MORPHOLOGICAL DIFFERENCES BETWEEN THE EASTERN PACIFIC GOBIID FISHES *QUIETULA GUAYMASIAE* AND *QUIETULA Y-CAUDA* (TELEOSTEI: GOBIIDAE) WITH EMPHASIS ON THE TOPOGRAPHY OF THE LATERAL LINE SYSTEM

by

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ABSTRACT. - *Quietula guaymasiae* and *Quietula y-cauda* occur sympatrically in the Gulf of California (Mexico). Both species are similar in their meristic values but differ in the topography of the lateral line system: the pattern of free neuromasts, their total number and their number in most rows. *Quietula guaymasiae* is generally somewhat larger than *Quietula y-cauda* but differences in the number of neuromasts between both species are not size dependent, and the neuromast pattern does not vary between juveniles and adults of either species. The lateral line system of *Quietula guaymasiae* and *Quietula y-cauda* is described in detail. For identification of the neuromast pattern and for the comparability of this feature with other gobiids, a nomenclature of the series and the rows of free neuromasts is given.

RÉSUMÉ. - Différences morphologiques entre deux Gobiidae du Pacifique Est *Quietula guaymasiae* et *Quietula y-cauda* avec l'accent sur la topographie du système de la ligne latérale.

Quietula guaymasiae et *Quietula y-cauda* sont des espèces sympatriques dans le Golfe de Californie (Mexique). Les deux espèces sont similaires dans leurs valeurs méristiques mais diffèrent dans la topographie du système de ligne latérale : le modèle de neuromastes libre, leur numéro total et leur numéro dans la plupart des rangs. *Quietula guaymasiae* est généralement un peu plus grand que *Quietula y-cauda*, mais les différences dans les nombres de neuromastes entre les deux espèces ne sont pas dépendantes de la taille, et la disposition des neuromastes ne varie pas entre les juvéniles et les adultes, pour les deux espèces. Le système de ligne latérale de *Quietula guaymasiae* et *Quietula y-cauda* est décrit en détail. Pour l'identification de la disposition des neuromastes et pour la comparaison de cette caractéristique avec d'autres Gobiidae, une nomenclature des séries et des rangs de neuromastes libres est donnée.

Key words. - Gobiidae - *Quietula* - PSE - Gulf of California - Lateral line system - Systematics.

Quietula guaymasiae and *Quietula y-cauda* (as *Gillichthys*) are two gobiid species which were originally described from Guayamas, Gulf of California, Mexico (Jenkins and Evermann, 1889). *Q. y-cauda* occurs from central California to Baja California Sur and in the Gulf of California, *Q. guaymasiae* is known only from the Gulf of California. They may occur sympatrically in estuaries of the Gulf, but only *Q. y-cauda* occurs outside of it. Seemingly *Q. guaymasiae* is confined to the Cortez and the northern part of the Panamic zoogeographic provinces, while *Q. y-cauda* occurs also in the San Diegan and the southern part of the Oregonian provinces.

Due to similar diagnostic characters, the validity of *Q. guaymasiae* has been questioned by several authors, the first time in the same year of its description (Gilbert, 1889; Jordan and Evermann, 1898; Castro-Aguirre *et al*., 1999). Other authors, using features of the head lateral line system and karyotypes, kept *Q. guaymasiae* separate from *Q. y-cauda* as two distinct species (Barlow, 1961; Macdonald, 1972; Cook, 1978). During studies of the lateral line system of gobiid fishes of the "*Chasmichthys*" - group sensu Birdsong *et al*. (1988) (Göschl, 2002; Göschl and Ahnelt unpubl. data) we investigated several samples identified as *Q. y-cauda* from various localities along the Pacific coast of California, Baja California and from the Gulf of California (Fig. 1). Some of these populations from the Gulf of California differ from those outside of the Gulf by significantly higher numbers of superficial neuromasts on the head. Barlow (1961) also compared two close related gobiid species with similar distributions, *Gillichthys mirabilis* and *G. seta*, the latter endemic to the Gulf of California. He demonstrated that the lateral line system undergoes changes during ontogeny and that in *G. mirabilis* the numbers of neuromasts varies dependent on the size of the individuals.

The aim of this study is the comparision of the topography of the lateral line system of two close related gobiid species which occur sympatrically in the Gulf of California and its significance as a taxonomic tool. Additionally it shall be demonstrated that a system for a descriptive terminology of the neuromast pattern developed by Sanzo (1911), criti-

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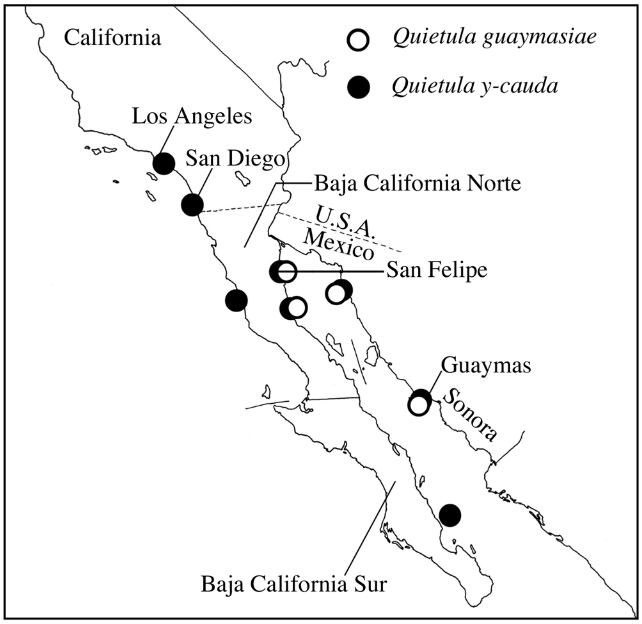

Figure 1. - Map showing localities for material examined for *Quietula guaymasiae* and *Quietula y-cauda* in California (USA) and Baja California and Gulf of California (Mexico). Some symbols represent more than one locality or lot of specimens.

cized as being too restrictive for use on Californian gobiid fishes (Barlow, 1961; Macdonald, 1972), is applicable to the species of *Quietula*.

MATERIALS AND METHODS

The following preserved specimens were examined (collection number, number of specimens, sex, SL in mm, sampling site). Length of specimens is given in standard length. The sex was determined by the shape of the urogenital papilla (Type A of Egami (1960)). Institutional abbreviations follow Leviton *et al*. (1985).

Quietula guaymasiae

59 specimens. CAS 26056, 14 males, 23.1 - 48.8, 5 females, 28.2 - 40.8, 3 juveniles, 14.4 - 21.7, out of 24 specimens, Baja California Norte, Gulf of California, San Felipe. CAS 55187, 3 males, 39.0 - 67.6, 4 females, 47.4 - 62.8, 3 sex ?, 39.8 - 48.8, out of 12 specimens, Baja California Norte, Gulf of California, Miramar Island. LACM 9937-6, 1 female, 52.1, 1 sex? 51.7, Sonora, Gulf of California, S end of Cabo Tepopa. LACM 30143-9, 7 males, 20.6 - 36.0, 16 females, 23.7 - 29.0, 1 sex?, 23.4, out of 50 specimens, Sonora, Gulf of California, Estero Soldado near Guaymas. LACM 47876-3, 1 female, 72.4 + 16.6, Baja California Norte, Gulf of California, San Felipe Bay, about 3/4 mi. S of San Felipe.

Cleared and stained. - CAS 26056, 2 males, 36.0 - 41.0, Baja California Norte, Gulf of California, San Felipe.

Quietula y-cauda

103 specimens. CAS 11497, 3 males, 36.4 - 39.5, 2 females, 29.5 - 35.6, 1 sex ?, 30.5, out of 14 specimens, California, Mission Bay, San Diego County, San Diego. CAS 41895, 2 males, 32.1 - 34.2, 9 females, 33.5 - 43.6, California, San Diego County, San Diego Bay. CAS 214894 (out of CAS 55187), 1 female, 37.0, out of 12 specimens, Baja California Norte, Gulf of California, Miramar Island. CAS 115221, 2 males, 32.9 - 47.3, 2 females, 37.8 - 47.3, out of 49 specimens, Baja California Norte, San Quintin Bay, around end of pier at old town of San Quintin. CAS 115287, 2 males, 38.5 - 43.2, 4 females, 40.0 - 52.9, out of 50 specimens, Baja California Norte, 3000 m NE of Sulphur Point. CAS 118467, 1 male, 25.1, out of seven specimens, Baja California Sur, Gulf of California, end of Amortajada Bay. CAS 200221, 13 males, 22.4 - 34.1, 22 females, 19.6 - 44.8, out of 96 specimens, California, Orange County, Upper Newport Bay, 0.5 mi. N of Hwy. 101 bridge. CAS 214896, 1 male, 33.3, 2 females, 36.2 - 38.0, out of five specimens, California, Orange County, Newport Bay. LACM 9937-5, 12 males, 16.7 - 24.8, 6 females, 13.6 - 30.3, 6 juveniles, 11.7 - 18.1, out of 37 specimens, Sonora, Gulf of California, S end of Cabo Tepopa. LACM 31586, 4 males, 20.7 - 27.2, 3 females, 17.6 - 30.3, 2 juveniles, 15.3 - 17.0, Sonora, Gulf of California, Bahia de San Carlos, just N of Guaymas. LACM 47876-2, 3 males, 20.8 - 27.9, Baja California Norte, Gulf of California, San Felipe Bay, about 3/4 mi. S of San Felipe.

Cleared and stained. - CAS 80520, 6 specimens, sex?, 53.9 - 59.8, California, San Luis Obispo County, mouths of Los Osos and Corro Creeks. CAS 200221, 1 male, 34.1, 1 female, 40.8, California, Orange County, Upper Newport Bay, 0.5 mi. N of Hwy. 101 bridge.

Radiographs. - CAS 115287, 4 specimens, sex ?, 44.2 - 47.8, out of 50 specimens, Baja California, San Quintin Bay, 3000 m northeast of Sulphur Point.

Terminology of zoogeographic provinces follows Moser (1996), neuromast system follows Sanzo (1911), cephalic pores follow Akihito (1986). Meristics follow Miller (1988), dorsal pterygiophore formula (dorsal pterygiophore insertion pattern) follows Birdsong *et al*. (1988).

Abbreviations. - 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 (from origin of A obliquely upwards and rearwards to base D2); V: pelvic disc.

The lateral line canals and free neuromasts of teleost fishes have a similar basic distribution pattern and are innervated by the same trunks and branches of the anterior and posterior lateral line nerves (Jakubowski, 1966; Coombs *et al*., 1988; Wongrat and Miller, 1991; Gibbs, 1999). This has also been demonstrated for Eleotridae (Wongrat and Miller, 1991) and Gobiidae (Ahnelt and Bohacek, in press). The terminology for the neuromasts of gobiid fishes, primarily based on their pattern, has been developed by Sanzo (1911) and is applicable to other gobioids, even modifications may be necessary. Most rows identified and marked with letters and numbers by Sanzo (1911) and subsequently by various authors (for example Iljin, 1930; De Buen, 1931; Miller, 1986; Larson, 2001; Shibukawa *et al.*, 2001), seem to be homologous through a wide range of gobioids (Wongrat and Miller, 1991; Ahnelt and Bohacek, in press; Ahnelt and Scattolin, 2003). We are currently investigating the lateral line system of north east Pacific gobiid fishes and will discuss the modifications in the terminology of the free neuromast series and rows of Sanzo (1911).

QUIETULA JORDAN & EVERMANN *IN* JORDAN & STARKS, 1895

Generic identification

Body elongate; head compressed, interorbital space narrow; eyes dorso-lateral and large; body covered with small cycloid scales; head, nape, predorsal area to about origin of pectoral fins, and breast naked; snout longer than eye diameter; mouth terminal, enlarged, lower jaw not projecting; maxillary elongate, posterior angle of jaws distinctly behind posterior margin of eye; anterior nostril a short somewhat downward oriented tube close to but not overlapping upper lip without process from rim; posterior nostril pore-like; gill opening wide with branchiostegal membrane attached to isthmus close to ventral origin of P; rays of P within membrane, but tips conspicuous; V complete, round, short and not reaching anus in both sexes, tips of rays conspicuous; C rounded, shorter than head; no sexual dimorphism in jaw length; 2 - 3 (mode) lobes on the anterior edge of cleithrum (pectoral girdle); 2 + 8 gill rakers on first gill arch; urogenital papilla in female short, rounded, only slightly longer then wide, and short, pointed and longer then wide in male; longitudinal neuromast pattern on head well developed; anterior oculoscapular canals of cephalic lateral line system reduced to supraorbital canals with pores B, D (single) and F present; posterior oculoscapular and preopercular canals absent. Total vertebrae 33-34.

Two species, *Q. guaymasiae* and *Q. y-cauda*, both occur sympatrically in the northern part of the Gulf of California but only the latter occurs outside of the Gulf along the west coast of Baja California (Mexico) and California (USA).

QUIETULA GUAYMASIAE (JENKINS & EVERMANN, 1889)

Specific identification

Quietula guaymasiae differs from *Q. y-cauda* (values of latter in parentheses) by (i) pectoral fin with higher number of fin rays, P 23-24 (P 20-21), (ii) lower numbers of scales in lateral and transversal series, generally LL < 73, TR < 20 (LL > 74, TR > 20), (iii) dark transverse marking on base of caudal fin (sideways y-shaped mark on caudal fin, anteriorly extending on caudal peduncle), (iv) anterior membrane (frenum) between spines of pelvic disc with crenate rear edge along its entire length (sides of anterior membrane crenate, median third generally smooth), (v) ventral series of trunk neuromasts with 5 - 6 rows (4 rows), (vi) longitudinal suborbital rows of the lateral line system with distinctly more neuromasts in each row, and (vii) absence of the primary replacement neuromasts in the course of the postorbital section of the absent anterior oculoscapular canal (primary replacement neuromasts present).

Fins

Quietula guaymasiae (n = 59). Mode: D1 V; D2 I,14; A I,12-13; P 23-24; V I,5+5,I; C 15 (segmented). Detailed values are given in figure 2 and table I.

Quietula y-cauda (n = 98). Mode: D1 V; D2 I,14; A I,13; P 20-21; V I,5+5,I; C 15 (segmented). Anal fin spine lacking in one specimen. Detailed values are given in figure 2 and table I.

Table I. - Comparision of selected meristic characters for *Quietula guaymasiae* and *Quietula y-cauda*. Generally one spine preceeds the fin rays of the second dorsal and anal fins. The number of these spines is not given.

	First dorsal-fin spines			Second dorsal-fin rays				Anal-fin rays				Pectoral-fin rays							Caudal-fin rays			
	4	5	6	12	13	14	15	12	13	14	15	19	20	21	22	23	24	25	14	15	16	17
Q. guaymasiae	.	53	2	.	3	47	6	42	14	1	.	.	.	.	3	23	23	9	1	52	3	.
%	.	96.4	3.6	.	5.4	83.9	10.7	73.7	24.6	1.8	.	.	.	.	5.2	39.7	39.7	15.5	1.8	92.9	5.4	.
Q. y-cauda (total)	.	88	.	1	8	63	20	8	66	17	1	7	27	33	12	4	.	.	1	71	9	11
%	.	100	.	1.1	8.7	68.5	21.7	8.7	71.7	18.5	1.1	8.4	32.5	39.8	14.5	4.8	.	.	1.1	77.2	9.8	12
Q. y-cauda,	.	36	.	.	2	25	11	2	24	11	1	.	5	15	7	3	.	.	.	36	1	.
Gulf of California, %	.	100	.	.	5.3	65.8	29	5.3	63.2	29	2.6	.	16.7	50	23.3	10	.	.	.	97.3	2.7	.
Q. y-cauda,	1	52	.	1	6	38	9	6	42	6	.	7	22	18	5	1	.	.	1	35	8	11
outside the Gulf, %	1.9	98.1	.	1.9	11.1	70.4	16.7	11.1	77.8	11.1	.	13.2	41.5	34	9.4	1.9	.	.	1.8	63.6	14.6	20

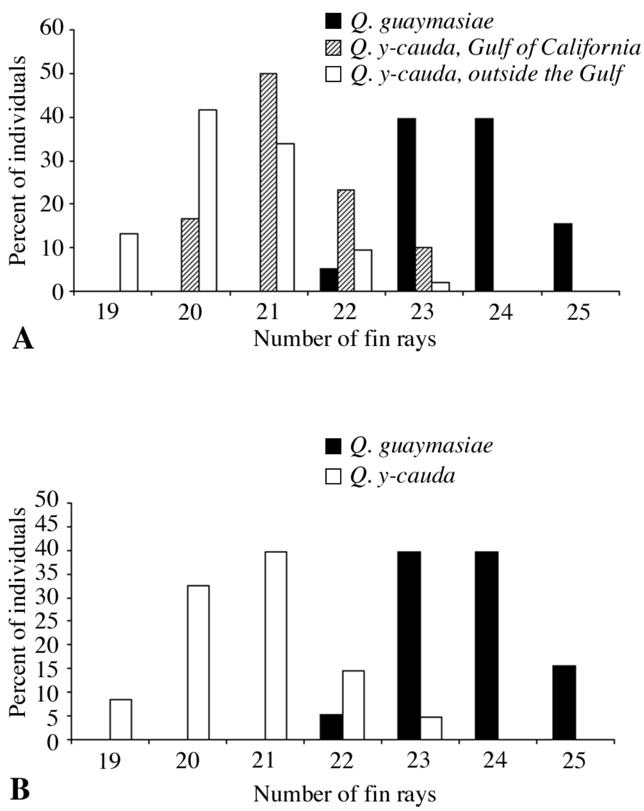

Figure 2. - Percent of individuals against number of pectoral fin rays of *Quietula guaymasiae* (n = 58) and *Quietula y-cauda*. Populations of *Q. y-cauda* from the Gulf of California (n = 30) and from outside of the Gulf (n = 53) shown separately (**A**) and together (**B**).

Scales

In many specimens the scales are at least partly abraded and are therefore often difficult to enumerate. Both species are characterized by a distinct range in scale number.

Quietula guaymasiae (n = 31). LL: mode 70-72, range: 65-76; TR: mode 17-19, range 16-20.

Quietula y-cauda (n = 14). Scales smaller than in *Q. guaymasiae*. LL: mode 74-78, range: 67-89; TR: mode 20-22, range 15-24.

Vertebrae and dorsal pterygiophore formula

Quietula guaymasiae (n = 2). Total number of vertebrae (including urostyle) in both specimens is 33; 15 precaudal and 18 caudal vertebrae. Dorsal pterygiophore formula (dorsal pterygiophore insertion pattern) 4-1210100, 4-2110100. First pterygiophore of the first dorsal fin inserts in the fourth interneural space between the neural spines of VT4 and VT5. First pterygiophore of the second dorsal fin inserts between the neural spines of VT11 and VT12.

Quietula y-cauda (n = 12). Total number of vertebrae (including urostyle) 33- 34 (33: 8, 34: 2); 14 precaudal and 19-20 caudal vertebrae (19: 8, 20: 2). Pterygiophore insertion pattern 4-1210100 (n = 10), 4-1211000 (n = 2). Otherwise as for *Q. guaymasiae*.

Lateral line system

Quietula guaymasiae

Cephalic canals. - In the anterior oculoscapular canal (AOS), only supraorbital canals present, with posterior nasal pore B (paired), posterior interorbital pore D (single) and postorbital pore F (paired); pores of equal size; B opens anteriorly, D opens dorsaly and F opens lateraly; anterior interorbital pores are lacking; interorbital canals separate, not unified to a single interorbital canal, but connected together with a short transversal tubule (supraorbital pseudocommissure of Takagi (1988)); pore D is located in the middle of this tubule; postorbital section of the AOS lacking (Figs 3, 4). Posterior oculoscapular and preopercular canals absent.

Compared with the pattern of the superficial neuromasts, cephalic canals develop relatively late in ontogeny of gobioid fishes. In gobies with cephalic lateral line canals present, these canals form during juvenile stages, generally reaching their final formation before maturity (Afzelius, 1956; Barlow, 1961; Takagi, 1988; Herler *et al*., 1999). The taxonomic utility of head canals should therefore only be considered when their final stage or variations in development are sufficiently known. In both *Quietula* species, the formation of the supraorbital canals is completed at a size of approximately 20-22 mm standard length. Nevertheless, in a sample of *Q. y-cauda* (CAS 41895) from the San Diego Bay three adults out of 11 specimens lack the transverse tubule between the left and the right supraorbital canals and thus have pore D paired.

Free neuromasts (= sensory papillae) (Figs 3-7; Tab. II). - Neuromasts present on head, trunk and caudal fin; rows represented by series of neuromasts, a few reduced to a single neuromast only. “Longitudinal“ uniserial suborbital neuromast type. Eight of the nine series of neuromast rows listed by Sanzo (1911) are present in both species; the ninth, the interorbital series, is lacking. Neuromasts are larger than in *Q. y-cauda*. Numbers of neuromasts per row are summarized in table II.

Preorbital. - Median series in four rows internal to nasal openings, $\mathbf{r^1}$, $\mathbf{r^2}$, **s** and $\mathbf{s^3}$. Rows $\mathbf{r^1}$ and $\mathbf{r^2}$, each reduced to a single neuromast, internal to row **s**; row **s** long, longitudinal from pore B to upper lip and a single neuromast external to it and close to anterior nostril (marked with an asterisk in figure 4); $\mathbf{s^3}$ as single neuromast close to upper lip, internal to **s** and in elongation of $\mathbf{r^1}$ and $\mathbf{r^2}$. Lateral series ($\mathbf{c^2}$, $\mathbf{c^1}$, $\mathbf{c_2}$ and $\mathbf{c_1}$) external to nasal openings, generally a more or less continuous row from posterior nostril to upper lip and posteriorly to above origin of longitudinal suborbital row **d**; two neuromasts ventral to anterior nostril; $\mathbf{c^2}$ longitudinal and close to nostrils; $\mathbf{c_1}$ generally as two transversaly arranged neuromasts dorsal to origin of suborbital row **d**.

The median preorbital series is positioned on the snout between the left and right nasal openings with rows **r** medial and **s** lateral (Sanzo, 1911; Iljin, 1930; Wongrat and Miller, 1991; Larson, 2001). In agreement with earlier authors, the lateral rows (**s**) are separated in this paper in two groups: (i) the longitudinal row anterior to pore B plus a single neuromast external to it (marked with an asterisk) are named **s** (Fig. 4), and (ii) a single neuromast close to upper lip $\mathbf{s^3}$. The latter differs from row **s** by its position close to the upper lip and internal to **s** and by its innervation. The neuromasts of **s** are innervated by the truncus supraorbitalis of the anterior lateral line nerve, while $\mathbf{s^3}$ is, like row **r**,

Table II. - Numbers of free neuromasts (sensory papillae) in the cephalic lateral line system of *Quietula guaymasiae*, *Quietula y-cauda* from the Gulf of California and *Quietula y-cauda* from outside of the Gulf. Characteristic for *Quietula guaymasiae* is the lack of row $\mathbf{u^1}$. This feature may occur rarely and has been found during this study in two specimens but only on one side of the head (see text). Series of neuromasts: AD: anterior dorsal; OP: opercular; OS: oculoscapular; PM: preopercular-mandibular; PO: preorbital; SO: suborbital.

		Quietula guaymasiae		*Quietula y-cauda* outside the Gulf		*Quietula y-cauda* Gulf of California	
		n = 13 (u^1: n = 27)		n = 13 (u^1: n = 28)		n = 9	
		SL 24.1 - 67.6		SL 23.9 - 44.8		SL 21.8 - 37.0	
		Range	Mean	Range	Mean	Range	Mean
PO	r^1	1-2	1.1	1-2	1.0	0-1	0.9
	r^2	1	1.0	1	1.0	1	1.0
	s	7-11	8.5	3-5	4.1	4-6	4.7
	s^3	1-2	1.1	1	1.0	1	1.0
	*	1-2	1.1	0-1	1.0	1	1.0
	c^2	5-8	6.1	3-5	3.9	3-5	4.7
	c^1	1-5	3.0	1	1.0	1-2	1.1
	c_2	3-6	4.1	2-4	2.9	1-4	3.0
	c_1	2	2.0	2-3	2.0	2-3	2.1
SO	a	3-12 + 13-23	6.1 + 18.5	4-9 + 6-11	5.5 + 7.6	3-7 + 7-12	4.6 + 8.8
	b	31-73	55.2	21-36	27.1	22-31	26.9
	c	14-27	22.4	6-11	7.5	6-10	8.2
	cp	1-10	5.4	1-7	3.8	3-9	4.8
	d	37-83	62.9	20-35	26.5	22-33	28.3
PM	e^1	49-93	70.7	29-39	33.9	33-56	41.8
	e^2	16-33	24.7	10-17	13.0	10-18	14.5
	i^1	36-48	40.7	18-27	22.0	22-36	26.2
	i^2	14-21	17.8	8-12	9.7	8-15	10.1
	i^3	2-4	2.4	2	2.0	2-3	2.1
	f	1	1.0	1	1.0	1	1.0
OP	ot	19-42	30.2	15-23	17.9	14-22	16.9
	os	14-24	18.1	7-14	9.7	7-11	8.6
	oi	7-15	11.0	4-8	5.5	3-8	4.9
OS	x^1	7-30	16.9	7-12	8.5	5-11	7.8
	x^2	11-22 + 5-13	15.5 + 9.5	5-9 + 3-6	6.6 + 4.5	3-9 + 3-8	6.3 + 5.0
	u^1	0-2	0.1	1-4	1.6	1-3	1.9
	u^2	4-14 + 2-7	6.5 + 3.7	2-3 + 1-3	2.1 + 2.0	2-3 + 2-3	2.1 + 2.1
	z	6-19	10.8	3-9	6.6	4-8	6.5
	q	4-10	6.7	3-8	5.0	4-7	4.8
	tra	4-8	6.1	4-7	5.5	3-7	5.2
	as^1	6-14	9.2	4-10	7.1	5-8	5.8
	as^2	6-15	8.5	5-10	6.2	4-7	5.1
	as^3	6-12	8.9	3-9	6.0	4-9	6.2
	la^2	5-18	9.9	3-10	5.5	4-7	4.7
	la^3	5-15	9.8	2-6	4.5	3-7	5.2
AD	n	4-10	6.4	2-7	5.3	3-7	5.2
	o	0-4	1.3	0-1	0.9	0-1	0.9
	g	7-19	12.2	6-12	7.9	5-11	7.8
	h	9-31	19.8	8-18	12.9	7-18	13.0

innervated by the ramus buccalis of the same nerve (Coombs *et al*.,1988; Wongrat and Miller, 1991; Ahnelt and Bohacek in press). The innervation of the **s**-neuromast marked with an asterisk is not known.

Suborbital. - "Longitudinal" uniserial suborbital neuromast type. Five rows on cheek, four longitudinal rows, **a**, **b**, **c** and **d**, and one transverse row, **cp**. Longitudinal rows long, and one below the other. Row **a** along lower edge of orbit, in two parts, neuromasts closely set; dorsally an irregular row of neuromasts, sometimes clustered, from below pore F ventrally; anterior to it, a uniserial row of neuromasts anteriorly ending dorsal to origin of row **d**. Rows **b** and **c** close together and in midline of cheek; **b** long, about twice the diameter of orbit; **c** extending posteriorly behind a vertical through pore F. Row **cp** immediately behind row **c**, never between longitudinal rows, generally in the shape of a T, with dorsally a short longitudinal and ventrally a short transverse row. Row **d** continuous, along edge of upper lip from below anterior margin of orbit to corner of mouth. Neuromasts of anterior part of **a**, **c** and **cp** larger than those of **b** and **d**. *Q. guaymasiae* is easily separated from *Q. y-cauda* by numerous neuromasts in the longitudinal suborbital rows and those of **c** and of the anterior section of **a** closely set (Figs 3, 7; Tab. II).

Preopercular-mandibular. - Three longitudinal rows, external **e** on lateral edge of lower jaw and preopercle, internal **i** medial, and mental **f**; neuromasts of **i** larger than **e**; rows **e** and **i** divided in mandibular ($\mathbf{e^1}$, $\mathbf{i^1}$) and preopercular ($\mathbf{e^2}$, $\mathbf{i^2}$, $\mathbf{i^3}$) sections by a gap at the lower jaw articulation; gap less distinct in **i**; neuromasts of $\mathbf{i^1}$ proceed in a groove; in dorsal extension of and clearly separated from $\mathbf{i^2}$ two closely set neuromasts ($\mathbf{i^3}$) in place of the absent preopercular canal ($\mathbf{i^1}$ of Miller (1963), **por** of Herler *et al*. (1999)) (Fig. 3). Mental rows **f** as single neuromast each in a groove posterior to the mandibular symphysis and distinctly separated from the anterior origin of $\mathbf{e^1}$ and $\mathbf{i^1}$.

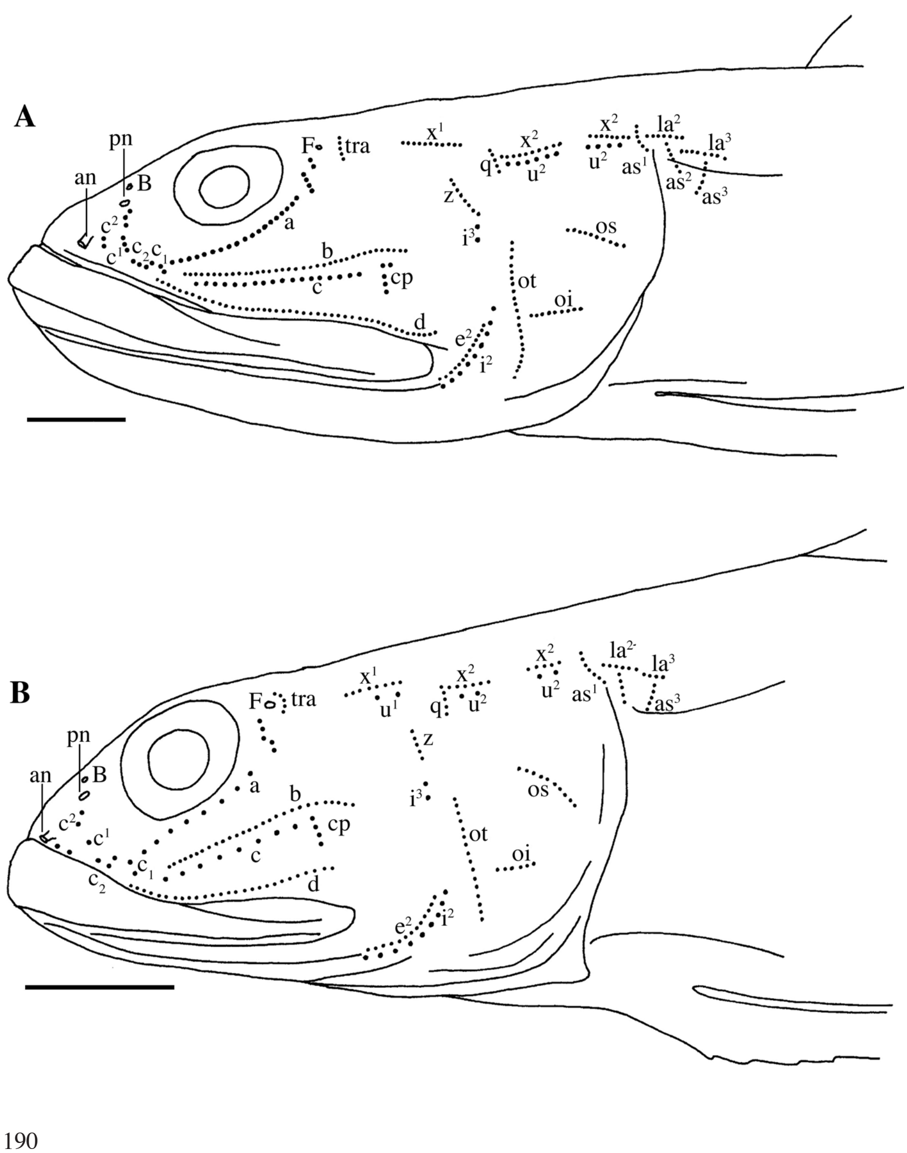

Figure 3. - Lateral view of head lateral line free neuromasts (sensory papillae) and canal pores (capitals). **A**: *Quietula guaymasiae*, **B**: *Quietula y-cauda*. Scale bars = 3 mm.

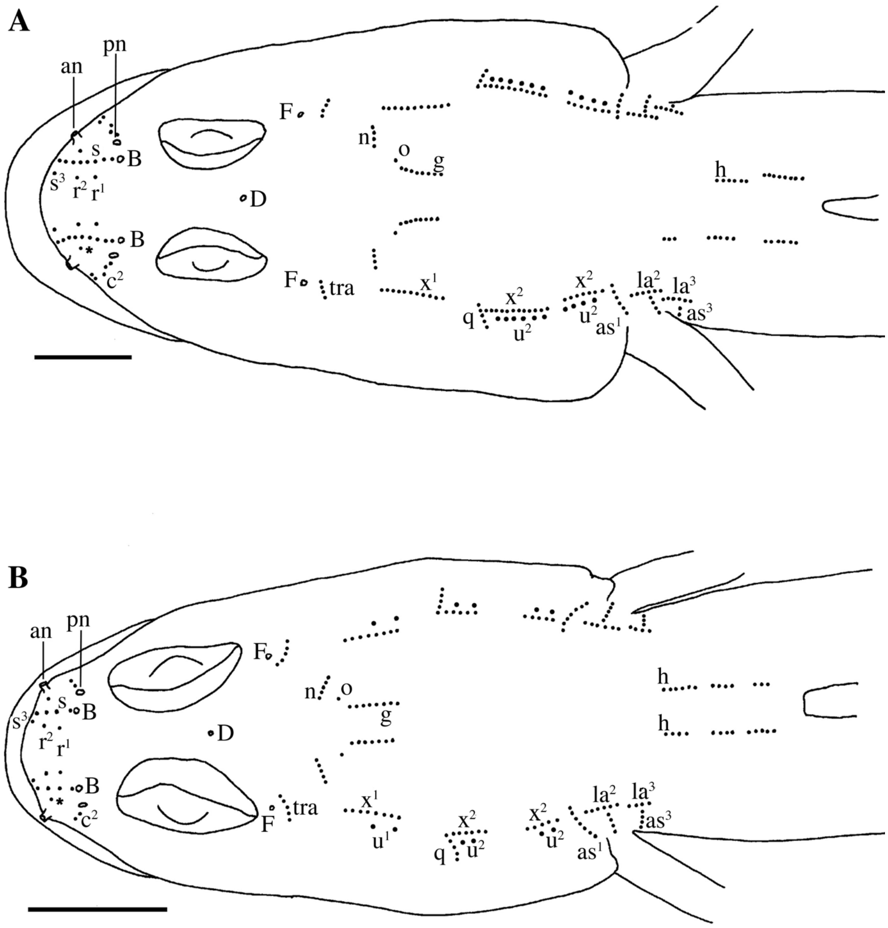

Figure 4. - Dorsal view of head lateral line free neuromasts (sensory papillae) and canal pores (capitals). **A**: *Quietula guaymasiae*, **B**: *Quietula y-cauda*. Scale bars = 3 mm.

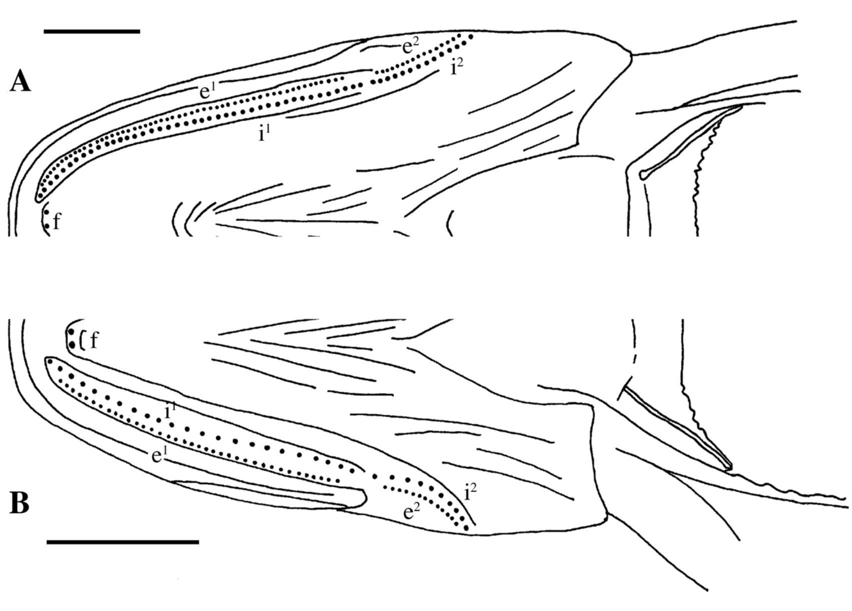

Figure 5. - Ventral view of head lateral line free neuromasts (sensory papillae). **A**: *Quietula guaymasiae*, left side. **B**: *Quietula y-cauda*, right side. Scale bars = 3 mm.

In most gobioid fishes with a developed preopercular canal, this canal is reduced to its vertical section. The mandibular canal is replaced by **i¹**, the horizontal section of the preopercular canal by **i²**. The neuromasts of **i¹** and **i²** are replacement neuromasts. Many gobiid taxa without a preopercular canal and with **i²** not extending along the entire preopercle display a similar situation with two neuromasts (**i³**) in place of the absent canal. These two neuromasts differ not only in position but also in innervation from **i¹** and **i²** (summarized in Ahnelt and Bohacek, in press) and seemingly represent primary neuromasts not enclosed in a canal.

Oculoscapular. - Five longitudinal rows (**u²**, **x¹**, **x²**, **la²⁻³**) and six transversal rows (**tra**, **z**, **q**, **as¹⁻³**), including the axillary series; **u²** divided in two distinct rows above opercle, replacing the posterior oculoscapular canal; **x¹** above cheek; **x²** divided, dorsal and parallel to **u²**; short anterior transversal row **tra** posterior to pore F; **z** long, dorsal to preopercular row **i³**; **q** short, at origin of opercle, immediately anterior to rows **x²** and **u²**; transverse axillary rows **as¹⁻³** from above origin of opercular membrane rearwards, latter two associated with **la** rows dorsally; longitudinal row **u¹** in course of postorbital canal above cheek and transverse rows **trp** and **y** above opercle lacking; only in two of 27 specimens is a single **u¹** neuromast developed on the left or on the right side, but never on both sides of the head.

In gobiids with the postorbital canal lacking this canal is replaced by transversal and/or longitudinal rows of neuromasts (for example Barlow, 1961; Wongrat and Miller, 1991; Akihito *et al.*, 2000). According to Wongrat and Miller (1991) the transverse rows **q** and **trp** are generally absent in taxa of the "longitudinal" type of eleotridines. While the latter row is absent in the two *Quietula* species, both have a row **q** developed. Transverse rows (**tra**, **q**, **trp**) in the course of the postorbital canal may be associated with this canal and do not necessarily replace it (Miller 1984, Ahnelt 2001). Interestingly *Q. guaymasiae* lacks **u¹**, the anterior generally longitudinal row which replaces the post-orbital section of the AOS in gobioids. Absence of this row of primary replacement neuromasts seems to be uncommon (for example compare Iljin, 1930; Miller, 1987; Akihito *et al.*, 2000; Larson, 2001). **u¹** is present in *Q. y-cauda* and is obviously the posteriormost remnant of a row which formerly replaced the postorbital canal above the cheek. It is likely that *Q. guaymasiae* evolved from a *y-cauda*-like ancestor (see below) and that the single **u¹** neuromast found in two specimens on one side of the head only is an atavistic feature.

Opercular. - Three rows, one transversal (**ot**) and two longitudinal rows (**os**, **oi**).

Anterior dorsal (*occipital*). - Two longitudinal (**g** and **h**) and two generally transversal (**n** and **o**) rows, but **o** represented by a single neuromast only; **n** posterior to rear of eye; **g** close to dorsal midline; **o** close to and generally anterior to or anterior and lateral to **g**; **h** divided in two to three rows, from origin of first dorsal fin anteriorly; row **m** lacking.

Trunk. - Three series of longitudinal and transversal rows (**ld**, **lm** and **lv**); each series in a characteristic pattern. Dorsal lateral series **ld** in three rows; first (**ld¹**) as short transverse row below origin of first dorsal fin; **ld²** longitudinal, below middle of first dorsal fin and close to **lm** series; **ld³** longitudinal, sometimes doubled or trebled, dorsal on caudal peduncle close to origin of caudal fin. Median lateral series **lm** in 30 - 31 (mode) rows, first row (**lm¹**) longitudinal, all other rows transversal; additionally short longitudinal rows may occur irregularly on top of transversal **lm** rows; last **lm**

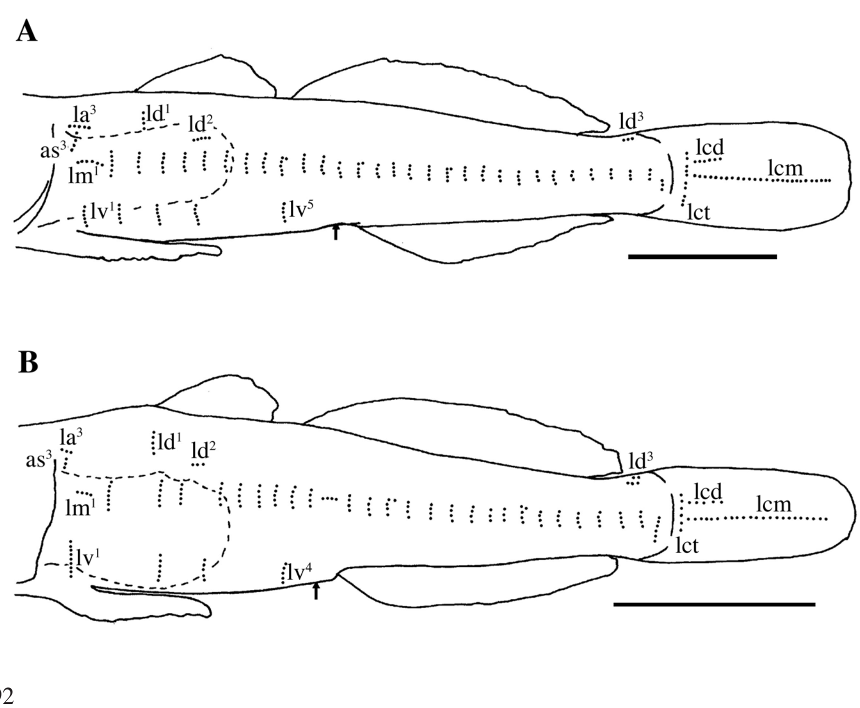

Figure 6. - Lateral line system of the trunk and caudal fin in lateral view. **A**: *Quietula guaymasiae*. **B**: *Quietula y-cauda*. Scale bar = 10 mm.

somewhat displaced ventrally; no distinct gap between **lm** rows which are covered by pectoral fin; no **lm** on scales of caudal fin base. Ventral series **lv** in five, rarely six, transverse rows from origin of pectoral fin (**lv**[1]) close to anus in a characteristic pattern; the anterior rows in regular distances to each other, the last row separated from them by a distinct gap (Fig. 6A).

Caudal fin. - One transversal (**lct**) and two longitudinal (**lcd**, **lcm**) rows (Fig. 6). Longitudinal rows on interradial membranes; anteriormost neuromasts largest, gradually decreasing in size rearwards, less obvious in short dorsal row **lcd** which extends approximately along anterior third of caudal fin only; median row **lcm** long, extending close to edge of caudal fin; **lcd** between fourth and fifth (4/5) branched caudal fin rays, **lcm** between 7/8. Transverse row **lct** in 4 - 5 short parts, at origin of caudal fin immediately posterior to last scale row; extends on interradial membrane from third (dorsal) to eleventh (ventral) branched caudal fin rays, passing **lcm** distinctly. A longitudinal ventral row (**lcv**) is lacking.

Information on the neuromast pattern on the trunk and

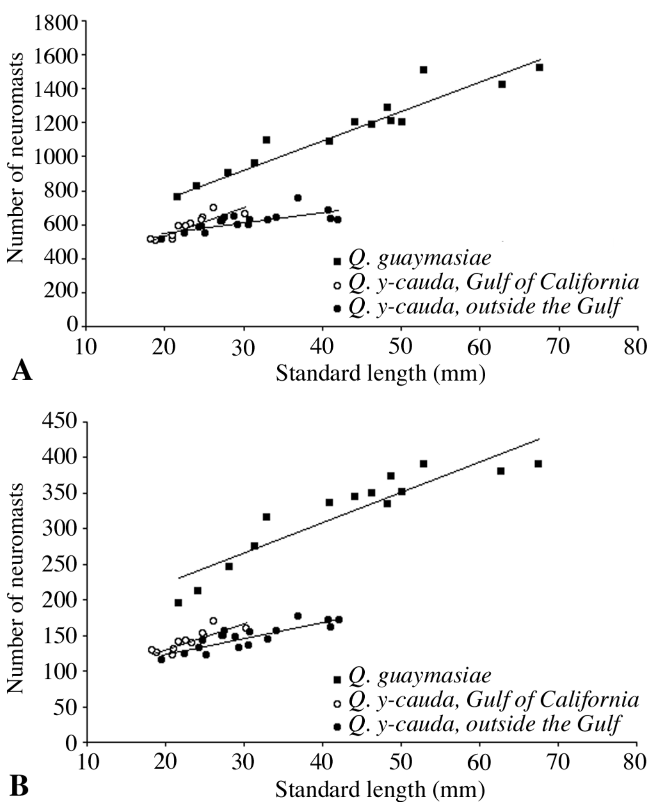

Figure 7. - **A**: Plot of total number of free head neuromasts against standard length for *Quietula guaymasiae* and *Quietula y-cauda* with regression lines. **B**: Plot of number of free neuromasts of the longitudinal suborbital rows **a**, **b**, **c** and **d** against standard length for *Quietula guaymasiae* and *Quietula y-cauda* with regression lines. Populations of *Q. y-cauda* from the Gulf of California and from outside of the Gulf are shown separately.

the caudal fin of gobioids are rare and often lacking. Seemingly three series of neuromast rows are characteristic for most gobioids along the trunk and in many species three longitudinal rows of neuromasts occur on the caudal fin (**lcd**, **lcm**, **lcv**) with a fourth, transversal row (**lct**) more or less distinctly developed (Sanzo, 1911; Miller and El-Tawil, 1974; Herler *et al.*, 1999; Ahnelt and Duchkowitsch, 2001; Shibukawa *et al.*, 2001). Species with two longitudinal rows on the caudal fin lack the ventral row **lcv** (Ahnelt *et al.*, 2000; Göschl, 2002). Such a feature occurs in Gobiinae, Gobionellinae, Oxudercinae and Sicydiinae and may be also found in other subfamilies of Gobiidae. A transversal row seems to be developed regularly, independently if two or three longitudinal rows are present (Ahnelt and Bohacek, in press). One of us (H.A.) investigated several Eleotridae (Butinae and Eleotrinae) which display three longitudinal rows (*Butis butis*, *Oxyeleotris marmorata*, *Oxyeleotris urophthalmoides* and *Dormitator latifrons mexicanus*, *Eleotris picta*, *Eleotris sandwicensis*) or only two longitudinal rows on the caudal fin (*Kribia nana*). In all these species a transversal row is developed on the base of the caudal fin. Two longitudinal rows (**lcd**, **lcm**) and a transversal row (**lct**) have been also found in *Odontobutis obscura* (Odontobutidae). Such a transversal row is absent in the Rhyacichthyidae (pers. obs.), but is present in *Terateleotris* (Shibukawa *et al.*, 2001).

These most basic gobioids, *Rhyacichthys aspro*, *Protogobius attiti* (Rhyacichthyidae), and *Terateleotris aspro* (unassigned genus), have three lateral line canals and/ or rows of neuromasts on the caudal fin (Springer, 1983; Shibukawa *et al.*, 2001; pers. obs.), possibly the plesiomorphic character state in Gobioidei. Possibly these two patterns of longitudinal neuromast rows on the caudal fin (two or three longitudinal rows) have developed several times independently. More than three longitudinal rows, known for example from the pelagic goby *Aphia minuta* (Mortara, 1918), is seemingly a derived condition.

Quietula y-cauda

Cephalic canals. - As in *Quietula guaymasiae*, but pores somewhat larger in diameter.

Free neuromasts (Figs 3-7; Tab. II). - Although in many rows the number of neuromasts differs distinctly from those of *Q. guaymasiae*, the pattern of the free neuromasts as a whole is similar for both species. Differences in the topography of the superficial neuromasts occur because of (i) the lack or presence of rows, (ii) the varying position of rows and, (iii) the differing number of neuromasts, which increases or decreases the length of a row. Numbers of neuromasts per row are summarized in table II. Differences in the numbers and the pattern of the free neuromasts compared with *Q. guaymasiae* occur in the following series:

Preorbital. - Longitudinal row **s** of the median series short, of only a few large neuromasts. The neuromasts in lateral series less numerous.

Suborbital. - Neuromasts less numerous and those of anterior part of **a** and of **c** large and well separated from each other. Rows **c** and **d** shorter. Row **cp** transversal, not in the shape of a T. *Q. y-cauda* is easily separated from *Q. guaymasiae* by distinctly less numerous neuromasts in the longitudinal suborbital rows (Fig. 7; Tab. II).

Preopercular-mandibular. - Rows **e** and **i** of less numerous and less closely set neuromasts.

Oculoscapular. - Six instead of five longitudinal rows; sixth row, $\mathbf{u^1}$, as a single or few neuromasts in course of postorbital canal always present; this row of primary replacement neuromasts occurs above rear of cheek and close to or below posterior end of $\mathbf{x^1}$; $\mathbf{u^2}$ posterior to $\mathbf{u^1}$, above opercle, divided in two short rows, each ventral and parallel to the two parts of $\mathbf{x^2}$.

Trunk. - **lm** series less numerous, 27 - 29 (mode) generally transverse rows; Pattern of **lm**-series less constant; $\mathbf{lm^1}$ longitudinal, a few other rows may be irregularly arranged longitudinal; between **lm** rows below pectoral fin gaps may occur (generally between second and third, often between third and fourth, and/or fourth and fifth rows); some transverse rows replaced by longitudinal rows; the gaps and these longitudinal rows seemingly cause the somewhat lower numbers of **lm** rows compared with *Q. guaymasiae*. **lv** series in four rows; $\mathbf{lv^1}$ below origin of pectoral fin and last **lv** close to anus; median rows separated from first and last **lv** row by a distinct gap (Fig. 6B).

Caudal fin. - **lct** a more or less continuous row and of less neuromasts.

DISCUSSION

Quietula guaymasiae differs from *Q. y-cauda* in following features: (1) number of fin rays, (2) number of scales in lateral and transversal series, (3) number and (in part) pattern of neuromasts of the lateral line system, and (iv) shape of dark marking at origin of caudal fin. Differences in the number of vertebrae seem to be likely but need confirmation by more specimens.

Quietula guaymasiae and the populations of *Q. y-cauda* from the Gulf of California display a lower variability in the number of fin rays, except for the anal fin and the ventral disc, compared with *Q. y-cauda* from outside of the Gulf (Tab. I). This is possibly due to the large distribution area (from Baja California Sur to Morrow Bay in Central California) of *Q. y-cauda* outside of the Gulf of California and a more homogenous stock of *Q. guaymasiae* and the populations of *Q. y-cauda* inside the Gulf which possibly were less drastically affected during the glacial period in the Pleistocene.

With the mode P 23-24 (79% of specimens) for the pectoral fin, *Q. guaymasiae* differs distinctly from *Q. y-cauda* (mode P 20-21, 70%) (Fig. 2, Tab. I). Differences in the anal and second dorsal fins are less obvious. *Q. guaymasiae* has predominantly 12 anal-fin rays (74%), *Q. y-cauda* 13 anal-fin rays (73%) (Tab. I). In both species 14 rays in the second dorsal fin are the predominant value, occurring in 84% of *Q. guaymasiae* but only in 70% of *Q. y-cauda*. Possibly there is also a difference in the variability of the spine number in the first dorsal fin. By far most specimens (96%) of both species have five spines in this fin. Two specimens of *Q. guaymasiae* have six spines, none has four, and one specimen of *Q. y-cauda* has four spines, but none six. Miller and Lea (1972) and Watson (1996) also found specimens of *Q. y-cauda* with only four instead the typical five spines in the first dorsal fin, but none with six.

Jenkins and Evermann (1889) mention "about 50" scales in lateral series for *Q. y-cauda*, a value repeated by subsequent authors (Jordan and Evermann, 1898; Miller and Lea, 1972). Scale counts from specimens of various localities show that the number in lateral series is distinctly larger than reported by Jenkins and Evermann (1889). In both species the scales are small and deeply embedded in the skin. They are somewhat larger and lower in number in *Q. guaymasiae*.

Macdonald (1972) illustrated for both species a stylized and partly incomplete cephalic neuromast pattern. He correctly mentioned that *Q. guaymasiae* is distinguished from *Q. y-cauda* "by greatly increased numbers of neuromasts "on the cheek and snout". Such increase in the numbers of neuromasts is also evident in most other neuromast rows. In addition to this obvious feature both species differ in the lateral line system (values of *Q. y-cauda* in parentheses) in having (i) the lateral area of snout with high number of neuromasts, and the lateral preorbital series difficult to distinguish (more distinct pattern of lateral preorbital series), (ii) complete loss of row $\mathbf{u^1}$ in course of postorbital canal ($\mathbf{u^1}$ present but short), and (iii) five to six neuromast rows in the ventral series on the abdomen (four rows only).

Quietula guaymasiae has higher numbers of pectoral-fin rays and neuromasts of the lateral line system compared with *Q. y-cauda*. These differences between both species and between the populations of *Q. y-cauda* are evident in the number of superficial neuromasts of the cephalic lateral line system, for example the longitudinal suborbital rows **a**, **b**, **c** and **d** and in the total number of the head neuromasts (Fig. 7). While both species display distinctly different numbers of neuromasts, these are in *Q. y-cauda* only slightly increased between the populations in the Gulf of California versus those from outside of the Gulf. As shown in figure 6, the number of neuromasts is size dependent. An increase of neuromasts during ontogeny is known for many gobiids with the possible exception of species which display an "abbreviated" neuromast type, i.e., most of the neuromast rows consist of one or very few neuromasts only (Ahnelt and Bohacek, in press), and species with a specialized life style such as the blind goby *Typhlogobius californiensis* (Ahnelt and Scattolin, 2003).

Contrary to the situation found in the two *Quietula* species, *Gillichthys seta* from the Gulf of California displays lower numbers of neuromasts than *G. mirabilis*, a species which occurs also outside of the Gulf (Barlow, 1961). We agree with this author that considerable changes in the number of neuromasts may occur during ontogeny especially in large gobiid species like *G. mirabilis*. To avoid misinterpretations, we compared individuals of the same size of both *Quietula* species and found that the differences in the number of neuromasts between the both species is striking (Fig. 7, Tab. II). There are small differences in this feature between the populations of *Q. y-cauda* inside and outside of the Gulf of California. We do not know why these differences occur, but they could be based on the separation of populations during past geological events (for example changes in salinity, temperature and water level during the last glaciation). Several authors observed morphological differences and genetic divergence between fish taxa with a disjunct distribution along the Pacific coast of Baja California and in the Gulf of California (for example Walker, 1960; Cook, 1978; Huang and Bernardi, 2001; Stepien *et al.*, 2001).

Geological events are proposed for the speciation of *Q. guaymasiae* from *Q. y-cauda* and *G. seta* from *G. mirabilis* (Cook, 1978; Huang and Bernardi, 2001), and for the genetic divergence between populations of *G. mirabilis* from the Pacific Coast of southern California and Baja California and the isolated populations in the Gulf of California (Huang and Bernardi, 2001). Speciation in both genera was accompanied by a different development in the number of superficial neuromasts. In the *Quietula* lineage, the numbers of neuromasts increased in the species endemic in the Gulf of California, whereas in *Gillichthys* the numbers decreased, in some rows drastically (Barlow, 1961; Göschl, 2002). On first sight, this seems to represent two independent developments between species of two gobiid genera. Cook (1978) hypothesized that *Q. y-cauda* was derived from *G. mirabilis* or a *mirabilis*-like ancestor. If this is correct, speciation from *G. mirabilis* to *G. seta* and then to *Q. y-cauda* led in both cases to a reduction in neuromast numbers, which were again increased in *Q. guaymasiae* which derived from *Q. y-cauda* (Cook, 1978). This is an hypothesis which needs to be tested, but *G. mirabilis* has the most basic configuration of the lateral line system of all four species and *G. seta* resembles *Q. y-cauda* in some neuromast series (Göschl, 2002). Recent molecular studies of Dawson *et al.* (2002) seemingly support the view that *G. mirabilis* has a basal position within the northeast Pacific species of the "*Chasmichthys*"- group (sensu Birdsong *et al.*, 1988).

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APPENDIX

Comparative material

Pattern of free neuromasts of the lateral line system on the caudal fin: three rows (one transversal **lct** and two longitudinal **lcd** and **lcm**) or four rows (one transversal **lct** and three longitudinal **lcd**, **lcm** and **lcv**). **lct** may be a continuous row at the base of the caudal fin or discontinuous, as two or three short rows anterior to each longitudinal row. **lct** is absent in Rhyacichthyidae. Species with two longitudinal rows are marked with an asterisk. Number in parentheses is number of investigated specimens.

Rhyacichthyidae. - *Protogobius*: *Protogobius attiti*, NMW 94266, NMW 94267 (2 paratypes); *Rhyacichthys*: *Rhyacichthys aspro*, CAS 38655 (2 specimens), NMW 45968, NMW 82972, NMW 82990 (3 spms).

Eleotridae. - *Butinae*: *Butis butis*, CAS 205539 (4 spms); *Oxyeleotris marmorata*, CAS 66251 (2 spms), *Oxyeleotris urophthalmoides*, CAS 49456 (1spm). *Eleotrinae*: *Eleotris picta*, SIO 59-358-58B (1 spm); *Eleotris sandwicensis*, SIO 61-425-58A (6 spms), *Kribia nana**, CAS 64486 (1 spm).

Odontobutidae. - *Odontobutis obscura**, CAS 32827, CAS 28154 (3 spms).

Gobiidae. - *Oxudercinae*: *Apocryptes bato*, CAS 89289 (2 spms); *Boleophthalmus boddarti***, CAS 140028 (3 spms) (one specimen with a short third longitudinal row **lcv** on both sides).

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