampling locations are shown in Figure 1.

Morphological methods

Fish were collected and killed with the aid of the anaesthetic 2-methylquinoline (diluted with 75% ethanol 1:15). Individuals were fixed in 4% formaldehyde for at least 7 days and

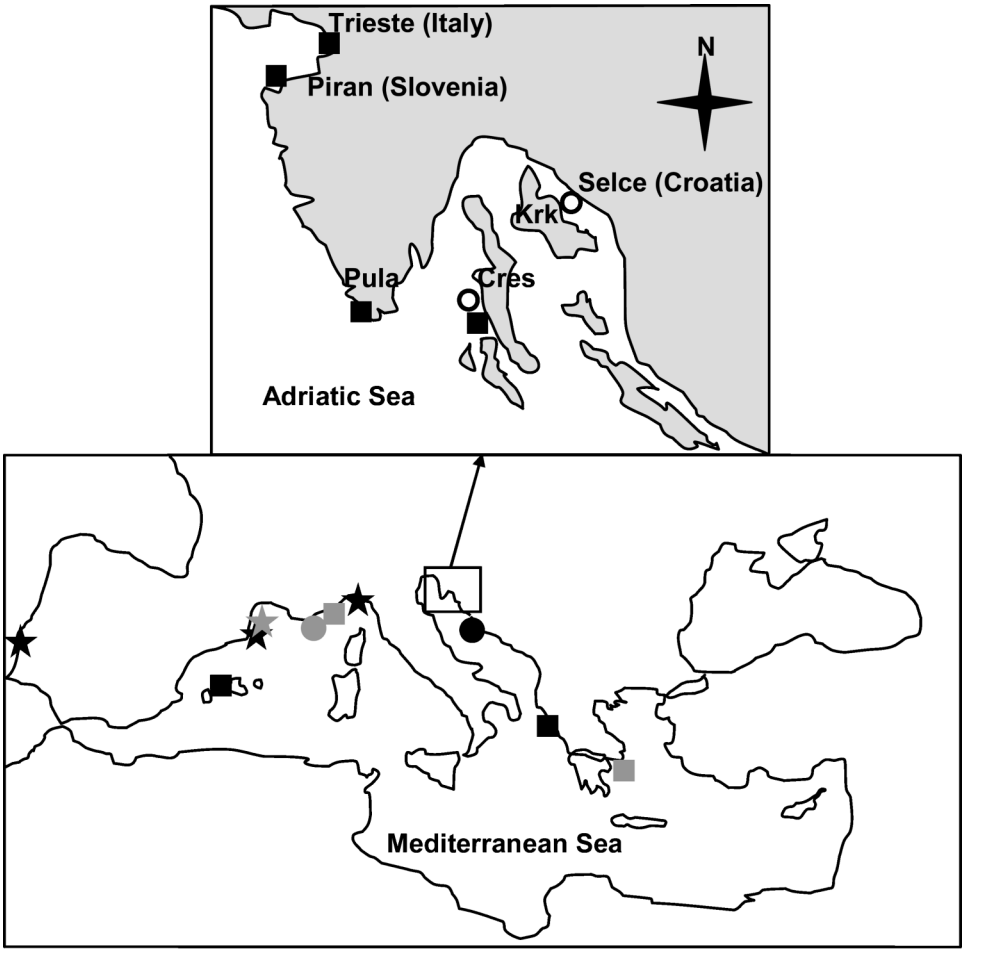

Figure 1. Mediterranean and eastern Atlantic locations of examined material. *G. auratus* colour morph 1 (full circles) and colour morph 2 (open circles), *G. fallax* (squares) and *G. xanthocephalus* (stars). Grey symbols indicate locations of type material by Sarato (1889), Bath (1971) and Heymer and Zander (1992). Insert shows part of the northern Adriatic Sea enlarged. Canary Island location not indicated.

finally stored in 70% ethanol. Body size of fishes is given as standard length + caudal fin length. Morphometric and meristic methods follow Miller (1988). Additional morphometric characters (UJ, V4l, V5l) were examined to describe the extension of the mouth and the ventral fin emargination (see below). The terminology of the lateral line system follows Sanzo (1911) and Miller (1986). The number of neuromasts (only adult specimens), scales and pectoral rays are counted on the left side of the fish. The seventh suborbital row, represented by one or rarely two papillae near pore α is provisionally designated as row "α" in this study.

Abbreviations

Morphometrics. Ab, anal fin base; Ad and Aw, body depth and width at anal fin origin; Cl, caudal fin length (d=damaged); CHd, cheek depth; CP and CPd, caudal peduncle length and depth; D1b and D2b, first and second dorsal fin bases; E, eye diameter; H and Hw, head length and width; I, interorbital width; Pl, pectoral fin length; PO, postorbital length; SL, standard length; SN, snout length; SN/A and SN/AN, snout to anal fin origin and anus; SN/D1 and SN/D2, snout to origin of first and second dorsal fins; SN/V, snout to pelvic disc origin; UJ, upper jaw length; V/AN, pelvic disc origin to anus; Vd, body depth at pelvic disc origin; Vl, pelvic disc length; V4l, length of fourth pelvic soft ray from insertion to tip of longest branch; V5l, length of fifth pelvic soft ray from insertion to tip of shortest (innermost) branch.

Meristics. A, anal fin; C, caudal fin; D1, D2, first and second dorsal fins; LL, scales in lateral series; P, pectoral fin; TR, scales in transverse series; V, pelvic disc.

Lateral line system. AD, anterior dorsal; OP, opercular; OS, oculoscapular; PM, preoperculo-mandibular; PO, preorbital; SO, suborbital.

Collections. MNHN, Muséum National d'Histoire Naturelle, Paris; NMW, Naturhistorisches Museum Wien; SMF, Senckenberg Museum Frankfurt; SMNS, Staatliches Museum für Naturkunde Stuttgart; ZMH, Zoologisches Museum Hamburg.

Molecular genetic analysis

DNA samples were taken from fin tissue of narcotized fish and immediately preserved in 100% ethanol. The sampling locations, number of specimens sequenced from each taxon and their GenBank accession numbers are given in Table I. DNA extraction was carried out by proteinase K digestion followed by NaCl extraction and ethanol precipitation (Bruford et al. 1998). Small pieces of fin tissue were placed in a mixture of 330 μl of extraction buffer, 80 μl of sodium dodecyl sulphate and 10 μl of proteinase K. By incubation at 37°C overnight and the addition of 180 μl of cooled 5 M NaCl and 420 μl of cooled isopropanol, with interim centrifugation at 13,000 rpm for 5 min, a DNA pellet was obtained. This was washed twice with 250 μl of cooled 70% ethanol and by centrifugation. After removing the supernatant, the pellet was dried and resolved in 50 μl of TE buffer (pH 7.5). Aliquots of these DNA extracts were directly used for polymerase chain reaction (PCR). PCR products were obtained from the first section of the control region, including 379 bp, using the forward primer L-PRO-F (5′-AACTCTCACCCCTAGCTCCCAAAG;

Table I. Collection sites and dates, and GenBank accession numbers of mitochondrial control region sequences of 31 individuals out of four gobiid species used for phylogenetic analysis.

Taxon	Collecting site	Collecting year	*n*	GenBank accession numbers
*Ga*1	Murter, Croatia	2001	1	AY 706960
	Murter, Croatia	2001	1	AY 706961
	Murter, Croatia	2001	1	AY 706962
	Murter, Croatia	2001	1	AY 706963
	Murter, Croatia	2001	1[b]	AY 706964
*Ga*2	Krk, Croatia	1999	1	AY 706965
	Krk, Croatia	1999	1	AY 706966
	Krk, Croatia	1999	1[a]	AY 706967
	Krk, Croatia	1999	1	AY 706968
	Krk, Croatia	2000	1	AY 706969
	Cres, Croatia	2001	3[a]	AY 706970
	Cres, Croatia	2001	1[c]	AY 706971
	Cres, Croatia	2001	1[b]	AY 706972
Gf	Piran, Slovenia	2001	4[a]	AY 706973
	Piran, Slovenia	2001	1	AY 706974
	Cres, Croatia	2001	2[a]	AY 706975
	Cres, Croatia	2001	1[c]	AY 706976
	Cres, Croatia	2001	1	AY 706977
	Cres, Croatia	2001	1	AY 706978
	Cres, Croatia	2001	1	AY 706979
	Cres, Croatia	2001	1	AY 706980
	Pula, Croatia	2002	1[a]	AY 706981
Gx	Arrabida, Portugal	2001	1	AY 706982
	Arrabida, Portugal	2001	1	AY 706983
Gb	Krk, Croatia	2000	1	AY 706984

Identical haplotypes from different localities within a taxon or belonging to different taxa are indicated by superscript letters. *Ga*1, *G. auratus* colour morph 1; *Ga*2, *G. auratus* colour morph 2; *Gb*, *G. bucchichi*; *Gf*, *G. fallax*; *Gx*, *G. xanthocephalus*; *n*, number of intraspecifically identical haplotypes within a locality.

Koblmüller et al. 2003) and the reverse primer TDK-D (5′-CCTGAAGTAGGAACC-AGATG; Kocher et al. 1989). Best PCR results were obtained mixing 2.5 μl of DNA extract with 14.5 μl of a prepared PCR master mix containing 6 μl of Aqua destillata AY 706984, 1.7 μl of both primers, 1.7 μl of dNTPs, 1.7 μl of 10 × buffer (20 mM Mg^{2+}), 1.62 μl of enzyme diluent and 0.085 μl of Taq-polymerase for each sample. The PCR reaction mix was transferred into glass capillaries and amplification was performed in an Idaho Technology RapidCycler using the following cycling parameters: 1 × : 94°C for 15 s, 40 × : 94°C/0 s—55°C/0 s—72°C/15 s, and a final extension phase at 72°C for 10 min. The PCR products were visualized by minigel-electrophoresis and ethidium bromide staining. Each PCR product was purified by enzymatic treatment using the ExoSAP-IT reaction kit containing exonuclease I and shrimp alkaline phosphatase. Enzyme solution (1.5 μl) was added to 5 μl of PCR product and incubated at 37°C for 15 min with a final inactivation of the enzymes by heating the samples to 80°C for 15 min. Afterwards 10 μl of A. dest. were added and the samples were frozen at −20°C. For chain termination sequencing (CTS), 0.8–1.2 μl of purified DNA were used, depending on the DNA concentration, and diluted with 3.0–3.4 μl A. dest. (4.2 μl total volume including DNA), 1.4 μl of Termination Reaction Mix, 0.7 μl of forward primer L-PRO-F and 0.7 μl of bovine serum albumin 10 × ,

resulting in a total volume of 7.0 μl. In half of the samples, both strands were also sequenced using the primer TDK-D. The following cycling protocol was used: 1×: 94°C/15 s and 27×: 94°C/0 s—52°C/0 s—60°C/45 s. After DNA sequencing a sodium acetate precipitation was carried out to remove the remaining ddNTPs. The dried pellets were then resolved in 4.4 μl of loading liquid, prepared in a mastermix containing 0.4 μl of loading dye, 0.8 μl of 25 mM EDTA and 3.2 μl of deionized formamide for each sample. Before loading 3 μl on to the Automatic Sequencer (ABI 373 and ABI 377), the samples were denaturated at 94°C for 2 min. Both strands were sequenced. DNA sequences correspond to the first 379 bp of the segment sequenced by Chen et al. (1998).

Phylogenetic analyses were carried out using the phylogenetic software package PAUP version 4.0 (Swofford 2000). *Gobius bucchichi* Steindachner 1870 was used as the outgroup, because this species is related to the taxa concerned but represents a morphologically clearly distinct species (Bath 1971; Ahnelt 1984; J. Herler, personal observation). Maximum parsimony was performed using heuristic search with equal weighting of characters, random stepwise addition of taxa and 100 replicates. In a second step, a neighbour-joining analysis was carried out based upon uncorrected p-distances and compared to the most parsimonious trees. Finally, a minimum-spanning tree was constructed on the basis of the neighbour-joining tree which turned out to be identical to one of the most parsimonious trees.

Results

Morphology

Gobius auratus Risso, 1810
(Figures 2A, 2B, 3A, 3B, 4)

Material

Colour morph 1 (uniformly yellow). Eastern Mediterranean: Croatia (n=6): 1♂, 46.5 + 13.6 mm, near Island of Murter, May 1999, J. Herler; 2♀♀, 34.3 + 9.7 and 44.4 + 12.5 mm (NMW 94843), 2♂♂, 33.1 + 9.3 and 36.2 + 10.7 mm (NMW 94844), and one juvenile, 28.4 + d mm, near Island of Murter, April 2002, T. Puchner.

Colour morph 2 (yellow with red dotted lines). Eastern Mediterranean: Croatia (n=54): 6♀♀, 48.0 + 13.9 to 64.3 + 18.3 mm, and 8♂♂, 51.8 + 15.5 to 69.9 + 21.9 mm, Selce, south of Rijeka, May + July 1999, J. Herler; 7♀♀, 35.0 + 10.4 to 49.9 + 13.3 mm, and 2♂♂, 45.0 + 13.3 and 55.6 + 15.4 mm, Island of Krk (east), Sveti Marak, May + July 1999, J. Herler; 10♀♀, 31.0 + 9.3 to 60.3 + 16.5 mm, 10♂♂, 33.0 + 9.9 to 65.0 + 20.6 mm, and 11 juveniles, 21.4 + 6.9 to 32.1 + 9.0 mm, Island of Cres (west), near Martinscica, June 1999, J. Herler. Two females and two males are stored at the Naturhistorisches Museum Wien with numbers NMW 94845–94848.

Compared material

Colour morph 1. Western Mediterranean: France (n=1): 1♀, 51.9 + 14.1 mm (MNHN 1988/0630, neotype by Heymer and Zander 1992), Le Lavandou, La Formigue, 5 September 1987, A. Heymer.

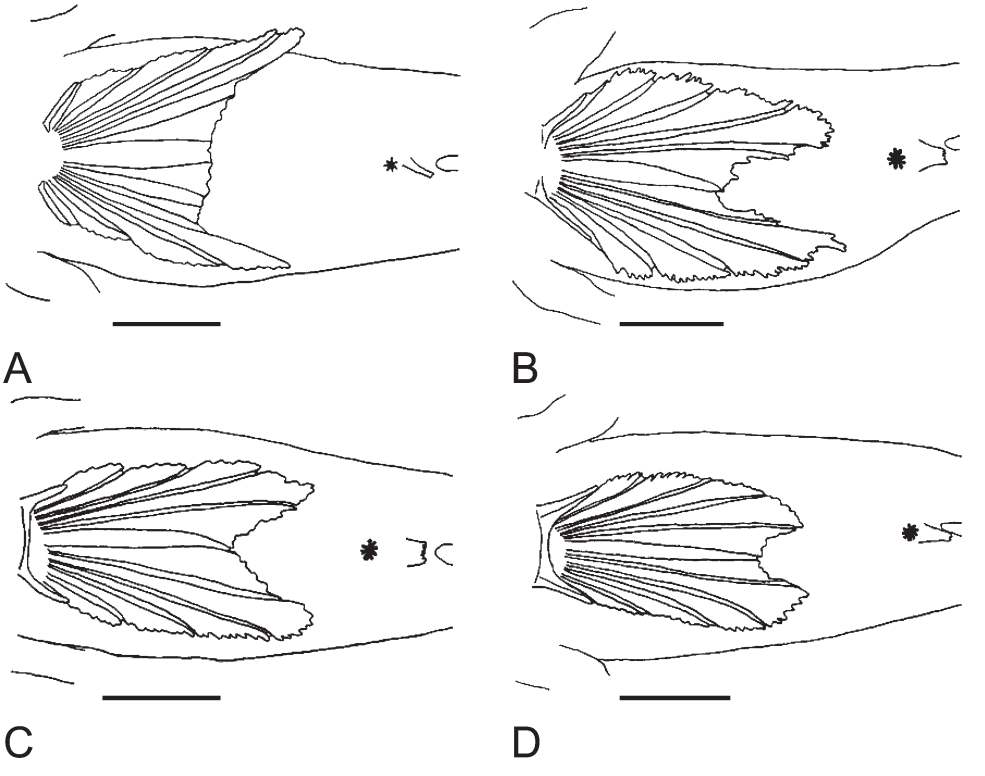

Figure 2. Morphology of the pelvic disc of closely related *Gobius* species. (A) *G. auratus* (colour morph 1), MNHN 1988-630 (neotype of *G. auratus* by Heymer and Zander 1992), male, 57.1 + 15.0 mm (right fourth ray damaged); (B) *G. auratus* (colour morph 2), female, 60.7 + 16.5 mm; (C) *G. fallax*, female, 55.3 + 15.2 mm; (D) *G. xanthocephalus*, male, 55.4 + 15.2 mm. Scale bar: 5 mm.

Identification

Maximum total length about 9 cm. *Gobius auratus* occurs in two main colour morphs in the Adriatic Sea. In the northern Adriatic (southern Istria and Kvarner area) the life coloration observed is a pale to vivid yellow basic coloration, with numerous red dots forming distinct longitudinal lines on the head, trunk and median fins. In more southern parts such as the central Adriatic coast of Croatia, specimens can be recognized in the field by their unique canary yellow basic coloration. A large black spot is usually visible at the base of the upper P-rays but is not always present. The branchiae appear as a distinct red area underneath the somewhat translucent opercle. The head appears somewhat tipped and the dorsal body side is more curved than the ventral side. Pelvic disc deeply emarginated, to almost half of its length. Important meristics are D2 I/14 (13–15), A I/13 (12–14) and LL 44–47 (42–48).

General morphology

As described in Heymer and Zander (1992, 1994) and in Miller (1986: as *G. luteus*). Body proportions for Croatian specimens and for the neotype designated by Heymer and Zander (1992) from France are given in Table II. Body moderately elongate, posterior half of trunk laterally compressed. Head large, length almost one-third of SL, ventral side anteriorly

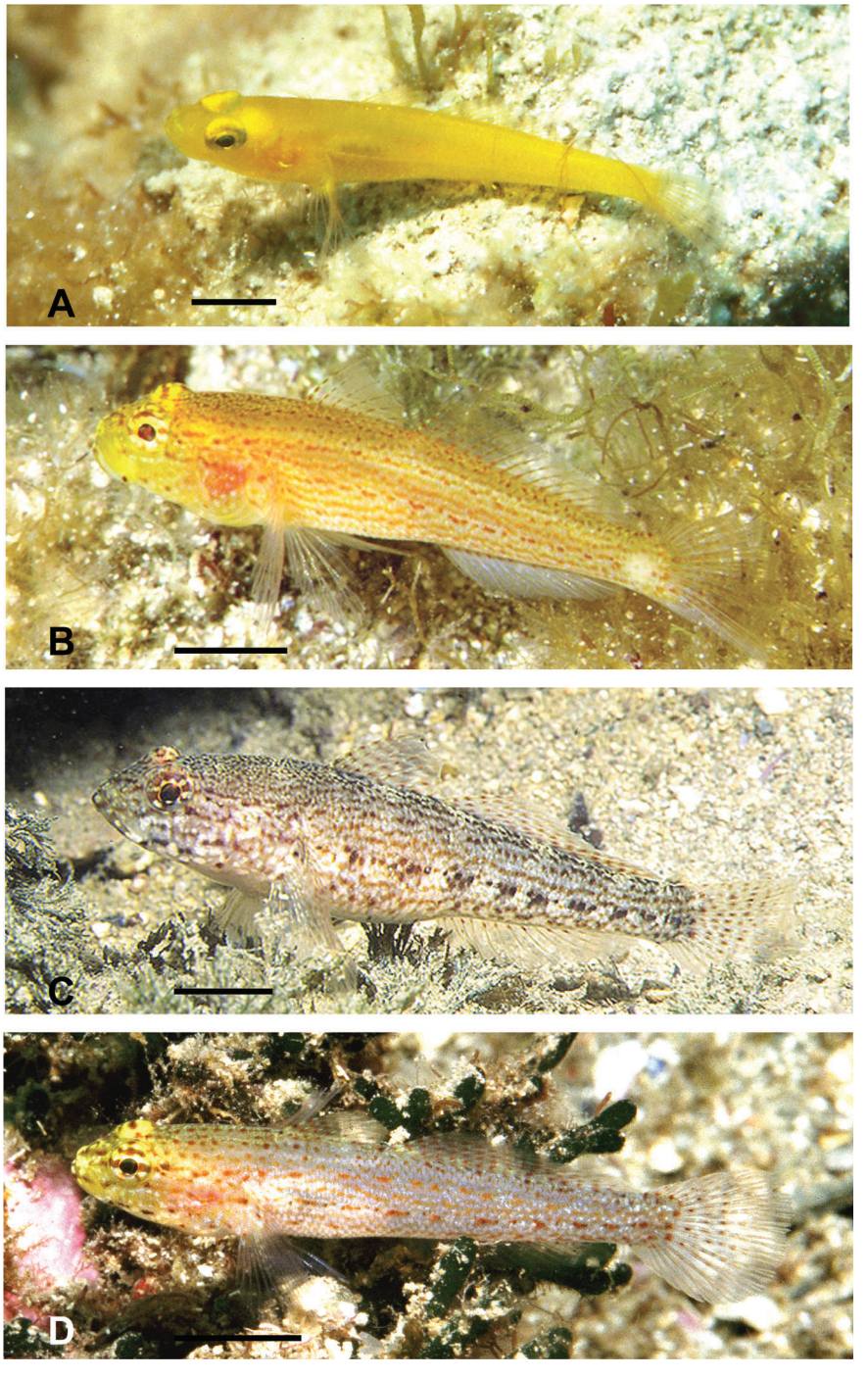

Figure 3. Life coloration of (A) *G. auratus* (colour morph 1: central Adriatic, Island of Murter, Croatia); (B) *G. auratus* (colour morph 2: northern Adriatic, Island of Cres, Croatia); (C) *G. fallax* (northern Adriatic, Island of Krk, Croatia); (D) *G. xanthocephalus* (western Mediterranean, Banyuls-sur-Mer, France). Scale bar: 1 cm.

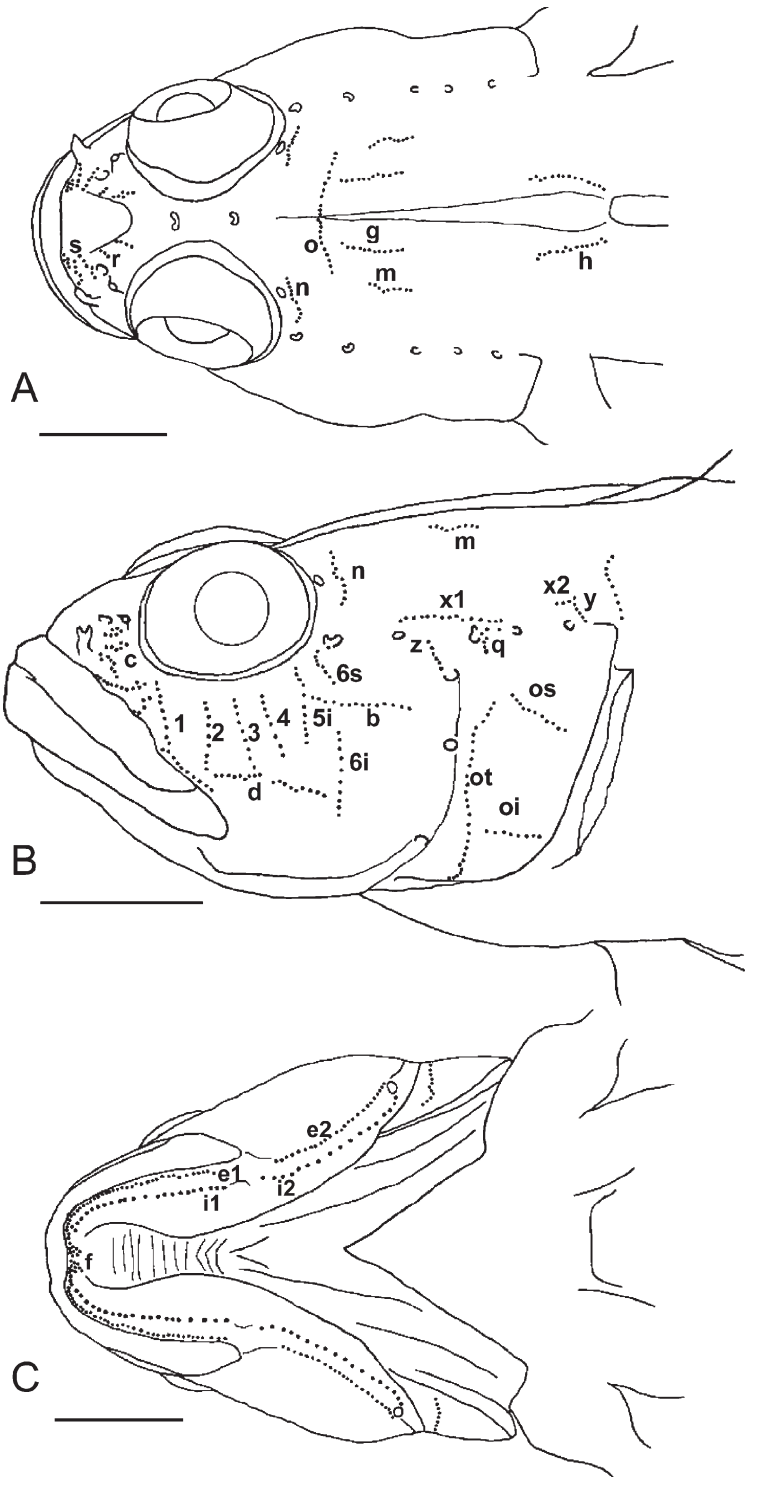

Figure 4. Lateral line system of *G. auratus* (colour morph 2), male, 61.6 + 19.9 mm, from the northern Adriatic Sea in dorsal (A), lateral (B) and ventral (C) view. Scale bar: 5 mm.

Table II. Morphometrics of closely related *Gobius* species from the Mediterranean Sea and Atlantic Ocean.

Taxon		*Gobius auratus*								
Location		Croatia								France
Sex SL mm (*n*)		Females 31.0–64.3 (25)				Males 33.0–69.9 (23)				Male 57.1 (1)
		Min	Max	m	SD	Min	Max	m	SD	Value
%SL	H	30.3	33.7	32.0	0.9	28.7	33.7	31.4	1.4	31.6
	Hw	13.5	17.6	15.2	0.9	13.6	16.5	15.0	0.8	15.1
	SN/D1	35.6	40.3	37.8	1.2	33.6	40.0	36.9	1.6	36.2
	SN/D2	55.5	60.6	57.9	1.4	53.3	59.6	56.7	1.4	55.6
	SN/AN	55.6	59.7	58.2	1.0	54.1	59.2	56.6	1.4	57.4
	SN/A	58.5	63.8	61.7	1.2	57.0	61.9	59.7	1.3	59.9
	SN/V	30.3	36.2	33.2	1.4	30.3	34.9	32.9	1.0	32.3
	CP	15.9	20.0	17.8	1.0	16.2	19.5	17.6	0.9	17.0
	D1b	11.4	14.1	12.8	0.6	11.7	13.5	12.6	0.5	12.1
	D2b	29.4	33.6	31.5	1.2	30.4	36.4	33.0	1.7	31.5
	Ab	21.5	25.7	23.7	0.9	22.7	29.8	25.5	1.7	26.0
	C1	26.5	30.3	28.5	1.0	27.7	33.0	29.8	1.5	26.3
	P1	24.7	30.0	27.2	1.3	24.6	31.8	27.9	1.9	26.0
	V1	21.0	27.6	25.4	1.4	22.3	26.1	24.8	0.9	22.8
	Vd	19.6	24.1	21.6	1.1	19.2	24.4	20.9	1.3	22.6
	Ad	17.5	21.5	19.5	1.0	18.3	21.4	19.4	0.9	20.9
	Aw	9.1	12.7	10.5	0.9	9.1	13.4	10.9	1.2	13.7
	CPd	9.5	11.8	10.4	0.5	9.9	12.1	10.7	0.6	11.8
	V/AN	24.0	28.1	26.0	1.2	20.8	27.0	24.3	1.6	26.9
%CP	CPd	48.0	72.3	58.6	5.4	51.4	73.2	61.3	5.2	69.7
%H	SN	21.2	25.0	22.9	1.0	21.4	25.9	23.6	1.1	26.1
	E	26.6	33.3	30.4	1.5	26.2	32.3	29.4	1.6	28.0
	PO	47.4	53.1	49.6	1.4	46.1	52.8	49.5	1.7	49.5
	CHd	15.5	24.4	20.1	1.9	14.9	25.5	21.2	2.5	21.1
	Hw	42.0	56.5	47.5	3.5	41.0	57.5	48.0	4.1	47.6
	UJ	31.7	41.1	36.4	2.1	33.9	41.8	37.4	2.2	34.8
%E	I	5.2	16.6	10.8	2.6	7.5	19.6	11.8	3.1	12.3
%V/AN	V1	81.1	112.2	97.4	7.7	92.1	124.7	102.3	8.0	84.8
%V41	V51	54.9	68.2	60.3	3.2	54.9	67.8	62.2	2.9	58.7

Table II. (*Continued*).

Taxon		*Gobius fallax*															
Location		Croatia								Greece							
Sex SL mm (*n*)		Females 30.5–58.0 (25)				Males 36.1–71.6 (20)				Females 42.5–46.7 (2)				Males 42.8–51.5 (2)			
		Min	Max	m	SD	Min	Max	m	SD	Min	Max	m	SD	Min	Max	m	SD
%SL	H	29.0	33.7	31.0	1.1	29.8	32.5	31.1	0.8	32.3	32.6	32.5	0.2	31.2	32.4	31.8	0.8
	Hw	13.8	16.6	15.3	0.6	14.0	16.2	15.2	0.7	14.0	14.8	14.4	0.6	14.0	15.1	14.5	0.8
	SN/D1	33.2	39.1	36.1	1.3	33.3	37.9	35.7	1.2	37.3	37.8	37.5	0.3	35.9	37.4	36.7	1.1
	SN/D2	54.3	58.1	56.5	1.1	54.5	56.9	55.5	0.8	55.8	57.2	56.5	1.0	56.4	56.6	56.5	0.2
	SN/AN	54.4	58.1	56.2	1.0	54.4	57.0	55.6	0.6	55.9	57.1	56.5	0.9	55.2	55.7	55.5	0.4
	SN/A	58.3	62.6	60.4	1.2	58.7	61.2	59.7	0.7	60.5	61.8	61.1	0.9	58.7	59.8	59.2	0.8
	SN/V	29.1	34.1	31.6	1.3	29.7	33.5	32.2	1.0	33.4	34.5	33.9	0.7	32.9	33.7	33.3	0.5
	CP	15.2	19.9	17.8	0.9	16.3	19.1	17.8	0.9	16.5	17.4	17.0	0.6	16.9	17.0	16.9	0.1
	D1b	12.0	15.0	13.1	0.7	11.2	13.9	12.9	0.7	12.4	12.7	12.6	0.2	12.5	12.5	12.5	0.0
	D2b	30.2	33.4	31.9	0.9	29.3	34.9	32.4	1.2	32.0	32.2	32.1	0.1	32.9	34.7	33.8	1.3
	Ab	22.0	26.1	24.2	1.0	23.9	28.2	25.6	1.2	24.3	25.2	24.7	0.6	25.5	26.2	25.9	0.5
	C1	26.0	30.1	27.9	1.1	26.0	29.8	28.3	1.0	24.2	24.2	24.2	0.0	24.2	30.4	27.3	4.4
	P1	23.8	29.3	27.1	1.5	23.7	28.7	25.8	1.5	29.0	29.0	29.0	0.0	29.5	29.5	29.5	0.0
	V1	21.7	26.2	23.7	1.2	21.8	26.3	23.8	1.2	25.4	25.4	25.4	0.0	24.5	26.7	25.6	1.5
	Vd	19.0	23.7	21.2	1.2	18.6	23.0	20.3	1.0	19.7	20.5	20.1	0.6	20.7	21.0	20.8	0.2
	Ad	17.3	21.1	18.7	0.9	17.6	20.0	18.7	0.7	17.8	19.2	18.5	1.0	18.4	19.0	18.7	0.4
	Aw	8.5	13.4	11.6	1.1	11.0	13.1	12.2	0.7	9.9	10.8	10.4	0.6	10.4	12.1	11.2	1.2
	CPd	9.6	11.2	10.3	0.4	9.0	11.3	10.5	0.6	9.9	10.0	9.9	0.0	9.9	10.5	10.2	0.4
	V/AN	23.3	28.3	25.3	1.1	22.0	26.3	24.3	1.0	23.8	23.9	23.9	0.1	21.8	23.1	22.4	0.9
%CP	CPd	51.8	68.8	58.6	4.4	52.6	67.9	59.1	4.5	57.3	60.1	58.7	2.0	58.3	62.0	60.2	2.6
%H	SN	22.6	26.7	24.5	1.1	21.9	26.4	24.6	1.2	24.0	25.4	24.7	1.0	25.1	25.4	25.2	0.2
	E	26.3	32.0	29.2	1.6	24.7	30.5	28.1	1.4	29.9	30.6	30.3	0.5	28.4	29.5	29.0	0.8
	PO	47.6	52.1	50.0	1.1	47.8	52.5	50.5	1.4	49.7	50.3	50.0	0.4	50.6	52.3	51.4	1.2
	CHd	16.4	21.4	19.3	1.4	16.7	23.8	20.1	1.8	18.7	19.1	18.9	0.2	18.5	21.5	20.0	2.2
	Hw	43.8	56.3	49.4	3.2	43.8	54.1	48.9	3.0	43.2	45.5	44.3	1.7	43.2	48.3	45.8	3.6
	UJ	31.9	38.6	35.1	1.9	33.2	39.3	35.5	1.7	35.5	36.5	36.0	0.7	35.2	37.7	36.4	1.7
%E	I	5.2	16.9	10.1	2.6	7.3	16.4	11.9	2.5	6.6	9.0	7.8	1.6	9.6	9.8	9.7	0.1
%V/AN	V1	85.4	103.1	93.8	5.8	83.0	108.6	98.5	6.0	106.6	106.6	106.6	0.0	106.2	122.4	114.3	11.4
%V41	V51	65.2	87.6	75.0	5.0	65.5	82.1	72.2	3.8	69.4	69.4	69.4	0.0	66.7	66.7	66.7	0.0

Table II. (*Continued*).

Taxon		*Gobius xanthocephalus*												
Location		Portugal and Italy								France				
Sex SL mm (*n*)		Females 54.0–69.1 (2)				Males 53.7–62.1 (3)				Females 44.6–51.9 (2)				Male 52.7 (1)
		Min	Max	m	SD	Min	Max	m	SD	Min	Max	m	SD	Value
%SL	H	27.3	29.4	28.3	1.5	28.3	28.8	28.5	0.2	28.7	29.7	29.2	0.7	28.8
	Hw	15.0	16.1	15.5	0.8	14.4	15.8	15.1	0.7	14.3	14.6	14.5	0.2	14.2
	SN/D1	35.4	37.2	36.3	1.3	33.3	35.7	34.5	1.2	34.3	34.7	34.5	0.3	34.0
	SN/D2	55.1	57.0	56.1	1.3	54.1	54.5	54.2	0.2	54.2	54.6	54.4	0.3	55.3
	SN/AN	56.0	56.6	56.3	0.4	54.5	57.0	55.9	1.3	54.0	54.7	54.4	0.5	55.1
	SN/A	58.9	59.0	59.0	0.1	56.2	58.4	57.5	1.2	58.7	59.1	58.9	0.3	59.7
	SN/V	27.9	28.7	28.3	0.6	28.5	29.8	29.1	0.7	31.7	32.7	32.2	0.7	31.8
	CP	16.9	17.4	17.1	0.4	16.0	18.3	17.1	1.1	17.3	17.5	17.4	0.1	16.2
	D1b	14.6	14.8	14.7	0.1	14.3	16.1	14.9	1.0	13.1	13.2	13.2	0.0	13.0
	D2b	34.4	36.6	35.5	1.6	35.2	35.6	35.4	0.2	30.9	34.8	32.8	2.7	33.7
	Ab	27.5	28.2	27.9	0.4	27.1	29.9	28.2	1.4	26.6	27.7	27.2	0.8	28.1
	C1	26.6	27.3	27.0	0.5	27.4	27.8	27.6	0.3	26.6	27.1	26.8	0.4	28.9
	P1	23.7	25.8	24.8	1.5	24.1	26.9	25.7	1.5	24.5	25.9	25.2	0.9	27.6
	V1	21.7	22.9	22.3	0.8	21.4	23.3	22.3	1.0	21.7	22.5	22.1	0.6	22.8
	Vd	21.0	23.4	22.2	1.7	19.1	22.4	20.9	1.7	20.0	20.4	20.2	0.3	19.5
	Ad	18.5	22.3	20.4	2.7	18.3	21.1	19.7	1.4	18.7	19.5	19.1	0.5	18.5
	Aw	12.6	13.8	13.2	0.9	11.6	13.2	12.4	0.8	10.1	11.1	10.6	0.7	10.5
	CPd	11.4	11.7	11.5	0.2	11.2	12.9	11.8	0.9	10.7	11.1	10.9	0.3	11.0
	V/AN	26.6	28.9	27.7	1.6	26.2	28.9	27.5	1.4	23.5	24.3	23.9	0.6	23.9
%CP	CPd	67.1	67.8	67.5	0.5	61.0	80.1	69.2	9.8	61.3	64.3	62.8	2.1	67.7
%H	SN	24.8	27.7	26.3	2.0	25.0	26.7	25.9	0.9	25.8	26.0	25.9	0.2	25.3
	E	27.7	28.8	28.2	0.7	26.2	28.6	27.3	1.2	28.4	29.0	28.7	0.4	27.6
	PO	48.2	50.2	49.2	1.4	49.8	50.8	50.4	0.5	49.0	50.0	49.5	0.7	51.6
	CHd	20.0	20.1	20.0	0.1	18.9	21.6	20.3	1.3	16.7	17.6	17.2	0.6	16.9
	Hw	54.7	54.9	54.8	0.1	50.9	55.6	53.0	2.4	49.3	49.9	49.6	0.4	49.3
	UJ	33.0	36.9	35.0	2.7	35.2	36.2	35.7	0.5	31.7	35.2	33.4	2.5	34.4
%E	I	7.7	13.0	10.4	3.8	12.0	13.6	13.0	0.9	9.5	11.5	10.5	1.4	11.9
%V/AN	V1	75.2	86.1	80.6	7.7	77.0	89.1	81.4	6.7	92.1	92.6	92.4	0.3	95.6

Table II. (*Continued*).

Taxon		*Gobius xanthocephalus*												
Location		Portugal and Italy								France				
Sex SL mm (*n*)		Females 54.0–69.1 (2)				Males 53.7–62.1 (3)				Females 44.6–51.9 (2)				Male 52.7 (1)
		Min	Max	m	SD	Min	Max	m	SD	Min	Max	m	SD	Value
%V41	V51	80.1	80.5	80.3	0.3	78.3	87.4	82.4	4.6	85.8	85.9	85.8	0.1	84.0

Underlined locations indicate compared (type) material. See Material and methods for measurement abbreviations. Values are range (Min, Max), mean (m) and standard deviation (SD).

obtuse-angled due to oblique mouth bending upwards. Posterior angle of jaw below middle of pupil (UJ 11.6% of SL). Snout slightly tipped and oblique, shorter than eye. Eyes large, diameter about 30% of H, dorsolateral with narrow interorbital space. Teeth in jaws in several rows, larger in first row, erect and caniniform in both jaws and pharynx. Pelvic disc deeply emarginate, divided medially almost half of its length. C slightly emarginate, truncate or slightly rounded, and shorter than head. Swim bladder well developed.

Fins (Table III)

D1 VI; D2 14 (13–15); A I/13 (12–14); C 14 (13–16) branched rays; P 18–19 (17–20); V I/5 + 5/I. Fin bases and lengths given in Table II. No remarkable elongation of D1 spines, fifth usually slightly projecting. Interdorsal space without membrane narrow, but present. D2 origin anterior of A origin. Fin rays in D2 and A grow longer, especially in males during breeding season, with rear tips reaching C origin. C usually slightly emarginate but almost rounded in large specimens. P, when pressed against the body, reaching back to below D2 3 in small specimens and males and to D2 2 in females. Three uppermost P-rays moderately free from membrane, with bifid ends. Pelvic disc deeply emarginate to almost half of its length (see Figure 2 and V4l/V5l ratio in Table II) with anterior membrane reduced to skin fold or absent. On average, longest tip of V reaches anus, exceeding it rather in males than in females but especially in smaller specimens.

Scales

LL 45 (42–48; Table III); TR 12–13 (11–14). Trunk mainly covered by ctenoid scales, but cycloid scales also present anterior of imaginary lines from dorsal P-base to D1-end or D2-origin and from ventral P-base to V-origin, respectively. Cheek naked. Nape, predorsal area and pectoral base with small cycloid scales. Opercle naked or with a few small cycloid scales on latter (especially in larger specimens). Larger cycloid scales on breast.

Coloration

Colour morph 1 (Figure 3A). This variant of *G. auratus* was found in the central Adriatic and western Mediterranean. The specimens exhibit a distinct canary yellow colour over the entire body including the upper rim of the eye, which in particular may exhibit a deep yellow colour. The opercle is somewhat translucent and the branchiae appear as a distinct red area underneath. A large black spot at the dorsal base of P is typical; its size is variable and its shape is rounded to rectangular. Hardly visible red dots can occur depending on the mood of the fish, especially when excited or stressed or in captivity, forming weak longitudinal lines along the lateral line and the median fins. The most obvious line is formed along the proximal part of A. Nevertheless, this colour pattern is not persistent and rarely displayed in the field, and it is never as intensive as it is in the second colour morph described below. When narcotized or freshly preserved in formalin, the red dots along the lateral midline and A remain weakly visible. D1, D2 and A may exhibit a reddish golden colour caused by small, irregularly distributed erythrophores. The yellow colour becomes distinctly darker due to numerous tiny black melanophores expanding all over the body. Some areas, such as parts of the cheek and opercle, may retain their yellow coloration because they lack dark melanophores.

Table III. Frequency distributions of fin rays counts in second dorsal, anal, caudal and pectoral fin and of scales in lateral series in closely related *Gobius* species from different geographical areas.

D2	13	14	15	Mean	*SD*	*n*
Ga-C	2	56	2	14.00	0.3	60
Ga-F	–	1	–	14.00	0.0	1
Gf-C	13	41	–	13.76	0.4	54
Gf-G	–	4	–	14.00	0.0	4
Gx-A/F/I	–	1	9	14.90	0.3	10
Gx-F	–	1	2	14.67	0.6	3

A	10	11	12	13	14	15	Mean	*SD*	*n*
Ga-C	–	–	3	51	6	–	13.05	0.4	60
Ga-F	–	–	–	1	–	–	13.00	0.0	1
Gf-C	1	1	10	41	1	–	12.74	0.6	54
Gf-G	–	–	–	4	–	–	13.00	0.0	4
Gx-A/F/I	–	–	–	1	8	1	14.00	0.5	10
Gx-F	–	–	–	–	3	–	14.00	0.0	3

C	13	14	15	16	Mean	*SD*	*n*
Ga-C	6	35	13	4	14.34	0.8	58
Ga-F	–	1	–	–	14.00	0.0	1
Gf-C	1	46	7	–	14.11	0.4	54
Gf-G	–	4	–	–	14.00	0.0	4
Gx-A/F/I	–	7	3	–	14.30	0.5	10
Gx-F	–	1	2	–	14.67	0.6	3

P	17	18	19	20	Mean	*SD*	*n*
Ga-C	2	23	34	1	18.57	0.6	60
Ga-F	–	1	–	–	18.00	0.0	1
Gf-C	1	33	19	1	18.37	0.6	54
Gf-G	–	–	4	–	19.00	0.0	4
Gx-A/F/I	–	–	4	6	19.60	0.5	10
Gx-F	–	–	3	–	19.00	0.0	3

LL	40	41	42	43	44	45	46	47	48	49	50	Mean	*SD*	*n*
Ga-C	–	–	1	5	13	18	10	11	2	–	–	45.25	1.4	60
Ga-F	–	–	–	–	–	1	–	–	–	–	–	45.00	0.0	1
Gf-C	2	4	9	17	14	7	1	–	–	–	–	43.15	1.3	54
Gf-G	–	–	–	3	–	1	–	–	–	–	–	43.50	1.0	4
Gx-A/F/I	–	–	–	–	1	1	2	2	–	–	4	47.89	2.1	10
Gx-F	–	–	–	–	–	–	–	1	–	2	–	48.33	1.2	3

Underlined abbreviations indicate compared (type) material. Values are mean, standard deviation (SD) and number of specimens (*n*). *Ga*, *Gobius auratus* from Croatia (C) and France (F; neotype MNHN 1988-630 by Heymer and Zander 1992); *Gf*, *Gobius fallax* from Croatia (C) and Greece (G; SMF 10803–10806 by Bath 1971); *Gx*, *Gobius xanthocephalus* from the Atlantic (Portugal and Canary Islands), France and Italy (A/F/I) and France (F; holotype ZMH 7328 and paratypes ZMH 6195 by Heymer and Zander 1992).

Transferred to 70% ethanol, the specimens lose their yellow and red colours soon and remain in a greyish brown basic coloration with a distinct pectoral spot and weak dotted lines along the median fins and the lateral midline, which represent the red dots in living specimens. The dark tiny dots all over the body may be denser in some areas, forming five hardly visible broad vertical bands on the trunk, the first below D1, the second below D1-end and D2-origin, the third and fourth below D2 and the fifth on the caudal peduncle.

Colour morph 2 (Figure 3B). The second variant, exhibited by populations of the northern parts of the Adriatic Sea, shows a distinct life coloration throughout the year. It is similar to that of *G. xanthocephalus* in some aspects, which may cause problems in discrimination. The basic coloration is yellow and covers the entire body but is usually brightest on head. Branchiae appear reddish underneath the translucent opercle. Pectoral spot may not be visible in living specimens, but is large in territorial males and bluish to black, bordered white posteriorly. In many specimens, four small red spots on pectoral base, two dorsally and two ventrally. Head and body covered with numerous orange to red dots forming longitudinal lines over entire length. The most distinct line is formed along the lateral midline by about 11 red horizontally doubled dots. Dorsally, four to five longitudinal rows with middle row reddish and originating at orbit. Underneath one or two rows of golden-orange dots, above two darker rows, the uppermost originating from interorbit and running along the dorsal fin bases. Below lateral midline row two rows of golden-orange dots. Dorsal fins with four, caudal fin with five red dots along the fin rays forming horizontal and vertical rows, respectively. Interspaces and fin membrane on D1 and D2 yellowish. Anal fin with one distinct longitudinal row of red dots near its base. Fin membranes of C, A and V often with a bluish gleam. Along P-rays, dark red or brownish dots, especially in large specimens, forming concentric lines. Predorsal area with numerous yellow dots mixed up with the red longitudinal rows described above. Head shows a characteristic coloration pattern. Eyes exhibit six dark red to brown radial stripes from pupil to rim of orbit, dorsally sometimes confluent. A V-shaped pattern is found on the snout, formed by two stripes from each anterior orbit that fuse at the upper lip. Along the upper part of the cheek and opercle a red line runs from the lower orbit to the dorsal P-base. Two to three dark dots can be found ventrally on the cheek in a line from the jaw angle to the preopercle. A large brown W-shaped pattern occurs on the anterior lower lip. Posteriorly, there is a distinct dot near the jaw angle. Dark dots are also found as five, rarely three or four geniohyoid dots and on the opercle. Small white dots can also be distributed over the ventral cheek and the opercle. Territorial males show a white-edged D1 and D2, and, especially during agonistic behaviour, a dark head. The latter was observed in the field as well as in the aquarium and was also found in females. After narcotization, the entire body becomes darker in most specimens. Preserved in 70% alcohol, the fish lose their yellow and red coloration and show a specific coloration: the red dots all over the body become pale, while the basic coloration becomes brown, lighter in the ventral parts. The most distinct patterns which remain are the black pectoral spot, extending ventrally as light brown, the dark geniohyoid dots and lines of grey dots on the median fins. The orbits become dark grey, and the jaw angle is also bordered by a dark grey area, reaching to the orbit. The trunk exhibits five broad darker vertical bands, the first below D1, the second below D1-end and D2-origin, the third and fourth below D2 and the fifth on the caudal peduncle. In the lateral midline there are sometimes 10 darker blotches, especially in large specimens. In large males, the fins and the head show a dark grey pigmentation.

Lateral line system

Head canal system fully developed with anterior and posterior oculoscapular canal and preopercular canal, with pores σ, λ, κ, ω, α, β, ρ; ρ*1*, ρ*2*, and γ, δ, ϵ, respectively. The variations of neuromast counts in head rows are given in Table IV. Arrangement of rows (Figure 4) generally as in Miller (1986: as *G. luteus*) and Sanzo (1911: as *G. auratus*). The papillae of rows c^2, c^1, c_2 and c_1 are simply named as *c* because of irregular arrangement and difficult assignation. Suborbital row *2* and especially row *3* sometimes extending down to or below row *d*, dividing it into two or three sections. But this separation of row *d* can also be observed without elongate rows *2* or *3*. Row *5* usually divided into superior and short inferior section by longitudinal row *b*, although latter does not extend much anteriorly. Row *6i* extends to below level of row *d*. Single papilla near pore α (row "α") always present. In the oculoscapular area, between pores ρ and ρ1, there are three papillae arranged in a longitudinal row, designated as row *u*. Sometimes, the last papillae of both *x1* and *u* show a ventral extension of one papilla, indicating a row *tr*. The real assignation of these papillae is uncertain. Left and right anterior dorsal row *o* slightly separated from each other or confluent in midline. Trunk rows arranged in dorsal series *ld1* (9–19 papillae) below D1 II, *ld2* (3–9) below D1-end, *ld3* (5–12) on caudal peduncle, in ventral series from below P-origin to anus, *lv1* (10–27), *lv2* (9–22), *lv3* (9–19) and in 25–32 median trunk series *ltm* (up to 17 papillae, longest rows below D1 and on caudal peduncle). The caudal fin shows three rows *lc* (19–47).

Biology

Gobius auratus is found in abundant populations on coasts with steep bedrock. Populations in the central Adriatic (colour morph 1) were observed to occur in deeper regions with minimum depths of about 15 m, while populations in the northern parts of the Adriatic (colour morph 2) also occurred in more shallower water of about 5 m depth. In the northern Adriatic the maximum depth of distribution was about 35 m and mostly limited by sand bottom. The specimens typically hover up to 30 cm above the substratum. The species is shy and difficult to collect due to long flight distances and hiding in deep clefts. This species was also observed in the Tyrrhenian Sea around the Islands of Elba and Giglio (R. Patzner, personal observation). Details on the habitat choice will be given in a separate paper.

Gobius fallax Sarato, 1889
(Figures 2C, 3C, 5)

Material

Eastern Mediterranean: Italy (*n*=4): 1♀, 45.8 + 12.6 mm, 2♂♂, 46.6 + 13.3 and 48.5 + 12.6 mm, and one juvenile, 21.2 + 6.4 mm, Trieste, near Miramare, July 1999, J. Herler. Slovenia (*n*=24): 12♀♀, 42.5 + 12.5 to 58.0 + 15.8 mm, 9♂♂, 43.8 + 12.2 to 71.6 + 20.6 mm, and three juveniles, 26.1 + 7.4 to 31.5 + 8.6 mm, near Piran, August 2000 and May 2001, J. Herler. Croatia (*n*=26): 12♀♀, 30.5 + 8.8 to 55.3 + 15.2 mm, 9♂♂, 36.1 + 10.4 to 62.9 + 18.7 mm, and five juveniles, 17.3 + 5.2 to 29.9 + 8.7 mm, Island of Cres (west), near Martinscica, September 2000 and May 2001, J. Herler. Two females and two males are stored at the Naturhistorisches Museum Wien (NMW 94849–94852).

Table IV. Counts of free head neuromasts of closely related *Gobius* species from the Mediterranean Sea and Atlantic Ocean.

Taxon		*Gobius auratus*					*Gobius fallax*								*Gobius xanthocephalus*							
Location		Croatia				France	Croatia				Greece				Portugal and Italy				France			
SL in mm (*n*)		33.1–69.9 (32)				57.1 (1)	37.6–71.6 (27)				42.5–51.5 (4)				53.7–69.1 (5)				44.6–52.7 (3)			
		Min	Max	m	SD	Count	Min	Max	m	SD	Min	Max	m	SD	Min	Max	m	SD	Min	Max	m	SD
PO	r1	2	6	4.2	0.9	3	2	6	3.8	1.0	3	4	3.8	0.5	3	6	4.8	1.5	4	5	4.3	0.6
	r2	3	6	3.7	0.9	3	1	6	3.1	1.1	2	4	2.8	1.0	3	5	4.5	1.0	3	3	3.0	0.6
	s1	3	9	5.6	1.1	6	4	7	5.0	1.6	3	6	4.5	1.3	5	6	5.3	0.5	3	5	4.0	1.2
	s2	4	9	6.1	1.4	6	4	10	6.0	1.4	4	7	5.8	1.3	6	8	7.0	0.8	5	7	5.7	1.5
	s3	4	10	6.7	1.7	8	4	10	6.3	1.4	5	7	6.3	1.0	6	13	8.5	3.1	2	7	5.0	1.2
	c	24	42	31.0	3.7	33	24	40	31.9	4.7	28	34	31.0	3.5	22	42	32.0	8.3	30	34	32.0	4.2
	Total	44	74	56.8	7.0	59	41	74	56.1	7.5	48	58	54.0	4.9	28	78	56.0	19.1	48	58	54.0	6.1
SO	1	8	15	11.1	1.5	13	8	15	11.2	2.6	10	11	10.5	0.6	10	17	13.8	2.8	10	12	11.0	1.5
	2	6	12	8.6	1.4	10	5	12	8.2	1.7	6	9	7.5	1.3	8	12	10.6	1.7	7	9	8.0	2.3
	3	7	13	8.8	1.4	10	5	11	8.6	1.5	7	10	8.8	1.3	9	15	11.8	2.8	8	13	10.7	1.2
	4	7	13	9.0	1.4	11	7	13	9.3	1.6	6	11	8.5	2.1	9	16	12.8	3.1	9	16	12.0	1.5
	5s	3	13	4.8	1.8	8	4	8	4.9	1.1	4	5	4.5	0.6	6	8	6.8	1.1	5	12	8.0	1.5
	5i	3	9	5.8	1.5	7	3	8	5.3	1.1	4	6	5.3	1.0	7	9	7.8	0.8	7	12	9.5	1.5
	6s	6	10	8.1	1.2	10	5	10	7.9	1.1	6	10	7.8	1.7	8	12	10.0	1.9	8	11	9.0	2.6
	6i	8	16	11.4	2.1	13	8	14	10.5	1.6	8	10	9.0	0.8	11	17	14.2	2.2	12	16	14.0	0.6
	"α"	1	2	1.1	0.2	1	1	1	1.0	0.0	1	1	1.0	0.0	1	2	1.2	0.4	1	1	1.0	0.0
	b	11	22	13.6	2.1	17	9	17	13.1	1.8	12	14	12.8	1.0	13	22	17.2	3.5	13	20	16.3	2.0
	d	20	34	25.4	2.8	31	17	37	25.5	4.1	24	31	27.3	2.9	25	36	30.2	4.0	26	32	28.0	6.0
	Total	92	147	107.6	11.2	131	82	133	105.4	12.8	93	112	102.8	7.8	114	158	136.4	18.7	111	148	124.3	18.2
PM	e1	26	41	33.7	3.5	31	10	44	34.9	5.9	30	37	32.8	3.0	30	40	34.2	4.3	27	36	32.3	1.5
	e2	21	30	25.2	2.6	28	18	32	25.5	3.1	23	24	23.8	0.5	25	32	28.8	3.1	26	33	29.7	4.2
	i1	15	23	18.1	1.9	17	15	24	18.8	2.3	18	21	19.0	1.4	18	23	20.8	1.9	17	17	17.0	3.2
	i2	14	23	17.8	1.7	19	14	22	17.4	1.8	16	17	16.5	0.6	19	22	20.0	1.4	16	19	17.3	1.2
	f	6	12	7.8	1.4	8	6	11	7.7	1.4	5	8	6.8	1.3	5	13	9.4	2.9	7	9	8.0	0.0
	Total	90	125	102.4	7.3	103	74	124	104.4	10.6	94	103	98.8	3.7	98	129	113.2	12.3	93	113	104.3	4.9

Table IV. (*Continued*).

Taxon		*Gobius auratus*					*Gobius fallax*								*Gobius xanthocephalus*							
Location		Croatia				France	Croatia				Greece				Portugal and Italy				France			
SL in mm (*n*)		33.1–69.9 (32)				57.1 (1)	37.6–71.6 (27)				42.5–51.5 (4)				53.7–69.1 (5)				44.6–52.7 (3)			
		Min	Max	m	SD	Count	Min	Max	m	SD	Min	Max	m	SD	Min	Max	m	SD	Min	Max	m	SD
OS	x1	10	18	14.1	1.7	16	10	17	14.0	1.7	14	15	14.5	0.6	14	20	16.0	2.3	13	16	15.0	2.0
	x2	1	7	4.7	1.2	7	3	8	5.2	1.1	3	5	4.0	0.8	6	11	7.6	2.1	4	9	6.3	1.2
	z	3	8	5.8	1.1	9	5	9	6.4	0.9	4	6	5.3	1.0	7	10	8.6	1.3	6	8	6.7	1.0
	q	3	7	4.6	1.1	5	3	7	3.8	1.0	3	5	4.0	0.8	3	6	4.8	1.1	4	7	5.3	2.0
	y	2	8	4.6	1.5	6	3	6	4.7	0.9	3	6	3.8	1.5	5	8	6.4	1.5	5	6	5.3	1.2
	tr	2	4	2.8	0.8	0	0	5	0.5	1.3	0	0	0.0	0.0	0	5	1.6	2.3	0	0	0.0	0.0
	as1	6	13	9.2	2.0	13	6	14	8.9	1.9	6	10	7.5	1.7	6	16	10.8	3.8	7	16	10.3	4.4
	as2	4	12	7.6	1.9	9	6	10	7.7	1.4	6	10	8.0	1.8	10	13	10.8	1.3	7	8	7.3	1.2
	as3	6	15	11.5	2.4	17	6	13	9.0	1.9	8	9	8.3	0.5	11	18	13.4	2.7	0	15	7.7	3.8
	la1	2	5	3.5	1.0	3	2	7	4.1	1.1	3	4	3.7	0.6	1	7	4.0	2.4	3	5	4.0	0.6
	la2	1	7	3.7	1.4	5	2	6	4.1	1.1	3	6	4.0	1.7	3	5	4.4	0.9	3	4	3.7	1.5
	la3	0	0	0.0	0.0	0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0
	u	2	4	2.7	0.5	3	2	4	3.0	0.3	3	3	3.0	0.0	2	5	3.2	1.1	3	3	3.0	0.0
	Total	56	93	72.5	8.9	93	61	86	71.4	7.3	58	72	64.0	6.1	74	117	91.6	16.6	71	79	74.7	13.4
OP	ot	19	35	26.2	3.1	32	21	32	26.9	2.8	23	27	24.8	1.7	27	34	30.2	3.1	24	31	28.0	1.5
	os	10	19	12.1	1.8	15	7	16	12.3	2.2	10	12	10.8	1.0	11	15	12.6	1.5	11	12	11.7	2.1
	oi	6	11	8.3	1.2	9	7	12	8.9	1.2	9	10	9.3	0.5	6	13	8.8	2.7	9	9	9.0	1.0
	Total	36	64	46.6	5.0	56	38	58	48.0	4.9	43	48	44.8	2.2	45	61	51.6	6.5	45	51	48.7	0.6
AD	n	7	20	11.3	2.2	12	7	13	10.1	1.5	8	11	9.8	1.3	11	15	12.4	1.9	11	11	11.0	0.6
	g	6	13	10.3	1.9	10	5	14	8.9	1.8	7	11	8.7	2.1	10	14	12.0	1.9	8	12	10.3	2.5
	o	6	13	10.0	1.5	11	4	12	9.4	1.7	7	10	8.3	1.5	8	13	10.2	1.9	8	10	9.0	1.5
	m	4	9	6.5	1.3	8	3	10	5.8	1.8	3	6	4.3	1.5	5	7	6.0	1.0	3	7	5.0	2.0
	h	9	21	13.4	2.8	16	8	19	13.1	2.8	10	11	10.7	0.6	12	20	15.8	3.3	10	14	12.0	3.8
	Total	38	64	51.4	6.3	57	29	62	47.2	7.2	11	45	33.8	15.4	47	69	56.4	9.5	37	53	43.3	9.5
	All	373	560	437.2	37.7	499	361	533	432.5	40.1	374	432	398.0	26.3	409	606	505.2	74.8	429	478	449.3	45.9

Underlined locations indicate compared (type) material. See Material and methods for neuromast regions abbreviations. "α" designates the papillae of a seventh transversal suborbital neuromast row near pore α. Values are range (Min, Max), mean (m) and standard deviation (SD).

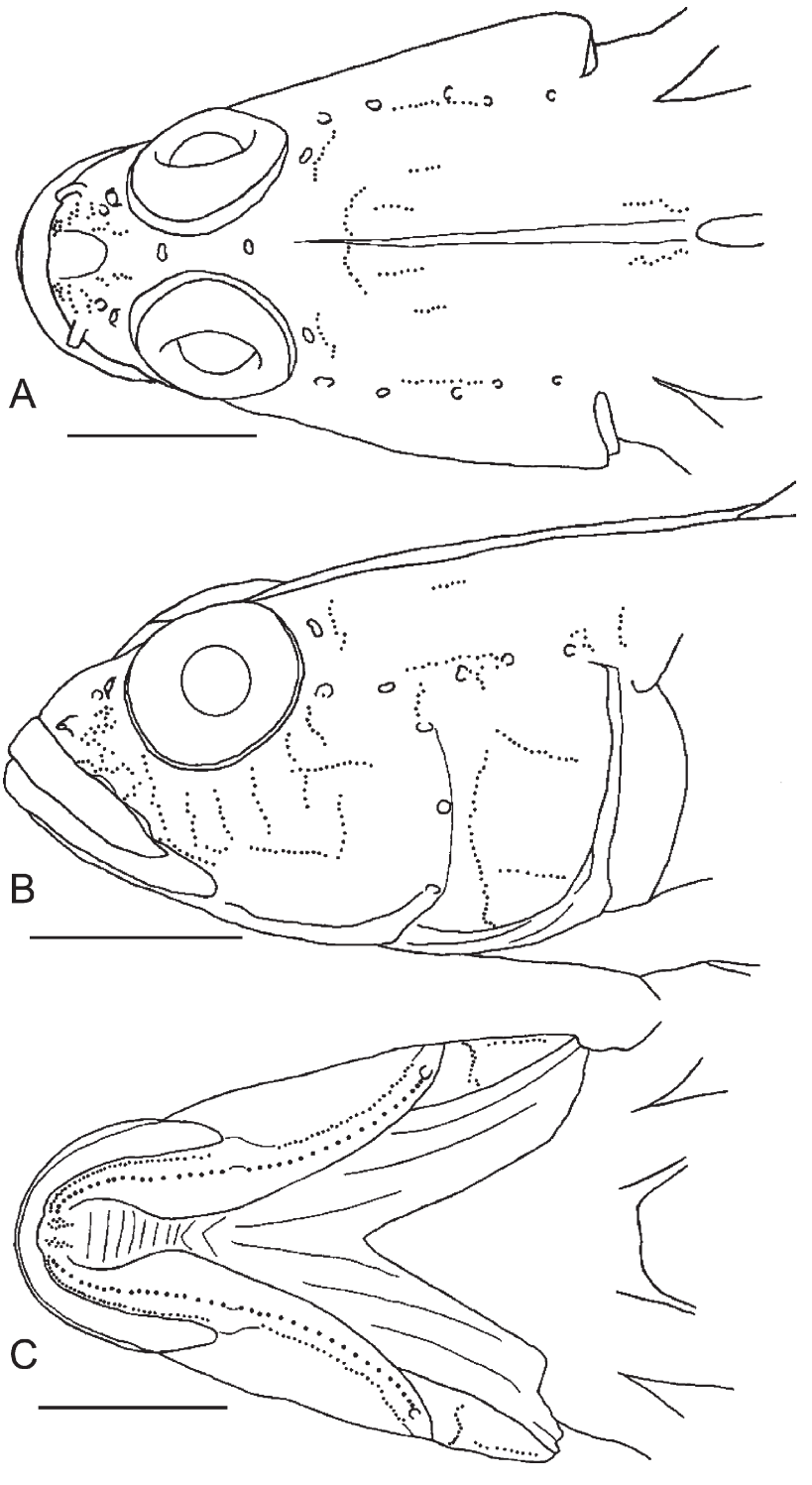

Figure 5. Lateral line system of *G. fallax*, male, 48.5 + 12.6 mm, from the northern Adriatic Sea in dorsal (A), lateral (B) and ventral (C) view. Scale bar: 5 mm.

Compared material

Western Mediterranean: France (n=3): three syntypes (MNHN 1888/0261–1888/0263, in poor condition), Nice, 1888, C. Sarato. Spain (n=1): 1♂, 54.6 + 14.8 mm, Balearics, Ibiza (north), near Portinatx, 17 September 1997, R. Patzner. Eastern Mediterranean: Greece (n=5): 2♀♀, 42.5 + d and 46.7 + 11.3 mm and 2♂♂, 42.8 + 10.4 and 51.5 + 15.7 mm (SMF 10803–10806), east Peloponnes, Palaea Epidavros, June 1970, H. Bath; 1♀, 42.9 + d mm (NMW 77932), north-western Greece, Bay of Parga, September 1980, B. Sagmeister. Croatia (n=4): 1♂, 38.2 + 8.4, 1♀, 50.3 + 12.9, and two juveniles, 27.6 + 8.4 and 31.9 + 9.1, Island of Solta, June 2000, M. Kovačić.

Identification

Maximum total length about 9 cm. Strict benthic behaviour. Basic coloration grey to olive-green, with conspicuous brown dotted longitudinal lines. In life easily confused with *Gobius bucchichi* but with the head more tipped and a larger mouth. Body in *G. fallax* rather torpedo-shaped and longitudinal rows of dots more abundant and distinct, therefore showing darker coloration as the former. Dark pectoral spot usually visible in living specimens. Yellowish coloration occurs sometimes on the eye rim and on snout. Pelvic disc emarginate, one-quarter to one-third of its length. C rounded. Important meristics are D2 I/14 (13–14), A I/13 (10–14) and LL 43–44 (40–46).

General morphology

Morphometrics of northern Adriatic and Greek specimens given in Table II. Body moderately elongate, laterally compressed and of dorsoventral symmetrical shape. Head large, almost one-third of SL, and somewhat tipped. Mouth oblique and large (UJ 11% in SL), jaw angle below middle of pupil. Snout oblique, shorter than eye. Eyes large, diameter about 29% of H, dorsolateral with narrow interorbital space. Caudal fin rounded, shorter than head. Swim bladder well developed.

Fins (Table III)

D1 VI, D2 I/13–14, A I/12–13 (10–14), C 14 (13–15) branched rays, P 18–19 (17–20), V I/5 + 5/I. Fin bases or lengths given in Table II. D1-spines not elongate, only fifth may slightly project. Narrow interdorsal space without membrane. D2 origin anterior of A origin. Rear tips of D2 and A reaching C origin, especially in males during breeding season. C rounded, rarely truncate. P, when pressed against the body, reaching back to below D2 3 rather in females and small specimens, in males to below D2 1 or D2 2. Three uppermost P-rays free from membrane. Pelvic disc with distinct emargination and reduced anterior membrane, which is not more than a skin fold in most specimens (Figure 2). Longest tips usually reach or exceed anus, latter rather in males than in females.

Scales

LL 43–44 (40–46; Table III); TR 12 (11–14). Trunk scales mostly ctenoid. Cycloid scales only anterior of imaginary line from dorsal P-base to middle or end of D1-base and from ventral P-base to V-origin. Cheek naked. Nape, including predorsal area, opercle and pectoral base with small cycloid scales. Larger cycloid scales on breast.

Coloration (Figure 3C)

In life, greyish to olive-green basic coloration, with remarkable longitudinal rows of brown dots almost forming confluent lines. Most distinct series in lateral midline on trunk, formed by dark brown spots. Above, three series of lighter brown colour, with median row somewhat wavy and originating from orbit. One to two irregular rows below lateral midline. In most specimens especially in females three tiny transversal and parallel bars are found on the lateroventral side of the abdomen between V-origin and anus. Predorsal area densely mottled with numerous brown dots. Large brown dots, centred black, forming lines on median fins. Four longitudinal series on D1, three on D2 and one on A, and five vertical on C. Head with one evident brown line running from the lower orbit to the dorsal P-base, anteriorly continued from the orbit to the upper lip. Many radial stripes on eyes, from pupil to rim of orbit. A V-shaped pattern on snout, from both orbits to median upper lip. Three distinct brown, double spots between jaw angle and preopercle. Numerous white spots on cheek, white and brown spots on opercle, latter continue the line from orbit. Four spots on pectoral base, the usual dark pectoral spot and one small anterior of it, and two other small dots ventrally. In most specimens, five dark geniohyoid dots, lower lip with vertical brown stripes and one dark dot in posterior corner, and dark stripe across upper lip. Local variations are given by certain populations at the western coast of the Island of Cres, Croatia, where the specimens can show a brighter basic coloration and lighter brown mottling than the specimens in the Gulf of Trieste. After preservation in 70% ethanol, the basic coloration pattern remains: weak broad, brown bands run vertically across the head and trunk. The most distinct patterns which remain are the dark row in lateral midline, formed by about 10 blotches connected by smaller dots, the median row above, dark geniohyoid dots, brown and white dots on cheek and opercle, and the four dots on the P-base, including the large black pectoral spot, edged white posteriorly. Median fins appear grey with dark dotted lines, four on D1, three on D2, one on A and five in C. Many specimens, especially males, exhibit a dark grey head when preserved.

Lateral line system

The head canal system is fully developed with anterior and posterior oculoscapular canal and preopercular canal, with pores σ, λ, κ, ω, α, β, ρ; $\rho 1$, $\rho 2$, and γ, δ, ϵ, respectively. The numbers of head neuromasts are shown in Table IV. The typical arrangement is shown in Figure 5. Suborbital rows *2* and *3* rarely reaching and not exceeding longitudinal row *d*. Nevertheless, latter often separated in two or three sections. Row *5* usually divided into superior and short inferior section by row *b*. Row *6i* usually reaches or exceeds level of *d*, rarely shorter. Row "α" always present as single papilla near pore α but showed three papillae on the right head side of one specimen. Last papilla of oculoscapular rows *x1* and of row *u* sometimes with a ventral extension, indicating a row *tr*, but with uncertain assignation. Left and right rows *o* usually separated in dorsal midline, but confluent in some specimens. Trunk rows *ld1* (7–18 papillae), *ld2* (2–7), *ld3* (3–16), *lv1* (13–25), *lv2* (6–18), *lv3* (8–20), and 27–31 median series *ltm* (up to 19 papillae, longest rows below D1 and on caudal peduncle). Three longitudinal rows *lc* (21–52) on caudal fin.

Biology

In the northern Adriatic, *G. fallax* was found in shallow water, most frequently at 2–8 m depth on little-sloping bedrock coasts. It exhibits a strong benthic behaviour and prefers

horizontal slits with sand bottom at the base of rocks as shelter. Details on the habitat choice will be given in a separate paper.

Gobius xanthocephalus Heymer and Zander, 1992
(Figures 2D, 3D)

Material

Western Mediterranean: France (n=3): one juvenile, 26.1 + 7.3 mm, Banyuls-sur-Mer, Ile Grosse, August 1982, R. Patzner; one juvenile, 28.8 + 9.2 mm, and 1♀, 60.0 + 17.8 mm, Banyuls-sur-Mer, Ile Grosse, September 1992, R. Patzner. Italy (n=2): 1♀, 54.0 + 14.7 mm (NMW 84864, part), and 1♂, 53.7 + d mm (NMW 84864, part), Gulf of Genova, Savona, 2 August 1984, G. A. C. Balma. Atlantic Ocean: Portugal (n=4): 3♂♂, 44.4 + 12.0 to 62.1 + 17.2 mm (NMW 94853), and 1♀, 69.1 + 18.4 mm, Arrabida, south of Lisboa, 2001, E. Gonçalves. Canary Islands (n=1): one juvenile 26.2 + d mm (SMNS 15430), Tenerife, Playa Paradiso, July 1994, P. Wirtz.

Compared material

Western Mediterranean: France (n=3): 1♀, 51.9 + 14.1 mm (ZMH 7328, holotype by Heymer and Zander 1992), 1♀, 44.6 + 11.8 mm, and 1♂, 52.7 + 15.2 mm (both ZMH 6195, paratypes by Heymer and Zander 1992), Banyuls-sur-Mer, Ile Grosse, 30 July 1974, A. Heymer.

Identification

Maximum total length about 9 cm. The life coloration of this species is similar to colour morph 2 of *G. auratus*, but with a pale trunk and red dots forming fewer distinct longitudinal lines along the body. A yellow coloration is characteristic for dorsal parts of the head. Detailed descriptions on the coloration pattern are provided by Heymer and Zander (1994). V short, not reaching anus, with disc only slightly emarginate. C rounded. Important meristics are D2 I/15 (14–15), A I/14 (13–15) and LL 47–50 (44–50).

General morphology

The morphometrics of western Mediterranean and Atlantic material, compared with the types designated by Heymer and Zander (1992) are given in Table II. Detailed morphological descriptions are provided by Heymer and Zander (1992, 1994). Body moderately elongate, trunk laterally compressed. Head large, but length less than 30% of SL, with rather straight ventral side due to relatively straight mouth. Latter short (UJ 10% in SL), not reaching middle of pupil posteriorly. Snout oblique, slightly shorter or equal to eye diameter. Eyes large, diameter about 28% of H. Caudal fin rounded, shorter than head.

Fins (Table III)

D1 VI; D2 I/15 (14–15); A I/14 (13–15); C 14–15 branched rays; P 19–20; V I/5+5/I. Fin bases or lengths given in Table II. D1 without elongate spines, only fifth projecting. Narrow interdorsal space without a membrane. D2 origin anterior of A origin. Rear tips of D2 and

A reaching back to C origin, especially in males. C rounded. Longest tip of P reaching back to below D2-origin or D2 1, when the fin is pressed against the body. Three to four uppermost P-rays clearly free from membrane, and with bifid ends. V short, not reaching anus, and not deeply emarginate (V5l about 83% in V4l, Figure 2). Anterior membrane reduced, with a maximum median extension of one-fifth of spine length.

Scales

LL 46–50 (44–50; Table III); TR 14–15 (13–15). Trunk scales mostly ctenoid, but cycloid anterior of imaginary line from dorsal P-base to about middle of D1-base and from ventral P-base to V-origin. Cheek naked. Predorsal area, including nape, upper corner of opercle and pectoral base with small cycloid scales. Larger cycloid scales on breast.

Coloration (Figure 3D)

Typical life coloration of *G. xanthocephalus* is a yellow head and a pale bluish trunk with numerous red to brown dots forming horizontal rows on both. The large pectoral spot, also typical for this species, may not be evident in living specimens. Branchiae not well visible through the opercle. Most distinct row of dots along lateral midline. About three not very distinct rows dorsally, with the median one most evident and originating from the orbit. Two somewhat irregular rows run ventral of the lateral midline row. About four rows forming longitudinal lines on D1 and D2 and vertical lines on C. Predorsal area with many irregularly distributed red dots. Head with one evident row running from the lower orbit to the dorsal P-base, anteriorly continued between orbit and upper lip. Six radial stripes on rim of the eye, confluent on the upper rim, and a V-shaped stripe on the snout, reaching from each orbit to the middle of the upper lip. Three large brown dots between jaw angle and preopercle. Four dark geniohyoid spots and one on the lower lip near jaw angle. After preservation in 70% ethanol, the basic coloration remains a bright brown. The red dots on head and body become substituted by pale mottling. Sometimes rows of small brown dots visible on trunk—one in lateral midline, one above and one below. Dots on median fins sometimes remain grey. Nine to 10 darker and narrow vertical stripes on trunk between P-base and C-origin, slightly oblique and zigzag-formed. Large black pectoral spot edged white. Cheek spots, geniohyoid spots and dots on lips dark brown and evident. Some small dark dots usually visible on opercle.

Lateral line system

The head canal system is fully developed with anterior and posterior oculoscapular canal and preopercular canal, with pores σ, λ, κ, ω, α, β, ρ; $\rho 1$, $\rho 2$, and γ, δ, ϵ, respectively. The counts of head neuromasts are given in Table IV. Arrangement of superficial head neuromasts resembles that of Miller (1986: as *G. auratus*) and Heymer and Zander (1992, 1994). Suborbital row *2* sometimes, row *3* usually reaching longitudinal row *d*, dividing latter into two or three sections. Row *b* relatively short, rarely exceeds row *5* anteriorly, therefore latter often confluent. When divided, inferior section *5i* relatively long. Row *6i* always extends to below level of row *d*. Row "α" always present with at least one, rarely with two papillae near pore α. Last papilla of oculoscapular rows *x1* and *u* sometimes with ventral extension, indicating row *tr*, but with uncertain assignation. Left and right anterior dorsal row *o* usually well separated from each other, rarely confluent. Trunk rows as *ld1*

(11–19 papillae), *ld2* (3–9), *ld3* (4–8), *lv1* (18–30), *lv2* (8–20), *lv3* (7–18), and as 25–31 *ltm* (up to 18 papillae, longest rows below D1 and on caudal peduncle). Three longitudinal rows *lc* (20–46) on caudal fin.

Biology

Gobius xanthocephalus shows a strong benthic behaviour. It is abundant on gently sloping bedrock coasts at Banyuls-sur-Mer, observed in depths between 3 and 12 m. The specimens can be found resting on the rocks or on small sandy patches in between.

Molecular genetic analysis

Of 379 bp sequenced, 344 characters were constant, 21 were parsimony-uninformative, and only 14 were parsimony-informative. The observed genetic variation turned out to be very low among all ingroup taxa (zero to eight mutations) and showed no insertion or deletion events, neither within nor between morphologically defined taxa. Thus, all taxa share common ancestry in the recent past. Parsimony analysis resulted in 125 most parsimonious trees of a length of 45 mutations (consistency index excluding uninformative sites, 0.7083; retention index, 0.7879, trees not shown). The neighbour-joining tree (Figure 6A) was identical to one of the most parsimonious trees. The latter was used to

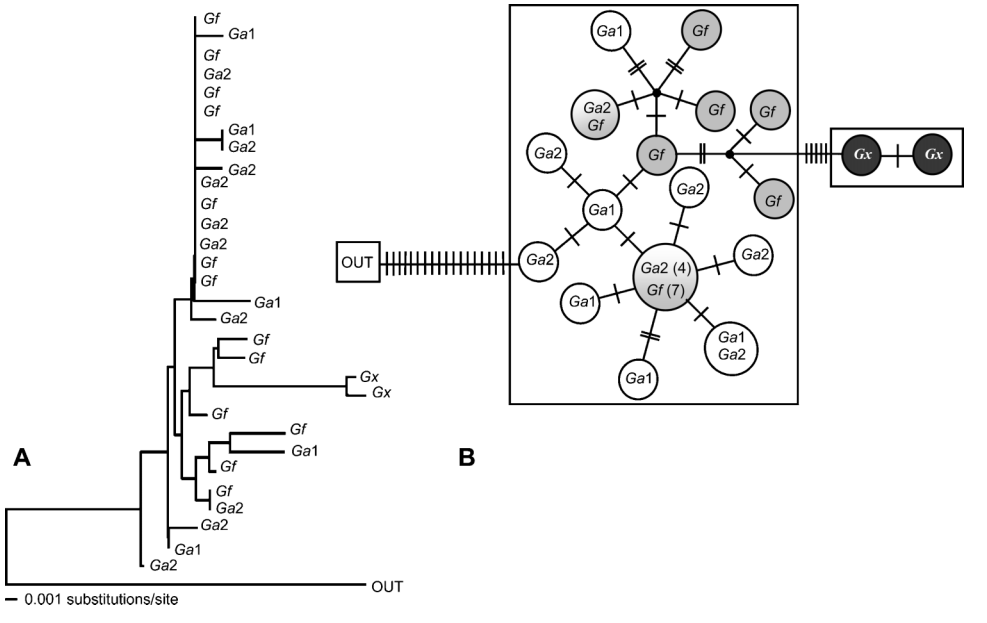

Figure 6. (A) Neighbour-joining tree based on a 379 bp segment of the mitochondrial control region of closely related gobiid taxa belonging to the *G. auratus* species complex. (B) Minimum-spanning tree constructed on the basis of one of the 125 most parsimonious trees (tree length: 45; consistency index excluding uninformative characters: 0.7083; retention index: 0.7879; rescaled consistency index: 0.6653), that was identical to the neighbour-joining tree. Each circle represents one mitochondrial haplotype. Black dots indicate intermediate haplotypes which were not found in the sequenced specimens. Each cross bar represents one mutation step. Abbreviations within circles represent species and colour morphs: *Ga*1, *G. auratus* colour morph 1; *Ga*2, *G. auratus* colour morph 2; *Gf*, *G. fallax*; *Gx*, *G. xanthocephalus*; OUT, outgroup *G. bucchichi*. Numbers of specimens having identical haplotypes are given in parentheses.

construct the minimum spanning tree (Figure 6B). Within the 30 specimens analysed of *G. fallax*, *G. auratus* and *G. xanthocephalus*, 18 different haplotypes were found, 15 of which are each represented by only one specimen (Figure 6). The remaining three occurred in more than one specimen, but only one of them was shared intraspecifically. More than one-third of all specimens investigated shared the same haplotype. This haplotype occurred not only in seven specimens of *G. fallax* but also in four of the colour morph 2 specimens of *G. auratus*. These *G. fallax* specimens originated from the Gulf of Trieste (Piran), from Pula and the Kvarner region (Cres), while all of the four *G. auratus* stem from the Kvarner region (Cres and Krk). The remaining specimens of *G. fallax* were placed in two other haplotype clusters. Apart from the most common haplotype, *G. auratus* was irregularly distributed over the minimum-spanning tree and also showed a second haplotype shared with *G. fallax*. Four out of five specimens of colour morph 1 of *G. auratus* clustered close to the most common haplotype, differing only by one or two base substitutions, but the fifth was placed within the second major haplotype cluster, which is mainly represented by *G. fallax* from the Kvarner region. The two specimens of *G. xanthocephalus* from Portugal were separated from each other by one substitution and represented the only intraspecific cluster, which differed by five unique mutations from all other specimens and by seven to eight mutations from the most frequent haplotype found in both *G. fallax* and *G. auratus*.

Discussion

Our examination of a gobiid taxon from the northern Adriatic Sea shows that individuals are similar to *G. xanthocephalus* Heymer and Zander, 1992 in life coloration, but indistinguishable from *G. auratus* Risso, 1810 in several key morphological features and molecular genetics. We thus conclude its assignment to the latter species, based on the following features: yellow basic coloration over the entire body, deeply emarginate pelvic disc (Vl5 about 60% of Vl4), meristics of median fins being typically D2 I/14, A I/13, P 18–19, scales in lateral midline about 45, corresponding body proportions and arrangement of head sensory papillae, and high similarities in preserved coloration as well as correspondence of mtDNA data. Nevertheless, the life coloration of the northern Adriatic specimens, despite exhibiting this yellow basic coloration, is more complex than the uniform golden-yellow coloration cited for *G. auratus* Risso, 1810 (Heymer and Zander 1994) because of distinct red dots forming several prominent longitudinal lines along the head and body.

Since the first description by Risso (1810), the real identity of *G. auratus* was uncertain for a long time and was repeatedly discussed by different authors. Risso (1810) defined *G. auratus* as a species with golden coloration, black mottling and a blue spot at the basis of the pectoral fin. Beside the conspicuous yellowish golden body coloration and reddish golden fins, one of the main morphological features given is the deep emargination of the pelvic disc to almost half of its length (Risso 1810, Figure 42, Plate XI). In this illustration, the emargination appears somewhat exaggerated and led Cuvier (1829) to the conclusion that *G. auratus* belongs to the eleotrids. This mistake was corrected later by Cuvier and Valenciennes (1837). The fin ray counts of *G. auratus* by Risso (1810) are inadequate, because if the counts of 14 for D2, 12 for A and 10 for V are supposed to include the spines, these values would be too low compared to other studies of this species (Cuvier and Valenciennes 1837; Moreau 1881; Heymer and Zander 1992, 1994) and, especially, the count for V would actually be incorrect, because the pelvic disc constantly has a total of 12 fin rays. The wrong count for the latter could be explained by the little-developed fifth

pelvic rays of the deeply emarginate fin, which may be overlooked if not carefully examined. The count of 15 for the pectoral fin by Risso (1810) and other authors (Moreau 1881; Ninni 1938) cannot be explained, because this count is always much higher in any of the species concerned (Miller and El-Tawil 1974; Heymer and Zander 1992, 1994). The counts of Risso (1810) can be explained only as a result of inadequate examination or bad condition of the specimens. Therefore the identification is easier when relying on his description of the coloration, which exactly resembles that of the golden-yellow Mediterranean species, and on the drawing by Risso (1810, Figure 42, Plate XI), which clearly shows a deep emargination of the pelvic disc. This deep emargination is typical for *G. auratus* and may be seen as an ecomorphological feature corresponding with the hyperbenthic behaviour of this species. A better description is given by Cuvier and Valenciennes (1837), who cite meristics of D2 I/13–14, A I/13–14 and yellow ochre to slightly golden coloration, and the habitat being deep rocky areas. The material examined by Steindachner (1868) probably contained different species, because the description of *G. auratus* from Spain is somewhat confusing due to the high values of lateral midline scale counts of up to 53. The material mentioned by this author and stored at the NMW, for example, contains numerous specimens identifiable as *G. fallax* Sarato, 1889, as examinations by one of us (J.H.) revealed. Moreover, the citation of dark brown spots along the median fins and brown spots along the lateral line confirms confusion with this species, although this does not explain the high scale counts, which rather resemble values for *G. xanthocephalus* or *G. bucchichi*. The coloration pattern given by Moreau (1881), who referred to Cuvier and Valenciennes (1837), described as golden-yellow with small black dots in life and grey-shaded reddish yellow in preservation, is much more typical for the golden goby now termed *G. auratus* than for the mottled species named *G. xanthocephalus* by Heymer and Zander (1992). Additionally, the fin ray count of I/13–14 for D2 (Cuvier and Valenciennes 1837; Moreau 1881) reflects a range rather frequent in *G. auratus* (Miller 1986: as *G. luteus*; Heymer and Zander 1992). Kolombatović (1891) cited different variations of *G. auratus*, and although the variation *G. auratus* var. *ruginosa* is a synonym of *G. fallax* Sarato, 1889, there is another colour morph mentioned in his description of the "true" *G. auratus*, termed *G. auratus* var. *lutea*. The dark yellow dots along the body, with the most conspicuous row in the lateral midline and one or more rows above and below it as well as black dots along the lower jaw, resemble the coloration of northern Adriatic *G. auratus* specimens examined herein and defined as colour morph 2. Since Kolombatović examined specimens from the Adriatic Sea, it is very probable that his material contained both colour morphs. Colour morph 2 was also observed in more southern parts of the Adriatic, e.g. near the Island of Zut (T. Puchner, personal communication), where there seems to be a transition zone between the two forms. Ninni (1938) notes hardly visible small dots on the yellow dorsal fins of *G. auratus*. According to this author, the pectoral spot can be absent in some specimens, but is represented by an accumulation of small dots, a condition that is also mentioned by Heymer and Zander (1992, 1994). Another important observation by Ninni (1938) was the extension of this spot down to the ventral origin of the pectoral fin. This condition was found to be characteristic for *G. auratus*, although the description of dots along the median fins and especially of the dark dots between the upper jaw and the eye rather resembles the life coloration of *G. xanthocephalus* or of colour morph 2 of *G. auratus* than of uniformly yellow *G. auratus*. The description of the ventral fin, i.e. as exceeding the anus, and the low meristics of D2 I/13–14 and LL 44–46 indicate *G. auratus* again. It is very probable that Ninni (1938) described *G. auratus* based on material which also contained other species. The drawing of a specimen from the

Tyrrhenian Sea (Ninni 1938, Plate IIc) very much resembles *G. xanthocephalus* in coloration and the large and complete pelvic disc shown in his Plate IId is not found in any of the species concerned. Ninni (1938) also did not recognize *G. auratus* var. *ruginosa* as a synonym for *G. fallax* and included this variation into the description of *G. auratus*. General confusion was caused by the description of small black dots covering the body of this species (Risso 1810). Bini (1969), on the advice of Miller, defined the golden-yellow Mediterranean goby as the ''true'' *G. auratus*, but a few years later this opinion was changed. Miller and El-Tawil (1974), basically referring to the black dots mentioned by Risso (1810) and the assumed lack of the pectoral spot in the yellow species as mentioned by Bini (1969), believed that *G. auratus sensu* Risso was another Mediterranean species, characterized by conspicuous dark mottling on the head and trunk. So the yellow species was named *Gobius luteus* (Miller and El-Tawil 1974; Miller 1986), raising the variation *G. auratus* var. *lutea* by Kolombatović (1891) to species level. Miller and El-Tawil (1974) believed the ''true'' *G. auratus* to be a Mediterranean species, which is characterized by a deeply emarginate pelvic disc, a conspicuous pectoral mark, and geniohyoid and cheek dots, which were mentioned as being absent by Bini (1969). Since the pectoral spot in the yellow goby is not always visible in living specimens and the black dots on the body are usually visible when the fish are caught or freshly preserved, Heymer and Zander (1992) concluded that the yellow Mediterranean goby, called *G. luteus* by Miller and El-Tawil (1974), is the ''true'' *G. auratus* described by Risso (1810) and designated a neotype. On the other hand, the species supposed to be *G. auratus* by Miller and El-Tawil (1974) was designated as an undescribed species and the new name *G. xanthocephalus* was applied after the investigation of abundant populations of both forms at Banyuls-sur-Mer, France (Heymer and Zander 1992). The small black dots mentioned by Risso (1810) are obviously not a specific coloration pattern as is the case in *G. xanthocephalus*; rather they represent numerous melanophores, which extend all over the body in the yellow species now named *G. auratus*, especially when the fish are captured or put into formaldehyde. The present study supports this view, but extends the known morphology of *G. auratus* in comprising two colour morphs. Discrimination between the colour morph 2 of *G. auratus* and *G. xanthocephalus* may be difficult due to somewhat similar life coloration. Since *G. xanthocephalus* is presently only known from the western Mediterranean Sea and the Atlantic Ocean, and this colour morph of *G. auratus* remains to be recorded from regions other than the northern or central Adriatic Sea, difficulties in discrimination should not occur. Nevertheless, to avoid confusion and to clarify the actual distribution ranges, fish should be collected in any region where they are found in order to enable detailed morphological examinations.

The morphology of *G. fallax* Sarato, 1889 from the northern Adriatic Sea, which was found to be the most abundant closest relative of *G. auratus* in this region, generally resembles the descriptions of previous authors (Moreau 1891; Bini 1969; Bath 1971; Ahnelt 1984). The poor condition of the syntypes MNHN 1888/261–1888/263 did not enable detailed morphological examinations but the coloration is well comparable with the specific pattern of the specimens collected in the northern Adriatic, which is maintained in preservation for a long time. Similar coloration was found in specimens from throughout the Mediterranean, including the specimens from Greece, the central Adriatic and the Balearics. A typical feature of the coloration pattern, the three tiny, dark bars on the abdomen between above the V-base and above the anus, was only recognized by Gridelli (1931) before. The high meristic counts of D2 I/15 and A I/14 as found by Bath (1971) and Ahnelt (1984) differ from this study and can be explained by different counting methods.

Both obviously did not count the last bifid rays in both fins as one, which was found out through examination of the material studied by these authors. Bath (1971) counted D2 I/14 in only one and A I/13 in only three specimens, but D2 I/15 in seven and A I/14 in five out of his nine specimens. But at least all of the four specimens SMF 10803–10806 described by Bath (1971) and also examined here contain only 14 soft rays in D2 and 13 in A, if the last bifid ray is counted as one. Thus, the overall ranges given by Bath (1971) have to be seen as D2 I/13–15 and A I/12–14. Similarly, one specimen (NMW 77932) out of the two examined by Ahnelt (1984) actually shows D2 I/13 and A I/12 instead of D2 I/14 and A I/13 as mentioned by this author, which alters the overall ranges of *G. fallax* in Ahnelt (1984) from D2 I/14–15 and A I/13–14 to D2 I/13–14 and A I/12–13. Nevertheless, the high values of D2 I/15 and A I/14, which remain from Bath (1971) for one specimen each, are unusual in the material from the northern Adriatic Sea with the former never found. The compared specimen from the Balearics exhibits I/14 and I/13, which is typical for *G. fallax*. The ranges in meristics of D2 and A are therefore relatively constant throughout the Mediterranean. The lateral scale counts given by Bath (1971) resemble those of this study, except for one specimen with 48 scales given by this author. Another exception is found in the western Greek specimen (NMW 77932), which displays 47 scales (Ahnelt 1984; this study).

Gobius fallax shows closest morphological affinities with *G. auratus* and *G. xanthocephalus* but can be distinguished by life coloration and habitat choice. These characters are rarely used in taxonomy, but their significance for identification of closely related but ecologically specialized species is important. All three species are similar in most of the key features such as the lateral line system, morphometrics and meristic values, which vary within a similar range. An important feature shared by these gobiids is a seventh suborbital neuromast row near pore α, here provisionally named "α". According to Miller (1986) the genus *Gobius* possesses only six suborbital rows and sometimes one to a few papillae in pore α. This is evident for all species investigated here. However, it is very probable that these neuromasts represent the suborbital row 7 as present in several other Mediterranean genera (Miller 1986). The proliferation of papillae within this row from one up to three and its position does support a designation as a remnant of a seventh row of suborbital secondary replacement neuromasts rather than as primary neuromasts of a shortened anterior ocluoscapular canal segment, with pore α more dorsal than in species such as *G. ater* Bellotti, 1888 or *G. paganellus* Linnaeus, 1758 (Miller 1986; Ahnelt 2001). Concerning the fin meristics and scale counts, *G. fallax* shows much lower values than *G. xanthocephalus*. Based on these differences, on the degree of ventral fin emargination and the coloration, two specimens stored as *G. fallax* Sarato, 1889 (both NMW 84864) in the Naturhistorisches Museum Wien, are now identified as *G. xanthocephalus* Heymer and Zander, 1992, which enlarges the known distribution range of the species to the Gulf of Genova, Italy. The mean meristics of D2, A and LL in *G. auratus* from the Adriatic Sea are somewhat higher than in *G. fallax*, although they vary within similar ranges. Easier differentiation between all three species is enabled by specific coloration patterns in life and preservation as well as by the length and shape of the pelvic disc. The shape of the caudal fin as an identification criterion, as mentioned by Heymer and Zander (1992, 1994), can only serve with some reservations. Especially, larger specimens of all species concerned may exhibit a slightly rounded caudal fin. In contrast to the description in the text this is already indicated for *G. auratus* in the drawings of Heymer and Zander (1992, p 299, Figure 2; 1994, p 87, Figure 11), who refer to Bini (1969) concerning this feature. Slightly rounded caudal fins were also found in large specimens of *G. auratus* in this study. In juveniles and

young adults, the caudal fin often shows a slight emargination in *G. auratus* but a rather truncate shape in *G. fallax* and *G. xanthocephalus*. We basically agree with Heymer and Zander (1992, 1994) in their general differentiation between *G. auratus* and *G. xanthocephalus*, although their citation of major differences in meristic counts can hardly be explained from their data given. The meristic ranges of LL, D2 and A given for *G. auratus* are much higher than those observed in the Adriatic material and do not obviously differ from the values given for *G. xanthocephalus* by these authors. The present study showed the highest meristic counts to be exhibited by *G. xanthocephalus* with values similar to that found by Almeida and Arruda (1998). Another agreement was found in the species' coloration described by these authors.

In summary, the main discriminating morphological features of *G. fallax* Sarato, 1889, *G. xanthocephalus* Heymer and Zander, 1992 and both colour morphs of *G. auratus* Risso, 1810 can be found in the coloration, the size and shape of the ventral fin, and in certain body proportions and meristics (Table V). *Gobius auratus* shows the longest head and ventral fin and the deepest emargination of the pelvic disc with a reduced anterior membrane. *Gobius xanthocephalus* exhibits a short head and ventral fin with only slight disc emargination and a small remnant of the anterior membrane. *Gobius fallax* is intermediate concerning these features. The meristics of D2, A and LL are highest in *G. xanthocephalus* and lowest in *G. fallax*. Despite *G. xanthocephalus* being somewhat distinct from both of the two other species, most of the morphometric and meristic ranges of the three species overlap with each other (Table III) and differences can only be cited by calculating the mean from a series of specimens (Table V).

Miller and El-Tawil (1974) included two more species into the *G. auratus* species complex. *Gobius gasteveni* Miller, 1974 and *G. couchi* Miller and El-Tawil, 1974, described from the north-eastern Atlantic, were supposed to be close relatives of the species investigated here, although they can be separated by possessing a complete pelvic disc with

Table V. Diagnostic morphometric and meristic characters of closely related gobiids belonging to the *G. auratus* species complex.

		Mean	SD	*n*	Gf	*Gx*
H in %SL	*Ga*	31.7	1.2	49	**	***
	Gf	31.1	1.0	49		***
	Gx	28.7	0.7	8		
Vl in %SL	*Ga*	25.1	1.3	49	***	***
	Gf	23.9	1.2	49		***
	Gx	22.3	0.7	8		
V5l in %V4l	*Ga*	61.2	3.2	49	***	***
	Gf	73.4	4.8	49		***
	Gx	82.9	3.3	8		
D2	*Ga*	14.0	0.3	61	***	***
	Gf	13.8	0.4	58		***
	Gx	14.9	0.4	13		
A	*Ga*	13.1	0.4	61	**	***
	Gf	12.8	0.6	58		***
	Gx	14.0	0.4	13		
LL	*Ga*	45.3	1.3	61	***	***
	Gf	43.2	1.3	58		***
	Gx	48.0	1.9	13		

See Material and methods for variable abbreviations. *Ga*, *G. auratus*; *Gf*, *G. fallax*; *Gx*, *G. xanthocephalus*. Values are mean, standard deviation (SD) and number of specimens (*n*). ***$P<0.001$, **$P<0.01$.

a well-developed anterior membrane, which was shown to be an important feature. Moreover, the recently described *G. kolombatovici* Kovačić and Miller, 2000 from the northern Adriatic Sea has to be considered as part of this species complex. Besides similarities in several morphological features it is also characterized by an emarginate pelvic disc and reduced anterior membrane, a feature which is obviously synapomorphic for this species complex. A close relationship of *G. kolombatovici* with the species examined herein was already mentioned by Kovačić and Miller (2000). It differs from the species investigated here by life coloration and a higher scale count in lateral series, which even exceeds that of *G. xanthocephalus*, while the fin meristics are rather similar to *G. fallax*.

The existence of a *Gobius auratus* species complex as proposed by Miller and El-Tawil (1974) is strongly supported by our analysis, both by morphological and by the molecular genetic results. Concerning the molecular phylogenetic analyses, the mitochondrial control region is known to represent the most variable section of the mitochondrial genome and can therefore be used to investigate the phylogeny of closely related species and populations (Faber and Stepien 1997). According to Chen et al. (1998), the region close to the 5′ end, which was sequenced in the present study, shows the highest genetic variation. In the 379 bp segment of the mitochondrial control region investigated here, however, the observed genetic variation turned out to be very low and showed no insertions or deletions, neither within nor between morphologically defined taxa. Thus, all taxa share common ancestry in the recent past. Despite a high number of different haplotypes found, most of these differed from each other by only one or two base substitutions. High numbers of different intraspecific haplotypes compared to the investigated specimens were also found by Chen et al. (1998) and Stefanni and Thorley (2003). The small degree of genetic variation observed did not allow for the establishment of a clear phylogeny for *G. xanthocephalus*, *G. auratus* and *G. fallax*. Surprisingly, the molecular data did not differentiate *G. fallax* and *G. auratus*. The most common haplotype was not only abundant in *G. fallax* but also found in both colour morphs of *G. auratus*. The closest affinity within a population was found in *G. fallax* from the Gulf of Trieste at Piran, where four of the five individuals investigated shared the same haplotype, and the fifth differed only by two substitutions. Although, the two haplotypes in *G. xanthocephalus* represent the only intraspecific cluster, their divergence is not that high. They are separated from all haplotypes of *G. fallax* and *G. auratus* by five unique base substitutions and differ from the most common haplotype by seven and eight mutations, respectively, which is the highest rate between all 18 haplotypes.

In Chen et al. (1998), the haplotypes of the entire control region sequence clearly discriminated between *Rhinogobius giurinus* (Rutter, 1897) and its sister species *R. maculafasciatus* Chen and Shao, 1996, and even showed several interspecific insertions and deletions. Stefanni and Thorley (2003) found a high genetic divergence between morphologically identical populations of *Pomatoschistus minutus* (Pallas, 1770) from the northern Adriatic Sea and the eastern Atlantic and therefore suggested a subspecies status for these populations caused by geographical isolation during glacial or post-glacial times. The present study shows quite different results, because the morphologically defined taxa do not, except for *G. xanthocephalus*, exhibit an obvious genetic differentiation. Even the *G. xanthocephalus* specimens, which stem from the eastern Atlantic, are not as distant from the other taxa as was expected. Compared to the results of genetic divergence as in *P. minutus*, it is supposed that the incomplete lineage sorting investigated here represents a continuing speciation of taxa, which were not genetically isolated in the past. In summary, the low level of genetic differentiation between morphologically defined taxa and the presence of identical haplotype shared between *G. fallax* and *G. auratus* suggest an extremely close

evolutionary relationship among these taxa. We thus suggest considering them as a species complex in which reproductive isolation might be incomplete among some members. The different life habits and habitat selection (the latter will be shown for *G. fallax* and *G. auratus* from the northern Adriatic Sea in a separate paper) indicate a speciation due to niche occupation in specific habitats. The lack of knowledge about the range of distribution of each species makes interpretations of the origin and evolution of this complex difficult. The colour morph 2 of *G. auratus* and *G. kolombatovici* are probably restricted to the northern Adriatic Sea, while *G. xanthocephalus* remains to be found in the eastern Mediterranean. To clarify the entire distribution area and the evolutionary history of all species within this complex, careful comparative examination of populations from throughout the Mediterranean and eastern Atlantic are required. Extended genetic examinations of at least the whole D-loop and including nuclear markers such as microsatellites or AFLPs, that include all relevant species from various geographical regions are needed to elucidate the relationships of this array of closely related taxa and their state of reproductive isolation.

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